Implementation of RFID Technology as an Innovative Solution for Payment Systems in Supermarkets

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Abstract

This research focuses on the application of Radio Frequency Identification (RFID) technology as an innovative solution for the payment system at Islamic Boarding School. The current manual payment system causes several problems, such as excessively long queues, human error, and lack of parental supervision of financial transactions. The purpose of this research is to design and implement an RFID-based payment system to address these problems by increasing transaction speed, reducing errors, and improving operational efficiency. This system is designed to facilitate fast and accurate payments while minimizing human intervention. This research uses a System Development Life Cycle (SDLC) approach with a Waterfall model to ensure the system development process runs systematically and structured, from the design stage to implementation. The results show that the RFID-based payment system successfully increases transaction efficiency, reduces queues, and provides better financial monitoring for administrators and students. This system is also in line with the goal of modernizing Islamic boarding school operations, creating a more professional and enjoyable environment. This research highlights the benefits and challenges in implementing RFID technology in an academic environment, and provides recommendations for further development in the future.
Keyword: RFID; Payment System; System Development Life Cycle.

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1. Introduction

Islamic boarding schools (pondok pesantren) in Ponorogo are educational institutions that integrate religious and general education. Aimed at producing a generation that is knowledgeable, faithful, and of noble character, these pesantren provide various facilities, including DT MART minimarket, which serves the daily needs of students (santri) and the surrounding community. Beyond functioning as centers for religious learning, pesantren in this context also actively support innovation and digitalization to improve service quality and strengthen pesantren-based economic activities.

At present, the pesantren still relies on manual payment methods, which result in long queues, inconvenience, and difficulties for santri in managing their personal finances. Funds sent by parents are often depleted quickly due to inadequate financial management. Consequently, santri may run out of money, while parental supervision remains challenging because of geographical distance (Fadila et al., 2024). In addition, pesantren administrators face difficulties in monitoring financial flows without an adequate system. This condition may contribute to deviant behaviors such as theft among santri when their funds are exhausted (Kommey et al., 2022). Therefore, an information-technology-based payment system is needed to facilitate financial monitoring through card-based transactions. Such a card-based payment system is capable of processing approximately 200-300 transactions per day with a transaction time of only 3-5 minutes, whereas manual transactions can take up to 10 hours, generating severe congestion during peak periods.

Considering the need for efficiency and convenience in payment operations, the adoption of Radio Frequency Identification (RFID) technology offers an innovative solution to replace the current manual payment system. Through RFID (Tundjungsari & Prisdianto, n.d.), customers can complete payments automatically using a card connected to this technology, thereby enabling faster and more accurate transactions while reducing the likelihood of human error. In addition to improving transaction efficiency, RFID implementation aligns with the broader trend of digitalization, providing pesantren with opportunities to innovate and remain competitive in the modern era (Rahim et al., 2020).

The implementation of an RFID-based payment system at DT MART is expected not only to enhance productivity and customer convenience, but also to foster a more modern and professional image within the pesantren environment. This study aims to explore the potential of RFID technology as a substitute for manual payment practices at DT MART and to identify the benefits and challenges that may emerge during implementation (Muhammad Ridho Assyifa, 2025).

With an RFID-based payment system, DT MART is anticipated to experience positive impacts in both operational and strategic dimensions. Beyond increasing transaction efficiency, the system may create a more modern and professional impression, which in turn can support the pesantren's broader development agenda. RFID payment technology is designed to enable contactless transactions between the card and the reader, offering convenience, efficiency, and speed in the payment process (Setiyani et al., n.d.).

2. State of The Art

This study adopts a mixed-methods design, combining qualitative and quantitative approaches to examine the implementation of Radio Frequency Identification (RFID) technology in a pesantren-based payment system. Grounded in information systems theory and the digitalization of payment services, the study aims to enhance efficiency and reduce errors commonly associated with manual payment transactions. Using the Software Development Life Cycle (SDLC) Waterfall model (Alif Ramadhan et al., 2023), the research develops and evaluates an RFID-enabled system integrated with the existing infrastructure of DT Mart, a minimarket operating within the pesantren environment. System testing is conducted to assess transaction processing speed (Yahya et al., 2022), RFID reading accuracy, and system resilience under high transaction loads. In addition, the study incorporates a literature review and direct field observation to gain insights into the social and operational challenges that may arise during implementation, as well as to evaluate the benefits of improved financial oversight through the integration of a santri balance-monitoring feature (Hamzah et al., n.d.). The findings are expected to provide a foundation for developing similar systems in other pesantren contexts and to contribute to the broader literature on information technology adoption in Islamic educational institutions.
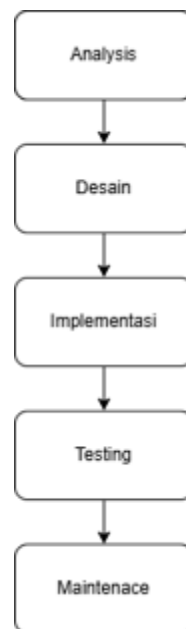
3. Method

Figure 1: Waterfall Research Method

The system development stages in this study follow a sequential workflow consisting of analysis, design, implementation, testing, and maintenance (Sri Rahayu et al., 2024). During the analysis phase, the researchers identify the core problems and user requirements and document them in a system requirements specification. The outcomes of this analysis are then translated in the design phase into a blueprint of the system architecture, database structure, and user interface, which serves as the reference for application development. Next, in the implementation phase, the design is converted into program code until a fully executable system is produced. The testing phase is subsequently conducted to ensure that each function operates in accordance with the defined requirements and to identify and resolve any

remaining errors. The final phase is maintenance, which involves sustaining the system after deployment through bug fixes, feature updates, and adjustments to emerging needs to ensure the system remains optimal and relevant (Wahid, n.d.).

Data collection in this study is conducted through two primary methods: a literature review and direct observation. The literature review involves examining a range of academic sources, including books, peer-reviewed journal articles (Karaman et al., 2020), and relevant case studies addressing the application of Radio Frequency Identification (RFID) technology in payment systems. This process aims to establish a comprehensive theoretical foundation to guide the design of a payment system that is efficient, effective, and aligned with user needs.

In addition, direct observation (Nikmah, 2023) is carried out at the research site to identify practical issues experienced by administrators and users within the manual payment system. Through this observation, the researchers gain deeper insight into transaction workflows, operational constraints, and user requirements, all of which inform the development of the RFID-based payment system.

System testing is performed to ensure that the developed RFID-based payment system functions properly and meets the expected performance criteria. The testing process focuses on three main aspects: RFID reading accuracy, transaction speed, and system robustness. The RFID accuracy test evaluates the reader's ability to detect tags with high precision across varied positions and distances. Transaction speed testing measures the total processing time per transaction, with a target response time of less than two seconds. Finally, robustness testing is conducted through large-scale transaction simulations to assess system stability and responsiveness when operating under high-load conditions.

4. Result

The implementation phase is carried out after the system design has been completed. This stage aims to operationalize the proposed system design, namely an RFID-based payment system for DT Mart. In this section, the system design and its usage procedures are also described.

1. Implementation

Figure 2: Interface Login

Figure 2 presents the login page, which requires users to enter an email address and password to access their accounts. Above the "Login" button, two main input fields are provided for entering the email and password. Directly below the password field, the "Remember me" option is available as a checkbox, allowing users to remain logged in on the same device without re-authentication. In addition, users may choose to sign in using Facebook through the "Login with Facebook" button. For users who forget their passwords, a "Forgot password" link is provided to restore account access. Users who do not yet have an account can create a new one by clicking the "Register here" link.
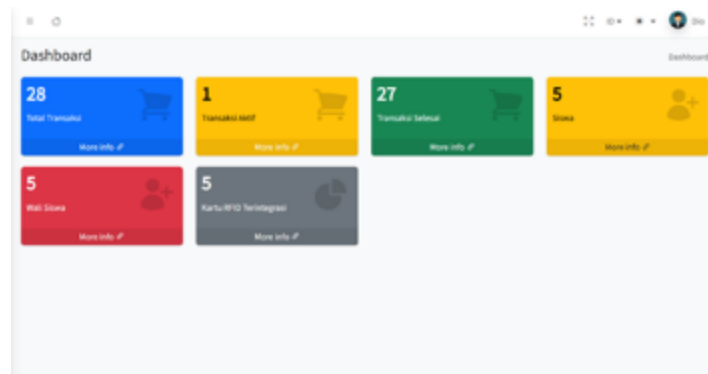

Figure 3 : Dashboard

Figure 3 displays the administrator dashboard of the cashier sales simulation system. The dashboard summarizes key system indicators, including total transactions, active transactions, completed transactions, student guardians, RFID cards, and students. The first panel reports a total of 28 recorded transactions. The second panel shows the number of active transactions, with one transaction currently in progress. The third panel indicates that 27 transactions have been completed. Below these, the dashboard presents the number of registered students, totaling five. On the lower right side, the dashboard reports integrated RFID card data, showing five active RFID cards. The final panel displays the number of registered student guardians, also totaling five.
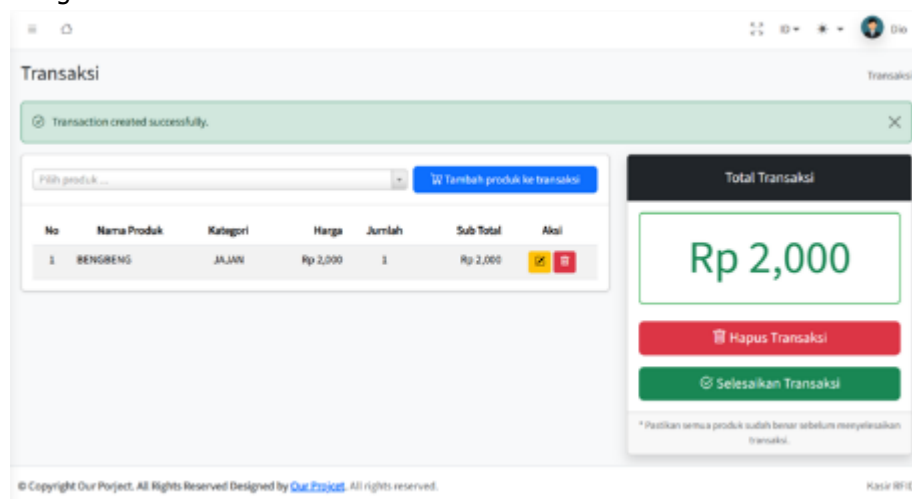

Figure 4: Transaction

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Figure 4 illustrates the cashier interface used to process product purchase transactions. After a transaction is successfully recorded, the system displays a confirmation message, "Transaction created successfully," at the top of the screen. Below this notification, a dropdown menu is available for selecting products, along with an action button to add selected items to the transaction list. In the transaction details table, the product "BENGBENG" appears under the category "Snacks," with a unit price of IDR 2,000, a quantity of one unit, and a subtotal of IDR 2,000. The table also provides action buttons to edit or remove items. On the right side of the interface, the system displays the total transaction value of IDR 2,000 along with two action buttons: "Delete Transaction" and "Complete Transaction." A reminder message is also shown to ensure all product data are correct before finalizing the transaction. At the bottom of the page, copyright information and the cashier system design identity are displayed.

Figure 5 : Complete the transaction

Figure 5 shows the final stage of a cashier application or payment system, with a total transaction value of IDR 2,000. The screen title, "Complete Transaction," indicates that the user is required to confirm and finalize the payment. Below the title, the payment method is set to "Card," followed by an input field labeled "RFID Card Number," which is already populated with a numeric value. A barcode icon appears on the left side of the field, indicating that the card can be scanned. Red text stating "Required" indicates that the RFID card number must be provided—either by scanning the card or entering it manually—before the transaction can be processed. At the bottom, two buttons are displayed: "Close," which cancels or closes the window, and the green "Complete Transaction" button, which confirms and finalizes the payment once all data are verified.

The implementation of RFID technology in a *pondok pesantren* in Ponorogo is intended to improve transaction efficiency and reduce errors commonly associated with manual payment systems (Hafid & Dewanto, 2025). The implementation results indicate a significant improvement in efficiency, where the average time required to process a single transaction is only 1.85 seconds—substantially faster than the manual system, which previously required up to 10 hours to complete transactions during peak periods. The system is capable of handling approximately 200 to 300 transactions per day, thereby reducing the long queues typically observed under manual payment operations (Cobantoro et al., 2024).

During the design and testing stages, an RFID reader operating at a frequency of 13.56 MHz was successfully integrated with DT Mart's existing infrastructure. Testing results show satisfactory RFID tag-reading accuracy, reaching 95%. The system is able to verify transaction data quickly and accurately, improving efficiency and minimizing human error in the payment process. A key advantage of the RFID-based system lies in its transaction speed. During testing, the system consistently processed transactions in under two seconds per transaction without failures or delays. This demonstrates that the RFID-based payment system is substantially more efficient than the manual approach, reducing queues and improving customer convenience (Magdalena & Dwisaputra, n.d.).

5. Discussion

Based on the implementation results, the RFID-based cashless payment system demonstrates reliable performance in supporting daily transaction processes. The integration between the RFID reader and the server enables consistent card detection, customer data verification, and real-time display of transaction information—including initial balance, purchase value, and remaining balance—through the available user interface. This indicates that RFID is technically feasible as an automated payment solution in environments with relatively high daily transaction volumes, as it can accelerate service delivery and reduce queue length (Widhyaestoeti et al., 2023).

However, these findings also emphasize that successful implementation is not determined solely by technical performance, but is strongly influenced by user experience—particularly among pesantren administrators and santri as the primary actors operating the system. Accordingly, strengthening the system from a usability perspective becomes essential. An intuitive interface, simplified interaction flow, and structured training programs are critical to minimizing operational errors, improving user comfort, and accelerating system-wide adoption (Siregar et al., 2025).

From the perspective of improving *santri* financial governance, RFID implementation in a pesantren environment provides broader value beyond transaction acceleration. A card-based system creates opportunities to integrate balance monitoring and transaction history features (Rekayasa et al., 2025), enabling guardians to observe spending patterns and regulate allowance usage remotely. This implication reinforces the argument that an RFID payment system may function not only as a cashless transaction mechanism, but also as an accountability tool that enhances transaction data accuracy and supports managerial decision-making for pesantren business units.

Thus, the findings from DT Mart not only confirm the benefits of RFID for cashless payments, but also expand its application context—from conventional school settings toward a more complex pesantren

economic ecosystem, where integrated financial control and transparent reporting are increasingly necessary, comparable to the operational requirements of modern retail systems (Ilmiah & Akuntansi, 2020).

In terms of security, the adoption of RFID in a cashless payment system also introduces critical considerations that must be addressed to ensure user trust and system integrity (K et al., 2024). Although RFID enables fast and contactless transactions, the technology may be vulnerable to risks such as unauthorized scanning, card cloning, data interception, and misuse when security controls are weak particularly in open environments with high user mobility such as pesantren (Cobantoro et al., 2023). Therefore, the system should be strengthened through layered safeguards, including secure authentication mechanisms (e.g., PIN-based verification for certain transactions), encrypted communication between the RFID reader and the server, unique card identifiers with access control, and role-based permissions for administrators (Cobantoro & Abdurrozzaq, 2025). In addition, routine security audits, activity logging, and monitoring of suspicious transaction patterns are recommended to detect anomalies early and prevent fraud. By integrating these security measures, RFID-based payments can remain efficient while also ensuring confidentiality, integrity, and accountability within pesantren financial transactions.

6. Conclusion

Based on the study findings, it can be concluded that implementing RFID technology in the payment system at DT Mart—one of the retail units within an Islamic boarding school (pondok pesantren) in Ponorogo—constitutes an innovative solution to replace the less efficient manual payment process. The system, developed using the Software Development Life Cycle (SDLC) with a Waterfall model, demonstrably improves transaction speed and operational efficiency, as reflected by an average transaction processing time of approximately 1.85 seconds and a throughput capacity of 200–300 transactions per day, thereby significantly reducing long queues. The integration of a 13.56 MHz RFID reader with the existing infrastructure achieves a tag-reading accuracy rate of 95%, minimizing human error and enhancing the reliability of transaction records. Moreover, the system creates opportunities for further feature development, such as balance monitoring and transaction history tracking for students, which can be accessed by administrators and students' guardians to strengthen financial oversight and transparency. Overall, this research indicates that RFID technology is feasible and effective for adoption in pesantren environments where economic activities resemble those of modern retail stores, and it provides a foundation for future enhancements, including integration with the institution's financial information system and the expansion of managerial functionalities.

Acknowledgments

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