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PACKAGE RECEIVER BOX BASED ON IOT USING FUZZY MAMDANI AND MOBILE APPLICATION

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Abstract—*The development of information technology is currently growing, where now everything has been transformed digitally. Consumers today to shop no longer need to come to the market. Consumers shop through e-commerce applications and just wait for the goods between the couriers from the expedition to arrive at their doorstep. Based on a survey conducted on March 10, 2021, with 100 respondents, it was concluded that 62% of the problems experienced were the process of receiving packages and security risks during package delivery Answering the IUI problem requires an IoT-based package receiving box that helps make it easier for couriers to send goods and helps package owners to monitor packages that have been delivered by couriers. This package recipient box is accompanied by an ESP32 Cam camera module to scan the QR code receipt number, ESP8266 helps connectivity and android-based mobile applications with a firebase real-time database to make it easier for package recipients to monitor packages. In helping to facilitate decision making, Mamdani fuzzy logic is used.* This research uses the Mamdani method in the use of fuzzy logic with the reason that the formation of fuzzy sets for input and output is formed so that the composition of rules obtained from a collection of correlations between rules and there is affirmation of input from the defuzzification process from the composition of fuzzy rules*. From the research experiment, it was found that the system can carry out the package storage process with an average time of 11 seconds and the time required to update to firebase is around an average of ±3 seconds.*

Keywords: *Fuzzy Mamdani, IoT, Package Receiver Box, Mobile*

Intisari—*Perkembangan teknologi informasi saat ini semakin berkembang, dimana sekarang semuanya telah bertransformasi secara digital. Konsumen saat ini untuk berbelanja tidak perlu lagi datang ke pasar. Konsumen berbelanja melalui aplikasi e-commerce dan tinggal menunggu barang antar kurir dari ekspedisi sampai di depan pintu mereka. Berdasarkan survei yang dilakukan pada 10 Maret 2021 dengan 100 responden, disimpulkan bahwa 62% permasalahan yang dialami adalah proses penerimaan paket dan risiko keamanan saat pengiriman paket, dimana kurir tidak menemukan pemilik paket di rumah. Menjawab permasalahan tersebut diperlukan kotak penerima paket berbasis IoT yang membantu mempermudah kurir dalam mengirim barang dan membantu pemilik paket untuk memantau paket yang telah dikirimkan oleh kurir. Kotak penerima paket ini disertai modul kamera ESP32 Cam untuk memindai nomor resi kode QR, ESP8266 membantu konektivitas dan aplikasi mobile berbasis android dengan firebase real-time database untuk memudahkan penerima paket dalam memantau paket. Dalam membantu mempermudah pengambilan keputusan, digunakan logika fuzzy Mamdani. Dari percobaan penelitian didapatkan bahwa sistem dapat melakukan proses penyimpanan paket dengan rata-rata waktu 11 detik dan waktu yang dibutuhkan untuk update ke firebase berkisar rata-rata ±3 detik.*

Kata Kunci: *Fuzzy Mamdani, IoT, Packages, Mobile*

INTRODUCTION

Entering the era of the industrial revolution 4.0, business and economic activities have transformed into a digital business and economy that is easy and fast to reach by the public. With the convenience that is obtained, people are starting to be active in using social media and e-commerce to buy goods [1]. One of the conveniences obtained by shopping through the internet is that the goods to be purchased are delivered directly to the house through the delivery company and the buyer can still communicate with the seller via online media or social media [2].

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In the process of delivering goods, it takes quite a long time and the estimated time of delivery of goods cannot be determined or uncertain [1]. Based on the survey that has been conducted, it was found that 62% of 100 respondents felt that the absence of people at home was the biggest obstacle in the process of receiving packages. Based on the problems that have occurred, the solution taken by the courier is to leave the goods to the neighbors, put the goods on the fence or the home environment, or store the goods and send them the next day.

From the problems that arise due to the process of receiving packages or goods, a system is needed that can replace the role of the recipient of the package who is not always at home. With this technology, it helps make it easier for users to be able to find out and get information related to their goods by using the internet network as an intermediary for communication [3][4].

Research related to problems that occur using infrared sensors as an indicator of the condition of the door for storing goods or packages that are connected via the homeowner's smartphone, but the drawback is that there is no feature to know when the condition of the box is full and there is no logic for decisions in the status of the box [5]. Another similar system development has been carried out in the manufacture of automatic post boxes by utilizing temperature and humidity sensors to determine the condition of the goods or packages in the box [6]. In system development, a decision-making system is needed to determine the conditions in the system to be made, one of the decision-making systems that can be used is fuzzy logic .

Fuzzy logic is an advanced level of Boolean logic that deals with the concept of truth values. In this regard, fuzzy logic has a condition when it is between 0 or 1 [4]. Fuzzy logic can prove to what extent a value is false and to what extent a value is true. Fuzzy logic has 3 methods, namely Tsukamoto, Mamdani, and Sugeno [7]. In Fuzzy Tsukamoto, each rule is represented by fuzzy sets, with a membership function that is monotonous. In the Mamdani method, when evaluating the rules in the inference engine, the Mamdani method uses the MIN function and the composition between rules uses the MAX function to generate a new fuzzy set. In the Sugeno method, the system output is not in the form of a fuzzy set, but the output is a constant or linear equation [8]. This study uses the Mamdani method in the use of fuzzy logic with the reason that the formation of fuzzy sets for input and output is formed so that the composition of rules obtained from a collection of correlations between rules and there is affirmation of input from the defuzzification process from the composition of fuzzy rules [9].

In research related to fuzzy logic, there is research on the determinants of controlling soil temperature and humidity for plants by utilizing two sensors to produce plant status decisions [10]. Another related research is the fuzzy logic decision making system, which is the scheduling of motorcycle service with the parameters of the condition of the motorcycle and the last date of service in the vehicle [8]. The use of mobile-based applications is easier to use and operate because it is more flexible [11][12]. Based on research that has been done before, when compared with the research done in this report there are differences in the outputs, methods, and tools used. In this study, adapting various reviews of studies that have been carried out and adapting them into the system that will be created. The research that will be carried out utilizes the ESP32-Camera as a Bar Code reader, uses an android smartphone application as a box unlock from the receiving side of the package, and uses Fuzzy logic to classify the status of the package box.

Based on the problems and research described above, an IoT-based package receiver box can be made by using a fuzzy logic decision-making system as a determinant of the state of the box using two inputs, namely the proximity sensor and the weight sensor, the system created will be integrated with the Android smartphone owner of the box and the data will be stored via Firebase.

MATERIALS AND METHODS

This study uses the method or stages of research completion which can be seen in Figure 1.

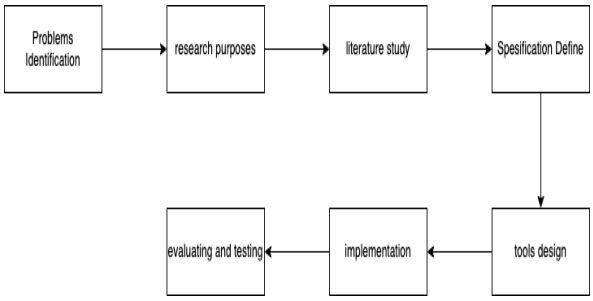

Figure 1. Research Flow

The method of this research consists of 7 stages consisting of:

1. Problems Identification

   At the problem identification stage is to find problems that occur in an environment or case study. At this stage, several obstacles that are often felt by respondents who carry out online shopping activities and use freight forwarding services are collected.

2. Research Objective
   This stage determines the goals that will overcome the problems that occur. The purpose of this research is to build a package receiver box that can receive packages and notify the package owner when the box is full and the condition when the package has been received by the box.
3. Study of Literature
   At this stage, the search for theories and methods in previous studies that are related and useful for building systems is carried out. In this stage determine what method is suitable for use in the decision-making system and determine the flow of the system. In this stage there is a literature study carried out to obtain the basic concepts and theories that underlie the research. Some of the basic theories in this research are:
   a. Package Delivery
      The definition of delivery is the activity of distributing goods from producers to recipients. Meanwhile, a package is an item that is sent in the form of a package and is usually sent by the post or shipping company [13].
   b. Fuzzy Logic
      Fuzzy logic is a decision-making system that allows decision making with values between 0 to 1 or false and true values [14]. Fuzzy logic calculations have three methods or systems, namely the Mamdani method, the Sugano method, and the Tsukamoto method. The difference between each of the existing methods is that they have different results and calculation methods. In fuzzy logic there are 3 stages, namely fuzzification, rule or reasoning, and defuzzification stage.
   c. ESP32-Camera
      ECP32-Camera is a camera module that has been equipped with Wi-Fi and uses the ESP32 microcontroller [15]. This camera module is a microcontroller that has been equipped with an OV2640 camera which can be easily programmed via Arduino IDE [16]. The system that will be made uses an ESP32-cam to be used as a QR Code reader for the package to be received.
   d. QR-Code
      Quick response code is a 2-dimensional bar code that provides information directly. QR Code is an image that can store data in it. QR Code is an evolution or development of the bar code [17]. QR Code can accommodate thousands of alphanumeric characters up to 4000 characters in one code, so it can be used by everyone to store information. There are 6 types of QR Code, namely QR Code Model 1, QR Code Model 2, Micro QR Code, SQRC, iQR, and LogoQ [18].
4. Determine Specification
   At this stage, the components needed for the manufacture of this system are determined. In the development of this system there are several main requirements [19]. The components used in this study are listed in Table 1.
5. Tool and Application Design
   At the tool design stage and specifications, the design of tools and applications that are in accordance with the function is carried out. At this stage also carried out the preparation of the workflow of the entire system. This box receiver system was developed using three microcontrollers ESP32-Camera, ESP32 and ESP8266 and connected to each other or communicated via Firebase. The interaction and workflow of this box receiving system is represented through a schematic diagram which can be seen in Figure 2.

Table 1. Hardware Requirements

No.	Name	Function
1.	ESP32	Microcontroller that functions as data processing.
2.	ESP32-Camera	ESP32-Camera functions to take a picture of the QR Code on the package
3.	HC-SR04	Ultrasonic sensor that functions to measure the distance between the package box and the package inside.
4.	Solenoid 12V	The 12V solenoid functions as a package box door lock and opener.
5.	Relay	The 12V solenoid functions as a package box door lock and opener.
6.	TFT LCD Display Module ST7735	The TFT LCD is used as a camera position viewer.
7.	LCD	LCD is used to display notification text to courier.
8.	Load/Weight Sensor	Measure the weight of the package in the box receiving the package.
9.	Keypad	As input for the password used to open the box door when the QR Code cannot be read.
10.	ESP8266	As a microcontroller to process keypad data.

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The workflow on the system is designed starting from the package owner entering the receipt number through the android application to the courier process entering the package into the IoT-based package recipient box.

In this stage, fuzzy logic is designed which is used as a decision-making system for the state of the box. The method used in fuzzy logic in the package receiving box system is the Mamdani method, the package status is determined by measuring 1 ultrasonic sensor and 4 weight sensors placed on the inside of the box. There are 3 stages in fuzzy logic design, these stages are fuzzification, inference system, and defuzzification [20].

The stages of fuzzy logic from this research are as follows:

a. Fuzzification

This process is a conversion process from crisp numerical or definite truth values into fuzzy sets by using the membership function [10]. The data from the parameter and variable values that will be used in this study are listed in Table 2.

Table 2. Fuzzification

Parameter Definition and Value	**Fuzzy Variable**
Ultrasonic Sensor (cm)	**Level**
45 – 100	Empty
15 – 50	Half Full
0 – 20	Full
Weight/Load Sensor (g)	**Level**
0-150	Not Heavy
100-15000	There is weight
12500-50000	Heavy
Output	**Box Level Condition (Value)**
Empty	LED gloomy, (**0 – 100)**
Half Full	LED lights up normally, (**70 – 180)**
Full	LED lights up bright, (**130 – 255)**

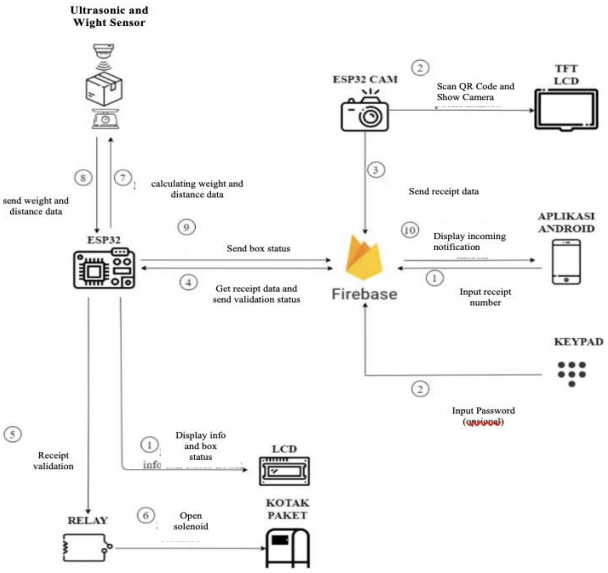

Figure 2. Schematic Diagrams

b. Inference System

Inference system or rule evaluation is a reference in describing the relationship between input and output variables. Explanation of the relationship between input and output usually uses "if-then" [20]. Fuzzy rules are created based on the circumstances to process the data entered. In this study using 2 inputs from sensors, namely 1 ultrasonic sensor and 1 weight sensor. The ultrasonic sensor has 3 variables and the weight sensor has 3 variables. Fuzzy logic rules that can be made using these two inputs form 9 fuzzy rules, namely:

1. Load Sensor "Tidak Berat", Ultrasonic Sensor "Kosong", then displays KOSONG.
2. Load Sensor "Tidak Berat", Ultrasonic Sensor "Setengah", then displays ADA.
3. Load Sensor "Tidak Berat", Ultrasonic Sensor "Penuh", then displays PENUH.
4. Load Sensor "Ada Berat", Ultrasonic Sensor "Kosong", then displays ADA.
5. Load Sensor "Ada Berat", Ultrasonic Sensor "Setengah", then displays ADA.
6. Load Sensor "Ada Berat", Ultrasonic Sensor "Penuh", then displays PENUH.
7. Load Sensor "Berat", Ultrasonic Sensor "Kosong", then displays ADA.
8. Load Sensor "Berat", Ultrasonic Sensor "Setengah", then displays ADA.
9. Load Sensor "Berat", Ultrasonic Sensor "Penuh", then displays PENUH.

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c. Defuzzyfication

The defuzzification stage is the last step in designing fuzzy logic. At this stage, the input obtained is confirmed in the previously determined fuzzy rules [10]. The method that will be used in defuzzification is the centroid method, which is a method with a crisp solution obtained by taking the center point (z*) Fuzzy area [21].

By using formula:

$$z^* = \frac{\int_z z\mu(z)dz}{\int_z \mu(z)} \quad \begin{matrix} \longrightarrow \text{Momen} \\ \longrightarrow \text{Area} \end{matrix} \qquad (1)$$

Description:
μ = Category Index
z* = Center Point

6. Implementation

The implementation stage is the stage of making the system, both hardware and software implementation, which has been planned at the design stage. The predefined components are assembled so that they can be connected to each other.

The hardware circuit in this system has 3 circuits, for the first series, namely a series of QR Code scanners, which has an ESP32-Camera as a camera module as well as a microcontroller. The description of the QR Code scanning series is shown in Figure 3.

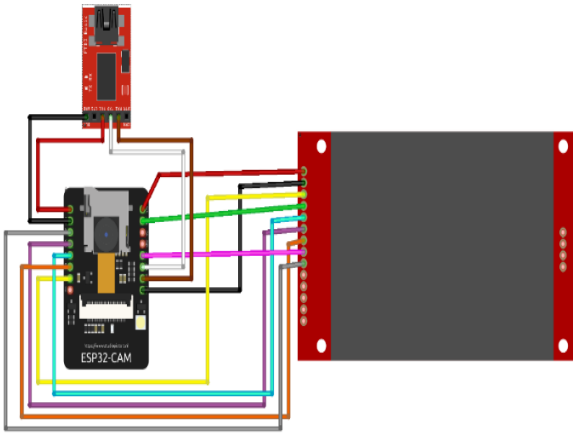

Figure 3. QR Code Circuit

The second circuit is a circuit for the box lock system. In this scheme using ESP32 as a microcontroller and using 2 sensors, namely the weight sensor and the distance sensor. In this circuit there is a calculation for fuzzy logic that will determine the status of the packet receiving box. The box lock system circuit is shown in Figure 4.

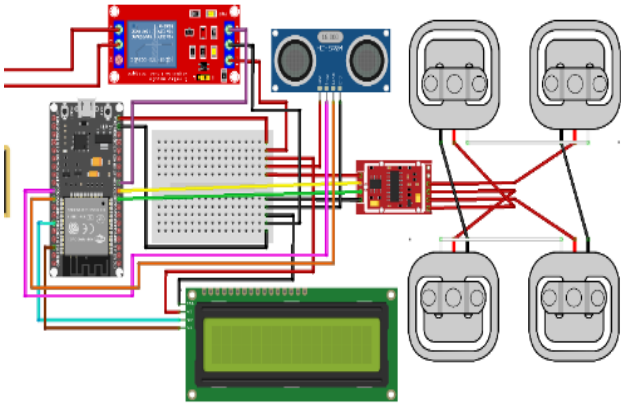

Figure 4. Box Locking System Circuit

The third system circuit is a circuit for password input. This circuit works for couriers if the QR Code on the package to be entered is not legible. In this circuit there is an ESP8266 as a microcontroller and a keypad for password input that will open the door of the package receiver box. The picture of the series of input passwords is shown in Figure 5.

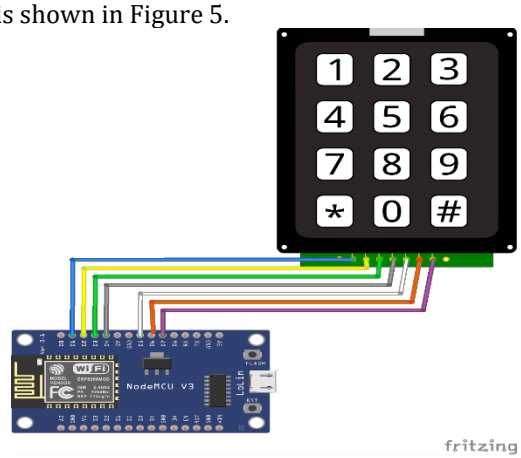

Figure 5. Input Password Circuit

RESULTS AND DISCUSSION

The research results section contains exposure to the results of the analysis related to the research qu

Making this package receiver box system produces a complete device whose all components are connected both hardware and software. This android-based software display has several features such as entering a history receipt number and a description of the status of the contents of the box. In this application there is also a notification feature when the box is full and a notification when a package arrives in the box. The display of the android application can be seen in Figure 6. The

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display of the package receiver box that has been made can be seen in Figure 7.

Figure 6. Package Receiver Box Application

Figure 7. Outside and inside view of the package receiving box

The results of making this package receiving box system were evaluated through several test scenarios, namely testing the entire system including hardware testing, software testing, fuzzy logic testing and database testing. In testing the entire system, it aims to determine the time obtained in one package reception process.

Hardware testing is done by testing the HC-SR04 sensor which is compared with a ruler to determine the accuracy of the distance measuring sensor. The experiments and test results of the HC-SR04 sensor can be seen in Table 3.

Table 3. Ultrasonic Sensor Test Result

Specimens	HC-SR04	Ruler	Difference
1.	20cm	±20cm	0cm
2.	40cm	±40cm	0cm
3.	61cm	±60cm	±1cm
4.	81cm	±80cm	±1cm
5.	100cm	±102 cm	±2cm
Average Error			±0.8cm

Hardware testing is done by testing the HC-SR04 sensor which is compared with a ruler to determine the accuracy of the distance measuring sensor. The experiments and test results of the HC-SR04 sensor can be seen in Table 3.

The next sensor test is a weight sensor which is carried out by measuring weight using test data that have different weights. The results of the tests carried out are in Table 4.

From the tests that have been carried out, the results show that the average error resulting from the measurement of the weight sensor is 32.2 grams. The average error results obtained are no more than 50 grams so that the success parameters are met.

Table 4. Weight/Load Sensor Test Results

Sample	Load Sensor	Original Weight	Difference
1.	130g	130,38g	0,38g
2.	500g	543g	43,79g
3.	550g	572g	22,93g
4.	1000g	1093g	93,20g
5.	5000g	5000,71g	0,71g
Error Average			32,2g

In the system flow the packets to be entered will be scanned through the camera module. In this system use ESP32-Camera as a scanner. Camera module testing is carried out to determine the accuracy and time required to open the package receiving box. The results of the tests that have been carried out can be seen in Table 5.

From the tests that have been carried out by scanning 5 QR Codes, it takes 1-2 seconds for the camera module to recognize the QR Code. The scanning speed of the camera depends on the size of the QR Code, the larger the size of the QR Code on the package, the faster the scanning time and the faster data transmission time to Firebase, and vice versa, the smaller the QR Code size on the package, the longer the scanning time and sending data to Firebase.

This test has 1 test item, namely processing the data obtained from the ultrasonic sensor and weight sensor with Fuzzy logic with the success parameter, namely getting the appropriate output results between the system to be made with Matlab references with the Mamdani Fuzzy logic algorithm.

The results of this test can be seen in Figures 8 and 9.

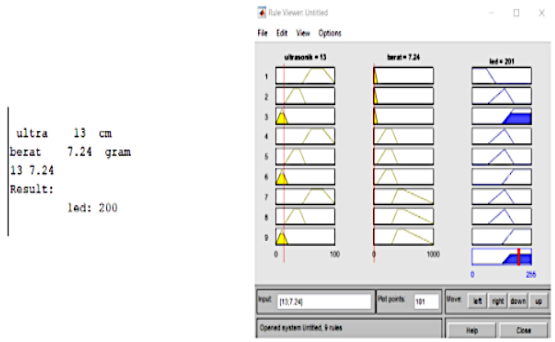


Figure 8. Fuzzy Logics Testing (1)

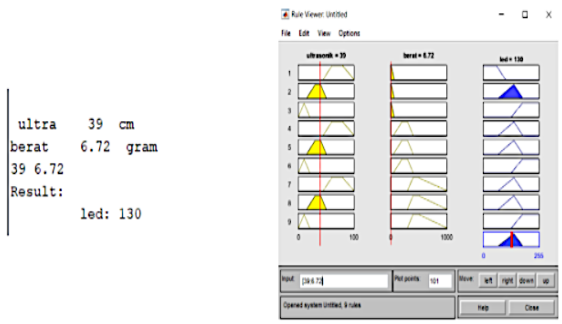
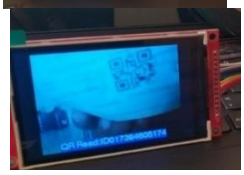


Figure 9. Fuzzy Logics Testing (2)

Table 5. ESP32-Camera Test Results

No.	Sizes	Object Display	Scanner	Result	Times
1.	1x1 cm			Failed	-
2.	2x2 cm			Success	±2s
3.	3x3 cm			Success	±1s
4.	4x4 cm			Success	±1s
5.	5x5 cm			Success	±1s

In Figure 8, with input data, the distance of the ultrasonic sensor reading to the top surface of the item is 13 grams and the package weight is 7.24 grams, the result is that the LED output reading is 200, the LED lights up brightly and it means the box is in full condition. In Figure 9, the ultrasonic sensor reading distance to the top surface of the item is 39 cm and the package weight is 6.72 gr, the reading result is LED 130, meaning the box is in a state of contents (half full). More details related to fuzzy test results compared between system and MATLAB output values can be seen in table 6.

Table 6. Fuzzy Value Measurement Results

Input		Output Value System	Output Value (*Mat-lab)	Difference	Descript-ion
Weight (gr)	Distance (cm)				
6.52	32	120	120	0	Full Package
5.94	14	200	202	2	Full Package
252.9	45	101	120	19	Package Available
513.68	98	0	120	120	Empty Package

With the results that have been obtained from fuzzy logic calculations on the tool and fuzzy logic in MATLAB there is 1 data that has the most difference, if the input distance is 120cm then the system calculation on the tool will experience an error.

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CONCLUSION

Based on the results of the research that has been done, it can be concluded that the development of an IoT-based package receiving system went well after going through a series of tests. In the process of opening the box door, a QR-Code scan is used using the ESP32-Cam camera module which can be scanned in ±2 seconds. The keypad can be used as a door opener when the QR Code cannot be scanned (damaged). The Android-based mobile application can be used to monitor incoming packets, box status, history, and can enter the package receipt number that will be received by the box. In the process of processing data in firebase, it takes ±3 seconds. The status of the box can be determined using Fuzzy Mamdani logic. In addition, in one packet reception process, the system has 11 seconds per packet, which is enough time to replace the role of the packet recipient.

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