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The Role of QR Code Technology in Revolutionizing Banking

Saurabh Bhattacharya*and Babita Singla

Chitkara Business School, Chitkara University, Chandigarh, Punjab, India 140401

Abstract

The financial services industry has undergone a significant digital revolution, with QR code technology playing a crucial role in the development of the banking sector. Evolving from basic barcodes, QR codes have become essential tools for identity verification, secure online transactions, and financial account management. They represent a shift from conventional banking practices, offering enhanced security and user convenience. In banking, QR codes are used for account management, payments, and robust security protocols. The widespread adoption of QR codes has transformed how customers interact with banks and has led to stronger security measures for online banking. This article examines the growing use of QR codes in banking, highlighting the convenience, security, and improved customer experience these codes offer. The increasing importance of QR technology in banking is further demonstrated by emerging trends such as Data Matrix QR Codes, Blockchain-Enabled QR Codes, Secure Timestamping, Encryption, and Dynamic QR Codes.

Keywords: QR Code Technology; Digital Banking Security; Customer Experience In Banking; Blockchain-Enabled QR Codes; Dynamic QR Codes

1 Introduction

A Quick Response (QR) code consists of a series of black and white squares that can be read by machines, typically used to store websites or other types of data that can be scanned by a smartphone camera. It is a two-dimensional barcode, capable of capturing and retrieving data instantly using the camera on a smartphone [1]. QR codes are not a recent development—they were first invented in 1994 by the Japanese company Denso Wave, a subsidiary of Toyota [2]. In the rapidly evolving landscape of digital transformation, the banking industry has been at the forefront of implementing advanced technologies to enhance customer experiences and streamline operations. One significant advancement in banking operations is the widespread use of QR codes, along with their multi-level equivalents, as effective substitutes for traditional paper-based documents. This article explores the potential of QR codes as a revolutionary technology in the banking industry, focusing on their role in transforming money transfers and document management. Through a comprehensive review of the literature, we examine the current state of QR code adoption in banking, its advantages over traditional paper-based methods, and its limitations. We also consider emerging developments and future directions, envisioning a financial ecosystem where QR codes are integral to improving user experiences and expediting processes. A QR code is a two-dimensional barcode made up of a grid of black squares on a white background that can store large amounts of data. Common applications of QR codes include storing text, contact information, URLs, and other types of data. With the appropriate QR code scanning software and a mobile device equipped with a camera, these codes can be easily scanned. The software decodes the information embedded in the code and performs the necessary actions, such as opening a webpage, dialing a phone number, or sending a text message. QR codes are widely used in applications such as marketing, payments, ticketing, and authentication. Figure 1 below illustrates the basic structure of a QR code after it has been scanned.

*Corresponding author: saurabhbhattacharya18@gmail.com
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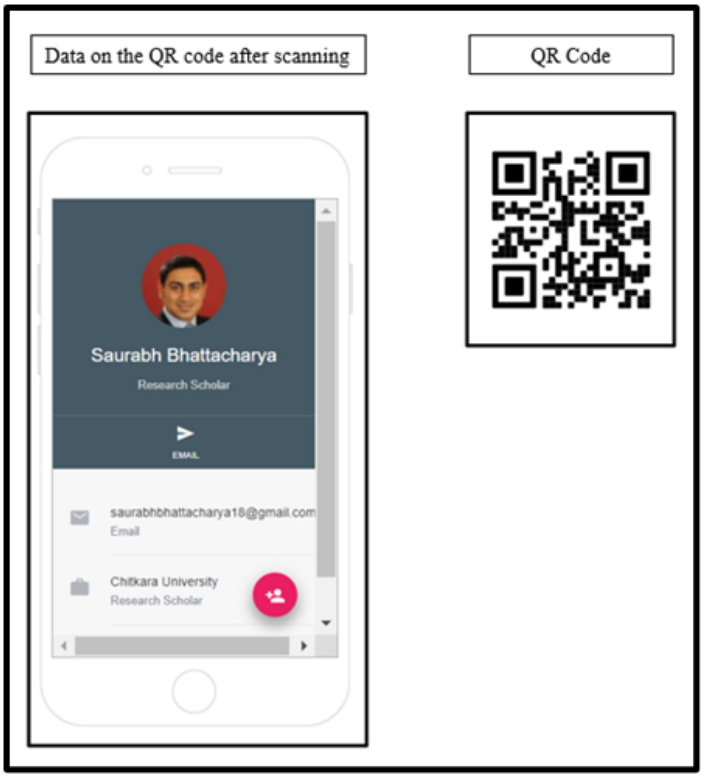

Figure 1: Basic QR code

The prevalence of QR codes in modern society reflects their convenience and efficiency in transmitting information. Within the banking sector, QR codes have revolutionized several processes by replacing traditional paper documents. This introduction examines the additional functionality offered by multi-level QR codes, which further enhance efficiency and security in banking operations. The introduction of QR codes has significantly improved reliability and customer satisfaction within banking. Traditional paper documents, such as account statements, invoices, and payment receipts, are increasingly being replaced by QR codes, which can be easily scanned using smartphones or other devices. This transition accelerates transaction times and reduces the environmental impact of paper usage, creating a more agile and responsive financial ecosystem [3]. QR codes are machine-readable, storing data both vertically and horizontally. They are also resilient—able to recover from errors if portions of the code are damaged—and can store up to 7,089 numeric characters, 4,296 alphanumeric characters, 2,953 bytes of binary data, or 1,817 Japanese Kanji/Kana characters, which is significantly more than a standard one-dimensional barcode [4]. The architecture of a QR code is layered, each layer contributing specific functionalities to ensure effective data encoding, structure, and decoding. Table 1 outlines the key layers involved in QR code architecture.

Table 1: QR Code Architecture Layers and Descriptions

Architecture Layer	Description
Data Layer	This layer includes the actual encoded data, such as alphanumeric characters, binary data, or byte arrays. It carries the information to be transmitted or stored.
Encoding Layer	The encoding layer involves the process of converting the data into a QR code matrix using specific algorithms, error correction codes, and patterns.
Structural Layer	The structural layer defines the format and structure of the QR code, including the positioning patterns, alignment patterns, timing patterns, and the overall grid layout.
Presentation Layer	This layer encompasses the visual representation of the QR code, including alignment markers, quiet zone, and potentially additional design elements, ensuring visual recognition.
Decoding Layer	The decoding layer involves the process of extracting and interpreting the encoded data from a scanned code using various algorithms and error correction techniques.

While manually decoding QR codes is not feasible for humans, scanning technology can easily interpret them. Many

free QR code scanner apps are available for download, and most smartphones now come equipped with built-in scanning software. Once the QR code is decoded, the software takes appropriate actions based on the information embedded in the code. Depending on the data stored, the code can initiate actions such as calling a phone number, sending an SMS, displaying a webpage, or launching a specific app. The next innovation in this paradigm is the multi-level QR code, which allows the storage of more complex data, such as user-specific information, encryption keys, and transaction details. This multi-layered approach enhances security by enabling the encryption and compartmentalization of sensitive data within the QR code, reducing the risk of unauthorized access. Multi-level QR codes also facilitate a more streamlined and personalized banking experience. By integrating various features into a single QR code, users can access comprehensive information and complete multiple transactions with a single scan. This highlights the banking industry's commitment to offering a cutting-edge, customer-focused experience, while simplifying interactions for users.

The Mobile Technology Acceptance Model (MTAM) was specifically developed to adapt to mobile environments in information technology research. It comprises two key factors: Mobile Usefulness (MU) and Mobile Ease of Use (MEOU) [5]. In essence, the adoption of QR codes and multi-level QR codes in banking represents a significant shift away from paper-based processes towards a digitally advanced future. This transition supports environmental sustainability goals while enhancing operational efficiency. As banks continue to leverage QR codes, the industry is poised for further innovation, paving the way for a more interconnected and technologically sophisticated banking environment. Initially developed for tracking parts in the automotive industry, QR codes have since evolved into versatile tools with applications across various sectors. In banking, they have emerged as a transformative technology, streamlining information sharing and transaction processing. QR codes and their multi-level variants have become indispensable in the digital age, transforming banking operations by introducing paperless efficiency. This article examines the ways in which QR codes have reshaped the banking industry, highlighting their ability to accelerate processes, improve account management, and enable secure document storage. The advanced data segmentation and error-correcting capabilities of multi-level QR codes further enhance efficiency. By significantly reducing paper usage, the adoption of QR codes not only simplifies banking processes but also contributes to environmental sustainability. As the banking sector increasingly adopts QR codes, the technology has far surpassed traditional methods, ushering in a new era of unmatched efficiency and digitalization. This article explores how QR codes can be leveraged to drive the banking industry toward a paperless future, with a particular focus on the potential of multi-level QR codes [6].

2 Motivation

The growing significance of QR codes in transforming the conventional banking sector is the driving force behind the decision to investigate the different applications of QR codes in the banking sector. QR codes have become a major force behind the ongoing digital revolution of financial services, offering a secure and adaptable way to handle transactions, identification checks, and account management. Understanding the implications of QR codes in the banking sector is crucial to appreciating their influence on account management, payment processes, and security protocols. Furthermore, examining the significance of QR codes within the broader context of the banking ecosystem can provide valuable insights into potential advancements in customer experience, security, and efficiency. Thus, this study aims to investigate the various functions of QR codes in banking and elucidate their importance in shaping the future of financial services.

Table 2: Research Objectives and their Motivation

Research Objective	**Motivation**
To investigate the different use cases of QR codes in the banking sector	Understanding the various applications of QR codes in banking is essential for comprehensively evaluating their impact and potential benefits within the industry.
To analyze the current trends and challenges related to the use of QR codes in the banking sector	Identifying current trends and challenges provides insights into the evolving landscape of QR code usage and potential obstacles that may affect its widespread adoption.
To examine the impact of QR code integration on transaction security and customer data protection within the banking sector	Understanding the effects of QR code integration on security and data protection is crucial for evaluating its overall suitability and impact on banking operations and clients.

3 Research Questions

RQ 1: What are the different ways QR codes are being used in the banking sector?
RQ 2: What are the current trends and challenges of using QR codes in the banking sector?
RQ 3: How does the integration of QR codes in banking impact transaction security and customer data protection?

The given objectives align with the investigation of several aspects of QR code use in banking, including its application, current trends, challenges, and effects on transaction security and customer privacy. These questions provide a comprehensive

framework for exploring the multifaceted role of QR codes in modern banking operations.

4 Related Work

The advent of mobile payment technologies, particularly Quick Response (QR) code-based systems, has resulted in notable disruptions across several business domains, with the retail industry being particularly affected. Despite this, significant obstacles remain in the widespread acceptance of mobile payment methods. Research has thus focused on important factors influencing the adoption of mobile payment technology based on QR codes in the retail industry. This research extends the Mobile Technology Acceptance Model (MTAM) to provide theoretical and practical insights for stakeholders in the retail business [5]. Two-dimensional barcodes are used in the QR-TAN authentication method to improve the security of electronic transactions. Unlike previous methods, QR-TANs enable users to validate transaction content on a trusted device, even if their computer has been compromised. When combined with smart cards, QR-TANs also facilitate secure offline transactions, offering critical protection against unauthorized transaction manipulation [7]. Dynamic capabilities have also been shown to significantly impact how well small and medium enterprises (SMEs) perform when using QR code payments and mobile money in developing nations. It is recommended that SMEs adopt digital financial services to improve performance and agility, particularly in volatile business environments such as the COVID-19 pandemic [8]. Mobile payments have transformed industries, especially retail, though government efforts have not yet fully increased the adoption rate in countries like Malaysia [5]. Systems incorporating security features, such as secret encryption algorithms and self-destruct mechanisms for security keys, offer additional protection against various attacks. The system also uses multiple key containers and physical security measures for enhanced safety [9]. QR codes are widely used in anti-counterfeiting and product traceability. However, since the source of QR codes is publicly available, the data they contain is not inherently secure. To mitigate this, encryption techniques like RSA and AES are recommended, though dynamic QR codes may be required to comply with national regulations and prevent duplication [10]. Researchers have explored using one-time passwords (OTPs) and QR codes as two-factor authentication (2FA) methods for website logins, emphasizing the need for 2FA in bolstering online security [11]. Honeywords and 2FA, when combined with mobile phones and QR codes, also improve password security [12]. For QR code payment security, visual secret sharing (VSS) is used in combination with QR codes to enhance anti-counterfeit safeguards. By stacking two QR code shares with merchant information, this technique confirms the legitimacy of QR code payments [13]. To combat product counterfeiting in e-commerce, blockchain technology and destructible QR codes can be employed, increasing transparency and authenticity [14]. Biometric authentication combined with QR code scanning is also used in online banking, reducing infrastructure costs and enhancing transaction security [9]. Research has shown that fingerprint-based identification with QR codes can streamline the check-in process for travelers by verifying their identity without requiring physical documentation [15]. Mobile banking security is improved with a hybrid solution that incorporates QR codes, OTPs, and digital watermarking [16]. QR codes are increasingly used in secure, visually appealing forms for digital payment and information sharing [17, 18]. To tackle counterfeit goods, Near Field Communication (NFC) technology has been proposed for consumer-level product authentication. By utilizing public key cryptography (PKC) and a public key infrastructure (PKI), this approach offers dual-layer authentication without relying on centralized databases [19, 20]. A systematic review of NFC technology highlights its applications in sectors like healthcare and public transportation [21, 22]. Finally, studies suggest that perceived risk, service quality, and transaction speed significantly affect the QR code mobile payment experience [23]. Insights into consumer behavior regarding mobile QR-code payments in China have shown that perceived security and utility are key factors driving user satisfaction and value perception [24]. Further analysis of the literature has identified key factors, such as personal innovativeness and social influence, that affect the adoption of QR code payment systems [25–28].

5 Research Methods

This study employed the Systematic Literature Review (SLR) methodology [29] to systematically investigate the role and use of QR codes in the banking sector. The SLR process consists of three main stages: planning, execution, and reporting. These stages are depicted in Table 3, which outlines the sub-stages and their descriptions. A total of thirty primary articles were included in this review, as illustrated in Figure 2. The steps involved in each stage of the process are described below. The search for relevant studies was conducted using a variety of academic databases, including Springer, Wiley, ScienceDirect, Google Scholar, and IEEE Xplore. The number of studies retrieved from each database is shown in Figure 2. After applying the inclusion and exclusion criteria, the final 30 studies were selected for detailed analysis.

Table 3: Stages and Sub-Stages of the SLR Process

Stage	Sub-Stage	Description
Planning	Formulate Research Questions	Clearly define the research questions and objectives for the review process.
Planning	Develop Search Strategy	Identify relevant databases, search engines, and repositories to systematically search for existing literature.
Planning	Preparation of Protocol	Outline the review process, inclusion/exclusion criteria, and data extraction methods.
Execution	Search and Screening	Implement the search strategy to systematically identify and retrieve relevant articles and documents.
Execution	Data Extraction	Extract relevant information from the selected studies using a standardized template for consistency.
Execution	Quality Assessment	Evaluate the quality and credibility of the selected studies using established tools or frameworks.
Reporting	Data Synthesis	Analyze and synthesize the findings from the selected studies, identifying common themes and gaps in the literature.
Reporting	Report Writing	Document the review findings in a comprehensive report, presenting the methodology, search results, and conclusions.
Reporting	Peer Review and Feedback	Seek feedback from peers, subject matter experts, or stakeholders to validate the review process and findings.
Reporting	Publication and Dissemination	Consider publishing the review in a reputable journal, presenting it at conferences, or disseminating the findings to relevant communities.

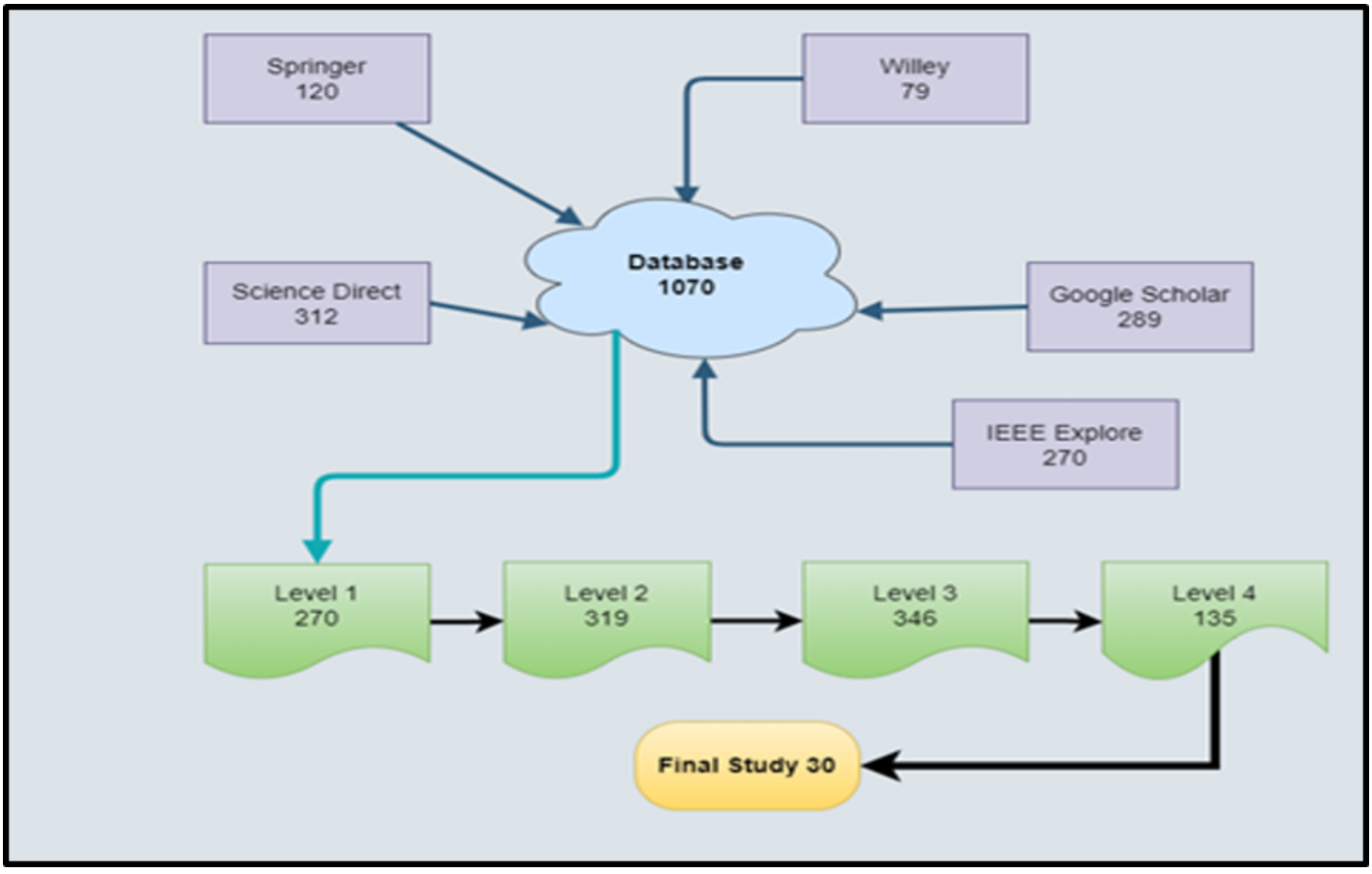

Figure 2: Search Database and Final Study Count

Table 4 provides the list of databases used in the search process along with their respective URLs. Based on the study's

objectives, the following keywords were used to perform the search: *("QR Code" OR "Dynamic QR Code" OR "Static QR Code" OR "Biometric Authentication" OR "Two-Factor Authentication.")*

Table 4: Search Databases

Source	Website
Scopus	https://www.scopus.com
IEEE Xplore	https://ieeexplore.ieee.org
Google Scholar	https://scholar.google.com
Springer	https://www.springer.com
ScienceDirect	https://www.sciencedirect.com

6 Discussion on Selected Articles

RQ 1: What are the different ways QR codes are being used in the banking sector?

The research questions are thoroughly addressed in this section to ensure that the goals of the study are clear. The introduction of QR codes in banking has resulted in substantial improvements in transaction security and customer data protection. QR codes streamline the authentication processes for a range of financial services, providing customers with a quick and secure way to initiate transactions. By utilizing QR codes, financial transactions expose less sensitive data, increasing transaction security. Furthermore, employing QR codes for authentication reduces risks associated with traditional methods, such as phishing and unauthorized access. QR codes have enabled contactless payments and peer-to-peer money transfers, eliminating the need for face-to-face interactions and reducing the potential exposure of sensitive data. Contactless payment technologies lower the risk of fraud by preventing the interception of payment information. The encrypted nature of QR codes enhances customer data security, lowering the risks of unauthorized access to financial and personal information. The various application of QR code authentication found in the banking sector are:

- **Mobile Banking Apps**: Financial institutions and banks use QR code authentication to ensure safe login and transaction authorization within their mobile apps.
- **Two-Factor Authentication (2FA)**: QR codes link and create secure user accounts, providing an additional layer of security to online services.
- **Secure Messaging Channels**: Messaging services use QR codes for safe device authentication and linkage, ensuring encrypted communication.
- **Access Control Systems**: QR codes manage and verify entry to restricted areas or buildings.
- **Secure Document Sharing**: QR codes validate documents and allow sensitive information to be transmitted efficiently and securely.

Table 5: Use Case with Pros and Cons of Various QR Code Types

Aspect	Static QR	Dynamic QR	2FA QR	Biometric QR	Blockchain-enabled QR
Data Storage	Store fixed data only	Store and display data that can be updated	Store data for two-factor authentication	Store biometric data for user authentication	Store data in a decentralized and secure manner
Use Case in Banking	Account information, payment requests	Real-time updates on account balance, promotions	Two-step verification, login authentication	User identification, access control, transaction authorization	Secure transactions, asset tracking, authentication, validation
Pros	Simple to generate and use, can be static for repeated use	Real-time updates, versatile applications, marketing tool	Added layer of security, mitigates unauthorized access	Enhanced security, convenience for users	Immutable data records, increased security, decentralized verification
Cons	Limited functionality, not suitable for real-time data	Complex generation and management, potential data misuse	Dependency on second factor, inconvenience for users	Reliability and accuracy of biometric data, potential privacy concerns	Integration challenges, specialized knowledge and support may be required

The latest QR code techniques in Banking in the present day are:

- **Dynamic QR Codes**: These QR codes can store information that changes over time, such as transaction amounts and details. This allows for flexible transactions while enhancing security.
- **QR Authentication**: By utilizing QR codes for multifactor authentication, users can securely access accounts and approve transactions.
- **QR-based Payment Applications**: Many banks are developing apps that enable customers to transfer money, pay bills, and make contactless purchases using QR codes.
- **Secure QR Code Scanning**: Organizations have implemented safe scanning systems to ensure QR codes are authentic and unmodified before processing transactions.

RQ 2: What are the current trends and challenges of using QR codes in the banking sector?

QR codes can serve as a vector for phishing attacks, potentially leading to fraudulent transactions and unauthorized access to personal financial information. Concerns have been raised regarding customer data privacy when using QR codes for transactions and authentication, especially if the data is intercepted or handled improperly. As the use of QR codes in banking grows, standardized methods and interoperable technologies are essential to ensure simple and secure transactions across multiple platforms and institutions. To mitigate potential security and privacy issues, it is crucial to inform customers about the risks and best practices associated with using QR codes in banking. The rise of mobile banking apps has completely transformed how payments are made, making it easier for customers to manage financial activities while improving the standard of service in the financial industry. The COVID-19 pandemic accelerated the widespread adoption of mobile banking applications, including the use of QR codes, as they provide a flexible and dynamic way to simplify many operations [28]. Customers can now perform payments, make purchases, and transfer money without physical interaction thanks to QR codes. These transactions are more efficient, eliminating the need for paper cards or manual data entry. Studies show that banks are increasingly using QR codes for a variety of purposes, such as client interactions, account management, and payment facilitation [30].

Table 6: Trends in QR Code Usage in the Banking Sector

Trend	Use Case for Banking	Pros	Cons	Challenges
Dynamic QR	Real-time payments, account management, secure data updates	Enhanced security, ability to change and update data	Requires network availability for real-time updates	Data synchronization, potential for abuse or misuse
Secure Encoding Standards	Secure transactions, data integrity assurance	Protection against tampering, unauthorized access, and modification	Implementation complexity, potential performance impact	Standardization, interoperability, education on secure coding and practices
Mobile Security Features	Secure customer authentication, transaction verification	Biometric and device-specific authentication, enhanced user security	Potential for user inconvenience, device compatibility concerns	Data privacy, user acceptance, secure storage of biometric data
Anti-Counterfeiting Measures	Secure payments, product authentication	Reduced counterfeiting, enhanced trust and authenticity	Additional production costs, potential user confusion	Standardization, scalability, validation methods
Secure QR Scanning Apps	Secure payment processing, user protection	Protection against malware, phishing, and other security threats	Dependence on app security, potential for false sense of security	User adoption, app standardization, threat landscape changes
Blockchain-enabled Verification	Secure and tamper-proof transactions, data integrity	Decentralized verification, tamper-resistance, transparency	Blockchain complexity, resource-intensive validation process	Integration with existing infrastructure, regulatory acceptance

Driving Forces Behind QR Code Adoption in Banking

QR codes have become a powerful tool in banking to improve client experiences and streamline operations. They are used for a range of purposes, from document authentication and transmission to payment systems and account management. QR codes allow consumers to quickly access information and complete transactions using their mobile phones. This technology has become a critical component of wireless payment solutions, enabling users to make purchases without needing cash or physical cards. QR codes also play a significant role in facilitating secure and fast money transfers between banks, offering a more practical alternative to traditional paper records [31]. The adoption of QR codes in banking has reached a pivotal stage, revolutionizing financial transactions and enhancing customer experiences. However, it is crucial to address security, standardization, and interoperability concerns to ensure sustainable expansion.

RQ 3: How does the integration of QR codes in banking impact transaction security and customer data protection?

The use of QR codes in banking can affect client data privacy and transaction security in both positive and negative ways. Security in the financial sector is critical. To ensure the secure storage of private financial information, QR codes have been rigorously evaluated. Numerous researchers have examined the security features of QR codes, identifying weaknesses and offering solutions to safeguard the integrity of financial transactions. QR codes provide various positive impacts in banking.

They enable contactless transactions, reducing the risk of in-person theft and unauthorized access to sensitive customer data. QR codes can also contain encrypted data, providing a secure method of transferring transaction data from the customer's device to the bank's servers. Moreover, some QR code payment systems support two-factor authentication (2FA), which adds an extra layer of security for verifying transactions and protecting client information. A novel approach to 2FA suggests replacing SMS-based authentication, which is considered less secure, with QR codes containing steganography. This method hides mobile transaction authentication numbers (mTANs) within the QR code, making the data accessible only through a specific scanner with the shared key [32, 11]. However, QR codes also come with potential negative impacts. Malicious actors can create fake QR codes to trick customers into scanning them, leading to data breaches or financial loss through phishing and spoofing. The security of the customer's device is also crucial when using QR codes because compromised devices could expose transaction data to unauthorized parties. Additionally, if proper security precautions and encryption are not employed, data encoded in QR codes could be intercepted during transmission. To mitigate these negative impacts and enhance transaction security and customer data protection, banks must implement robust encryption mechanisms, authentication protocols, and customer education programs. These measures help ensure that QR codes can be safely integrated into banking operations, protecting both customer data and transaction integrity. Several studies have highlighted the critical role of QR codes in transforming financial payment systems. Researchers demonstrate that QR codes can be used in mobile payments, making transactions safe and easy to execute [33]. Customers benefit from QR codes through greater convenience, as they can easily complete various banking transactions using mobile devices, such as paying bills and checking account balances, without needing cumbersome authentication methods or physical cards. Banks increasingly adopt QR codes to enhance security during login and transaction authorization processes, with additional layers of protection offered by technologies like tokenization, encryption, and dynamic QR codes. These solutions help reduce the risk of fraud and unauthorized access while offering cost-effective modernization for banking institutions, with minimal infrastructure required to implement QR code-based services.

QR codes are also improving the overall management of customer accounts. With a quick scan, customers can securely access account balances, view transaction histories, and perform other account management tasks, streamlining the user experience. For instance, QRAM (Quick Response Code-based Authentication Methods) enhances security in IoT applications and real-time systems by speeding up verification times for QR codes, demonstrating higher resilience against unauthorized access attempts. Additionally, watermarked QR codes have been integrated into mobile banking apps, providing high security against unauthorized access and eavesdropping during online transactions [34]. The transition to QR code-based digital alternatives in banking has significant implications. First, it promotes environmental sustainability by reducing paper use and minimizing resource consumption. Moreover, QR codes improve operational efficiency by enabling faster, more accurate data processing, saving time and resources previously used for manual document handling. This shift to digital methods also aligns with the larger trend of digitization within the banking industry. By adopting these technologies, banks can remain competitive, satisfy the demands of tech-savvy customers, and stay at the forefront of innovation. The ease of use provided by QR codes improves the overall customer experience, enhancing satisfaction and loyalty.

7 Conclusion

The use of QR codes in banking has provided customers with a safe and efficient way to access banking services through mobile apps while ensuring data protection. Given the widespread adoption of smartphones, users can now securely access sensitive data and log into their accounts using QR codes, which have proven to be a useful and user-friendly technology. Compared to traditional username-and-password-based security methods, QR codes offer enhanced customer data protection. In summary, the adoption of QR codes in banking has delivered significant benefits in both transaction security and customer data protection. The introduction of QR codes has notably reduced the exposure of sensitive data, accelerated identification processes, enabled contactless payments, and improved accessibility to financial services via mobile applications. Consequently, QR codes have become a valuable tool in the banking sector for strengthening transaction security and safeguarding customer data. However, further research and ongoing evaluation are necessary to ensure the long-term sustainability of QR code integration in banking and to adapt to evolving security challenges. This study emphasizes the importance of QR code technology in enhancing transaction security and customer data protection, ultimately offering clients a safer and more secure banking experience.

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Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contribution

Saurabh Bhattacharya: Conceptualization, Methodology, Investigation, Writing - original draft, review, and editing. **Babita Singla**: Investigation, Visualization, Resources.

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