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Design and Innovation of a Coin Sorter Device

Ruby Gaygay Ducan[1], Joel Vocales Misanes, PhD[2]
[1]*Master of Technology Education, University of Southern Mindanao- Kidapawan City Campus, Cotabato, Philippines*
[2]*Associate Professor V/Dean, College of Trades and Industries, University of Southern Mindanao-Kabacan Campus, Cotabato, Philippines*

Email of Corresponding Author: rubygaygay09@gmail.com

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Abstract

This study aimed to design, construct, and evaluate an automated coin sorter device integrating coin sorting, counting, biometric authentication, and dispensing for Philippine currency. Anchored in Automation Theory, Sensor Basics Theory, Biometric Authentication Theory, and Systems Theory, the study employed a developmental research design involving device fabrication, programming, performance testing, and acceptability evaluation. The device was tested using 40 mixed Philippine coins through 10 performance trials, while 30 sari-sari store owners and staff evaluated its performance, design, and usability using a validated researcher-developed questionnaire. Data were analyzed using descriptive statistics, including frequency counts, means, weighted means, and accuracy rates. Results revealed that coin sorting and counting achieved 90% accuracy, with average processing times of 13.91 and 13.84 seconds, respectively. Biometric authentication and coin dispensing achieved 100% accuracy, with average processing times of 2.04 and 2.24 seconds, respectively. The device was rated Highly Acceptable in design (4.75) and usability (4.81). Minor limitations involving sensor alignment, counting accuracy, and coin-jamming prevention were identified. The study concluded that the developed device provides a functional, secure, and user-friendly solution for automated coin management. Improvements in sensor calibration, programming, structural design, and additional transaction features were recommended. The study aligns with Sustainable Development Goal (SDG) 8, Decent Work and Economic Growth, and SDG 9, Industry, Innovation and Infrastructure. Its potential sustainability contribution lies in supporting technological innovation, reducing repetitive manual tasks, and improving cash-management efficiency in small-business operations.

Keywords: Biometric Authentication; Coin Counting; Coin Dispensing; Coin Sorting; Philippine Currency; Technological Innovation; Usability

1. Introduction

Manual coin handling remains essential in Philippine small-business operations but is often time-consuming, labor-intensive, and susceptible to counting errors and security risks. This study addresses these challenges through the design and innovation of an automated coin sorter device that integrates coin sorting, counting, biometric authentication, and dispensing. It aims to construct and evaluate a device specifically designed for Philippine coins, focusing on operational performance and user acceptability in terms of design and usability. The study contributes to technological innovation and more efficient cash management among small businesses.

Coins remain important in daily Philippine business transactions, particularly in sari-sari stores, where accurate counting and dispensing of change are essential. The New Generation Currency Coin Series, introduced in 2018, includes denominations commonly used in commercial transactions (Bangko Sentral ng Pilipinas, n.d.). However, similarities among coin denominations complicate manual identification, sorting, and counting. These processes are time-consuming and susceptible to human error, contributing to operational inefficiencies and inaccuracies in financial management (Casaclang et al. (2024); Casaclang et al. (2024). Automated systems offer potential solutions to these difficulties. Dela Cruz et al. (2022) developed a coin sorter that achieved 95% sorting accuracy and 92.86% counting accuracy, demonstrating the feasibility of automated coin handling. Nevertheless, operational security remains a concern, particularly in coin storage and dispensing. Biometric authentication provides identity verification through unique physical characteristics (NIST (2025), while fingerprint-based systems can enhance access control and reduce unauthorized transactions (Awad et al. (2024). Fingerprint modules also facilitate rapid verification of authorized users (Martins et al. (2024). Existing commercial coin sorters may not adequately accommodate Philippine currency or integrate security and dispensing functions (Aquino & Francisco, 2022). Consequently, the present study developed a coin sorter that combines sorting, counting, biometric authentication, and dispensing to support more secure, accurate, and convenient cash handling in small-business operations.

Automated coin-handling technologies integrate mechanical mechanisms, electronic sensors, microcontrollers, and programmed control systems. Arduino-based platforms provide accessible environments for integrating sensors, actuators, and user interfaces (Dela Cruz et al. (2022). Infrared sensors facilitate coin detection and counting through rapid signal generation (Dela Cruz et al. (2022), while motor-driven mechanisms, solenoids, and servos support controlled movement and coin separation (Mayekar et al. (2023); Dela Cruz et al. (2022). Mechanical components such as bearings, rollers, hoppers, and coin trays influence vibration, alignment, and operational reliability (Mayekar et al. (2023). Reliable mechanical construction, visible status indicators, and accessible user interfaces also contribute to operational acceptability (Mayekar et al. (2023). Studies demonstrate the effectiveness of automated sorting and counting technologies. Dela Cruz et al. (2022) reported 95% sorting accuracy and 92.86% counting accuracy in a Philippine currency coin sorter. Automated systems employ infrared, optical, and magnetic sensors to classify coins according to their physical characteristics (Casaclang et al. (2024), reducing manual workload and operational errors (Casaclang et al. (2024). Optical recognition further identifies coin dimensions and design characteristics to improve classification accuracy (Hamzah and Abbas, 2022). However, previous developments have predominantly emphasized sorting and counting rather than integrating biometric security and dispensing functions (Dela Cruz et al., 2022; Mayekar et al., 2023). Mechanical sorting channels can separate coins according to size (Casaclang et al., 2024), while infrared and optical sensors enhance denomination detection (Khakim, 2024). Microcontrollers process sensor inputs and coordinate the sorting mechanism (Hamzah and Abbas, 2022). Casaclang et al. (2024) emphasized that automation improves sorting efficiency, while Casaclang et al. (2024) highlighted improvements in speed and accuracy. Nevertheless, Anritsu (2023) identified signal interference and overlapping objects as potential causes of detection errors, while Anritsu (2023) noted that electrical noise may produce inaccurate sensor readings. Biometric authentication strengthens access control through distinctive physical characteristics (NIST (2025). Fingerprint recognition is widely applied because of its reliability, affordability, and integration capabilities (Martins et al. (2024). Its application in security systems supports accurate verification (Awad et al. (2024)) and authorized access (NIST, 2025). Biometric integration has also been associated with improved security in storage applications (Modi & Devaraj, 2022) and emerging developments in cash-handling systems (GlobeNewswire, 2023). Martins et al. (2024) emphasized the accuracy and speed of fingerprint verification, while Awad et al. (2024) highlighted its role in reducing fraud risks. Coin dispensing requires coordinated electronic and mechanical components. Joel et al. (2025) developed an Arduino-based dispenser using servo motors, push buttons, and an LCD. Similarly, Kotwal, et al. (2025) demonstrated coin validation and automated dispensing using an embedded controller. Utomo et al. (Antia et al., 2025) also presented sensor-based coin detection and programmed dispensing in an automated vending application. These developments demonstrate the feasibility of integrated coin-handling mechanisms, although dispensing accuracy remains dependent on motor speed, timing, and mechanical alignment (Hamzah and Abbas, 2022). Device acceptability depends on functional design and usability. Hamzah and Abbas (2022) emphasized that proper mechanical and electronic integration minimizes operational errors. User-centered design improves functionality and satisfaction (Ortiz-Escobar et al. (2023), while product design influences durability, performance, and reliability (Berni et al. (2023). Security-oriented features can strengthen system protection (NIST (2025), and effective interface design enhances user confidence (Weichbroth (2024). These findings are consistent with the emphasis of Ortiz-Escobar et al. (2023) on usability and Berni et al. (2023) on product quality and acceptance. Usability further encompasses effectiveness, efficiency, and user satisfaction (Weichbroth (2024). Casaclang et. al (2024) demonstrated the operational efficiency and acceptability of an Arduino-based coin-counting machine. Accessible interfaces and automated dispensing can reduce manual workload and improve convenience (Weichbroth (2024). Similarly, Weichbroth (2024) associated accurate coin recognition and responsive interfaces with operational efficiency, while Weichbroth et al. (2024) emphasized usability assessment in determining system effectiveness and user satisfaction. Collectively, the literature supports integrating reliable mechanical mechanisms, sensor-based automation, biometric security, and user-centered design into a comprehensive coin-handling device.

At the local level, sari-sari store owners and personnel regularly handle mixed coins during daily transactions. The study specifically involved small-business operators and their staff in Barangay Perez, Kidapawan City, North

Cotabato, where the device was evaluated for its practical application in coin management. Nationally, the continued circulation of Philippine coin denominations creates a need for currency-compatible sorting and counting systems (Bangko Sentral ng Pilipinas, n.d.). Existing automated coin sorters demonstrate the feasibility of Philippine currency recognition, although integrating sorting, counting, security, and dispensing remains an area for further development (Aquino & Francisco, 2022). Globally, developments in coin-processing technologies include centrifugal sorting mechanisms, sensor-equipped coin conveyors, automated dispensers, and optical fingerprint identification. These innovations establish the technological foundations for combining coin classification, transaction automation, and access control within a single device.

The study is anchored in Automation Theory, Sensor Basics Theory, Biometric Authentication Theory, and Systems Theory. Automation Theory explains how sensors, controllers, and actuators coordinate repetitive operations to improve efficiency and accuracy. Hamzah and Abbas (2022) emphasized the integration of these components in automated technological processes. Accordingly, the proposed device uses programmed controls to automate coin sorting, counting, and dispensing. Sensor Basics Theory explains how sensors detect physical changes and convert them into electrical signals for processing (Hamzah and Abbas (2022). Infrared sensors detect objects through interruptions in light signals, providing a basis for coin detection and counting (Khakim, 2024). Biometric Authentication Theory supports identity verification through distinctive physical characteristics. Fingerprint recognition compares scanned fingerprints with stored templates to authenticate authorized individuals (NIST, 2025). This principle provides the basis for securing access to the device's dispensing mechanism. Systems Theory explains the interdependence of components within an integrated system. Effective operation requires coordinated inputs, processing mechanisms, outputs, and corrective feedback. System adaptability and coordination are essential for maintaining functionality under varying operating conditions (Bui and Galanou, 2022). The study adopts an Input–Process–Output framework. Inputs include relevant literature, prior technological designs, materials, tools, equipment, labor, trials, and evaluation instruments. The process involves planning, designing, fabrication, assembly, programming, testing, revision, and evaluation. These procedures produce an integrated coin sorter device designed for Philippine currency.

Existing studies have demonstrated the feasibility of automated coin sorting, counting, biometric verification, and dispensing. However, these functions are frequently examined or implemented separately. Available commercial devices may also lack compatibility with Philippine coins and integrated security features. The identified gap concerns the development of a single device that combines four essential functions: coin sorting, coin counting, biometric authentication, and coin dispensing. Furthermore, sensor interference, mechanical misalignment, operational inaccuracies, and usability concerns indicate the need for continued device development and evaluation. The present study addresses these gaps by designing and constructing an integrated coin sorter for Philippine currency. Specifically, it evaluates the device's performance in sorting, counting, biometric authentication, and dispensing, together with its acceptability in terms of design and usability. The study aims to provide a practical technological solution to the cash-handling requirements of small-business operators.

The study is aligned with two Sustainable Development Goals that correspond to its technological and economic objectives. SDG 8 – Decent Work and Economic Growth. The development of an automated coin sorter supports the operational efficiency of small businesses by reducing repetitive manual coin-handling activities, minimizing counting errors, and facilitating more convenient transactions. Its application may contribute to improved productivity and cash-management practices among sari-sari store operators. SDG 9 – Industry, Innovation and Infrastructure. The study promotes technological innovation through the integration of microcontrollers, sensors, mechanical components, biometric authentication, and automated dispensing. Developing a currency-compatible prototype demonstrates the application of embedded systems and automation to practical business challenges. These alignments represent the study's intended contributions; broader economic and technological sustainability outcomes were not directly measured.

The study contributes to technological, socio-economic, and operational sustainability by addressing cash-handling challenges through an integrated automated system. From a technological perspective, combining sensors, programmable controllers, mechanical mechanisms, and biometric authentication demonstrates the practical application of embedded technology to everyday commercial operations. The device also provides a foundation for further improvements in calibration, reliability, and system functionality. From a socio-economic perspective, automated sorting, counting, and dispensing may help small-business operators manage coins more efficiently, reduce manual workload, and minimize transaction errors. Biometric authentication additionally supports controlled access to stored currency. In terms of operational sustainability, the integration of multiple coin-handling functions into a single device offers a practical approach to improving transaction consistency and convenience. Overall, the study connects engineering innovation with small-business operational needs, demonstrating how automated and secure coin-handling technology may support technological advancement and more efficient business practices.

2. Material and methods

2.1 Research Design
The study utilized a developmental research design involving the planning, designing, fabrication, assembly, programming, and testing of a coin sorter device. A descriptive method was employed to evaluate device performance in terms of coin sorting, coin counting, biometric authentication, and coin dispensing, as well as its acceptability in terms of design and usability. Performance trials and survey responses provided the quantitative data for evaluating the developed device.

2.2 Locale of the Study
The study was conducted in Barangay Perez, Kidapawan City, North Cotabato, where permission to conduct the research was secured from the barangay captain. The locale provided access to small-business operators and personnel involved in daily coin-handling transactions.

2.3 Respondents of the Study
The respondents consisted of 30 small-business owners and their staff, particularly those operating sari-sari stores. They were selected because of their experience in handling coins during daily business transactions. Their assessments provided information on the device's performance in sorting, counting, biometric authentication, and dispensing, as well as its design and usability.

2.4 Sample and Sampling Procedure
The study involved 30 respondents comprising sari-sari store owners and their staff. Participants were approached individually and assessed against predefined criteria, particularly their experience in daily coin-handling activities. The researcher explained the study's purpose before gathering their responses. The original manuscript did not specify a formal sampling technique.

2.5 Research Instrument
A researcher-developed questionnaire was used to evaluate the device's performance and acceptability. The instrument was validated by a pool of experts from the University of Southern Mindanao–Kabacan Campus and University of Southern Mindanao–Kidapawan City Campus, obtaining a validation rating of 4.80, interpreted as Very Highly Valid. The instrument employed a five-point rating scale to assess coin sorting, coin counting, biometric authentication, and coin dispensing based on performance time and accuracy. Performance accuracy was classified as Highly Accurate (91%–100%), Accurate (81%–90%), Moderately Accurate (71%–80%), Less Accurate (61%–70%), or Not Accurate (60% and below). Design and usability were evaluated using a five-point Likert scale, with mean scores interpreted as Highly Acceptable (4.50–5.00), Acceptable (3.50–4.49), Undecided (2.50–3.49), Not Acceptable (1.50–2.49), and Highly Not Acceptable (1.00–1.49).

2.6 Data Gathering Procedure
The researcher developed an evaluation questionnaire and subjected it to expert validation before data collection. Written permission was secured from the barangay captain of Barangay Perez, Kidapawan City, North Cotabato. Following approval, the researcher approached qualified respondents individually, explained the study's purpose, and verified their eligibility. The constructed device underwent 10 performance trials conducted by the researcher to evaluate coin sorting, counting, biometric authentication, and dispensing. The device was tested using 40 mixed Philippine coins consisting of ₱1, ₱5, ₱10, and ₱20 denominations. A questionnaire was also administered to 30 respondents to assess device performance and acceptability in terms of design and usability. The collected responses and performance results were compiled and subjected to statistical analysis to determine whether the study objectives were achieved.

2.7 Data Analysis Techniques
The collected data were analyzed using descriptive statistics. Frequency counts, means, and accuracy rates were employed to evaluate device performance in coin sorting, counting, biometric authentication, and dispensing. Frequency counts, means, and weighted means were used to determine the respondents' assessments of design and usability. Performance accuracy and acceptability were interpreted using the established rating scales to determine the extent to which the developed device achieved the study objectives.

3. Results and Discussion

3.1 Design and Construction of the Coin Sorter Device

3.1.1 Design of the Coin Sorter Device
The coin sorter device was designed through conceptual sketches and Computer-Aided Design (CAD) modeling to establish its structure, dimensions, component placement, and operational flow. The design incorporated a frame enclosure, coin entry slot, sorting channels, storage compartments, biometric module, LCD display, keypad, dispensing mechanism, and electronic component housing. The arrangement was developed to support accessibility, operational convenience, and integration of the device's functions. The design process enabled the

identification and correction of structural conflicts before fabrication. Berni et al. (2023) emphasized that conceptual design and sketching improve functionality and manufacturability, while Berni et al. (2023) highlighted the role of CAD in improving design precision and visualization. Similarly, Berni et al. (2023) explained that digital modifications reduce fabrication errors and improve design optimization. The application of user-centered principles also supports the findings of Ortiz-Escobar et al. (2023), who emphasized that product design should consider user needs, convenience, and operational efficiency.

3.1.2 Construction of the Coin Sorter Device

The device was successfully constructed through the assembly of mechanical components, installation of electronic circuits and sensors, and programming of the control system. Plyboard was used as the structural casing, while motors, sensors, and microcontroller components facilitated automated operations. The system enabled real-time coin detection, counting, dispensing, and information display. Initial sensor misalignment and variations in readings were addressed through calibration and programming adjustments, resulting in a functional prototype. The successful construction demonstrates the importance of integrating mechanical, electronic, and programmed components. Hamzah and Abbas (2022) explained that effective automation requires coordination among these systems. Hamzah and Abbas (2022) also emphasized the role of microcontrollers in managing communication between inputs and outputs. The improvements following calibration further support Hamzah and Abbas (2022), who highlighted the importance of proper calibration in achieving optimal system performance.

3.2 Performance of the Coin Sorter Device

3.2.1 Coin Sorting Performance

The device was tested using 40 mixed Philippine coins consisting of ₱1, ₱5, ₱10, and ₱20 denominations. The three respondent-evaluated trials recorded sorting times of 14.06, 13.91, and 13.77 seconds, with an overall mean of 13.91 seconds and a mean rating of 4.37, interpreted as Accurate. In 10 researcher-conducted trials, nine were successfully completed, while one was unsuccessful, resulting in a 90% accuracy rate, also interpreted as Accurate. The results indicate that the device consistently classified mixed coins within the established operational time range, although minor sorting errors remained. The unsuccessful trial may have resulted from sensor misalignment or overlapping coins. Hamzah and Abbas (2022) emphasized that sorting precision depends on reliable sensor calibration, while Hamzah and Abbas (2022) explained that calibrated sensors and microcontroller-based controls improve sorting accuracy. NIST (2025) also highlighted the importance of stable inputs and signal processing. The findings are consistent with Dela Cruz et al. (2022), who demonstrated high sorting accuracy in automated systems, and Casaclang et al. (2024), who emphasized that size-based mechanisms reduce classification errors.

3.2.2 Coin Counting Performance

The coin counting function recorded trial times of 13.96, 13.78, and 13.80 seconds, producing an overall mean of 13.84 seconds and a mean rating of 3.87, interpreted as Accurate. Of the 10 researcher-conducted trials, nine successfully counted the 40 mixed coins, while one was unsuccessful. The device consequently obtained a 90% counting accuracy rate, interpreted as Accurate. The findings demonstrate consistent counting performance, although occasional errors were observed. These may have resulted from overlapping coins, interrupted sensor readings, or signal interference. Hamzah and Abbas (2022) emphasized that sensor calibration and minimized interference improve counting reliability. Hamzah and Abbas (2022) also explained that microcontroller-based systems simplify counting and reduce manual computational errors. Furthermore, Hamzah and Abbas (2022) highlighted the contribution of automated counting systems to operational productivity and reduced human error.

3.2.3 Biometric Authentication Performance

Biometric authentication recorded trial times of 2.03, 2.10, and 2.00 seconds, with an overall mean of 2.04 seconds and a mean rating of 4.40, interpreted as Accurate. All 10 researcher-conducted authentication trials successfully granted access to registered users, resulting in a reported accuracy rate of 100%, interpreted as Highly Accurate. The findings indicate that the fingerprint module consistently recognized enrolled fingerprints and provided rapid access to authorized users during testing. The integration of biometric verification supports the device's security and usability. Awad et al. (2024) emphasized that biometric authentication strengthens security by preventing unauthorized access, while Martins et al. (2024) highlighted the reliability of fingerprint-based identification. Similarly, Martins et al. (2024) explained that fingerprints provide distinctive identification characteristics, and Martins et al. (2024) identified fingerprint recognition as an accurate technique for electronic user authentication.

3.2.4 Coin Dispensing Performance

The coin dispensing function recorded trial times of 2.23, 2.30, and 2.20 seconds, resulting in an overall mean of 2.24 seconds and a mean rating of 4.20, interpreted as Accurate. All 10 researcher-conducted trials successfully dispensed the requested coin amounts, producing a reported accuracy rate of 100%, interpreted as Highly Accurate. The results indicate consistent dispensing performance and effective coordination among the sensors, servo mechanism, and microcontroller. Hamzah and Abbas (2022) explained that automated mechanical systems may experience slight variations because of motor speed fluctuations and component tolerances. The successful dispensing trials also support Abdullah et al. (2022), who emphasized that accurate dispensing requires proper calibration and synchronization of mechanical components.

3.3 Acceptability of the Coin Sorter Device

3.3.1 Acceptability in Terms of Design

The design evaluation conducted among 30 respondents yielded a weighted mean of 4.75, interpreted as Highly Acceptable. Nine of the 10 design indicators were rated Highly Acceptable, while the indicator concerning prevention of coin jamming received a mean of 4.43, interpreted as Acceptable. Respondents positively evaluated the device's organization, structural stability, compatibility with Philippine coins, biometric security, component accessibility, safety, and suitability for its intended purpose. The findings suggest that the device's structural arrangement and integration of components contributed to favorable user assessments of functionality, convenience, and reliability. However, coin-jamming prevention remains an area for improvement. Ortiz-Escobar et al. (2023) emphasized that effective product design enhances usability and user satisfaction. Similarly, Berni et al. (2023) explained that well-developed product designs improve performance, reliability, and user acceptance.

3.3.2 Acceptability in Terms of Usability

The usability evaluation obtained a weighted mean of 4.81, interpreted as Highly Acceptable. All 10 usability indicators received Highly Acceptable ratings, ranging from 4.67 to 4.90. Overall convenience and satisfaction received the highest rating of 4.90, while task completion with minimal errors obtained the lowest rating of 4.67. Respondents positively assessed the device's ease of use, clarity of instructions, LCD display, biometric and dispensing interfaces, responsive controls, and suitability for daily business operations. The findings indicate that the device provides an accessible and user-friendly interface, allowing users to understand and perform its integrated functions with relative ease. The positive evaluation reflects the contribution of its LCD display, keypad, and operational workflow to user convenience. Weichbroth (2024) emphasized that usability encompasses effectiveness, ease of use, and user satisfaction. Additionally, Weichbroth (2024) explained that highly usable systems reduce operational errors and improve overall system performance.

4. Conclusion & Recommendations

The study successfully designed, constructed, and evaluated an automated coin sorter device integrating coin sorting, counting, biometric authentication, and dispensing. The device achieved 90% accuracy in coin sorting and counting and 100% accuracy in biometric authentication and dispensing. It was rated Highly Acceptable in terms of design and usability, demonstrating its functionality, reliability, security, and convenience for small-business operations. The findings establish the device's potential as a practical solution for automated coin management.

Future improvements should focus on providing instructional labels for first-time users, enhancing sensor calibration and programming to improve sorting and counting accuracy, and developing a better coin-receiving compartment to prevent coin scattering. Integrating receipt-printing or transaction-recording features and bill-to-coin exchange functionality is also recommended. Additionally, the device's structural design should be improved using more ergonomic, durable, lightweight, and aesthetically appropriate materials to enhance its functionality, efficiency, usability, and reliability.

5. Compliance with ethical standards

The study was conducted in accordance with ethical principles for research involving human participants. Written permission was obtained from the barangay captain of Barangay Perez, Kidapawan City, North Cotabato. The researchers individually informed prospective respondents about the study’s purpose and verified their eligibility before administering the evaluation questionnaire. Data were gathered through non-invasive device performance trials and assessments of design and usability. The collected responses were analyzed and reported in aggregate to evaluate the developed coin sorter device.

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