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A Comprehensive Review of RFID-Based Smart Library Management Systems Using IoT and ESP32

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Abstract: *The Internet of Things (IoT) technologies have evolved at a very high rate, replacing the traditional library management systems with smart, automatic, and efficient management systems. Among these, RFID-integrated library systems have come out as an effective solution in the automation of issuing and returning library books and controlling their location and use of their hardware by the users. The paper is a critical overview of RFID-based library management systems merged with IoT systems based on ESP32, ESP8266, and Arduino microcontrollers. The research examines different systems that integrate RFID technology within wireless communication system such as Wi-Fi, cloud systems, and mobile apps, for real-time data synchronization and links. Also, recent research work is analyzed to be able to see the major tendencies in automating, tracking in real-time, intelligent security, and the implementation of advanced technologies, including machine learning and robotics. The benefits of increased efficiency, low human input, higher accuracy, and user experience are clarified, whereas such weaknesses as security vulnerability, network reliance, the expensive cost of implementation, and the complexity of the system are examined critically. Also, the comparative analysis of the existing systems requires that scalable, secure and intelligent solutions are needed. The potential future developments, such as the automation of systems based on artificial intelligence, edge computing, and security utilizing blockchain methods, are also discussed to improve the performance and reliability of the system. The results of this survey have great value in explanation to researchers and developers of tomorrow working on structuring and furnishing next-generation smart library systems as bespoke, safeguarded and scalable structures*

Keywords: RFID, IoT, Library Management System, ESP32, Smart Library, Automation, Book Tracking, Wireless Communication

I. INTRODUCTION

The continued development of digital technologies and, in particular, the Internet of Things (IoT) has dramatically changed the traditional systems into smart, automated, and networked solutions. The library management systems are one of the largest spheres where this change can be observed. Conventional libraries are time-consuming, prone to errors and inefficient manual procedures of issuing, returning and maintenance of books. As the need to automate more and make libraries accessible in real-time, RFID-based and IoT-based smart library systems have become an efficient method of enhancing efficiency and user experience [1], [10].

Barcode-based technologies were useful in the automation of libraries in earlier library systems, but barcode technologies need manual handling and line of sight in scanning, which restricts their performance and scale. The RFID technology addresses these shortcomings because it allows contactless identification, quicker processing, and

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simultaneous reading of multiple tags. Research like [11], [12] points out that the speed, accuracy, and tracking of transactions in an RFID-based system are much better than the old-fashioned methods. These systems offer automated check-in/check-out services, inventory management, and improved security mechanisms; hence, they are appropriate in the current digital libraries.

IoT also improves the RFID-based systems by facilitating real-time communication between the hardware and cloud-based applications. ESP32 and ESP8266 microcontrollers are very common as they have an inbuilt Wi-Fi feature and are low-cost with high processing power [1], [6]. The systems are linked to RFID readers, databases, and web interfaces to give real-time tracking, user authentication and transactional control. Studies like [8], [9] prove that smart library systems made possible by the IoT can enhance data synchronization, automate the process of tracking books, and make the entire operation more efficient.

The recent developments have gone beyond basic automation of smart library systems by adding other functionalities like mobile applications, robotic navigation, and intelligent recommendation systems. To provide an example, robotic-assisted library systems are suggested in studies such as [2], [3], which automate the process of book search and retrieval to minimize human efforts and enhance the convenience of the users. On the same note, deployment of machine learning tools, as addressed in [1], allows personalization of recommendations and smart decision making, which further improves the use of smart libraries.

In addition, cloud computing and mobile-based access have greatly enhanced the interaction of the user with the library systems. Android-based systems that can be integrated with cloud platforms enable users to search, book and manage books remotely, thus saving on waiting time and enhancing accessibility [19]. The transparency is ensured by real-time notification, fine calculates automatically, and user dashboards, which enhance the overall satisfaction of the users. These developments coincide with the idea of smart campuses and the digitalization of educational institutions.

Although these have been developed, there are still a number of issues in RFID and IoT-based library systems. The problem of security and privacy is an important matter since user-sensitive information is passed through the network [5], [7]. Moreover, the performance of most systems in the low-connectivity environment is highly reliant on the network connectivity. Such other issues are high implementation cost, complexity of the system, absence of standardization and scaling issues of large-scale deployment [6], [15]. Such limitations denote that there is a necessity to conduct further research, in an attempt to come up with more secure, scalable, and cost-effective smart library systems.

The major aim of the review paper is to offer an in-depth discussion on the RFID-based smart library management systems by identifying available researches, methodologies and technologies. The purpose of this paper is to (i) investigate the current trends in RFID and IoT-based library systems, (ii) review literature on various implementation strategies and their efficacy, (iii) find major challenges and gaps in the research literature, and (iv) discuss the future opportunities in designing smart, intelligent, and secure library management systems.

II. LITERATURE REVIEW

Keerthana et al. [1] introduce an intelligent library management system that combines RFID, IoT and machine learning to achieve intelligent automation. RFID scanner modules (MFRC-522, ESP8266), web applications based on Django, MySQL database, and recommendations systems based on ML models are used as a methodology. Efficient data processing and real-time communication are achieved with the help of a three-tier architecture (hardware, application, data layer). Outcomes indicate better performance by operations, minimized human error, high data accuracy, and individual user suggestions. The discussion identifies scalability, smart decision-making, and better interaction with users with the help of ML integration. Limitations, however, are dependency on network infrastructure, complexity of the system and cost of hardware. The gap in the research is to optimize the ML models on the real-time performance, enhance system reliability, as well as lowering the cost of implementation to allow widespread implementation in educational institutions.

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B. Yagna Sudhamani et al. [2] introduce the RFID-based smart library system with robots to search books automatically. This is carried out through the methodology of giving the subject categories RFID tags and having a robot that will follow a specific path in order to lead users to a specific shelf. This is an Arduino-based system, which combines an RFID reader, motors, display module to provide real-time feedback. The outcome is that it is more efficient in searching books and less manual work than traditional systems. It improves the user experience by reducing the search time and human reliance. The system is, however, not very flexible in dynamic path planning and real-time obstacle avoidance. The gap in research is the lack of intelligent navigation, database integration, and scalability to large libraries, which implies that it should be offered to have AI-based path optimization and real-time tracking systems.

Mithun Jaya Kumar et al. [3] introduce a self-guided library management robot that consists of RFID, line-following navigation using IR, and robotic arm movements. The control methodology includes an ESP32 microcontroller, RFID-based book recognition, and a robotic arm with a gripper to be used to automatically retrieve books. The system also has a mobile application to interact with the users and to monitor in real time. Findings indicate accuracy in book identification and a decrease in manual workload, as well as effective navigation and retrieval tasks. Improved automation and ease of use over the traditional systems are noted in the discussion. Limitations, however, are that it relies on predetermined paths, does not avoid obstacles and is not scalable in dynamic environments.

Baskar M et al. [4] introduce a Dropbox technology with an IoT-enabled automated system for book returning on RFID. The RFID-tagged books, an ESP32 microcontroller, an RFID reader, and a web-based backend based on PHP and MySQL are used as the methodology to update the database in real-time. The system automates the checking-in of books and makes changes to library records immediately. The findings reveal 100 percent detection and less time of processing (1.2 seconds per transaction), which is much better about efficiency than the manual systems. The discussion includes workload reduction in librarians, accelerated work and improved user experience. Nevertheless, the system is dependent on constant Wi-Fi connectivity and requires extra expenses on RFID tags. The gap in the research is the incorporation of modern features such as mobile notifications, security warnings, and predictive analytics to increase automation and scalability.

Jay Singh et al. [5] introduce an IoT-based RFID and ESP32-based device identity mechanism that is secure. The algorithm includes identification of RFID-based devices, ESP32 microcontroller processing, and incorporation of cloud-based database authentication and access control. The system checks RFID-tagged devices with LEDs and buzzer alerts to give real-time feedback. Findings indicate that there is enhanced security, effective authentication, and scalability of the IoT systems. The points of discussion include improved management of devices, less illegal access, and effective real-time processing. But some of its limitations are that RFID communication may be vulnerable to security attacks and reliance on a network connection. Some gaps in the research include the creation of a more sophisticated encryption method, enhancing the security measures, and using AI-threat detection as a means of creating more resistant and scalable security systems in IoT.

In reference [6], Igbinosa et al. offer a performance analysis of an RFID-based smart library system that will enhance operational performance when compared to traditional systems. The methodology consists of the synthesis of passive RFID tags, an ESP32 microcontroller, Wi-Fi communication, and a cloud-based Library Management System to monitor and automate the process of transactions with the books in real-time. Performance of the system is measured by network stress testing and performance measures. Findings indicate that more than 99% of the systems are up, that overall detection was high, and that the transactions were faster than the manual workload, which substantially decreased manual work and increased customer satisfaction. The discussion points out the advantages of increased automation, real-time tracking, and scalability compared to the barcode-based system. However, the problem has some drawbacks that include dependence on infrastructure and the cost of the initial setup. The research gap is in achieving system robustness of a heavy-traffic system, improving the security features, and integrating smart analytics for resource prediction.

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Another developed system of smart library security using RFID-based technology and cognitive sensing is presented in the research paper by Krishnamoorthy et al. [7]. It can be defined as the process of using integrated RFID technology, IoT sensors, machine learning algorithms, and edge computing for authentication and other purposes. In this system, the RFID values are obtained using smart perception layers and can be implemented using security algorithms for real-time monitoring. The results have shown that the system provides better recognition (97.8%), fewer false positives, and the response time was faster than that of the traditional system. From the discussion, it is clear that the system provides high security and resource tracking and can adapt to changing environments. However, some of the challenges associated with the system include complexity, computational power, and privacy. The research gap in the paper is the need to develop new protocols based on security and privacy while improving real-time processing and balancing privacy and intelligent monitoring in a smart library.

Bhavya Sri et al., in their research paper titled "Design and Development of an Improved Library Management System Using RFID and IoT," propose an RFID and IoT-based improved library management system that aims to achieve the goals of tracking and automation in real time. In the research approach, the researchers have used the concept of using RFID tags, ESP8266 microcontrollers, Firebase database, and web-based interfaces to ensure a smooth flow of communication. Other features include book location indicators using LEDs, notifications, and finding lost books. The results have shown that the accuracy of book tracking has improved, business transactions have become faster, and the user experience has become better. In the talk, the features of the system, being scalable, managing the system effectively, and improving the security of the system by authenticating users, have been highlighted. However, some drawbacks of the system, being hardware-dependent and the system being complex, have also been noted. The gap in the research has been noted as the combination of an AI-based recommendation system, an increase in the reliability of the system, and its expansion to libraries with huge user traffic.

Sagar Kale et al. [9] proposed a smart library management system based on RFID-IoT technology that is implemented on a shelf to track and organize books effectively. The research methodology used is based on implementing RFID books, IoT devices, Atmega328 microcontrollers, cloud-based library management system technology, and web-based monitoring and controlling technology. The research study has identified that there is better inventory management, human intervention is less, and consumer engagement is better through automated notifications and tracking. The discussion has identified that there is better efficiency in the system, better scalability and convenience for the consumer too. The limitations identified in the study are based on dependency on hardware and cost factors, too. The gap identified in the research is based on how AI-based analytics can be integrated to improve the efficiency of the system and intelligent library management systems, too.

Jadhav et al. [10] present an introduction to the application of the RFID technology in transforming traditional libraries to smart libraries that are digital in nature. The methodology is based on the analysis of applications in RFID technology for automated check-in/check-out, inventory management, self-service kiosk, and anti-theft systems. The research undertaken is based on comparing the RFID system with the traditional barcode system to assess the level of improvement in its performance. From the discussion presented, some of the issues that come up include staff efficiency, resource management and security in the operation of libraries. However, there are some drawbacks to its application, including its high cost of installation, lack of standardization, and the issue of confidentiality of information on user data. The gap that is identified in the research is the minimization of cost, standardization of systems, and the development of secure systems to ensure confidentiality in data security and efficiency in its application in a digital library.

Abdo et al. [11] introduce an RFID implementation, which is combined with the IoT, to create smart library systems. It is a methodology which includes RFID tags, the wireless sensor networks and the IoT frameworks to allow real-time monitoring, automatic circulation and effective data handling. The methodology applied in a qualitative content analysis is the review of various research studies to assess system effectiveness. It has resulted in increased efficiency in operations, less manual workload, increased security and an accelerated process of book tracking and retrieval. As discussed, RFID systems enabled by the IoT can greatly enhance the experience of users and promote the smart library

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environment through the possibility to automate and monitoring processes in real-time. Nevertheless, privacy issues, security risks of the data, and the complexity of the implementation are pointed out. The gap in the research is the creation of secure and scalable IoT-based architectures, issues of privacy, and the overall interoperability across various library systems to implement on a large scale.

Arfan et al. [12] report the adoption of the RFID-based smart library system to enhance the quality of services and efficiency. Some of the processes found in the system workflow diagram on page 7 include tagging, self-check-in/out and anti-theft detection. Findings reveal a decrease in transaction time, accuracy, security and effective management of large-scale library activities. It is highlighted in the discussion that it has led to faster data processing, less staff work and increased user satisfaction. Nonetheless, issues such as high implementation cost, privacy concerns, and signal interference problems can be considered as challenges. The research gap is closing the gaps in the cost-effective RFID solutions, enhancing data security, and incorporating the smart capabilities of predictive analytics and automated decision-making in smart libraries.

Vipashyana Jangale et al. [13] propose smart shelf inventory management using IoT technology with the aid of a sensor and ESP32 microcontroller technology. The methodology of the study includes the use of ultrasonic sensors in the inventory level monitoring, the use of IoT technology in the real-time transmission of data, and the monitoring of the inventory using the cloud. The study has demonstrated the following findings: there is improved efficiency in the monitoring of the inventory, there is less human involvement in the inventory management, and the inventory is monitored in real-time. The discussion has demonstrated the improved decision-making using data analysis and the automation of the inventory. The limitations of the study are the errors in the sensors and the failure of the sensors to queue the untracked manual deletion of the inventory. The gaps in the research are the need for the hybrid technology of IoT and RFID in inventory management, the need for accuracy in the inventory, and the smart prediction models in the decision-making process.

In the paper by Shiny Christobel et al. [14], the RFID-based system and the IoT-based smart student identity card for the management of libraries are introduced. The methodology of the research involves the RFID-based ID cards with the IoT infrastructure, which enables the RFID reader, sensors, and server to communicate with each other by using the client/server architecture. The results show that the system improves the efficiency of the book transactions, minimizes the errors, and ensures the security of the book transactions by real-time monitoring. Some of the reasons for the research, as identified in the discussion, include the improved user experience, speed, and smooth access to the library services. However, the system relies on the network connectivity, and the hardware needs to be deployed to a large extent for the system to be effective. The gap identified in the research is to improve the data security and manage the large scale of the system, as well as the introduction of AI-based analytics to be used to predict the usage of the system and provide intelligent recommendations for the library system.

The article by Maharwal et al. [15] can be discussed as the analysis of the integration of RFID technology in the library systems in terms of automation and efficiency. The methodology comprises system design that involves RFID tags, readers, software integration and self-checkout systems to have a smooth running of the libraries. Such implementation steps discussed in the study include requirement analysis, selecting tags and integrating the system. The outcomes are better quality of service, decreased human error, greater security with anti-theft systems and increased speed of access to resources. The argument concentrates on the enhanced user convenience, effective circulation control and enhanced library services. Nevertheless, some weaknesses are that they need a lot of start-up capital, require maintenance, and are dependent on technology. The research gap is in minimizing costs, scaling of the system, and the incorporation of advanced technologies such as AI and analytics in making intelligent decisions in libraries today.

Aniket Pattanshetti et al. [16] introduce a smart library system based on RFID and face recognition through the IoT to manage the books automatically. The methodology will comprise RFID-enabled book tracking, face recognition to identify the users and a cloud-based database to manage real-time data. The system enables the person to self-borrow and make returns of the books, which minimizes reliance on librarians. Findings indicate that there have been major improvements in queue time, better book tracking accuracy and convenience to users due to automation. The

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transactions are also notified through email in the system, and enhance user interaction. Nevertheless, the system is highly reliant on network connectivity and can be problematic with regard to privacy and security of biometric information. The research gap incorporates the requirement of enhanced data security, offline capabilities, and the incorporation of intelligent recommendation systems to enhance user experience and scaling of the system.

Reshma Patil et al. [17] introduce a library management system that is based on RFID and that deals with the automation of inventory, circulation, and security. The approach includes RFID tags, readers, antennas, and integrated software systems that will be used to mechanize the check-in/check-out processes and tracking of library materials. It shows that there is increased efficiency in the processes of circulation, less human error, shorter time in managing inventory, as well as improved security by anti-theft systems. The debate focuses on improved user convenience in self-service systems and efficient staff usage. Among other drawbacks, however, are high costs of implementation and reliance on RFID infrastructure. The area warranting research is minimizing the cost of systems, enhancing their ability to integrate with the existing systems and the employment of sophisticated analytics to forecast inventory and user behavior.

Maizatul Mazni Suhaimi et al. [18] introduce the RFID-based Smart Portable Library Management System (SPLMS) that is concentrated on the optimization of the performance of the system. The system design framework that is discussed in the methodology is the ESP8266, RFID reader, Node-RED dashboard, and MySQL database, as well as experimental testing in various angles and distances. The findings demonstrate 100 per cent accuracy in short distances (1-3 m) and lower accuracy in longer distances because of the overlapping of signals, and the best results have been obtained at 90-degree viewer positions. It focuses on the enhanced tracking, increased scanning of various books and increased productivity of the librarians. But this is limited by signal interference problems and the need to have correct reader placement. The gap in the research is the development of adaptive RFID systems that reduce the interference and have smart positioning and incorporation with advanced analytics that enhance reliability and scalability of the system in real-world scenarios.

The proposed library management system by Pai et al. [19] uses RFID technology with an Android-based application to enhance accessibility. The methodology consists of RFID-based identification, server-side database, and Android mobile application, whereby the user could search, request and manage books remotely. The system architecture links the librarian, database server and the users via the mobile devices in real-time. The findings include the shortened waiting time, increased user convenience, effective book tracking, and better system usability. The discussion stipulates the advantages of mobile integration, access in real-time, and less reliance on manual procedures. Nevertheless, it suffers certain drawbacks such as high start-up capital requirements, reliance on the internet connection, and security issues associated with mobile access. The research gap will be addressed in the improvement of security on mobile, expanding the scale, and implementing AI-based recommendations systems to provide individual user experience.

Younis et al. [20] introduce a smart library management system (SLMS), which is an RFID-based library management system used to automate the processes in a library. The methodology will consist of passive RFID tags, readers, door lock systems, database servers and distributed network architecture. The modules included in the system are user entry, tracking of books, borrow and returning, and remote access. RFID readers are installed at the points of entry and transactions, where they are more effective in monitoring. Findings show better automation, less waiting time, a higher level of tracking accuracy and better management of resources. The advantages associated with remote access, better security, and management of large datasets are mentioned in the discussion. But some of the weaknesses include reliance on the network infrastructure and system complexity. The research gap involves an enhancement of real-time processing, better security mechanisms and better scaling of the system in case of large and dynamic libraries.

III. SUMMARY OF LITERATURE SURVEY

Literature review of RFID-based smart library management system indicates that there has been a major improvement in automating the traditional library operations through the use of IoT, RFID, and intelligent technologies. Other researchers have suggested systems based on microcontrollers like ESP32, ESP8266, Arduino, and ATmega-based

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systems and communication technologies such as Wi-Fi, Bluetooth and cloud-based systems. Such systems have allowed automated library operations of issuing and returning books, tracking, managing inventory, and authentication of the user. The researches reveal that RFID technology has been very instrumental in enhancing the efficiency of the system through contactless identification, increased processing speed, and real-time tracing of the library resources. RFID-based systems are more accurate, less manpower-intensive, and user-friendly than traditional barcode-based systems. Moreover, IoT allows real-time synchronization of data, remote monitoring and control of the central database, which is why the library systems have become more scalable and efficient. The introduction of sophisticated technologies, including machine learning, robotic automation, and intelligent security measures, is also a recent trend in research.

The above developments notwithstanding, a number of limitations and gaps in research have been noted. RFID infrastructure is costly, and the requirement for stable network connectivity is a major requirement in most systems. Besides, the common disadvantages of current systems are scalability problems, the absence of standardization, and weak utilization of intelligent analytics. Thus, there is a necessity to create safe, economical, expandable, and intelligent smart library systems that come with new powerful technologies like AI, data analysis and cloud computing to improve on its performance and functionality.

Table I gives a summary of the literature survey.

TABLE I. SUMMARY OF LITERATURE SURVEY

Ref	Author & Year	Technology Used	Controller	Communication	Key Features	Results	Limitations
[1]	Keerthana et al., 2026	RFID + IoT + ML	ESP8266	Wi-Fi	Automation, recommendation system	High efficiency & personalization	Complex system, high cost
[2]	Sudhamani et al., 2025	RFID + Robotics	Arduino UNO	Embedded/Local Control	Book a navigation robot	Faster book search	No AI navigation, limited scalability
[3]	Jaya Kumar et al., 2025	RFID + Robot	ESP32	Wi-Fi	Automated book retrieval	Reduced manual effort	No obstacle avoidance
[4]	Baskar et al., 2025	RFID Dropbox	ESP32	Wi-Fi	Auto book return system	Fast processing (1.2 sec)	Network dependency
[5]	Singh et al., 2025	RFID Security	ESP32	Cloud / Wi-Fi	Device authentication & access control	Improved security	Weak encryption
[6]	Igbinosa et al., 2025	RFID + IoT	ESP32	Wi-Fi	Real-time tracking & monitoring	99% uptime	Network dependency
[7]	Krishnamoorthy et al., 2025	RFID + AI Security	Edge/IoT System	Cloud / IoT Network	Intelligent security & anomaly detection	High accuracy (97.8%)	Complex & costly
[8]	Bhavya Sri et al., 2025	RFID + IoT	ESP8266	Wi-Fi	Book tracking, alerts, and	Improved tracking	Maintenance required

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					misplaced detection		
[9]	Kale et al., 2025	RFID Shelf System	ATmega328	Cloud / IoT	Inventory tracking & voice alerts	Better organization	Hardware dependency
[10]	Jadhav et al., 2025	RFID Library System	Embedded System	RFID + Database Network	Automation, tracking, anti-theft	Faster processing	High cost
[11]	Abdo et al., 2024	RFID + IoT	IoT-Based System	Cloud	Real-time monitoring & data management	Improved efficiency	Security issues
[12]	Arfan et al., 2024	RFID System	RFID Controller Unit	Wired/Wireless Network	Inventory automation & access control	Better accuracy	Signal interference
[13]	Jangale et al., 2024	IoT Inventory	ESP32	Wi-Fi	Stock monitoring & alert system	Real-time alerts	Sensor errors
[14]	Christobel et al., 2024	RFID + IoT	Microcontroller-Based	Client-Server Network	Smart ID system & authentication	Faster transactions	Network dependency
[15]	Maharwal et al., 2024	RFID Analysis	RFID System	Integrated System	Library automation & system analysis	Improved services	High cost
[16]	Pattanshetti et al., 2023	RFID + Face Recognition	IoT-Based Controller	Cloud / Wi-Fi	Smart automation & biometric authentication	Reduced queue time	Privacy concerns
[17]	Patil et al., 2023	RFID System	RFID Integrated System	Network	Inventory, circulation & security	Reduced errors	High cost
[18]	Suhaimi et al., 2023	RFID System	ESP8266	Wi-Fi	Performance analysis & tracking	High accuracy	Signal issues
[19]	Pai et al., 2018	RFID + Android	Embedded System	Mobile / Wi-Fi	Remote access & mobile integration	Improved usability	Security issues
[20]	Younis et al., 2012	RFID SLMS	Distributed System	Network	Full automation & tracking	Efficient system	Complex architecture

The comparative analysis provided in Table I provides a clear demonstration of how the RFID-based library management systems have been developed over the years to transform simple automation systems into smart IoT-based intelligent systems. The initial systems were mainly aimed at automating the issuing of books, taking back books, and tracking the stock in the form of RFID. Nevertheless, current studies show the changes towards incorporating IoT,

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cloud computing, and other innovative technologies to improve system performance and user experience; machine learning, robotics, and intelligent security systems. ESP32 and ESP8266 microcontrollers have gained popularity in the market because of low costs, built-in connectivity and high processing speeds. There are also real-time tracking, automated notifications, mobile application integration, and intelligent recommendation systems, among others, which are also being integrated into contemporary library systems.

With the above developments, the comparison has identified areas of challenge, including security risks, the need for a stable network connection, the high cost of implementation, and the lack of standardization of the system. Most of the solutions available do not have advanced analytics and predictive capabilities, which can be applied to large libraries. There has also been little emphasis on the incorporation of artificial intelligence to enable intelligent decision-making and improve the reliability of a system in a dynamic environment. The results have shown that, despite the fact that the RFID and IoT-based library management systems have improved a lot in terms of automation, there is a lot of room for better, more secure, more scalable, more cost-effective, and more intelligent library management systems to be developed.

IV. DISCUSSION

The concept of RFID-based smart library management systems is a broader trend related to learning spaces and their automation and digitalization. The previously used library management systems were more related to manual or barcode systems, and these systems required a lot of human intervention and were prone to errors, delays, and inefficiencies. The previously used library management systems were also limited in terms of scaling, monitoring, and automation. The development and emergence of RFID systems were a big step forward because they allowed contactless identification and improved the efficiency of transactions and inventory management. However, previously used RFID systems were not highly connected and were not related to modern IoT structures.

In the past years, there has been a strong shift in the implementation of IoT-capable smart library systems, which integrate the RFID technology with cloud computing, web applications, and wireless communication protocols. In recent platforms, there has also been the integration of microcontrollers like ESP32 and ESP8266 with Wi-Fi capabilities and proficient processing capabilities. In these smart library systems, there are also other features like the issuance and return of books, real-time features, calculation of fines, and authentication of users, which have become common in recent implementations. Furthermore, the use of mobile applications and cloud platforms has also been employed in the development of smart library systems, in which the library resources are tracked and managed outside the library.

The other significant development in recent systems is the addition of intelligent and automated capabilities like machine learning, robot navigation, and cognitive security systems. There are systems where robotic assistants are being used in searching and retrieving books, or there are systems where a recommendation system is used based on user behavior. Smart security systems based on AI and cognitive detection have also been introduced in order to enhance authentication and unauthorized access. This is a sign of a decisive tendency towards the creation of smarter, more adaptive and more user-friendly library management systems.

The current systems still have several challenges and limitations in spite of these improvements. Cybersecurity is one of the most important problems because most IoT-based systems are not encrypted, authenticated, or have secure communication protocols, leaving them unprotected against cyberattacks. Another significant issue is network dependency because the functioning of the system is largely dependent on the availability of a stable internet connection that is not always present in any setting. Moreover, the cost of implementation of RFID infrastructure and IoT gadgets is high and may restrict implementation, particularly in small or resource-starved institutions.

Interoperability and scalability also become a major challenge, since most of the systems are configured towards particular environments and are not compatible with other systems or devices. The lack of common communication standards complicates the process of incorporating heterogeneous systems into an integrated system. More so, the complexity of the system is augmented by further functionality like robotics, machine intelligence, and cloud

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connection, which can influence reliability and maintenance. The problem of signal interference, hardware dependency and real-time responsiveness is also found in several implementations.

According to the literature, there are a number of research gaps. Artificial intelligence and data analytics are not entirely applied to make predictive decisions in most of the existing systems, including predicting the demand for a book or understanding user behavior. Little studies have also been done on how to come up with secure IoT architectures that are intended to be used in smart library setups. Also, edge computing and fog computing technology have not been widely investigated to minimize latency and enhance real-time processing. Most systems also do not effectively emphasise user-centric design, particularly with regard to accessibility and ease of use.

It can be projected that in the future, smart library management systems will be smarter, more secured and scalable. Predictive analytics, individualized suggestions, and automated decisions may be facilitated by means of the integration of artificial intelligence and machine learning. Edge and fog computing can enhance the functioning of a system by lessening its reliance on cloud infrastructure and reducing latency. The blockchain technology can be researched to improve the safety of data and provide secure transactions. Moreover, interoperability of various systems and devices will be enhanced due to the creation of standardized communication schemes. The implementation of energy-saving hardware and green design solutions will also help in coming up with cost-effective and green solutions. Altogether, the development of RFID and IoT-based library systems should be the main focus of the construction of next-generation smart libraries and digital educational ecosystems.

V. CONCLUSION AND FUTURE DIRECTIONS

The current review paper will provide a thorough discussion of RFID-driven smart library management systems within the scope of IoT and modern-day automation technologies. The research analyzed several research studies devoted to the system architecture, hardware architecture, communication protocols and implementation methodologies. It is noted that the systems used to manage libraries have changed in terms of abilities, where the traditional and barcode-driven systems have been replaced by the developed RFID and IoT-enabled systems, which can determine the changes in real time and automate the work in such a way that intelligent data processing is possible. The ESP32 and ESP8266, and cloud-based technology have been critical towards facilitating efficient and scalable library systems that are cost-effective and smart. The major solutions that have enhanced the efficiency, accuracy and user experience of library systems in the contemporary world include, without limitation, automated issuance and returns of books, enabling managers to gauge fines on users in real time, mobile and remote access and user identification.

Nevertheless, even with all these developments, there are several issues facing the practical humanization of the smart library systems. Weak encryption and the absence of secure communication protocols, among others, remain one of the biggest security vulnerabilities in IoT-based systems. There is also the dependency on constant network connection, high upfront setup and the complexity of the system, which restricts the adoption of such systems in most institutions. Scalability, interoperability, signal interference and maintenance are all problems the large-scale deployment must face. Moreover, not all of the available systems are fully automated with the application of intelligent technologies like artificial intelligence and data analytics to support advanced automation and decision-making.

More secure, scalable and intelligent smart library management systems should be created and studied in the future by research. With the assistance of artificial intelligence and machine learning, it is possible to provide predictive analytics, automatic decision-making, and individual user services. The use of edge and fog computing systems can be used to enhance real-time responsiveness and decrease latency through reduced dependency on cloud infrastructure. Also, it is possible to consider blockchain-based structures that contribute to guaranteeing data safety and secure and transparent transactions. Interoperability will require the standardization of communication protocols among various systems and different devices. Besides, the needs assessment of cost-effective solutions, energy-efficient hardware, and friendly interfaces will assist in enhancing their usage in different educational institutions.

Summing up, RFID and the IoT-based smart library systems are understood as part of a significant leap in the direction of the digitalization of traditional libraries. As technologies continue to improve and the current issues are properly

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resolved, those systems can become smarter, safer and more effective, contributing to the creation of the next generation smart libraries and smart learning environments.

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