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(RESEARCH ARTICLE)

DESIGN AND DEVELOPMENT OF AN AUTOMATED COIN-OPERATED MOTORCYCLE SYSTEM

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ABSTRACT

This study aimed to design and develop an Automated Coin-Operated Motorcycle System and evaluate its acceptability in terms of functional stability, performance efficiency, usability, reliability, security, and maintainability. Employing a Design and Development Research (DDR) approach guided by the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model, the study developed an Arduino-based embedded control system integrating an electronic coin acceptor, liquid crystal display (LCD), relay modules, and a motorcycle starter switch interface. The evaluation involved 50 purposively selected respondents from Northwest Samar State University, comprising 40 Automotive Technology students and 10 faculty members. Data were analyzed using frequency, percentage, weighted mean, and standard deviation. Results revealed that the developed system obtained an overall weighted mean of 4.45 (SD = 0.69), interpreted as Excellent. Among the six evaluation dimensions, maintainability received the highest rating (M = 4.52), followed by security (M = 4.47), reliability (M = 4.45), functional stability and performance efficiency (M = 4.43 each), and usability (M = 4.42). Group-based evaluations likewise indicated favorable assessments, with faculty members obtaining an overall mean of 4.52 and students obtaining 4.44, both interpreted as Excellent. These findings indicate that the developed prototype was favorably evaluated by its intended users across the identified quality dimensions. The findings highlight the potential of embedded control technology in integrating coin-based payment validation with motorcycle activation, while further technical validation is necessary to establish the system's operational performance and practical applicability. Further technical testing, particularly on coin recognition accuracy, activation response time, electrical safety, and long-term operational reliability, is recommended to establish its performance and suitability for practical application.

Keywords: Automated motorcycle system, Arduino-based automation, Coin-operated mechanism, Embedded control system, Motorcycle activation

1 INTRODUCTION

Automation and embedded control technologies have increasingly influenced the development of intelligent equipment and transportation-related applications through the integration of microcontrollers, sensors, actuators, and automated transaction mechanisms. Among the accessible platforms for developing low-cost automation systems is Arduino, an open-source microcontroller platform widely used in electronic control and automation applications. Previous studies have demonstrated its potential in automated payment processing. Alkausar and Husnaini (2021) developed an

Arduino-based vending machine using a TCS3200-DB color sensor, achieving an 86.6% banknote recognition success rate. Similarly, Suppatoomsin et al. (2022) developed an Arduino Mega 2560-based vending machine capable of accepting coins and banknotes, processing transactions, and dispensing change, with testing indicating almost zero errors. Ardhan et al. (2025) developed an ESP32-based cash payment system integrating bill and coin acceptors, achieving an 87.5% success rate across 40 transactions. These studies establish the applicability of embedded systems in payment recognition and automated equipment operation, although their applications primarily focus on vending and product dispensing.

Microcontroller-based technologies have likewise been explored in motorcycle ignition control, access authorization, and vehicle security. Supriyono et al. (2020) developed a fingerprint-based motorcycle ignition system using Arduino Uno, achieving an 80% activation success rate with clean and dry fingerprints, although performance declined under unfavorable fingerprint conditions. Arifin (2022) developed an Arduino Mega-based motorcycle activation system integrating fingerprint and voice recognition, reporting varying recognition performance depending on environmental and user conditions. Meanwhile, Husni et al. (2021) developed an Internet of Things (IoT)-based vehicle security system integrating GPS, GSM, and relay modules for vehicle monitoring and remote control. Brahmana and Megarani (2024) developed a Bluetooth-based motorcycle security mechanism using an ATmega328 microcontroller and HC-05 module to provide proximity-based alerts and ignition deactivation. Collectively, these studies demonstrate the potential of embedded technologies for motorcycle access management and security. However, their applications primarily emphasize biometric authentication, wireless connectivity, and vehicle monitoring rather than payment-based motorcycle activation.

Despite these developments, the integration of automated coin payment mechanisms with motorcycle activation remains an area requiring further investigation. Existing studies have separately established the feasibility of automated payment processing and electronic motorcycle control, but the reviewed applications do not demonstrate their integration into a single, stand-alone motorcycle activation prototype. To address this gap, the present study designed and developed an Automated Coin-Operated Motorcycle System using an Arduino-based embedded control architecture. The prototype integrates a coin acceptor, microcontroller, display module, power regulation components, relay-based switching mechanism, and motorcycle electrical interface. Its operation involves receiving and validating coin inputs, processing signals through the microcontroller, displaying system information, and activating the motorcycle interface upon satisfaction of the required payment condition. Unlike conventional vending systems and motorcycle security technologies, the proposed prototype applies physical coin-based transaction validation as the authorization mechanism for motorcycle activation. Its development was guided by the systems approach and the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model to ensure systematic conceptualization, construction, implementation, and assessment.

The developed prototype was evaluated using six researcher-selected quality dimensions: functional stability, performance efficiency, usability, reliability, security, and maintainability. These dimensions were informed by the product quality assessment principles of ISO/IEC 25010:2023, which establishes nine quality characteristics for information and communication technology and software products (International Organization for Standardization [ISO] & International Electrotechnical Commission [IEC], 2023). The six dimensions represent context-specific evaluation criteria adapted to the hardware, software, and intended functions of the prototype rather than a direct reproduction of the standard's nine characteristics.

Accordingly, this study aimed to: (1) design and develop an Automated Coin-Operated Motorcycle System by identifying its hardware, software, electrical, and electronic requirements, system architecture, and operational sequence; (2) evaluate the developed prototype in terms of functional stability, performance efficiency, usability, reliability, security, and maintainability; and (3) compare the evaluations of faculty members and Automotive Technology students across the six quality dimensions. The findings are expected to contribute to the application of embedded automation in motorcycle-related services and provide a basis for further technological improvement and practical implementation.

2 METHODOLOGY

This study employed a Design and Development Research (DDR) approach to design, develop, and evaluate an Automated Coin-Operated Motorcycle System using the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. During the Analysis phase, the system's intended functions and hardware, software, electrical, and electronic requirements were identified. The Design phase involved preparing the system architecture, circuit connections, hardware configuration, and operational sequence. The Development phase covered prototype fabrication, assembly, integration, and programming using an Arduino Uno microcontroller. Implementation involved operating and demonstrating the prototype, including preliminary operational testing to assess component integration and basic functionality. Finally, the Evaluation phase gathered assessments from faculty members and Automotive Technology

students using six dimensions: functional stability, performance efficiency, usability, reliability, security, and maintainability.

2.1 System Components and Operating Principle

The prototype integrated an Arduino Uno microcontroller, electronic coin acceptor, relay modules, liquid crystal display (LCD), motorcycle starter switch, buck converter, battery, connecting wires, and other necessary electronic components. The Arduino Uno served as the central controller, processing coin-acceptor signals and controlling the relay-based switching mechanism. The coin acceptor received payment inputs, the LCD displayed operational information, and the relays provided the electrical interface with the motorcycle starter switch. The battery supplied power, while the buck converter regulated the voltage for the electronic components.

Upon system initialization, an inserted coin generated an electrical signal transmitted to the Arduino Uno for processing according to the programmed activation condition. Once the required coin-input condition was satisfied, the microcontroller activated the relay connected to the motorcycle starter switch. The LCD displayed programmed system-status messages throughout the process. The control program was developed using the Arduino Integrated Development Environment (IDE) and C/C++ programming language.

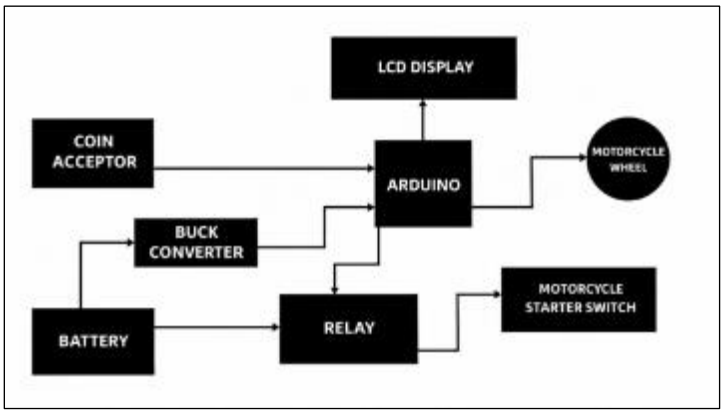


Figure 1: Block Diagram

2.2 Research Setting and Respondents

The study was conducted at the Automotive Technology Laboratory of Northwest Samar State University (NwSSU), Calbayog City, Philippines, which provided the facilities, tools, and technical resources for prototype fabrication, assembly, troubleshooting, and testing. The respondents comprised 50 purposively selected participants: 10 faculty members (20%) and 40 Automotive Technology students (80%). Participants were selected based on their relevant knowledge, experience, or exposure to automotive systems and technology. Faculty members provided professional and instructional perspectives, while students contributed assessments based on their automotive technology exposure and practical learning activities.

Table 1: Distribution of respondents

Respondent Group	Frequency	Percentage
Faculty members	10	20%
Automotive Technology students	40	80%
Total	50	100%

2.3 Research Instrument

A researcher-made evaluation questionnaire was used to assess the developed system based on six dimensions of product quality. Each dimension consisted of five statements focusing on the prototype's operational and maintenance characteristics.

Table 2: Evaluation dimensions and corresponding indicator focus

Evaluation Dimension	Indicator Focus
Functional stability	Intended functions, coin-input response, and operational consistency
Performance efficiency	Response time, transaction processing, smooth operation, delays, and hardware resource utilization
Usability	Operating procedures, LCD instructions, and user-friendliness
Reliability	Consistent operation, malfunction prevention, valid-coin acceptance, and transaction recovery
Security	Prevention of unauthorized activation, valid-coin acceptance, safe operation, and electrical protection
Maintainability	Inspection, component replacement, repair, modification, upgrading, and routine maintenance

Each statement was rated using a five-point Likert scale: 5 – Excellent, 4 – Very Good, 3 – Good, 2 – Fair, and 1 – Poor. Weighted mean scores were interpreted as follows: 4.21–5.00 (Excellent), 3.41–4.20 (Very Good), 2.61–3.40 (Good), 1.81–2.60 (Fair), and 1.00–1.80 (Poor). Content validity was established through expert review involving specialists in Automotive Technology, Industrial Technology, and research methodology, whose recommendations on clarity, relevance, organization, and appropriateness were incorporated into the questionnaire

2.4 Data Gathering Procedure

Permission to conduct the study was secured from the appropriate university authorities. Following approval, the prototype was developed, assembled, and subjected to preliminary operational testing. Purposively selected respondents were oriented on the prototype's components, coin-insertion process, operating sequence, and intended motorcycle starting function. They were given sufficient time to observe or operate the system before completing the evaluation questionnaire.

Participation was voluntary, with informed consent obtained from all respondents. Confidentiality and anonymity were maintained, and participants were informed of their right to decline or withdraw without penalty. Retrieved questionnaires were checked for completeness and consistency before responses were organized, tabulated, and prepared for statistical analysis.

2.5 Statistical Treatment of Data

Descriptive statistical techniques were employed to analyze and interpret the collected data. Frequency and percentage were used to describe the distribution of respondents according to their respective groups. Weighted mean was utilized to determine the respondents' evaluations of the developed system across the six quality dimensions: functional stability, performance efficiency, usability, reliability, security, and maintainability. Standard deviation was used to measure the variability or dispersion of the respondents' ratings around the mean. Furthermore, the weighted mean scores of faculty members and Automotive Technology students were compared descriptively to identify similarities and differences in their assessments of the developed system.

3 RESULTS AND DISCUSSION

The results and discussion are organized according to the three objectives of the study: (1) the design and development of the Automated Coin-Operated Motorcycle System; (2) the evaluation of the developed prototype in terms of functional stability, performance efficiency, usability, reliability, security, and maintainability; and (3) the comparison of the evaluations of faculty members and Automotive Technology students across the six quality dimensions. The findings are presented using descriptive statistical analysis and comparative evaluation of the respondents' assessments.

3.1 Design and Development of the Automated Coin-Operated Motorcycle System

In response to the first objective, the study designed and developed an Automated Coin-Operated Motorcycle System by identifying and integrating the necessary hardware, software, electrical, and electronic requirements. The development process followed the Analysis, Design, Development, Implementation, and Evaluation (ADDIE)

framework, which guided the identification of system requirements, preparation of the system architecture, fabrication and assembly of the prototype, programming, implementation, and evaluation.

Table 3: Major components and functions of the developed Automated Coin-Operated Motorcycle System

Component	Function
Arduino Uno	Processes signals from the coin acceptor and controls the programmed activation sequence.
Electronic coin acceptor	Detects inserted coins and transmits corresponding signals to the microcontroller.
LCD display	Provides operational messages and system status to the user.
Relay module	Performs the electrical switching function between the microcontroller and motorcycle starter switch.
Battery	Supplies electrical power to the system.
Buck converter	Regulates the voltage supplied to the electronic components.
Connecting wires	Establish electrical connections for power and signal transmission.
Motorcycle starter switch interface	Connects the developed control system to the motorcycle starting mechanism.

The developed prototype integrated an Arduino Uno microcontroller, an electronic coin acceptor, an LCD display, relay modules, a battery, a buck converter, connecting wires, and a motorcycle starter switch interface. The Arduino Uno served as the central controller, receiving and processing signals from the coin acceptor according to the programmed activation condition. Once the required coin-input condition was satisfied, the microcontroller generated a control signal that activated the relay module connected to the motorcycle starter switch. The LCD display provided programmed messages indicating the system's operational status.

The system was programmed using the Arduino Integrated Development Environment (IDE) and the C/C++ programming language. Its operational sequence began with system initialization, followed by coin insertion and signal transmission from the coin acceptor to the Arduino Uno. The microcontroller then processed the input according to the programmed activation condition. Once the required condition was met, the relay module performed the switching function connected to the motorcycle starter switch, while the LCD displayed the corresponding operational information.

The integration of the identified components demonstrates the application of embedded control technology in developing a coin-operated motorcycle activation mechanism. The resulting prototype provided the basis for the subsequent respondent evaluation.

3.2 Evaluation of the Developed System

The developed Automated Coin-Operated Motorcycle System was evaluated by 50 purposively selected respondents, comprising 10 faculty members and 40 Automotive Technology students, across six dimensions: functional stability, performance efficiency, usability, reliability, security, and maintainability.

Table 4: Overall evaluation of the developed Automated Coin-Operated Motorcycle System

Evaluation dimension	Weighted Mean	SD	Interpretation
Functional stability	4.43	0.69	Excellent
Performance efficiency	4.43	0.70	Excellent
Usability	4.42	0.70	Excellent
Reliability	4.45	0.69	Excellent
Security	4.47	0.70	Excellent
Maintainability	4.52	0.65	Excellent
Overall evaluation	4.45	0.69	Excellent

As presented in Table 4, the system obtained an overall weighted mean of 4.45 (SD = 0.69), interpreted as Excellent. Maintainability received the highest rating (M = 4.52), followed by security (M = 4.47) and reliability (M = 4.45). Functional stability and performance efficiency both obtained 4.43, while usability received the lowest mean of 4.42. Despite these slight variations, all six dimensions were rated Excellent, indicating generally favorable respondent assessments of the developed prototype.

In terms of functional stability, the system obtained a mean of 4.43 (SD = 0.69). Consistent performance of required operations received the highest rating (M = 4.56), followed by operation according to its designed purpose (M = 4.52). Motorcycle activation after valid coin acceptance and accurate coin-input response both obtained 4.30. These results suggest that the prototype generally performed its intended functions, although coin recognition and response accuracy may require further refinement.

For performance efficiency, the system obtained a mean of 4.43 (SD = 0.70). Effective hardware resource utilization received the highest rating (M = 4.50), followed by system response after coin insertion (M = 4.46). Smooth motorcycle operation and the absence of unnecessary delays both received 4.38. These findings indicate favorable assessments of operational efficiency, although improvements in response time and transaction processing may further enhance performance.

Regarding usability, the system received a mean of 4.42 (SD = 0.70). Ease of following operating procedures obtained the highest rating (M = 4.54), followed by LCD display clarity (M = 4.52). Ease of understanding received the lowest rating (M = 4.34), while user-friendly controls and overall ease of operation both obtained 4.36. This suggests that the prototype was generally easy to operate, although clearer instructions and interface improvements could further enhance user experience.

For reliability, the system obtained a mean of 4.45 (SD = 0.69). Stable performance throughout use received the highest rating (M = 4.52), while operation without frequent malfunction and recovery after transactions both obtained 4.44. Consistent operation and accurate acceptance of valid coins both received 4.42. These results reflect favorable perceptions of operational consistency; however, questionnaire-based assessments should not be interpreted as evidence of long-term reliability or fault-free performance.

In terms of security, the system obtained a mean of 4.47 (SD = 0.70). Safe operation received the highest rating (M = 4.52), followed by prevention of unauthorized motorcycle activation (M = 4.50). Electrical component protection received 4.46, while valid-coin acceptance and prevention of accidental activation both obtained 4.44. These findings indicate favorable assessments of the system's intended security features, although further technical testing of invalid-coin rejection, unauthorized activation prevention, and electrical protection is necessary.

Finally, maintainability received the highest overall rating (M = 4.52, SD = 0.65). Ease of inspection and system upgrading or modification both obtained the highest mean (M = 4.56), followed by routine maintenance (M = 4.54). Component replacement and repair both received 4.46. These findings suggest that respondents perceived the prototype as relatively easy to inspect, maintain, and modify, potentially owing to its component-based configuration. Nevertheless, actual maintenance requirements and long-term serviceability require further testing and documentation.

3.3 Comparative Evaluation of the Developed System According to Respondent Group

To further examine the assessments of the developed Automated Coin-Operated Motorcycle System, the evaluation results were compared between faculty members and Automotive Technology students across the six quality dimensions. The comparison focused on their respective weighted mean scores and the differences in their evaluations to identify similarities and variations in their perceptions of the developed prototype.

As presented in Table 5, faculty members obtained an overall mean of 4.52, slightly higher than the 4.44 obtained by Automotive Technology students. Both respondent groups rated the developed system as Excellent across all six evaluation dimensions, indicating generally favorable assessments of the prototype from both instructional and student perspectives.

Among the six dimensions, usability recorded the largest mean difference (0.14), followed by maintainability (0.13) and reliability (0.11), with faculty members providing higher ratings in these areas. These differences suggest that faculty members perceived the system more favorably in terms of ease of operation, maintenance, and operational consistency. In contrast, performance efficiency showed the smallest difference (-0.01), indicating nearly similar assessments between the two groups, with students providing a marginally higher rating.

Table 5: Comparative Evaluation of the Developed System According to Respondent Group

Evaluation dimension	Students (n = 40)	Faculty (n = 10)	Mean difference
Functional stability	4.42	4.46	0.04
Performance efficiency	4.43	4.42	-0.01
Usability	4.40	4.54	0.14
Reliability	4.43	4.54	0.11
Security	4.46	4.52	0.06
Maintainability	4.49	4.62	0.13
Overall mean	4.44	4.52	0.08

The relatively small differences in the weighted mean scores indicate that faculty members and Automotive Technology students provided generally similar evaluations of the developed prototype. Both groups expressed favorable assessments across the six quality dimensions. Nevertheless, these findings represent descriptive comparisons and do not establish whether statistically significant differences exist between the two respondent groups.

4 CONCLUSION

The study successfully designed and developed an Automated Coin-Operated Motorcycle System using an Arduino-based embedded control architecture that integrates coin validation and motorcycle activation. The developed prototype obtained an overall weighted mean of 4.45 (SD = 0.69), interpreted as Excellent across the six evaluation dimensions. Maintainability received the highest rating (4.52), followed by security (4.47), reliability (4.45), functional stability and performance efficiency (4.43 each), and usability (4.42).

The comparative evaluation further revealed favorable assessments from both faculty members (M = 4.52) and Automotive Technology students (M = 4.44), with both groups rating the system Excellent. Although slight variations were observed across the six dimensions, the findings indicate generally positive evaluations from both respondent groups.

Overall, the findings indicate that the developed prototype presents a promising application of embedded control technology for integrating coin-based payment validation with motorcycle activation. Although the system received favorable evaluations from faculty members and Automotive Technology students, further technical testing is necessary to establish its coin recognition accuracy, operational reliability, electrical safety, and suitability for practical implementation. The evaluation was based on the perceptions of purposively selected respondents; therefore, the findings should be interpreted within the context of the study population and the evaluation procedures employed.

Recommendations

The developed system may be further improved by enhancing coin recognition accuracy, optimizing transaction response time, and strengthening security mechanisms to prevent invalid inputs and unauthorized activation. The use of durable, weather-resistant materials and improved electrical protection is also recommended to ensure reliable operation under varying environmental conditions. Further testing involving actual motorcycle users and transport operators is encouraged to assess the system's practicality, durability, and user acceptability. Future studies may also explore the integration of alternative cashless payment options, improved monitoring features, and enhanced power management. Finally, extended operational testing is recommended to establish the system's long-term reliability, safety, and potential for practical implementation.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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