

# Smart Academic Libraries: Leveraging RFID Technology for Seamless Management

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## ABSTRACT

*The evolution of ICT has significantly modernized library operations across the globe, elevating the effectiveness, accessibility, and service quality in information delivery. Among these emerging technologies, Radio Frequency Identification (RFID) has become a significant innovation that enables automation and smart management of library resources. This paper examines the integration and effectiveness of RFID technology in academic libraries, focusing on both its technical and practical dimensions. Using a case study approach, the research explores how RFID supports daily library functions such as circulation, cataloguing, stock verification, and security management. The findings indicate that RFID facilitates seamless transactions, minimizes manual workload, and improves user satisfaction by providing faster and more accurate services. Despite its advantages, challenges such as high implementation costs, dependence on commercial vendors, lack of technical expertise among library professionals, and privacy concerns limit its widespread adoption. The study concludes that RFID technology represents a transformative step toward smart library management, provided that institutions address financial, technical, and ethical constraints through proper planning, training, and collaboration with reliable vendors.*

**KEYWORDS:** RFID, Library Automation, ICT, Academic Libraries, Smart Library Management, Case Study.

## INTRODUCTION

In the modern era of digital transformation, libraries have evolved from traditional information repositories into dynamic, technology-driven service institutions. The integration of Information and Communication Technology (ICT) in library operations has played a vital role in redefining how information is organized, accessed, and disseminated. Among various ICT innovations, Radio Frequency Identification (RFID) has emerged as one of the most significant developments, offering a robust solution for automation, efficiency, and user convenience in library management.

RFID technology utilizes electromagnetic fields to automatically capture and track information from tags affixed to various items. Its use in the library has transformed key functions such as circulation, stock verification, resource tracking, and security control. Unlike barcode-based systems, by allowing multiple tagged items to be detected concurrently without a line-of-sight requirement, RFID substantially reduces manual handling and speeds up

transactions. This technological automation enhances operational efficiency and improves the service experience for library personnel and patrons alike.

In India, the adoption of RFID technology in academic libraries is still in its early stages, primarily due to financial constraints, limited technical expertise, and dependency on commercial vendors. Nevertheless, as the demand for smart libraries grows, institutions are increasingly exploring RFID as a feasible tool for improving service quality and operational accuracy.

This study investigates the adoption, application, and impact of RFID technology in academic library environments, highlighting both the technical framework and practical experiences associated with its implementation. Using a case study approach, the paper evaluates the impact of RFID on day-to-day library functions, identifies challenges faced during adoption, and discusses strategies for sustainable implementation.

## **REVIEW OF LITERATURES**

Krishnan (2021) highlighted various parts of the RFID system in the library like RFID tag, reader, security door and receiving wire and furthermore talked about the advantages of RFID system in libraries and principles of RFID in libraries. Kariapper (2020) said that the RFID based library the executives system is a much better framework than standardized tags and other traditional library frameworks and furthermore featured that a hybrid RFID library framework was proposed as per the quantity of poor functionalities. Malipatil...et.al. (2020) highlighted how RFID technology solved the problems of earlier library systems using radio waves. It also identifies the large number of tagged books using radio waves and the benefits of the technology in libraries. Pal and Sharma (2017) discussed the capability of RFID innovation in working with effective library tasks and shows the way that RFID can be utilized in libraries to ensure security and work with creative administrations and features main points of contention that should be addressed to accomplish effective execution of RFID in Libraries and furthermore analyzes key difficulties in the sending of the technology. Rajeshwari (2017) focused on passive RFID technology, in which the tag carries no power source, but is instead powered by a radio signal from a separate RFID reader and it also discussed the utilizations of RFID systems in automatic identification applications. Rani (2017) discussed utilization of barcode technology in libraries which was slow and how it is getting replaced by RFID to automated day-to-day library activities. Singh and Mahajan (2014) talked about various parts and technical features of RFID based library systems, its advantages and difficulties connected with utilization of RFID in libraries. It likewise talks about the ongoing status of RFID implantation in Indian libraries and gives a few ideas for carrying out RFID in libraries.

## **OBJECTIVES OF THE STUDY**

The primary aim of this research is to examine the role and effectiveness of Radio Frequency Identification (RFID) technology in enhancing academic library operations. The study seeks to understand both the technical and practical dimensions of RFID integration within the library environment. The specific objectives are as follows:

- To identify and describe the key components and working mechanisms of RFID technology used in libraries;
- To examine the significance of RFID in improving operational efficiency and user services in academic libraries.
- To analyze how RFID supports day-to-day library activities such as circulation, stock verification, and security management.

- To identify the major challenges and limitations associated with the implementation of RFID systems in academic libraries.
- To provide recommendations for effective and sustainable adoption of RFID technology in higher education institutions.

### **Research Questions:**

Based on the objectives and scope of this study, the following research questions have been formulated to guide the investigation:

1. What are the major components and technical requirements for implementing RFID technology in academic libraries?
2. How does RFID technology improve day-to-day library operations such as circulation, stock verification, and resource security?
3. What challenges and limitations do academic libraries face in adopting and maintaining RFID systems?
4. To what extent does RFID contribute to the development of smart and automated library management practices?
5. How can academic libraries overcome financial, technical, and organizational barriers to successful RFID implementation?

### **SCOPE OF THE STUDY**

The present study focuses on exploring the integration and application of Radio Frequency Identification (RFID) technology in academic library environments, with particular reference to the Sammilani Mahavidyalaya Library under the University of Calcutta. The scope of this research is confined to analyzing the technical, functional, and managerial aspects of RFID implementation in a real-world institutional setting.

The study covers:

- The technical infrastructure required for RFID adoption, including tags, readers, servers, middleware, and integration with Library Management Software (LMS).
- The operational impact of RFID on routine library services such as circulation, cataloguing, stock verification, and theft detection.
- The advantages and limitations observed during the implementation and maintenance of the system.
- The staff and user perspectives on the effectiveness and usability of RFID-based services.

However, the study does not extend to public, special, or corporate libraries. It also excludes large-scale quantitative analysis, as the emphasis is on a case-based qualitative assessment of RFID's applicability and performance within a single academic institution.

The findings and observations derived from this case study may serve as a reference framework for other academic libraries planning to adopt RFID technology for automation and smart management of their resources.

### **METHODOLOGY**

This study adopts a case study approach to examine the implementation and effectiveness of Radio Frequency Identification (RFID) technology in academic library management. The research is both descriptive and analytical, focusing on the practical experience of integrating RFID at Sammilani Mahavidyalaya Library, affiliated with the University of Calcutta

The study relies on qualitative data gathered through direct observation, staff interaction, and analysis of library records related to RFID operations. Emphasis was placed on understanding the workflow before and after RFID adoption to evaluate its impact on library services such as circulation, stock verification, and security management.

To ensure reliability, data were collected from multiple sources, including:

- Documentation provided by the RFID vendor and library administration,
- Middleware and integrated library management system (ILMS) logs, and
- Practical demonstrations of system functionalities.

The research also incorporated an assessment of hardware components (tags, readers, security gates, and kiosks) and software infrastructure (RFID middleware and ILMS integration). Comparative analysis was conducted to highlight differences between RFID-based and traditional barcode systems in terms of efficiency, accuracy, and user convenience.

### **Technical aspect of RFID**

Here we have discussed the technical composition of RFID and also discussed prerequisites requirements for implementation of RFID in libraries.

#### **Components of RFID:**

RFID technology is not only the single technology or components it is the combination of the list of technology or components those are as follows:

**Operating System:** It needs an operating system to install the middleware application; it may be windows, linux or any other. It depends on the vendor.

**Middleware Application:** The middleware associate with the RFID readers and Integrated Library Management Software (ILMS) which is used by the library. RFID middleware acts as an interface between tag readers and enterprise applications, regulating data movement and guaranteeing data consistency, accuracy, and usability. It is the interface needed between the interrogator and the existing company databases and Library Management Software. So, it is a bridge between Library Management Software's database and RFID server.

**Database:** Database is an important part for store and dissemination of data. Data obtained through RFID systems can be saved in standard database management platforms, including relational and non-relational databases. The database would contain about the details information about libraries items, members, circulation history, fines, uses statistics, visitors' visiting time, date, the unique RFID serial number associated with that item, and fields related to when and where the associated tag was interrogated etc. It may be MySQL, MSSQL, SQLite, Maria DB, PostgreSQL etc.

**Server:** To implement an RFID system, a server is an essential component, as the system cannot function without it. The server acts as a communication gateway between the various elements of the RFID infrastructure. It receives data from one or more RFID readers, verifies the information against its stored database, and then exchanges data

with the circulation database of the library's integrated management system. Depending on the setup, the server may be configured as a cloud-based server or a local (on-premise) server.

**Tag:** The RFID tag is typically a thin, flexible label, approximately 2" × 2" in size, allowing it to be placed discreetly inside the front or back cover of a book. Each tag contains a small chip along with an attached antenna, which stores basic bibliographic details, including a unique identification number for individual item recognition. RFID tags are mainly classified into three types: active tags, passive tags, and semi-passive tags.

- I. **Active Tag:** It contains a power source and a transmitter, in addition to the radio wire and chip, and conveys a nonstop signal. These labels commonly have read/write capacities; label information can be revised and changed. It can start correspondence and impart over a longer distance up to 750 feet, depending on the battery power.
- II. **Passive Tag:** the most recent form of RFID tags that don't contain their own power source, similar to a battery, and can't begin correspondence with the reader. The passive tag gets its power from the energy waves conveyed by the reader and replies to the reader's radio repeat releases; subsequently the passive tag relies absolutely upon the reader as its power source. A passive tag should store, at least, an extraordinary identifier for the items tagged, and can be read from a scope of around 10 to 20 feet under wonderful circumstances.
- III. **Semi Passive Tag:** It is also called semi-active tags. It doesn't start correspondence with the reader, however contains batteries that permit the tag to carry out different roles, for example observing ecological circumstances and powering the tag's inside hardware. This type of tags can be associated with sensors to store data for holder security gadgets.

#### **Frequency of RFID tags:**

RFID tags operate at various radio frequencies, most of which fall under the Industrial, Scientific, and Medical (ISM) frequency bands. These frequencies are categorized into three primary ranges:

- a. **Low Frequency (LF):** Low Frequency RFID systems operate between 30 kHz and 500 kHz, with 125–134 kHz being the most commonly used range. LF technology is widely used in animal tracking, vehicle immobilizers, security access systems, and asset tracking. LF tags are particularly suitable for environments with liquids, metals, or electrical noise, and where high reading speed is not required. Most LF systems do not require an internal battery, feature a short reading range, and are generally low cost compared to other RFID technologies.
- b. **High Frequency (HF):** High Frequency RFID operates between 10 MHz and 15 MHz, with 13.56 MHz being the most widely used standard, especially due to the widespread adoption of RFID-based smart cards. HF systems are relatively affordable, though slightly more expensive than LF systems. They offer longer reading ranges and faster read speeds than LF tags. HF technology is commonly used in smart cards, library systems, access control, and contactless payment applications.
- c. **Ultra High Frequency (UHF) and Microwave Frequency:** UHF RFID functions between 400 MHz and 1,000 MHz, while microwave RFID ranges between 2.4 GHz and 2.5 GHz. These systems are generally more expensive than LF and HF solutions. UHF tags are considered one of the most practical options for item-level tracking due to their longer read range and high reading speed, though they require a line of sight

for optimal performance. UHF and microwave RFID systems are commonly used in railway car tracking, automated toll collection, logistics, and other large-scale tracking applications. Radio waves in these frequency bands are also utilized in Bluetooth, Wi-Fi, and similar wireless communication systems.

**Reader:** A RFID reader is used to read data from tags and transmit the information to the middleware. The reader uses its built-in antenna to communicate with tags by emitting radio waves, to which all tags within its range respond. RFID readers can process multiple tagged items simultaneously, allowing for faster data collection. They may be mobile (handheld) or stationary (fixed), and are classified based on their storage capacity, processing capability, and operating frequency.

**Security Gate:** A security gate on library entrance restricts movement of unchecked library resources by giving alarms and linking them to record events for easy tractability and audit purposes. It will ensure the foot falls in the library easily and get recorded with an inbuilt circulation counter at the RFID security gate in the library.

**Book drop Station:** To collect issued books by using book drop stations, for library automation which can ease the transactional burden on the circulation desks. At the same time, it also saves time for the Patrons who just need to return a particular item. They don't need to stand in long queues at the circulation desks just to return the item. Further, they can also return the items at their ease. This means even when the circulation counter is closed, the items can be returned from the Book Drop system. Also, they get intimations through an email/text message or a printed slip that the item has been returned properly.

**Self Check in Check out Kiosk:** The library is equipped with an RFID-based system that enables self-issue, return, and renewal of books through a kiosk. Users can access the kiosk, located near the security desk, to independently issue, return, or renew library materials without staff assistance. This service is designed to operate round the clock, thereby enhancing user convenience and promoting seamless circulation activities.

### **Practical aspect of RFID Technology in academic**

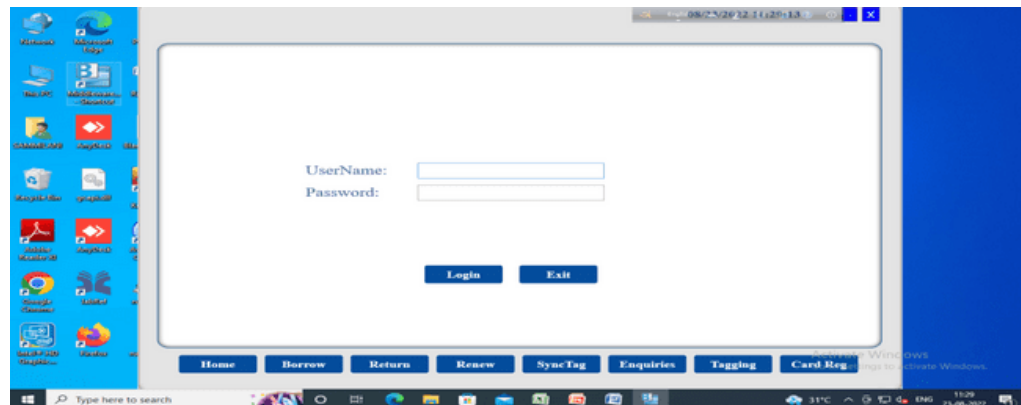
We have experience in each step as used RFID technology in our college library since 2019. So we have explained step by step with screen shot flowingly:

#### **How to RFID working in the Library:**

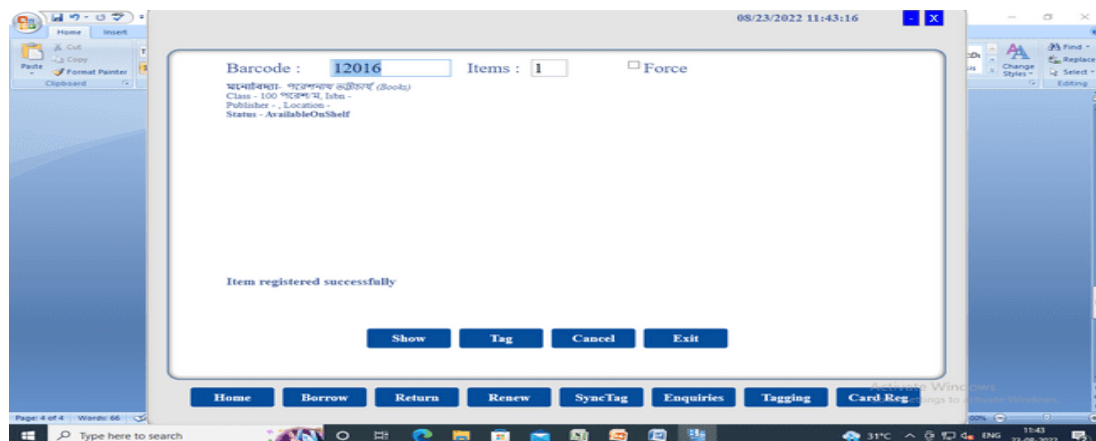
RFID technology does day-to-day library work in two ways in libraries e.g. users self handling and staff handling the system. Most of the libraries follow the users self handling the system to reduce the manpower. These technologies are used in libraries to do following tasks e.g. circulation, stock verification, theft detection, showing various reports etc. Now we discuss how to do the following work by using a staff interface.

1. **Log in the staff interface:** Fig 1 clearly shows how RFID staff interface log in through user id and password.
2. **New book/item registration:** Fig-2 show that how book/item registered in RFID database, for this purpose the items or books are need to entry in Library Management Software which one are use by the said library,

then pest the RFID tag on the item and put it on the reader and click the tagging option; it show the item registered successfully.



**Fig 1-** Staff Interface: Open the Middleware shortcut from client computer > write the username and password then > login



**Fig 2:** New book/item registration- pest the RFID tag on item's > put the book/item (only registered book/ item on Library Management Software) on reader > click on tagging

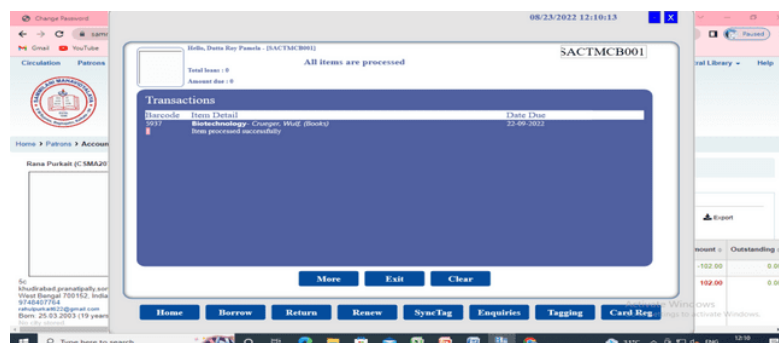
3. **Member Registration:** Fig 3 highlighted that how library users are registered in RFID database; for this purpose it is necessary to entry the patron in Library Management Software and need the RFID tag base smart card then it will put on the reader; click on Card Reg option and write or scan the member id on the given box then click the enter option from PC; and it will successfully registered in RFID database.



**Fig 3:** Member Registration- Click on Card Reg option > RFID based smart put on the reader > give the member id (registered on Library Management Software)> press the enter option from PC.

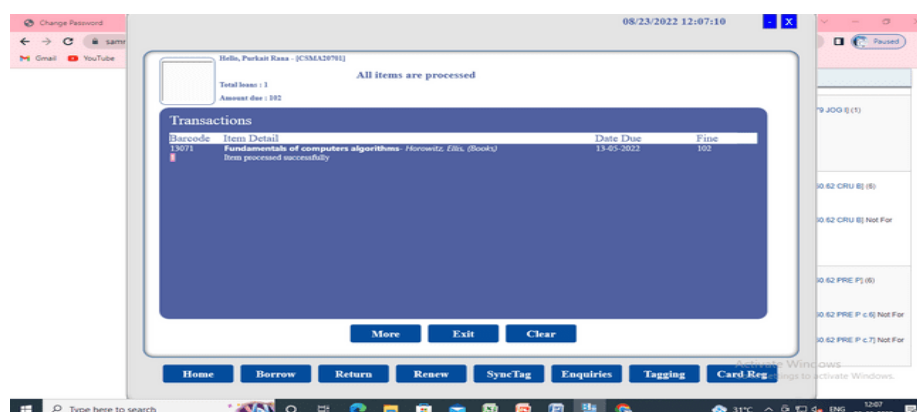
#### 4. Circulation:

**4.1. Item Issue in RFID System:** for this purpose (see the Fig 4) it is necessary to put the member card on reader for automatic detect the member or write or scan using the scanner (Barcode Scanner) the member id on given box, then put the item of RFID reader and click the borrow option, and it show the item process successfully and give the return date. At times more than one item will be issued to one member if required.



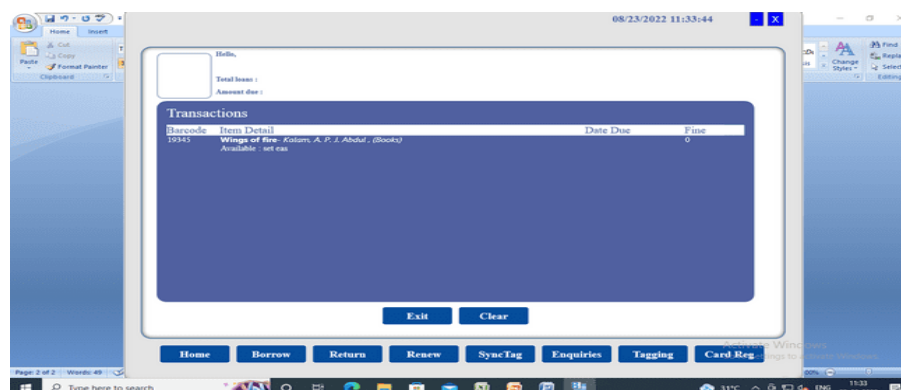
**Fig 4:** To issue the book- Put the register member card on reader or write or scan the member id on the given box> put the items on reader>click on borrow

**4.2. Item return in RFID:** Fig 5 shows how item returns through RFID system for this reason just put the item on the reader and click the return option. At times more than one item will be returned; those are issued by one member.



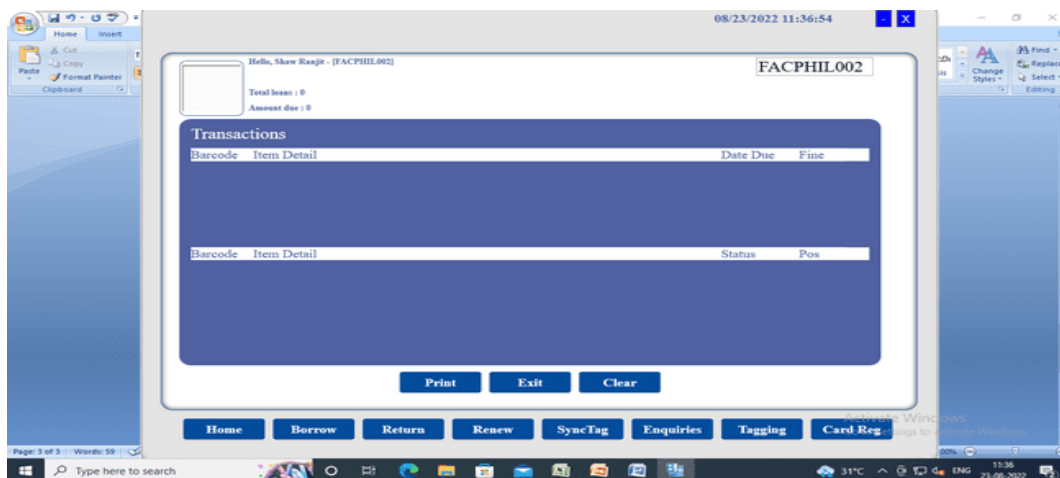
**Fig 5:** To return the book- put the items on the RFID reader > click the return option

**4.3. Sync tag:** Fig 6 highlighted that syne tag process, when the RFID server is not working due to the maintenance and other reasons we can circulate the items using library Management Software. But next time synchronize the item using the SyneTag to incorporate the circulation history in the RFID system.



**Fig 6:** For Sync Tag- Put the item on reader > click the SyncTag

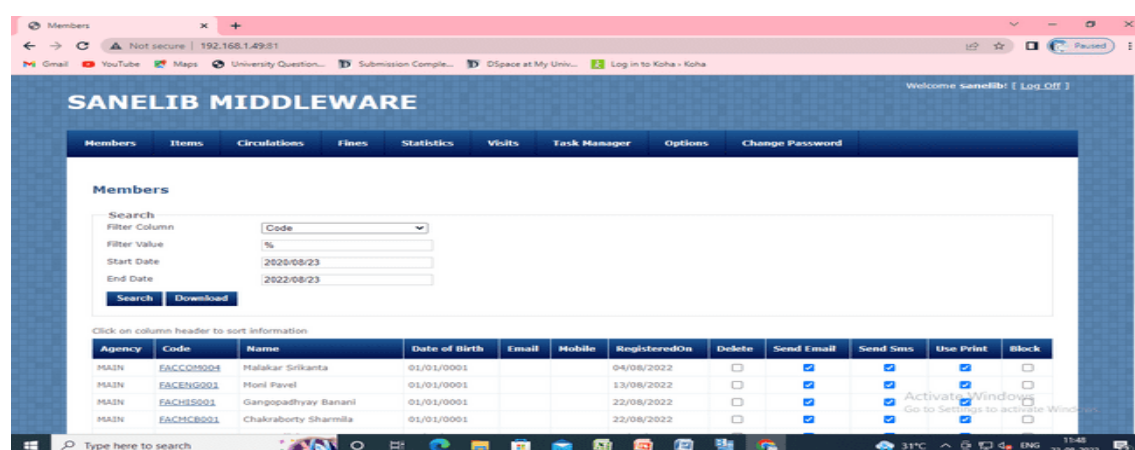
5. **Enquiries:** Fig 7 shows the enquiry process, when any enquiries about any library member to know his/her circulation history, fine etc; using enquiries option to solve this purpose. Just put the library card on the reader or write the membership id on the box, it shows the result.



**Fig 7:** To Enquiries about Specific Patron > put the library card on the reader or write the membership id on given box

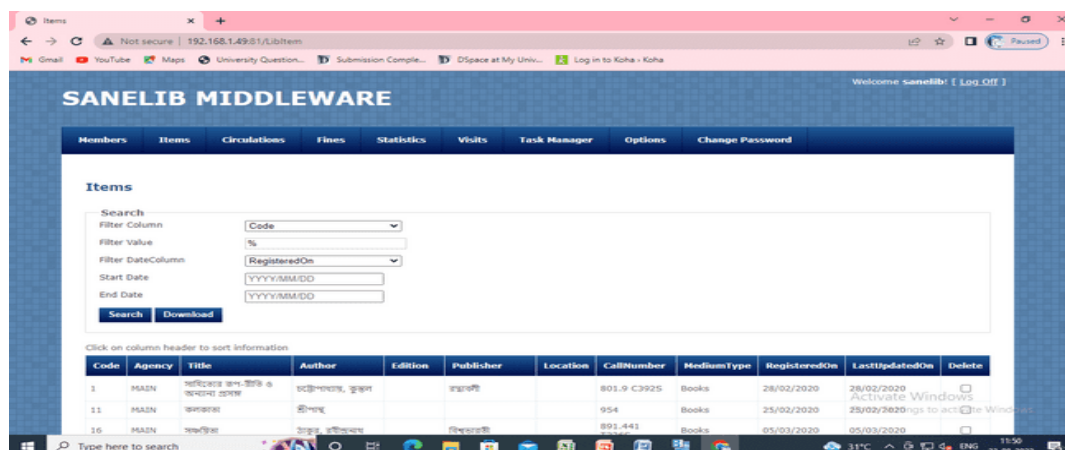
6. **Report:** One library's need report for many purposes, it may be members' details, registered items, circulation history date wise, fine, library use statistics reports, library users visit how much time at the library and so on RFID system will give the actual report for this purpose we need to open the middleware application and log in and there are all option to know the required report and it will visible in ms excel format.

**6.1. Report about registered members:** Use members option in middleware application to know about registered members' details and it will show the member branch code, members id, name, date of birth, mobile no, email and other detail and if need to delete or block or sending any sms to their mobile number, or sending email to any member; just click on the checkbox and update and if needed the total report can be download. (See Fig 8)



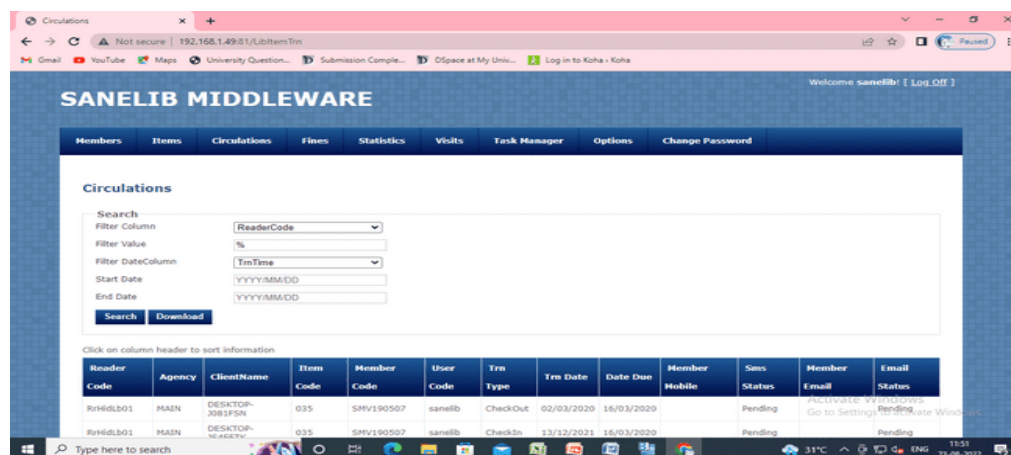
**Fig 8:** To get the report about registered members- Open the middleware application > click on members option

**6.2. Report about registered items:** Fig 9 shows how getting report about registered books or any other resources of the library for this purpose use Items option in middleware application to know about registered items details and if needed the total report can be downloaded.



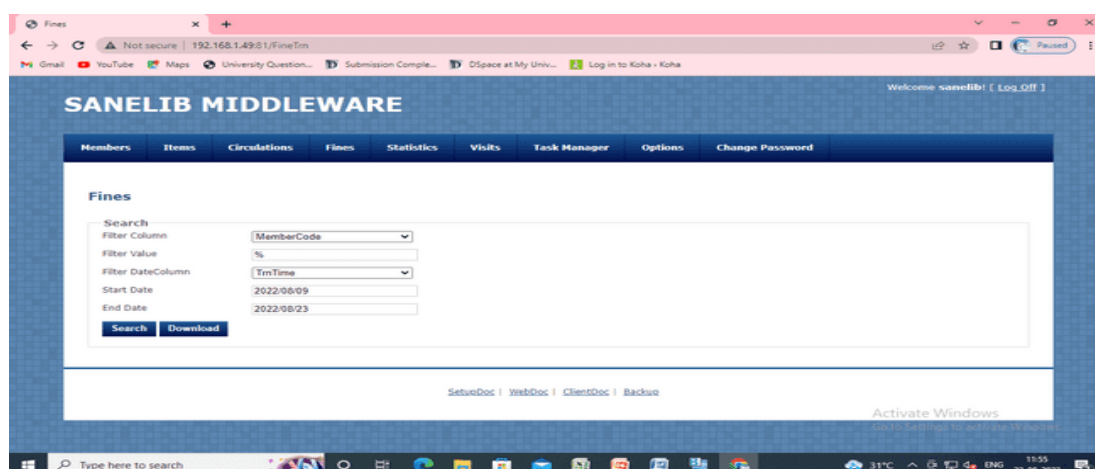
**Fig 9:** To get the report about registered items- Open the middleware application > click on items option

**6.3: Report about circulation:** Fig 10 shows how to get circulation report from RFID system, for this purpose just open the middleware application and go to the circulation option; it will be the circulation history date wise.



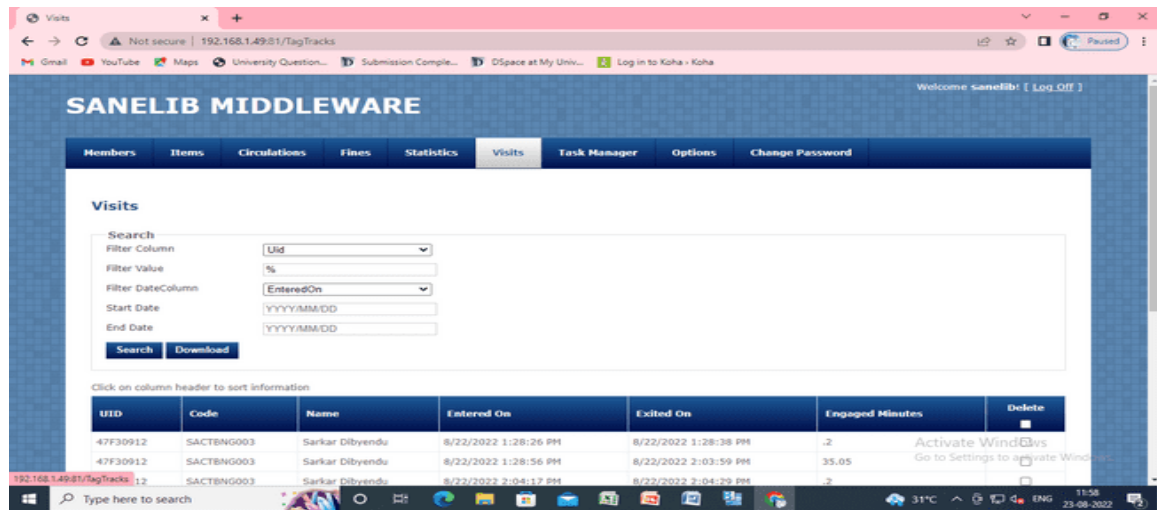
**Fig 10:** To get the circulation report-Open the middleware application > click on circulation option > put the start date and end date.

**6.4: Report about fine:** Fig 11 shows how to get a fine report from an RFID system. It is very important to know how much fine will be collected from the library. Using this report it will get the clear calculation and details about fine, collected from members date wise.



**Fig 11:** To get the report about fine - Open the middleware application > click on fine option > put the start date and end date

**6.5. Report about library visitors:** Using RFID based digital gate register, it will give a detailed report about how much time one visitor spent at library and also how many members are visiting the library date wise. (See Fig 12)



**Fig 12:** To get the report about visitors - Open the middleware application > click on visits option > put the start date and end date

**7. Stock Verification:** Fig 13 shows how libraries can easily verify their stock using RFID technology. Every library needs to verify their stock. The RFID technology helps to do this job in a very easy way. RFID handheld readers need to move row wise in the library stack area and it will note the accession number then just copy it on the excel file for betterment.



**Fig 13:** Stock Verification- Moving the RFID handheld reader on the shelf> Note down the Accession Number on the excel sheet

7. **Theft Detection:** Fig 14 highlighted detection through RFID security gate. One most important work is the security for the library, because unauthorized users carry out the library resources in various ways, but in these cases RFID security gates give the briefing with light and make the library staff instantly.



**Fig 15:** Theft detection through RFID security gate

**Basic reason behind implementation of RFID in academic libraries:**

- a. **Reduce the time:** The utilization of RFID reduces the time of circulation tasks as well as stock verification of library resources it helps library professionals eliminate valuable staff time spent scanning barcodes or writing the accession numbers or member's id, while circulating library resources. For users, RFID technology significantly accelerates the borrowing and return processes. Library staff can engage in doing other duties to develop better library services.
- b. **Speedy and Easy Inventorying:** A unique advantage of RFID systems is their ability to scan books directly on the shelves without removing or shifting them. A handheld inventory reader can be swiftly passed across a row of books to capture all the unique identification information stored in the tags. Using wireless technology, RFID not only enables real-time updating of inventory but also helps identify misplaced or improperly shelved library materials.
- c. **Reduce the Manpower:** It is an advanced and automated process, users can easily access the circulation process after proper training, and it reduces the library work as well as manpower.
- d. **Tag Life:** RFID tags have a longer lifespan than barcodes and other standardized labels because they do not require physical contact for scanning. Most RFID manufacturers guarantee that a tag can withstand at least 100,000 transactions before it may need replacement.
- e. **Security of library resources:** RFID technology serves a dual purpose in libraries by enabling both resource identification and security. With RFID implementation, the use of traditional electromagnetic security strips is no longer required. Instead, RFID-enabled security gates are used to prevent unauthorized removal of library materials. Unlike electromagnetic systems, RFID does not require manual sensitizing or desensitizing of items during check-in or check-out. Security activation and deactivation occur automatically when items are placed on or passed over an RFID-enabled pad at the circulation workstation.

**Issues for using RFID technology in academic libraries:**

- a. **Cost:** Cost of RFID technology is very high, because it involves RFID tags cost, tagging cost, hardware cost, equipment cost and it also requires regular maintenance. Most academic libraries think about this.

- b. **Commercial Technology:** RFID technology is not open source technology, it is close source and commercial technology. The specification of the technology is different from vendor to vendor, and the library authority always depends on the purchasing vendor for regular maintenance, which is very costly.
- c. **Lack of knowledge:** Most library professionals have no clear knowledge about RFID technology, how to handle it or solve the arise problems using this technology and they are always dependent on the vendor.
- d. **Not a single technology:** RFID technology is not a single technology, without Library Management Software RFID can't work, it always depends on Library Management Software, to apply this technology in libraries to implement the Library Management Software and enter all bibliographic information of library materials as well as users details and then need to registration or tagging all resources and users, it is the double works to implement this technology.
- e. **Health Issue:** RFID technology used Radio Waves to connect tag with reader and other equipments, in small environment, it may rise the health issue
- f. **Fine Collection:** Fine collection is the one important task of the academic library but RFID technology has no option to collect the fine, it just shows the fine and to collect the fine needs to go to library management software.
- g. **User Privacy Concerns:** Privacy concerns related to item-level tagging represent a significant challenge in the adoption of RFID technology in libraries. A key issue with current library RFID systems is that the tags store static information, which can be relatively easily accessed by unauthorized readers, potentially compromising user privacy and the confidentiality of library transactions.
- h. **Removal of exposed tags:** If you need to replace the RFID tags, it is very critical to remove, because it pests within the back cover or front cover page of the books.

## **CONCLUSION**

The study emphasizes that the integration of Radio Frequency Identification (RFID) technology in academic libraries represents a major step toward automating library operations and achieving more efficient, smart management of resources. The findings from the case study at Sammilani Mahavidyalaya Library demonstrate that RFID enhances the overall efficiency of circulation, stock verification, and resource security processes. By minimizing manual intervention, the technology allows library professionals to devote more time to user-oriented services and knowledge management activities.

Despite its numerous advantages, the adoption of RFID in academic libraries faces several challenges, including high implementation and maintenance costs, dependency on vendors, lack of interoperability between systems, and insufficient technical knowledge among library staff. Additionally, privacy and ethical concerns related to RFID use require careful consideration and the establishment of clear policy guidelines.

The research concludes that RFID has strong potential to transform academic libraries into smart, user-friendly, and automated information centers. However, its successful implementation demands strategic planning, institutional commitment, adequate funding, and continuous staff training. Future studies may explore comparative analyses across different library types or examine the long-term cost-effectiveness and user satisfaction associated with RFID adoption.

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