

SMART LIBRARIES: QUANTITATIVE INSIGHTS INTO IoT AND RFID ADOPTION IN ISLAMIC HIGHER EDUCATION INSTITUTIONS

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Abstract: *While Internet of Things (IoT) and Radio Frequency Identification (RFID) technologies are increasingly recognized as catalysts for library innovation, empirical evidence on their practical impact within Islamic higher education libraries remains limited. This quantitative study examines how IoT and RFID adoption influence management efficiency in university libraries. Data was collected through a structured survey involving UIN Imam Bonjol Padang Library librarians. Statistical analysis demonstrates significant improvements in collection tracking, user service responsiveness, and resource security attributable to these technologies. However, the study also uncovers persistent barriers, including insufficient infrastructure investment and gaps in technical competencies among library staff. The findings suggest that while IoT and RFID systems enhance operational capabilities, successful implementation requires strategic planning, continuous staff development, and institutional support. This research offers critical insights for policymakers and library managers aiming to navigate the complexities of digital transformation in academic environments.*

Keywords: *Smart Libraries, IoT, RFID, Library Management, Digital Transformation*

Introduction

Smart libraries have gained increasing attention in the library and information science field in recent years. Smart library is a digital ecosystem that integrates various advanced technologies to optimize library operations and improve user experience, and acts as a node in an interconnected smart city ecosystem by collaborating with schools, hospitals, and local governments to provide integrated access to information and services (Naikar & Paul, 2025). The core components of a smart library include the Internet of Things (IoT), Radio Frequency Identification (RFID), cloud computing, and artificial intelligence (AI), among others. These technologies allow for greater automation, real-time monitoring, and personalized services, all of which are essential to meet the ever-changing demands of users, particularly in academic settings (Xu et al., 2024). In addition to enhancing user services, integrating smart technologies fundamentally transforms library management practices (Yu et al., 2019). Functions such as collection tracking, resource allocation, user behaviour analysis, and infrastructure maintenance can now be performed more precisely and efficiently. Smart library management emphasizes proactive decision-making, data-driven service development, and continuous adaptation to technological innovations, making it a critical factor for the sustainability and relevance of academic libraries in the digital era.

In the context of Islamic higher education institutions, the transition to smart libraries is of particular significance. These institutions face increasing pressure to adapt to technological advances to remain competitive and relevant. Academic libraries, once considered primarily as repositories of printed books and journals, are now evolving into dynamic digital service hubs. Integrating technologies such as the IoT and RFID plays a significant role in this transformation, enabling libraries to operate more efficiently and align their services with contemporary students' and faculty's digital habits and expectations.

Smart university libraries are increasingly exploring the use of immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) to develop virtual reading rooms and digital literature exhibition spaces, thereby enriching the learning experience (Lu & An, 2025). RFID technology has revolutionised resource management by automating the circulation of goods, minimizing human error, and improving inventory accuracy (Nizetic et al., 2020). Meanwhile, IoT applications such as smart shelving systems and environmental monitoring sensors enable libraries to optimize space usage, regulate environmental conditions, and generate data-driven insights into user behaviour (Venugopal & Somanadh, 2024).

As higher education institutions increasingly recognize the value of these technologies, adopting IoT and RFID in academic libraries presents both opportunities and challenges. On the one hand, these technologies promise to increase the efficiency and effectiveness of library operations, reduce operational costs, and provide a more engaging and responsive experience for library users. On the other hand, successful implementation requires significant investments in infrastructure, continuous staff training, and overcoming resistance to change (Kaba & Ramaiah, 2019). Additionally, concerns about security and the complexities of integrating these technologies into existing library systems remain significant barriers to widespread adoption (Igwe & Sulyman, 2022).

IoT technologies facilitate real-time monitoring, automation, and intelligent data collection, allowing libraries to optimize space utilization, monitor environmental conditions, and personalize user services (Ram et al., 2023). Meanwhile, RFID technology offers substantial benefits in automating circulation processes, improving inventory management, and enhancing

the security of library resources. Using IoT technology, most of the activities carried out in libraries can be done smartly (Zhou, 2024). The convergence of IoT and RFID within library systems promises operational efficiency and transformative service delivery models that align with users' evolving expectations in the digital age.

Despite its promising potential, implementing IoT and RFID technologies in academic libraries faces significant challenges. Key barriers to digital adoption in developing countries include high implementation costs, limited infrastructure, data privacy concerns, and the need for continuous staff training (Kuntoro & Suseno, 2024). Furthermore, empirical studies assessing these technologies' practical impact on library management efficiency remain scarce, particularly within higher education institutions in developing regions. To date, no quantitative research has specifically examined the impact of IoT and RFID integration in the libraries of State Islamic Higher Education Institutions (Perguruan Tinggi Keagamaan Islam Negeri or PTKIN) in Indonesia.

This study aims to quantitatively analyse the impact of implementing IoT and RFID technologies on library management in Islamic higher education institutions, focusing on the UIN Imam Bonjol Padang Library. Specifically, it investigates the effects of IoT and RFID on collection tracking, user service responsiveness, and resource security. In addition, this study explores the challenges associated with limited infrastructure investment and the technical capacity of library staff. By identifying both the benefits and barriers, the findings are expected to contribute to formulating technology implementation policies in PTKIN libraries and enrich academic discourse on smart libraries in developing country contexts.

Literature Review

Integrating IoT and RFID technologies into academic libraries marks a transformative shift toward realising smart libraries. These technologies enable real-time collection tracking, automated resource management, and enhanced user service responsiveness, aligning library operations with the demands of the digital era. In the context of higher education institutions, smart libraries are not merely about adopting new tools, but about reengineering library management practices to become more data-driven, user-centered, and operationally efficient. By embedding IoT sensors, RFID-enabled inventory systems, and automated service kiosks, libraries can optimize resource accessibility, improve security, and deliver personalized experiences to their academic communities. Understanding the dynamics of this technological integration is critical for evaluating how libraries can sustainably evolve to meet the increasingly complex expectations of users in a rapidly changing information environment.

Smart Libraries

The concept of Smart Library is a further evolution of library digitalization that combines advanced technology, smart users, and innovative services in creating an integrated, adaptive, and user-friendly information system. Based on the article by Giri (2024), smart libraries emerged in response to rapid developments in computer technology, the internet, human-computer interaction, and telecommunications since the early 2000s. Various software and tools support routine library activities in smart library management while providing new services. RFID technology, Internet of Things, big data, cloud computing, artificial intelligence, and other cutting-edge technologies provide superior and intelligent library services (Bairagi & Lihitkar, 2024). Cloud computing enables scalable and flexible storage solutions, making extensive digital collections accessible from anywhere. AI supports intelligent search functions, predictive analytics, and automated content curation, assisting users and administrators in

navigating increasingly complex information environments. Furthermore, data mining empowers libraries to uncover user behaviour patterns, informing strategic decisions regarding collection development and service enhancements.

This approach addresses specific challenges by bringing computing capabilities closer to the data source (edge), enabling real-time data processing, and providing localised services, which is especially beneficial in a library environment (Das & Inuwa, 2023). By utilizing user profiles, interaction histories, and recommendation systems, libraries can provide targeted information resources that enhance user engagement and satisfaction. Moreover, operational automation through automated doors, intelligent lighting systems, and self-service kiosks supports 24/7 service accessibility with minimal staff intervention. Facilitate automation using analytics and machine learning, enabling IoT systems to manage processes autonomously and respond to conditions without human intervention (Choudhary, 2024). These innovations increase user convenience and allow library staff to allocate more time to high-value services like research support and academic outreach, positioning smart libraries as efficient, adaptive, and sustainable pillars of modern higher education.

By utilizing user profiles, interaction histories, and recommendation systems, libraries can provide targeted information resources that enhance user engagement and satisfaction. Moreover, operational automation through automated doors, intelligent lighting systems, and self-service kiosks supports 24/7 service accessibility with minimal staff intervention (Padhi & Nahak, 2019). These innovations increase user convenience and allow library staff to allocate more time to high-value services like research support and academic outreach, positioning smart libraries as efficient, adaptive, and sustainable pillars of modern higher education.

Smart library is a new generation library that integrates smart technology, smart users, and smart services. By adopting cutting-edge technology, the library bridges traditional services with the needs of the digital society, thus remaining relevant, efficient, and user-oriented (Gul & Bano, 2019). Manikpare & Bherwani (2024) emphasize that Smart library management is the application of advanced technology and digital systems such as IoT, RFID, AI, and automation to improve operational efficiency, user experience, and optimize the use of library resources. Orji & Anyira (2021). Smart Automation enables automation based on embedded systems and wireless technology, culminating in the IoT that connects objects through sensors without human intervention. In libraries, IoT is at the heart of smart libraries through RFID, self-check kiosks, and metadata-based semantic search. Together, these objectives position smart libraries as proactive, adaptive environments capable of meeting the evolving needs of academic communities.

IoT and RFID

IoT offers transformative opportunities for libraries, enabling them to evolve into intelligent environments that enhance user experiences and operational efficiency. By integrating IoT technologies, libraries can provide innovative services, improve resource accessibility, and foster a more interactive learning atmosphere. Smart libraries enhance management efficiency and effectiveness by using IoT to automate operations and enable real-time resource control through applications like energy management, environmental monitoring, and logistics data collection (Farkhari et al., 2024). Employing data analysis and big data on user behaviour and preferences empowers libraries to tailor their services and collections to meet user needs (Farkhari et al., 2024). Technologies such as RFID tags and smart sensors significantly enhance resource accessibility and assist users in navigating library spaces more effectively (Jacobs,

2022). These developments illustrate how IoT can reshape traditional library operations, creating more dynamic and responsive environments.

In academic library settings, integrating IoT technologies supports the development of hybrid services that adapt to physical and virtual learning environments, a shift that has become increasingly important in the post-COVID-19 era (Jacobs, 2022). Innovative technologies like cloud computing and artificial intelligence further allow libraries to design adaptive and intelligent service models (Jacobs, 2022). However, despite the promising potential of IoT, the current research landscape reveals significant gaps. Empirical studies on the practical application of IoT in libraries remain scarce, limiting a comprehensive understanding of its impacts (Amaral et al., 2024). Moreover, advancing IoT applications in libraries necessitates interdisciplinary collaboration between computer science and library science fields (Amaral et al., 2024). Addressing these challenges is crucial for realizing the full potential of IoT in academic library environments and ensuring that technological innovation translates into meaningful improvements in service quality and operational effectiveness.

Library Management Transformation through Technology

Technology integration into library management has been driven by the need to increase efficiency, enhance user experience, and adapt to the evolving information landscape. Libraries are no longer just physical knowledge repositories but have transformed into dynamic, technology-driven hubs offering various digital services and resources. This transformation is rooted in several theoretical frameworks, including sociotechnical systems theory, which emphasizes a complex interaction between technology and the social subsystems (Zhou et al., 2023).

IoT also plays a significant role in transforming library management. IoT technologies, such as smart shelves and RFID tags, have enabled libraries to automate routine tasks such as inventory management and circulation, freeing staff to focus on more strategic and user-oriented activities. Implementing artificial intelligence systems in libraries has proven that these systems are less likely to make errors than humans; they can work 24/7 without getting tired, freeing librarians to do other work (Oname & Alex-Nmecha, 2019).

Prasad & Jahnavi (2019) IoT facilitates seamless resource tracking, personalised recommendations, and real-time data analytics, while offering task automation, remote monitoring, large-scale data analysis, and cost efficiencies, all of which empower librarians to make informed decisions and provide optimal support to users. Meanwhile, Novida et al. (2024) underlined the importance of cross-sector collaboration between librarians, technology developers, and institutional management to build a sustainable smart library ecosystem. Without policy support and HR training, the transformation towards a smart library is challenging to achieve comprehensively.

Results and Discussions

Results

The research on adopting IoT and RFID in State Islamic Higher Education Institutions was conducted by distributing questionnaires to librarians. The results were categorized into three aspects: the utilization and application of IoT and RFID for collection tracking, the responsiveness of user services, and the security of existing resources. Through this analysis, it

is anticipated that the effectiveness and efficiency of library management within these institutions can be enhanced.

The questionnaire was distributed to stakeholders, including general administrators, Professional Librarian I, Professional Librarian II, and Professional Librarian III. The distribution proportions were as follows: general administrators (10%), Professional Librarian I (30%), Professional Librarian II (40%), and Professional Librarian III (20%). This allocation aims to obtain representative feedback from each group involved in the study, as illustrated in Figure 1.1 below.

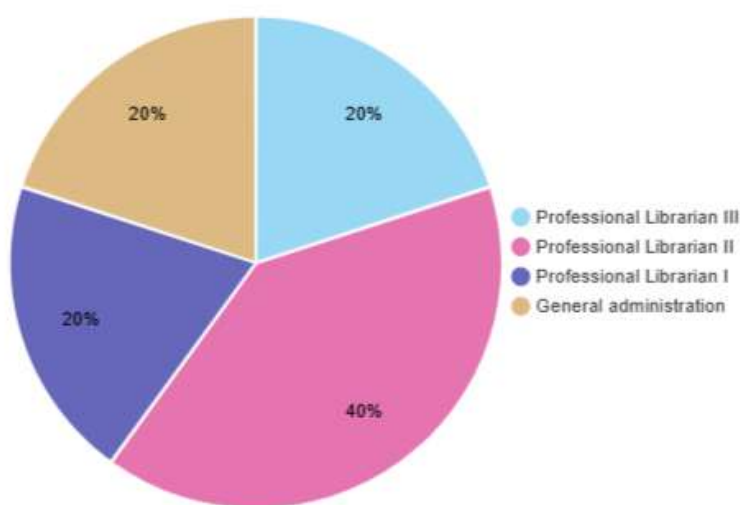


Figure 1: Librarian Distribution Proportion

Source: Research Results

As shown in Bar Chart 1, most librarians agreed that implementing IoT and RFID systems significantly enhanced the accuracy of inventorying collections. Additionally, other librarians reported that these systems facilitated the process of locating collections, enabling quicker identification of misplaced or missing items and improving overall service efficiency. These findings underscore the positive operational impact of IoT and RFID technologies on library collection management.

However, the other librarians who strongly disagreed highlighted that the adoption experience was not uniform across all staff. Such differing perceptions may arise from variations in technical proficiency, confidence in system usage, or disparities in training received. From a managerial perspective, these results emphasize the need for targeted training, structured capacity-building initiatives, and user-focused system adjustments to ensure consistent adoption and fully maximize the benefit of IoT and RFID systems.

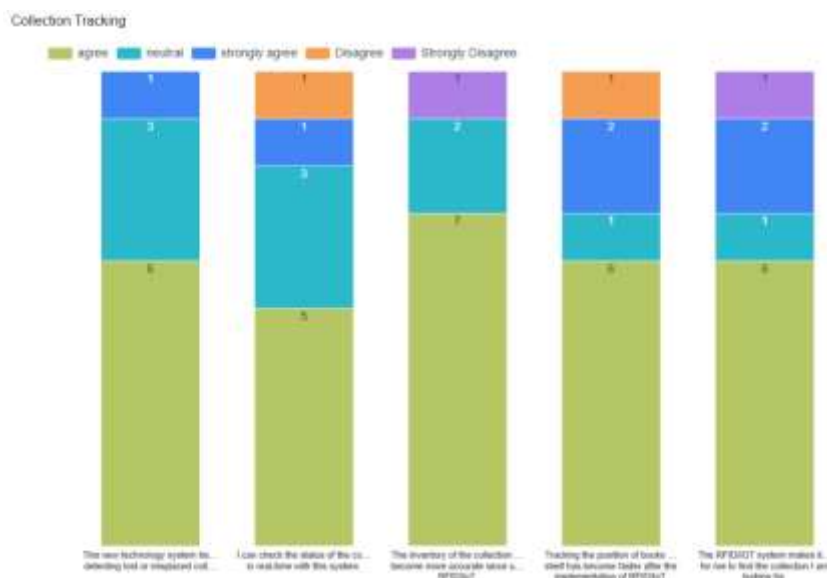


Figure 2: Collection Tracking

Source: Research Results

The survey results presented in Figure 3 show that most librarians agreed that the IoT and RFID system made it easier to locate collections, demonstrating the positive operational benefits of these technologies in improving efficiency and simplifying collection tracking. However, the neutral response from a mid-level librarian and a junior librarian's strong disagreement highlight divergent staff experiences. These differences may stem from technical proficiency variation, confidence in the system, or the extent of training received. From a managerial perspective, these findings underscore the need for structured capacity-building programs, tailored technical training, and ongoing user support to ensure consistent adoption and equitable benefits of IoT and RFID systems across all librarian levels.



Figure 3: Collection Tracking - The IoT and RFID System Makes It Easier for Me to Find the Collection I am Looking For

Source: Research Results

Most librarians agreed that the IoT and RFID system made it easier to locate collections, highlighting the positive operational impact of these technologies on efficiency. However, the responses of one neutral and one strongly disagreeing librarian, particularly the junior librarian

who disagreed, signal divergent perceptions among staff. These differences may stem from variations in technical proficiency, confidence in system usage, or limited training exposure. From a managerial standpoint, these findings underscore the importance of tailored capacity-building initiatives and continuous user support to ensure consistent adoption and optimal utilization of the IoT and RFID systems across all librarian levels

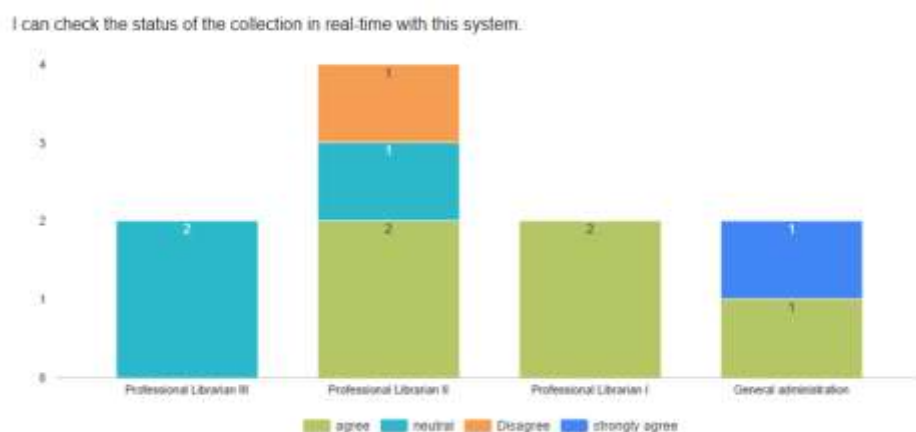


Figure 4: Collection Tracking - I Can Check the Status of the Collection in Real-Time With This System

Source: Research Results

Most respondents agreed that IoT and RFID systems significantly enhance user service responsiveness by accelerating borrowing and returning processes and streamlining interactions with library staff. These improvements meet user expectations, increase engagement and satisfaction, and demonstrate the technologies' critical role in modernizing service delivery. By automating routine circulation tasks, these systems allow librarians to focus on value-added services, such as consultation and guidance. The data they generate enables timelier and more personalized information delivery, improving the quality of user interactions.

However, neutral and dissenting responses highlight that not all users and staff experience these benefits equally. These differences may be due to technical challenges, varying levels of training, or user familiarity with the systems. From a managerial perspective, this underscores the need for continuous training, proactive user education, and ongoing system evaluation to ensure equitable benefits and optimal performance. By addressing these gaps, libraries can fully leverage IoT and RFID technologies, resulting in higher operational efficiency, improved user experiences, and stronger patron loyalty.

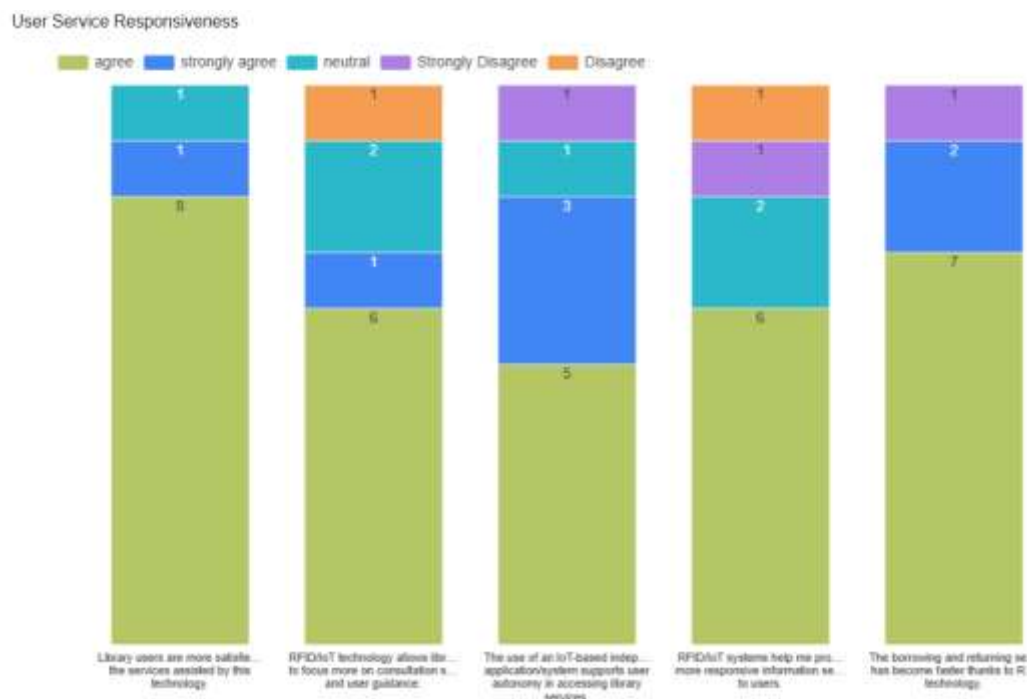


Figure 5: User Service Responsiveness

Source: Research Results

The utilization of IoT-based self-service applications assists users in accessing library services more independently. In this context, most librarians expressed support for implementing IoT-based applications at their libraries, enabling users to take greater initiative in utilizing library services. This shift towards increased user autonomy is illustrated in the figure below. Such advancements empower users and enhance overall service efficiency, reflecting a positive trend in library management practices and user engagement.

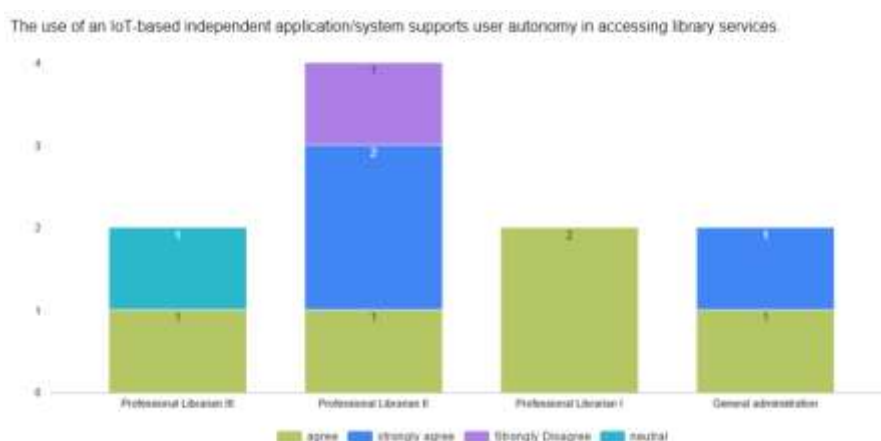


Figure 6: User Service Responsiveness - The Use of an IoT-Based Independent Application/System Supports User Autonomy in Accessing Library Services

Source: Research Results

The findings show that the majority of respondents agreed that IoT and RFID based security systems effectively prevent the loss of library collections. This underscores the positive impact

of advanced security measures in protecting valuable assets, fostering trust among library visitors, and increasing staff confidence in managing resources. The use of security alarms and automatic notification has proven effective in providing early warnings, minimizing risks, and ensuring that collections remain well-maintained. Such proactive measures are crucial for establishing a secure and trustworthy library environment.

Respondents also highlighted the benefits of automatic monitoring and notification systems, considering them vital for detecting misuse and improving operational efficiency by reducing manual oversight. These features allow librarians to focus more on user services and strategic tasks, rather than routine monitoring.

However, the survey also revealed neutral and dissenting responses, indicating divergent perceptions among librarians. The differences may stem from variations in technical skills, confidence in the reliability of the systems, or the level of training received. From a managerial standpoint, this highlights the importance of continuous system evaluation, structured staff training, and ongoing technical support to ensure seamless adoption and uniform benefits across all staff levels. By addressing these challenges, librarians can fully optimize IoT and RFID solutions, enhancing security, operational efficiency, staff confidence, and a more reliable environment for all users.

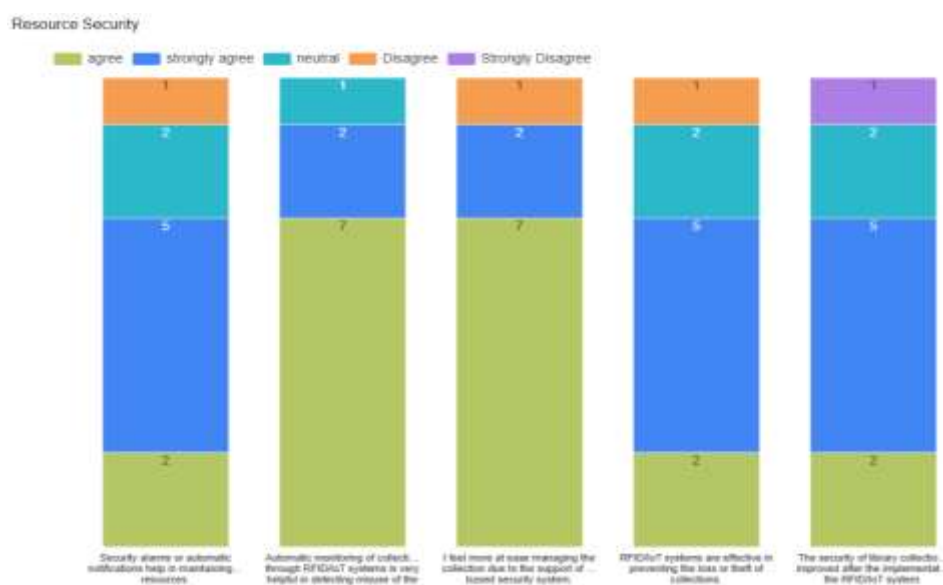


Figure 6: Resource Security

Source: Research Results

Implementing IoT and RFID systems in libraries has significantly improved the security of collections, with most respondents indicating that these technologies effectively protect library assets. These systems not only help reduce the rate of collection loss but also play a critical role in strengthening user trust in library services. As libraries adopt more advanced security features, they can deliver more optimal and reliable services to their patrons.

Across various professional levels (Professional Library I-III), most librarians strongly or moderately agreed on these systems' effectiveness. This reflects broad professional recognition of the importance of smart technologies in modern library management, which, in turn, facilitates smoother adoption and greater institutional support.

However, neutral and dissenting responses signal a divergence in perceptions. These variations likely stem from differences in training exposure, technical familiarity, or confidence in the reliability of these systems. From a managerial perspective, this underscores the need for continuous evaluation, structured staff training, and targeted capacity-building initiatives to ensure that all librarians can fully utilize these technologies. By closing these gaps, libraries can maximize IoT and RFID's operational and security benefits, enhance staff confidence, and create a more trustworthy, efficient, and adaptive library environment faster.

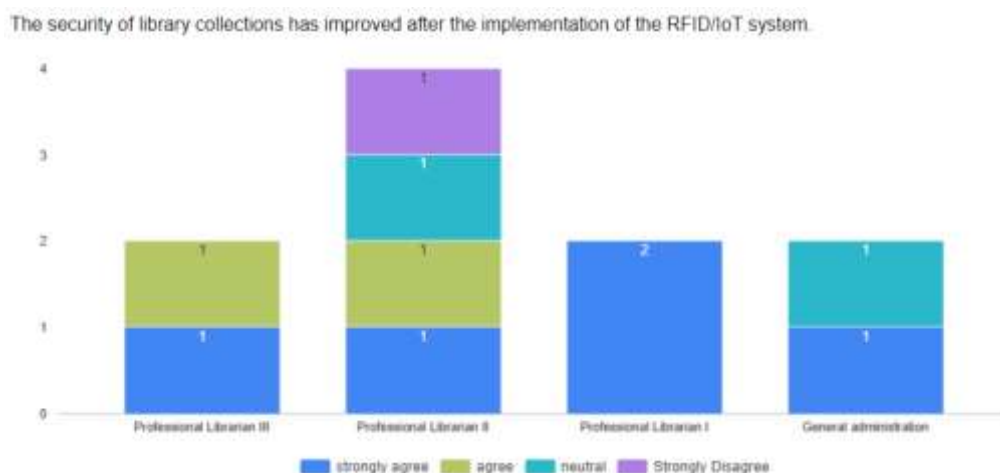


Figure 7: Resource Security - The security of library collections has improved after the implementation of the IoT and RFID system

Source: Research Results

Discussions

The results of this study affirm the transformative potential of IoT and RFID technologies in redefining academic library management. At Perpustakaan UIN Imam Bonjol Padang, both technologies have enhanced three core dimensions: accuracy in collection tracking, responsiveness in user services, and robustness in resource security. These findings align with global literature highlighting how smart technologies introduce automation, reduce human error, and facilitate real-time data flows within library systems (Adigun et al., 2024). In particular, RFID enables seamless circulation and inventory management, reducing reliance on manual input and freeing up staff time for more value-added tasks such as research assistance and information literacy training. However, the study also reveals a critical disparity between technological potential and institutional capacity. One of the most persistent challenges identified is the insufficient investment in infrastructure.

Although the intent to digitize and modernize is present, many academic libraries, particularly in Islamic higher education institutions, are constrained by limited budgets, bureaucratic procurement procedures, and competing institutional priorities. This infrastructural lag becomes even more problematic when integrating multiple smart systems such as automated doors, sensor-based lighting, or personalized digital interfaces. As Amaral et al. (2024) argue, IoT systems risk becoming fragmented or underutilized without sustained infrastructure support, functioning only as isolated pilot projects rather than being scaled as institutional standards. Equally significant is the issue of human resource development. This study confirms that many library staff lack the technical competencies to operate, maintain, and adapt IoT-based systems. Training is often ad hoc, limited to introductory workshops, and not integrated into continuous professional development programs. This competency gap not only undermines

the effectiveness of the technology but also contributes to resistance to change among staff members.

The findings from this research provide actionable insights for policymakers, library administrators, and higher education leaders who aim to advance the digital transformation of academic libraries. First, there is an urgent need for institutional policies prioritizing infrastructure investment for smart technologies. Without dedicated budget allocations for IoT systems, including RFID, sensors, and integrated platforms, libraries will continue to lag in service innovation. Government funding schemes, especially for Islamic higher education institutions, should include technology grants that are earmarked for smart library development. (Adigun et al., 2024; Farkhari et al., 2024)

Second, strategic capacity building must become a core component of library modernization. Professional development programs should go beyond general ICT training and focus on emerging competencies related to IoT integration, data analytics, and system troubleshooting. Khan et al. (2023) and Vijayalatha (2023) say library science curricula in higher education should also be revised to include modules on smart technologies and digital service design, thereby preparing a new generation of tech-literate librarians.

Third, adopting IoT and RFID should be guided by a clear digital transformation roadmap at the institutional level (Parra-Sánchez, 2025). This roadmap must align with broader academic goals, such as improving research productivity, enhancing student digital literacy, and supporting hybrid learning models. Furthermore, implementation should be phased, allowing for iterative assessment and feedback from users and staff. This would reduce resistance to change and ensure sustainable integration.

Fourth, interdisciplinary collaboration and stakeholder engagement are essential. University IT departments, faculty representatives, and even student organizations should be involved in the planning and evaluation smart library systems (Meesad & Mingkhwan, 2024). Such collaboration can help ensure that technological implementations are relevant, ethical, and aligned with user needs. For institutions with Islamic identity, it also opens opportunities to frame digital policies sensitive to local cultural and moral values.

Lastly, the study encourages the development of national or regional smart library frameworks under the coordination of professional associations (Jinendran Jain & Kumar Behera, 2023) such as APPTIS (Asosiasi Perpustakaan Perguruan Tinggi Islam). These frameworks could provide guidelines, benchmarks, and case studies to assist member institutions in designing, implementing, and evaluating IoT-based library innovations. By institutionalizing these policies and managerial recommendations, libraries in Islamic higher education can more confidently embrace the smart library paradigm, not merely as a trend, but as a strategic pathway to institutional excellence and user empowerment.

Conclusion

The conclusion of this study quantitatively analyzes the impact of the adoption of IoT and RFID technologies on library management within the context of Islamic higher education, specifically at the UIN Imam Bonjol Padang Library. The findings indicate that integrating these technologies has significantly improved collection tracking, user service responsiveness, and resource security. Implementing IoT and RFID systems has enhanced the efficiency of library operations, making resources more accessible and services more personalized for users.

However, the research also highlights persistent challenges, particularly related to insufficient infrastructure investment and limited technical competencies among library staff, which hinder the complete optimization of these technologies.

The study underscores the need for continued investment in technological infrastructure and professional development to fully leverage the benefits of IoT and RFID in library management. Additionally, it emphasizes the importance of strategic planning and collaborative efforts to overcome the barriers to effective technology integration. By addressing these challenges, libraries in Islamic higher education institutions can better harness the potential of smart technologies to improve library services and operational efficiency. Ultimately, this research offers valuable insights and strategic recommendations for the future development of smart library systems in higher education settings.

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