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A Fuzzy Cognitive Mapping Approach to Analyzing RFID Implementation Barriers in Iranian Academic Libraries

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A R T I C L E I N F O

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A B S T R A C T

In recent years, academic libraries have increasingly sought to enhance service quality and operational efficiency through the adoption of advanced technologies such as Radio Frequency Identification (RFID). Despite its well-documented benefits, the implementation of RFID systems faces numerous challenges. This study aims to identify and analyze the key barriers to RFID adoption in academic libraries in Iran. The research is applied in nature and employs a descriptive-survey methodology. Initially, potential barriers were extracted through a comprehensive literature review and previous studies. These were then validated via expert input using a structured questionnaire. Subsequently, to examine the interrelationships among the identified factors, a second questionnaire was administered, and the data were analyzed using Fuzzy Cognitive Mapping (FCM). The findings reveal that "High Implementation Cost," "Resistance to Change," and "Technical Issues" are among the most influential barriers in the RFID implementation process. These insights can support library managers and IT policymakers in developing more strategic and effective approaches for the successful integration of RFID technology in academic environments.

1. Introduction

Technological advancements over recent decades have significantly transformed various industries, optimizing processes across many fields. One of the most impactful innovations in this regard is Radio Frequency Identification (RFID). RFID, a key member of the Automatic

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Identification and Data Capture (AIDC) family, uses radio waves for object and individual identification. Known for its speed and accuracy, RFID has become one of the most reliable methods for identification (Ahmad & Nababa, 2021a). RFID systems rely on RFID tags, which are attached to objects or individuals, to transmit data to a reader via radio waves (Ahmad & Nababa, 2021b). In recent years, RFID has gained increasing attention across multiple sectors, thanks to its cost-effectiveness, time-saving capabilities, resource efficiency, and ease of integration. The technology has found widespread applications in areas such as supply chain management, inventory tracking, transportation, healthcare, and the Internet of Things (IoT) (Haibi et al., 2022; Qureshi, 2020). Moreover, ongoing advancements in RFID technology have led to increased memory capacity, faster processing speeds, and longer reading ranges (Ahmad & Nababa, 2021b). Libraries, crucial for preserving knowledge and facilitating learning, have also evolved over time. The introduction of Library Management Systems (LMS) in the mid-1950s aimed to automate various functions within libraries. Over time, LMS has been further refined and often referred to as Integrated Library Systems (ILS) to emphasize that all library operations are controlled by a single, unified database, facilitating seamless data exchange between components such as catalog records and circulation transactions (Yusuf et al., 2023). However, many libraries continue to rely on outdated manual processes, which hinder efficiency and limit the quality of user experiences. The manual tracking and management of library materials is a time-consuming process, burdening librarians and reducing their ability to provide optimal services. While some libraries use barcode scanners for managing operations, this technology is becoming increasingly obsolete. We argue that RFID technology offers a more efficient, faster, and reliable alternative to barcode systems (Dande et al., 2023). One significant area where RFID has made a notable impact is in academic libraries. These libraries, housing vast collections of books, periodicals, and electronic resources, face considerable challenges in managing such large-scale collections (Kanwar, 2020). The adoption of RFID technology in library management systems has greatly enhanced tasks such as book lending, returns, sorting, and tracking, improving both the speed and accuracy of operations while enabling better resource management (Zhou, 2019).

Beyond library management, RFID technology has broader applications in academic processes, including resource management, access control, and enhancing student services (Chanda & Sinha, 2019). For instance, RFID can replace traditional barcodes, significantly improving operational efficiency and reducing the need for manual labor. These benefits have made RFID technology a preferred choice in both industrial and academic sectors (Munoz-Ausecha et al., 2021).

Despite these advantages, there are several challenges and limitations to implementing RFID in libraries. These barriers include a shortage of skilled technical personnel, the complexity of technological interfaces, insufficient bandwidth, the high cost of digital infrastructure, and inadequate funding (Abifarin et al., 2023). Such issues hinder the widespread adoption of RFID technology and must be addressed to fully realize its potential in library settings. This paper aims to explore the role of RFID systems in optimizing academic processes, focusing specifically on the barriers and challenges associated with implementing RFID in university libraries. The paper reviews the fundamentals of RFID technology, analyzes its impact on library management, and concludes with recommendations for overcoming implementation barriers in academic environments.

2. Literature Review

2.1 RFID (Radio Frequency Identification)

Radio Frequency Identification (RFID) is a technology that uses radio waves to identify and track objects equipped with RFID tags when they pass near a reader. Unlike traditional barcodes, RFID allows for data to be read, written, and retrieved without the need for direct line-of-sight, enhancing efficiency and accuracy (Haibi et al., 2022). The origins of RFID can be traced back to the 1940s with metal detection devices, evolving into antitheft systems in the 1960s and finally full-scale radio identification systems in the 1970s. Texas Instruments introduced one of the first commercially available RFID systems, known as TIRIS (Waszkowski & Nowicki, 2020). RFID systems consist of readers (or transceivers), tags, and a central processing unit. Readers send and receive signals via electromagnetic fields, activating the tag, which then transmits stored information. This information is decoded and transferred to a computer system for further processing, enabling autonomous data management without human intervention (Figure 1) (Timoshenko, 2017; Yusuf et al., 2023). The ability of technology to interact with data distinguishes it from conventional identification methods. RFID tags can be reused, modified, and embedded into objects without performance issues, unlike barcodes that are prone to errors due to contamination and are not reusable (Korotkov, 2016; Viji et al., 2024). The adoption of RFID has transformed inventory tracking, logistics, and supply chain management across industries. Companies such as Wal-Mart, General Electric, and various government departments have benefited from its speed, accuracy, and automation capabilities (Qureshi, 2020). RFID's application extends beyond industrial use; it is now employed in academic libraries, where managing vast collections of resources poses challenges. By automating processes such as lending, returning, and sorting books, RFID helps librarians enhance service efficiency and adhere to the principle of library growth (Yusuf et al., 2023). RFID's advantages, including its small size, flexibility, and ability to gather and transmit information without physical contact, make it a superior alternative to barcode technology. These features allow RFID systems to optimize processes while minimizing manual effort, ultimately improving organizational productivity and resource management (Haibi et al., 2022; Yusuf et al., 2023).

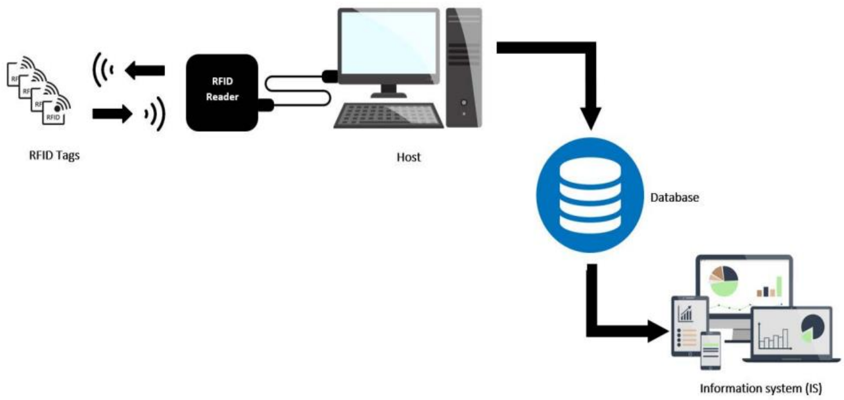

Figure 1

Functionality of the RFID System (Haibi et al., 2022)

2.2 Composition of RFID System

Tag: RFID tags are small, programmable devices that serve as unique identifiers for objects such as books, CDs, and DVDs in libraries. Each tag consists of a coupling element and a control chip, which is attached to the item being identified. The tags include a unique electronic code that allows precise tracking and identification (Viji et al., 2024; Zhou, 2019).

Reader: The RFID reader serves as the central component of the Radio Frequency Identification (RFID) system, playing a crucial role in its functionality. Often referred to as interrogators, these devices facilitate communication with RFID tags by transmitting and receiving radio waves. An RFID reader collects data from RFID tags and employs radio waves to transfer this information from the tag to the reader for further processing (Ahmad & Nababa, 2021a).

Antenna: In RFID systems, antennas facilitate communication between readers and tags by transmitting and receiving radio frequency signals (Grover & Ahuja, 2010). They play a key role in item identification and can simultaneously activate or deactivate the antitheft function of tags. For larger-scale operations or enhanced coverage, additional antennas can be integrated into readers or connected externally, improving efficiency and processing capacity (Viji et al., 2024; Zhou, 2019).

Middleware: RFID middleware software acts as a bridge between RFID readers and enterprise applications, playing a crucial role in the management and operation of RFID systems. Beyond managing RFID printers and readers, it processes, filters, aggregates, and interprets the data received from RFID tags. Due to the massive volume of data generated by RFID tags, especially when thousands are read simultaneously, advanced middleware is required to handle this efficiently. Traditional middleware primarily focuses on connecting various applications, both internally and externally, to enterprise systems while also enabling tasks such as decoding data into different formats, providing web services, and routing data through various transport protocols (Baballe, 2021).

Server: A server can be integrated into an RFID system, serving as a communication hub for its various components. It collects data from one or more RFID readers and compares it with its internal database or exchanges it with the circulation database within the library's integrated management system. Additionally, the server often incorporates a transaction database to enable the generation of reports (Singh & Mahajan, 2014).

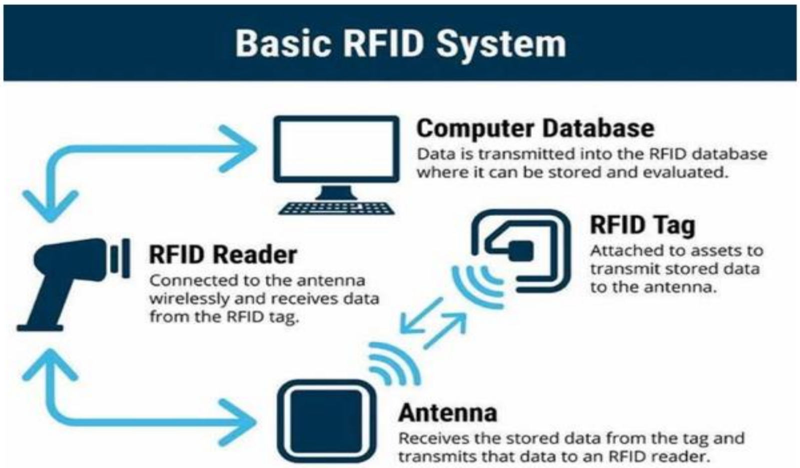

Figure 2

RFID System (Viji et al., 2024)

2.3 How RFID Works in a Library

Radio Frequency Identification (RFID) technology is revolutionizing library operations by automating traditional tasks and enhancing efficiency. At its core, RFID involves embedding small, unique tags into each book or resource in the library. These tags store essential bibliographic data and communicate wirelessly with RFID readers installed at critical locations such as entry and exit points, circulation desks, and inventory areas. When a book is scanned by an RFID reader, the tag transmits its information to the library's central database, allowing real-time tracking and ensuring accurate cataloging (Gao et al., 2017; Xu et al., 2017). A key feature of RFID in libraries is its access detection mechanism. This system identifies and authenticates users, distinguishing between library staff and patrons. It also prevents the unauthorized removal of books by triggering alarms if items pass through detection points without proper check-out. Each book is embedded with a unique RFID tag that interacts with the system to ensure security and streamline circulation processes. For example, when users borrow or return books, RFID-enabled kiosks handle these transactions automatically, updating the database in seconds and reducing manual workload (Viji et al., 2024). RFID also plays a vital role in inventory management. Portable RFID readers allow library staff to scan shelves without manually handling each book, transmitting the scanned data to the central database for stock-taking. This process significantly reduces the time and effort required for inventory checks while maintaining accuracy. Furthermore, RFID integrates seamlessly with other library systems, such as cataloging and resource-sharing platforms, ensuring a cohesive and efficient management framework (Chanda & Sinha, 2019; Kisilu, 2016).

2.4 The Applications and Benefits of RFID Library Management System

The adoption of Radio Frequency Identification (RFID) technology has significantly enhanced library management by automating critical operations and improving service quality. RFID enables libraries to handle tasks such as cataloging, circulation, inventory checks, and theft prevention more effectively. This integration creates a seamless library experience, benefiting both users and staff through advanced technological solutions (Chanda & Sinha, 2019; Munoz-Ausecha et al., 2021). RFID tags embedded in library materials facilitate non-contact data transmission to RFID readers. This capability allows for real-time tracking, precise inventory management, and automated book borrowing/returning processes. Users can independently check out or return books via self-service kiosks, even outside library hours, thereby reducing queues and enhancing convenience (Howard & Anderson, 2007). Additionally, RFID significantly reduces theft by alerting staff if a book is removed without proper authorization (Kisilu, 2016). Another remarkable feature of RFID is its efficiency in inventory management. Staff can perform stock verifications quickly using handheld RFID readers without manually handling each item. This capability not only saves time but also minimizes errors, ensuring accurate and efficient resource management (Sumi & Kumar, 2007). Furthermore, RFID supports broader applications, such as integrating with IoT systems, enabling better data management and interconnectivity in modern libraries (Munoz-Ausecha et al., 2021). The table below provides an overview of the numerous applications and benefits of RFID technology in libraries and demonstrates its transformative potential in various library functions.

Table 1

Applications and Benefits of RFID

Application/Benefit	Description	References
Self-Service Kiosks	Users can independently borrow and return books anytime, improving accessibility and reducing queues.	Howard & Anderson (2007)
Real-Time Inventory Management	Enables fast and accurate inventory checks without manual handling.	Sumi & Kumar (2007)
Improved Security	RFID tags trigger alarms at exits if books are removed without authorization, reducing theft.	Kisilu (2016)
Streamlined Circulation	Automated borrowing and returning processes save time for users and staff.	Munoz-Ausecha et al. (2021)
Integration with IoT	RFID supports IoT applications, enabling interconnected library systems and better resource management.	Munoz-Ausecha et al. (2021)
Enhanced Staff Productivity	Reduces manual workloads, allowing staff to focus on user-centric tasks.	Chanda & Sinha (2019)
Easy Book Tracking	Facilitates locating misplaced or reserved books, improving retrieval efficiency.	Chanda & Sinha (2019)
Automated Stock Verification	Allows staff to perform fast and error-free stock verification using handheld readers.	Sumi & Kumar (2007)
Minimized Workplace Injuries	Reduces physical strain on staff by automating book handling and sorting.	Chanda & Sinha (2019)
Support for Multi-Item Transactions	Users can borrow or return multiple books, simultaneously saving time.	Munoz-Ausecha et al. (2021)
Data Storage Capability	RFID tags store more data than traditional barcodes, allowing for advanced tracking and cataloging.	Pandey (2010)
Integration with Other Technologies	Can be used alongside barcode systems to enhance overall efficiency.	Ahmad & Nababa (2021b)

Application/Benefit	Description	References
Long-Term Cost Efficiency	Reduces material costs and operational inefficiencies over time.	Chanda & Sinha (2019)
Improved User Experience	Streamlined processes and faster services enhance library user satisfaction.	Kisilu (2016)
Anti-Theft Mechanisms	Advanced detection systems prevent unauthorized book removal.	Abadi (2023)
Automated Book Sorting	Simplifies the sorting of returned books for re-shelving, improving staff efficiency.	Sumi & Kumar (2007)
Support for Accessibility	RFID systems can cater to visually impaired users by integrating with assistive technologies.	Munoz-Ausecha et al. (2021)
24/7 Service Availability	Self-service kiosks allow users to access library services beyond regular hours.	Howard & Anderson (2007)

2.5 The Barriers and Challenges of RFID Library Management System

Despite the transformative benefits of RFID technology in library management, its adoption comes with several significant challenges. These include high implementation costs, privacy concerns, system vulnerabilities, and operational inefficiencies. Below is a summarized analysis of the key barriers.

Table 2

The Barriers and Challenges of RFID Library Management System

Challenge	Description	References
High Cost	Initial and ongoing costs for RFID tags, security gates, and equipment hinder adoption.	Kisilu (2016)
Privacy Concerns	The risks of unauthorized reading, writing, and tracking of patron activities through RFID tags.	Singh & Mahajan (2014)
Vulnerability to Compromise	Techniques such as signal blocking or overlapping can disrupt RFID functionality.	Kisilu (2016)

Tag Removal	Exposed tags can be easily removed, compromising the security of library assets.	Kisilu (2016)
Exit Sensor Issues	Difficulty in detecting tags at longer ranges affects the system's reliability.	Kumar (2008)
Lack of Standardization	The absence of global standards leads to compatibility and integration issues.	Zhou (2019)
Power Limitations	Disruptions during power outages can hinder operations.	Baballe (2021)
Reader Collision	Interference occurs when multiple RFID readers operate in proximity.	Pandey (2010)
Tag Collision	Signal interference arises when multiple tags are read simultaneously.	Pandey (2010)
Limited Security	Inadequate encryption and security measures expose the system to hacking risks.	Zhou (2019)
Technical Maturity Issues	Limited technological readiness affects large-scale deployment.	Zhou (2019)
Interoperability Challenges	Difficulty in integrating RFID systems with existing infrastructure.	Pandey (2010)

2.6 Implementation Barriers in RFID

While RFID technology offers transformative potential for academic libraries, a review of existing literature reveals that its implementation is hindered by a complex set of barriers. High implementation costs remain a primary obstacle, as the initial investment for hardware, tags, and infrastructure is often prohibitive for libraries with limited budgets (Baradan et al., 2019; Kineber et al., 2023). Beyond financial constraints, infrastructure and power supply challenges are significant, particularly in developing regions where consistent electricity is required for stable system operation (Oke et al., 2023; Osunsanmi et al., 2018;).

From a technical perspective, the literature highlights technical issues, such as signal interference from metal surfaces, which affects tag performance (Pereira et al., 2024). This is compounded by maintenance issues, where the lack of local technical expertise leads to increased downtime and replacement costs (Osunsanmi et al., 2019). Furthermore, the lack of global standards creates interoperability problems, making it difficult to integrate disparate systems and equipment (Zhou, 2019). As systems scale, data overload and management challenges also emerge, with libraries struggling to store and process the massive volume of data generated by RFID readers (Roy & Roy, 2023).

Security and human factors are equally critical. Privacy concerns regarding the unauthorized tracking of patrons and the lack of security against data manipulation are among the frequently cited risks (Mitrokotsa et al., 2010; Molnar & Wagner, 2010). Finally, organizational hurdles such as inadequate training for staff (Oke et al., 2023; Osunsanmi et al.,

2018) and inherent resistance to change due to job security concerns can severely stall adoption efforts (Roy & Roy, 2023). All these identified factors are categorically presented in Table 3.

Table 3

Implementation Barriers in RFID

Row	Barrier	Description	Reference
1	High Cost	High costs associated with purchasing hardware, tags, and maintaining infrastructure, especially challenging for smaller organizations.	Baradan et al. (2019); Kineber et al. (2023)
2	Lack of Security	Concerns about privacy and vulnerability to unauthorized access and data manipulation stored on tags.	Mitrokotsa et al. (2010); Molnar & Wagner (2010)
3	Maintenance Issues	Need for proper maintenance to reduce the replacement costs of hardware and tags. The lack of technical knowledge among staff exacerbates the challenge.	Osunsanmi et al. (2019)
4	Power Supply Challenges	Need for stable and sufficient power supply for consistent RFID operation, especially in areas prone to power outages.	Osunsanmi et al. (2018); Oke et al. (2023)
5	Inadequate Training	Lack of training programs for the effective use of RFID technology and limited staff familiarity with its functionality.	Osunsanmi et al. (2018); Oke et al. (2023)
6	Resistance to Change	Staff resistance due to concerns about job security, the need for retraining, and adapting to new processes.	Roy & Roy (2023)
7	Technical Issues	Metal surfaces reflect electromagnetic waves, causing interference that affects the performance of RFID tags. This is a significant issue in applications where tags are mounted on or near metal surfaces.	Pereira et al. (2024)
8	Privacy Concerns	Worries about the unauthorized tracking of individuals or access to sensitive data stored on tags.	Mitrokotsa et al. (2010); Molnar & Wagner (2010)
9	Lack of Global Standards	Absence of universal operational and regulatory standards for RFID, leading to inconsistencies in systems and equipment.	Zhou (2019)
10	Data Overload and Management Challenges	RFID readers collect vast amounts of data, leading to issues with storage and effective data management.	Roy & Roy (2023)

Prior research on complex technology and system interventions in uncertain environments shows that implementation success depends not only on identifying barriers, but also on understanding their causal interdependencies and feedback structures. In this regard, Fuzzy Cognitive Mapping (FCM) provides a well-suited representation for modeling complex causal relations under uncertainty, while hybridization with causal-structuring techniques, such as fuzzy DEMATEL, strengthens the inference of influence directions and intensities among factors. Building on this logic, Fathi et al. (2024) demonstrated how combining FCM with fuzzy DEMATEL can organize interacting indicators into a coherent causal system, enabling clearer prioritization of leverage points and intervention pathways. Complementing this, barrier-focused studies using causal methods, such as DEMATEL, have shown that implementation obstacles typically form interdependent clusters (e.g., infrastructure, financial constraints, regulatory conditions, and human capital), where some barriers act as “cause” factors that trigger cascades across the system (Fathi et al., 2025). In addition, readiness-oriented research emphasizes that large-scale organizational change initiatives require prerequisite capabilities and supportive infrastructures; without sufficient readiness, implementation projects may become ineffective or costly, highlighting the need to assess organizational preparedness alongside barrier analysis (Nafchi et al., 2021). Taken together, these streams support an RFID-barriers research design that moves beyond static ranking toward systemic causal modeling, allowing academic libraries to target upstream constraints and design more robust implementation roadmaps (Fathi et al., 2024; Fathi et al., 2025; Nafchi et al., 2021).

3. Methodology

To analyze and structure the key barriers to implementing RFID in Iranian academic libraries, this study employs the Fuzzy Cognitive Mapping (FCM) method. FCM is a semi-quantitative decision-making tool utilized to model complex systems that involve interdependent concepts. It integrates expert opinions with graph theory to effectively capture the causal relationships among the identified barriers.

The implementation steps of FCM in this study were as follows:

1. The Identification of Key Barriers:

Through an extensive review of existing literature, ten key barriers to the implementation of RFID technology have been identified, including high cost, the lack of security, maintenance issues, power supply challenges, inadequate training, resistance to change, technical issues, privacy concerns, the lack of global standards, and data overload and management challenges, which is detailed in Table 3.

2. Expert Survey Design and Data Collection:

To ensure the validity of the data, a purposive sampling technique was employed to identify and select qualified participants. A total of five experts were selected based on their specific expertise in library information systems and practical experience in RFID deployment. These experts included senior library managers and IT specialists with a proven track record in smart library technologies. A structured questionnaire was then administered among the domain experts who were asked to assess the extent to which each barrier influences others, using a Likert scale ranging from 0 (no influence) to 4 (very high influence). Table 4 presents a part of the resulting Influence Matrix Structure (IMS), indicating raw expert responses.

Table 4

A Part of Extract of IMS Matrix

Expert	High Cost → Security	High Cost → Maintenance Issues	High Cost → Power Supply Challenges	High Cost → Inadequate Training	…
1	0	1	2	3	…
2	1	1	2	2	…
3	4	4	4	1	…
4	4	4	4	2	…
…	…	…	…	…	…

3. Construction of FMS Matrix

The average influence values from the IMS were calculated to create the Final Map Structure (FMS) matrix. This matrix contains the mean influence score for each barrier-to-barrier relationship.

Table 5

Part of the FMS Matrix

FMS	High Cost	Security	Maintenance Issues	Power Supply Challenges
High Cost	0	2.688	2.375	2.438
Security	1.938	0	2.250	1.125
Maintenance Issues	2.313	2.563	0	2.938
Power Supply Challenges	1.813	1.688	2.375	0

4. FCM Model Characterization

Using the data extracted from the FMS matrix, the network structure of the cognitive map was defined. The model comprises 10 nodes and 90 directional connections. All nodes are classified, as each one both influences and is influenced by others.

Table 6

General Information on the FCM Model

Density	Total Nr. Factors	Total Nr. Connections	Nr. Transmitter	Nr. Receiver	Nr. Ordinary
0.9	10	90	0	0	10

5. Indicator Calculation

Based on the FMS matrix, three key network metrics were calculated for each concept.

- Outdegree (the total influence a barrier exerts on others)
- Indegree (the total influence received from others)
- Centrality (the sum of Outdegree and Indegree)

Table 7

The Calculation of Indicators Related to FCM Model

Rate	Indicator	Outdegree	Indegree	Centrality
1	Technical Issues	22.125	22.5	44.625
2	Global Standards	22.6875	20.0625	42.75
3	High Cost	22.0625	18.8125	40.875
4	Maintenance Issues	20.3125	20.5625	40.875
5	Data Overload Challenges	18.5	18.3125	36.8125
6	Security	17.0625	19.5	36.5625
7	Resistance To Change	18	18.3125	36.3125
8	Inadequate Training	18	17.75	35.75
9	Privacy Concerns	17.1875	18.5	35.6875
10	Power Supply Challenges	15.6875	17.3125	33

6. Visualization of Indicator Metrics

Figures 3 to 6 illustrate the outdegree, indegree, and centrality values for each barrier in the form of bar charts. These visualizations facilitate the identification of the most influential and affected barriers within the system.

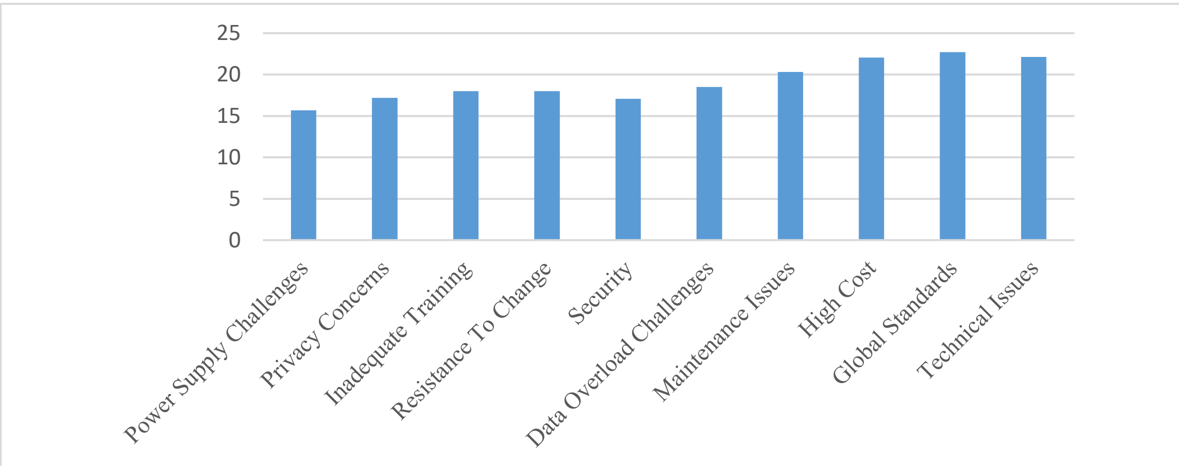

Figure 3

Outdegree of Indicators

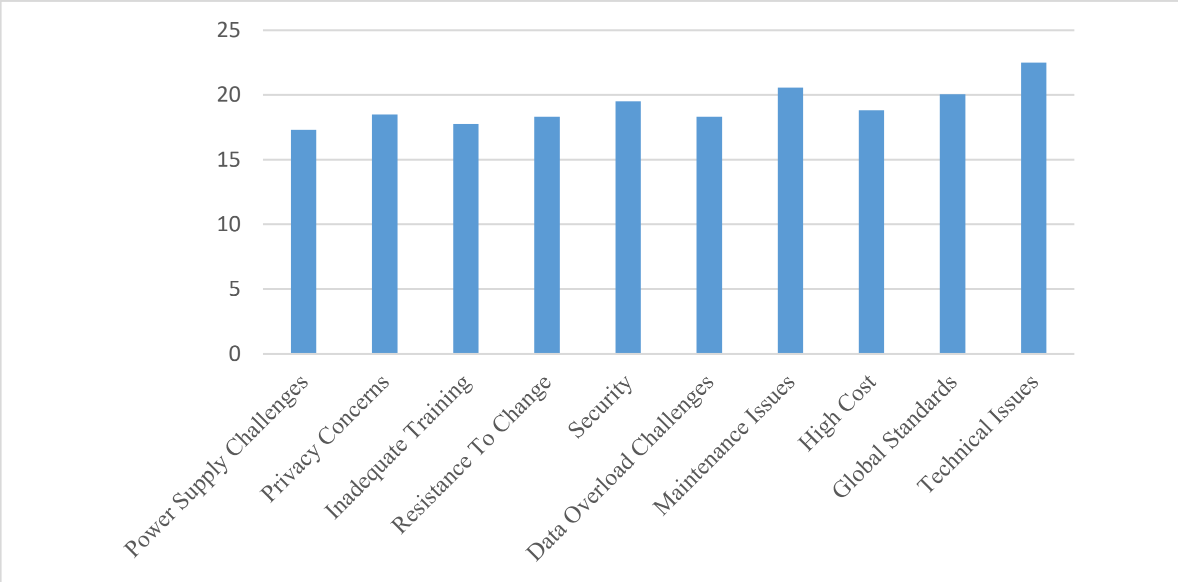

Figure 4
Indegree of Indicators

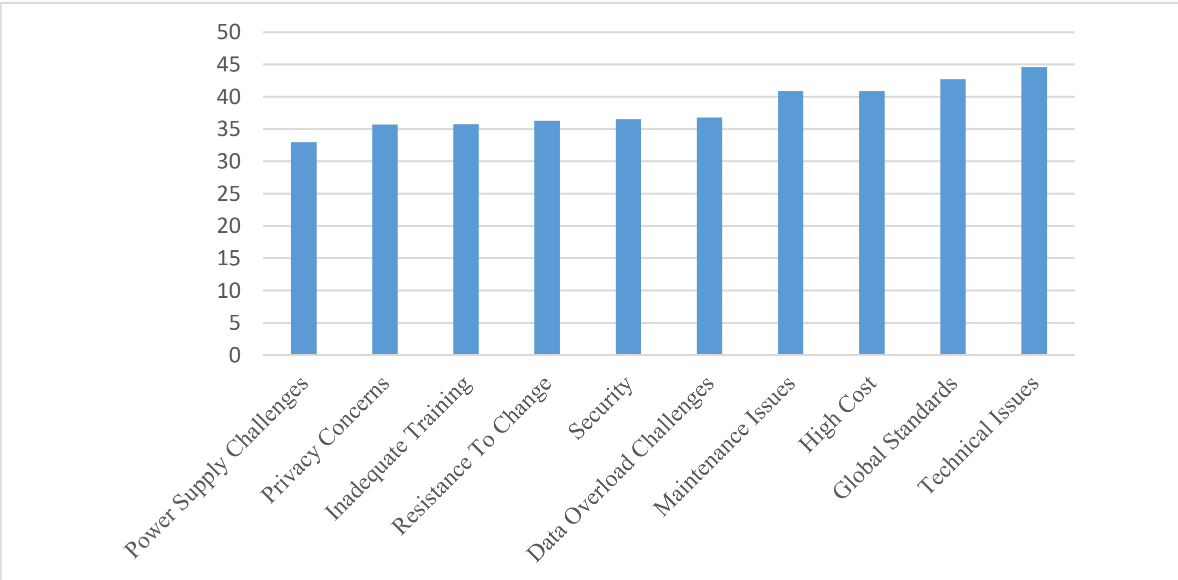

Figure 5

The Centrality Degree of Indicators

Graphical Mapping and Network Visualization

Two types of visualizations were created using Pajek software. Figure 6 presents the visual matrix (heatmap) of all inter-barrier relationships, while Figure 7 illustrates intra-barrier relationships.

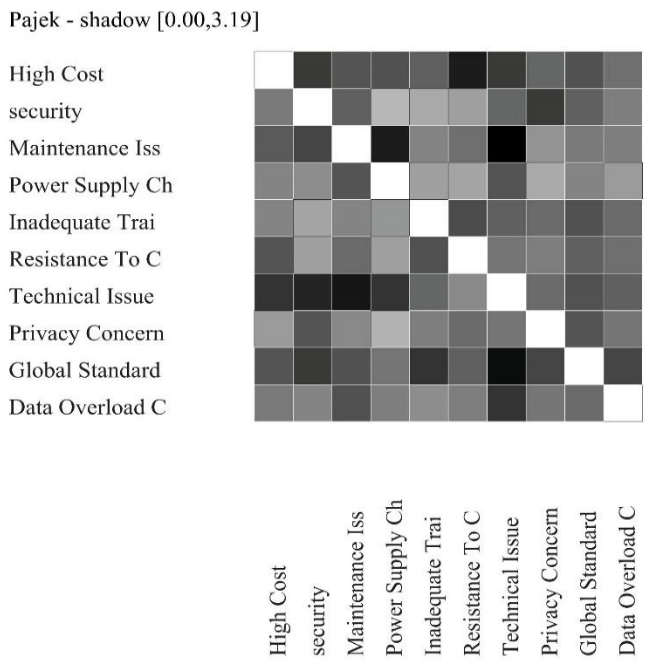

Figure 6

Shadow Matrix Visualization (Pajek)

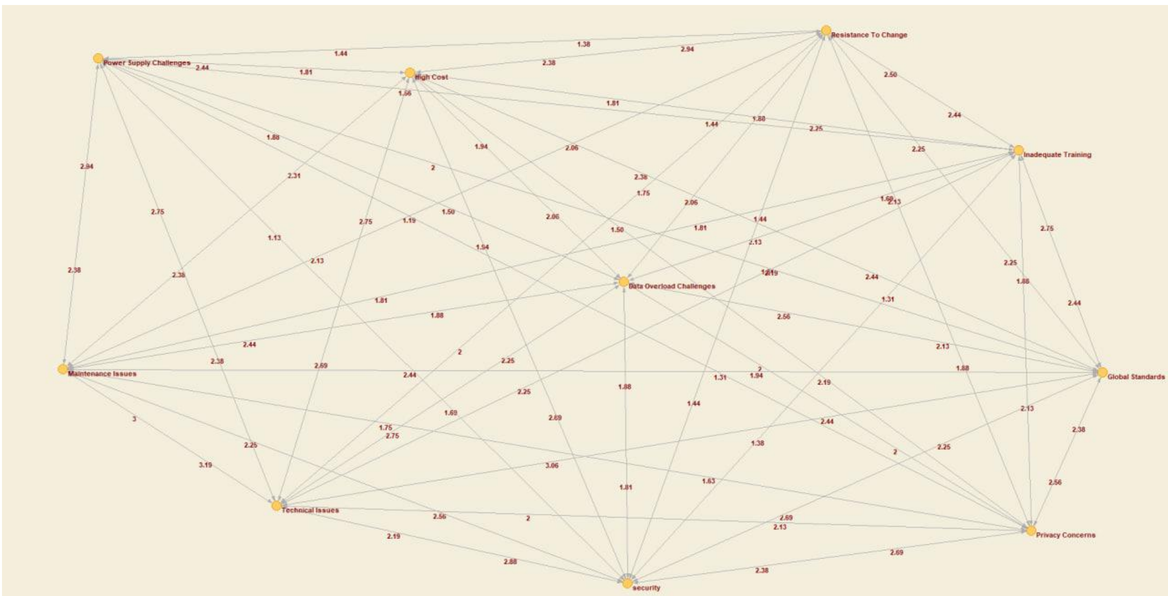

Figure 7

Final Cognitive Map of RFID Barriers

4. Discussion

The findings of this study offer a structured and quantifiable understanding of the barriers that impede the successful implementation of RFID systems in academic libraries. By employing the Fuzzy Cognitive Mapping technique, the causal relationships among ten identified barriers were modeled, facilitating a deeper interpretation of their interdependencies and systemic influence.

The Fuzzy Cognitive Map (Figure 7) reveals a complex web of interdependencies, highlighting two distinct causal chains: a technical-operational chain and a socio-economic one. In the technical domain, the strongest influence in the entire network is observed from maintenance issues to technical issues (Weight: 3.19). This indicates that inadequate maintenance is the primary driver of technical failures. This situation is significantly exacerbated by the lack of global standards (Weight: 3.06), suggesting that the absence of unified protocols acts as a major catalyst for technical incompatibilities. Consequently, these compounded technical challenges have a direct and severe impact on system safety, as evidenced by the strong link between technical issues and security (Weight: 2.88). Tracing the root causes further reveals that infrastructure limitations, specifically power supply challenges, are a critical precursor, significantly increasing maintenance issues (Weight: 2.94) by damaging sensitive components. Parallel to these technical hurdles, the model identifies a critical organizational barrier: High implementation cost serves as a powerful driver of resistance to change (Weight: 2.94), creating a financial bottleneck that fuels staff and management hesitation.

The findings of this study align with and significantly extend existing literature by mapping the causal pathways between isolated barriers. Regarding financial and organizational dynamics, our model identifies high implementation cost as a primary driver of resistance to change (Weight: 2.94). This validates the findings of Kisilu (2016) and Baradan et al. (2019), who highlighted costs as the main adoption hurdle, while simultaneously supporting Roy and Roy's (2023) study, who argued that staff resistance is often a direct downstream consequence of financial constraints and operational uncertainty rather than mere behavioral unwillingness.

In the technical domain, the strong relationship between technical issues and the lack of global standards (Weight: 3.06) corroborates Zhou (2019), confirming that without unified protocols, libraries face persistent interoperability failures.

Critically, our study deepens the understanding of infrastructural and security dynamics. Regarding infrastructure, our results corroborate Oke et al. (2023) and Osunsanmi et al. (2018), who identified power supply challenges as a major hurdle. However, our FCM analysis extends their findings by quantifying the causal mechanism, demonstrating that power instability is a direct precursor to severe maintenance issues (Weight: 2.94). This, in turn, fuels technical failures. In the domain of security, while the findings align with Mitrokotsa et al. (2010) and Molnar and Wagner (2010) regarding RFID vulnerabilities, our model reveals the root cause: security risks are not isolated but are significantly exacerbated by underlying technical issues (Weight: 2.88). Consequently, unlike previous studies that analyzed these barriers in isolation, our research proves that maintenance and power supply failures are the upstream drivers that eventually manifest as downstream security risks.

5. Conclusion

This study aimed to investigate and structure the primary challenges associated with the implementation of RFID systems in Iranian academic libraries. By employing the Fuzzy Cognitive Mapping (FCM) technique, the causal relationships among ten identified barriers were modeled, offering a deep interpretation of their interdependencies.

Contrary to traditional approaches that examine barriers in isolation, the findings of this research revealed that implementation challenges operate within two intertwined causal chains:

The Technical-Operational Chain: The analysis demonstrated that infrastructural challenges, particularly power supply instability, are not merely operational nuisances but act as critical precursors, leading to a severe increase in maintenance issues. This condition serves as the primary driver of technical failures, which ultimately manifest as security vulnerabilities within the system. Furthermore, the lack of global standards acts as a catalyst for technical incompatibilities, exacerbating system complexity.

The Socio-Economic Chain: In the organizational dimension, it was determined that high implementation costs are the primary and direct factor inducing resistance to change. This indicates that the hesitation of staff and managers is rooted in financial constraints and operational uncertainties, rather than mere behavioral unwillingness.

Ultimately, this study demonstrates that effective intervention for RFID success requires moving beyond addressing "symptoms" (such as security risks or staff resistance) and focusing on "root causes" (infrastructure stability and cost management) to halt cascading effects throughout the system.

Based on the findings of the FCM analysis, the following strategies are proposed to enhance the success rate of RFID implementation in university libraries:

- Focusing on Infrastructural Stability as a Security Prerequisite: Given that power fluctuations are the root cause of maintenance and technical issues, initial investment must focus on guaranteeing a stable power supply and protecting sensitive equipment to prevent the emergence of security risks in later stages.
- Prioritizing Standardization to Reduce Technical Overhead: Collaborating with national and international bodies to adopt or develop unified RFID protocols, thereby mitigating technical incompatibilities that lead to maintenance complexities.
- Managing Resistance through Financial and Operational Transparency: Since staff resistance is a consequence of cost concerns and ambiguity, developing transparent budgeting plans and providing comprehensive technical training can facilitate organizational acceptance by reducing uncertainty.
- Shifting Approach from "Repair" to "Prevention": Establishing Preventive Maintenance (PM) programs to disrupt the causal pathway where technical failures escalate into security flaws, ensuring vulnerabilities are neutralized before threatening the system.

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