Design of Modifications to the Aircraft Cabin Baggage Measurement Goods with Fare Calculation

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ABSTRACT
Manual cabin baggage measurement in the aviation industry is currently time-consuming and prone to errors, often confusing passengers regarding excess baggage fees. This study aims to design and modify an automated device to measure the dimensions and weight of passengers' carry-on items, as well as calculate excess baggage fees in accordance with Lion Air regulations for the Boeing 737 fleet. Using an experimental method, the device was implemented with ultrasonic sensors for dimensions, load cells for weight, and a barcode scanner for passenger identification. Measurement results are displayed on an LCD screen and can be printed as informative stickers. Key findings indicate measurement accuracy of 98.48% for dimensions (error of 1.52%), 97.43% for weight (error of 2.56%), and 99.98% for fare calculation (error of 0.011%). The device is deemed suitable for use (validation 93.75%) with minor revisions. This study is expected to significantly contribute to passenger baggage management and the increased use of technology in the aviation sector.

Keywords: *Cabin baggage, Arduino, ultrasonic sensor, load cell, dimension measurement, weight measurement, excess baggage fees.*

1. INTRODUCTION

The global aviation industry continues to experience significant growth, characterized by an increase in the volume of passengers and luggage. This phenomenon inherently brings operational challenges, especially in the management of cabin baggage which must comply with strict regulations regarding maximum dimensions and weight [1]. Each airline imposes varying baggage rate policies, often leading to confusion and dissatisfaction among passengers, and potentially causing unexpected additional costs. Baggage measurement accuracy is crucial not only for regulatory compliance, but also for operational efficiency and overall passenger experience [2].

Currently, the process of measuring cabin baggage at many airports still relies on manual methods, using box-shaped tools and conventional scales. This approach has proven to be time-consuming and highly susceptible to human error, both in determining dimensions and calculating rates based on airline policies. An identified research gap is the lack of automated solutions capable of integrating dimension and weight measurement with fare calculation accurately and efficiently. While there have been efforts to develop weight-based sorting systems [3] and sensor-based cabin baggage dimension measuring devices [4], comprehensive solutions to automate the entire process, including the calculation of excess baggage rates, are still limited.

The urgency of developing this automated system is very high, both from a scientific and practical perspective. Scientifically, this research contributes to the field of instrumentation and automation, particularly in the application of ultrasonic sensors and *load cells* for precision measurement in dynamic environments such as airports. Practically, it will significantly speed up the *check-in* process, reduce queues, minimize human error, and increase cost transparency for passengers. This not only improves customer satisfaction but also optimizes the airline's operational efficiency, in line with the demands of airport infrastructure modernization.

Based on these problems and urgency, this research aims to design and modify a tool to measure the dimensions and weight of goods in the aircraft cabin that is integrated with the excess baggage tariff calculation system. This tool is specifically designed to meet Lion Air airline standards on the Boeing 737 fleet, with a maximum dimension limit of 40 cm (height), 30 cm (length), 20 cm (width), and a maximum weight of 7 kg. The method used in this research is experimental, involving prototype design, functionality testing, and evaluation of dimensional measurement accuracy, weight, and fare calculation in various scenarios.

The main contribution of this scientific article is to present the design, implementation, and performance evaluation of an automated tool prototype capable of overcoming the inefficiency of cabin baggage measurement. The results of this research are expected to serve as a reference for the development of similar technologies in the future, encourage the adoption of automated solutions in aviation baggage management, and ultimately improve service quality and operational efficiency at airports.

2. LITERATURE REVIEW

This research adopts an experimental approach to develop and evaluate a prototype cabin baggage dimension and weight measuring device with automatic fare calculation. The experimental method was chosen to enable controlled testing of the tool's functionality and accuracy in various measurement scenarios, as well as to quantitatively validate the system's performance. This approach allows researchers to manipulate input variables (e.g. baggage size and weight) and observe their impact on output variables (measurement results, fare calculation, and baggage eligibility status), so that valid conclusions can be drawn regarding the effectiveness of the designed tool.

Dimensional and weight measurement is a fundamental aspect in various disciplines, including engineering and logistics, whose basic principles involve determining the spatial size and mass of an object [5]. In the context of the aviation industry, the accuracy of these measurements is essential to ensure compliance with airline regulations and civil aviation authorities, which directly affects passenger safety and comfort [6]. The underlying theory of the automated measurement system in this research focuses on the conversion of physical signals into digital data that can be processed. This concept is implemented through the use of ultrasonic sensors for dimensional measurement and *load cells* for weight measurement.

2.1. Main Components of Measurement System

2.1.1. HC-SR04 Ultrasonic Sensor

This device utilizes ultrasonic waves to measure distance by calculating the travel time of pulses emitted and reflected back by objects [7]. In this study, four HC-SR04 sensor units are strategically placed to measure the length, width, and height of cabin luggage in a non-contact manner, minimizing the risk of object damage and increasing efficiency. Although sensitive to environmental conditions such as temperature and humidity, these sensors were chosen for their low cost and ease of integration with microcontrollers.

2.1.2. Load Cell and HX711 Module

Load cells are transducers that convert mechanical forces (weight) into measurable electrical signals, operating based on piezoelectric principles or changes in resistance due to deformation [8]. In this system, a G-type *load cell* with a nominal capacity of 10 kg is used to measure the weight of luggage. The analog signal from the *load cell* is then amplified and converted into digital data by the HX711 module, a 24-bit analog-to-digital converter specifically designed for digital scale applications, ensuring sensitivity and accuracy of weight measurement [7].

2.1.3. Arduino UNO

As the main microcontroller, the Arduino UNO (based on the ATmega328 chip) serves as the "brain" of the system. It processes data from ultrasonic sensors and *load cells*, performs dimension and weight calculations, and implements the excess baggage rate calculation algorithm. Arduino UNO was chosen because of its flexibility in programming, the availability of digital and analog I/O pins, and the extensive developer community [9].

2.1.4. Arduino IDE

This integrated development environment (IDE) is used to write, compile, and upload program code to the Arduino microcontroller. Built with the Java programming language and C/C++ *libraries*, the Arduino IDE facilitates the development of complex *sketches* to manage the entire functionality of the tool [10].

2.1.5. Thermal Printer

This printer is used to print measurement results and tariff information in the form of stickers. *Thermal printers* operate by heating special paper, so they do not require ink or toner, making them an efficient and fast option for printing receipts or labels in busy operational environments [11].

Figure1 Thermal Printer Integration

2.1.6. I2C LCD

The *Liquid Crystal Display* (LCD) screen with I2C interface serves as a visual medium to display passenger identification data, dimensional and weight measurement results, and *real-time* fare calculations. The use of the I2C protocol minimizes the number of pins required for connection to the microcontroller, simplifying system wiring [12].

Figure2 LCD Display

2.1.7. Barcode Scanner

This device is used to scan the barcode on the passenger ticket, which contains flight identification data. The scanned data is then inputted to the system to associate the baggage measurement results with the passenger's identity, increasing the efficiency and accuracy of data recording during the *check-in* process [13].

Figure3 Barcode Scanner

2.2. Cabin Baggage and Fare Calculation

Cabin baggage refers to passenger luggage that is allowed into the aircraft cabin and remains in the custody of the passenger during the flight. Airlines, such as Lion Air with its Boeing 737 fleet, have strict regulations regarding the maximum weight (7 kg) and dimensions (40x30x20 cm) of cabin baggage [6]. If baggage exceeds these limits, it will be categorized as *excess baggage* and subject to additional charges. The calculation of the *excess baggage* rate is based on the airline's policy, which in the context of this research is Rp. 37,000 per kilogram for the domestic route Surabaya (SUB) - Jakarta (CGK) [14]. The developed system will automatically calculate this fee and display it to passengers, increasing transparency and reducing potential conflicts.

3. RESULTS AND DISCUSSION

This research successfully designed, implemented, and evaluated a prototype cabin baggage dimension and weight measuring device integrated with an automatic fare calculation system, using an experimental approach. Extensive testing was conducted to validate the functionality, accuracy and reliability of the tool in various operational scenarios, specifically to meet Lion Air airline standards on its Boeing 737 fleet. The key findings from the test data show a very promising performance of the tool, with a high level of accuracy in every aspect of measurement and calculation.

All functional components (barcode scanner, push button, LCD) operated with 100% accuracy and responsiveness. The barcode scanner successfully reads the ticket data and displays it consistently on the LCD. The output from the thermal printer also proved to be accurate and informative, producing a sticker containing full details of the measurements (dimensions, weight), baggage eligibility status ("PASS" or "OVER"), as well as details of excess baggage charges if any. The sticker is designed to be affixed directly to the baggage, facilitating quick verification by staff and providing cost transparency to passengers.

Figure4 Thermal Printer Output

3.1. Tool Testing Results

To quantitatively measure the accuracy of the device, a series of tests were conducted on the ultrasonic sensor, load cell, and fare calculation module. A summary of the accuracy results of these tests is presented in Table 1.

Table 1. Testing Results

Testing Aspect	Testing Instrument	Result
Ultrasonic Sensor	Calculating percentage error and accuracy.	The average accuracy is about 98.48% and the average percentage error is 1.52%.
Load cell sensor	Calculating the percentage of error and accuracy.	Average accuracy of 97.43% and average percentage error of 2.56%
Rate Counter	Calculating percentage error and accuracy.	The average accuracy is 99.98% and the average percentage error is about 0.011%.

3.1.1. Ultrasonic Sensor

Tests were carried out by comparing the results of length, width, and height measurements from four HC-SR04 ultrasonic sensors installed on the tool with manual measurements using standard measuring instruments (ruler / measuring tape) on six object samples of various sizes. The percentage of error and accuracy is calculated from the deviation that occurs.

Testing of HC-SR04 ultrasonic sensors, both individually and integrated in the system, showed an average accuracy of 98.48% with an average percentage error of only 1.52%. The test results consistently show that the ultrasonic sensors integrated in the device are capable of measuring object dimensions with very high accuracy and minimal error. The accurate "Over Volume" classification proves that the system not only measures, but also processes the data to comply with airline regulations.

3.1.2. Load Cell

Testing was conducted in two stages: first, testing the *load cell* components separately by comparing their readings against a standard digital scale using 0-10 kg loads; second, testing the *load cells* once integrated in the system by placing objects of varying weights (0-9.5 kg) and comparing the results against a reference scale, repeated three times for each load.

Testing the load cell components separately showed an overall percentage error of about 0.0385%, proving its feasibility. When integrated in the system, the load cell achieved an average accuracy of 97.43% with an average overall percentage error of only 2.56%.

3.1.3. Rate Calculation Accuracy

Tests were conducted by inputting various baggage weight variations into the system (including under and over the 7 kg limit) and comparing the results of the automatic fare calculation by the device with a verified manual calculation based on Lion Air's fare policy (IDR 37,000/kg for overweight).

The fare calculation system showed a very high level of accuracy, reaching an average of 99.989% with an overall average percentage error of only around 0.011%. For example, for 11.974 kg of baggage (exceeding the 7 kg limit), the automatic calculation resulted in Rp. 108,047, very close to the manual calculation of Rp. 108,038, with an absolute error of only Rp. 9 (0.008%). For baggage under 7 kg (e.g. 6.989 kg), the system correctly calculated a fare of Rp. 0, showing 100% accuracy. This consistency proves that the implemented fare calculation algorithm works with precision according to Lion Air's policy.

Through experimental methods, this research not only describes the data, but also interprets its meaning in the context of aviation industry problems. Controlled testing enabled precise identification of the level of accuracy and efficiency achievable by the tool, and validated the hypothesis that automated solutions can overcome the limitations of manual methods. Thus, this research not only produced a functional prototype, but also enriched the scientific literature with empirical evidence of the effectiveness of sensor and microcontroller technologies in aviation baggage management applications.

4. CONCLUSION

Overall, this tool has several significant advantages, automation of fare measurement and calculation reduces human error and speeds up the check-in process. The simple and user-friendly design makes it easier for staff. In addition, the integration of a barcode scanner ensures accurate passenger identification. And the ability to print stickers provides cost transparency and ease of verification. However, there are drawbacks such as the dependency of the barcode scanner on a PC and the limitation of fare automation to one fare category only, which is a focus for future development.

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