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Research Original Article

Design and Construction of a Plastic Bottle Waste Collector Integrated with a Microcontroller-Based IoT System

M. Furqan✉[1], Misbahul Jannah[2], Taufiq[3], Salahuddin[4], Dedi Fariadi[5]
[1]Electrical Engineering Study Program, Universitas Malikusaleh, Aceh, Indonesia, furqan.190150044@mhs.unimal.ac.id
[2]Electrical Engineering Study Program, Universitas Malikusaleh, Aceh, Indonesia, mjannah@unimal.ac.id
[3]Electrical Engineering Study Program, Universitas Malikusaleh, Aceh, Indonesia, taufiq.te@unimal.ac.id
[4]Electrical Engineering Study Program, Universitas Malikusaleh, Aceh, Indonesia, salahuddin@unimal.ac.id
[5]Electrical Engineering Study Program, Universitas Malikusaleh, Aceh, Indonesia, dedifariadi@unimal.ac.id
✉Corresponding Author: **furqan.190150044@mhs.unimal.ac.id | Phone: +6285296305804**

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Abstract
Automatic garbage cans use ultrasonic sensors to automate manual garbage cans to make it easier for people to dispose of garbage and increase awareness of environmental cleanliness. Automatic bins using ultrasonic sensors are controlled via microcontrollers. In the design of Plastic Bottle Waste Collection Equipment Integrated with a Microcontroller-Based IoT System, several stages of research were carried out: literature study, system design and implementation, and system testing. The process of Plastic Bottle Waste Collection Equipment Integrated with a Microcontroller-Based IoT System is that when a person puts plastic bottle waste into the plastic bottle waste collection device, the load cell will weigh the weight of the bottle waste. Next, the data is processed by Arduino Uno, and then I press the push button to print the generated data. Press the push button II to drop the plastic bottle waste into the garbage bin. From the results of testing the weight of plastic bottle waste using a load cell, it can be concluded that it works well. And the difference in the accuracy of the weight of plastic bottle waste using a load cell with a digital scale of 0.01 > 0.05 Kg.
Keywords: Automatic Trash Can, Plastic Bottle, Load Cell, Ultrasonic

Introduction
Waste is a crucial issue around the world, including in Indonesia, because it can cause environmental pollution that can potentially threaten the surrounding community. The impact includes establishing mosquito breeding grounds and spreading diseases such as malaria and dengue fever due to the accumulation of garbage (Dzul, n.d.). According to data from the Ministry of Environment and Forestry (MoEF), the average waste production in Indonesia reaches 175,000 tons per day or 64 million tons per year (MoEF, 2019).

Novrizal Tahar, Director of Waste Management of the Ministry of Environment and Forestry, stated that public awareness of waste management is still low in Indonesia. Data from the Central Statistics Agency in 2018 showed that 72% of Indonesians do not pay attention to waste management, with the indifference index reaching 0.72. This waste problem is caused by people's behavior, culture, and habits. Novrizal emphasized that the role of local governments in overcoming this problem is still far from ideal (Fernandez, 2019).

Law Number 18 of 2008 concerning Waste Management and Government Regulation Number 81 of 2012 emphasized the need for a paradigm change in waste management from a collect-transport-disposal model to an approach focusing on waste reduction and handling. This new paradigm views waste as a resource with economic value that can be used for energy, compost, fertilizer, and industrial raw materials. This concept is applied starting from upstream, namely since a product has the potential to become waste, to downstream, when the product has been used and becomes waste, which must then be returned to the environment safely (Nurikah et al., 2022).

Waste reduction efforts aim to involve all levels of society, including the government, the business world, and the general public, in activities to limit waste generation, recycling, and reuse waste, known as the 3R principle (Reduce, Reuse, Recycle) (Putri & Wiwik, 2019). However, the main obstacle is the lack of public awareness of sorting waste.

Waste collection plays an important role in Government Regulation Number 81 of 2012, which regulates the obligation of producers to carry out 3R activities (Wibowo & Jundiani, 2023). The Waste Bank allows producers to cooperate in managing waste by the regulation's mandate. The accumulation of garbage is increasingly a problem, especially plastic waste, which is difficult for microorganisms to decompose. Plastics have replaced traditional materials with their malleable, durable, and market-trend-following properties (Setiarto, 2020). Therefore, handling plastic waste, especially plastic bottles, is crucial.

Therefore, researchers have designed a tool to overcome this problem. The tool discussed here is the Design and Construction of Plastic Bottle Waste Collectors Integrated with Microcontroller-Based IoT (Internet of Things) Systems. This tool is designed to solve various challenges simultaneously, making collecting plastic bottle waste easier. It is equipped with smart sensors that can detect the presence and number of plastic bottles that enter. These sensors are connected to microcontrollers to control the device's operation and send data to the IoT platform. When the amount of garbage reaches a certain limit, this tool will automatically send a notification to the waste manager to be collected.

Using an IoT platform, data on the amount and type of waste collected can be tracked in real-time. This allows waste managers to plan waste management strategies more effectively and efficiently. Additionally, IoT connectivity allows users of the tool to monitor their contribution to waste reduction, encouraging public awareness and participation in waste management efforts. In addition, the tool is equipped with machine learning features that help identify patterns of waste usage behavior. This data can be used to optimize waste collection routes, reducing the time and cost required. Thanks to the intelligent combination of sensor technology, microcontrollers, and IoT connectivity, this plastic bottle waste collection tool not only represents innovation in waste management but also becomes a real example of how to utilize its technology to create sustainable, environmentally friendly products so that the existence of this tool is an effort to help the government overcome the accumulation of plastic bottle waste.

Literature Review

1. Plastic Bottle Waste

Plastic bottle waste left over from human activities that have been used is called plastic bottle waste. This waste directly results from complex human activities throughout the day, from waking up to going back to sleep. Waste income is a natural consequence of people's lifestyles. Lack of waste management can seriously impact the environment, including air and soil pollution and even flood risk (Arum et al., 2019).

2. IOT (Internet of Things)

The term Internet of Things (IoT) refers to various Gadgets and innovations that empower cooperation between Gadgets and Cloud and between Gadgets. With Microchip's advanced and high broadcast communication transfer speeds, we currently have billions of gadgets connected to the web. This means that ordinary devices such as toothbrushes, vacuum cleaners, vehicles, and machines can utilize sensors to collect information and provide intelligent reactions to clients. Everything is put into the internet network by the Internet of Things (IoT) (Yudhanto & Azis, 2019).

3. Bot Telegram

Web bots, commonly called web robots, are mechanical programming applications that work over the web. These bots generally complete basic and organized commands but are more complex than normal humans (Suharjo & others, 2020). However, Message bots differ, especially regarding the Programming interface (Application Programming Interaction Points).

4. Arduino Uno

Board is a Dfrobot product that is indistinguishable from Arduino Uno, with the fundamental difference being the USB chronic converter. The Arduino Uno uses an ATMega328 microcontroller that is given a wiring-based programming language derived from linguistic structures and libraries (Hasibuan et al., 2023). Although these cable-writing computer programs are generally like C/C++, they are simplified and changed to simplify application development (Hasibuan et al., 2021).

5. Motor DC

A DC engine is an electrical machine requiring direct current (DC) to work. In these machines, the direct current is converted into mechanical energy, which generally appears as a revolution or development. There is a coil inside the DC motor that rotates the device. The quantity of transformation the DC engine produces is communicated in RPM (Cycles Every Moment). For example, DC engines generally produce spin at speeds ranging from 3000 to 8000 RPM. The functional voltage of a DC engine typically ranges from 1.5 to 3 volts (Firmansyah & Marniati, 2017).

6. Thermal Printer

A thermal printer is a printing device that harnesses intensity to transmit text or images on paper. How it works Printer Thermal Among other things is a roll of paper, where the roll is taken and becomes dull if heated (Fitrianto, 2021). Unlike other types of printers, Printer Thermal No ink or toner is required, thus reducing maintenance costs. Another advantage is that this printer is quieter than Dotmatrix or Inkjet printers.

7. Pust Button

Push or push buttons are simple switch mechanisms that control various aspects of a particular machine or process. Push buttons are generally made of hard materials such as plastic or metal. The surface is designed to be flat or shaped in such a way as to facilitate pressing or pushing by human fingers or hands. The Thrust button often functions as a triggerable switch. However, some non-triggerable buttons (due to their physical nature) still require a spring to return to the starting position after being pressed (AKRAMULLAH, 2017).

8. LCD 16X2

According to Heri Andrianto and Aan Darmawan, the 16 x 2 LCD storefront uses liquid precious stone material and is made with a grid frame. The 16 x 2 LCD is equipped to display 32 characters separated into two lines, where each line can display 16 characters (Royhan, 2018), (Nasution et al., 2018).

9. Power Supply

A power supply is a device that is the primary supplier of DC voltage for CNC processing, including as a hotspot power for stepper and shaft machines. The primary capability of a power supply is to convert the voltage from rotary current to coordinate current. The power supply is trusted to keep the power produced consistent, thus providing the ideal power supply to the engine and shaft. Direct current power supply terminals have a voltage of 24 volts DC and a certain electric current (Fathulrohman & Saepulloh, 2019).

10. Sensor Load Cell

The load cell is a transducer device that produces an output proportional to the load or force applied. Its function is to provide accurate measurements of forces and loads. Load cell It is used to convert the strain on metals into varying resistances. This is done through mechanical adjustments that capture deformations in the strain gauge (Hidayat, 2021).

11. WeMos

WeMos The D1 mini based on ESP8266 is a WiFi-based development board that can be programmed with Arduino IDE software, similar to NodeMCU (AZZIZI & others, 2022). One of the advantages of WeMos The small D1 compared to other ESP8266-based upgrade sheets is the presence of a safety module to help install and play the equipment.

12. Step Down Module

The LM2596 DC voltage drop or drop module can handle the difference between the required and accessible voltage. Generally, when planning an electronic circuit or microcontroller module, there is a functional voltage difference between the modules, requiring a controller module to change the voltage. This LM2596 DC to DC voltage reduction module can help reduce voltage to a lower level, depending on the situation (Salma Ashila, 2021).

13. Ultrasonic Sensor

Ultrasonic sensors work using ultrasonic waves, which are mainly used to distinguish the existence of an object by assessing the distance between the sensor and the object. These sensors play a role in converting actual signs, such as sound waves, into electrical signs and vice versa. These ultrasonic waves have a frequency of about 20,000 Hz, beyond the range of human hearing (Giyartono & Kresnha, 2015).

Materials & Methods

1. Literature Studies

First of all, the initial stage of this research involves searching for literature relevant to the research. This research focuses on developing plastic bottle waste collection devices integrated with microcontroller-based IoT systems, using weight sensors, microcontrollers, and LCD screens to display bottle price and weight information. This tool highlights the advantages of ease of use and accuracy and can increase efficiency in exchanging plastic waste bottles for money.

2. Hardware Design

The garbage ATM that has been made requires a place to store programs to run using a microcontroller. In this design, the Arduino Uno is used as the main microcontroller or processing unit to run this tool's system. The Arduino Uno was chosen because of its simple and practical shape and use, which does not require special skills. Details of the microcontroller design can be found in Figure 1 below:

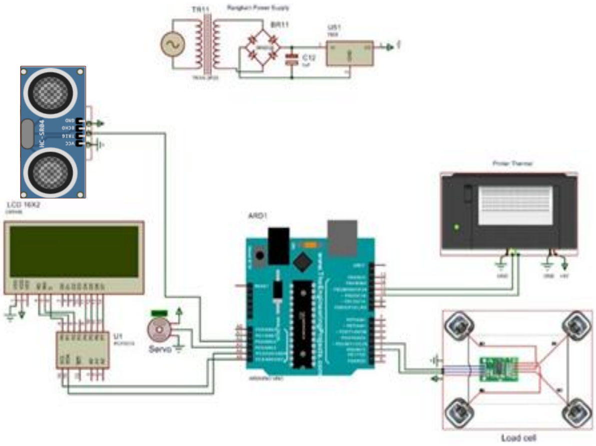

Figure 1. Hardware design

3. Software Design

Arduino IDE is a software used to develop and upload programs to the Arduino microcontroller board. It is an open-source software available for free through the Arduino website. In the context of its use for plastic bottle waste collection devices integrated with microcontroller-based IoT systems, the Arduino IDE is used to write programs that regulate payments based on the weight of plastic bottles put into the container. This program will later generate a paper slip through a thermal printer showing the price to be paid. The following is the program flowchart that has been created in Figure 2 below:

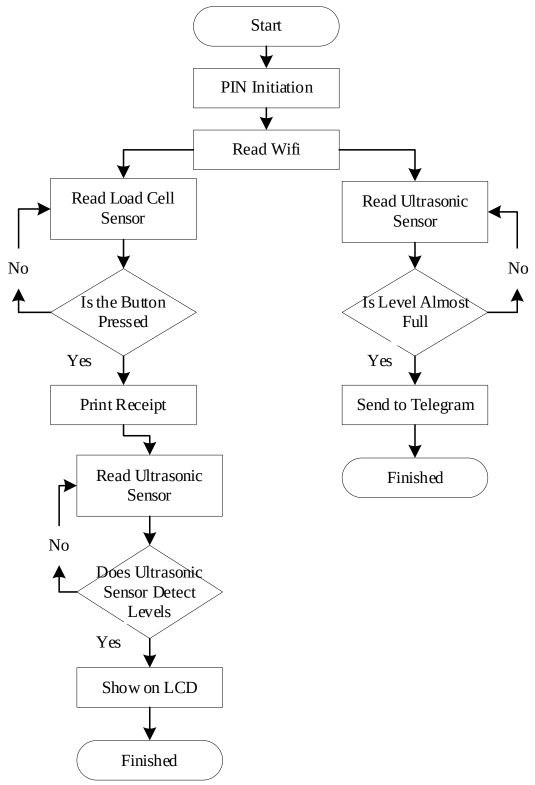

Figure 2. Program flowchart

4. System Implementation and Box Framework

The implementation process of an Arduino Uno-based microcontroller system that connects one component to another is as follows:

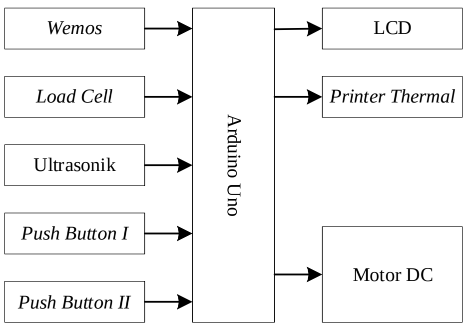

Figure 3. Block diagram

The Internet of Things (IoT)-based waste ATM is designed with the overall size of this plastic bottle waste ATM with a length of 52 cm, a width of 39 cm, and a height of 120 cm. The frame of this box has two different shapes.

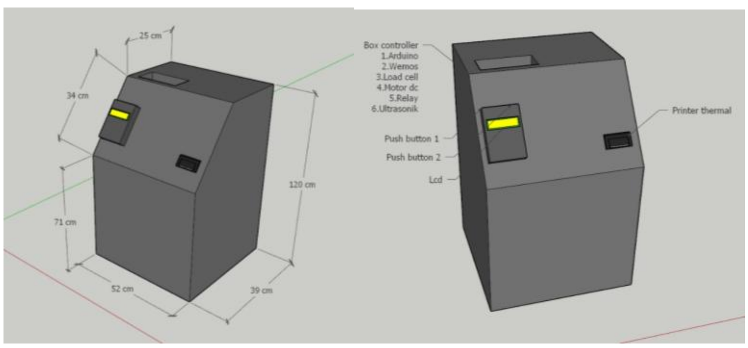

Figure 4. Box frame

5. System Testing

The testing carried out here ensures that all components run correctly and that the readings tested by the weighing machine are based on the program that has been made. If the tool is declared to have failed to operate, then we go back to the initial step of making the tool, which is to reassemble the failed tool so that it can operate. Moreover, adequate power is needed for each component installed to operate this plastic bottle waste collection device. This aims to ensure that the performance of this plastic bottle waste collection device can run optimally. The calculation of the power used in the appliance can be calculated using the following equation:

$$P = V.I \tag{1}$$

Description:
P = Power (VA)
V = Voltage (V)
I = Current (A)

Results and Discussion

1. Results of Tool Design

The plastic bottle holder integrated with the microcontroller-based IoT system is designed to resemble as much as possible with the initial design. The main structure of this tool is plywood or plywood material. The tool comprises a main frame, a plastic waste weight counting module, and a control box. An overview of the actual design results can be seen in Figure 5.

Figure 5. Tool design

Moreover, to run this plastic bottle waste collection device, an adequate power supply is needed for each component that has been installed. This step aims to ensure that the performance of the plastic bottle waste collection device runs optimally. The total calculation of power usage based on equation 1 on the plastic waste bottle storage device resulted from 0.753 W.

2. Tool Test Results

The tests carried out were a comparison of weight accuracy using a load cell with a digital scale, a comparison of the accuracy of the size using ultrasound with a bar, and a test of the weight of plastic bottle waste from 0.2 Kg to 1.2 Kg.

Table 1. Weight accuracy comparison

Testing	Load cell (Kg)	Digital scales (Kg)	Difference	Error %
Experiment 1	0,1	0,1	0	0
Experiment 2	0,3	0,33	0,03	0,1
Experiment 3	0,7	0,7	0	0
Experiment 4	0,8	0,81	0,01	0,012
Experiment 5	0.9	0,95	0,05	0,055
Experiment 6	1,02	1,02	0	0
Experiment 7	1,10	1,11	0,01	0,009
Experiment 8	1,15	1,16	0,01	0,0086
Experiment 9	1,20	1,21	0,01	0,0083
Experiment 10	1,25	1,24	0,01	0,008
Experiment 11	1,30	1,30	0	0
Experiment 12	1,35	1,34	0,01	0,0074

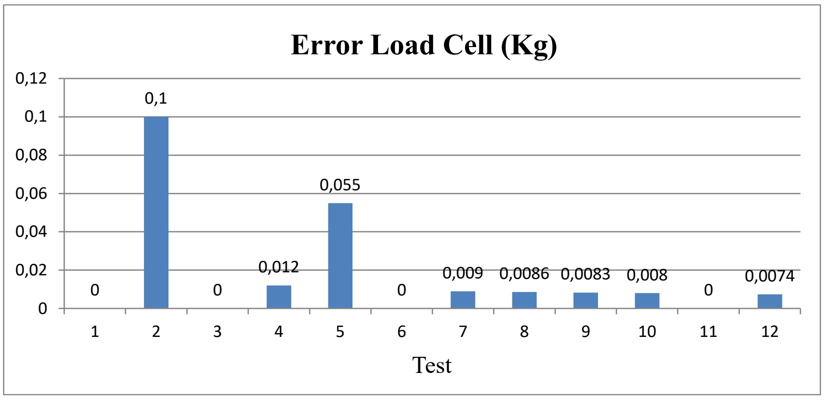

Figure 6. Error graph on load cells

Figure 6 shows that the difference in the weight of plastic bottle waste using a load cell is not as accurate as using a digital scale; the difference in value is 0.01 > 0.05 Kg.

Table 2. Comparison of volume measurement using ultrasound with barricades

Testing	Ultrasonic (cm)	Bar (cm)	Difference	Error %
Experiment 1	1	0,5	0,5	0,5
Experiment 2	3	3	0	0
Experiment 3	4	3,8	0,2	0,05
Experiment 4	5	5	0	0
Experiment 5	10	10	0	0
Experiment 6	15	14,7	0,3	0,02
Experiment 7	20	20	0	0
Experiment 8	22	22,8	0,8	0,03

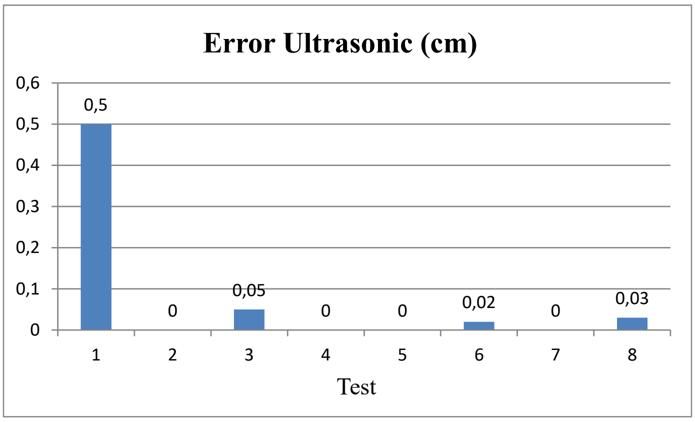

Figure 7. Error values on ultrasonic sensors

From Figure 7, it can be seen that the comparison of the accuracy of measuring the volume of garbage cans using ultrasonic sensors is not as accurate as using a bar. The difference in values is 0.2 > 0.8 cm.

Table 3. Plastic waste weight testing

Customer ID	Time	Weight (Kg)	Price (Rp)	Receipt status
001	20.30/22-10-2023	0,2	200	In Print
002	20.32/22-10-2023	0,4	400	In Print
003	20.34/22-10-2023	0,8	800	In Print
004	20.36/22-10-2023	0,7	700	In Print
005	20.38/22-10-2023	0,5	500	In Print
006	20.40/22-10-2023	0,9	900	In Print
007	20.45/22-10-2023	1,0	1000	In Print
008	20.50/22-10-2023	1,1	1100	In Print
009	20.53/22-10-2023	1,2	1200	In Print

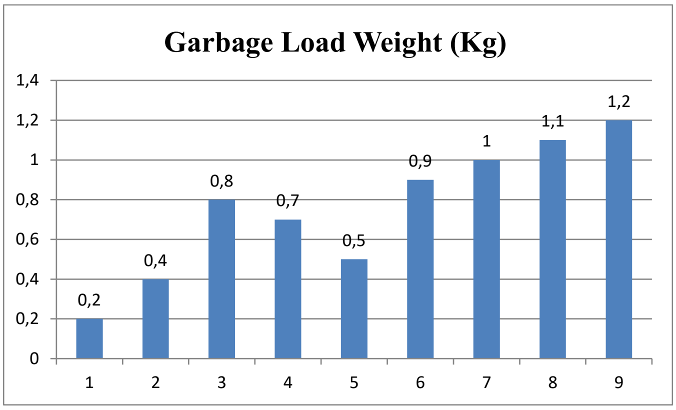

Figure 8. Garbage weight graph (Kg)

Figure 9. Price amount chart

Figures 8 and 9 show that some tests carried out by several customers with different weights of plastic waste can show that the price of 0.1 Kg is 100.00 (Rp). From customer ID 001, plastic waste weight 0.2 Kg at the cost of Rp.200.00 with the receipt status on the print, customer ID 002, plastic waste weight 0.4 Kg at the cost of Rp.400.00 with the receipt status on the print, customer ID 003 plastic waste weight 0.8 Kg at the cost of Rp.800.00 with the receipt status on the print, customer ID 004 plastic waste weight 0.7 Kg with a cost of Rp.700, 00 with the status of the receipt in print, customer ID 005 weight of plastic waste 0.5 Kg at the cost of Rp.500.00 with the status of receipt in print, customer ID 006 weight of plastic waste 0.9 Kg at the cost of Rp.900.00 with the status of receipt in print, customer ID 007 weight of plastic waste 1 Kg at the cost of Rp.1000.00 with the status of receipt in print, Customer ID 008 plastic waste weight 1.1 Kg at a cost of Rp.1100.00 with receipt status on print, Customer ID 009 plastic waste weight 1.2 Kg at a cost of Rp.1200.00 with receipt status on print.

3. Program Testing

The results of the software test can be seen in Figure 10.

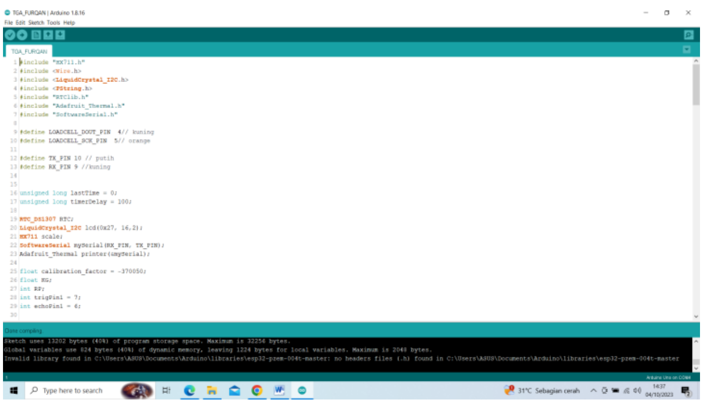

Figure 10. Running program testing

Based on Figure 10 and the program's running, it is known that the program that has been designed is the desired one, and there are no errors. Programming this tool uses C language through the Arduino IDE application. Programming is designed according to the needs of tools and references of several journals. We can monitor the volume of the garbage can by sending a message/check in the automatic telegram application; the telegram bot will notify the level of waste. Plastic bottle waste collection equipment integrated with a microcontroller-based iot system will notify us when the volume of the garbage bin is almost complete.

Conclusions

Based on the findings of the research on plastic bottle waste collection devices integrated with microcontroller-based IoT systems, the following conclusions can be drawn:

1. The process of a plastic bottle waste collection device integrated with a microcontroller-based IoT system is as follows: when someone puts plastic bottle waste into a plastic bottle waste collection device, the load cell will measure the weight of the bottle waste. After that, the Arduino Uno processes the data, and the user can press the I button to print the generated data. Button II is used to drop plastic bottle waste into the garbage bin.
2. The results of testing the weight of plastic bottle waste using a load cell show that the tool works well. The difference in the accuracy of the weight of plastic bottle waste using a load cell with a digital scale is 0.01 > 0.05 Kg.

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