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AN EMPIRICAL STUDY OF SMART TECHNOLOGY ADOPTION IN ACADEMIC LIBRARIES: EVIDENCE FROM SELECTED PRIVATE UNIVERSITY LIBRARIES IN THE FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

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ABSTRACT

This study examines the adoption and implementation of smart technologies in academic libraries in private universities in the Federal Capital Territory, Abuja, Nigeria, with a focus on identifying key benefits, challenges, and institutional factors influencing their integration within a developing country context. A mixed-methods approach was employed, combining quantitative and qualitative data collection techniques. Survey data were obtained from 79 respondents across 10 private university academic libraries located within the Federal Capital Territory, and analyzed using descriptive statistics, while open-ended responses were examined through thematic analysis to identify emerging patterns and insights. The findings reveal that smart technologies, including artificial intelligence (AI), Internet of Things (IoT), and big data analytics, significantly enhance library service delivery, accessibility, and user experience. However, major challenges such as high implementation costs (77.9%), poor infrastructure (53.2%), and limited technical expertise (45.5%) hinder effective adoption. Qualitative results further highlight issues related to user awareness, staff training, and resistance to change. The study is limited by its sample size and regional focus, which may affect the generalizability of the findings. Future research could expand the scope to include comparative studies across regions and incorporate longitudinal data to assess long-term impacts of smart technology adoption. It provides actionable insights for academic library managers and policymakers by emphasizing the need for strategic investment, capacity building, and infrastructure development. It also highlights the importance of change management and user engagement in ensuring successful implementation and contributes to the growing body of knowledge on smart libraries by providing empirical evidence from a developing country perspective and integrating quantitative and qualitative insights to offer a comprehensive understanding of adoption dynamics.

Keywords: Smart libraries, Academic libraries, Smart technology adoption, Digital librarianship, Digital transformation

INTRODUCTION

Academic libraries have evolved from traditional repositories of printed materials into digitally driven knowledge ecosystems that actively support research, data management, and scholarly communication. This transformation is largely influenced by the digitalization of higher education, where access to information and knowledge sharing are increasingly technology-enabled (Cox et al., 2019). Modern academic libraries now function as hybrid environments that combine physical and digital infrastructures to provide personalized, efficient, and ubiquitous access to information. Their effectiveness depends not only on technological infrastructure but also on institutional culture, staff competencies, and user engagement, as explained by socio-technical systems theory (Bostrom & Heinen, 1977). Furthermore, the emergence of "smart libraries" reflects the principles of Industry 4.0, where automation, cyber-physical systems, and data-driven decision-making redefine library environments (Asemi et al., 2021).

The integration of smart technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and blockchain has significantly transformed library operations and services. These technologies facilitate intelligent, adaptive, and user-centered service delivery by enabling automation, predictive systems, and real-time decision-making (Zhang et al., 2022; Smith & Wong, 2023). Their adoption in academic libraries can be understood through the Technology Acceptance Model and the Diffusion of Innovation Theory, which emphasize perceived usefulness, ease of use, institutional readiness, and social influence as critical determinants of technology adoption (Davis, 1989; Rogers, 2003). Empirical studies further indicate that smart technologies improve information retrieval, automate routine tasks, and enhance operational efficiency, although their effectiveness depends on the availability of supporting infrastructure and alignment with user needs (Cox et al., 2019; Asemi et al., 2021).

Artificial intelligence has become central to intelligent library systems through applications such as machine learning recommendation systems, natural language processing, automated metadata generation, chatbots, plagiarism detection, and semantic search tools (Asemi et al., 2021). These innovations enhance operational efficiency and user experience; however, scholars have raised concerns regarding algorithmic bias, transparency, and ethical accountability in AI-driven systems (Floridi et al., 2018). Consequently, the implementation of AI in academic libraries requires appropriate ethical frameworks and governance mechanisms. The Internet of Things also contributes to smart library infrastructure through interconnected devices such as RFID-enabled smart shelves, occupancy sensors, and environmental monitoring systems, which improve resource management, automation, and user convenience (Atzori et al., 2010). Despite these benefits, the implementation of IoT technologies in developing countries is often constrained by inadequate infrastructure, unreliable internet connectivity, and inconsistent power supply.

Big data analytics has transformed academic libraries into evidence-based institutions capable of analyzing large volumes of user data to improve decision-making, collection development, and personalized services (Kitchin, 2014; Salman et al., 2022). Libraries can now monitor usage patterns, predict future information needs, and recommend relevant resources based on users' research interests, similar to recommendation systems used by platforms such as Amazon and Netflix (Kumar et al., 2021). Although these capabilities improve operational planning and user engagement, they also raise concerns regarding privacy, surveillance, and ethical data governance.

Blockchain technology further enhances trust and transparency in digital libraries by providing secure and decentralized systems for managing digital records, intellectual property, and scholarly communication (Casino et al., 2019). Its applications include digital rights management, secure credential verification, copyright protection, and decentralized resource sharing among libraries (Kumar et al., 2021; Smith & Wong, 2023). Additionally, blockchain supports open-access publishing and research integrity by ensuring the authenticity and immutability of digital information (Salman et al., 2022).

MATERIALS AND METHODS

This study employed an online survey to collect both quantitative and qualitative data using the Google Forms platform. The survey instrument consisted primarily of close-ended questions, with one open-ended question included to allow respondents to elaborate on their perspectives, thereby complementing the quantitative data with qualitative insights. Given the geographical dispersion of the target respondents, and to facilitate ease of participation, the survey link was disseminated through email, WhatsApp, and LinkedIn. A snowball sampling technique was adopted; wherein initial recipients of the survey were encouraged to forward the link to colleagues and peers within their professional networks.

The survey targeted a diverse group of respondents considered to be critical stakeholders, including library staff across various library types, students, IT specialists, and faculty members within the researcher's online network. This approach enabled broad and convenient access to potential participants.

A total of 79 valid responses were obtained during the data collection period, as illustrated in Figure 1. Quantitative responses were analysed using the analytical tools available in Google Forms, while qualitative responses were reviewed manually using thematic analysis. To maintain respondent confidentiality, qualitative data were anonymized and presented using alphanumeric coding.

RESULTS AND DISCUSSION

Demographic Characteristics of Respondents

The survey attracted 79 respondents from diverse academic environments, including librarians, students, faculty members, and administrative personnel. This heterogeneous composition of respondents provided a broad perspective on the awareness, utilization, and perceived impact of smart technologies within academic libraries. As indicated in Figure 1(a-c), participants represented varying age groups and educational backgrounds, with the majority holding undergraduate or postgraduate qualifications. The relatively high educational attainment of respondents reflects the scholarly environment in which academic libraries operate and suggests that participants were well positioned to evaluate technological innovations in library services.

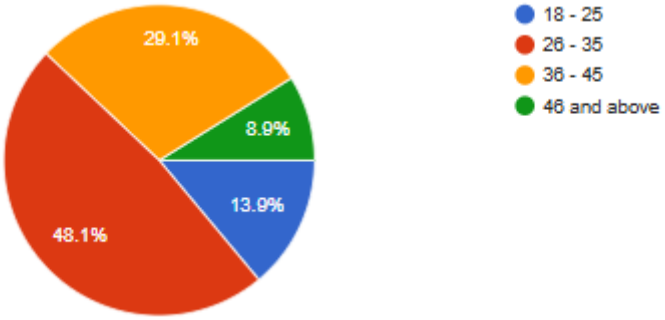

Figure 1(a): Age Distribution

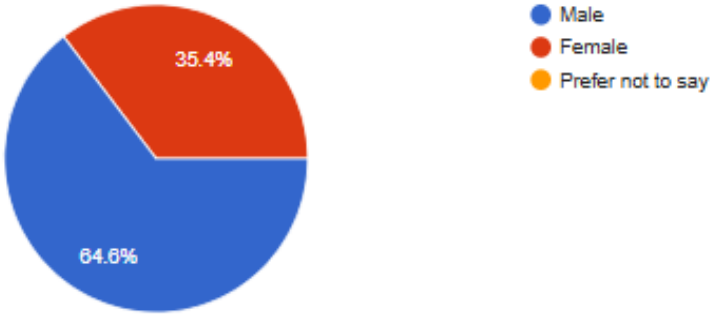

Figure 1(b): Gender Distribution

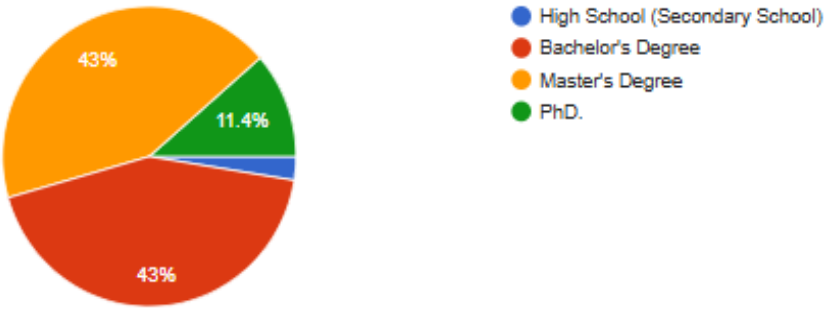

Figure 1(c): Educational Background

Awareness and Adoption of Smart Technologies

The findings from the survey indicate a generally high level of awareness regarding smart technologies in academic libraries. Respondents demonstrated familiarity with a range of technologies that are increasingly associated with the concept of the "smart library". Figure 2(a-b) presents respondents' views on the awareness and current state of smart technologies implementation in their academic libraries, based on 79 survey responses.

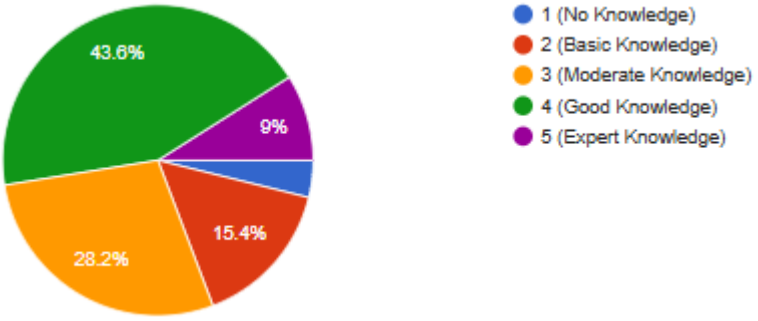

Figure 2(a): Self-assessment Rate of Smart Technologies

The chart illustrates respondents' self-assessment of their knowledge of smart technologies in academic libraries, based on a five-point Likert scale, where 1 represents no knowledge and 5 represents expert knowledge. A total of 78 responses were recorded for this question. The results indicate that the largest proportion of respondents rated their knowledge as good, with 43.6% selecting level 4. This suggests that a significant portion of participants perceive themselves as having a solid understanding of smart technologies and their applications within academic library environments. The second largest group of respondents, representing 28.2%, rated their knowledge as moderate (level 3). This indicates that while many respondents are familiar with smart technologies, their understanding may still be developing and may not extend to advanced or technical aspects of implementation. A smaller proportion of respondents (15.4%) reported basic knowledge (level 2) of smart technologies. These respondents likely possess only introductory awareness or limited exposure to smart library systems. Notably, 9% of respondents identified themselves as having expert knowledge (level 5). Although this represents a relatively small segment of the sample, it suggests the presence of individuals likely librarians, technology specialists, or researchers who possess advanced expertise in the deployment or management of smart technologies within library contexts.

Finally, only a very small proportion of respondents indicated no knowledge (level 1), suggesting that awareness of smart technologies is generally widespread among the study participants. This indicates that most respondents possess at least moderate to good knowledge of smart technologies in academic libraries, reflecting a growing level of technological awareness among academic stakeholders. This level of familiarity is important for the successful adoption and implementation of smart technologies, as user awareness and competence often influence the effectiveness of technological innovations in academic institutions.

On the level of adoption of smart technologies, the survey results as shown in Figure 2(b) indicates varying levels of adoption of different smart technologies across institutions. The Internet of Things (IoT) emerged as the most widely implemented technology, with 39.2% respondents indicating that IoT systems are currently used in their libraries. This suggests that many academic libraries are adopting IoT-enabled solutions such as RFID-based inventory systems, smart shelves, environmental monitoring devices, and automated circulation technologies to improve operational efficiency and resource management. The second most frequently reported technology is Artificial Intelligence (AI), identified by 34.2% respondents. The adoption of AI in academic libraries reflects the increasing integration of AI-driven search tools, automated reference services, chatbots, and intelligent recommendation systems that support information retrieval and user engagement.

Similarly, Big Data Analytics is implemented in several libraries, with 30.4% respondents reporting its use. This indicates that some academic institutions are beginning to leverage data-driven decision-making tools to analyze user behaviour, optimize collection development, and improve service delivery. Interestingly, a notable proportion of 31.6% respondents reported that none of the listed smart technologies are currently implemented in their libraries. This highlights the existence of significant disparities in technological adoption across academic institutions, possibly due to variations in funding, infrastructure, or institutional priorities. In contrast, Blockchain technology appears to have the lowest level of adoption, with only 13.9% respondents indicating its implementation. This finding suggests that

blockchain applications in academic libraries remain in an emerging or experimental stage, likely due to the complexity and relatively recent development of this technology in information management systems. A very small number of respondents (approximately 1.3% each) selected alternative responses such as "*reading cloud"*, "*not sure"*, or "*I don't know"*. These responses indicate a limited level of awareness among some participants regarding the technological infrastructure of their libraries.

In summary, the findings reveal that IoT, AI, and Big Data Analytics are the most adopted smart technologies in academic libraries, while blockchain remains relatively underutilized. At the same time, the presence of institutions without any smart technology implementation underscores the need for greater institutional investment, technological infrastructure development, and digital transformation strategies to enable academic libraries to evolve into fully future-ready knowledge environments.

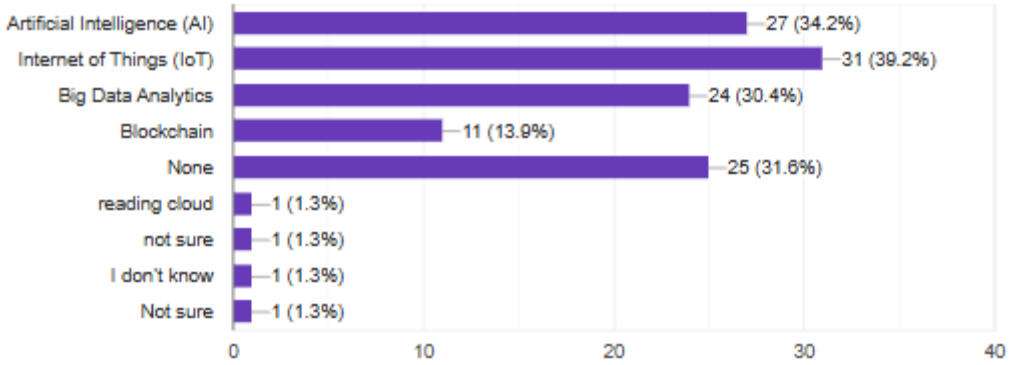

Figure 2(b): Smart Technologies Adoption Rate among Institutions

Perceived Impact of Smart Technologies on Academic Library Services

Respondents overwhelmingly acknowledged the transformative potential of smart technologies in enhancing the functionality and relevance of academic libraries. Three primary benefit categories emerged from the analysis: *improved resource accessibility*, *efficient library management*, and *enhanced user experience*.

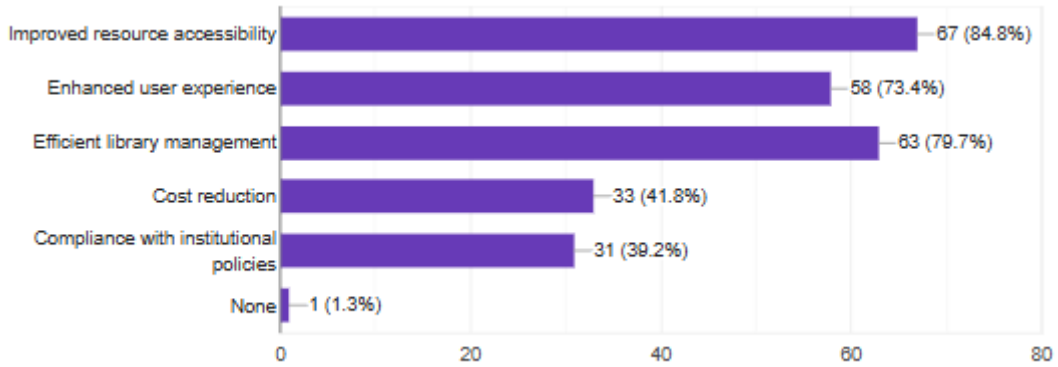

Figure 3: Impact of Technologies in Academic Libraries

First, 67 respondents (84.8%) emphasized that smart technologies facilitate faster and more precise access to information resources. AI-enabled search algorithms and recommendation engines were widely perceived as improving resource discoverability by delivering contextually relevant search results and personalized research suggestions.

Second, 63 respondents representing 79.7% of the survey highlighted the role of smart technologies in improving operational efficiency within libraries. Technologies such as automated cataloguing systems, smart shelving solutions, and digital circulation tools were viewed as reducing manual workloads for library staff while improving the accuracy and speed of routine processes. IoT-based systems track library materials in real time, thereby improving inventory management and reducing resource loss.

Third, smart technologies were recognized by 58 respondents (73.4%) for their capacity to enhance user experience and engagement. Intelligent learning environments, AI-powered research assistants, and interactive digital platforms support personalized learning pathways. These technologies enable libraries to shift from traditional service models toward data-driven and user-centered service delivery. Other respondents highlighted *"cost reduction (41.8%)"* and *"compliance with institutional policies (39.2%)"* respectively as other perceived benefits of adopting smart technologies in academic libraries.

Institutional and Behavioural Barriers to Implementation

Beyond the structural challenges identified, the findings also reveal important institutional and behavioural barriers influencing the implementation of smart technologies in academic libraries. Notably, 31.2% of respondents as shown in Figure 4, identified *resistance to change* as a significant challenge, indicating that organizational culture plays a critical role in shaping technology adoption outcomes. This suggests that even where financial and infrastructural resources are available, reluctance among staff to adopt new systems may limit successful implementation. Furthermore, the combination of *limited technical expertise* (45.5%) and

resistance to change points to deeper issues related to institutional readiness. These findings highlight the importance of leadership support, staff engagement, and change management strategies in facilitating digital transformation. Unlike the broader challenges discussed in Section 3, these results provide empirical evidence that internal organizational dynamics such as attitudes, skills, and readiness for change are equally critical in determining the success or failure of smart technology initiatives.

The findings therefore suggest that addressing implementation challenges requires not only investment in infrastructure and technology but also deliberate efforts to build a culture of innovation, enhance staff competencies, and promote institutional alignment toward digital transformation goals.

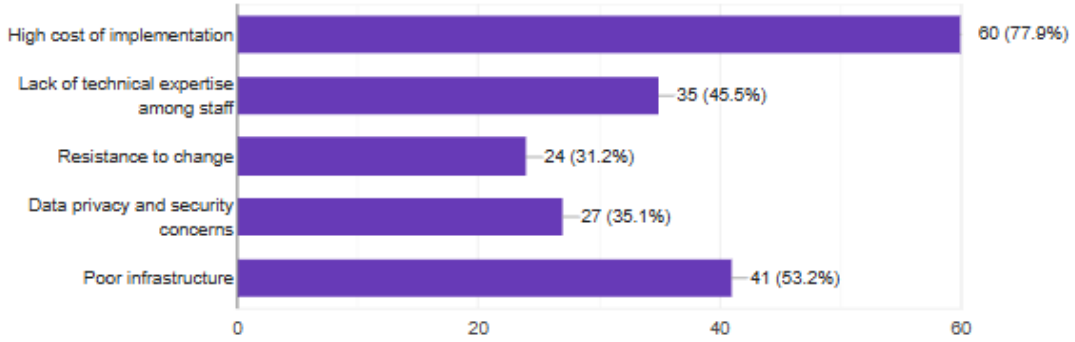

Figure 4: Barriers in Implementing Smart Technologies

The findings demonstrate that the challenges to implementing smart technologies in academic libraries are multidimensional, encompassing financial, infrastructural, technical, ethical, and organizational factors. These results underscore the need for a holistic and strategic approach to digital transformation, one that addresses not only technological acquisition but also capacity building, infrastructure development, and institutional change management.

Qualitative Themes from Open-Ended Responses on the Adoption of Smart Technologies in Academic Libraries

The open-ended responses regarding the role of smart technologies in academic libraries were analyzed using a thematic analysis approach, leading to the identification of several key themes. These themes capture respondents' perceptions of the benefits, challenges, and future implications of smart technologies within academic library environments.

Enhanced Accessibility and Inclusive Library Services

A prominent theme emerging from the responses is the role of smart technologies in improving accessibility and inclusivity, particularly for users with disabilities. Respondent 28 highlighted tools such as "*text-to-speech systems, augmented reality (AR), and digital Braille devices"* as important innovations that make library resources more accessible. Additionally, smart technologies were perceived by Respondent 12 as enabling *remote access to information*, allowing users to retrieve academic resources "from the comfort of their homes" according to Respondent 58. This underscores the role of smart libraries in supporting flexible, inclusive, and distance learning environments.

Improved Efficiency and Service Delivery

Respondents 10 & 24 emphasized that smart technologies significantly enhance the efficiency of library operations and overall service delivery. Technologies such as *automation tools, intelligent systems, and reasoning engines* were identified as improving routine library processes, including cataloguing, information retrieval, and resource management. This suggests that smart technologies contribute to increased operational effectiveness and streamlined service provision.

User Experience and Personalized Learning

Closely related to efficiency is the theme of enhanced user experience. Respondent 10 noted that smart technologies improve user interaction with library systems through *personalized recommendations, seamless search capabilities, and interactive learning tools.* The concept of smart study spaces "where students can book seats, access digital tools, and collaborate in real time" was also highlighted by Respondent 22. This indicates that academic libraries are increasingly evolving into technology-enabled, user-centered, and collaborative learning environments rather than merely serving as information repositories.

Awareness, Communication, and User Engagement Challenges

A critical issue raised by one of the respondents has to do with lack of effective communication and awareness regarding available smart technologies. Respondent 33 specifically noted "*Institutions providing smart technologies in academic libraries will not be effective if the innovations are not communicated properly to those who will use them*" this shows that technological innovations may fail if they are not adequately communicated to users, suggesting that a communication gap between library management and user communities. This highlights the importance of user education, awareness campaigns, and engagement strategies in ensuring the effective utilization of smart technologies.

Capacity Building and Staff Training

Another recurring theme is the need for training and capacity development among library staff. According to Respondent 56, "*Government and stakeholders should provide adequate funds for development of IT infrastructures and training",* this suggests that the effective use of smart technologies depends on the technical competence of librarians, and that continuous training initiatives are necessary to maximize their benefits. This finding reinforces the importance of human resource development as a critical component of successful smart library implementation.

Complementarity not Replacement

An important conceptual theme that emerged is that smart technologies should complement rather than replace traditional library functions. Respondent 20 suggested that, "*Smart libraries should serve as added functionality of academic libraries not a replacement*". While technology enhances library services, it should not eliminate the core roles of librarians or the relevance of physical library spaces. This highlights the need for a balanced integration approach, where technology augments human expertise and traditional services rather than substituting them entirely.

Discussion

The findings of this study provide strong empirical support for the growing role of smart technologies in transforming academic libraries into intelligent, user-centered knowledge ecosystems, a trend widely acknowledged in recent studies (Rahman *et al.*, 2025). By integrating the *Technology Acceptance Model (TAM), Diffusion of Innovation (DOI) theory*, and the *Technology-Organization-Environment (TOE) framework*, this section offers a comprehensive interpretation of the adoption dynamics and challenges identified in Sections 3 and 5.

From the perspective of TAM, the high level of awareness and positive perceptions of smart technologies among respondents indicate that these systems are widely regarded as useful in enhancing library services. Technologies such as artificial intelligence (AI) and the Internet of Things (IoT) were particularly associated with improved efficiency, accessibility, and user experience. This supports the argument that perceived usefulness significantly influences technology adoption (Davis, 1989; Venkatesh & Davis, 2000). Similarly, prior studies have shown that AI-driven tools enhance information retrieval, automate routine tasks, and improve user engagement in academic libraries (Asemi *et al.*, 2021; Cox *et al.*, 2019; Ayinde *et al.*, 2026).

However, the uneven adoption of smart technologies observed in this study reflects key insights from Diffusion of Innovation theory. While IoT and AI technologies appear to be moving toward mainstream adoption, blockchain remains at an early stage of diffusion, largely due to its complexity and high implementation costs. This aligns with Rogers' (2003) assertion that innovations perceived as complex and resource-intensive tend to experience slower adoption rates. Empirical studies further confirm that emerging technologies such as blockchain are still experimental within academic library systems (Casino *et al.*, 2019; Zhang *et al.*, 2022).

Financial constraints emerged as the most significant barrier, with 77.9% of respondents identifying cost as a major challenge. Within the TOE framework, this reflects organizational readiness, where limited financial capacity restricts the acquisition and sustainability of advanced technologies. This finding is consistent with existing literature, which highlights funding limitations as a critical barrier to digital transformation in libraries, particularly in developing contexts (Cox *et al.*, 2019; Salaam *et al.*, 2023). The high cost of implementation also contributes to disparities in technological adoption across institutions, reinforcing systemic inequalities.

Infrastructure-related challenges, reported by 53.2% of respondents, further emphasize the environmental dimension of the TOE framework. Reliable internet connectivity, stable power supply, and access to digital infrastructure are essential prerequisites for the effective deployment of smart technologies. In many developing regions, these infrastructural deficiencies significantly hinder the operationalization of IoT systems, big data analytics, and cloud-based services, despite their recognized potential to enhance automation and resource management (Adhikari & Paswan, 2024). These findings align with broader studies on the digital divide, which highlight the uneven distribution of technological resources and its implications for access to information (Kitchin, 2014; Salaam *et al.*, 2023).

Human capacity also plays a critical role in technology adoption. The identification of technical skill gaps by 45.5% of respondents underscores the importance of aligning technological innovation with staff competencies. From a socio-technical systems perspective, the success of smart library initiatives depends on the interaction between technology and human actors (Bostrom & Heinen, 1977). A lack of technical expertise can reduce perceived ease of use, thereby limiting the effective utilization of available technologies. This finding reinforces the need for continuous professional development and targeted training programs for library staff.

Ethical and governance concerns, particularly those related to data privacy, algorithmic bias, and user surveillance, represent another important dimension of smart technology adoption. Although these concerns were less dominant quantitatively, they emerged as significant themes in qualitative responses. This aligns with growing scholarly discourse on responsible AI, which emphasizes the need for transparency, accountability, and ethical oversight in data-driven systems (Floridi *et al.*, 2018; Islam *et al.*, 2025). Without robust governance frameworks, the adoption of smart technologies may undermine user trust and compromise intellectual freedom.

Furthermore, challenges related to interoperability and system integration highlight the complexity of transitioning from legacy systems to advanced technological infrastructures. Many academic libraries operate on outdated platforms that are not easily compatible with emerging technologies, leading to inefficiencies and increased implementation costs. This reflects the role of technological complexity in slowing adoption, as emphasized in Diffusion of Innovation theory (Rogers, 2003). Also, the findings demonstrate that the adoption of smart technologies in academic libraries is influenced by a complex interplay of financial, technological, human, and institutional factors. These challenges are deeply interconnected, with financial constraints affecting infrastructure development and staff training, while governance gaps exacerbate ethical and operational risks. This interdependence underscores the need for a holistic and strategic approach to digital transformation.

Finally, the study highlights the importance of sustained investment, capacity building, infrastructure development, and ethical governance frameworks in enabling academic libraries to fully leverage smart technologies. Institutions that adopt such integrated strategies will be better positioned to transition into future-ready, intelligent knowledge ecosystems that support innovation, inclusivity, and lifelong learning.

CONCLUSION

The rapid advancement of smart technologies is fundamentally reshaping the operational and service delivery frameworks of academic libraries. This study investigated the role of emerging technologies in transforming traditional libraries into future-ready knowledge environments capable of meeting the evolving needs of modern academic communities.

The findings demonstrate that awareness and perception of smart technologies among academic stakeholders are generally positive, with respondents recognizing their potential to significantly enhance information accessibility,

operational efficiency, and personalized user experiences. Despite these promising developments, the results also reveal several important challenges that may hinder the effective implementation of smart technologies in academic libraries. Key constraints include inadequate technological infrastructure, limited financial resources, and insufficient technical expertise among library personnel. In addition, concerns regarding data privacy, ethical use of artificial intelligence, and potential inequalities in access to digital technologies underscore the need for careful planning and governance.

The study therefore concludes that while smart technologies offer transformative opportunities for academic libraries, their successful adoption requires strategic institutional commitment**,** continuous professional development**,** and robust technological governance frameworks**.** Libraries must move beyond ad hoc technological adoption and instead pursue systematic digital transformation strategies that align technological innovation with educational objectives, ethical standards, and user needs.

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