Residential Trash Container Automation Alternatives

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Abstract

The process and organization of garbage collection in metropolitan cities is inefficient for the current requirements. Which has brought problems such as pollution, crime and bad appearance and consequently a tendency to develop a bad habit by the population. This article provides two alternative solutions for the automation of the garbage container by means of the NodeMCU and Raspberry Pi board with the help of ultrasound sensors, photovoltaic system, and instant messaging (Telegram). As a result, it allowed the municipality to know when the right time is to pick up the garbage in the residential. The SUS instrument was used as validation, which gave us a result of 80% and 75% in terms of usability and feasibility.

Keywords

IoT, NodeMCU, Garbage Container, Photovoltaic System, Mobile Application

1. Introduction

Technological advances such as the Internet of Things have been proven to improve the quality of life of human beings [1]. This paradigm includes a set of sensors, microcontrollers, communication technologies, and protocols that allow us to create connected solutions in an automated way, giving us the possibility to monitor [2] or execute actions without the need for human intervention [3]. These proposals are increasingly used in different essential areas such as health [4], government, homes [5], among others. Continuously searching for those problems with the highest impact, such as those that prevent us from guaranteeing the health of people and the environment, as is the case of poor solid waste management [6].

Recently, population growth as well as current production and consumption habits have resulted in an impressive increase in the generation of solid waste. This has resulted in an overload of the often-scarce public cleaning services, due to the lack of infrastructure and unsustainable practices that have resulted in the deterioration of waste management and ultimately lead to environmental contamination [7]. In countries such as Peru, since containers

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are often filled beyond their capacity. There are frequent daily accumulations of garbage in public places, which represent infectious foci with high health risks for people with consequences such as the transmission of bacterial and parasitic diseases, skin infections and chronic diseases, as well as being a significant problem for the environment [8]. This allows us to conclude that environmental and sanitary problems are related to poor waste management [9], because even in many residential areas of the country, they have a traditional service that operates on a single schedule and does not provide adequate monitoring. Based on the problems presented above, this paper shows an effective and efficient IoT-based solid waste management system that allows the identification, tracking, and monitoring of garbage levels in containers in residential areas to be emptied in a timely manner.

2. Motivation and background

One of the most essential services, especially when it comes to urban areas is solid waste management services. In 2016, according to the World Bank, the world's cities generated 2.01 billion tons of solid waste, which was a footprint of 740 g. per person per day. However, due to immense population growth, an increase in waste generation of 70% has been predicted, resulting in the generation of more than 3400 million tons by 2050 [10]. It is even more worrisome considering that in countries such as Peru, only in urban areas, more than 7 million tons of solid waste are generated annually [11], i.e., about 20,000 tons per day and an average of 1000 tons per hour.

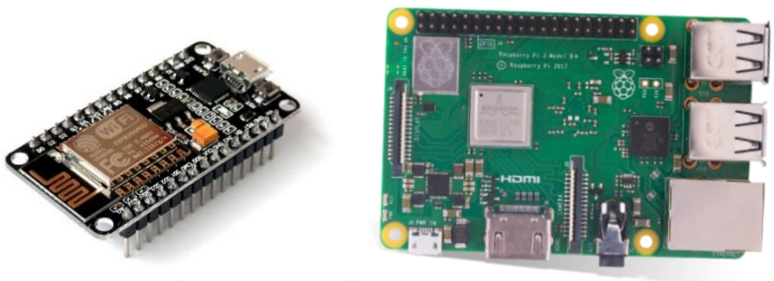
Currently, solid waste is managed using garbage containers, which are cleaned 1 to 3 times per week depending on the area; however, their inadequate management leads to the following problems [12]:

- On occasions the containers are almost empty generating waste of time, fuel and manpower.
- When the containers exceed their capacity, which results in people leaving their garbage on top or on the sides, there is a risk of starting an infectious pole, which causes diseases and consequently increases the number of dogs or other stray animals that open the garbage bags and spread their contents.

As a solution to these problems, the use of the Internet of Things (IoT) [13], [14] is proposed for the construction of an automated container, which will also make use of a photovoltaic system, making it a totally ecological proposal.

3. Garbage container automation

Knowing the problems that exist in garbage containers, two alternative solutions are proposed using the NodeMCU board or the Raspberry Pi with different add-ons to automate the garbage container (see figure 1).



NodeMCU **Raspberry Pi 3 B+**

Figure 1: Alternatives of development boards for automation of garbage containers

a) NodeMCU. - It is a module based on the ESP8266 microcontroller integrated with Wi-Fi [15].
b) Raspberry Pi 3B. - It is a low-cost computer with Linux installed, based on a Broadcom BCM2837B0 microprocessor [15].
c) Home Assistant. - It is a Home Automation System, which runs Linux [16].
d) Adafruit IoT. - It is a system that allows connecting electronic devices to the cloud.
e) Photovoltaic System. - It requires the following equipment [3]:

- Charge controller. - It controls the charge that will be made from our photovoltaic panel to the battery charge, protecting the battery bank from possible surges [17].
- Battery (AGM). -Supply energy to all our control system, has the function of supplying energy collected from the photovoltaic panels.
- Photovoltaic panel. - Generates energy to power the electronic circuits [18].

f) Ultrasonic sensor (mic-340/D/M). - These are proximity detectors that work free of mechanical friction and detect objects from a distance. The sensor emits a sound imperceptible to the human ear to calculate the distance. It will be used to know when the dumpster is full or empty [19].
g) Temperature and humidity sensor (DHT11). - Measures the ambient temperature and humidity in the surrounding area [20].
h) Voltage regulator module (Step Down). - It has the function of adjusting the incoming 12V supply voltage to a voltage of 5V.
i) Servomotor (S3003). - Rotary actuator that allows position and speed control of a rotating shaft.
j) Capacitor. - It is a device that stores energy, it allows us to eliminate the bouncing of some sensors and actuators.

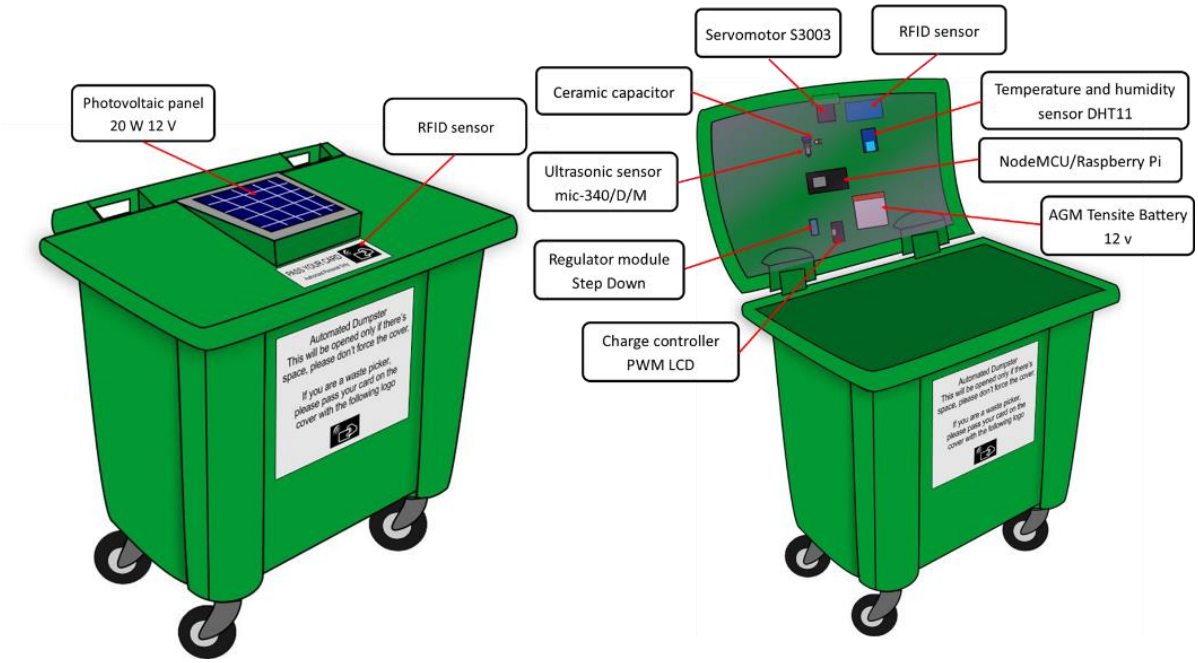


Figure 2. Proposal for the automation of the garbage container

The proposal will start when the system is connected to the power supply to operate with the photovoltaic system. then every time a user wants to open the container the system will check if the container is full or not (see figure 2). If the garbage can is full, the system will close and send

a message to Telegram [21] that it is full and only the cleaning staff can open it with an RFID card or the administrator of the automation platform (Adafruit IO [22] or Home Assistant [16]). When the garbage is emptied from the container again, we start with the first initial step (see Figure 3), where it will allow you to open the garbage container. In case the garbage container can is not yet full the cleaning staff can ask the question and a message will be sent in Telegram indicating the percentage that is full.

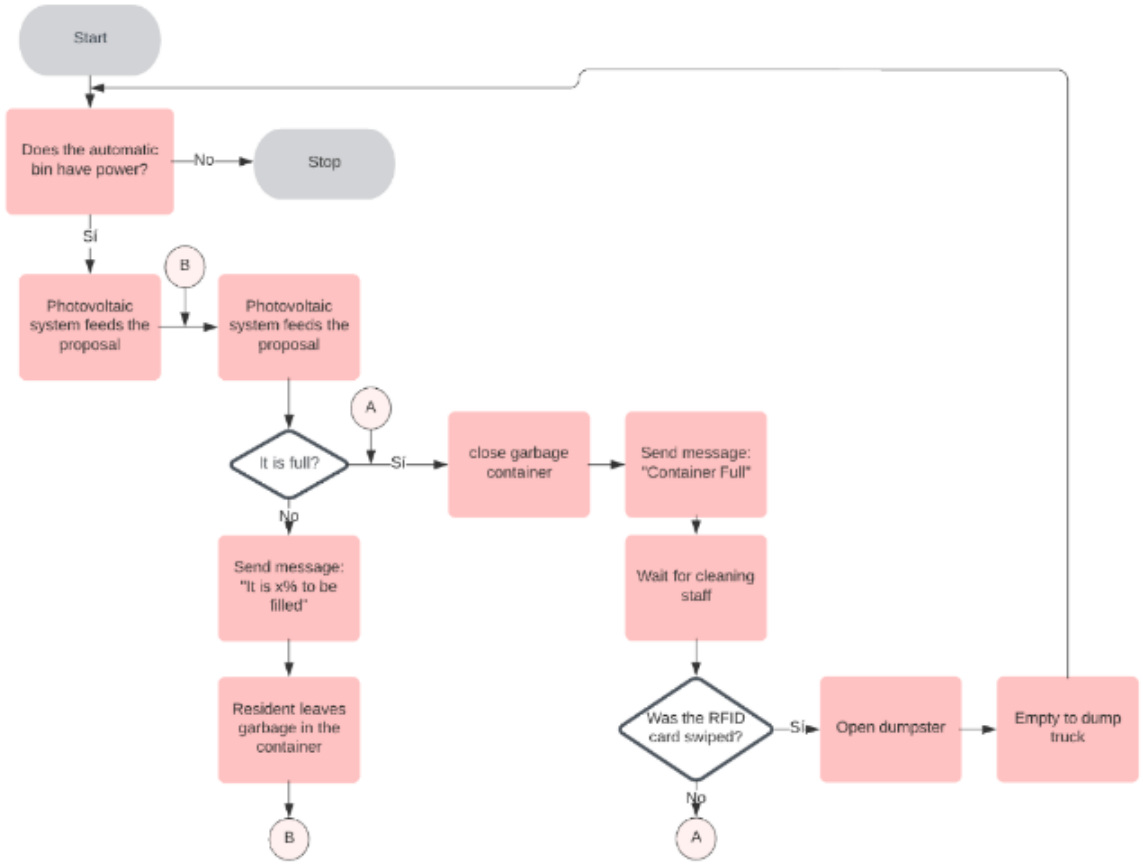


Figure 3. Process Diagram

We present two options that could be used for the automation of the garbage container.

3.1. Option 1: Garbage container with NodeMCU, Adafruit IoT and Telegram

It is necessary to have NodeMCU as the core, this board must communicate with the photovoltaic system (regulator, battery, photovoltaic panel, Step Down), which allows to provide daily electrical energy. To know the temperature of the circuits, a temperature and humidity sensor (DHT11) has been integrated, also a servo motor (S3003 Futaba) has been added to open the door of the garbage container. In addition, to detect the amount of garbage in the container, a precision ultrasonic sensor has been integrated to detect if the container is full (with respective 6.8 nF capacitor). Also, an RFID receiver has been incorporated to allow the cleaning personnel to use it when they want to empty the garbage container (see figure 4).

For the monitoring configuration, the use of the Adafruit IO platform has been incorporated, which through its Dashboard allows integration to the proposed solution [15].

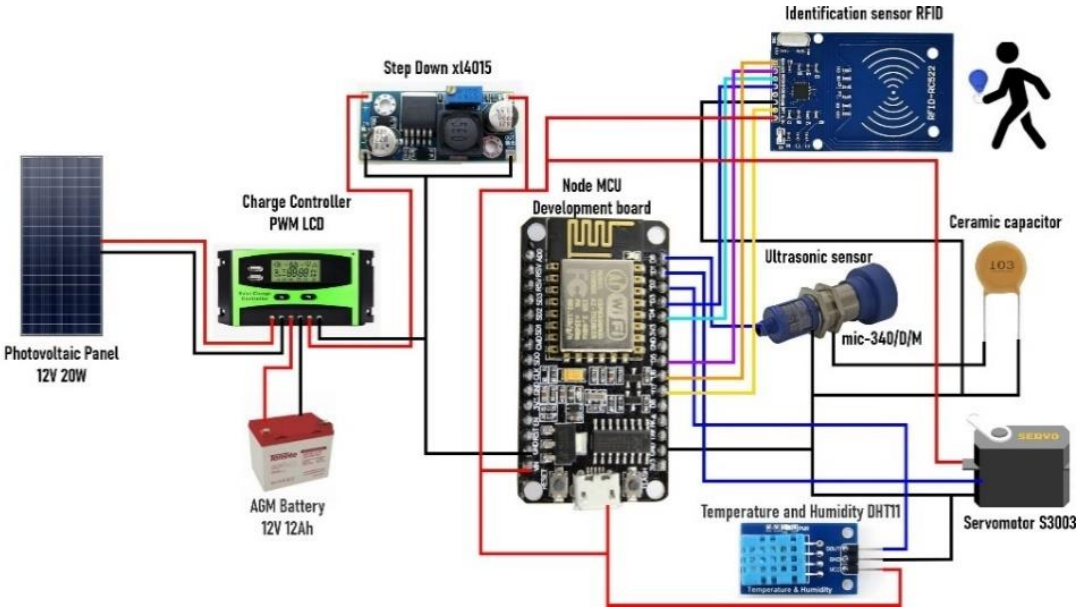


Figure 4. Proposed design with NodeMCU

3.2. Option 2: Garbage container with Raspberry Pi, Home Assistant and Telegram

With the Raspberry Pi board, it is necessary to use the same sensors and actuators of the previous proposal, but now we will be using its GPIO of the Raspberry Pi, to connect the ultrasonic sensor, temperature, and humidity sensor as well as the servomotor (see figure 5).

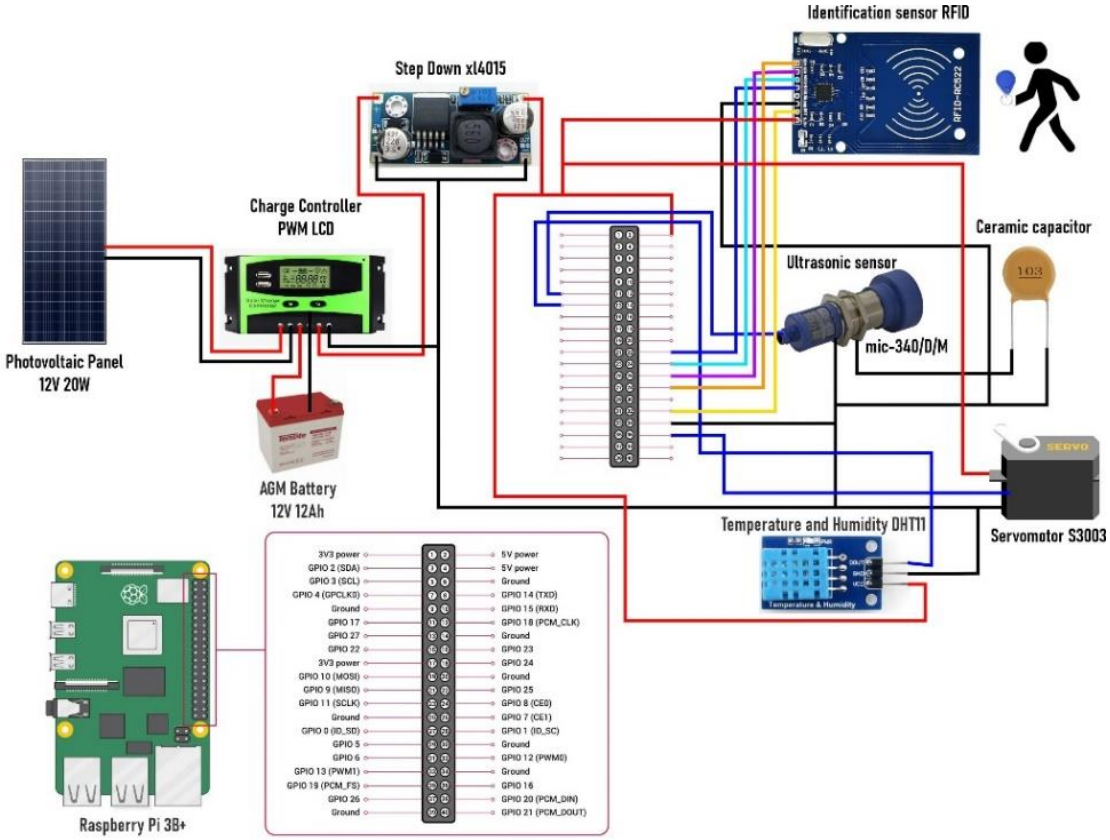


Figure 5. Proposed design with Raspberry Pi 3 B+

For the implementation of the proposal, it is always necessary to place a 6.8 nF capacitor between the servomotor and the ultrasound as recommended by the manufacturer. For the power supply of the whole system is integrated with a photovoltaic system, which includes a 20W photovoltaic panel, a regulator and a 12AH AGM battery. The entire solution will be used to power the automated system. To lower the voltage, a Step Down was required, which will allow powering all the electronic components.

For the configuration, the Home Assistant must be installed on the Raspberry Pi 3 B+ [16], then the switch for each of the garbage containers must be created from the Home Assistant Dashboard. After that, use the Ngrok tool, to have to the Internet a URL that is displayed towards the central of the municipality in charge of the garbage collection [23]. By having the RFID card configured, the garbage cleaning personnel and the security guard of the residential are provided with it, so that every time the garbage truck is present, the cleaning personnel will be able to open the garbage container and perform the garbage emptying procedure.

Finally, for both proposals, the instant messaging system Telegram has been integrated on the NodeMCU board [24] and on the Raspberry Pi [25].

4. Results and discussion

A small functional prototype was made to confirm the operation of the two options mentioned in this article, in addition to showing the reference cost of each option, the comparative and energy consumption of each proposal.

4.1. Option 1: NodeMCU with Telegram and Adafruit IO

Using the Adafruit IO platform allowed us with its dashboard to perform the process of enabling or disabling the dumpster lock (toggle block), as well as having the ability to monitor the container if it is full (Gauge block), also with Telegram instant messaging you can monitor the current status of how is the container from a smartphone, this could be useful for the garbage cleaning staff when performing the process of garbage collection (see figure 6). But there are also some disadvantages of using the Adafruit IoT platform because its free version has some limitations, such as data storage for 30 days and the use of 10 blocks in its dashboard.

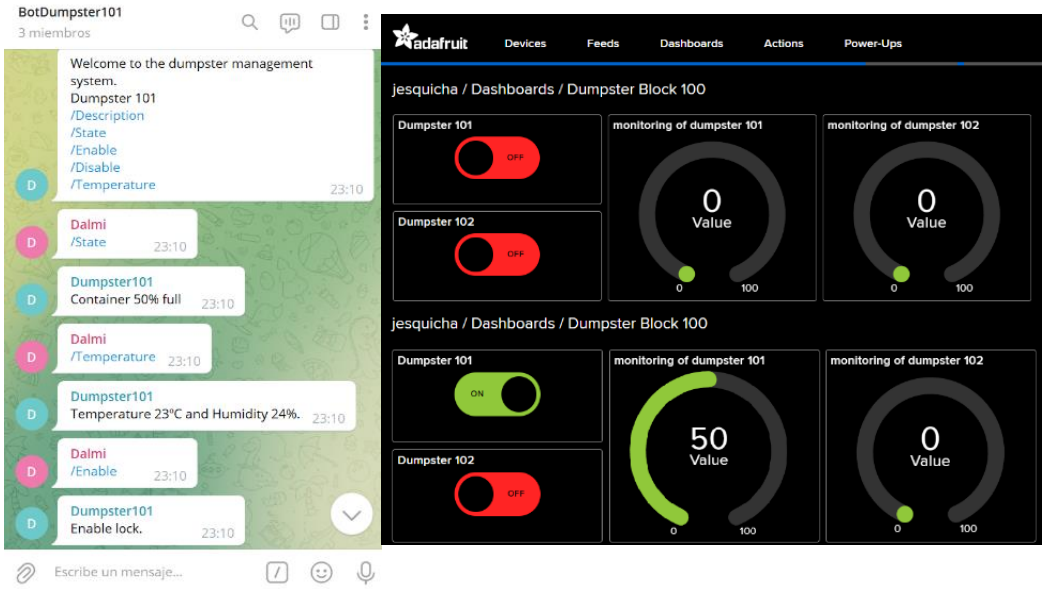


Figure 6. NodeMCU with Telegram and Adafruit IO

4.2. Option 2: Raspberry Pi with Telegram and Home Assistant

The Raspberry Pi board was used to install and configure the Home Assistant system, which allows customization especially for home automation. For this research it was used because of its versatility and the amount of compatible components that are used in this proposal. Also, Telegram instant messaging has been integrated to know the current situation of garbage containers. Like the previous proposal, this last alternative also has disadvantages such as the complexity of the initial customization of the system, since it requires more advanced technical knowledge, in addition when several components are used within the platform it could require many more resources in the system that could generate slowness or instability; but for the proposal it has been analyzed that each dumpster will have an independent Home Assistant system, so it will not have any inconvenience (see figure 7).

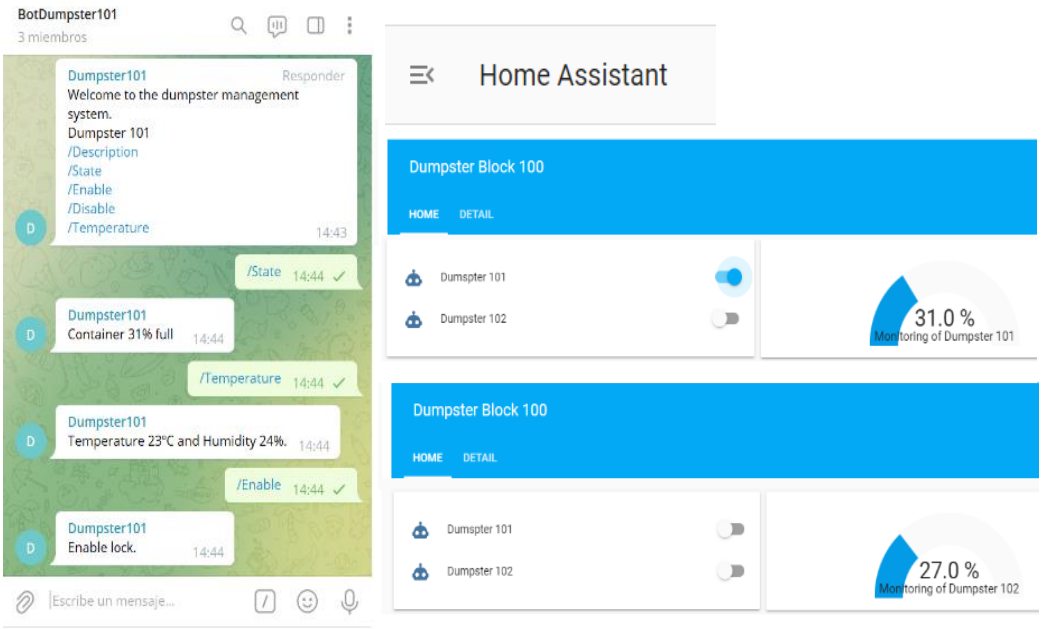


Figure 7. Raspberry Pi with Telegram and Home Assistant

The two proposals present three ways to open the garbage container door: by IoT platforms (Adafruit IoT, Home Assistant), Telegram instant messaging or by using the RFID card. The last option (RFID card) would be used in case the internet communication with the garbage container is lost (see figure 8).

Figure 8. Using RFID card in the dumpster

Table 1 shows the comparative prices (in US Dollars) of the two proposals analyzed in this research, where option 1 is 13% cheaper than option 2, because this option has an Operating System, i.e. it integrates a microprocessor, which will allow better resource management, while the first option only has a microcontroller in its core for sequential operation as programmed.

Table 1
Component price comparison

Components	Price ($) option 1	Price ($) option 2
Total in U.S. Dollars	298.51	344.58

In Table 2, the comparison of the two boards is made, it is concluded that the NodeMCU board is more economical and consumes less electricity in operation, while the Raspberry Pi has better hardware features, in addition to having a better Wi-Fi antenna for wireless data transmission.

Table 2
Comparison between NodeMCU and Raspberry Pi 3B+

Features	NodeMCU	Raspberry Pi 3B+
Price ($)	8.93	55
SoC	-	Broadcom BMC2837BO
CPU	-	1.4Ghz (4 cores)
Input voltage	5v	5v
RAM	64KB	1GB
Wi-Fi	Wi-Fi 802.11 b/g/n	Wi-Fi 802.11 b/g/n/ac
Consumption	90mA	350 mA

Analyzing the power consumption (see Table 3), option 1 consumes 15% less than option 2, since the board integrates a microcontroller, whereas when a board that integrates a microprocessor is used, it requires more power consumption because it has an operating system in operation

Table 3
Comparison of electricity consumption

Option	Amperage (mA)	Voltage (V)	Power (W)	Wh/Day	Wh/Month
1	827 mA	5V	4.1375W	99.3Wh/D	2.98KWh/M
2	1087mA	5V	4.8625W	116.7Wh/D	3.5KWh/M

Finally, to inspect the results, the System Usability Scale (SUS) instrument was used (see figure 9), which allows measuring on a scale between 1 and 100 the experience of usability and user experience in the two proposals, with the result of the sample being 80% and 75% respectively, since these show a higher result than the average of the instrument, meaning that

they are a positive coefficient in terms of its assessment in functionality of both proposals by the population living in an urbanization.

Weighting for each question asked

1. Would you agree with the implementation of automated dumpsters in your residential?
2. Would you be satisfied using the automated garbage container system??
3. Would you use the automatic container system frequently?
4. I find this automated garbage container unnecessarily complex
5. This automated garbage container is easy to use.
6. The functions of this automated garbage container are well integrated.
7. The automatic garbage container is very inconsistent
8. I think most people would learn to use this automated garbage container very quickly.
9. I find this automated garbage container very difficult to use.
10. I feel confident using this automated garbage container.
11. I need to learn before I can use this automated waste garbage container.
12. I think I will need the help of a specialist technician for the use of this automated waste garbage container.
13. Does your residential facility have the necessary security to implement these automated garbage containers?
14. How would you rate the garbage collection service in your municipality?
15. How often does the collection truck pass through your municipality?

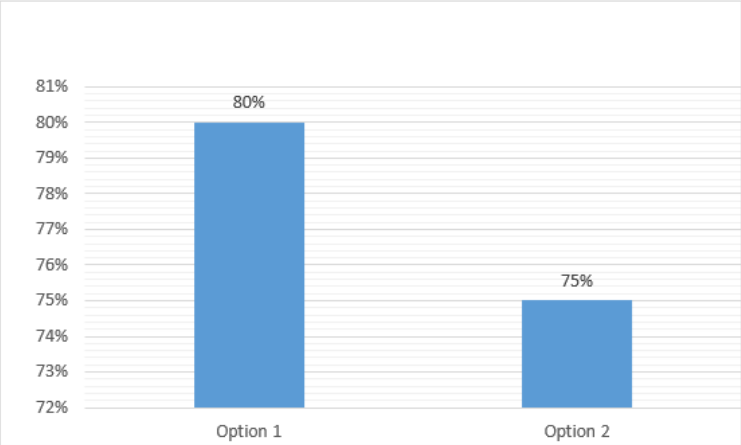


Figure 9. SUS Test Results

5. Conclusion

The two proposals were prototyped for dumpster automation, being the first option the most economical because it allowed us to monitor up to 5 containers from its Adafruit IoT dashboard, while the second option required the Home Assistant system independent for each container, this could be favorable if you need to customize each one with more sensors, actuators or even video surveillance camera, to be visualized by the operator in charge of the municipality. Also, the energy consumption was analyzed, concluding that option 1 consumes less electricity by 15% compared to option 2. Finally, by using the Brooke System Usability Scale (SUS) instrument, the usability tests of both proposals were determined to be satisfactory with 80% and 75%, respectively.

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