MERATECH
Vol. 01, No. 1 (2025), pp. 12-20
ISSN: XXXX-XXXX

Design and Development of an Automated Quail Feeding System Using IoT Technology and Nutrient Mixing

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Received: 28-08-2025 | **Accepted:** 31-08-2025

Abstract

This study aims to design an automated quail feeding system based on the Internet of Things (IoT) integrated with a nutrient mixing system. The system uses an ultrasonic sensor to monitor feed levels and four servo motors to control the input, mixing, and distribution flow automatically. Test results show that the system works as designed, with centralized control via a microcontroller and stable servo responses. The most optimal nutrient mixing is achieved at a duration of 150 seconds, resulting in an evenly mixed output. The entire process runs automatically with real-time monitoring. The system can deliver feed on time with an average delay of 3–4 seconds and a dosage error rate of 1–3%, still within a tolerance of ±5 grams. Therefore, this system is effective, precise, and suitable for small-scale use, with the potential to be further developed for large-scale farming.

Keywords: Automation, Internet of Things, Quail Feed, Nutrient Mixing, Feeding Efficiency

1. INTRODUCTION

The quail farming sector in Indonesia plays a significant role in meeting the community's demand for animal protein. The Japanese quail (Coturnix japonica) is recognized as an efficient and high-quality source of protein. Advantages such as a short reproductive cycle, relatively low capital requirements, and ease of maintenance make quail farming an attractive option for both small- and medium-scale farmers [1]. In recent years, the demand for quail eggs has continued to grow in line with increasing public awareness of their health benefits, including aiding blood formation, boosting metabolism, and strengthening bones [2][3]. Quail farming has the potential to increase household income in rural areas and support economic self-reliance [4][5]. Given these opportunities, the quail farming sector has become an essential component in strengthening national food security.

Feed is a key factor in the success of quail farming. The use of high-quality feed tailored to the birds' nutritional needs can significantly increase egg production [6]. Innovations in feed composition, such as the use of organic waste, fish meal from marine by-products, and natural supplements, have been introduced to improve efficiency and sustainability in the sector [2]. The addition of ingredients such as Artemisia annua and turmeric to feed has been reported to enhance feed conversion efficiency and improve production quality [7].

However, manual feed management often faces challenges such as inaccurate measurements, contamination risks, and high labor requirements, all of which can hinder productivity [8][9]. Stress caused by human interaction during manual feeding may affect quail feeding patterns, health, and productivity [10][11]. Feed quality, including feeding schedules, can influence lipid content in quail eggs, highlighting the importance of proper feed management to ensure high-quality end products [12]. These challenges demand innovative solutions that can help farmers optimize feed management practices.

The Internet of Things (IoT) offers an innovative approach to addressing these challenges. IoT enables automated, accurate, and efficient feed management. IoT-based systems allow real-time monitoring of feed intake, cage environmental conditions, and livestock health [13]. Data collected from IoT sensors can be integrated into cloud-based platforms, enabling remote access and in-depth data analysis [14][15]. Moreover, IoT integration in feed distribution ensures even and demand-based allocation, directly impacting livestock productivity and product quality [16][17].

The implementation of IoT can also significantly reduce stress in quails. Automated IoT-supported feeding systems minimize direct human intervention, creating a more comfortable environment for the birds and enhancing production outcomes. Automation also reduces feed wastage, which is often encountered in manual systems, thereby improving feed resource efficiency [18].

The objective of this study is to develop an automated quail feeding system capable of enhancing efficiency, accuracy, and consistency in feed distribution and nutrient mixing. The system is designed to minimize manual intervention by using sensors to detect feed requirements and actuators to control feed dispensing and nutrient mixing automatically. Additionally, the system aims to provide IoT-based monitoring and control features, enabling farmers to access real-time data and manage feeding processes remotely through an application. This research seeks to create an innovative solution that supports farmers in improving productivity and operational efficiency.

The urgency of developing an IoT-based automated quail feeding system is high, given the significant challenges in the livestock industry, such as feed measurement inaccuracies, contamination risks, and high labor demands. In the context of increasing demand for animal protein and optimal quail egg quality, the adoption of modern technology is essential for improving efficiency and productivity. Through automation and the integration of nutrient mixing technology, this research not only aims to improve precise feed distribution—which can directly affect quail health and productivity—but also to provide farmers with a convenient remote management system. Therefore, this innovation is expected to contribute significantly to the sustainability of the quail farming sector and to improve the welfare of both farmers and the wider community.

2. METHOD

2.1 Research Flowchart

This study aims to design a quail feeding system that reduces labor and operational costs through the integration of a nutrient mixing system and automated feed dispensing. The system is supported by Internet of Things (IoT) technology, enabling farmers to remotely schedule feeding times. This approach ensures that quails receive feed at consistent intervals, thereby supporting optimal growth and productivity. An illustration of the proposed automated feeding system design is presented in Figure 6.

The detailed explanation of the research methodology is as follows:

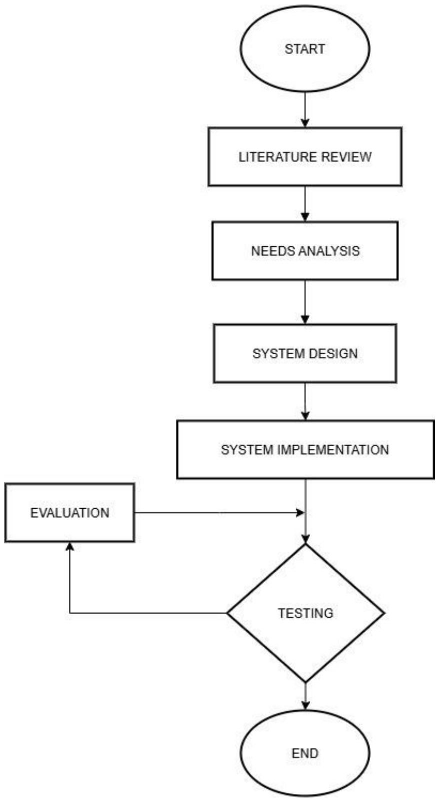

Figure 1. Development Flowchart

2.2 Hardware Design

The proposed system is constructed using several key components, including an ESP32 microcontroller, servo motors, an L298N motor driver, DC motors, an AC motor, ultrasonic sensors, relays, and limit switches. The ESP32 functions as the main processing unit, connecting to the internet and enabling real-time data transmission via the Flutter application. Servo motors are employed to control the opening of feed flow gates between the mixing tank, the mixing tank to the distribution tank, and from the distribution tank to the feeding container. The L298N motor driver is used to control the movement of the DC motor responsible for feed distribution. An AC motor is utilized as the feed mixer. Ultrasonic sensors are installed to detect the feed capacity in both the distribution and mixing tanks. Relays function as switches for controlling the AC motor, while limit switches are used to stop the DC motor movement during the feed distribution process.

2.3 Block Diagram

This system is an automated control system managed by an ESP32 microcontroller. It is designed to receive input from various sensors and issue commands to multiple actuators. An ultrasonic sensor is employed to measure the amount of feed in the tank, while limit switches are used to detect the position of the feed tank. Data from these sensors are processed by the ESP32, which then sends control signals to various output components such as DC motors, relays, and the L298N motor driver. Servo motors are utilized to operate gates as required, relays are used to control the AC motor for the mixing system, and the L298N driver is used to manage the DC motor in the feed tank. Through the integration of these components, the system can perform various automated tasks, including activating the mixing motor, opening and closing feed gates, and controlling feed distribution automatically. The block diagram of the system is presented in Fig. 2.

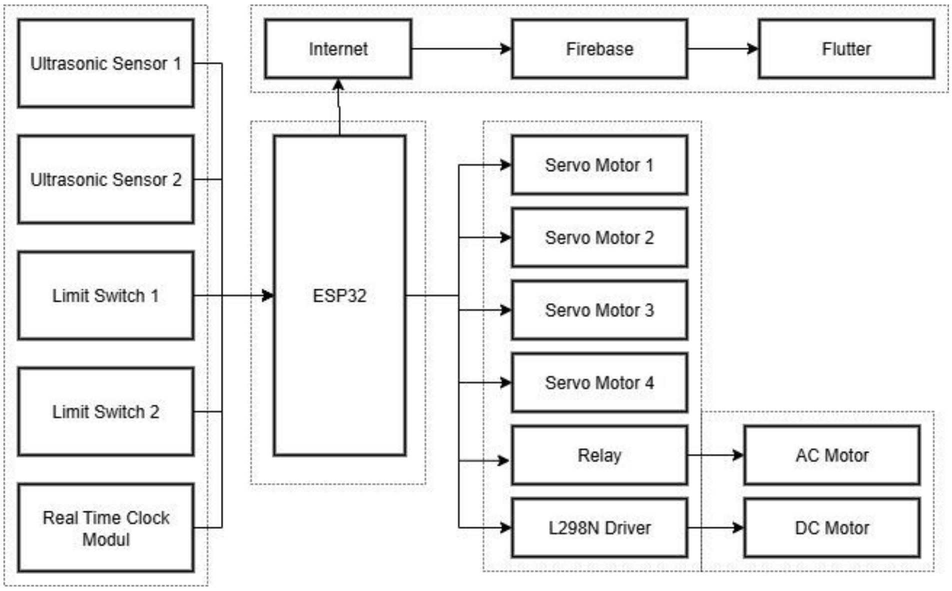

Figure 2. Block Diagram

2.3.1 Working Principle

The automation system comprises several key components that work in synergy to perform the automated feeding and nutrient mixing functions for quail birds. The ESP32 microcontroller serves as the central control unit, receiving data from sensors, processing it, and generating control signals for the actuators. One of the primary sensors employed is an ultrasonic sensor, which detects the amount of feed in the storage tank by measuring distance using sound waves reflected from the feed surface. Additionally, a limit switch sensor is utilized to determine the position of the feed tank by detecting physical contact when the tank reaches a specific location.

Once the ESP32 processes the sensor data, control signals are transmitted to actuators such as servo motors, an AC motor, and a DC motor. The servo motor is responsible for precisely opening and closing the feed tank gate, leveraging its accurate angular control capability through PWM signals. The AC motor is employed to mix the feed and nutrients inside the mixing tank, converting electrical energy into mechanical rotation. Meanwhile, the DC motor, driven by an L298N motor driver, facilitates the movement of the feed tank along a rail.

A relay functions as an electronic switch to regulate the AC motor, enabling the low-power ESP32 to control higher-power devices such as the AC motor. All these components are interconnected and operate synchronously, allowing the system to perform various functions, including feed mixing, automated feed distribution, and controlled feed tank movement based on real-time sensor data. This working principle ensures efficient, accurate, and reliable operation tailored to the automation requirements of quail feeding systems.

2.3.2 System Workflow Diagram

The automated quail feeding system begins by activating all components, including sensors, actuators, and the ESP32 microcontroller. The AC motor and Servo Motor 1 are initiated first to drive the mixing mechanism inside the mixing tank. This mixing process continues for a predefined duration to ensure uniform blending of feed and nutrients. Once mixing is complete, Servo Motor 2 opens the mixing gate, and the system reads data from the ultrasonic sensor to detect the feed level in the tank. If the feed level falls below the predetermined threshold, the distribution process is halted.

If the conditions are met, Servo Motor 3 is activated to open the bottom gate of the mixing tank, allowing the mixed feed to flow into the distribution tank. A limit switch is used to verify whether the distribution tank is correctly positioned. The feed distribution process is triggered only when the scheduled feeding time is reached, at which point Servo Motor 4 opens the distribution channel toward the quail feeding tray. Simultaneously, the DC motor moves the feed tank along a preinstalled rail.

The limit switch is employed again to confirm that the distribution mechanism has reached the end of the rail and properly returns to its initial position. Upon completion of the entire process, the system automatically stops and enters standby mode until the next scheduled distribution cycle. The overall system workflow is illustrated in Fig. 3.

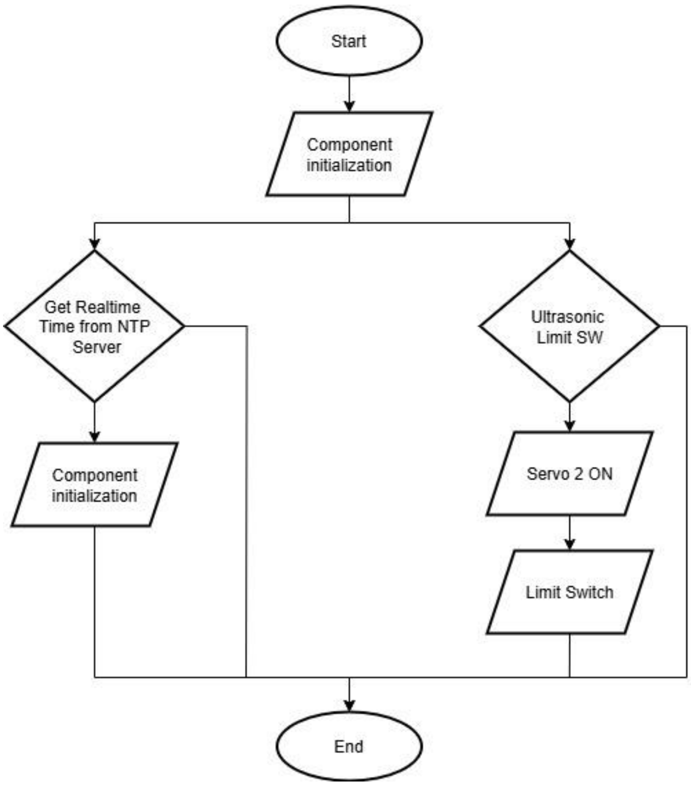

Figure 3. Hardware System Flowchart

2.4 Software Design

2.4.1 Wiring Design

Fig. 4 presents the wiring design of the entire system, created using the Fritzing application. This wiring diagram illustrates the pin connections utilized by each component within the system. The ESP32 is connected to several other components, enabling full system integration.

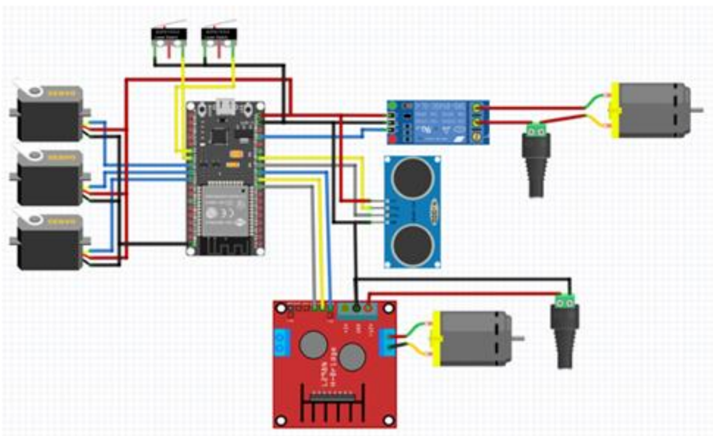

Figure 4. System Wiring Design

2.5 Quail Cage Design

Fig. 5 presents a 3D illustration providing an initial overview of the overall design, serving as a preliminary guideline for the development of the device. Fig. 5 depicts the initial design of the automated feeding system. Fig. 6 illustrates the mixing system, which is integrated with the automated feeding mechanism, showing how all components are interconnected.

Figure 5. Automatic Feeding Design

Figure 6. Feed Mixing Design

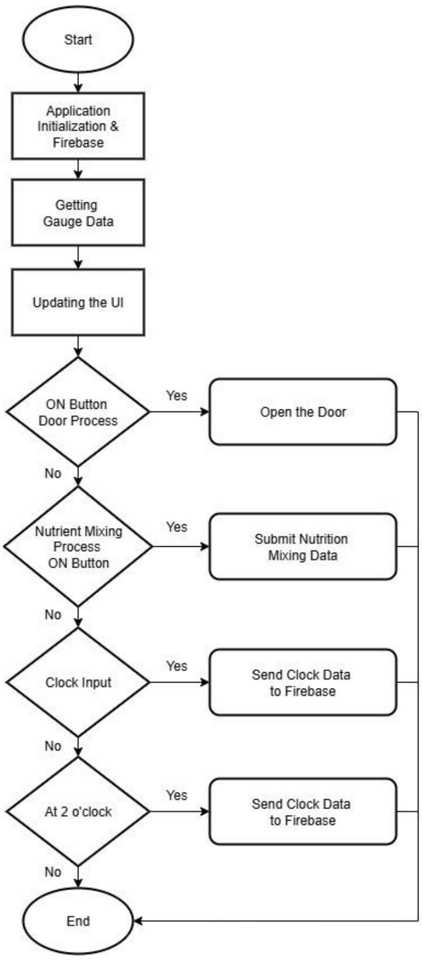

Figure 7. Software Flowchart

2.5.1 Control Application Interface Design

The system design also includes the development of a graphical user interface (GUI) within the application used for remote monitoring and control. The application interface displays real-time readings from the ultrasonic sensors, which indicate the remaining amount of feed in both the mixing tank and the distribution tank. Additionally, it provides control buttons for operating Servo 1, which is used to open or close the mixing tank gate. The application also includes a button to manually activate the mixing process when necessary. The design of the application interface is shown in Fig. 8.

Figure 8. Application Display Design

3. RESULTS AND DISCUSSION

3.1 Implementation of the IoT-Based Automated Quail Cage System Design

3.1.1 Physical Design and Assembly Results

Fig. 9 shows the final assembled product, developed in accordance with the initial design specifications. Fig. 10 presents the final implementation of the automated feeding system. Fig. 11 illustrates the mixing system integrated with the automated feeding mechanism, in which all components are interconnected, utilizing an AC mixing motor and a servo motor as the transfer gate.

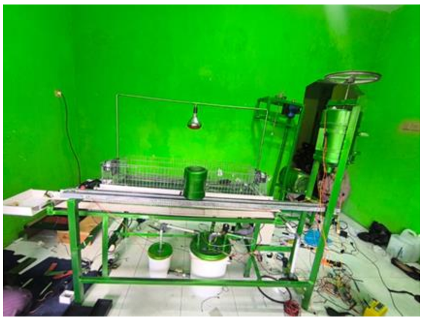

Figure 9. Quail Cage Design Results

Figure 10. Feed Distribution Plan

Figure 11. Feed Mixing Design

3.1.2 Ultrasonic Sensor Monitoring Test

At this stage, testing was conducted on the ultrasonic sensor used to monitor the feed level inside the tank. The objective of this test was to ensure that the sensor could provide accurate readings of feed height, which is crucial for the automated feeding and distribution process. The testing was carried out under actual operational conditions to directly evaluate the sensor's performance. The results of this test are presented in Table 1, providing an overview of the sensor's accuracy and consistency in reading the feed levels.

Table 1. Ultrasonic Sensor Testing

No	Feed Level	Sensor Distance (cm)	Tank Fill Percentage	Description
1	Empty	28.5	5.00%	Nearly Empty
2	Half	16.0	46.67%	Half Full
3	Full	6.0	80.00%	Nearly Full

3.1.3 Servo Motor Operation Testing

This test aims to ensure that the servo motor controlling the gate in the automation system operates in accordance with the commands issued by the microcontroller. Each servo motor was tested to verify its ability to open and close the gate accurately, without interruptions or delays. This testing is crucial to guarantee that the feed transfer and mixing processes can be executed smoothly. The results of the servo motor testing are presented in Table 2.

Table 2. Servo Motor Operation Test

No	Controlled Gate (Servo)	Gate Name	Command Status	Servo Movement
1	Servo 1 (Gate to Mixing Tank)	Material Input Gate	Close	Functional
2	Servo 2 (Mixing Board)	Mixing Board	Open	Functional
3	Servo 3 (To Distribution Tank)	Transfer Gate	Open	Functional
4	Servo 4 (Distribution to Cage)	Distribution Gate	Close	Functional

3.2 Implementation of Nutrient Mixing System in Automated Feeding

At this stage, the nutrient mixing system is implemented as an integral part of the automated feeding process. The objective of this implementation is to ensure that the nutrients required by the quails are optimally blended before being dispensed, thereby enhancing feeding efficiency and supporting optimal growth. The process involves the automatic control of both the mixing and distribution systems, utilizing sensors, actuators, and a microcontroller-based control unit that was previously designed.

3.2.1 Nutrient Mixing Evaluation

The nutrient mixing evaluation aims to assess the degree of uniformity and consistency of the feed mixture produced by the system. The evaluation was carried out by examining the color and texture of the feed after the mixing process to ensure that all ingredients were evenly blended. The results of this mixing evaluation are presented in Table 3.

Table 3. Nutrient Mixing Test

No.	Mixing Duration	Mixture Color	Presence of Clumps (Yes/No)	Remarks
1	60 seconds	Uneven	Yes	Requires improvement
2	90 seconds	Slightly uneven	Yes	Requires additional mixing time
3	120 seconds	Even	Yes	Requires increased mixing speed
4	150 seconds	Even	No	Perfectly uniform

ISSN: XXXX-XXXX

3.2.2 Servo Control Testing

This test aimed to evaluate the performance of the servo motors in precisely opening and closing the feed distribution gates. The performance assessment was based on response time, smoothness of motion, and operational stability during multiple feed distribution cycles. The results of this evaluation are presented in Table 4.

Table 4. Servo Control Testing

No.	Controlled Gate	Application Command	Servo Response	Response Time (s)	Status
1	Servo 1 (Gate to Mixing Tank)	Open	Moving	0.4	Yes
2	Servo 2 (Mixing Board)	Open	Moving	0.3	Yes
3	Servo 3 (Gate to Distribution Tank)	Open	Moving	0.4	Yes
4	Servo 4 (Distribution to Cage)	Open	Moving	0.3	Yes

3.2.3 Real-Time Monitoring and Feedback System Testing

This test aimed to ensure that the IoT-based monitoring system is capable of delivering real-time data on the status of the feed mixing and distribution processes. Sensor and motor data were observed to evaluate the accuracy and timeliness of information transmission. The results of the monitoring system test are presented in Table 5.

Table 5. Real-Time Monitoring and Feedback System Testing

No.	Sensor/Component	Data Received	Data Accuracy	Remarks
1	Ultrasonic Sensor	Received	Accurate	Smooth
2	Servo 1 (Inlet Door to Mixing Tank)	Received	Accurate	Smooth
3	Mixing Status	Received	Accurate	Smooth

3.3 Performance and Effectiveness of the Developed System

3.3.1 Automated Quail Feeding System Functionality Test

A functionality test was conducted to verify that the automated quail feeding system operates according to the predetermined schedule and is capable of dispensing feed at the desired rate without interruptions. The objective of this test was to evaluate the system's responsiveness to automated commands during feeding cycles. The results of the system response test are presented in Table 6.

Table 6. Automated Feeding System Functionality Test

No	Scheduled Time (UTC+7)	Motor Activation Time (UTC+7)	Feed Dispensing Time (UTC+7)	Delay (seconds)	Remarks
1	07:00	07:00:02	07:00:04	4	Success
2	12:00	12:00:01	12:00:03	3	Success
3	15:00	15:00:01	15:00:01	3	Success

3.3.2 Feed Quantity Accuracy Test

The feed quantity accuracy test was conducted to evaluate whether the amount of feed dispensed by the system matched the predetermined target. The feed requirement for a quail is 20.67 grams per feeding. In this test, the target weight was set to 100 grams, corresponding to the feed for five quails, resulting in an actual target of 103.35 grams with an allowable tolerance of ±5 grams. The difference between the dispensed feed weight and the target weight was calculated to determine the system's error rate and accuracy. The test results are presented in Table 7.

Table 7. Feed Quantity Accuracy Test

No	Target Quantity (grams)	Actual Weight (grams)	Difference (grams)	Error Percentage
1	100	101	+1	1%
2	100	103	+3	3%
3	100	102	+2	2%

This test was conducted to ensure that the amount of feed released matches the predetermined portion, thereby meeting the nutritional requirements of each bird accurately. The feed weight was measured directly using a digital scale at the moment it was dispensed from the system to obtain precise data regarding the performance of the feed distribution mechanism.

4. CONCLUSION

Based on the results of the research, implementation, and testing of the IoT-based automated quail feeding system with integrated nutrient mixing, the following conclusions can be drawn:

a. The IoT-based automated quail feeding system was successfully designed and implemented using an ESP32 microcontroller. The system is capable of connecting to the IoT platform in real time, controlling the servo motor to open and close the feed gate, and reading feed levels through an ultrasonic sensor.
b. The integration of the nutrient mixing system was successfully achieved. Optimal mixing was reached within 150 seconds, producing evenly mixed feed without clumps, indicating the effectiveness of the mixing process.
c. The system demonstrated effective performance with high portioning accuracy (error <5%) and low delay (2–4 seconds). All processes run automatically and can be monitored in real time.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Department of Electronic Systems Engineering Technology, Faculty of Vocational Studies, Universitas Negeri Malang, for providing the facilities and academic guidance during the course of this research. Thanks are also expressed to all parties who have supported the implementation of this research.

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