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A Motorcycle Security System Based on Rfid Technology Using the Indonesian Electronic Identity Card (E-KTP) as an Ignition Key

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Abstract

Motorcycle theft is one of the most frequent criminal acts in Indonesia and is closely related to the limitations of conventional vehicle security systems in preventing unauthorized access. This study proposes the design and implementation of a motorcycle security system based on Radio Frequency Identification (RFID) technology that utilizes the Indonesian electronic identity card (e-KTP) as an ignition key. The research employs a Research and Development (R&D) approach with the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation—to ensure a systematic and iterative development process. The proposed system consists of an RFID RC522 module, Arduino Uno microcontroller, relay-based ignition switching, and an LM2596 step-down DC–DC power regulator. Experimental testing shows a 100% authentication success rate for registered e-KTP cards, with an effective reading distance of up to 2 cm. Non-metallic enclosure materials have negligible impact on reading performance, whereas metallic materials significantly attenuate the RFID signal. These results indicate that the proposed design is effective and feasible as a low-cost embedded security enhancement that integrates the national ID infrastructure into motorcycle access control.

Keywords: *e-KTP, Motorcycle Safety, Vehicle Security System, Arduino,*

Abstrak

Pencurian sepeda motor merupakan salah satu tindak kriminal yang paling sering terjadi di Indonesia dan berkaitan erat dengan keterbatasan sistem keamanan kendaraan konvensional dalam mencegah akses tanpa izin. Studi ini mengusulkan desain dan implementasi sistem keamanan sepeda motor berbasis teknologi Radio Frequency Identification (RFID) yang menggunakan kartu identitas elektronik (e-KTP) Indonesia sebagai kunci kontak. Penelitian ini menggunakan pendekatan Riset dan Pengembangan (R&D) dengan model ADDIE—Analisis, Desain, Pengembangan, Implementasi, dan Evaluasi—untuk memastikan proses pengembangan yang sistematis dan berulang. Sistem yang diusulkan terdiri dari modul RFID RC522, mikrokontroler Arduino Uno, sakelar pengapian berbasis relay, dan regulator daya DC-DC step down LM2596. Pengujian eksperimental menunjukkan tingkat keberhasilan otentikasi 100% untuk kartu e-KTP yang terdaftar, dengan jarak baca efektif hingga 2 cm. Material penutup non-logam memiliki dampak yang negligible terhadap kinerja pembacaan, sedangkan material logam secara signifikan melemahkan sinyal RFID. Hasil ini menunjukkan bahwa desain yang diusulkan efektif dan layak sebagai peningkatan keamanan terintegrasi berbiaya rendah yang mengintegrasikan infrastruktur identitas nasional ke dalam kontrol akses sepeda motor.

Kata kunci: Jaringan syaraf tiruan, Bayessian regularization, MAPE

Introduction

Motorcycles are the most widely used and preferred means of transportation in Indonesia, where, according to Article 47, UU No. 47, 2009 paragraph (1), vehicles are classified into two categories: motorized vehicles and non-motorized vehicles [1]. Their relatively affordable price, fuel efficiency, simple maintenance, and ability to navigate narrow and diverse road conditions make them the main choice for many road users. In both cities and villages, motorcycles play a crucial role as vehicles for daily commuting, transporting goods, and supporting various small-scale businesses. Official statistics from the Ministry of Transportation of the Republic of Indonesia indicate that in several regions, more than 80% of residents depend on motorcycles as their primary mode of daily travel [2]. However, the rapid increase in motorcycle ownership has been accompanied by a worrying escalation in motorcycle theft. Data from the Indonesian National Police indicate that thousands of vehicle theft cases are recorded annually, particularly in densely populated cities with high mobility levels [3]. Although there is extensive literature on vehicle theft in general, relatively few studies specifically focus on bicycle and motorcycle theft [4]. The growth rate of motorized vehicles is not proportional to the growth of roads or the length of roads available [5]. This situation underscores the limitations of existing vehicle security systems, which largely depend on conventional mechanical ignition keys that are vulnerable to manipulation and unauthorized access. In many older motorcycle models, traditional keys are still used to lock and unlock the ignition system, making them particularly susceptible to theft [6].

Conventional mechanical ignition keys, which are still predominantly used in motorcycles, have a high susceptibility to theft. These keys can be duplicated with relative ease and the locking mechanism can be overridden through various techniques used by offenders. Conventional ignition keys have one weakness, when the key used is lost, the motorbike cannot be used and the cost to repair it is not small [7]. In many reported incidents, thieves utilize counterfeit or modified keys, damage the ignition lock assembly, or even directly short and connect the motorcycle's electrical wiring to start the engine—an approach widely known as the "T-key" method [3]. The most common method used by thieves to steal motorcycles involves forcibly damaging the ignition lock using a so-called "T-shaped key," enabling the vehicle to be started and taken away with relative ease [8]. Weaknesses inherent in conventional mechanical systems substantially undermine the effectiveness of standard motorcycle security. Consequently, more sophisticated, technology-driven protections that are difficult to manipulate are urgently required. One attractive alternative is the application of Radio Frequency Identification (RFID) technology. Basicly, Radio Frequency Identification (RFID) technology is considered as an emerging sensing paradigm, owing to its cost efficiency, passive wireless power transfer capability, high flexibility, and ability to operate without requiring line-of-sight communication [9]. Through contactless authentication, RFID verifies a tag containing a unique identification code that is difficult to duplicate or forge, making it a more secure substitute for traditional keys. In turn, this approach can enhance protection against unauthorized access to vehicles and markedly lower the likelihood of motorcycle theft [10].

The use of RFID technology to strengthen vehicle security has been widely discussed in prior research and has also been implemented in a number of practical systems. In many cases, these solutions are able to provide secure, contactless access by authenticating an RFID tag before the vehicle can be unlocked or the engine activated. By integrating RFID tags for precise identification and leveraging onboard diagnostic data, the system offers a proactive solution to traffic violations and vehicle maintenance issues [11]. A common drawback, however, is that most designs still rely on separate RFID cards or tokens that must be carried in addition to the user's everyday items. This dependence adds an extra layer of complexity and increases the potential for inconvenience when the card is lost, misplaced, or unintentionally left behind. In the Indonesian context, a more practical and innovative solution is the utilization of the national electronic identity card (e-KTP) as an RFID-based authentication medium. The Single Identification Number embedded in the e-KTP enables it to function effectively as a multi-purpose digital identifier, thereby simplifying access and identification processes for the public [12].

The e-KTP contains an RFID chip that can be detected by compatible readers and, because its ownership is mandatory and it is already held by almost all citizens, it provides an immediately available resource for system integration. The chip is embedded between the white and transparent plastic on the top two layers. This chip has an antenna in it that will emit waves when rubbed [13]. Using the e-KTP in motorcycle security systems eliminates the need for separate RFID cards, simplifies user interaction, and aligns with Indonesia's existing digital identification infrastructure, thereby providing a highly relevant and efficient approach to enhancing vehicle access control [14]. In this system, access to the motorcycle is strictly limited to the owner's e-KTP or other registered cards, ensuring that the vehicle can only be started by authorized users [15]. This study is intended to design and realize a motorcycle security system based on RFID technology by employing the e-KTP as the ignition key. The research adopts a Research and Development (R&D) framework with the ADDIE model, encompassing the stages of analysis, design, development, implementation, and evaluation. The resulting system is expected to become an alternative security solution that is more effective and efficient, relatively easy to apply by the wider community, and still attentive to aspects of user practicality and technological cost.

Literature Review

Radio Frequency Identification (RFID) is an automatic identification technology that utilizes radio waves to transmit data between a tag and a reader without direct physical contact [12]. This technology has been widely applied in various fields, including logistics, building security systems, attendance monitoring, and asset management. In its application to motor vehicles, RFID provides a higher level of security compared to conventional mechanical keys, as each tag contains a unique identification code that is difficult to duplicate. Moreover, the RFID-based authentication process operates rapidly and efficiently, making it highly suitable for integration into motorcycle security systems.

Several previous studies have demonstrated that the application of RFID is effective in enhancing vehicle security. RFID is the process of identifying a person or object using radio frequency transmission. RFID uses radio frequencies to read information from small devices called tags or transponders (transmitters and responders) [16]. However, for the RFID-based card reading system to function properly on a motorcycle, all related components and cables must first be correctly connected to the motorcycle's battery as the main power source [17].

In this research, a different approach is adopted by utilizing the electronic identity card (e-KTP) as the authentication medium instead of a conventional RFID card. The e-KTP, which is based on a Population Identification Number, functions as a smart card equipped with an embedded chip that enables secure and reliable identification [18]. The e-KTP, as Indonesia's official national identity card, is already embedded with an RFID chip and is owned by almost all citizens, making its use highly practical. Applying the e-KTP as a motorcycle ignition key not only improves the level of security but also removes the need for users to carry an additional RFID card. This approach represents a novel contribution to the implementation of RFID technology by offering a solution that is more practical, cost-efficient, and aligned with the demands of contemporary society.

Method

This study employs a development-oriented research approach, commonly referred to as Research and Development (R&D). R&D is a research methodology designed to produce new products or to refine existing ones through rigorous scientific investigation and a systematic development process. This approach involves a series of structured stages that emphasize not only the exploration and validation of theoretical concepts but also their practical implementation in the form of usable products or systems that can be applied in real-world contexts [19]. R&D involves collecting, analyzing, and interpreting quantifiable data to test hypotheses and generate generalizable findings [20]. Based on these characteristics, the R&D approach ensures that the developed system is not only theoretically sound but also empirically validated, reliable, and applicable for solving practical problems in real-world settings.

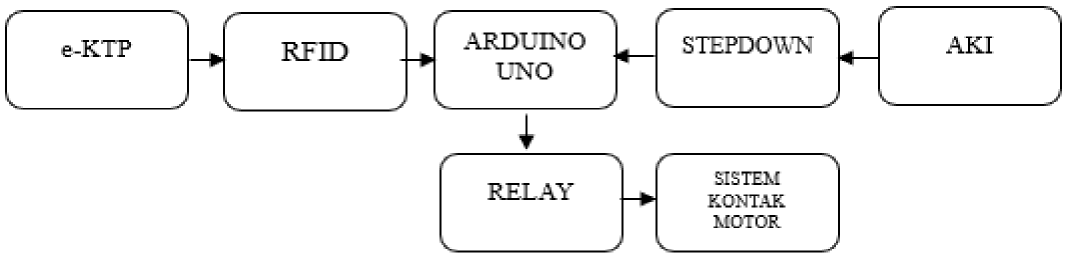

Figure 1. System Block Diagram

The RFID-based motorcycle security system developed in this research is composed of several integrated components. The e-KTP serves as the RFID tag, containing an embedded chip that stores unique identification data and functions as the motorcycle's ignition key. When the e-KTP is brought close to the RFID reader, the stored data are detected and transmitted to an Arduino Uno microcontroller. The Arduino Uno then processes and verifies whether the received data correspond to the identification data programmed in the system. Upon successful verification, the microcontroller triggers a relay that operates as an electronic switch, enabling the electrical current to flow to the motorcycle's ignition system and allowing the engine to start. To maintain safe system operation, a step-down module is employed to convert the 12 V battery voltage into a 5 V supply compatible with the Arduino. The battery functions as the primary power source for the entire circuit, providing electrical energy to the step-down module, Arduino, and relay. If the scanned e-KTP is unrecognized or does not match the registered data, the relay remains inactive, preventing the flow of electrical current to the ignition system. Through this integrated configuration, the system is able to deliver secure and automatic vehicle access control based on e-KTP authentication.

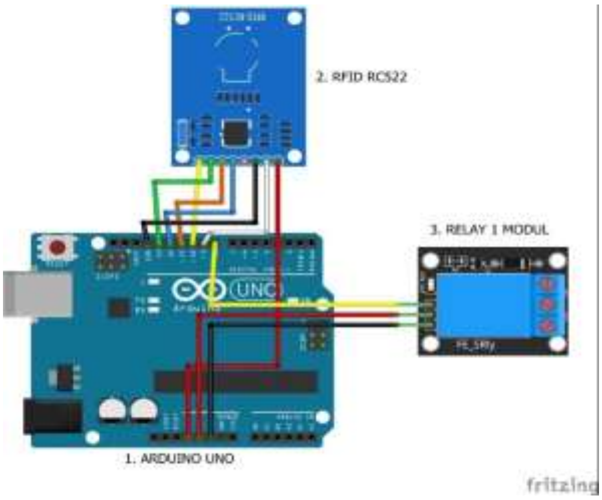

Figure 2. Starter System Circuit Using RFID

The Arduino Uno functions as the central processing unit in the RFID-based motorcycle security system. After the RFID module receives data, the Arduino microcontroller processes the information to determine whether the scanned e-KTP is valid and registered within the system. Upon successful validation, the Arduino issues control signals to connected components, such as the relay and LED, to activate or deactivate the system accordingly. The RC522 RFID module acts as the input device responsible for scanning the RFID tag—in this case, the e-KTP—and transmitting its UID data to the Arduino via data and signal cables connected to the digital pins, GND, and 3.3V. Meanwhile, the relay is used to control components that require higher voltage, such as the locking motor. If the scanned e-KTP is verified as valid, the Arduino activates the relay, allowing electrical current to flow and triggering the vehicle's ignition or locking system.

Result and Discussion

a. Authentication Succes Rate

Table 1 presents the results of testing the authentication success rate of the RFID-based motorcycle security system using the e-KTP as the authentication medium. This test was conducted to evaluate the system's ability to accurately recognize and verify both registered and unregistered e-KTP unique identification numbers (UIDs). Each trial represents a different e-KTP scanning attempt, with the authentication outcome recorded as either successful or unsuccessful, along with the corresponding reason for failure when applicable. The data in this table illustrate the reliability of the system in distinguishing authorized users from unauthorized ones, thereby demonstrating its effectiveness in ensuring secure vehicle access control

Table 1. Authentication Succes Rate

Trial	UID	Success (Yes/No)	Comment (If Failed)
1	4115cb29c5c80	Yes	-
2	1245a7b893f02	No	UID not registered
3	88c2f1d7a9b34	No	UID not registered
4	4e56d1c9127f3	No	UID not registered
5	19a4cb73f8d25	No	UID not registered
6	63f8b2d1a97c4	No	UID not registered

b. Results of RFID Reading Distance and Time Testing on e-KTP

Table 2 presents the results of testing the RFID reading distance and response time of the e-KTP-based authentication system. The test was conducted to evaluate the maximum effective reading distance of the RFID reader as well as the time required to successfully read and process the e-KTP data at different distances. The results show that the system was able to read the e-KTP successfully at distances ranging from 0 cm to 2 cm, with the reading time gradually increasing as the distance increased. The fastest response time, 0.24 seconds, occurred when the e-KTP was placed directly on the reader, while the longest successful reading time, 1.03 seconds, was recorded at a distance of 2 cm. However, at a distance of 3 cm, the system failed to detect the e-KTP, indicating that this distance exceeds the effective operating range of the RFID reader. These findings demonstrate that the RFID reader operates reliably within a short-range distance, which is suitable for secure and controlled authentication in motorcycle ignition systems.

Table 2. Results of RFID Reading Distance and Time Testing on e-KTP

Trial	Test Distance (cm)	Duration/Time (Seconds)	Conclusion
1	0 cm	0,24	Successful
2	0,5 cm	0,37	Successful
3	1 cm	0,69	Successful
4	2 cm	1,03	Successful
5	3 cm	-	Unsuccessful

c. RFID Scan Test Results with Obstructing Materials

Table 3 presents the results of RFID scan testing under different obstructing materials to evaluate the system's reliability when the e-KTP is not scanned in direct contact with the RFID reader. The test examines how various materials affect the reading time and success of RFID authentication. The results indicate that the system successfully reads the e-KTP when obstructed by non-metallic materials such as paper, plastic, fabric, and cardboard, although the reading time increases as the thickness or density of the material increases. The fastest response time (0.23 seconds) occurs with no obstruction, while the longest successful reading time (0.98 seconds) is observed when cardboard is used as the barrier. This trend shows that additional material layers introduce signal attenuation, resulting in longer processing times.In contrast, when metal is used as an obstructing material, the system fails to record a response time, indicating that the RFID signal is blocked or severely disrupted. This outcome highlights the known limitation of RFID technology, as metal materials interfere with radio wave propagation. Overall, the results demonstrate that the system performs reliably under common non-metallic obstructions, supporting its practicality for real-world use, while also emphasizing the need to avoid metallic interference during authentication.

Table 3. RFID Scan Test Results with Obstructing Materials

Test Trial	Obstructing Material	Duration/Time (Seconds)	Conclusion
1	No Obstruction	0,23	Successful
2	Paper	0,37	Successful
3	Plastic	0,44	Successful
4	Fabric	0,69	Successful
5	Cardboard	0,98	Successful
6	Metal	-	Successful

d. Security System Indicator Test Results Using the Black Box Method

Table 4 presents the results of security system indicator testing using the Black Box method, which focuses on evaluating the functional behavior of the system based on inputs and outputs without examining the internal program structure. This testing aims to verify whether each main component of the RFID-based motorcycle security system operates in accordance with its intended function. The test results show that the Arduino circuit functions properly, with all components correctly connected and no hardware damage detected. The RFID module is able to accurately recognize registered e-KTP UIDs while successfully rejecting unregistered or non-e-KTP tags, indicating reliable authentication performance. Additionally, the relay module operates as expected, activating after the first e-KTP tap (low logic) to allow ignition and deactivating after the second e-KTP tap (high logic) to cut off the ignition system. Overall, the test results confirm that all system indicators perform in line with the expected outcomes, demonstrating that the developed security system operates reliably and meets its functional design requirements.

Table 4. Security System Indicator Test Results Using the Black Box Method

NO	Test Item	Indicator	Expected Result	Test Result
1	Arduino Circuit	Ensure all components are properly connected	Circuit operates properly with no damaged components	Works properly
2	RFID	Correct recognition of e-KTP	RFID can recognize registered e-KTP UID	Works properly

		Reading UID from non-e-KTP tags	RFID does not recognize unregistered or non-e-KTP UIDs	Works properly
3	Relay	First tap of e-KTP: Sends low logic	Relay turns on after first e-KTP tap	Works properly
		Second tap of e-KTP: Sends high logic	Relay turns off after second e-KTP tap	Works properly

This study aimed to develop an RFID-based motorcycle security system utilizing the national electronic identity card (e-KTP) as an authentication medium. One of the key technical improvements implemented in the prototype was the replacement of the conventional L7805 voltage regulator with a more efficient LM2596 step-down module. This change resulted in improved energy conversion efficiency, reduced heat generation, and minimized the need for external components, thereby contributing to a more compact and practical system design. The test results indicate that the developed system successfully fulfills its primary objective of enhancing vehicle security. The authentication process using e-KTPs yielded a 100% success rate in recognizing registered UIDs, as shown in Table 1. No authentication failures occurred during testing, indicating the reliability of the system in validating legitimate users.

Distance testing between the RFID reader and the e-KTP revealed optimal performance up to 2 cm, with reading times increasing proportionally with distance (see Table 2). At a distance of 3 cm, the system failed to read the tag, thus defining the effective operational range of the RFID module used (RC522). This limitation is consistent with the module's technical specifications. Further evaluation was conducted to determine the system’s ability to function in the presence of physical obstructions between the RFID reader and the e-KTP (see Table 3). The results confirmed that the system could accurately read the UID through non-metallic materials such as paper, plastic, fabric, and cardboard. However, when obstructed by metal, the system failed to perform authentication. This is aligned with the fundamental limitations of RFID technology, where metal surfaces interfere with electromagnetic signal propagation.

In addition, black box testing was performed to evaluate the functional performance of the system components. The Arduino microcontroller was able to correctly interpret input data from the RFID module and regulate the relay module in accordance with the defined authentication logic. The relay was triggered after the first successful scan and subsequently switched off following the second scan, demonstrating accurate control logic and effective integration among the hardware components. In summary, the RFID-based motorcycle security system demonstrated high reliability, user convenience, and efficient design. The integration of e-KTP as the authentication key offers a novel, practical solution tailored to the Indonesian context, where e-KTP ownership is widespread. The use of the LM2596 module is a significant improvement over previous designs, contributing to better energy efficiency and overall system compactness. This research offers valuable insights for future applications of RFID in personal vehicle security systems, particularly in developing countries with similar infrastructure.

Conclusion

This research successfully developed and implemented an RFID-based motorcycle security system that employs Indonesia's electronic identity card (e-KTP) as a contactless ignition mechanism, serving as an alternative to conventional motorcycle starting systems. The system integrates several key components, including the Arduino Uno as the central controller, the RC522 RFID module as the e-KTP reader, a relay as an electronic switch, and the LM2596 step-down module to regulate voltage from the vehicle's 12V battery. Test results demonstrated that the system achieved a 100% authentication success rate for registered e-KTPs, with an optimal reading distance of up to 2 cm. Furthermore, the system was capable of functioning properly when non-metallic materials obstructed the RFID reader, although it failed to read the e-KTP through metal, which aligns with the inherent characteristics of RFID signals.

In addition to its technical performance, the developed system demonstrated reliable functionality and a high level of usability. The overall design and operational mechanism were considered intuitive, enabling users with minimal technical background to operate the system effectively. The utilization of the e-KTP as an authentication medium provides added efficiency, as it removes the necessity for supplementary devices such as dedicated RFID cards or remote controllers. This approach represents a practical and relevant innovation, particularly given that the e-KTP is an official identity document possessed by the vast majority of Indonesian citizens.

In conclusion, the developed system not only significantly enhances motorcycle security but also offers an economical and accessible solution for broad public adoption. It demonstrates considerable potential for broader adoption, both for personal use and large-scale industrial applications, especially within the automotive and transportation industries. However, additional studies are required to enhance the RFID reading distance and to reduce signal interference caused by metallic materials, so that the system can maintain optimal performance under various environmental conditions and operational scenarios.

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