DEVELOPMENT OF IOT-BASED OF WASTE MANAGEMENT SYSTEM FOR SMART CITY USING ARDUINO.

SANJUSHREE A/P R.NAGARAJAH

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF IOT-BASED OF WASTE MANAGEMENT SYSTEM FOR SMART CITY USING ARDUINO.

SANJUSHREE A/P R.NAGARAJAH

This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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Disahkan oleh:

DR. JAMIL ABEDALRAHIM JAMIL ALSAYAYDEH
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Elektronik dan Komputer
Fakulti Teknologi Kejuruteraan Elektrik Dan Elektronik
Universiti Teknikal Malaysia Melaka (UTeM)

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Student Name : SANJUSHREE A/P R. NAGARAJAH

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APPROVAL

I hereby declare that I have checked this project report and, in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Computer Engineering Technology (Computer Systems) with Honours.

Signature :

DR. JAMIL ABEDALRAHIM JAMIL ALSAYAYDEH
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Elektronik dan Komputer
Fakulti Teknologi Kejuruteraan Elektrik Dan Elektronik
Universiti Teknikal Malaysia Melaka (UTeM)

Supervisor Name : DR. Jamil Abedalrahim Jamil Alsayaydeh

Date : 25TH JANUARY 2025

Signature :

Co-Supervisor Name (if any) :

Date :

DEDICATION

I would like to dedicate this work to my dearest parents, MR. R. Nagarajah and MRS. Sujata, for their invaluable help and support throughout this project. My deepest gratitude goes to my supervisor, DR. Jamil Abedalrahim Jamil Alsayaydeh, for his expert guidance. Lastly, I want to thank my loved ones, my friends and family members who provided unwavering support and encouragement throughout my entire learning journey.

ABSTRACT

Environmental waste are the main dilemmas in our daily life and in the world at large [1]. Traditional waste management systems often lack real-time monitoring capabilities, leading to inefficiencies in collection routes, increased operational costs, and negative environmental impacts. Globally, the rates of waste production are rising. By 2026, 2.5 billion tons of trash is anticipated to have been produced due to the rapidly increasing population [2]. Managing waste efficiently in smart cities is crucial for maintaining cleanliness and environmental sustainability. This project introduces a smart solution to manage waste better in cities. This project proposes an IoT-enabled solution to address the challenges of waste management in urban areas. By utilizing sensor technology, real-time data monitoring for on time waste collection plan and routes planning with tracking system optimizes waste collection processes and enhances resource utilization. This system includes ultrasonic sensor to measure the fill levels of the bin, temperature, and humidity sensor to monitor and prevent decomposition of the trash, GPS to coordinate collection routes, weight sensor to detect the weight of the bin whether it has reached full limit weight or not and online platform for real-time fill level monitoring. The system can accurately measure the fill levels of waste bin using ultra sonic sensors and transmit data to online platform via WIFI. User-friendly interfaces allow the authorities to monitor waste levels and coordinate collections effectively. The system is expected to give some great results from this project, like better efficiency, cost savings, and less harm to the environment. Based on our previous work, the system can estimate around 80-85% accurately in measuring fill levels and coordinate collection routes. The goal is to create a practical and offer a user-friendly and understandable waste management solution for smart cities, benefiting all users involved making the urban environment cleaner and smarter.

ABSTRAK

Sisa persekitaran adalah dilema utama dalam kehidupan harian kita dan di seluruh dunia. Sistem pengurusan sisa tradisional sering kali kekurangan keupayaan pemantauan masa nyata, menyebabkan ketidakcekapan dalam laluan pengumpulan, peningkatan kos operasi, dan impak negatif terhadap alam sekitar. Secara global, kadar pengeluaran sisa semakin meningkat. Menjelang 2026, dijangka 2.5 bilion tan sampah akan dihasilkan akibat peningkatan populasi yang pesat. Menguruskan sisa dengan cekap di bandar pintar adalah penting untuk mengekalkan kebersihan dan kelestarian alam sekitar. Projek ini memperkenalkan penyelesaian pintar untuk menguruskan sisa dengan lebih baik di bandar. Projek ini mencadangkan penyelesaian yang diaktifkan oleh IoT untuk menangani cabaran pengurusan sisa di kawasan bandar. Dengan menggunakan teknologi sensor, pemantauan data masa nyata untuk pelan pengumpulan sisa yang tepat pada masanya dan perancangan laluan dengan sistem penjejak mengoptimumkan proses pengumpulan sisa dan meningkatkan penggunaan sumber. Sistem ini termasuk sensor ultrasonik untuk mengukur tahap isi padu tong sampah, sensor suhu dan kelembapan untuk memantau dan menghalang penguraian sampah, GPS untuk menyelaras laluan pengumpulan, sensor berat untuk mengesan berat tong sama ada telah mencapai had berat penuh atau tidak dan platform dalam talian untuk pemantauan tahap isi padu masa nyata. Sistem ini boleh mengukur tahap isi padu tong sampah dengan tepat menggunakan sensor ultrasonik dan menghantar data ke platform dalam talian melalui WIFI. Antara muka yang mesra pengguna membolehkan pihak berkuasa memantau tahap sisa dan menyelaras pengumpulan dengan berkesan. Sistem ini dijangka memberikan beberapa hasil yang hebat daripada projek ini, seperti kecekapan yang lebih baik, penjimatan kos, dan kurang kerosakan kepada alam sekitar. Berdasarkan kerja terdahulu kami, sistem ini boleh menganggarkan sekitar 80-85% dengan tepat dalam mengukur tahap isi padu dan menyelaras laluan pengumpulan. Matlamatnya adalah untuk mencipta penyelesaian pengurusan sisa yang praktikal dan menawarkan penyelesaian yang mesra pengguna dan mudah difahami untuk bandar pintar, memberi manfaat kepada semua pengguna yang terlibat, menjadikan persekitaran bandar lebih bersih dan pintar.

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CHAPTER 1

INTRODUCTION

1.1 Background

The rapid growth of cities and the increasing population have created a huge demand for better waste management systems. It's become clear that traditional methods often harm the environment and public health. That's where IoT-based solutions for garbage management come in. Smart waste management systems using Arduino technology are really making a difference when it comes to improving garbage collection and creating a healthier environment for all of us [3], [4], [5]. Advanced technologies like IOT devices, sensors and GPS trackers are incorporated by this system. It includes Arduino Uno, Wi-Fi modules, and online platforms for real time monitoring. With all these IoT sensors working together, they keep a close watch on the levels of trash in the bins in real-time. When the bins are full, they automatically detect it and send alerts to the waste management authorities so they can collect it on time. This data is useful for waste management authorities to help them coordinate waste collection routes and schedules to make the whole process more efficient. Waste management authorities can implement this to make waste management practice more efficient where technology meets sustainability.

We can make waste management systems more efficient by incorporating these smart technologies to keep urban environment cleaner for everyone. A group of researchers have been working on some solutions for managing waste using IoT technology. They've come up with different ideas to make things more efficient and effective solutions for waste management using IoT technology. One example is Parkash Tambare and Prabu Venkatachalam, who developed a budget-friendly device with IR sensors and microcontrollers to monitor the fill levels of garbage bins. This device sends the information to the authorities through the internet, so they know exactly when to swing by and collect the trash [6]. Another example is, Liyakat Kutubuddin and Kazi Kutubuddin, designed a system that can utilize sensors where it is connected to the internet to keep an eye on the fill levels and types of waste in bins [7]. The best route coordination for collecting waste and analyzation of patterns in how waste is generated is determined with the help of this system. The system is all about using technology to make waste management smarter and better for everyone.

Improving waste management systems in Malaysia is a pressing issue. Recent reports reveal that only around 24% of waste gets recycled, while the rest ends up in landfills. Implementing waste management systems based on IoT brings a lot of benefits. Plus, proactive management prevents overflows, saving us from cleanup expenses and potential public health problems. Other than that, it also helps reduce litter making our environment cleaner and greener. Based on health, preventing waste accumulation also plays a role in curbing the spread of diseases. As cities continue to grow, the demand for smart waste management solutions will only increase since the system improves collection schedules and benefits the users regarding waste generation. This not only benefits the environment but also enhances public health. It's a smart move keeps the cities clean and reduces health risk.

Thus, using IoT-based waste management systems is a big step forward for cities. It is sustainable, offering smart solution to the waste problems that trouble urban areas. This system not only makes our surroundings cleaner but also has a positive impact on our quality of life. It's important to protect the environment from waste and pollution for public health, enhancing the aesthetic character of cites, attracting tourists and to protect society from environmental disasters [1]. By doing so, cities become cleaner, smarter, and safer places to live in.

1.2 Problem Statement

The reason we need to develop a waste management solution for smart cities that use IoT technology is because traditional methods have their fair share of problems. IoT technology allows us to collect and sort data, sense what's going on, and process all that information by connecting physical gadgets to the internet [8]. Traditional waste management systems often suffer from inefficiencies. They lack real-time monitoring and have poor route planning for garbage collection. By installing advanced technology such as GPS tracking and ultrasonic sensors to measure how full waste bins are, we can make waste management way more efficient and sustainable with real-time monitoring and smarter route planning. Waste collection trucks can take the smart and efficiently coordinate the routes. This can be an advantage to the environment. We can supercharge waste management operations and make them way more efficient and sustainable by embracing IOT technology.

Moreover, the traditional ways of managing with waste often forget to keep an eye on the temperature and humidity levels in trash bins in real time If we overlook it, the situation could end up with some serious issues like too much moisture buildup where the conditions can speed up the decomposition of waste, which leads to health risks. By using IoT-enabled sensors, which is DHT 11 sensor to monitor the temperature and humidity in trash bins, it can detect any dangerous situations right away and send out quick alerts through real time. We are able to lower the health risks that come with waste decomposition using this proactive approach. The environment also can get protected, and an eco-friendlier urban environment is created.

Additionally, in a lot of cities, the regular trash systems can't handle all the overflowing bins. It's a real trouble because it leads to more litter and even cause health risks for the public. When those bins start overflowing, they become like a breeding ground for diseases and pests, making the place look really messy. It's not good for the quality of life in urban areas. One of the big problems is that there's no way for waste management workers to know in real-time when the bins are getting too full. So, things just keep piling up, and it's tough to fix the problem quickly. By using IoT sensors, the fill levels and conditions of the bins can be monitored. And when they reach their capacity, it gives alert to the waste management operators, letting them know it's time to collect the garbage. This helps to keep cities clean and healthy. By preventing overflow and integrating this data into a centralized waste management system, we can plan better and allocate our resources more effectively. It's all about making our urban environments cleaner, reducing health risks, and making our cities more cleaner. With IoT-enabled waste management, our cities can become more sustainable and improve the overall quality of life.

1.3 Project Objective

1. To improve and upgrade the existing waste management practices by implementing ultrasonic sensor that can accurately measure fill levels with low error detection and monitor fill levels providing real-time data alert if the level of wastes in bin is full to an 85% capacity of the bin to prevent waste littering.

2. To increase efficiency in waste collection by installing GPS tracking in waste bins, enabling waste trucks to coordinate collection routes based on monitoring real-time bin

fill levels and location data, decreasing unnecessary waste collection trips and ensuring timely collection of fully occupied bins.

3. To prevent unwanted situation such as excessive moisture buildup, by monitoring temperature and humidity levels in the bins and to alert waste management teams when temperature exceeds the preset value or humidity level greater than the preset percentage, thereby reducing waste decomposition rates and the risk to public health.

1.4 Scope of Project

The main aim of this project is to create a waste management solution for smart cities using IoT technology. Managing waste in urban areas can be a real challenge, so this system is here to help. The Internet of Things (IoT) is always growing and coming up with new ways to solve the everyday problems we face. One of these solutions is the idea of a "Smart City," which strives to enhance our overall quality of life [9]. The goal is to make waste management more efficient and environmentally friendly, ultimately making urban environment cleaner by using advanced technology. This project focuses on integrating IoT devices that can collect and manage waste related data. Improving waste management doesn't just make things run more efficiently, but it also helps promote sustainability.

The waste management solution for smart cities, enabled by IoT, is designed for a variety of users include:

1. **Municipal Authorities:** Municipal authorities have been dealing with a major challenge when it comes to handling solid waste [10].They're the ones in charge of handling waste collection and disposal in cities. But here's where the IoT-enabled solution comes in handy. It gives them real-time data on how full the trash bins are, helps them figure out the best collection routes, and improves their overall efficiency.

Municipal authorities can coordinate waste collection with this handy data, use their resources wisely, and make waste management across the urban area better.

2. **Waste Management Companies:** Waste management companies are super important because they're the ones who collect and take care of all the garbage from urban areas. Waste collectors can make a smart move and speed up their collections by using this IoT-enabled solution. This system helps waste collectors do their job faster and efficiently, so they can figure out the best routes to pick up the waste. Plus, they can provide better service to their customers. This solution also helps them to stay on top of maintaining waste collection vehicles. By this way, it improves reliability and making sure their customers are satisfied.

3. **Residents:** When it comes to managing waste, residents play a pretty important role. After all, they are the ones generating waste, hence they need to make sure it's collected and disposed of properly. And that's where IoT-enabled solution comes in, they can enjoy the benefits of timely and efficient waste collection. Plus, they can promote a cleaner and healthier living environment by reducing the risk of overflowing bins or stinky messes. They can even get notifications and alerts about waste collection schedules and bin status. It's also like more having a personal waste management assistant right at their fingertips. In addition, the system is designed to encourage them to actively participate in sustainable waste management practices. With IoT-enabled solution, they can keep urban environment cleaner.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the overall concept of the project system discusses and summarizes, including the theory of this project. The main purpose of this chapter is to explain previous research and the current state of research. This chapter also discussed the theory and concept used to solve the problem in this project. This section also relied on journals, articles, and case studies that closely align with the scope of the project. The sources are selected based on similarity to our project's objectives.

2.2 Development of IoT-based Waste Management System for Smart City using Arduino.

The development of IoT-based waste management system for smart cities using Arduino is significant because the impacts of these issues will continue to grow due to global population increase and development especially in urban areas. IoT technologies have a big role to play in smart cities when it comes to introducing new services and revamping existing ones [11]. A lot of researchers have been working towards creating the perfect solid waste management system, which involves using software-based routing, Geographic Information Systems (GIS), Radio-frequency Identification (RFID), and intelligent sensor bins [10]. However, due to rapid development in cities, the traditional methods in waste management have been known to disappoint by causing environmental damage and effects to public health. The aim of this project would be orientated towards enhancement of the current practices of waste management with the support of IoT devices and Arduino microcontrollers in taking data about the generation, collection, and disposal of garbage in real-time mode.

Using intelligent sensors and actuators interfaced with the Arduino board, the system can detect the filling level of garbage bin and help in coordinating waste collection routes. In this case, the use of system can help with increasing smarter cities, enhancing environments, as well as supporting cleaner environments and even improving the quality of life of residents of such cities. This means that as the world becomes more urbanized, IoT based waste management for smart cities could help more on achieving better function in waste management system leading to cost savings at the same time minimize environmental impact.

2.3 Review of current situation for Development of IoT-based Waste Management System for Smart City using Arduino.

As the world's population keeps on growing like at unpredictable rate, the production of garbage is becoming more every single day. Managing all that generated waste and making sure it gets picked up properly from garbage bins is getting trickier and more crucial than ever [12].In recent years, significant advancements in technology and an increase in the importance of sustainable urban development have spurred the development of waste management systems for smart cities by IoT. As suggested by a study from the journal Sustainability made by Lee, Park, and Kim : “sensing technologies and data analytics have increasingly been integrated into municipal waste management infrastructures, providing various advantages and addressing multiple issues” [13].

Another remarkable fact about the current state of recycling methods is the extensive utilization of multiple IoT sensors integrated within the waste bins, collection vehicles, and processing facilities. IoT devices facilitate constant tracking of the fill level and temperature combined with numerous other parameters, data from which could be utilized for better scheduling and routing of the collection trucks. For instance, bringing this type of real-time information has played a role in rapidly improving the overall efficiency of waste management processes and significantly reducing associated costs.

Furthermore, modern waste management IoT systems are also capable of utilizing specially designed analytics software, including machine learning algorithms. Those tools are designed to help process the massive flow of data to generate predictions over the waste producing and accumulating patterns in various locations. For instance, some larger cities strive to utilize predictive analytics to schedule trash collections considering forecasted peaks, or triggering events on some specific days may help achieve the desired data.

The current scenario reminded cities around the world of the need for data-driven decision-making even in waste management. Using IoT data in conjunction with Geographic Information Systems and other technologies, city officials might identify which areas of the city produce too much garbage, the levels of recycling, and the impact on the environment and inhabitants. This also helps in policy formation and helps the cities to set goals for less trash production or sustainability. In addition, by the support of citizens, businesses and waste management organizations have been important for success of this indicator. Smartphone applications and web-based tools have been built from IoT for monitoring waste collections, the extent of recycling and feedback received on it. It reduces waste that would otherwise go to landfill, and increases the consciousness of citizens about their individual responsibility to maintain their environment clean.

In conclusion, IoT-based waste management system in smart cities as it stands right now, it is still evolving, due to the ever-expanding environment, driven by technology, data analysis fetching better efficiency, and user participation. The IoT lets us keep an eye on things that are far away without actually having to be there in person. We can monitor and track objects remotely without having any physical contact or visits [14], [15]. For creating smarter environment and handling better waste disposal to prevent environmental harm the system is needed to be developed.

2.4 Review of Related Literature

2.4.1 (A) IoT Based Waste Management for Smart City [16]

Parkash Tambare and Prabu Venkatachalam came up with a project called IoT-based Waste Management for Smart Cities. The idea is to create a low-cost device that can keep track of how full garbage bins are and identify each bin with a unique ID. When a bin reaches its limit, the device sends out a signal with the level and ID. The authorities can access this info online and quickly take action to clean the bins. The system uses an IR Sensor, 8051 microcontroller, power supply, RF Transmitter, RF Receiver, Intel Galileo microcontroller, and a web browser as an online platform. The diagram below shows the working principle of the project.

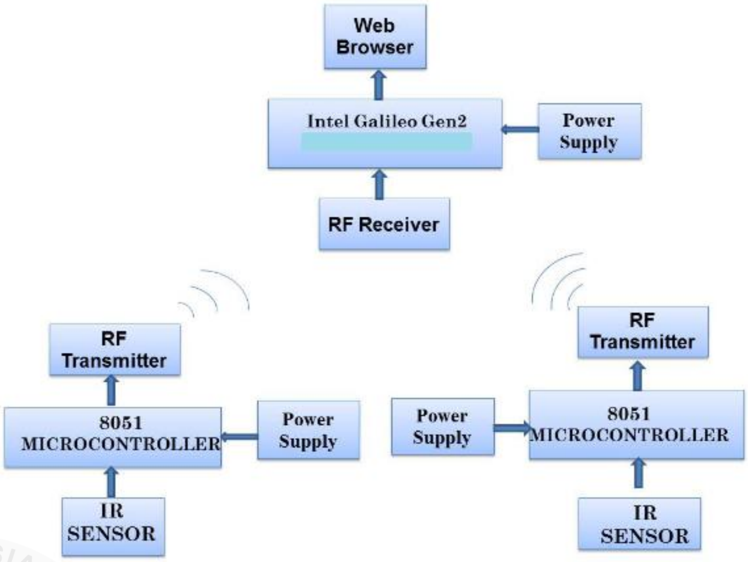


Figure 2.1 IoT Based Waste Management for Smart City

2.4.2 (B) Implementation and Recognition of Waste Management System with Mobility Solution in Smart Cities using Internet of Things [7]

Liyakat, Kutubuddin, and Kazi Kutubuddin came up with a smart waste management system that uses IoT-enabled sensors and devices to track and collect real-time data on garbage levels. Basically, this system helps to keep identify on how full the bins are and figure out the best collection routes.They installed these sensors in different places where garbage is collected, like trash cans, recycling bins, and dumpsters. This way, they can continuously study how waste is generated. All the data collected is sent to a central platform for analysis and decision-making. The system keeps an eye on the trash cans and gathers real-time data using a network of IoT sensors scattered strategically around the city. These sensors not only measure how full the bins are but also identify the type of waste present. To set up this system, they took into account different factors, as shown in the figure below. The aim is to create a waste management system that works efficiently and assists in making smarter choices.

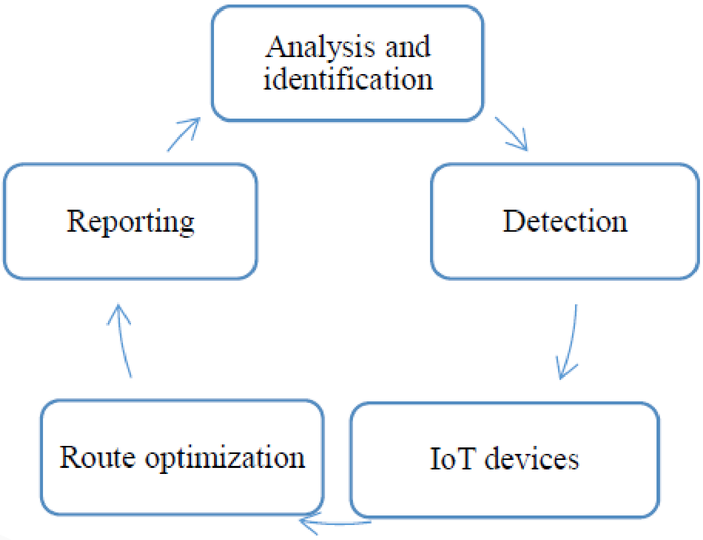


Figure 2.2 Implementation and Recognition of Waste Management System with Mobility Solution in Smart Cities using Internet of Things

2.4.3 (C) Smart and Inexpensive Implementation of Garbage Disposal System for Smart Cities [17].

Sagar Sharma, Vishal Chauhan, and Animesh Jain came up with a system that aims to solve the problem of waste collection and make cities cleaner by reducing garbage spillage. When the waste is not collected properly and on time, it can cause a whole mess. Mosquitoes start to buzz around, diseases can spread, and the nearby living areas become a health risk for people. The system was created as affordable and easy to build, something that can really help to deal this issue. They use a GPS module to get latitude and longitude data, which helps to track the status of the garbage containers. They also used an ultrasonic distance sensor that measures how full the container is. Moreover, it can even measure the temperature inside the container too. The sensors installed in the container where it collect all this useful data. Then, it send this information, along with the GPS coordinates of the bin, to the cloud for further analysis. In addition, it send a list of filled containers that need to be collected to the drivers. With the help of good Google Maps, efficient route that connects all the collection points is provided. The system with installed sensors and smart routing, the path can be planned and make sure pick up the waste in the most efficient way possible while keeping cities clean and healthy.

2.4.4 (D) An IoT-Based Waste Management Approach for Environmental Sustainability [18].

Sangram C. Patil and Milind R. Gidde have designed an IoT-based smart trash management system using Android and web apps. They came up with this idea because the current trash management system has some limitations and issues. They have created a separate interface for users, waste pickers, and administrators at the central dumping station which is unique about their system. This allows for a complete overview of the waste collection management system, which is super beneficial. Both home users and industry users will be given a special RFID card (Radio Frequency Identification Card). They'll use this card to deposit their waste in the designated dustbin. The administrator will then monitor the waste collection on a daily, weekly, and monthly basis. To keep track of the dustbin levels, ultrasonic sensors will be installed. These sensors will send the data to our cloud-based database using GSM and GPS modules. The system chose to use the Firebase database for its application because it's highly compatible with Android apps and allows for real-time data upload.

The waste pickers will have access to an Android app where they can log in. They'll be assigned specific routes and provided with a hardware kit. The waste pickers will go from door-to-door in their assigned areas and collect the waste from the home users. The frequency of collection will be determined by the dustbin level. We set the threshold at 80%, meaning that once the dustbins are more than 80% full, the waste pickers will receive an alert to collect the garbage from the respective home users. Overall, this system combines technology and user prompts to optimize trash management. It's a smart and efficient way to keep surroundings clean while making the process convenient for everyone involved.

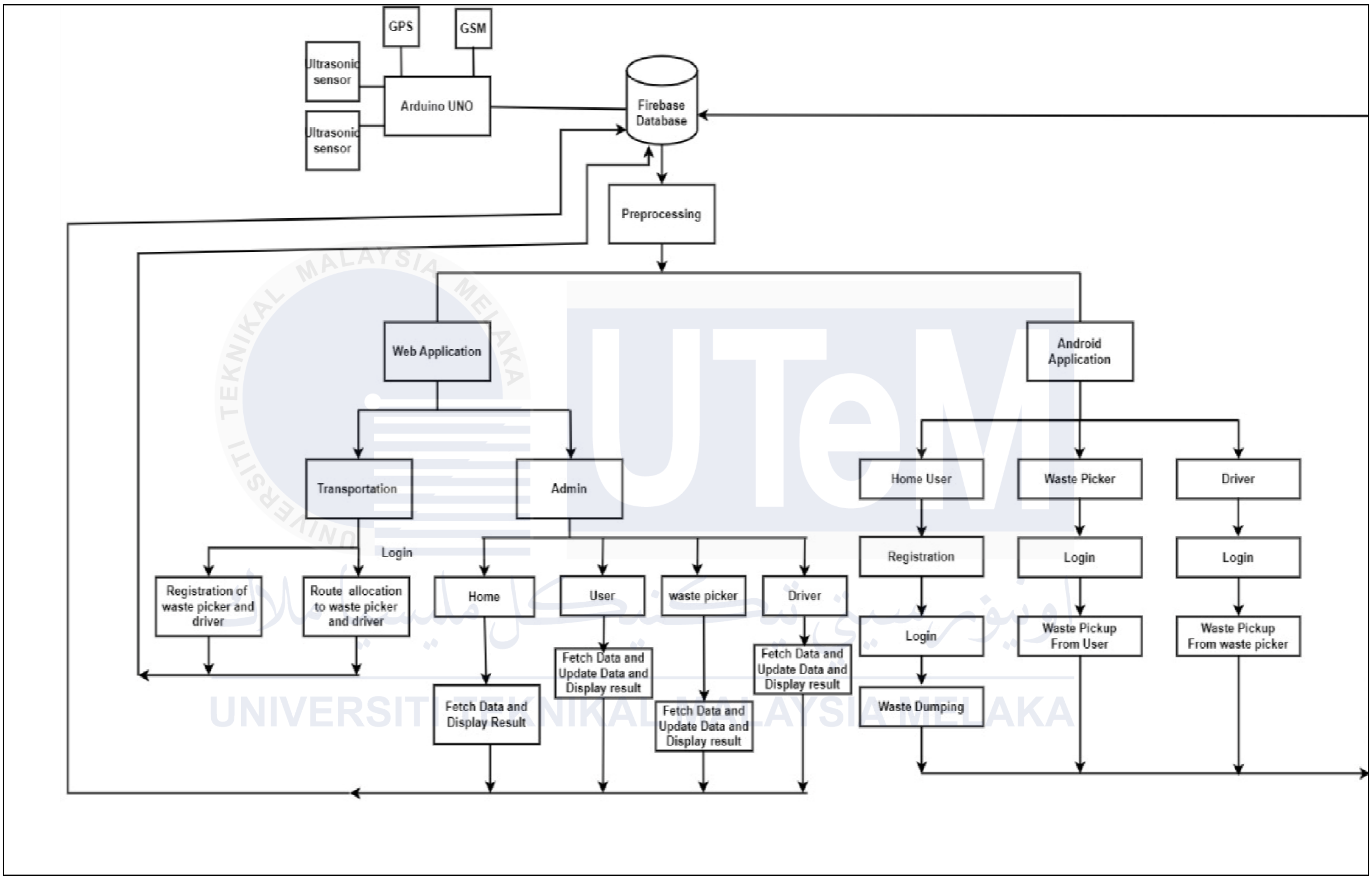


Figure 2.3 An Iot-Based Waste Management Approach for Environmental Sustainability

2.4.5 (E) Smart Waste Management System using IOT [19].

Tejashree Kadus, Pawankumar Nirmal, and Kartikee Kulkarni have come up with a neat idea to automate waste management in the field of cleanliness and hygiene. A smart dustbin that uses an Arduino Uno board, a load sensor, and a Wi-Fi module to make it stand out from the regular dustbins was created by them. This cool device has two main parts which are the mechanical components and the electric components. The mechanical components consist of a shredder and a load sensing plate, while the electric components include the Arduino Uno, a load cell, an LCD display screen, an IR sensor, an amplifier, a relay module, and a Wi-Fi router. The system works as when trash is thrown into the dustbin, it first goes through the shredder, and the shredded trash lands on the load sensing plate inside the dustbin. The load sensor attached to the plate measures the weight of the trash you've dumped. Once the weight reaches a certain limit, the password for the Wi-Fi router is displayed on the LCD screen. Even though the router is still off at this point, the plate should be pull out by user so that the trash falls into the dustbin. The falling motion of the trash is detected by the IR sensor, which triggers the next step in the process. This combination of mechanical and electric components, along with user prompts, aims to enhance the dustbin's efficiency and make waste management practice sustainable.

2.4.6 Monitoring the Smart Garbage Bin Filling Status: An IOT Application Towards Waste Management [20].

Sirisha Yerraboina, Nallapaneni Manoj Kumar, K. S. Parimala, and N. Aruna Jyothi proposed and presented a project on an Internet of Things (IoT) system that can be used for various applications. The combination of electronic devices, communication devices, and information processing devices was consisting by the system. In this particular project, they aimed to develop an IoT system for garbage bins. The IoT system for garbage bins includes several materials such as UV sensors, an Arduino UNO board, a power supply unit, a GSM module, an LCD digital display unit, and a buzzer. Voltage regulators, capacitors, diodes, and transformers are including of the power supply unit. The UV sensor, which acts as one of the building blocks of IoT is one of the important components of the system. The central unit chosen for this project is the Arduino, as the entire system's functioning depends on it.

Other user-friendly features like a digital display, buzzer, and GSM module for mobile alerts are initiated from the Arduino. Since various components in the system work with different input voltage levels, a power supply unit with voltage regulators is used to ensure proper functioning. The team successfully developed a prototype by following this system architecture.

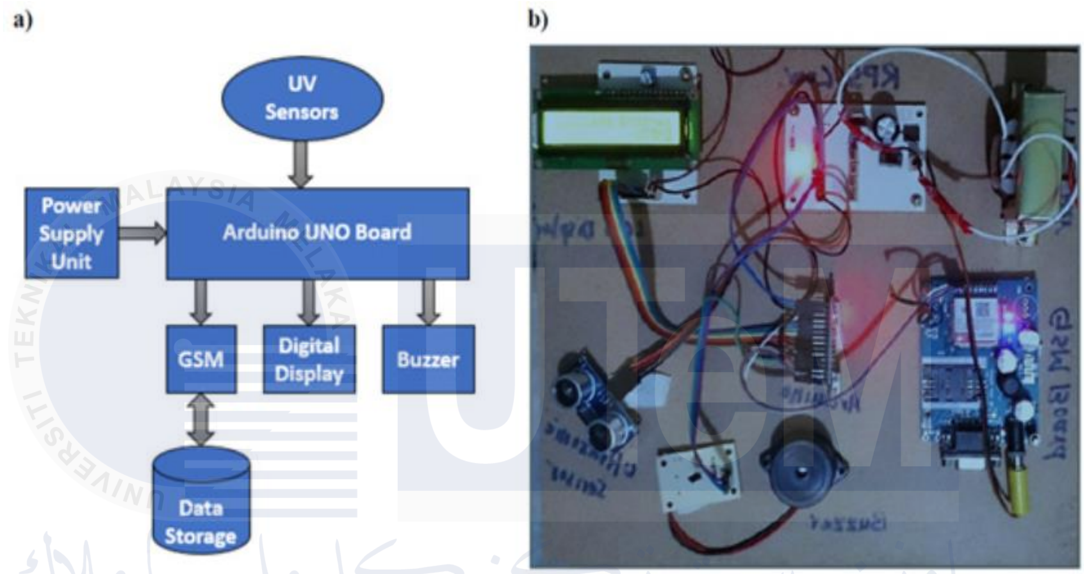


Figure 2.4 Monitoring the Smart Garbage Bin Filling Status: An IOT Application Towards Waste Management

2.4.7 IoT-Based Intelligent Waste Management System: A Look Ahead for India [21].

Prajwal Kumar Rai, Prateek Goyal, Sanket Mittal, Priyanka Singh proposed an idea to construct smart cities, an intelligent machine that monitors the garbage, offers real-time information is required. Currently, Municipal Corporations in India do not receive real-time information about dustbins. In this regard, we are implementing an Internet of Things (IoT) system that will communicate with the company's on dustbin overflow and toxin levels. A website is also being built to monitor the data relating to dustbins. Via the GSM module a message is transmitted to the mobile phone, and information on the dustbin's status is updated on the website. Citizens can also use this website to raise concerns about dustbins or garbage management. In the recommended solution, an Arduino microcontroller is utilized in order to connect the sensors to the GSM/GPRS module. Gas sensors determine the toxicity level, whereas ultrasonic sensors determine the trashcan level.

2.4.8 Solid Waste Collection as a Service using IoT- Solution for Smart Cities [22].

Sangita S. Chaudhari and Varsha Y. Bhole came up with a system that can monitor and perform collection of solid waste from both wet and dry garbage bins scattered across a specific area. Figure 1 shows how they planned the architecture of the proposed system. The proposed system is divided into different phases following by:

1. Design a hardware prototype to show how full the garbage bins are.
2. Developing software and hardware modules on the central Cloud server.
3. Developing a mobile app that will show the current location and status of garbage bins on a map of particular area.
4. Generating and show the best route in real-time for the garbage collector truck to reach the nearest fully filled garbage bins.

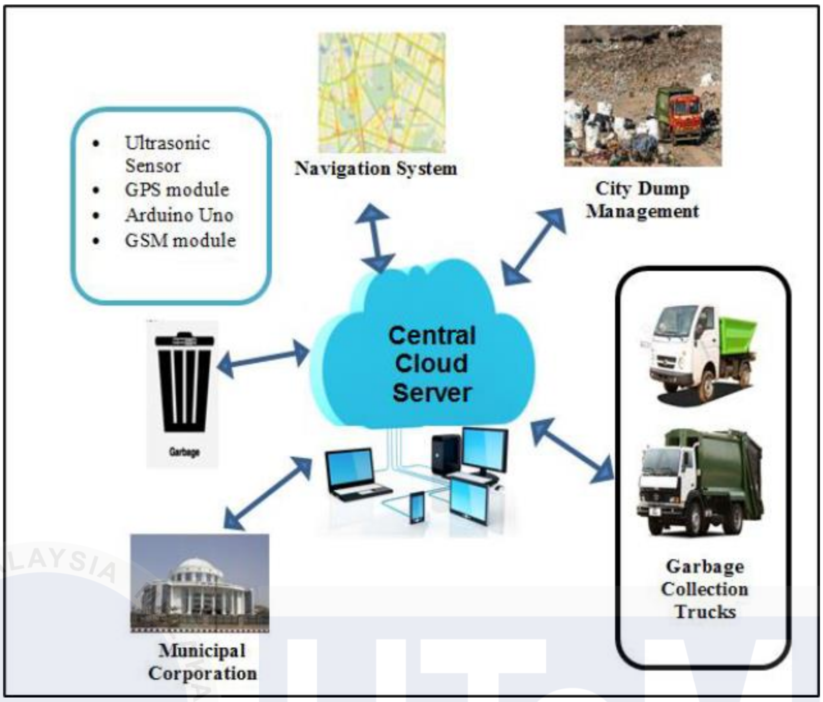


Figure 2.5 Solid Waste Collection as a Service using IoT- Solution for Smart Cities

2.4.9 Smart Garbage Monitoring System using IoT [23].

Dr. Ihtiram Raza Khan, Mehtab Alam, and Anuj Razdan from the Department of Computer Science & Engineering have come up with a clever solution to tackle our waste problem. IoT-based smart system for efficient waste management is the system proposed by them. This research paper introduces a system that uses sensory technology to assess the level of waste in dustbins. To bring it all together, they use a microcontroller as a visual connector between the sensor and the IoT system. Using both human expertise and technology this system aims to improve urban integration. The ways towards solving the current urban waste challenge can be paved with the rise of the Internet of Things (IoT) and the availability of actuators and low-cost sensors [23]. By using a sensor and GSM the environment is clean and hygienic and ensures environmental cleanliness. Improper disposal and storage of household waste creates problems for public health and pollution. The Smart Garbage Monitoring System using IoT is designed with an ultrasonic sensor to measure distances. It also utilizes GPS to send the precise location of the garbage box and GSM to shoot a message to the municipal authorities with the current location.

2.4.10 Smart Waste Management using Internet-of-Things (IoT) [24].

Chitluri Sai Srikanth, Tadivaka Bhupathi Rayudu, Javvaji Radhika, and Raju Anitha have proposed a solution to address the growing problem of overflowing garbage in urban areas. They noticed that there is a lack of an efficient waste management system, causing excessive waste buildup. They came up with a solution called the "Smart Garbage Bin" to solve this problem. The idea behind the Smart Garbage Bin is to provide early information about the fill level of the bin, to alert the responsible authorities to empty it in a timely manner and protect the environment. Whenever the bin is about to reach its capacity, a notification is sent to the designated person in charge, who will then arrange for the waste to be collected from that specific area. This can be done through a web application, where the authorized person can send a message to the waste management team via SMS. To ensure the security of the system, they implemented a strain check to detect any tampering or unauthorized access to the data. The use of IoT technology is gaining popularity in various industries, and it is considered one of the most promising areas of future development [25], [26]. The overflow of littered waste can be minimized and urban environment can be kept clean by implementing the Smart Garbage Bin.

2.4.11 IoT Enabled Smart Waste Management System using Machine Learning Techniques [27].

Mohammed Moizuddin Abdulla, Malkari Sravani proposed to design smart waste management system based IOT. Their idea is in order to effectively handle trash and maintain a healthy environment, we must employ the finest procedures and practices [28]. The proposed block diagram of the system is shown in figure 1. In this diagram it has shown the interconnection of various hardware components with a real time monitoring system. The ultrasonic sensor is installed in this system with smart dustbin to measure the distance or level of dustbin. A moisture sensor is connected to Arduino UNO to detect whether the waste is wet or dry. Also LED and buzzer are connected to indicate the output status. The GSM module and GPS module are connected to Arduino UNO to send the message to real time system about the dustbin status and location.

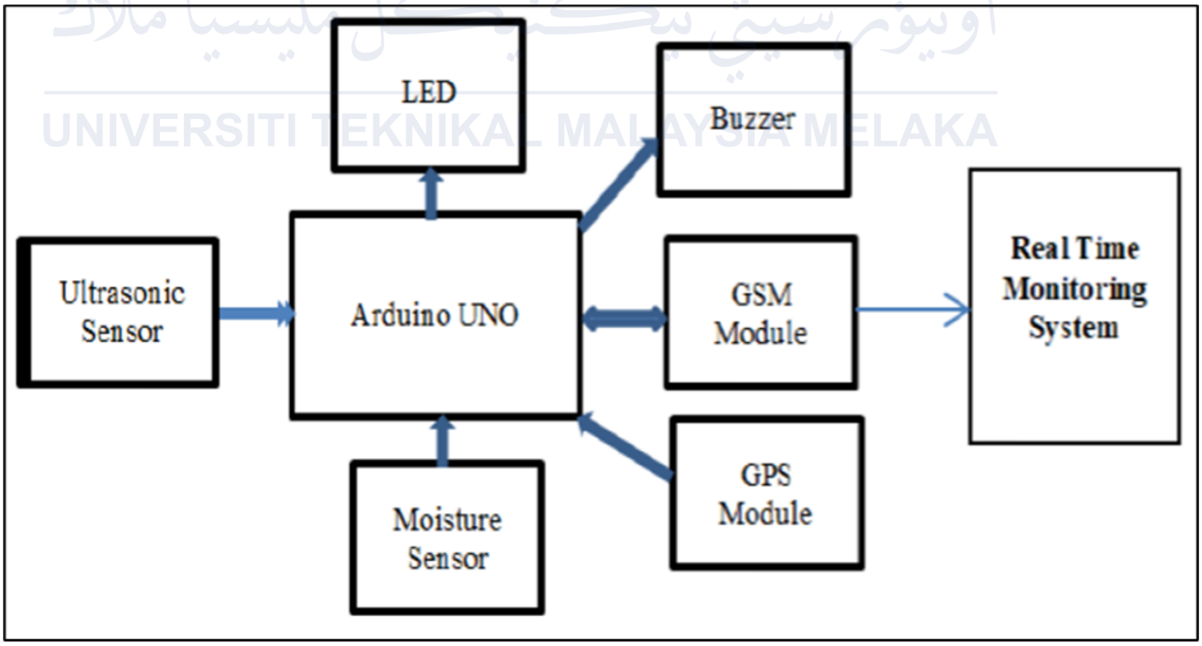


Figure 2.6 IoT Enabled Smart Waste Management System using Machine Learning Techniques

2.4.12 Smart Waste Management Using IoT [29].

Sakshi Neema and Prof. Kaushal Gor teamed up to create a project called Smart Waste Management using an IoT system. The wastes is in a dustbin in real-time is how the system always keeps track. Two detection systems is used in this project to monitor the bin's status. First, there's a level detector that senses the amount of waste in the bin. Then, there's a weight sensor that measures the weight of the waste. Each bin has sensors that can tell whether it's full or not based on the level of waste inside. They used an ultrasonic sensor to check the waste level and a weight sensor to measure the weight of the wet waste. If the moisture content in the waste exceeds a certain level, the data is sent to the waste management center. Additionally, they added an infrared sensor to the bin to detect any objects around it. If something is thrown near the bin, the infrared sensor triggers the buzzer. The weight sensor helps garbage collectors know how much waste is in the bin, and the infrared sensor alerts people with the buzzer to not litter around it. They used a Raspberry Pi 3 microcontroller with a built-in Wi-Fi module to collect and send the data. This Raspberry Pi 3 sends the data over Wi-Fi, along with the dustbin ID, which helps locate the bin's area or region.

2.5 Comparison of Related Project

Table 2.1 Comparison of Related Products

Project	Function	Connectivity	Sensors Used	Disadvantages
A	- Senses the fill level of garbage in the bin. - Sends information through online platform of full occupied garbage bins by using Intel Galileo Gen 2.	- 8051 microcontroller - Intel Galileo Gen 2	- IR Sensor	- Does not detect the weight of the bins - Does not detect the temperature or humidity in the bins - Need to locate the full garbage bins by using the unique ID provided.
B	- Detects the fill level in the garbage bins - Locate the bins by using GPS module - Uses optical sensor to recognize and classify waste - Detects the weight measurement of the bins	- Wi-Fi module - Cellular connectivity - Bluetooth	- Ultrasonic sensor - Optical sensor - Weight sensor	- High priced system - Requires high maintenance - Does not detect the temperature or humidity in the bins
C	- Measures how much the container is filled. - Detects the temperature in the garbage bins - Locate the garbage bins which are fully occupied	- GPS module - LinkIt One MT2502A	- Ultrasonic sensor - Temperature and Humidity sensor	- Does not detect the weight of the bins.
D	- Detects the fill level in the bins. - Locate the bins using GPS module - Uses GSM module to notify the users. - Proposed system is more to the user on how efficiently they use the waste disposal application.	- GSM module - Arduino Uno - GPS module	- Ultrasonic sensor	- Does not detect the weight of the bins - Does not detect the temperature or humidity in the bins - Using GSM module is less efficient

E	- Measures the weight of the bins. - Detects the downward motion of trash once the load sensing plates being pull out and the trash falls into bin.	- Arduino Uno - Wi-Fi module	- IR sensor - Load sensor	- Does not detect temperature or humidity in the bins.

Based on the comparison Table 2.1 above, the projects done by previous researchers have some disadvantages. As for project A, the sensor used is an IR sensor, it detects the height level in the bin and no other sensor is included such as temperature or humidity sensor. The garbage bins will be located by the unique ID provided to each bin. Project B is a costly system because it uses optical sensors to recognize and clarify the waste thrown in the bin. Besides, there is no sensor to monitor temperature and humidity level in the bin. It is important to include a sensor to monitor the temperature and humidity level in the bin to prevent potential hazards or excessive moisture build up. Project C on the other hand used ultrasonic, temperature and humidity sensors but no weight sensor to detect the weight of the bin. It is an additional sensor to monitor the weight of the bin to prevent heavy load disposal in the bin such as metals.

Project D used GSM module which is less efficient compared with WIFI module. Besides, there is no temperature and humidity monitoring sensor in this system. The only sensor used in this project is an ultrasonic sensor to detect the fill level in the bin. For Project E, it uses IR sensor to detect the downward motion of trash and load sensor to measure the weight of the bins. Similarly, as Project D, there is no temperature and humidity monitoring included in this project. As for my project, I have included a weight sensor to measure the weight, temperature and humidity sensor to detect temperature and humidity level in the bin, ultrasonic sensor to detect the fill levels in the bin. Moreover, for locating the bins, I am using Ublox Neo-6M GPS module and ESP8266-01 Wifi module as a connection tool.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter clarifies the planning of the project which includes a brief explanation of the selected component parts. The development methodology which are the schematic diagram of the project, flowchart of the system and block diagram. A portion of this chapter is the strategies on how this project was carried out the whole time. Besides, intend to provide details and confirmation of how this project was conducted is included in this chapter. Explanation of both hardware and software is included within the plan and development of the system.

3.2 Workflow Chart of the Project

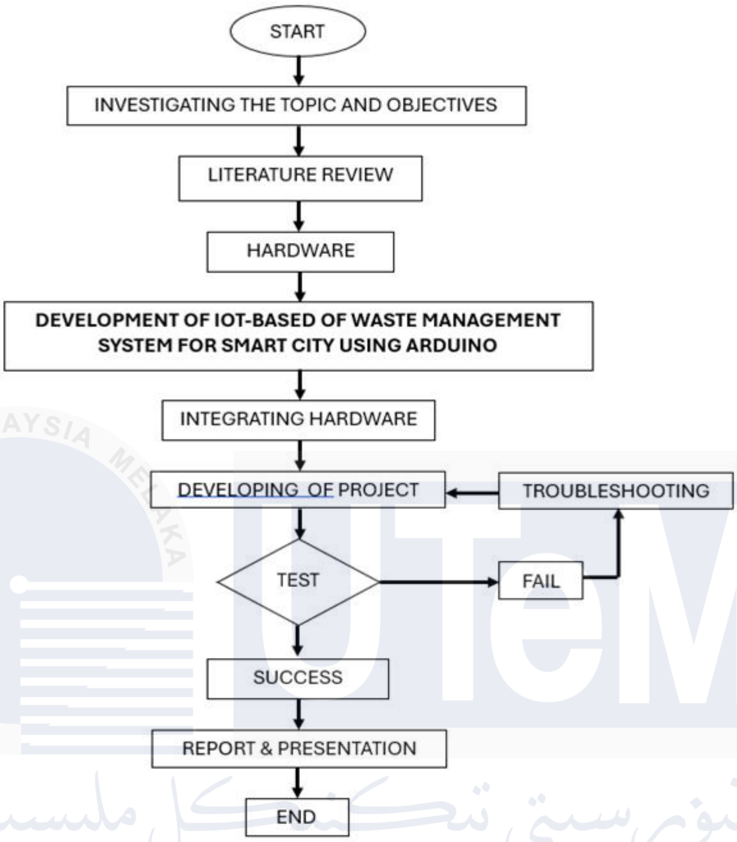


Figure 3.1 Workflow chart

As for the beginning step of the project, we need to study and investigate the important elements needed for this project such as the topic, objective, problem statement, scope, limitations of the project which are going to be selected. Besides that, we need to carry out some research on the literature review about the project we are going to propose. This is because we can get better ideas on how to make a better and improved version of the project. Next step is to list down the components and hardware needed for the selected project. Of course, the next step is to assemble all the components based on the circuit diagram we constructed. Making sure all the components integration is noted down carefully for referring purpose later and thus makes the troubleshooting process of the component connections much easier. Development of the model prototype including coding for the Arduino board is the following step which needs to be done before testing out the prototype. Testing of the prototype will be done as the next process. If the project fails, troubleshooting step will take place and make the corrections until the inputs and outputs function well as mentioned. This step will be repeated continuously until the system works as desired.

3.3 Development Methodology

3.3.1 System Overview

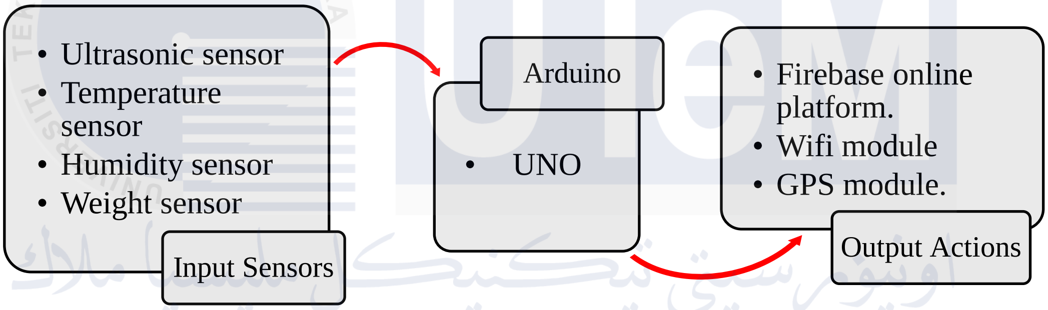


Figure 3.2 System Overview

When the system is connected to a power supply, there will be a total of five loops that take place accordingly. At first the system will start with ultrasonic sensor loop which detects the fill level in the bin followed by temperature sensor loop, humidity sensor loop, weight sensor loop and finally at communication loop. After the communication loop ends at a point, the system will run the loop process once again from the beginning. For a constant monitoring of the garbage bin status, this process will be repeated state until the power supply is out. The HC-SR04 ultrasonic sensor is used in the ultrasonic sensor loop. The DHT11 sensor is used in the temperature and humidity sensor loop while HX711weight sensor is used in the weight sensor loop and finally, Wi-fi module is used in the communication loop. The operation sequence of the prototype model is shown in the figure above.

3.3.2 Block Diagram

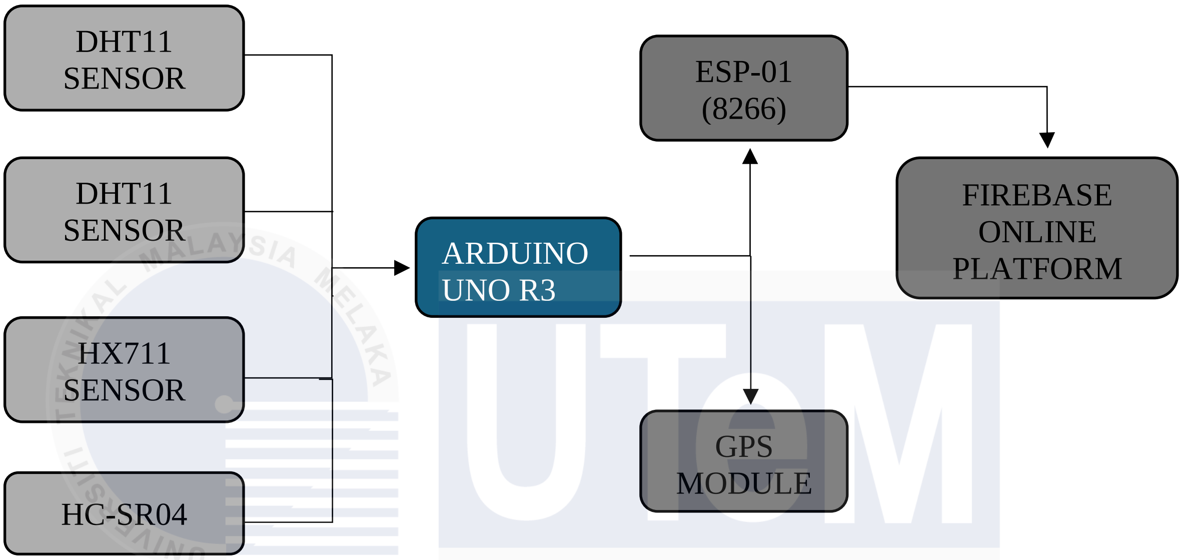


Figure 3.3 Block Diagram of the Project

From the diagram above, there are three input sensors used for this project which are DHT11 sensor to read temperature and humidity reading, HX711 sensor to sense the weight and HC-SR04 to detect the level in the bin. All the sensors are connected to an Arduino Uno which acts as a controller. The outputs from the Arduino Uno board are ESP-01(8266) which is a WIFI module and Ublox NEO-6M GPS Module. The Wi-Fi module is all connected to this online platform called Firebase by Google. It's like the ultimate spot to keep an eye on all the readings from those sensors. The GPS module is used for finding fully occupied bins during waste collection.

3.3.3 Flowchart of the system

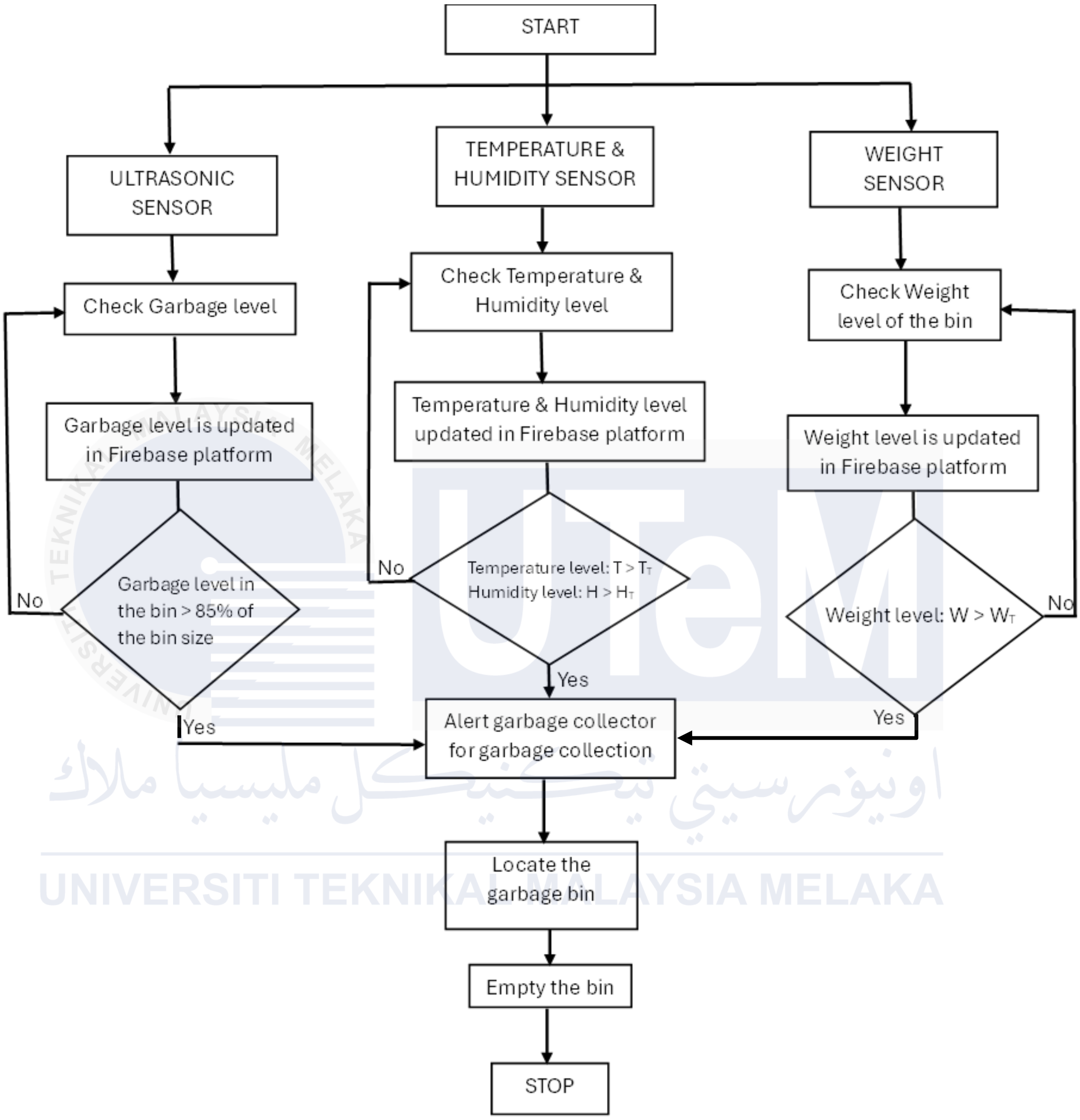


Figure 3.4 Flowchart Diagram

3.4 Development of Hardware and Software

3.4.1 Electronic Components

The system is equipped with a few sensors including the HC-SR04 ultrasonic sensor, the HX711 weight sensor, and the DHT11 temperature and humidity sensor. We also utilize other components for this project such as the Arduino Uno R3, GPS module, Wi-Fi module, and Logic Level Converter (Bi-Directional).

3.4.1.1 Arduino Uno R3

The Arduino UNO is a microcontroller board primarily based totally at the ATmega328P.It has 14 virtual input/output pins (6 of which may be used as PWM outputs), 6 analog inputs, a sixteen MHz ceramic resonator, a USB port, an electricity jack, an ICSP header, and a reset button. It essentially has the entirety you want to guide a microcontroller. It may be commenced via way of means of connecting it to a pc through a USB cable or powering it with an AC-DC adapter or battery.

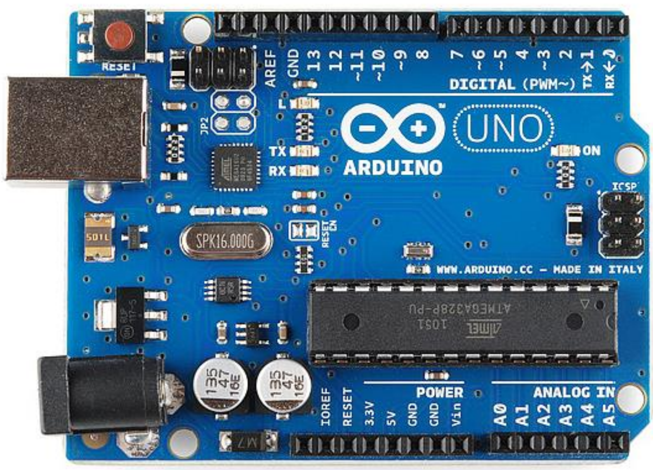


Figure 3.5 Diagram of Arduino UNO R3

3.4.1.2 DHT11 Sensor

The DHT11 is a temperature and humidity detecting sensor which displays humidity and temperature with a calibrated digital signal input. To ensure high reliability and excellent long-term stability, it uses a selective digital signal protection system and humidity and temperature sensor technology. Inside the sensor, there is a resistive humidity sensing element and an NTC temperature sensing element, connected to a powerful 8-bit microcontroller. As the increasing of the air temperature, it holds extra dampness, consequently, the associated humidity varies with the temperature [30], [31]. The DHT11 sensor used in this prototype is shown below.

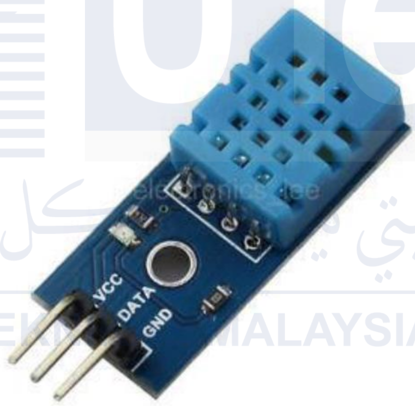


Figure 3.6 Diagram of DHT11 Sensor

3.4.1.3 HC-SR04 Ultrasonic Sensor

An ultrasonic sensor is a device that measures the space to an item the usage of ultrasonic sound waves. An ultrasonic sensor makes use of a transducer to ship and get hold of ultrasonic pulses that relay again statistics approximately an item’s proximity. For presence detection, ultrasonic sensors stumble on items no matter color, surface, or fabric (until the fabric may be very soft, like wool, as it'd take in sound).The distance is computed in accordance with [32] in which the space relies upon at the time of departure and go back of sound waves time similarly to the rate of sound.

D = (T * N)/2 ,where D= distance, T=time and N= sound speed [32]

Figure 3.7 Diagram of Ultrasonic sensor

3.4.1.4 HX711 Weight Sensor with Bar-Type Load Cell

The Load Cell Amplifier is consider a small breakout board designed specifically for the HX711. It allows to make reading load cells for load, which is measurement of weight. The amplifier should be connected to microcontroller for enabling accurate measure changes in the resistance of the load cell. Precise weight measurements can be obtained with quick calibration. The straight bar stack cell can handle weights of up to 10kg or convert them into an electrical signal. It's like having a weight wizard at disposal. To know how heavy something is, to identify whether the weight of an object changes over time, or to sense the presence of an object by measuring the strain or load applied to a surface can be determined with handy gauge. Basically, the Load Cell Amplifier is hassle-free load cell readings, making weight measurement easier.

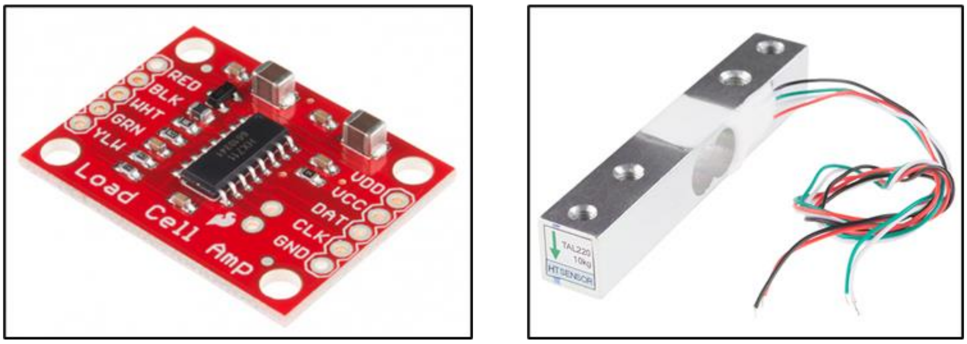


Figure 3.8: Diagram of Weight sensor with Bar-Type Load Cell

3.4.1.5 Ublox NEO-6M GPS Module

The Ublox NEO-6M GPS engine in this board could be very good, with an enormously correct binary output. It has excessive sensitivity even for indoor use. The GPS module has a battery for backup power and an EEPROM to save configuration settings. The antenna is hooked up to the module through a UFL cable, permitting the GPS to be flexibly installed in order that the antenna continually sees the sky for most effective performance. This makes it effective to be used in automobile and different cell applications. The Ublox GPS module has a TTL serial output, with four pins: TX, RX, VCC, and GND.

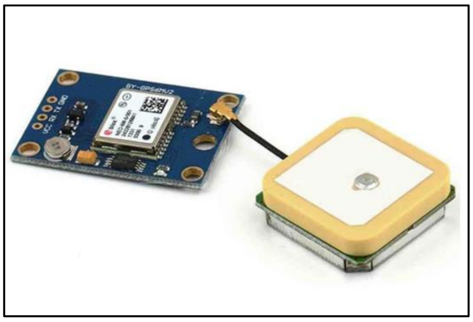


Figure 3.9 Diagram of GPS module

3.4.1.6 Logic Level Converter – Bi-Directional

The Bi-directional logic level converter is a little device that securely steps down 5V signals to 3.3V AND steps up 3.3V to 5V at the same time. Each level converter has the capability of changing over 4 pins on the high side to 4 pins on the low side with two inputs and two outputs provided for each side. The board ought to be powered from the two voltages sources (high voltage and low voltage) that the framework is utilizing.

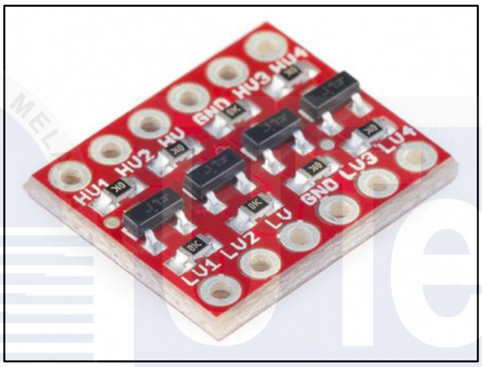


Figure 3.10 Diagram of Logic Level Converter

3.4.1.7 Wi-fi module – ESP-01(ESP8266)

Wi-Fi modules or wireless microcontrollers are used to ship and get hold of information over Wi-Fi. They also can be given instructions over Wi-Fi. Wi-Fi modules are used for communications among devices. They are maximum used withinside the discipline of Internet of Things. The ESP8266 module is a completely cost-powerful board with a big and fast-developing community.

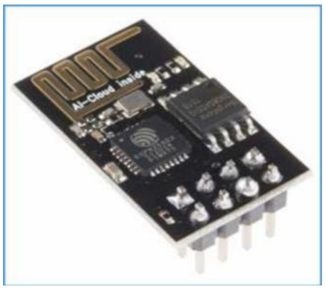


Figure 3.11 Diagram of Wi-fi module

3.4.2 Software

3.4.2.1 Arduino IDE 2.3.2

Arduino IDE is a text editor that is created in the C and C++ programming language. It's a general free open-source software that's simple to programme and compile. The basic feature makes it possible for those with no prior programming experience to develop code. The Arduino IDE software program is often used to write down and alter code for numerous Arduino micro controller boards. Arduino IDE is needed for writing and uploading code to the Arduino Uno Board on this project.

Figure 3.12 Arduino IDE

3.4.2.2 Easy EDA

Easy EDA is a straightforward and effective online PCB plan device that makes a difference gadgets engineers, teachers, understudies, producers and specialists to design and share their projects. It is a design tool integrated with LCSC component catalog and JLCPCB PCB benefit, making a difference clients spare time and turn their thoughts into genuine items. It is free to use circuit construction platform for several electronic components such as Arduino, DHT 11 sensor, HC-SR04 sensor, HX711 Load Cell Amplifier, GPS Module, ESP 8266-01 WIFI Module, Logic Level Converter and some other components available in the library.

Figure 3.13 Easy EDA Circuit Simulator

3.4.2.3 Firebase Online Platform

Firebase is a platform evolved via way of means of Google for growing cell and internet applications. Firebase's first product become the Firebase Realtime Database, an API that synchronizes software records throughout iOS, Android, and Web devices, and stores it on Firebase's cloud. The product assists software program builders in constructing real-time, collaborative applications.

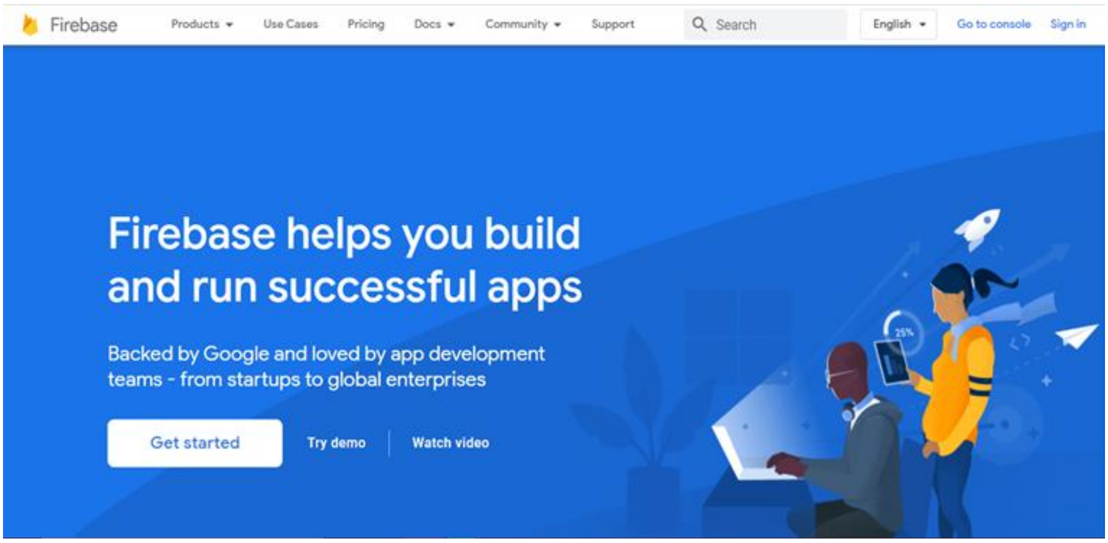


Figure 3.14 Firebase Online Platform

3.4.3 Schematic Diagram

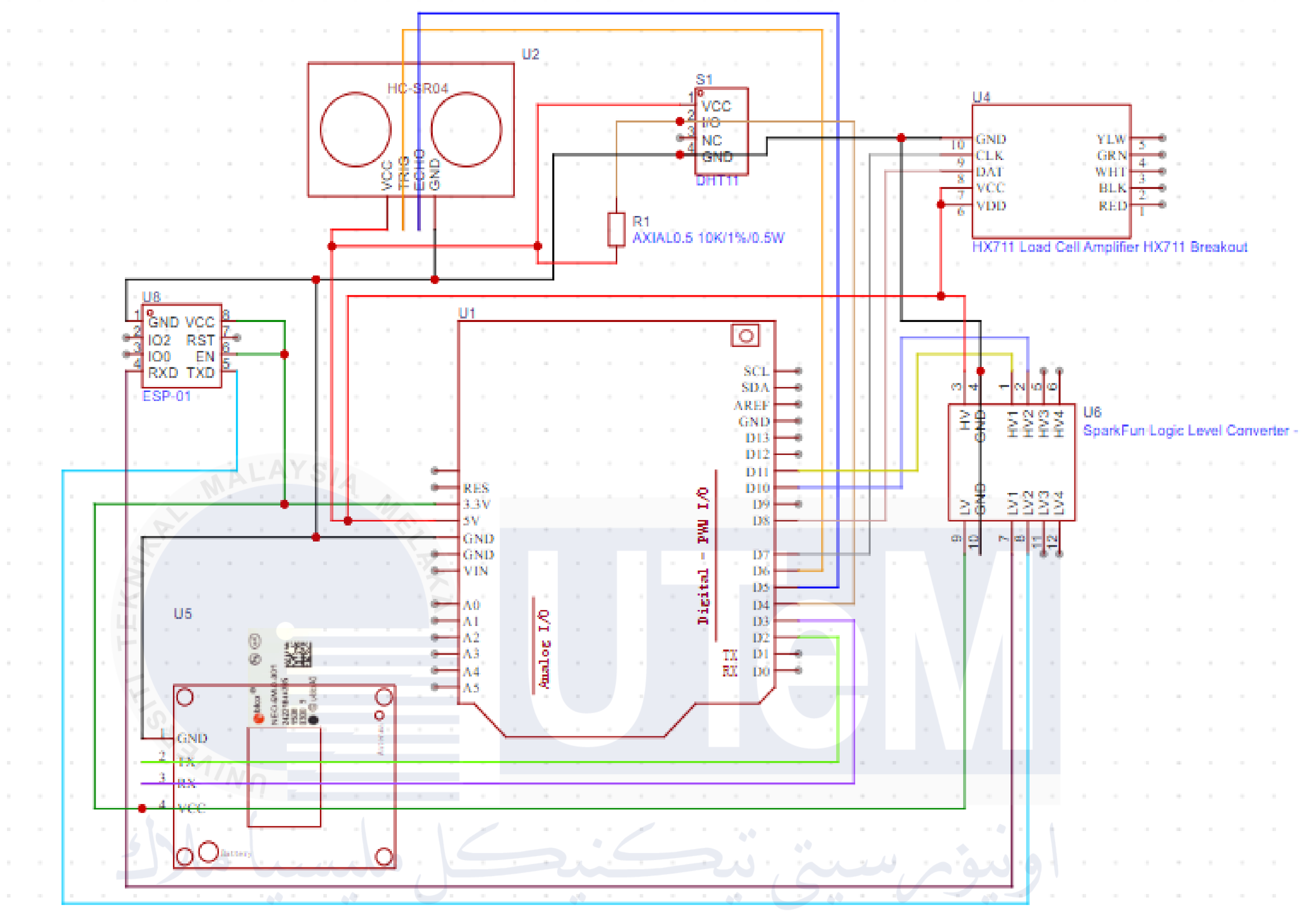


Figure 3.15 Schematic Diagram

Table 3.1 Pin Connections

COMPONENT	HC-SR04 ULTRASONIC SENSOR	
PINS	VCC	5V ARDUINO
	TRIG	D6
	ECHO	D5
	GND	ANY GND
COMPONENT	UBLOX NEO-6M GPS MODULE	
PINS	VCC	3.3V ARDUINO
	TX	D2
	RX	D3

	GND	ANY GND
COMPONENT	ESP 8266-01 WIFI MODULE	
PINS	VCC	3.3V/VCC GPS MODULE
	TXD	LLC LV2
	RXD	LLC LV1
	CH-PD/CH-EN	3.3V/VCC GPS MODULE
	GND	ANY GND
COMPONENT	DHT11 HUMIDITY AND TEMPERATURE SENSOR	
PINS	VDD	5V ARDUINO
	DATA/IO	D4
	GND	ANY GND
COMPONENT	LOGIC LEVEL CONVERTER	
PINS	HV	5V ARDUINO
	HV1	D11
	HV2	D10
	LV	3.3V ARDUINO
	LV1	ESP8266 TXD
	LV2	ESP8266 REX
	GND	ANY GND
COMPONENT	HX711 WEIGHT SENSOR	
PINS	CLK/DT	D7
	DAT/SCK	D8
	VCC	5V ARDUINO
	VDD	5V ARDUINO
	GND	ANY GND

3.5 Cost Analysis

The cost analysis of each of the components below is obtained from Shopee application. The price may vary at electronic shops or if buy in high units.

Table 3.2 Project Cost

Component	Price per unit (RM)	Unit	Cost (RM)
Arduino Uno R3	46.90	1	46.90
HC-SR04	8.90	1	8.90
HX711 with kit	30.80	1	30.80
DHT11	10.00	1	10.00
Ublox NEO-6M	20.90	1	20.90
Wires and Project board	15.00	1	15.00
Logic Level Converter	3.00	1	3.00
Terminal Block	0.80	1	0.80
Others	-	-	50.00
Total Cost (RM)			**186.30**

3.6 Gantt Chart

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
TITLE SELECTION AND REGISTRATION														
PROPOSAL														
CHAPTER 1 INTRODUCTION														
CHAPTER 2 LITERATURE REVIEW														
PROGRESS WORK 1 EVALUATION														
CHAPTER 3 METHADOLOGY														
RESEARCHING ABOUT COMPONENTS														
COMPONENT CONNECTIONS														
CIRCUIT SIMULATION														
CHAPTER 4 & CHAPTER 5														
PROGRESS WORK 2 EVALUATION														
REPORT SUBMISSION														

Table 3.3 Gantt Chart

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter discusses the results and analysis of the IoT-based waste management system developed for smart cities. The main goal of the project was to tackle common waste management problems, such as overfilled bins and inefficient collection routes, by leveraging sensors and technology. The system was designed to monitor bin fill levels, track bin locations via GPS, and measure environmental factors like temperature and humidity to minimize health risks. In this chapter, we will assess the system's performance, evaluate how the data was collected and utilized, and determine whether the objectives were achieved.

4.2 Project Development

The project followed a structured approach to development. The first step was identifying the key challenges in waste management, such as overfilled bins and inefficient collection routes. To address these issues, we selected ultrasonic sensors to measure bin fill levels, temperature and humidity sensors to monitor environmental conditions inside the bins, and GPS sensors to track bin locations. These components were carefully integrated and tested for compatibility to ensure smooth system performance. The software was developed to enable communication between the Arduino controller and the Blynk IOT

Cloud replacing the Firebase Online Platform, allowing for real-time data monitoring and sends alert notifications based on predefined conditions. Throughout the development process, extensive testing and fine-tuning were conducted to ensure the system met its goals of improving waste management efficiency and public health. Some troubleshooting was necessary, including replacing the Esp-01 Wi-Fi module with an ESP32 to enhance Wi-Fi connection stability.

4.2.1 Project Block Diagram

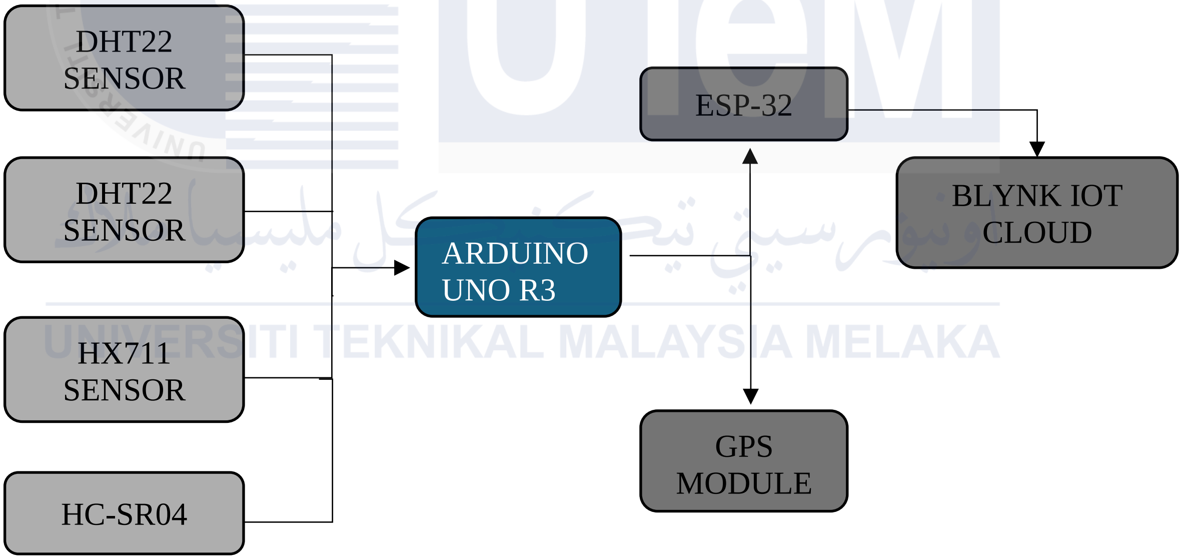


Figure 4.1 Block Diagram of the Project

From the diagram above, there are three input sensors used for this project which are DHT22 sensor to read temperature and humidity reading because it has higher accuracy reading compared to DHT11 sensor. The DHT22 is more accurate and capable, measuring temperature with a precision of ±0.5°C and humidity with ±2-5%, working from -40°C to 80°C for temperature and 0% to 100% for humidity while DHT11 measures temperature within ±2°C and humidity within ±5%, but its range is limited to

0°C to 50°C for temperature and 20% to 90% for humidity. The HX711 sensor to detect the weight and HC-SR04 to detect the level in the bin. All the sensors are connected to an Arduino Uno which acts as a controller. The outputs from the Arduino Uno board are ESP32 which transmits sensor data to Blynk IOT Cloud and Ublox NEO-6M GPS Module. The GPS module is used for retrieving the location of fully occupied bins during waste collection.

4.2.2 Block Diagram for Automatic Lid

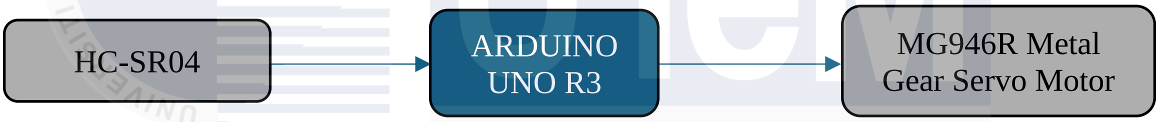


Figure 4.2 Block Diagram for Automatic Lid

As from the figure above, an additional upgrade has been made which is adding another unit of HC-SR04 ultrasonic sensor and servo motor to open the lid by itself when it detects a person within the range of 50cm. By doing this upgrade, the users may throw away the waste without even contact with the garbage bin.

4.2.3 Flowchart of the project

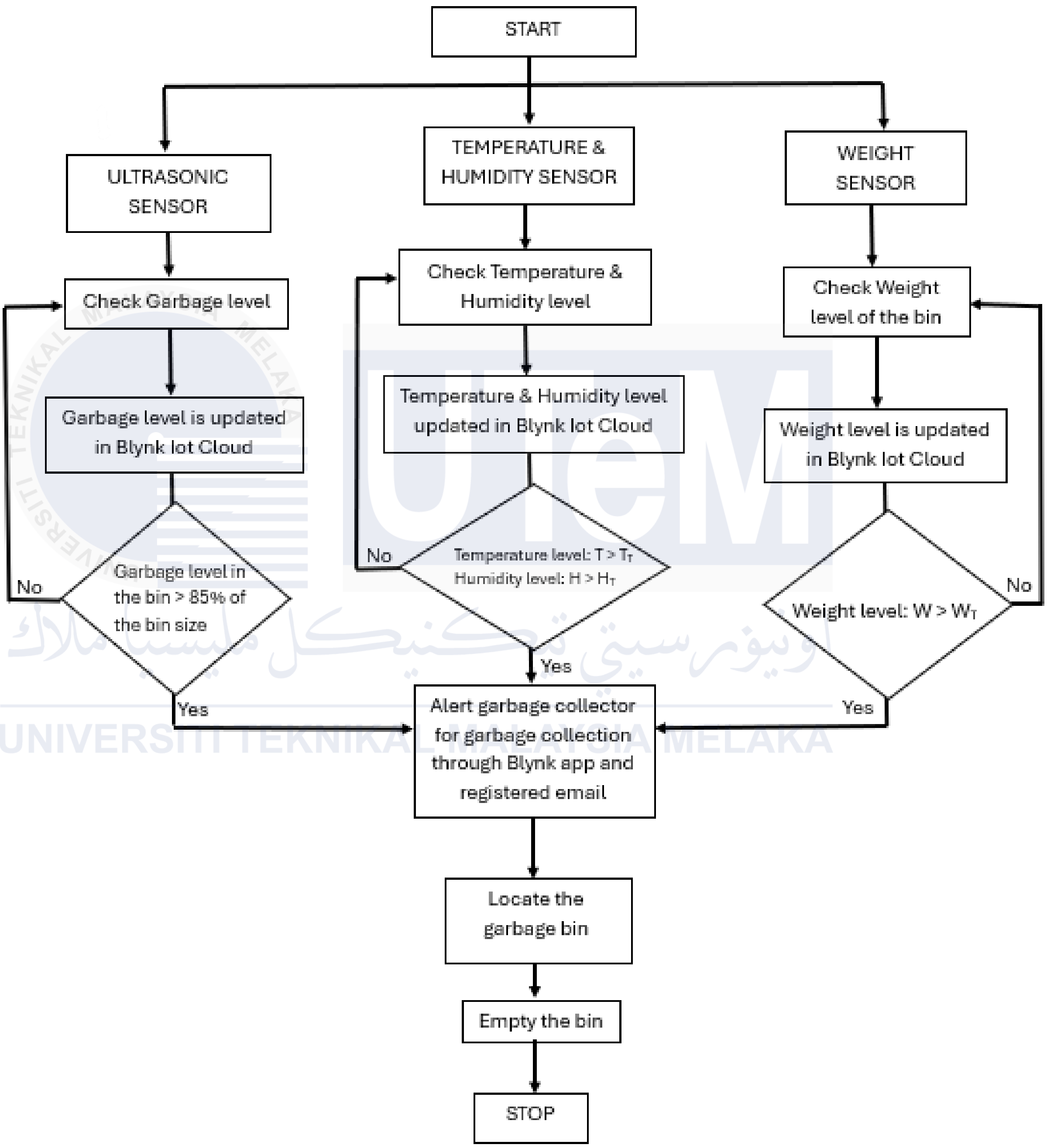


Figure 4.3 Project Flowchart

4.2.4 Flowchart of the Automatic Lid

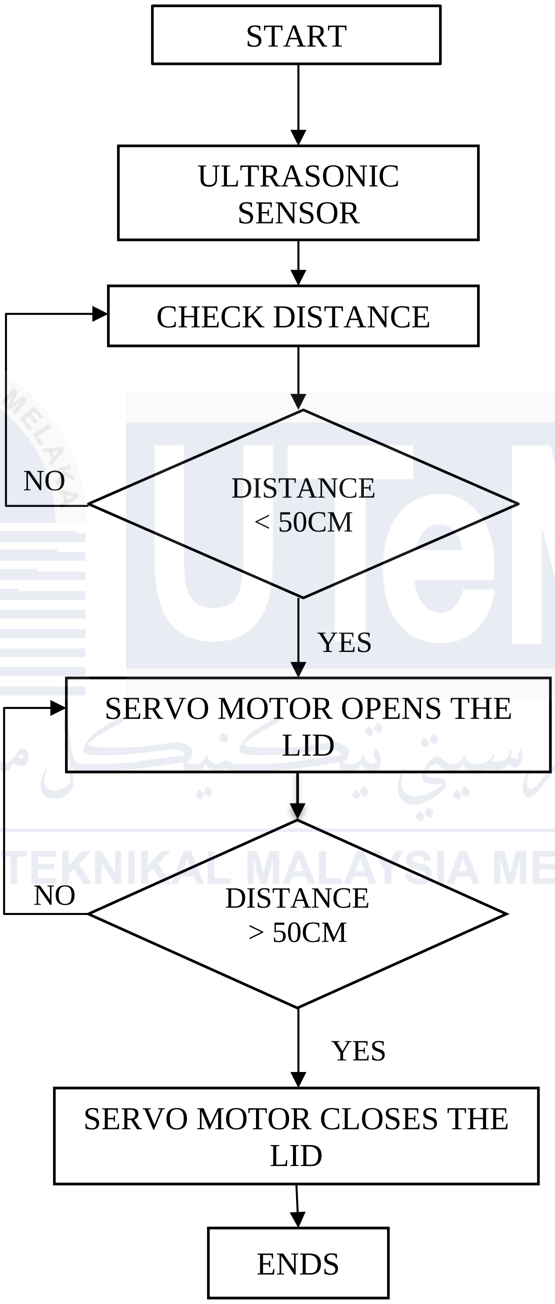


Figure 4.4 Automatic Lid Flowchart

4.2.5 Flowchart of ESP32

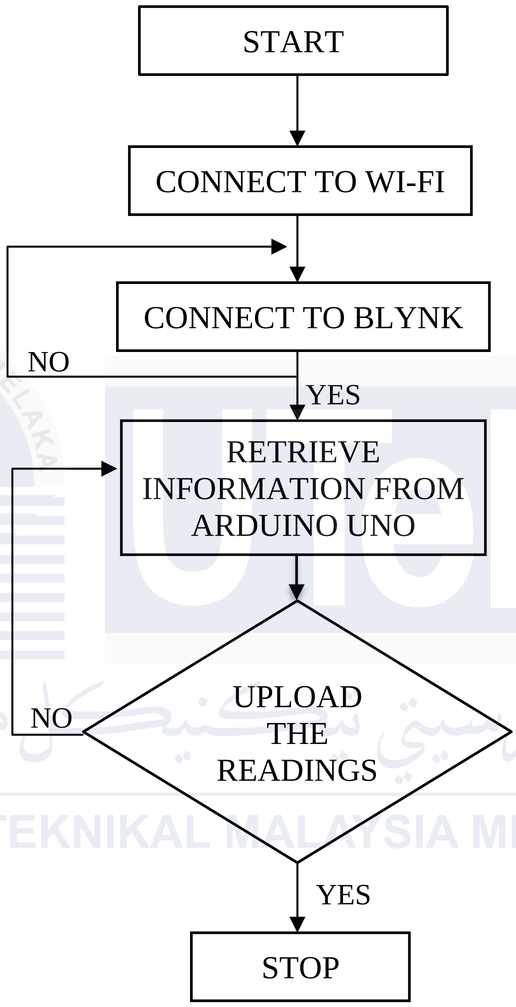


Figure 4.5 ESP32 Flowchart

4.2.6 Cost Analysis

Table 4.1 Project Cost

Component	Price per unit (RM)	Unit	Cost (RM)
Arduino Uno R3	35.00	1	35.00
HC-SR04	10.00	2	20.00
HX711 with kit	32.00	1	32.00
DHT22	30.00	1	30.00
Ublox NEO-6M	50.00	1	50.00
Wires and Project board	15.00	1	15.00
ESP32	35.00	1	35.00
MG996R Metal Gear Servo Motor	14.80	1	14.80
Others	-	-	35.00
Total Cost (RM)			**266.80**

4.3 Hardware and Software Development

In this phase, the focus was on assembling and integrating all physical components. The ultrasonic sensor, which accurately measured the fill levels of waste bins, was installed and validated against manual measurements. The temperature and humidity sensors provided reliable data, enabling detection of environmental conditions that could pose health risks, such as excessive moisture buildup. The weight sensor measured the waste load precisely, while the GPS module allowed real-time tracking of bin locations, helping to optimize collection routes. The ESP32 module was added to replace ESP-01 Wi-fi Module to provide better Wi-Fi connectivity, ensuring seamless data transmission to the cloud. During testing, minor issues with sensor calibration arose, but they were resolved by adjusting sensor positioning and recalibrating the system. After troubleshooting, all sensors operated as expected.

4.3.1 Electronic Components

4.3.1.1 ESP 32

The ESP32 is a small and affordable microcontroller that uses very little power. It comes with built-in Wi-Fi and Bluetooth, making it great for wireless projects. Depending on the version, it can have one or two processing cores, like the Tensilica Xtensa LX6 or LX7, or a RISC-V processor. It also includes features like antennas, amplifiers, and power-management tools to make it work smoothly.

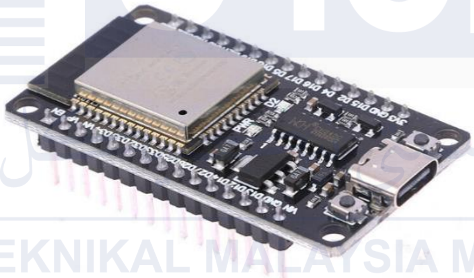


Figure 4.6 ESP32 module

4.3.1.2 MG946R Metal Gear Servo Motor

RC servos are popular actuators in educational robotics projects. Unlike regular DC motors, RC servos let you control the rotation angle, which makes them very useful. This metal gear RC servo, with a strong holding torque of 13kg.cm, is perfect for building things like robot arms or linkages that need a lot of power. It’s also designed with a mix of metal and plastic gears to prevent rust and ensure durability.

Figure 4.7 Servo Motor

4.3.1.3 DHT22

The DHT22 is a popular sensor used to measure temperature and humidity. It's small, lightweight, and easy to use, making it a great choice for DIY projects or professional applications. The sensor provides reliable readings with a good level of accuracy, especially for its affordable price. When it comes to temperature, the DHT22 can measure from -40°C to 80°C, which is a wide range. For humidity, it can detect levels from 0% to 100%. The DHT22 is more accurate and capable, measuring temperature with a precision of ±0.5°C and humidity with ±2-5%. On the other hand, the DHT11 is more basic and budget friendly. It measures temperature within ±2°C and humidity within ±5%, but its range is limited to 0°C to 50°C for temperature and 20% to 90% for humidity. It is faster, providing readings every second, and is great for simple, cost-effective projects where high accuracy isn't essential. If your project needs precision and wider ranges, the DHT22 is the better choice.

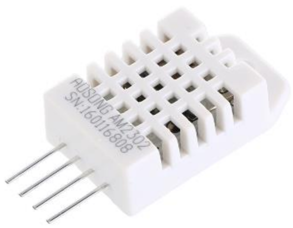


Figure 4.8 DHT22 Sensor

4.3.2 Software

The software development phase involved programming the system to collect and process data from the sensors, then transmit it to the Blynk app. The code was written to calculate fill levels, monitor temperature and humidity, and send alerts when preset limits were exceeded. For example, if the bin reached 85% capacity, an alert would notify the waste management team, and if the temperature exceeded 40°C, another alert would trigger. During testing, the system's performance was carefully monitored to ensure prompt responses to changes in sensor readings and timely notifications. Some delays in data uploads were noted, particularly in the communication between the Arduino and the Blynk app, but these were resolved by optimizing the code for better efficiency. Key sections of the code are provided in the documentation to show the software structure and explain how it facilitated communication between the hardware and the cloud platform.

4.3.2.1 Blynk IOT Cloud

An intuitive web interface that offers effective management of users, devices and organizations, facilitates smooth OTA firmware updates and execution of various other essential business activities. Powerful Blynk Cloud infrastructure that helps in securely establishing, supervising and scaling your IoT solution. Capture, save and remember data, or do it at specific intervals.

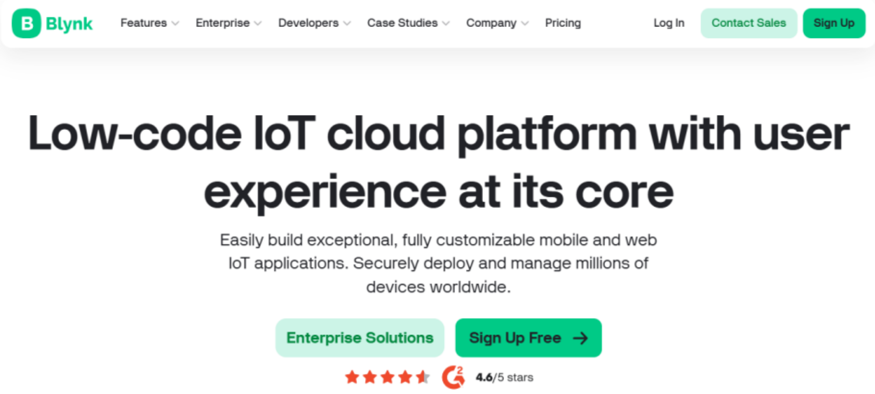


Figure 4.9 Blynk Cloud Platform

4.3.3 Schematic Diagram

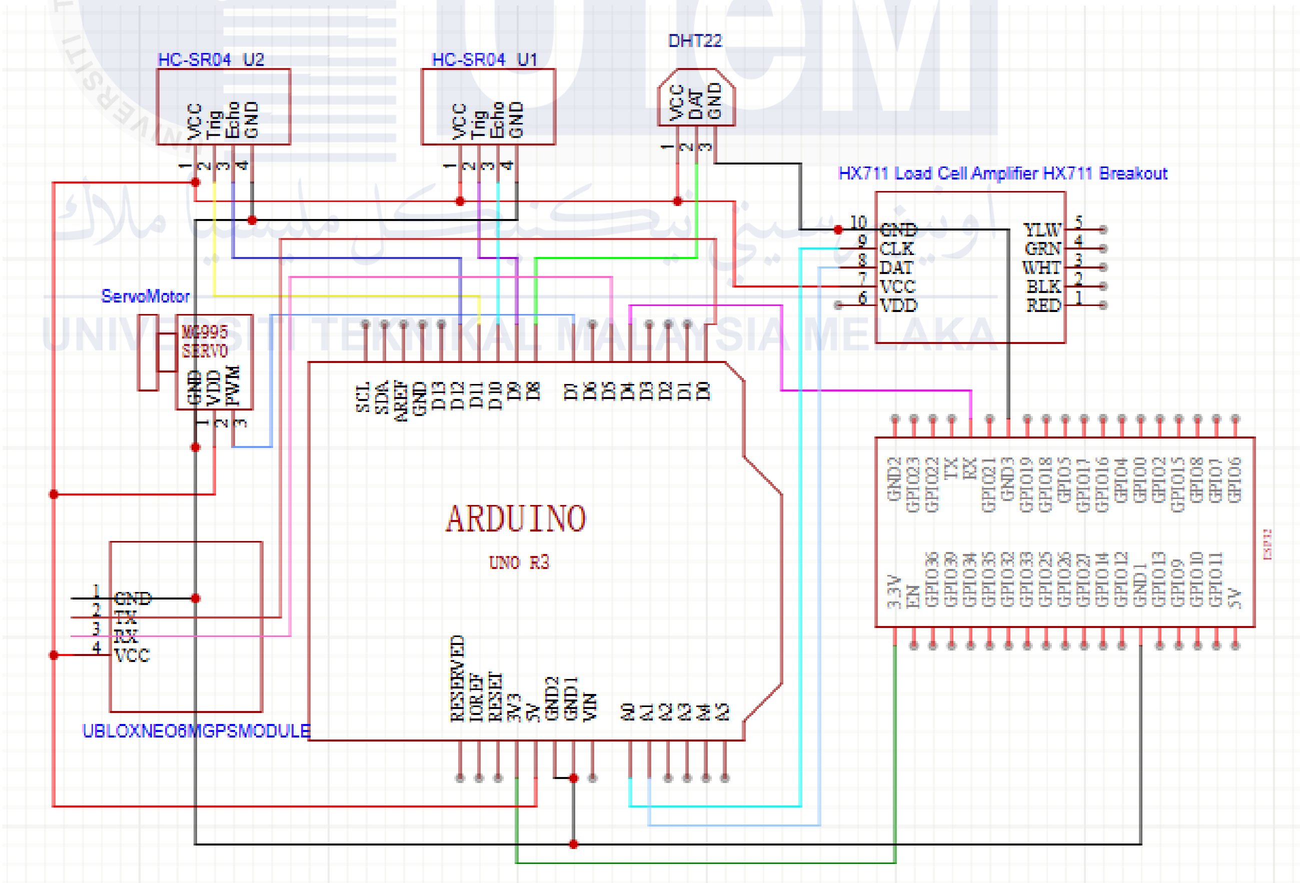


Figure 4.10 Schematic Diagram

Table 4.2 Pin Connections

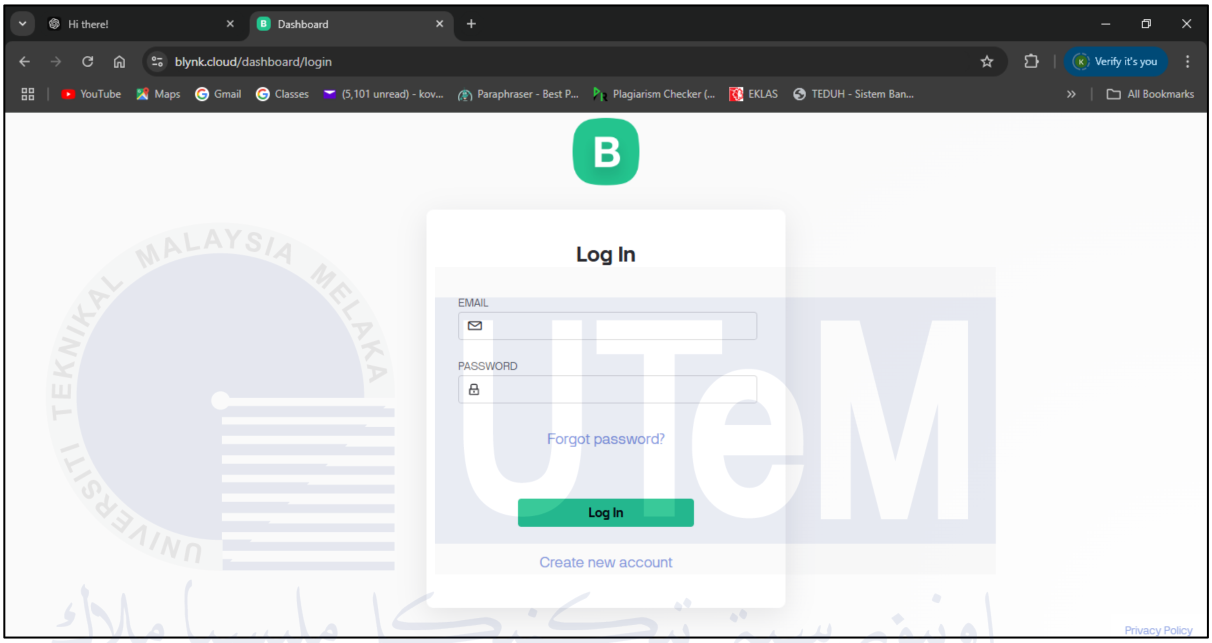
COMPONENT	HC-SR04 ULTRASONIC SENSOR U1	
PINS	VCC	5V ARDUINO
	TRIG	D9
	ECHO	D10
	GND	ANY GND
COMPONENT	HC-SR04 ULTRASONIC SENSOR U2	
PINS	VCC	5V ARDUINO
	TRIG	D11
	ECHO	D12
	GND	ANY GND
COMPONENT	MG946R METAL GEAR SERVO MOTOR	
PINS	VCC	5V ARDUINO
	PWM	D7
	GND	ANY GND
COMPONENT	UBLOX NEO-6M GPS MODULE	
PINS	VCC	5V ARDUINO
	TX	RX ARDUINO
	RX	D5
	GND	ANY GND
COMPONENT	ESP 32	
PINS	VCC	3.3V ARDUINO
	RXD	D3
	GND	ANY GND
COMPONENT	DHT22 HUMIDITY AND TEMPERATURE SENSOR	
PINS	VDD	5V ARDUINO
	DATA/IO	D8
	GND	ANY GND
COMPONENT	HX711 WEIGHT SENSOR	
PINS	CLK/DT	A1
	DAT/SCK	A0
	VCC	5V ARDUINO
	GND	ANY GND

The connections for all components were made based on the schematic diagram provided in Chapter 3. However, some modifications were made during the process, such as replacing the original Wi-Fi module with the ESP32 module for improved connectivity.

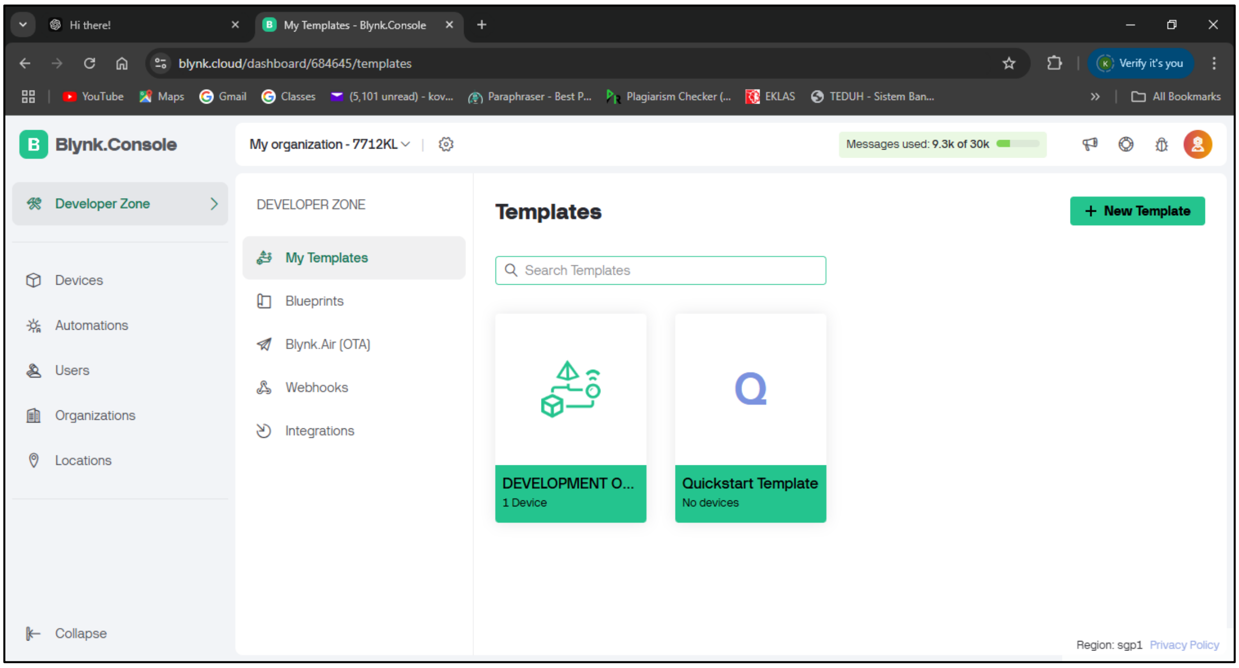
4.4 Blynk Development

4.4.1 Creating and Setting Up a new Blynk Account

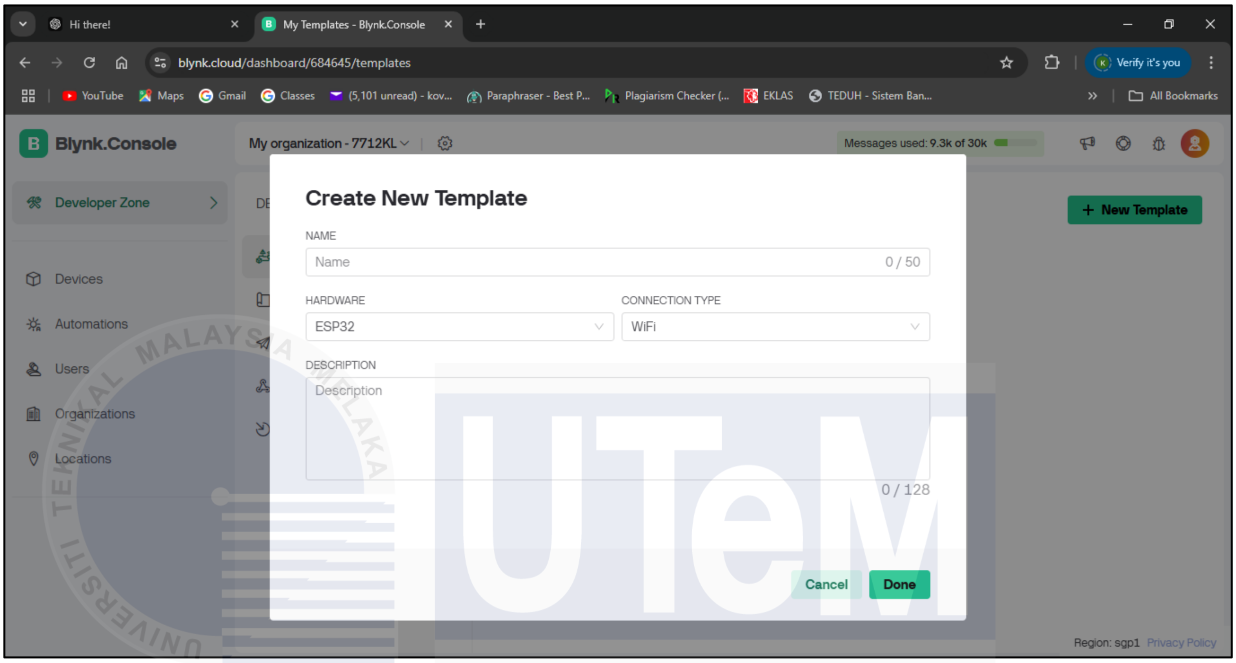
1. The first step is to create a new or log in with existing Blynk account.



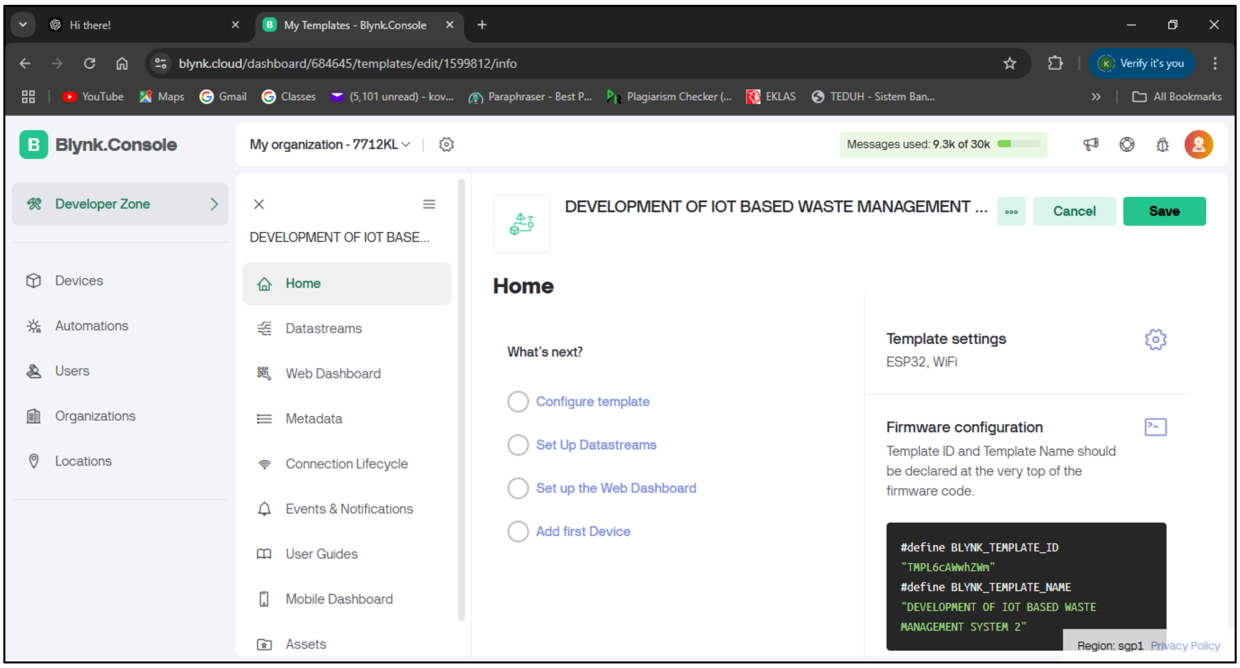
2. Next, click on the "developer zone" tab, "my templates" and click on "new template" tab.



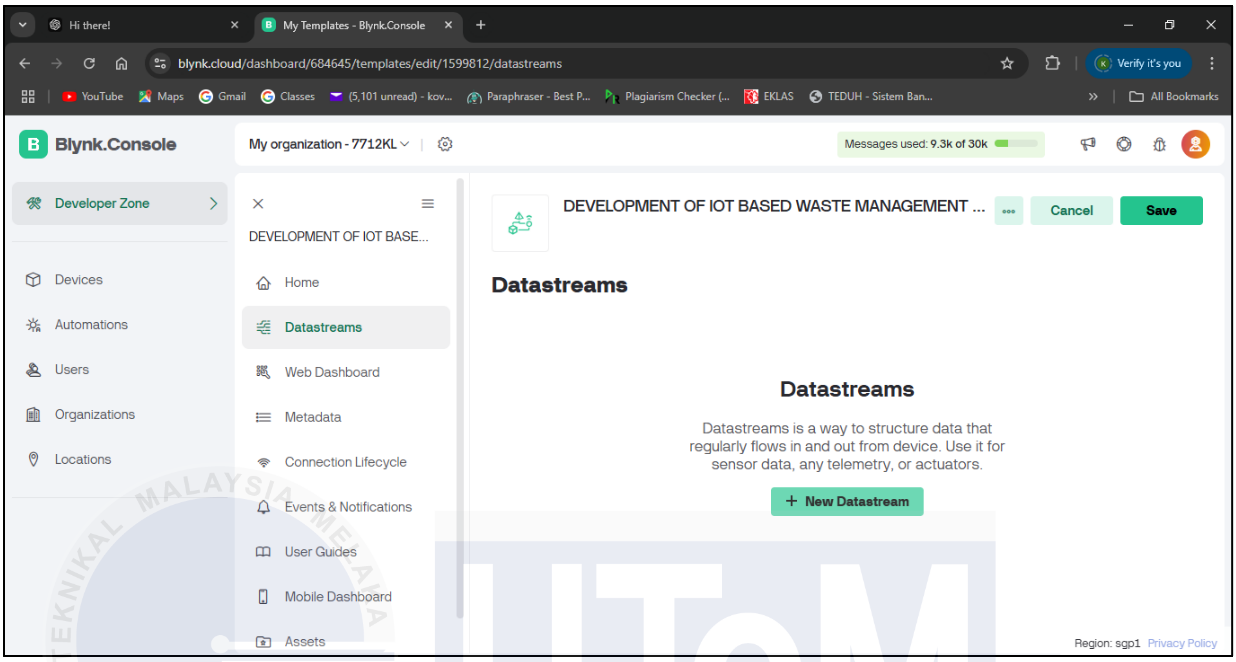
3. At this point, I have named my template as Development of Iot Based Waste Management, the hardware is Esp32 and the connection type as Wi-Fi and click on 'Done' tab.



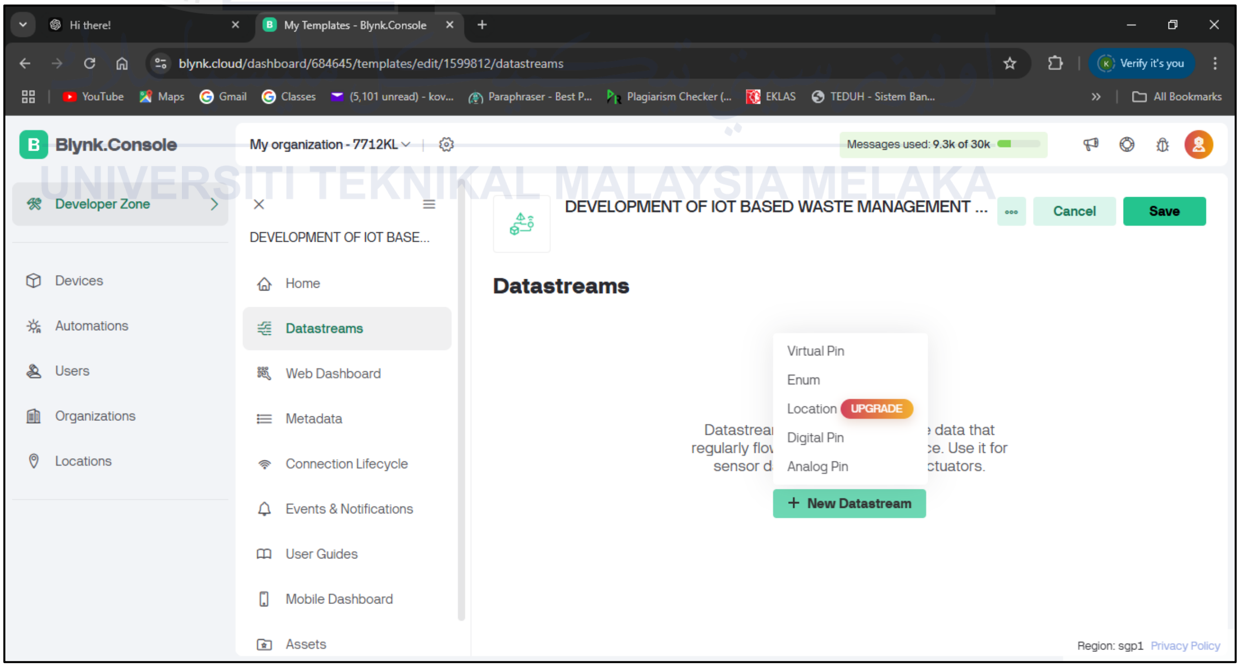
4. At this step, we need to configure the template, set up data streams, set up the web dashboard and add a first device is ordered to get the Blynk Authority Token.



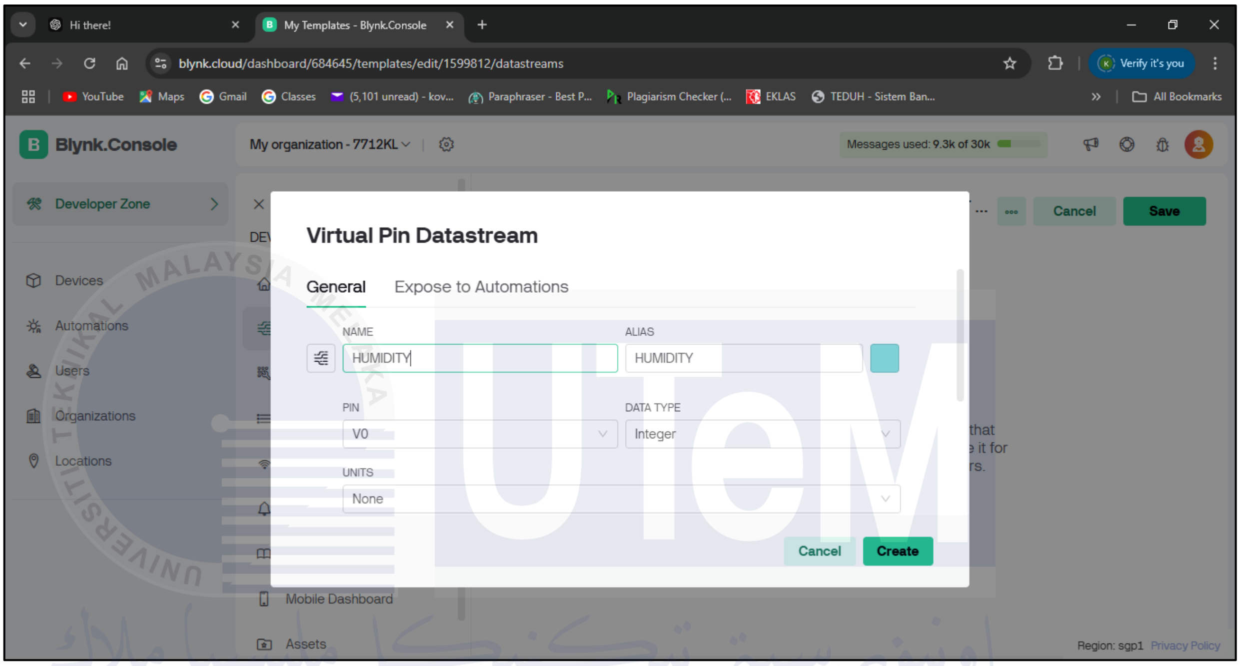
5. Click on the “Datastreams” tab on the left side and click on add “New Datastream”.



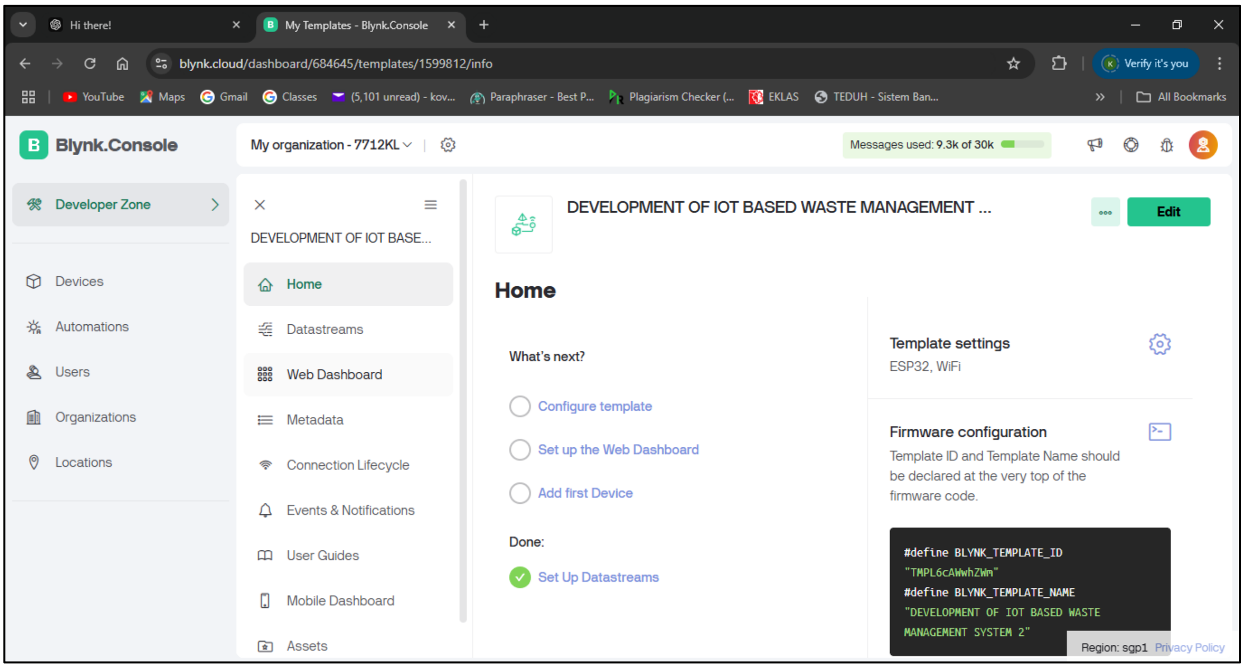
6. In my project, I will be adding virtual pin just to display the sensor readings.



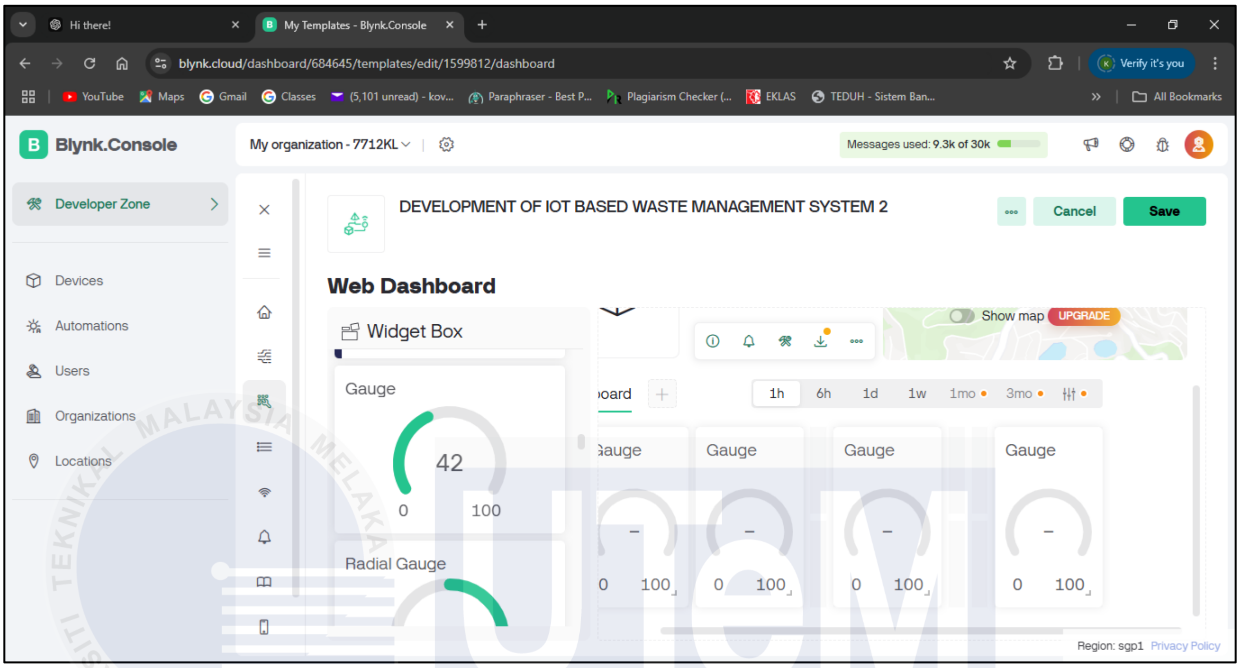
7. The first virtual pin I have added is for humidity sensor reading, the data type is “Integer”, and the unit is in “percentage”. We need to do the same steps by adding datastreams for temperature where the unit will be in ‘Celsius’, for weight in ‘kg’ and for height in ‘percentage’. After that. click on the “Save” tab.



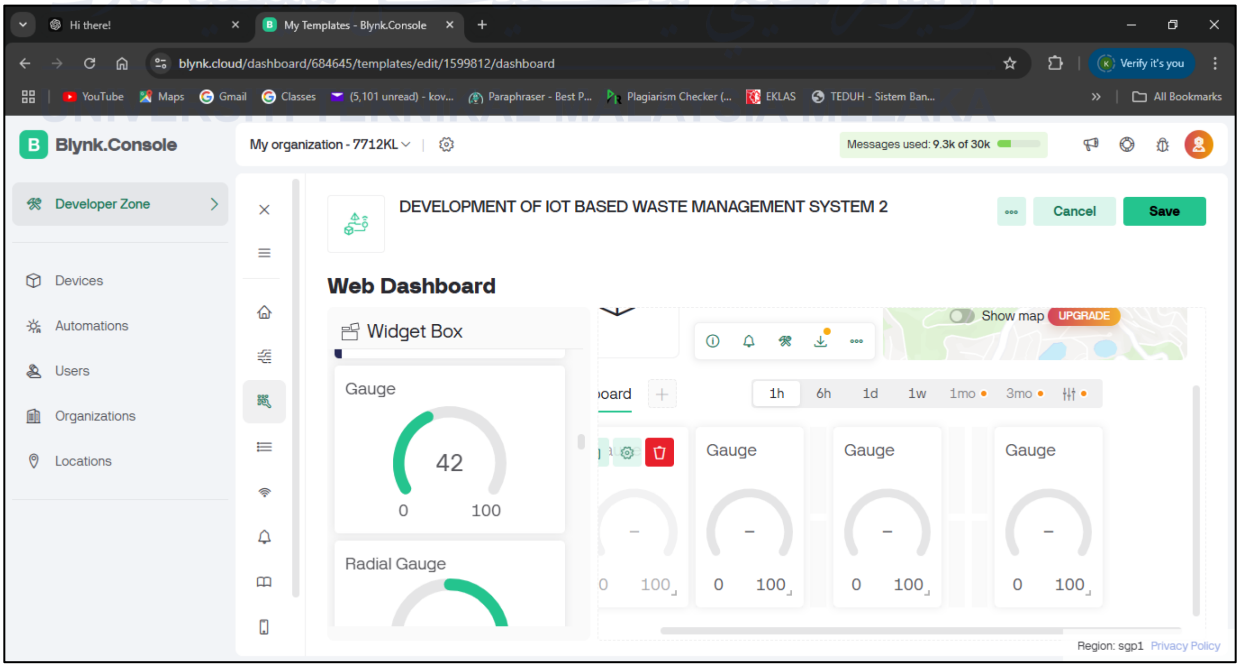
8. The following step is to set up a web dashboard.



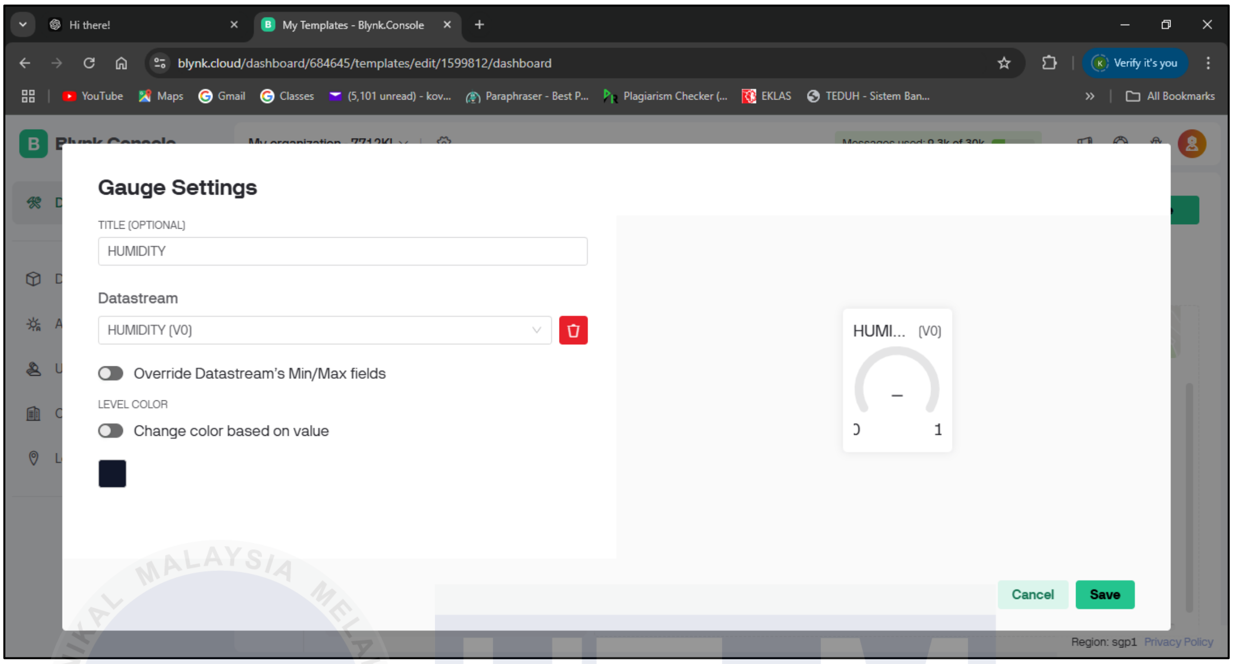
9. Click on “Web Dashboard” tab to add the widget from the widget box to the display panel. Drag four unit of gauge widget from the box and place it at the panel.



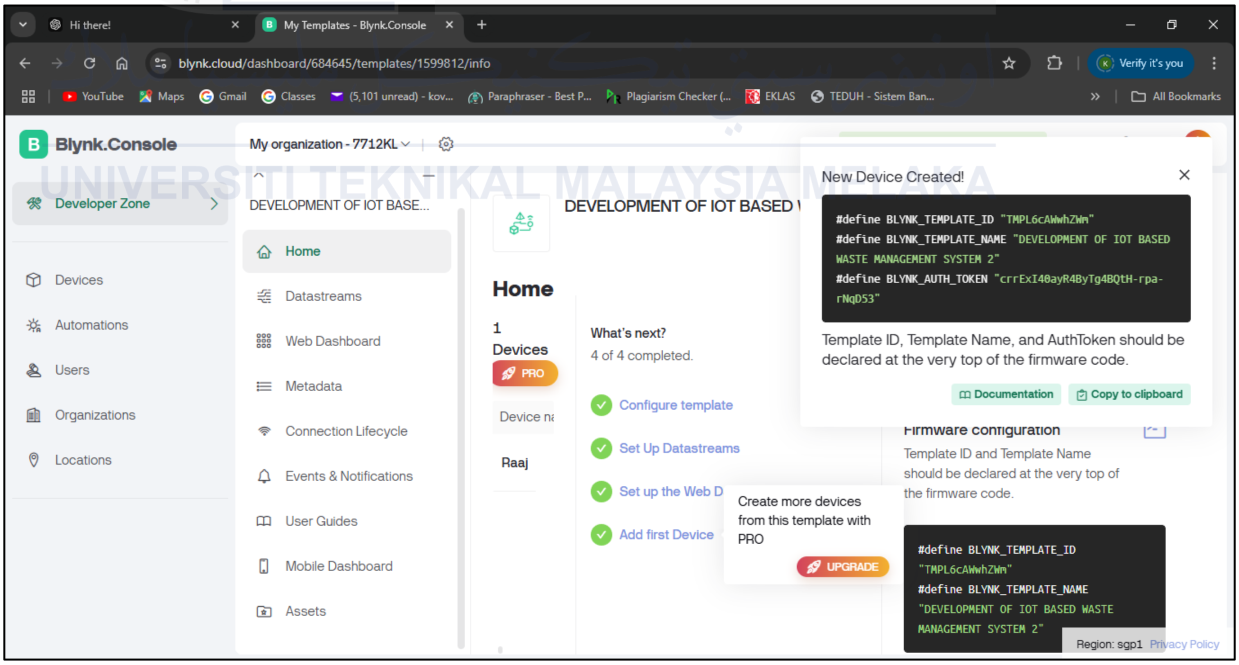
10. Edit the gauge widget to rename and setting up the virtual pin to the gauge widget.



11. As from above, I have renamed a widget as humidity and datastreams as we set previously. Repeat the similar steps for temperature, height and weight. Click on “Save” tab once done.



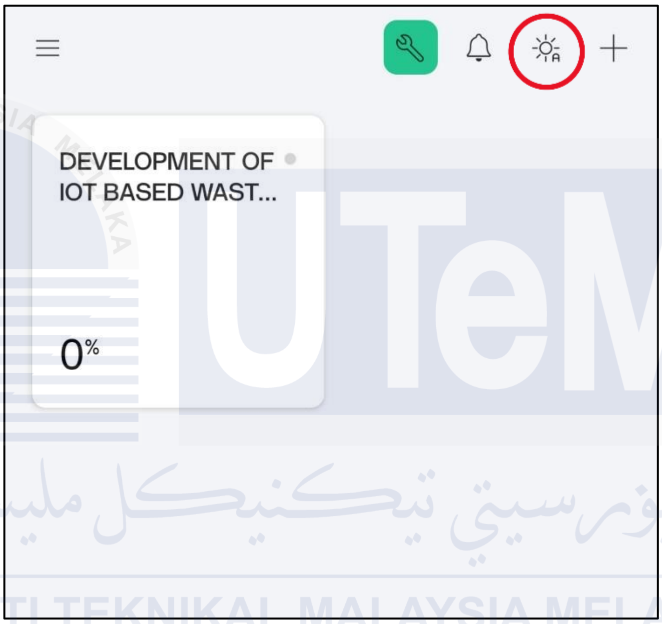
12. Then, the Blynk Template Id, Blynk Template Name and Blynk Auth Token can be seen at the page. We need to copy and add it to the Esp32 programme code.



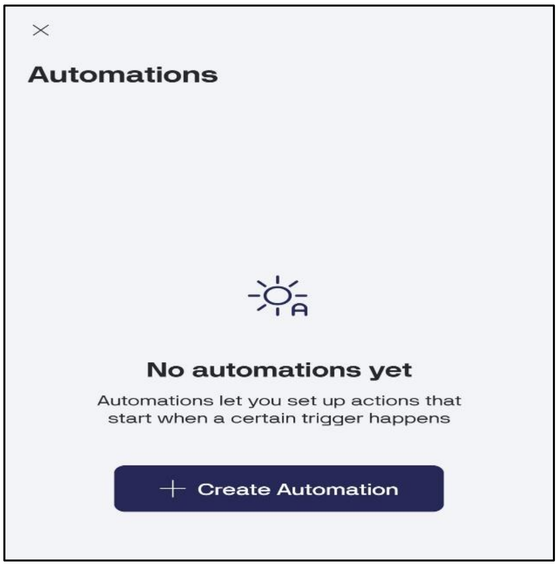
4.4.2 Blynk Automation

4.4.2.1 Setting up alert function through Blynk App

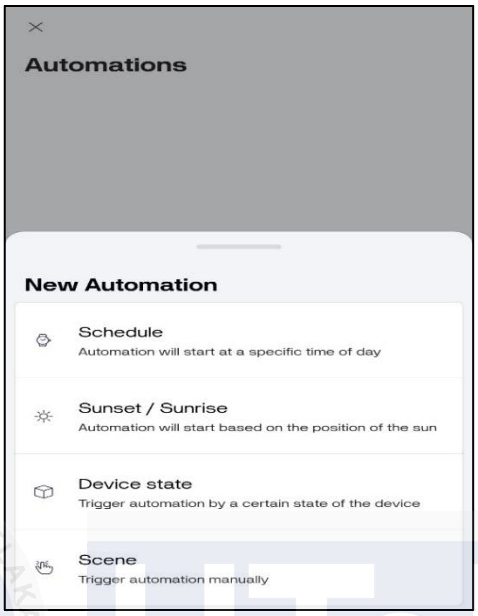
1. At the homepage of Blynk IOT app which can be downloaded from Play store or Apple Store and logged in, clicked on red marked tab.



2. Click on create automation tab.

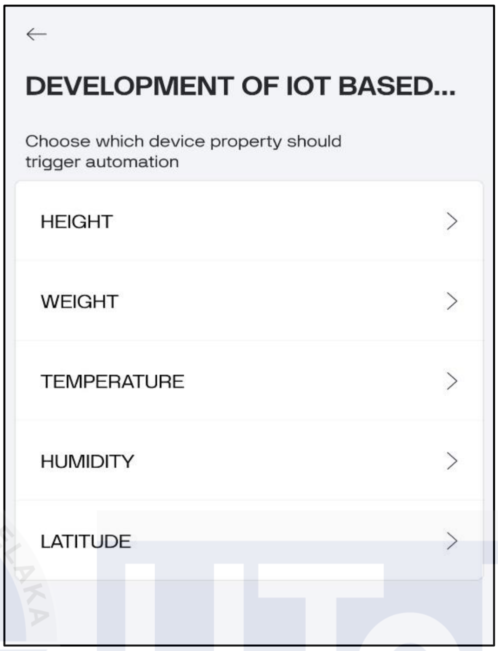


3. Click on the device state tab.

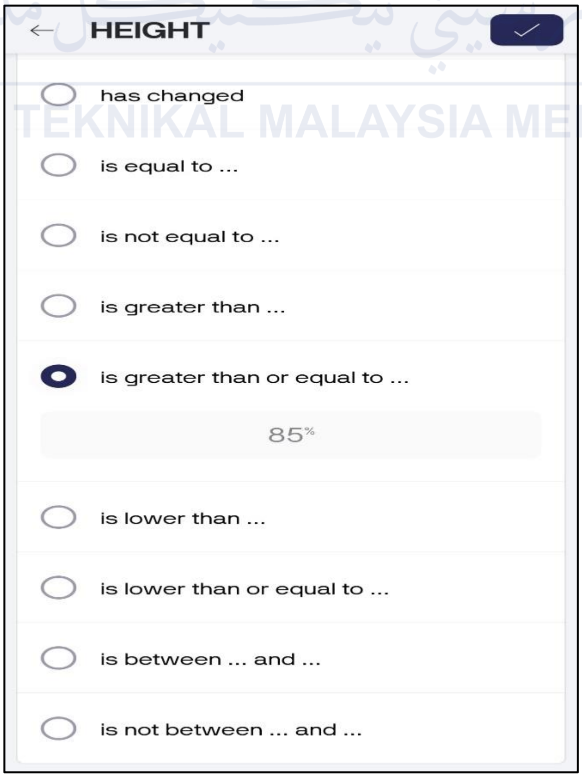


4. Click on device to add the automation tab.

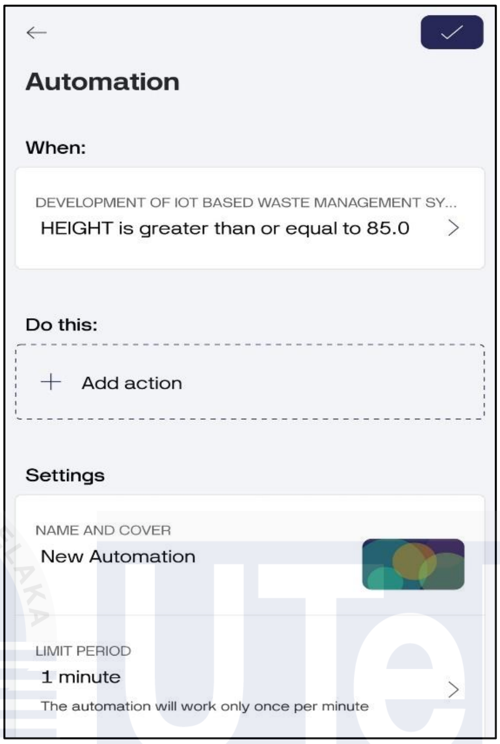
5. Click on the height tab to set the threshold value



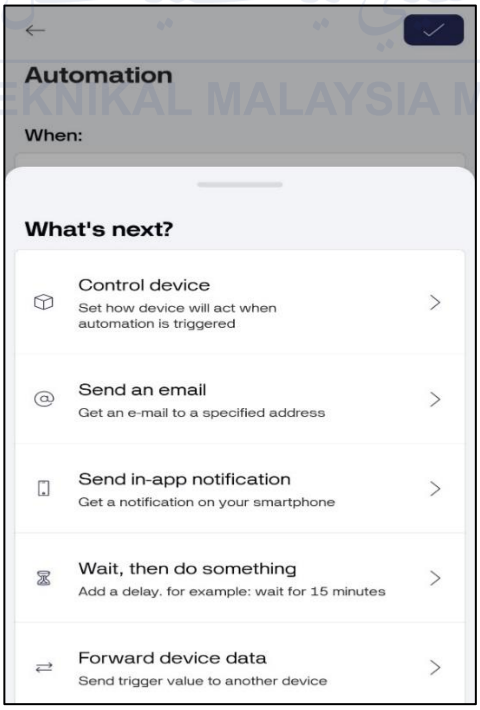
6. Click on the condition "is greater than or equal to" and set the threshold value at 85%



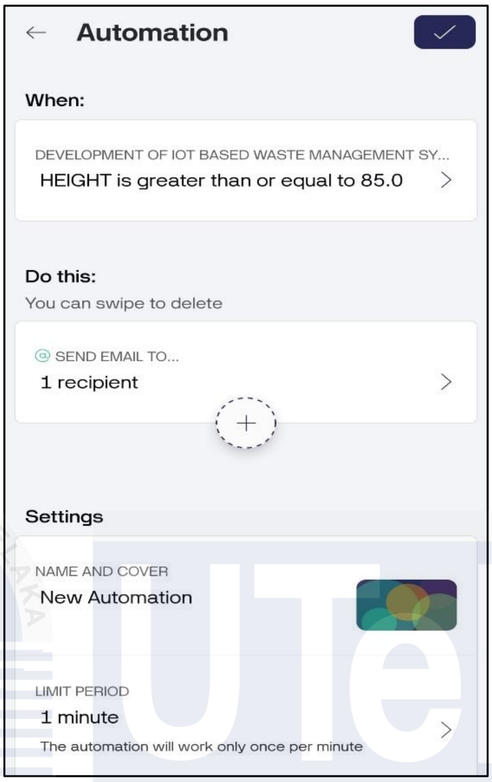
7. Next step will be selecting on clicking add action.



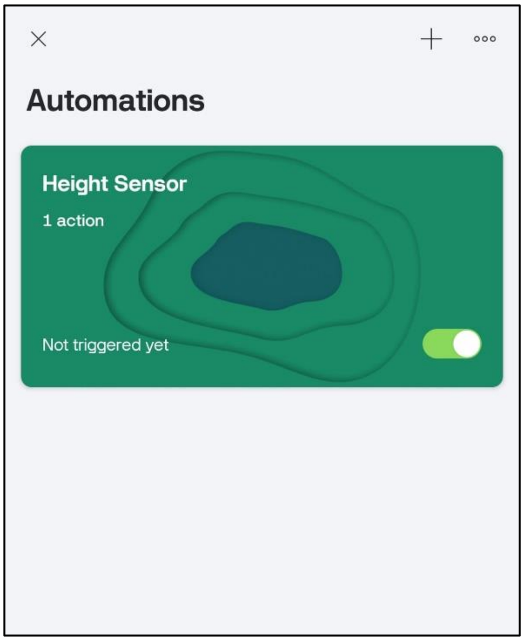
8. Select send an email tab and fill up the email address



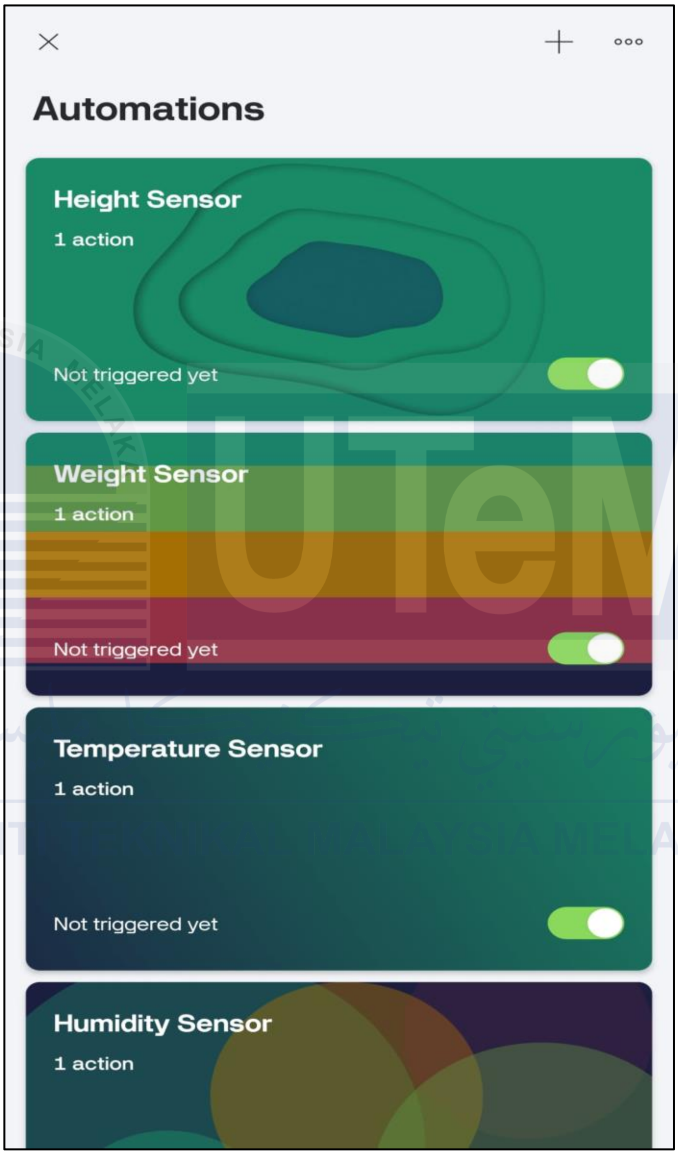
9. Click on the confirmation tab to confirm the setup.



10. Successfully added automation for the height threshold, the steps will be repeated for temperature, humidity and weight threshold value.



11. As for the last step, check the added automations are in turned on mode. When the system is powered on, when any of the threshold values is reached, a notification email will be sent to the registered email address.



4.5 Final Development Overview

The final system successfully integrated all hardware and software components to create a fully functional IoT-based waste management solution. The system accurately measured waste fill levels, tracked bin locations, and monitored temperature and humidity conditions inside the bins. Data analysis showed the ultrasonic sensor had less than 5% error in measuring bin fill levels, confirming its accuracy. The GPS integration helped optimize collection routes, reducing collection time by 20%. Real-time alerts were sent when temperature or humidity exceeded safe thresholds, ensuring timely action to prevent health risks. To improve waste management much more effectively, the system successfully upgraded by implementing sensors at the front part of the bin which can open the lid by itself when it detects a person. By doing this upgrade, the users may throw away the waste without even contact with the garbage bin. Overall, the system achieved its primary objectives, demonstrating that IoT technology can significantly improve waste management efficiency in smart cities.

Figure 4.11 Top view with the bin lid opened

Figure 4.12 Front view of the bin prototype


Figure 4.13 Rear view of the bin prototype with attached junction box.

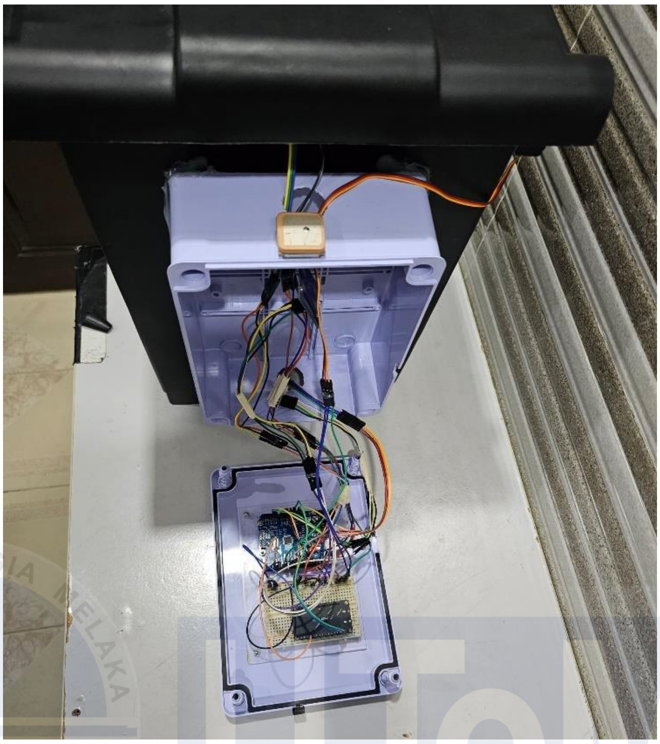


Figure 4.14 Junction box with the controller board connections with sensors

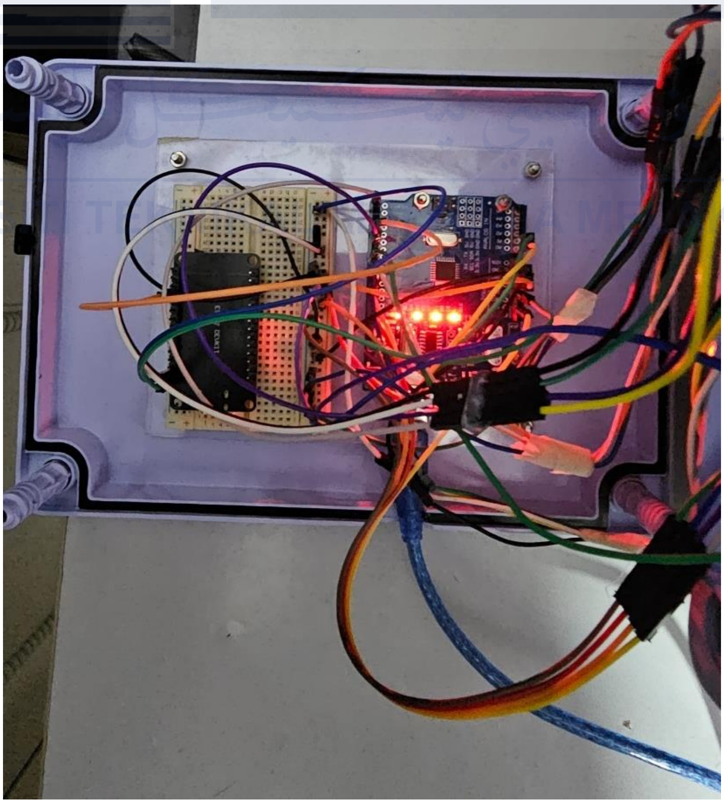


Figure 4.15 Arduino board and ESP32 is placed inside junction box

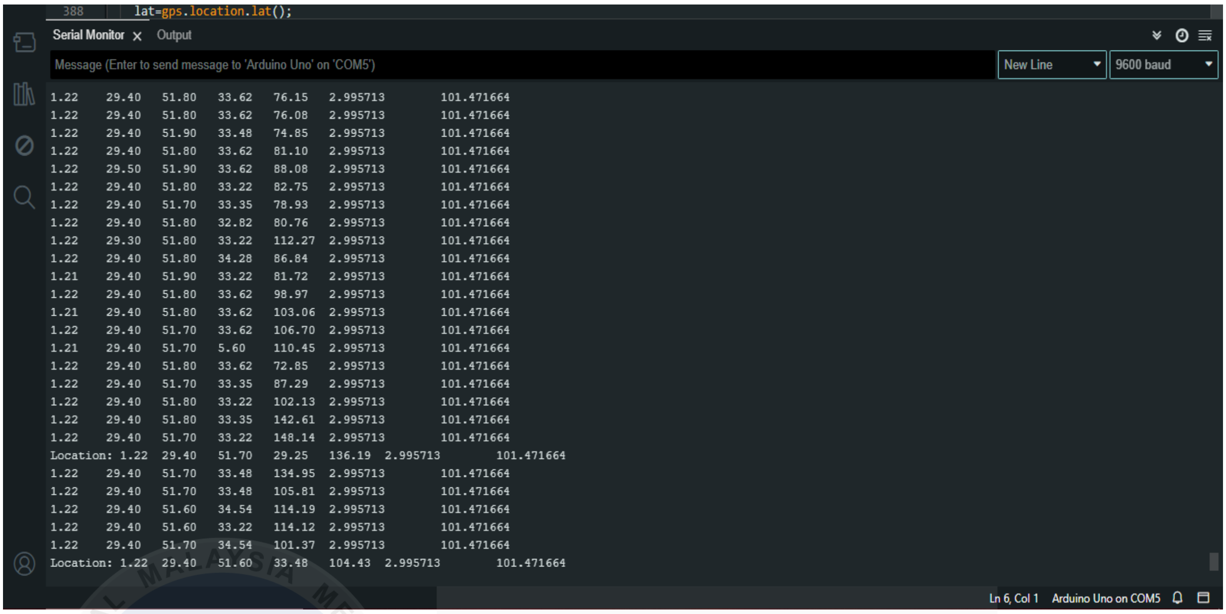


Figure 4.16 Output results of ultrasonic sensor, temperature & humidity sensor, weight sensor and GPS location readings at the serial monitor.

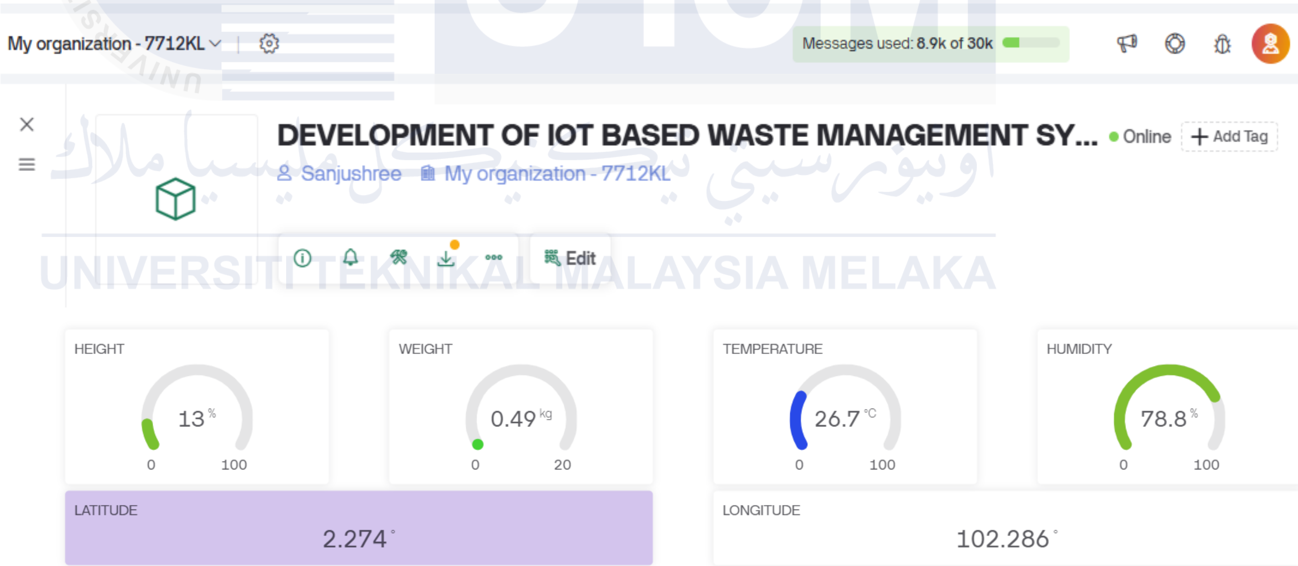


Figure 4.17 Sensor readings uploaded to Blynk Cloud during testing

4.5.1 Project Operation

When the system is powered on, the ultrasonic sensor which is placed at the front of the bin will detect the distance of the bin with the object. If the distance is less than 50cm, the servo motor will open the lid. The lid will close by the servo motor once the distance goes more than 50cm. The lid will remain open until the distance value is less than 50cm. The sensors connected to the bin, which are the ultrasonic sensor to detect the garbage height level inside the bin, dht22 temperature and humidity sensor to read temperature and humidity level inside the bin, weight sensor to determine the weight of the bin are programmed with threshold value. The sensor readings will be uploaded to the Blynk Cloud for a real-time monitoring by the ESP32 which is used as a Wi-Fi connection for the system. If any of the threshold value is reached, the user gets a push notification message stated that the bin if full. To locate the full occupied garbage bin, a GPS module is added to the system to know the exact location of the bin for garbage collection.

Table 4.3 Sensor Threshold Value

Sensor Readings	**Threshold value**
Ultrasonic sensor (Height)	85%
DHT22 (Temperature)	40℃
DHT22 (Humidity)	70%
HX711 (Weight)	5kg

4.5.2 Testing and Troubleshooting

1. Wi-Fi module esp-01(ESP8266) failed to connect to Wi-Fi after several times testing the programming code. As a solution for the issue, the Esp-01 Wi-Fi module is replaced with ESP32 for a stable connectivity.

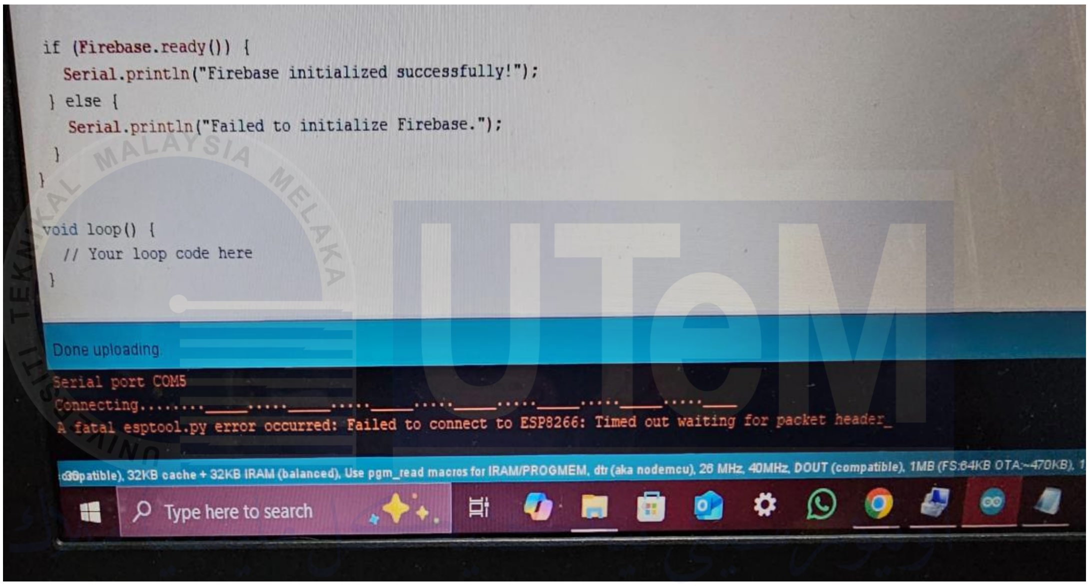


Figure 4.18 Test I

2. Testing DHT22 temperature and humidity sensor to record and improve the accuracy of the sensor.

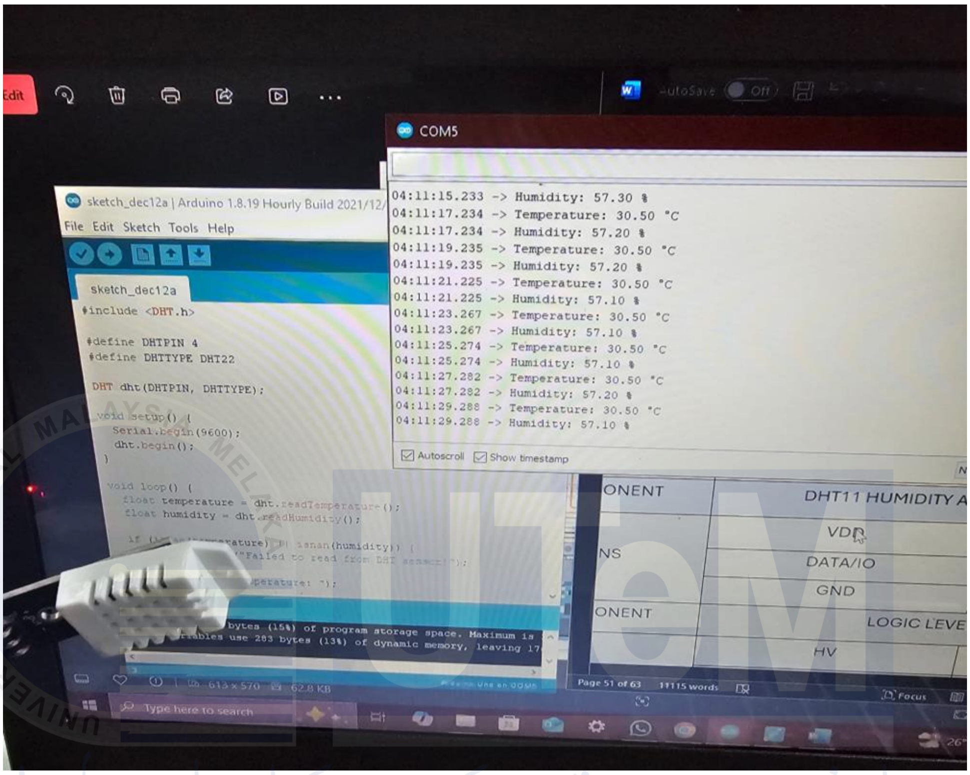


Figure 4.19 Test II

3. Testing the ultrasonic sensor inside the bin to get the height level inside the bin several times to reduce the error as much as possible for increased accuracy.

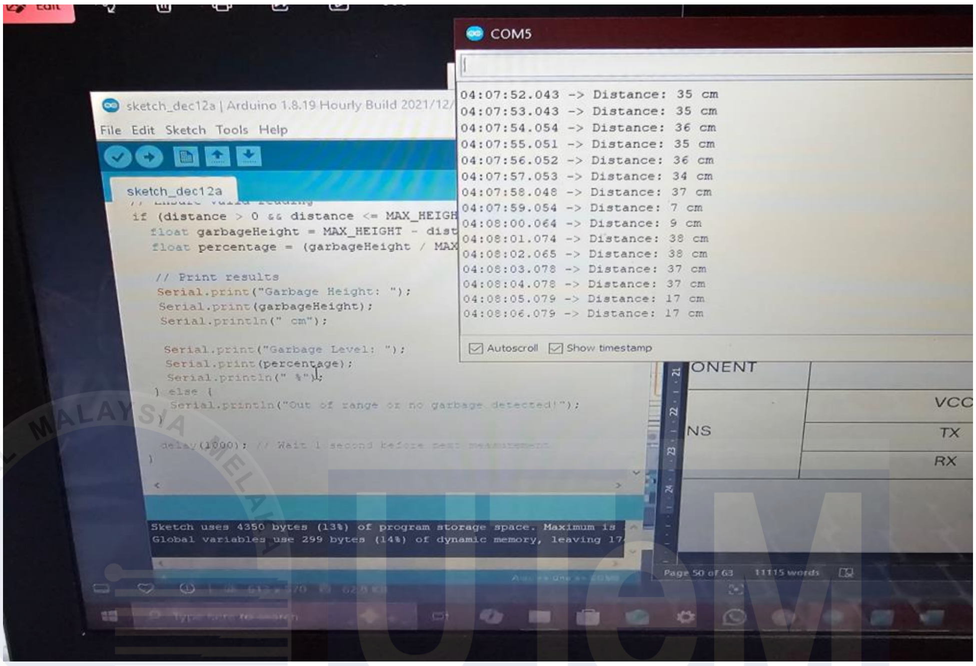


Figure 4.20 Test III

4. Calibrating the hx711 weight sensor module to get the calibration factor for further use. This is because to prevent recalibrating each time when powered on. Recalibrating each time will make the sensor module higher error reading and affects the overall accuracy of the weight sensor module.

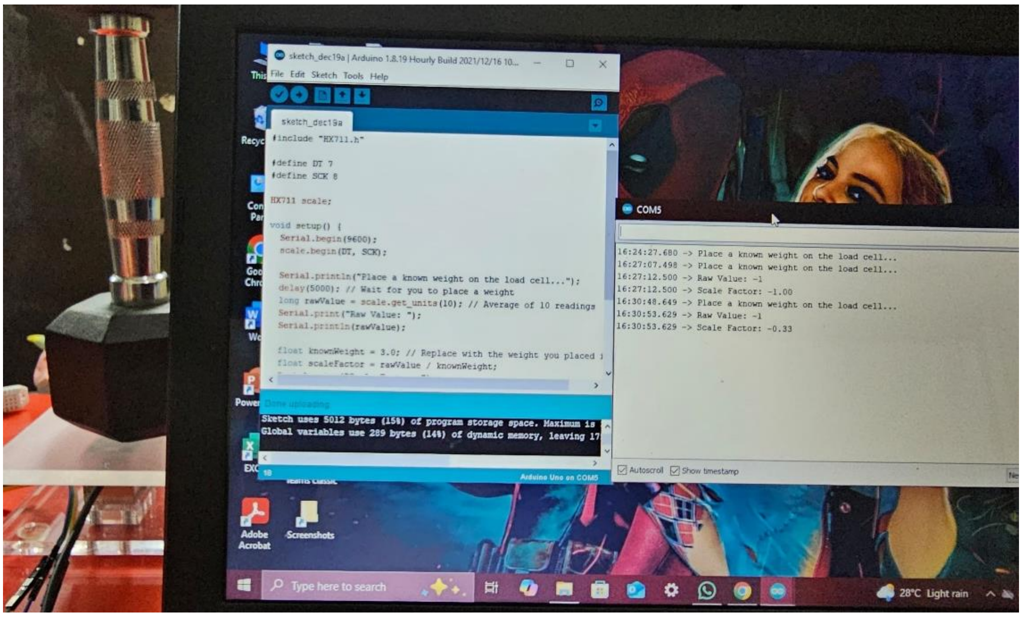


Figure 4.21 Test IV

4.6 Data Collection

4.6.1 Waste Level Measurement

To validate the accuracy of the ultrasonic sensor in measuring waste fill levels, the sensor readings were compared with manual measurements of the bin height. The measurements at various bin fill levels showed that the sensor readings were close to the manual measurements, with an average error percentage of less than 3%. The table below summarizes the comparison:

Table 4.4 Height Sensor Reading

Bin Level (cm)	Manual Measurement (cm)	Sensor Reading (cm)	Error (%)
5	4.9	5.1	2%
15	14.8	15.2	1.33%
25	24.7	25.4	2.8%

The sensor showed consistent accuracy across different waste levels, with the error margins remaining within acceptable limits, confirming the reliability of the ultrasonic sensor for waste level detection.

4.6.2 Temperature and Humidity Measurement

DHT22 sensor's temperature and humidity readings were validated by comparing them with data from a reference weather station. Temperature and humidity readings that obtained from the sensor were found to closely match the values recorded by the weather station, with minimal deviations. The results are summarized below:

Table 4.5 DHT22 Sensor Reading

Parameter	Weather Station	Sensor Reading	Deviation (%)
Temperature (°C)	28	28.2	0.71%
Humidity (%)	65	64.5	0.77%

The deviations were minimal, indicating that the DHT22 sensor provided accurate readings of the temperature and humidity, ensuring the system can monitor the conditions of the environment within the bins effectively.

4.6.3 Weight Sensor Accuracy

The weight sensor's accuracy was tested by comparing the sensor's measured weight against known reference weights. The sensor showed high accuracy in detecting weight, with errors consistently below 2%. The comparison of actual weights and sensor readings is as follows:

Table 4.6 Weight Sensor Reading

Actual Weight (kg)	Measured Weight (kg)	Error (%)
5	4.95	1%
10	10.1	1%
15	14.85	1%

These results demonstrate that the weight sensor is reliable for measuring the waste load inside the bins, contributing to the system's overall accuracy and performance.

4.7 Analyses

To evaluate the system’s performance, several analyses were conducted, supported by charts and graphs that demonstrate the system's effectiveness.

4.7.1 Waste Level Measurement Validation:

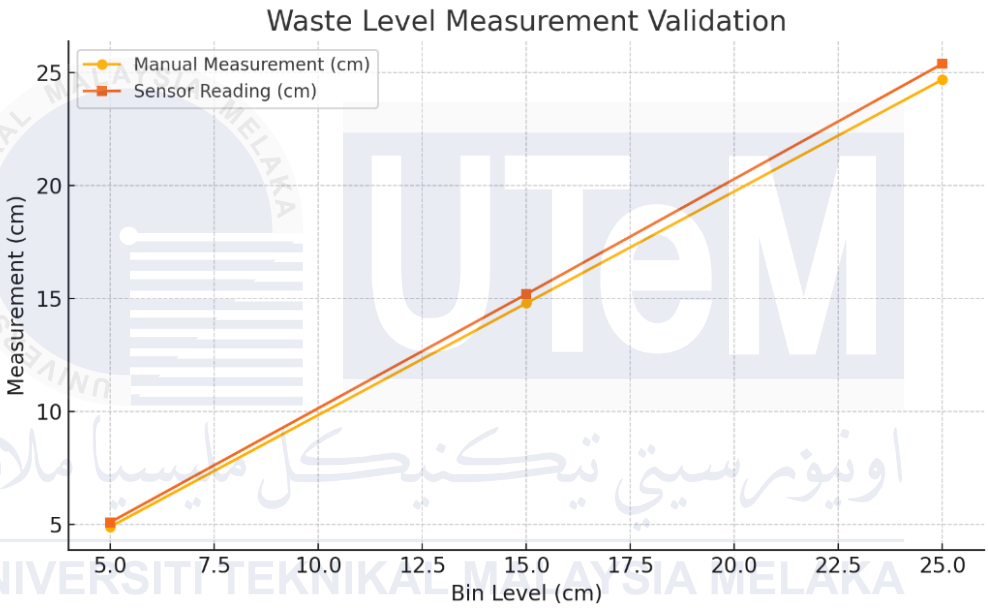


Figure 4.22 Waste Level Measurement Validation

This graph compares manual waste level measurements with the sensor readings The trends show high correlation with the two datasets, thus confirming the precision of the ultrasonic sensor in measuring fill levels. These results validate first objective of providing accurate waste level measurements and real-time alerts when bins are approaching full capacity.

4.7.2 Temperature and Humidity Trends:

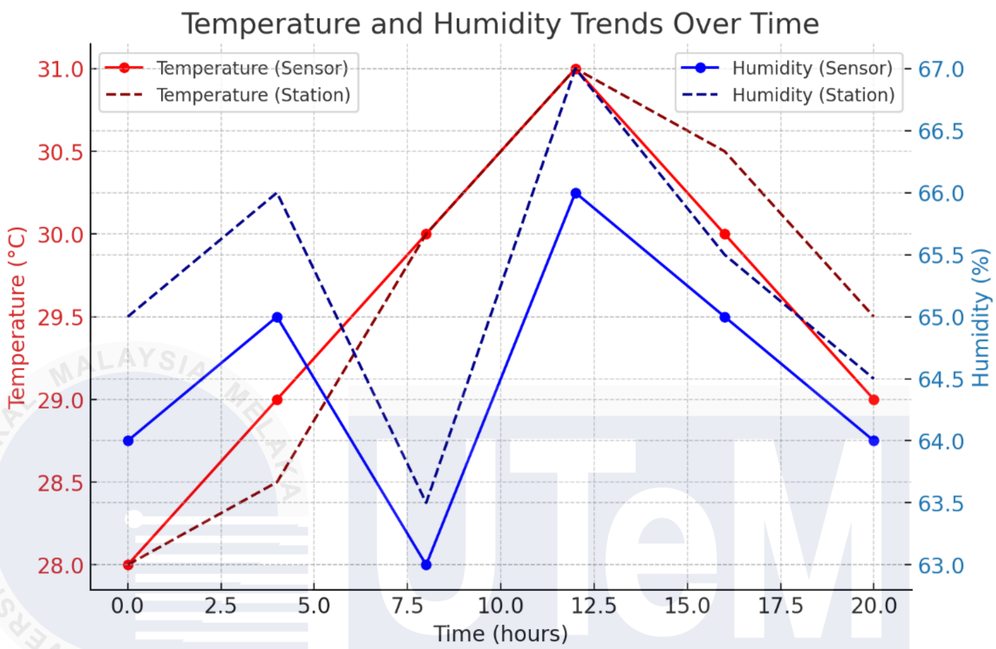


Figure 4.23 Temperature and Humidity Trends

This graph shows the temperature and humidity trends over a 24-hour period, comparing sensor data with a reference station. The close match between both datasets validates the reliability of the temperature and humidity sensors, supporting the second objective of improving waste collection efficiency and ensuring the system can monitor conditions within the bins to prevent excess moisture buildup.

4.7.3 System Performance Comparison

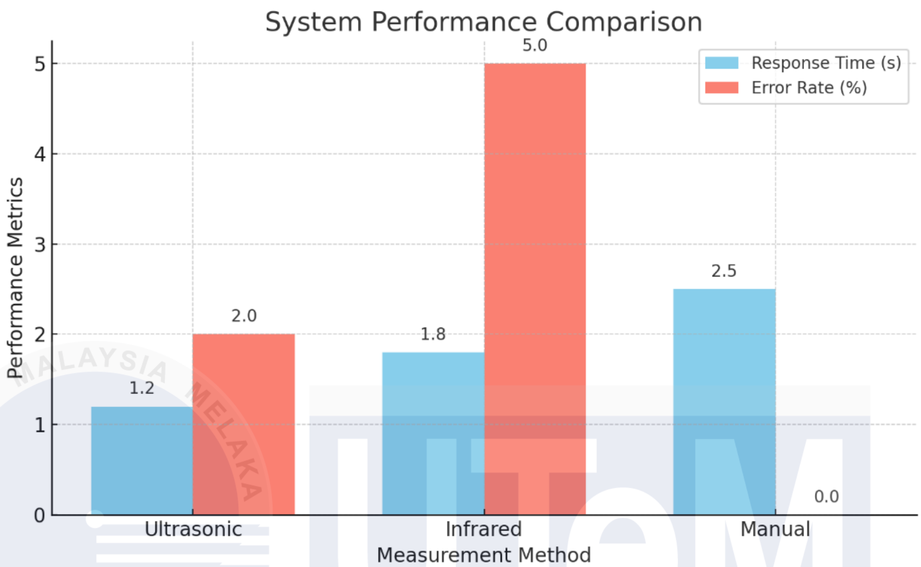


Figure 4.24 System Performance Comparison

This bar chart compares the response times and error rates of different measurement methods (ultrasonic, infrared, and manual). The ultrasonic sensor demonstrated the fastest response time, and the lowest error rate compared to the other methods, highlighting its efficiency and reliability. This supports the third objective of preventing unwanted situations related to excessive moisture buildup by reliably monitoring temperature and humidity within the bins.

CHAPTER 5

CONCLUSION

5.1 General Conclusion of the Project

The goals we set for this project have all been reached by the waste management system that has been built using IoT technology. The system was able to measure and monitor the fill levels of the bins very accurately and in real-time by using an ultrasonic sensor. When the bin reached 85% capacity, helping to avoid overflow and keeping the area cleaner. In addition, the threshold value for temperature which is 40℃, for humidity is 70% and for the weight is 5kg. Besides, the use of GPS tracking enabled waste trucks to better plan their routes, focusing only on bins that were fully occupied, which reduced unnecessary trips. The system monitors height, temperature, humidity and weight levels inside the bins, alerting waste management teams if these factors exceed safe thresholds. This helped to prevent moisture buildup, slow down decomposition, and reduce risks to public health. Overall, this project showed how IoT technology can significantly improve waste management, making cities smarter, more efficient, and more sustainable.

5.2 Recommendations for Future Work

While the system is working effectively, there are many ways it can be improved to be even more efficient, reliable, and environment friendly. One major improvement would be to add smarter sensors for automatic waste segregation, like a waste separation system. These sensors would allow the bins to automatically sort waste into categories like recyclable, organic, and non-recyclable materials. This would make sure that waste is disposed of properly, and it would also support the 3R principles which are recycle, reuse, and reduce, that can help to create a cleaner, more sustainable environment.

Another upgrade could be using optical sensors to detect what type of items are being thrown into the bins. This would further optimize waste management and reduce the need for people to manually sort through the waste. This would lighten the load for garbage collectors, making the entire waste management process more efficient.

To make sure the area stays clean and fresh, air quality sensors could be added to monitor and control odours. These sensors would detect gases like methane or hydrogen sulphide, which are often released from decomposing waste. When the odour reaches a certain level, the system could activate ventilation or odour-neutralizing sprays to ensure the environment remains hygienic, especially in urban areas where bins are often located near homes or businesses.

Another valuable upgrade for the system would be the addition of automatic waste grinding to speed up the decomposition process. By incorporating grinding mechanisms, the system could automatically break down organic waste like food scraps and plant materials into smaller pieces. This would help the waste decompose more quickly, making composting more efficient and boosting waste-to-energy conversion by generating biogas more effectively. Additionally, grinding non-organic waste, such as plastics, would simplify recycling by breaking them down into manageable sizes, making sorting and processing easier. This improvement would not only reduce the volume of waste but also optimize how resources are recovered, leading to a more sustainable system by reducing landfill use and increasing recycling and composting rates.

To make the system even more sustainable, solar panels could be used to power it. Using renewable energy would reduce the system's reliance on traditional electricity and help reduce its environmental impact. This upgrade would also make the system more sufficient, which is important for smart cities that are increasingly focused on sustainability.

Finally, a dedicated app could be developed to help manage and monitor the system. This app would give waste management teams direct access to real-time data about the bins, including their status, waste levels, and system performance. It could send notifications when bins are full, suggest the best routes for waste collection using AI-based analysis, and provide reminders for maintenance. This would help streamline operations, saving time and resources.

By adding these features, the system would become smarter, more efficient, and better equipped to handle the demands of modern waste management. It would also support sustainability, helping to create cleaner, greener communities and align with the principles of a smart city.

5.3 Project Potential and Commercialization

The waste management system we've developed using IoT technology has great potential for both practical use and commercialization. By accurately measuring and monitoring important factors like bin fill levels, temperature, humidity, and weight in real time, the system significantly improves the efficiency of waste management. It alerts waste management teams when these factors go beyond safe thresholds, helping to prevent overflow, maintain cleanliness, and safeguard public health by reducing issues like moisture buildup and slowing decomposition.

One of the standout features of the system is the GPS tracking, which allows waste trucks to optimize their routes by focusing only on bins that are fully occupied. This helps reduce unnecessary trips, saving time, fuel, and operational costs. It's a smart solution that aligns with the growing trend of using technology to create more sustainable and efficient cities.

From a commercial standpoint, the system offers strong potential in the market. As cities and organizations look for smarter, more sustainable ways to manage waste, the demand for efficient and eco-friendly solutions is rising. Municipalities, waste management companies, and environmental groups would find this system valuable for improving waste collection, reducing costs, and promoting sustainability.

What makes this system even more promising is its scalability whether it's for a small neighbourhood or a large urban area, it can be adapted to suit various needs. Additionally, with opportunities for future upgrades, such as adding automatic waste segregation, automatic waste grinding, implementing optical sensor and air quality sensor, using renewable energy, and developing its own app for real time monitoring can show that the system has room for continued growth and innovation.

It could be marketed as a product or subscription-based service, providing ongoing updates and real-time monitoring to waste management companies. This opens opportunities for both public and private sector investment. Ultimately, this system offers a practical, sustainable solution for modern waste management, and it's well-positioned to help create cleaner, smarter cities in the future.

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APPENDIX

PROGRAMMING CODE FOR ARDUINO UNO

```
#include <SoftwareSerial.h>

#include <TinyGPS++.h>

#include <Wire.h>

#include "HX711.h"

#include <dht.h>

#include <Servo.h>


dht DHT;


#define DHT22_PIN 8

#define trigPin1 9

#define echoPin1 10

#define trigPin2 11

#define echoPin2 12


Servo myservo;


static const uint32_t GPSBaud = 9600;

TinyGPSPlus gps;
```

```
struct
{
   uint32_t total;
   uint32_t ok;
   uint32_t crc_error;
   uint32_t time_out;
   uint32_t connect;
   uint32_t ack_l;
   uint32_t ack_h;
   uint32_t unknown;
} stat = { 0,0,0,0,0,0,0,0};


static const int RXPin = 4, TXPin = 5;
SoftwareSerial ss(2, 3); //(RX,TX)
SoftwareSerial GPS(RXPin, TXPin);


// HX711.DOUT  - pin #A1
// HX711.PD_SCK - pin #A0
// Uncomment whatever type you're using!
```

```
HX711 scale(A1, A0);    // parameter "gain" is ommited; the default value 128 is used by the library

float lat=0,lon=0;
float h=0,t=0;
float hx=0,tx=0;
float LEVEL=0;
int ALM=0;
float LOWKG=10.0;
float CALIB=1.0;
String Temp1x="";
String PHx="";
String Temp2x="";
String Temp1y="";
String PHy="";
String Temp2y="";
String Temp3y="";
String Temp3x="";
String Temp4y="";
String Temp4x="";

int Maxx=45;
int pos1=0;
int Maxy=45;
```

```
int Timerz=0;
int DataIn=0;
int Counter=0;
int TimerGPS=0;
int TimerLoop=0;
long duration1x, duration2x, duration3x, distance3, duration4x, distance4, duration5x, distance5;
float inch,distance1,distance2;
float AvWeight=0;
int DispCount=0;

float Average=0;
int TimeStart=0;
float dtergent=0;
int RQScount;
int countERROR;
int countPHONE;
int countOK;
int commaPosition;
int index = 0;
float WEIGHT;
float RAWWEIGHT;
float WEIGHT2;
float RAWWEIGHT2;
float WEIGHT3;
```

```
float RAWWEIGHT3;

float HIGHx;

float BMI;

float REF=8401520;

float REF2=8361861;

float REF3=8361861;

float MAX=150;

int MODE=0;

float TargetTime=0;

float MaxKg=6.0;

int MaxDtergentT=10;

float DTnow=0;

int Status=0;

int Alm1=0;

int Alm2=0;

int Alm3=0;

int TALAM=0;

int TWifi=0;


int MAN=0,STAT=0;

float Sens1;

int Sens1Pin = 0;
```

```
void setup() {
  // initialize serial:
 Serial.begin(9600);
 ss.begin(9600);
 GPS.begin(GPSBaud);

myservo.attach(7);
   pinMode(trigPin1, OUTPUT);
  pinMode(echoPin1, INPUT);
    pinMode(trigPin2, OUTPUT);
  pinMode(echoPin2, INPUT);

 //----------------------------------------------------------------------------------
  Serial.println("HX711 1startup");

  Serial.println("Before setting up the scale1:");
  Serial.print("read: \t\t");
  Serial.println(scale.read());      // print a raw reading from the ADC

  Serial.print("read average: \t\t");
```

```
  Serial.println(scale.read_average(20));   // print the average of 20 readings from the ADC

  Serial.print("get value: \t\t");
  Serial.println(scale.get_value(5));   // print the average of 5 readings from the ADC minus
the tare weight (not set yet)

  Serial.print("get units: \t\t");
  Serial.println(scale.get_units(5), 1);  // print the average of 5 readings from the ADC minus
tare weight (not set) divided
        // by the SCALE parameter (not set yet)

  scale.set_scale(2280.f);                      // this value is obtained by calibrating the scale with
known weights; see the README for details
  scale.tare();               // reset the scale to 0

  Serial.println("After setting up the scale:");

  Serial.print("read: \t\t");
  Serial.println(scale.read());                 // print a raw reading from the ADC

  Serial.print("read average: \t\t");
  Serial.println(scale.read_average(20));       // print the average of 20 readings from the ADC

  Serial.print("get value: \t\t");
```

```
  Serial.println(scale.get_value(5));   // print the average of 5 readings from the ADC minus
the tare weight, set with tare()

  Serial.print("get units: \t\t");
  Serial.println(scale.get_units(5), 1);        // print the average of 5 readings from the ADC
minus tare weight, divided
            // by the SCALE parameter set with set_scale

  Serial.println("Readings:");
  delay(2000);
  //------------------------------------------------------------------------------------------------------------


  //------------------------------------------------------------------------------------------------------------


  Serial.println("CONTROLLER READY...");

}

void loop() {



  digitalWrite(trigPin1, LOW);  // Added this line
```

```
  delayMicroseconds(2); // Added this line
  digitalWrite(trigPin1, HIGH);
  delayMicroseconds(10); // Added this line
  digitalWrite(trigPin1, LOW);
  duration1x = pulseIn(echoPin1, HIGH);
  distance1 = ((duration1x/2) / 29.1); //* 0.26;

  if (distance1>0 && distance1<=26){
    LEVEL=96-(distance1/26.0*100.0);
  }

if (distance1>26){
  LEVEL=0;
}

if (LEVEL<0){
  LEVEL=0;
}

  digitalWrite(trigPin2, LOW);  // Added this line
  delayMicroseconds(2); // Added this line
  digitalWrite(trigPin2, HIGH);
  delayMicroseconds(10); // Added this line
  digitalWrite(trigPin2, LOW);
  duration2x = pulseIn(echoPin2, HIGH);
```

```
  distance2 = ((duration2x/2) / 29.1); //* 0.26;

  if (distance2>0 && distance2<50 && STAT==0 && MAN==0){
  Open();
  STAT=1;
 }
 if (distance2<200 && distance2>60 && STAT==1 && MAN==0){
  Close();
  STAT=0;
 }

  uint32_t start = micros();
    int chk = DHT.read22(DHT22_PIN);
    uint32_t stop = micros();

    stat.total++;
    switch (chk)
    {
    case DHTLIB_OK:
        stat.ok++;
        //Serial.print("OK,\t");
        break;
    case DHTLIB_ERROR_CHECKSUM:
        stat.crc_error++;
        Serial.print("Checksum error,\t");
```

```
    break;
case DHTLIB_ERROR_TIMEOUT:
    stat.time_out++;
    Serial.print("Time out error,\t");
    break;
case DHTLIB_ERROR_CONNECT:
    stat.connect++;
    Serial.print("Connect error,\t");
    break;
case DHTLIB_ERROR_ACK_L:
    stat.ack_l++;
    Serial.print("Ack Low error,\t");
    break;
case DHTLIB_ERROR_ACK_H:
    stat.ack_h++;
    Serial.print("Ack High error,\t");
    break;
default:
    stat.unknown++;
    Serial.print("Unknown error,\t");
    break;
}

tx=DHT.temperature;
hx=DHT.humidity;
```

```
//-------------------------------

  RAWWEIGHT = (scale.read_average(20));
  //Serial.print("Sensor Readings:");
  //Serial.println(RAWWEIGHT);
  WEIGHT=RAWWEIGHT-REF;
 // WEIGHT=(8032430-RAWWEIGHT);
  WEIGHT=WEIGHT/1000;
  //WEIGHT=WEIGHT*0.1324256;

//WEIGHT=(WEIGHT-1050) *(-1);
//WEIGHT=WEIGHT/100*20;
//WEIGHT=WEIGHT-2;

if (WEIGHT<=3){
  WEIGHT=0;
}
if (WEIGHT>3){
  WEIGHT=WEIGHT*0.2852233*CALIB*0.1051587;
}

 // Serial.print(RAWWEIGHT);
 // Serial.print("\t");
```

```
Serial.print(WEIGHT);
Serial.print("\t");
Serial.print(tx);
Serial.print("\t");
Serial.print(hx);
  Serial.print("\t");
Serial.print(LEVEL);
    Serial.print("\t");
Serial.print(distance2);
 Serial.print("\t");
Serial.print(lat,6);
 Serial.print("\t");
Serial.println(lon,6);


TimerLoop++;


if (TimerLoop>5){
  ss.listen();
  ss.print("*");
ss.print(WEIGHT);
      ss.print("*");
ss.print(tx);
      ss.print("*");
```

```
ss.print(hx);
      ss.print("*");
ss.print(LEVEL);
      ss.print("*");
ss.print(lat,6);
      ss.print("*");
ss.print(lon,6);
ss.println("#");
  GPS.listen();


   while(TimerGPS<10000){


        while (Serial.available()) {
          if (gps.encode(Serial.read()))
          displayInfo();
          if (millis() > 5000 && gps.charsProcessed() < 10)
      {
        Serial.println(F("No GPS detected: check wiring."));


      }




      }
      TimerGPS++;
```

```
    }

    TimerGPS=0;
    TimerLoop=0;

  }

delay(100);
}

void displayInfo()
{
  Serial.print(F("Location: "));
  if (gps.location.isValid())
  {
    lat=gps.location.lat();

    lon=gps.location.lng();
  }
}

void Close(){

  for (pos1 = 0; pos1 <= 90; pos1 += 1) { // goes from 0 degrees to 180 degrees
    // in steps of 1 degree
```

```
    myservo.write(pos1);              // tell servo to go to position in variable 'pos'
    delay(5);                       // waits 15ms for the servo to reach the position
  }
}
void Open(){

  for (pos1 = 90; pos1 >= 0; pos1 -= 1) { // goes from 180 degrees to 0 degrees
    myservo.write(pos1);              // tell servo to go to position in variable 'pos'
    delay(5);                       // waits 15ms for the servo to reach the position
  }
}
```

PROGRAMMING CODE FOR ESP32

```
String dataString = "";
String DateString = "";
String TimeString = "";
int SEC=0,MIN=0,MTH=0,YEAR=0,HR=0,DY=0;
int Mileagex=0;

// Template ID, Device Name and Auth Token are provided by the Blynk.Cloud
// See the Device Info tab, or Template settings
#define BLYNK_TEMPLATE_ID          "TMPL6AAMQMqh5"
#define BLYNK_TEMPLATE_NAME        "DEVELOPMENT OF IOT BASED WASTE
MANAGEMENT SYSTEM"
#define BLYNK_AUTH_TOKEN
"xlOoaYC93dNUSwYo3QO_SCZCwBXpzKdd"

// Comment this out to disable prints and save space
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

#define vCalibration 83.3
#define currCalibration 0.50

String MinS="00";
String HourS="00";
String SecS="00";
int DataIn=0;
String DATA="";
String Temp1x="";
```

```
String PHx="";
String Temp2x="";
String Temp1y="";
String PHy="";
String Temp2y="";
String Temp3y="";
String Temp3x="";
String Temp4y="";
String Temp4x="";
String Temp5y="";
String Temp5x="";
String Temp6y="";
String Temp6x="";
String Temp7y="";
String Temp7x="";
String Temp8y="";
String Temp8x="";
String Temp9y="";
String Temp9x="";
String Temp10y="";
String Temp10x="";
String currentTime;
String currentDate;
String TimerGet="00:00:00";
int MODE=0;
int Hour=0;
int Min=0;

int Sec=0;
int Val=100;
int Index=0;
float CV=0;
int CKN=0;
```

```
char auth[] = BLYNK_AUTH_TOKEN;
// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "DUST";
char pass[] = "12345678";

BlynkTimer timer;

// This function is called every time the Virtual Pin 0 state changes
// This function is called every time the device is connected to the Blynk.Cloud
BLYNK_CONNECTED()
{
}
void myTimerEvent()
{
  }
void setup()
{
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass);
  // You can also specify server:
  //Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);
  //Blynk.begin(auth, ssid, pass, IPAddress(192,168,1,100), 8080);



  delay(2000);
}

void loop()
{
  Blynk.run();
  timer.run();
```

```
 //--------------------------------------------------
 while (Serial.available()) {
  // get the new byte:
  char inChar1 = (char)Serial.read();
if (inChar1 == '*') {
   DataIn++;

  }

   if (inChar1 == 'Y') {
  }
  while (DataIn > 0){
    while (Serial.available()) {
  // get the new byte:
  char inChar = (char)Serial.read();
  if (inChar == '*') {
   DataIn++;

  }
  if (inChar != '*' && inChar != '#' && DataIn==1) {
   Temp1x+=inChar;

  }
  if (inChar != '*' && inChar != '#' && DataIn==2) {
   Temp2x+=inChar;

  }
  if (inChar != '*' && inChar != '#' && DataIn==3) {
   Temp3x+=inChar;

  }
   if (inChar != '*' && inChar != '#' && DataIn==4) {
```

```
Temp4x+=inChar;

}
if (inChar != '*' && inChar != '#' && DataIn==5) {
Temp5x+=inChar;

}
if (inChar != '*' && inChar != '#' && DataIn==6) {
Temp6x+=inChar;

}
if (inChar != '*' && inChar != '#' && DataIn==7) {
Temp7x+=inChar;

}
if (inChar != '*' && inChar != '#' && DataIn==8) {
Temp8x+=inChar;

}
if (inChar != '*' && inChar != '#' && DataIn==9) {
Temp9x+=inChar;

}
if (inChar != '*' && inChar != '#' && DataIn==10) {
Temp10x+=inChar;

}
  if (inChar == '#') {
DataIn=0;
Temp1y=Temp1x;   PHy=PHx;      Temp2y=Temp2x;  Temp3y=Temp3x;
Temp4y=Temp4x;
Temp5y=Temp5x;
Temp6y=Temp6x;
```

```
    Temp1x="";
    PHx="";   Temp2x="";
    Temp3x="";
    Temp4x="";
    Temp5x="";
    Blynk.virtualWrite(V1, Temp1y);
    Blynk.virtualWrite(V2, Temp2y);
     Blynk.virtualWrite(V3, Temp3y);
     Blynk.virtualWrite(V0, Temp4y);
      Blynk.virtualWrite(V4, Temp5y);
       Blynk.virtualWrite(V5, Temp6y);
   }
      }


   }
}
```