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Smart libraries and the internet of things (IoT): Transforming user experience, space management, and knowledge delivery

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Abstract

The emergence of Smart Libraries powered by the Internet of Things (IoT) has introduced a transformative shift in library operations, services, and user engagement. IoT integrates physical devices such as sensors, RFID tags, smart shelves, mobile applications, and connected systems to create intelligent library environments. These technologies enable real-time monitoring, automated services, personalized user experiences, and efficient resource management. Smart libraries move beyond traditional information repositories to become interactive, adaptive, and user-centric knowledge hubs. This study explores how IoT technologies are reshaping user experience, space management, and knowledge delivery in academic libraries. Smart access systems, automated circulation, indoor navigation, and personalized recommendations enhance user satisfaction and accessibility. IoT-based space utilization tools support optimal use of reading rooms, study spaces, and collections. Furthermore, real-time data analytics improves decision-making and service planning for librarians. However, challenges such as high implementation costs, data privacy concerns, technical expertise requirements, and infrastructure limitations remain significant, particularly in developing regions. This research analyzes usage patterns, benefits, challenges, and the evolving role of librarians in smart library ecosystems. The findings highlight that IoT adoption significantly improves efficiency, accessibility, and learning outcomes while demanding strategic planning, policy frameworks, and continuous professional development.

Keywords: Smart libraries, internet of things, RFID, user experience, space management, digital libraries

1. Introduction

The rapid advancement of digital technologies has significantly accelerated the transformation of academic libraries from traditional information repositories into smart, technology-driven knowledge environments (Gupta, 2021) ^[3]. In the contemporary digital era, libraries are no longer confined to the management of physical collections; instead, they increasingly function as dynamic service hubs that support learning, research, and innovation through intelligent and automated systems (Mehta, 2022) ^[6]. This transformation has been driven by the growing demand for faster access to information, personalized services, and efficient resource management in higher education institutions.

Among the emerging technologies influencing this shift, the Internet of Things (IoT) has gained considerable importance for its ability to connect physical objects with digital networks (Patel, 2020) ^[7]. The Internet of Things refers to a network of interconnected devices such as sensors, RFID tags, smart shelves, surveillance systems, and mobile applications that can collect, exchange, and analyze data in real time (Singh & Kaur, 2021) ^[10]. In library environments, IoT technologies enable real-time monitoring of collections, automated circulation processes, user behavior analysis, and intelligent environmental control, thereby improving both service delivery and operational efficiency (Aharony, 2019) ^[1]. Smart libraries integrate IoT technologies with existing library management systems to deliver automated, responsive, and personalized services (Zhang & Liu, 2020) ^[11]. These intelligent systems facilitate seamless access to information resources, enhance space utilization, and support data-driven decision-making for librarians and administrators. Users benefit from faster services, improved indoor navigation, personalized notifications, and enhanced accessibility, while librarians gain advanced tools for inventory management,

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space optimization, and service planning (Mehta, 2022; Sharma, 2023) ^[6, 9]. As academic institutions increasingly prioritize digital transformation and smart campus initiatives, the adoption of IoT in libraries represents a strategic shift toward creating user-centric, efficient, and sustainable knowledge ecosystems.

2. Literature Review

Patel (2020) ^[7] highlighted that IoT based RFID systems significantly improved circulation efficiency and inventory control. Singh and Kaur (2021) ^[10] reported enhanced user satisfaction through smart access and real-time resource tracking. Mehta (2022) ^[6] emphasized the role of IoT in optimizing library space utilization and energy management. Asim & Arif (2023) ^[2] conducted a systematic literature review on IoT adoption in academic libraries, synthesizing global research published across high-impact databases. The study highlights that IoT technologies such as auto-notifications, inventory tracking, user tracking, and virtual tours significantly improve efficiency, service quality, and accessibility of library collections. The analysis also identifies opportunities for future research in enhancing service delivery and operational processes using IoT tools. Hema Adhikari & Pramod Paswan (2024) ^[4] explored innovations and challenges of smart library systems in the IoT era. Their review highlights how IoT enabled tools automate routine library tasks, support personalized services, and enable real-time monitoring. The paper also discusses key challenges such as interoperability of devices, standardization issues, and integration with legacy systems, making it a valuable contribution to understanding both benefits and barriers of smart library adoption. Samuel Uwaifo (2025) ^[8] reviewed Smart Library IoT deployments in African libraries, focusing on user experience and resource management. The review demonstrates that core IoT technologies including RFID systems, sensor networks, and mobile wayfinding improve discovery, space utilization, and decision-making capabilities. However, the study also notes uneven deployment due to infrastructure and funding constraints and emphasizes the need for data governance and training for librarians. Hussain Shah *et al.* (2025) ^[5] investigated the implementation status of IoT in university libraries, highlighting opportunities, challenges, and ethical concerns. Through interviews with librarians, this research uncovers that while IoT tools like RFID-based tracking and smart surveillance enhance operations, barriers such as financial limitations, technical skills gaps, and data privacy issues persist. The authors call for structured ethical guidelines and capacity building for sustainable IoT adoption. Pamungkas *et al.* (2025) ^[12] provided a focused review on the impact of IoT on library collection management efficiency. The findings suggest that integrating IoT technologies particularly RFID, smart sensors, and cloud computing can streamline inventory management, improve resource accessibility, and strengthen security controls. The review also indicates that practical challenges such as investment costs and staff training must be addressed for effective implementation.

3. Objectives of the Study

- 1) To examine the role of IoT in enhancing library user experience.
- 2) To analyze IoT applications in library space and resource management.

- 3) To identify challenges in implementing smart library technologies.
- 4) To assess the impact of IoT on librarians' professional roles.

4. Methodology

Table 1: Research Design and Sample Composition

Component	Details
Research Design	Mixed-method approach (Quantitative & Qualitative)
Users	180
Librarians	20
Academic Libraries	5

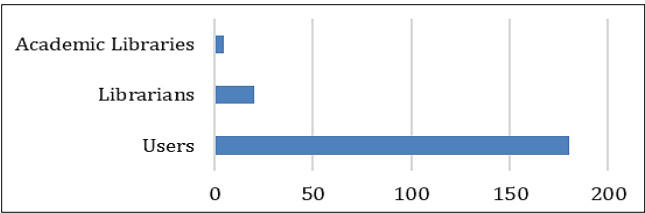


Fig 1: Details Mixed-method approach (Quantitative & Qualitative)

The adoption of a mixed-method research design allowed the study to capture both quantitative trends and qualitative insights related to the implementation of IoT in academic libraries. The inclusion of 180 library users, 20 librarians, and 5 academic libraries ensured a balanced representation of key stakeholders involved in smart library services. This sample composition strengthened the reliability of the findings by incorporating user perspectives alongside professional and institutional viewpoints. The diversity of respondents enabled a comprehensive assessment of user experience, operational efficiency, and managerial challenges associated with IoT adoption.

Table 2: Data Collection Tools Used in the Study

Data Collection Tool	Purpose
Questionnaire	To collect quantitative data from users
Interview	To gather qualitative insights from librarians
Observation	To assess IoT infrastructure and library environment

The use of multiple data collection tools enhanced the validity of the study through data triangulation. Questionnaires provided measurable data on user awareness, usage patterns, and perceived benefits of IoT enabled services. Interviews with librarians offered in-depth qualitative insights into implementation challenges, skill requirements, and changes in professional roles. Observational methods helped assess the actual availability and functionality of IoT infrastructure within library spaces. The combination of these tools ensured a holistic understanding of smart library practices.

Table 3: User Awareness of Smart Library Services

Awareness Level	Percentage (%)
Aware	72%
Not Aware	28%

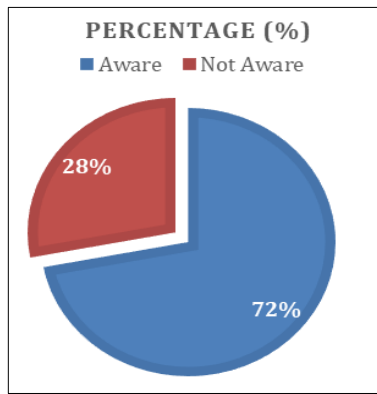


Fig 2: Pie chart shows user awareness levels of smart library services.

The findings reveal that 72% of users are aware of smart library services, indicating a relatively high level of exposure to IoT-enabled facilities. This suggests that academic libraries have made noticeable progress in introducing smart technologies such as RFID circulation and digital access systems. However, the presence of 28% unaware users highlights a significant gap in user orientation and information literacy initiatives. This indicates the need for awareness programs, user training sessions, and promotional activities to maximize the utilization of smart library services.

Table 4: Major IoT Applications Used in Libraries - Interpretation

IoT Application	Users (%)
RFID-based Circulation	80%
Smart Access Systems	65%
Space Monitoring Systems	58%
Mobile Notifications	62%

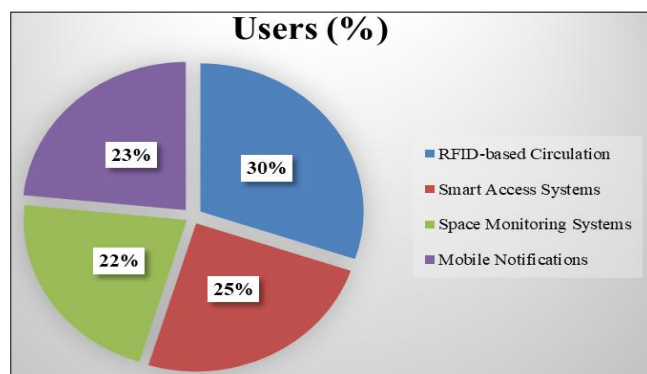


Fig 3: Pie chart shows usage and benefits of IoT applications in libraries.

The results indicate that RFID-based circulation systems (80%) are the most widely used IoT application, reflecting their effectiveness in automating issue-return processes and improving inventory control. Smart access systems (65%) and mobile notifications (62%) further demonstrate libraries' efforts to enhance user convenience and service responsiveness. The comparatively lower usage of space monitoring systems (58%) suggests that while space management technologies are gaining attention, their adoption remains limited due to cost and infrastructure constraints. Overall, the data confirms that libraries prioritize IoT applications that directly improve operational efficiency and user services.

A significant 78% of users reported faster library services, underscoring the positive impact of IoT technologies on service delivery. Improved navigation and access (60%)

reflect the effectiveness of smart guidance systems and digital access tools in reducing user effort and time. Additionally, 55% of users benefiting from personalized alerts indicates growing acceptance of customized services such as due-date reminders and new arrival notifications. These findings collectively justify the role of IoT in enhancing user satisfaction and engagement in academic libraries.

7. Conclusion

Smart libraries enabled by IoT technologies significantly enhance user experience, optimize space utilization, and improve knowledge delivery. While challenges persist, strategic investment, training, and policy support can ensure sustainable smart library development.

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