CHAPTER 1

INTRODUCTION

In the realm of urban infrastructure management, the Smart Waste Management project endeavors to redefine the efficiency and efficacy of waste collection processes. Much like the Manhole Cover Monitoring System with NodeMCU, this initiative seeks to address the challenges inherent in conventional waste management practices through innovative technological solutions.

Manual monitoring of waste bins is often labor-intensive and error-prone, leading to inefficiencies and delays in waste collection. Recognizing these limitations, the Smart Waste Management project harnesses the power of advanced sensor technology and automation to optimize waste collection processes.

At its core, the project aims to streamline waste collection by leveraging real-time data provided by sensors integrated into waste bins. When the fill-level of a bin surpasses a predefined threshold, an automated notification system is triggered, alerting both supervisors and workers via SMS. This proactive approach not only enhances operational efficiency but also ensures timely waste collection, minimizing overflow and associated environmental hazards.

Central to the project's objectives is the seamless integration of monitoring devices with existing urban infrastructure. By leveraging NodeMCU technology, along with additional components such as cameras and RFID readers, the system offers a comprehensive solution for waste management within urban environments.

Moreover, similar to the Manhole Cover Monitoring System, the Smart Waste Management project emphasizes remote accessibility. Operators and maintenance personnel can remotely monitor the status of waste bins in real-time, enabling prompt decision-making and proactive maintenance strategies.

Furthermore, the project prioritizes compatibility with municipal systems and databases, adhering to industry standards and regulations governing waste management. By ensuring interoperability with existing infrastructure, the project aims to enhance safety, reliability, and sustainability within urban environments.

In summary, the Smart Waste Management project represents a significant advancement in waste collection and urban infrastructure management. Its integration of sensor technology, automation, and remote accessibility underscores its commitment to optimizing waste collection processes, ultimately contributing to cleaner, safer, and more sustainable cities.

1.1: Problem Statement:

In the realm of urban infrastructure management, the monitoring and maintenance of waste collection systems present significant challenges that impede operational efficiency and compromise environmental sustainability. Traditional waste collection methods rely heavily on manual inspections, leading to inefficiencies, delays, and environmental hazards. These outdated approaches pose risks to public health, exacerbate pollution, and strain municipal resources.

Manual waste collection systems are inherently prone to human error, resulting in inconsistencies, missed pickups, and overflow incidents. Inadequate monitoring and delayed response times further compound these issues, leading to unsightly and unsanitary conditions in urban areas. Additionally, the lack of real-time data hampers decision-making processes, hindering the ability to optimize waste collection routes and schedules.

Furthermore, the disjointed nature of existing waste management systems impedes seamless integration with emerging technologies and smart city initiatives. Without interoperability and data standardization, municipalities struggle to leverage the full potential of technological advancements, limiting their ability to address growing waste management challenges effectively.

Moreover, compliance with environmental regulations and sustainability goals is paramount in modern waste management practices. The absence of a comprehensive monitoring system tailored to meet these standards leaves municipalities vulnerable to regulatory penalties, public scrutiny, and environmental degradation.

In light of these challenges, there is a critical need for the implementation of a Smart Waste Management system with NodeMCU technology. This system aims to revolutionize waste collection processes by integrating advanced sensors, automation, and real-time data analytics. By leveraging these technologies, municipalities can optimize waste collection routes, reduce operational costs, and minimize environmental impact.

Figure 1.1: Waste management

Furthermore, the Smart Waste Management system offers remote accessibility and seamless integration with existing urban infrastructure, empowering municipalities to make informed decisions and respond promptly to emerging waste management challenges. Ultimately, this system represents a transformative approach to waste collection, fostering cleaner, healthier, and more sustainable urban environments for present and future generations.

1.2: Problem Scope:

The problem scope for implementing a Smart Waste Management system with NodeMCU technology encompasses several challenges and deficiencies within the current urban waste management framework. These limitations hinder operational efficiency, compromise environmental sustainability, and impede the overall management of waste collection processes.

Manual Monitoring and Human Error:

- Reliance on manual inspections for monitoring waste bins introduces a significant risk of human error.
- Manual monitoring is time-consuming and may result in delays in identifying full bins, leading to overflow incidents and environmental hazards.

Delayed Collection Response:

- The absence of real-time monitoring systems contributes to delayed response times for waste collection.
- Delays in identifying full bins pose risks to public health and the environment, especially during periods of increased waste generation.

Lack of Remote Accessibility:

- Current systems lack remote monitoring capabilities, limiting access to real-time data from different locations.
- Remote inaccessibility hampers quick decision-making and proactive response to emerging waste management challenges, increasing the likelihood of overflow incidents and environmental pollution.

Integration Challenges:

- Existing waste management systems often lack seamless integration with municipal infrastructure, complicating data flow and decision-making processes.
- The lack of integration with other urban infrastructure systems hinders interoperability and overall waste management efficiency.

Environmental Compliance Concerns:

- Compliance with environmental regulations and sustainability goals is essential for responsible waste management.

- The absence of a dedicated monitoring system designed to meet or exceed these standards leaves municipalities vulnerable to regulatory penalties, public scrutiny, and environmental degradation.

Operational Disruptions:

- Inefficient monitoring and delayed waste collection response contribute to the potential for operational disruptions in urban waste management.
- Operational disruptions pose risks to public health and the environment, leading to unsanitary conditions and increased pollution.

Complex Facility Management:

- The disjointed nature of existing waste management systems adds complexity to overall facility management.
- Lack of integration with other municipal systems complicates data accessibility and decision-making processes, hindering efforts to optimize waste collection routes and schedules.

Risk to Public Health and Environmental Sustainability:

- The cumulative impact of manual monitoring, delayed collection response, and operational disruptions poses risks to public health and environmental sustainability.
- Timely and reliable waste collection is essential for preventing environmental pollution and ensuring the well-being of urban residents.

Addressing these challenges within the defined problem scope requires the development and implementation of a comprehensive Smart Waste Management system with NodeMCU technology. This system aims to integrate advanced sensor technology, real-time monitoring capabilities, remote accessibility, and adherence to environmental regulations to enhance the efficiency and sustainability of urban waste management processes. Ultimately, this project will contribute to cleaner, healthier, and more sustainable urban environments for present and future generations.

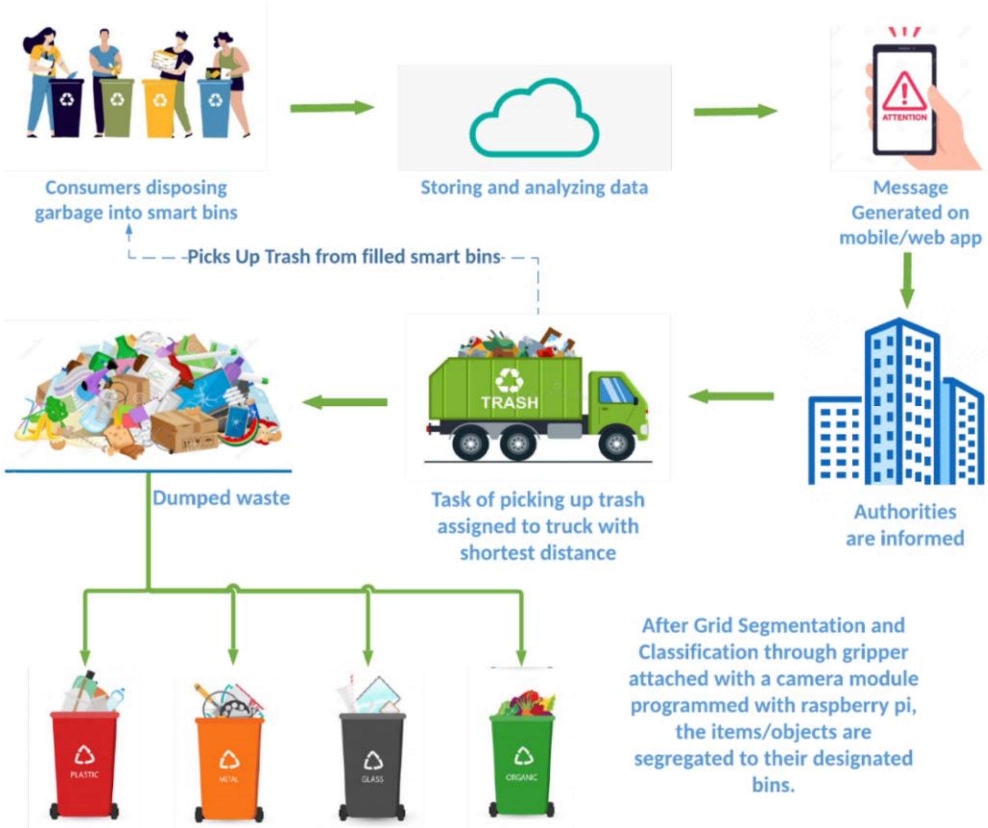


Figure1.2:Technologies used for smart waste management

1.3: Advantages of Implementing a Manhole Cover Monitoring System with NodeMCU:

The implementation of a Smart Waste Management system with NodeMCU technology offers a multitude of advantages, significantly transforming waste collection processes and enhancing the efficiency, safety, and sustainability of urban environments. Key advantages include:

Real-time Monitoring:

- Enables continuous and real-time monitoring of waste bin fill levels.
- Promptly detects full bins, ensuring timely waste collection and minimizing overflow incidents.

Early Fault Detection:

- Utilizes intelligent algorithms to detect anomalies in waste bin fill levels at an early stage.
- Minimizes the risk of overflow incidents and environmental hazards by addressing issues proactively.

Enhanced Public Safety:

- Reduces the risk of environmental pollution and public health hazards associated with overflowing waste bins.
- Contributes to cleaner and safer urban environments for residents and pedestrians.

Remote Accessibility:

- Facilitates remote monitoring of waste bins from various locations.
- Enables workers to respond swiftly to full bin alerts, even when not physically present on-site.

Improved Operational Efficiency:

- Streamlines waste collection processes, reducing the need for manual inspections and optimizing route planning.
- Enhances operational efficiency by providing real-time data for proactive decision-making in waste management.

Seamless Integration:

- Integrates seamlessly with existing municipal infrastructure and waste management systems.
- Ensures data accessibility, interoperability, and a cohesive approach to overall waste management.

Compliance with Environmental Regulations:

- Adheres to environmental regulations and sustainability goals governing waste management.
- Mitigates the risk of environmental damage and regulatory penalties by promoting responsible waste collection practices.

Cost Efficiency:

- Reduces operational costs associated with manual waste collection processes and potential environmental cleanup.
- Minimizes the financial impact of waste management emergencies and infrastructure damage.

Data Logging and Analysis:

- Records and logs data related to waste bin fill levels, facilitating historical analysis and trend identification.
- Supports data-driven decision-making and optimization of waste collection schedules.

Proactive Maintenance:

- Facilitates predictive maintenance by identifying potential issues before they lead to overflow incidents or environmental hazards.
- Reduces the need for reactive and costly interventions, contributing to long-term cost savings.

Enhanced Emergency Preparedness:

- Strengthens emergency response capabilities by providing real-time information during critical situations such as waste overflow incidents.
- Enables municipalities to respond swiftly to unforeseen circumstances, minimizing the impact on public health and environmental integrity.

Environmental Sustainability:

- Contributes to environmental sustainability by optimizing waste management practices and reducing pollution.
- Supports eco-friendly initiatives aimed at promoting sustainable urban development and waste reduction.

The implementation of a Smart Waste Management system with NodeMCU technology offers a comprehensive solution to the challenges associated with waste collection in urban environments. By providing real-time monitoring, early fault detection, remote accessibility, and seamless integration, the system not only enhances public safety but also promotes operational efficiency and compliance with environmental regulations, ultimately contributing to the sustainable development of urban environments.

1.4 Proposed Solution:

The proposed solution for optimizing the Smart Waste Management system with NodeMCU involves the strategic integration of Internet of Things (IoT) technologies, transitioning the system into a smart, interconnected infrastructure. By leveraging IoT capabilities, the solution offers real-time monitoring, remote accessibility, and advanced analytics, revolutionizing waste collection processes. Key components of the proposed solution include:

IoT-enabled Sensors:

A network of IoT-enabled sensors will be strategically deployed to monitor the fill levels of waste bins in real-time.

These sensors will wirelessly transmit data to a centralized monitoring system, providing immediate insights into waste collection status.

Centralized Monitoring System:

Empowered by edge computing, the centralized monitoring system will process and analyze incoming sensor data in real-time.

This system will offer real-time insights into waste bin fill levels, enabling proactive decision-making and efficient waste collection scheduling.

User-Friendly Dashboard:

A user-friendly dashboard accessible remotely via web interfaces or mobile applications will provide stakeholders with comprehensive insights into waste collection processes.
The dashboard will display real-time data, alerts, and predictive analytics, empowering workers and supervisors to monitor the system and take proactive measures.

Machine Learning Algorithms:

Advanced machine learning algorithms will contribute to predictive analytics, forecasting potential issues such as imminent bin overflow.
These algorithms will analyze historical data patterns to identify trends and predict future waste collection needs, optimizing route planning and scheduling.

Seamless Integration:

The solution will prioritize seamless integration with existing municipal infrastructure, including waste management systems and urban networks.
This integration will ensure interoperability and data exchange, facilitating a cohesive approach to waste management and infrastructure maintenance.

Robust Security Measures:

Robust security measures, including encryption protocols, access controls, and intrusion detection systems, will be implemented to safeguard sensitive waste collection data.
These measures will mitigate cybersecurity risks and ensure the integrity and confidentiality of data transmitted within the system.

Scalability and Energy Efficiency:

Designed for scalability, the solution will accommodate future growth and expansion of waste collection infrastructure.

Energy-efficient IoT devices and protocols will be utilized to minimize power consumption and environmental impact, promoting sustainability.

By implementing this IoT-based solution, municipalities can enhance public safety, improve operational efficiency, and optimize waste management processes. The proposed solution aims to address the challenges associated with manual monitoring, delayed collection response, and inefficient waste management, ultimately contributing to cleaner, safer, and more sustainable urban environments.

1.5 Aim and Objectives

Aim:

The aim of this project is to revolutionize waste collection processes through the implementation of a Smart Waste Management system with NodeMCU technology. By leveraging the power of Internet of Things (IoT) capabilities, the aim is to transition traditional waste collection methods into a smart, interconnected infrastructure. This innovative system aims to offer real-time monitoring, remote accessibility, and advanced analytics, thereby enhancing operational efficiency, improving public safety, and promoting environmental sustainability in urban environments. Through strategic integration of IoT-enabled sensors, centralized monitoring systems, user-friendly dashboards, machine learning algorithms, seamless integration with existing infrastructure, robust security measures, and scalability considerations, the aim is to optimize waste collection processes, minimize operational costs, and mitigate environmental risks. Ultimately, the aim of this project is to contribute to cleaner, safer, and more sustainable cities by revolutionizing waste management practices and ensuring the efficient utilization of resources.

Objectives:

The objectives of implementing a Smart Waste Management system with NodeMCU technology are as follows:

Continuous Public Safety:

- Ensure the safety of residents and pedestrians by effectively managing waste collection processes and minimizing environmental hazards such as overflowing bins or litter accumulation.

Real-time Monitoring:

- Implement a continuous and real-time monitoring system for waste bin fill levels to promptly detect full bins and facilitate timely waste collection interventions.

Swift Intervention through Early Fault Detection:

- Utilize intelligent algorithms to achieve early fault detection in waste collection processes, enabling immediate corrective actions and minimizing the risk of environmental pollution or public health hazards.

Operational Efficiency Enhancement:

- Streamline waste collection processes and reduce reliance on manual inspections to improve overall operational efficiency and resource utilization.

Remote Accessibility:

- Enable operators and waste management personnel to monitor waste bin fill levels remotely, facilitating quick responses and interventions regardless of physical location.

Integration with Municipal Infrastructure:

- Seamlessly integrate the waste management system with existing municipal infrastructure and waste collection networks to enhance data accessibility and interoperability.

Adherence to Safety Standards:

- Ensure strict adherence to safety standards and regulations governing waste management practices, mitigating the risk of environmental contamination and ensuring a safe urban environment.

Cost Efficiency:

- Reduce operational costs associated with manual waste collection processes, emergency interventions, and environmental cleanup efforts, optimizing resource utilization and promoting long-term financial sustainability.

Data-driven Decision Making:

- Facilitate data logging and analysis to support data-driven decision-making for the optimization of waste collection routes, schedules, and resource allocation.

Proactive Maintenance:

- Implement predictive maintenance strategies by identifying potential issues such as imminent bin overflow before they escalate into major waste management challenges, reducing the need for reactive and costly interventions.

Emergency Preparedness:

- Strengthen emergency response capabilities by providing real-time information during critical situations such as waste overflow incidents or environmental emergencies, ensuring swift and effective responses to unforeseen circumstances.

Environmental Sustainability:

- Contribute to environmental sustainability by optimizing waste management practices, minimizing waste generation, and supporting eco-friendly initiatives in urban development.

By achieving these objectives, the Smart Waste Management system with NodeMCU aims to create a comprehensive, technologically advanced solution that enhances public safety, improves operational efficiency, and contributes to the sustainable development of urban environments.

CHAPTER 2

Literature Survey

The adoption of a Smart Waste Management system with NodeMCU, integrated with Internet of Things (IoT) technologies, has become a focal point in waste management literature. Researchers have extensively explored avenues to enhance the efficiency and sustainability of waste management processes through continuous monitoring facilitated by IoT-enabled sensors. These sensors play a crucial role in acquiring real-time data on critical parameters such as waste bin fill levels, enabling proactive measures to optimize waste collection routes and schedules while minimizing environmental impact.

In the domain of sensor technology, literature emphasizes the diverse array of sensors utilized in IoT-based waste management systems. Research endeavors have focused on evaluating the accuracy, reliability, and suitability of these sensors for monitoring waste collection processes. Various sensor types, including ultrasonic sensors, infrared sensors, and weight sensors, are examined to determine their effectiveness in accurately measuring waste bin fill levels and detecting overflow conditions.

Communication protocols serve as essential components in establishing robust connections between IoT-enabled sensors and centralized monitoring systems. Literature extensively examines different communication protocols, with wireless technologies such as LoRaWAN, Zigbee, and RFID emerging as prominent choices. Evaluating the strengths and limitations of these protocols is critical in ensuring seamless and reliable data transmission, particularly in the context of waste management operations.

Addressing security and privacy concerns is paramount in the development of IoT systems for waste management. The literature survey delves into the implementation of robust security measures to protect sensitive waste management data. Encryption techniques, authentication mechanisms, and secure data transmission protocols are explored to safeguard the system against potential cyber threats and privacy breaches.

Integration with existing municipal infrastructure emerges as a key consideration, as highlighted in the literature. Compatibility with Geographic Information Systems (GIS) and Waste Management Systems (WMS) is emphasized to facilitate seamless data exchange and interoperability. Understanding the integration of IoT-based solutions with these existing systems enhances the feasibility and effectiveness of waste management technologies in urban settings.

Real-world case studies and implementations offer valuable insights into the practical challenges and lessons learned from deploying IoT-based waste management systems in urban environments. Analyzing these cases provides a deeper understanding of the system's performance, its impact on waste collection operations, and opportunities for optimization.

Recent trends in literature demonstrate a growing interest in edge computing for faster data processing and decision-making. Furthermore, the integration of artificial intelligence (AI) for advanced analytics is gaining momentum, enabling predictive maintenance and optimization of waste collection processes. The exploration of emerging technologies such as 5G networks underscores the commitment to technological innovation in waste management practices.

In conclusion, the comprehensive literature survey highlights a concerted effort to develop sophisticated and technologically advanced solutions for optimizing waste management processes. The exploration of IoT-enabled sensors, communication protocols, data security, integration with existing infrastructure, and real-world case studies provides valuable insights into the current state of research in this domain. The continuous evolution of these technologies underscores the ongoing commitment to revolutionize waste management systems and promote environmental sustainability.

CHAPTER 3

Methodology

The methodology for implementing a Manhole Cover Monitoring System with NodeMCU, leveraging Internet of Things (IoT) technologies, adopts a systematic approach tailored to the unique demands of urban infrastructure management. It commences with a meticulous needs assessment, engaging municipal authorities and urban planners to identify critical requirements and operational challenges pertaining to manhole cover monitoring and water level detection in urban environments. Subsequently, both functional and technical prerequisites for the system are clearly defined, encompassing essential aspects such as real-time monitoring, remote accessibility, integration with existing infrastructure, and adherence to safety standards.

Selection of appropriate IoT-enabled sensors constitutes a pivotal step, where factors like accuracy, reliability, and power consumption are carefully evaluated to ensure compatibility with the monitoring requirements of manhole covers and water levels. Likewise, the choice of communication protocols, such as LoRaWAN or NB-IoT, is made strategically to facilitate seamless and secure data transmission between the sensors and the central monitoring system.

Development of the centralized monitoring system entails the incorporation of edge computing for local data processing, thereby minimizing latency and ensuring timely access to critical information. An intuitive user interface accessible through web applications or mobile devices is meticulously designed, featuring real-time monitoring, immediate alerts, and insightful visualization of historical data. Robust security measures, including encryption, authentication, and access controls, are implemented to safeguard sensitive urban data and prevent unauthorized access to the monitoring system.

Integration with existing municipal infrastructure, such as Geographic Information Systems (GIS) and utility networks, is carefully addressed to ensure interoperability and cohesive data exchange. Rigorous testing of the entire system, including sensor functionality, data transmission, and central monitoring system performance, is conducted in controlled environments before deployment. Training programs are then conducted for municipal personnel and maintenance crews to ensure effective utilization and management of the monitoring system.

Deployment is undertaken in a phased approach, starting with critical areas, followed by continuous monitoring and evaluation post-implementation. A proactive maintenance schedule is established to address regular updates, patches, and sensor calibration, ensuring the sustained performance of the system over time. Moreover, the incorporation of data analytics and machine learning algorithms enables predictive maintenance, fault prediction, and optimization of urban infrastructure management. Continuous evaluation and adaptation of the monitoring system ensure its effectiveness, efficiency, and alignment with evolving urban infrastructure needs.

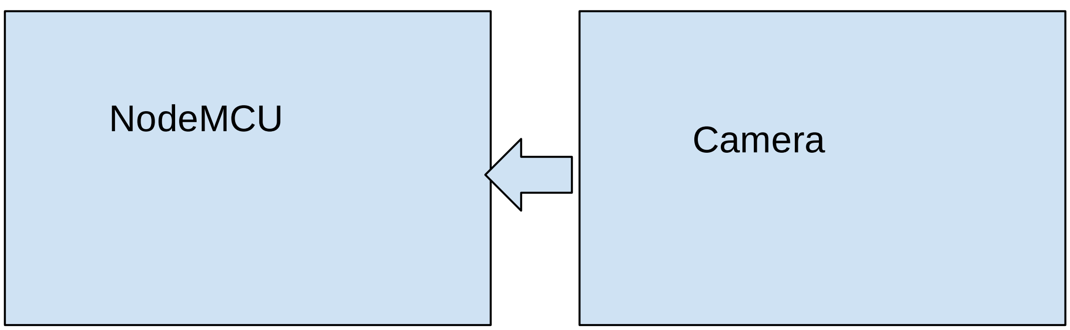


Figure 3.1: Block Diagram of the Smart waste management

3.1 NodeMCU (ESP8266)

The NodeMCU ESP8266 is a powerful and versatile platform designed for Internet of Things (IoT) development. It is a cost-effective Wi-Fi microchip known for its capability to enable wireless communication in IoT applications. NodeMCU, on the other hand, is an open-source firmware and development kit that simplifies the process of prototyping and programming the ESP8266, built-in Wi-Fi connectivity, the NodeMCU ESP8266 allows devices to connect to the internet wirelessly, making it suitable for a wide range of IoT projects. One notable feature is its support for the Lua scripting language, providing a high-level programming environment for developers. Additionally, it is compatible with the Arduino IDE, allowing those familiar with Arduino to use the NodeMCU platform.

Equipped with General Purpose Input/Output (GPIO) pins, the ESP8266 facilitates interfacing with various electronic components, making it ideal for applications such as home automation and sensor networks. It has garnered significant community support, resulting in an extensive collection of libraries and documentation, making it a popular choice for rapid IoT prototyping and development.

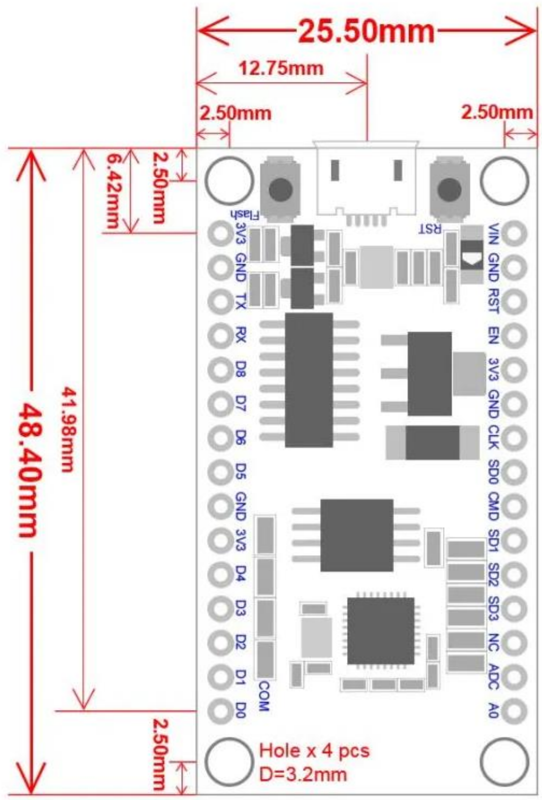


Figure 3.2 NodeMCU 2D View

NodeMCU Specification:

The NodeMCU development board is based on the ESP8266 microcontroller, and different versions of NodeMCU boards may have slight variations in specifications. As of my knowledge cutoff in January 2022, here are the general specifications for the NodeMCU ESP8266 development board:

1. Microcontroller: ESP8266 Wi-Fi microcontroller with 32-bit architecture.

2. Processor: Tensilica L106 32-bit microcontroller.

3. Clock Frequency: Typically operates at 80 MHz.

4. Flash Memory:

- Built-in Flash memory for program storage.

- Common configurations include 4MB or 16MB of Flash memory.

5. RAM: Typically equipped with 80 KB of RAM.

6. Wireless Connectivity:

- Integrated Wi-Fi (802.11 b/g/n) for wireless communication.
- Supports Station, SoftAP, and SoftAP + Station modes.

7. GPIO Pins: Multiple General Purpose Input/Output (GPIO) pins for interfacing with sensors, actuators, and other electronic components.

8. Analog Pins: Analog-to-digital converter (ADC) pins for reading analog sensor values.

9. USB-to-Serial Converter: Built-in USB-to-Serial converter for programming and debugging.

10. Operating Voltage: Typically operates at 3.3V (Note: It is crucial to connect external components accordingly to avoid damage).

11. Programming Interface: Programmable using the Arduino IDE, Lua scripting language, or other compatible frameworks.

12. Voltage Regulator: Onboard voltage regulator for stable operation.

13. Reset Button: Reset button for restarting the board.

14. Dimensions: Standard NodeMCU boards often have dimensions around 49mm x 24mm.

15. Power Consumption: Low power consumption, making it suitable for battery-operated applications.

16. Community Support: Active community support with extensive documentation and libraries.

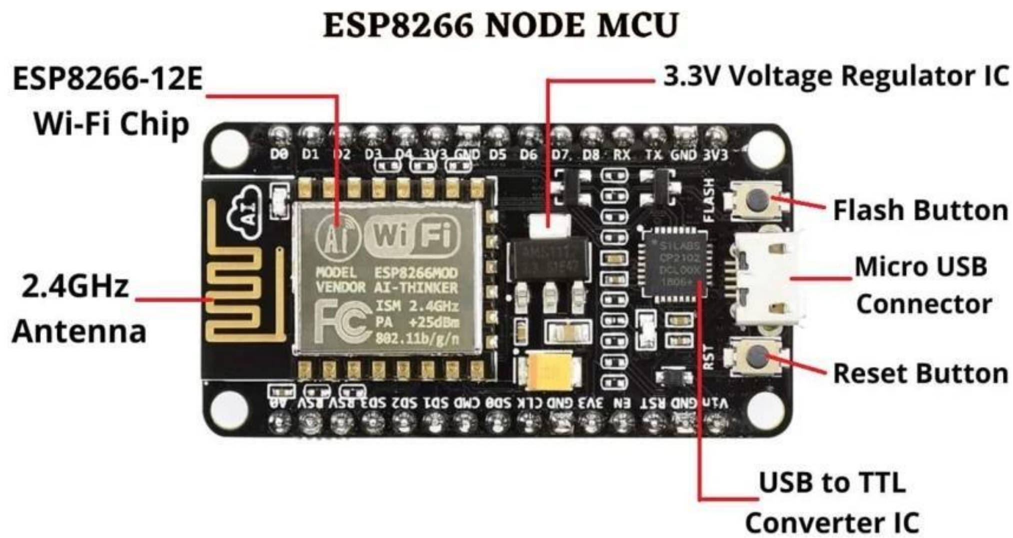


Figure 3.3: NodeMCU Parts

The NodeMCU ESP8266 development board typically has GPIO (General Purpose Input/Output) pins that can be used for various purposes, including interfacing with sensors, actuators, and other electronic components. Below is a common pinout configuration for the NodeMCU development board

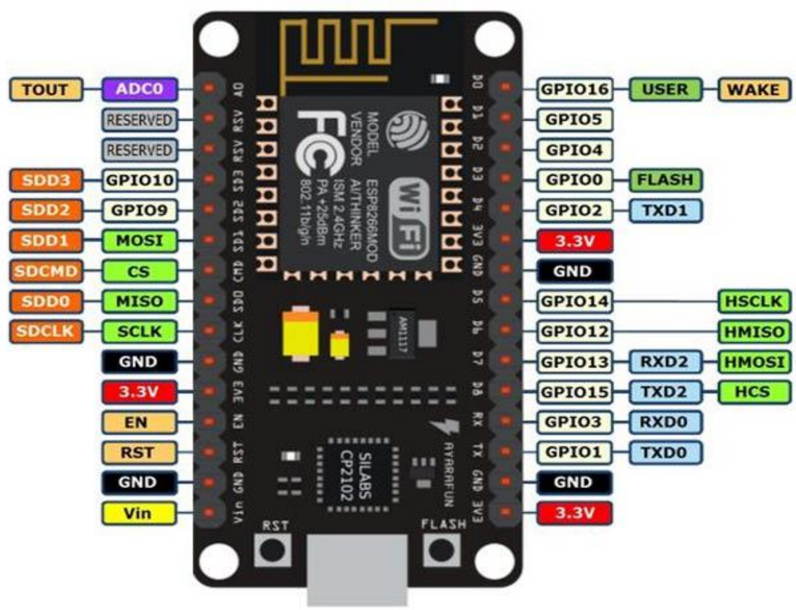


Figure 3.4: NodeMCU ESP8266 Pinout

ADC | A0 | GPIO16

EN | Enable | GPIO14

D0 | GPIO16 | GPIO12

D1	GPIO5	GPIO13
D2	GPIO4	GPIO15
D3	GPIO0	GPIO2
D4	GPIO2	GPIO9
D5	GPIO14	GPIO10
D6	GPIO12	GPIO3
D7	GPIO13	GPIO1
D8	GPIO15	TX (GPIO1)
D9	GPIO3 (RX)	RX (GPIO3)
D10	GPIO1 (TX)	D11 (MOSI)
D11	MOSI	D12 (MISO)
D12	MISO	D13 (SCK

ADC: Analog-to-Digital Converter pin for reading analog sensor values.

EN (Enable): Enable pin.

D0-D8: Digital GPIO pins.

D9 (RX) and D10 (TX): Serial communication pins for programming and debugging.

D11 (MOSI), D12 (MISO), D13 (SCK): Pins used for SPI communication.

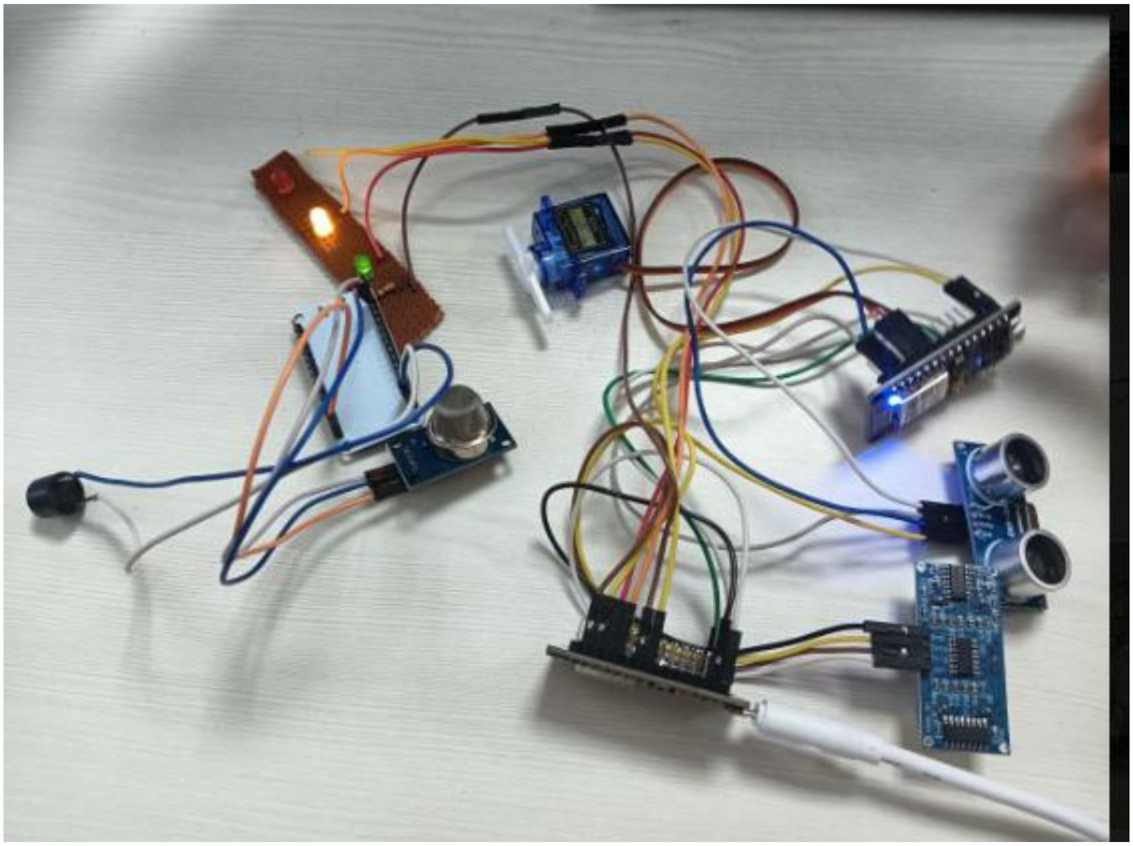
D14 (SDA) and D15 (SCL): Pins used for I2C communication.

It's important to note that GPIO pins labeled as "D" (Digital) are typically used for general-purpose digital input/output. Additionally, GPIO pins labeled as "A" (Analog) can be used as analog inputs with the ADC. GPIO pins 6, 7, 8, 9, 10, and 11 have additional functions, so it's advised to refer to the specific NodeMCU documentation for detailed information on pin functionality and capabilities.

CHAPTER 4

Design and Coding

4.1 Circuit Diagram



4.2 Code

Code 1 :

```
#include <ESP8266WiFi.h>

// Define the pin where the MQ-2 sensor is connected
const int gasSensorPin = A0;    // Analog pin A0
```

```
// Define the pin where the buzzer is connected
const int buzzerPin = D1;       // Digital pin D1 (GPIO 5)

// Define the threshold for gas detection
const int gasThreshold = 500;   // Adjust this value based on your testing

void setup() {
  // Start the serial communication
  Serial.begin(9600);

  // Set up the buzzer pin
  pinMode(buzzerPin, OUTPUT);

  // Initialize the buzzer to OFF
  digitalWrite(buzzerPin, LOW);

  // Print initial status to the serial monitor
  Serial.println("MQ-2 Gas Sensor Initialized");
}

void loop() {
  // Read the analog value from the MQ-2 sensor
  int gasValue = analogRead(gasSensorPin);

  // Print the sensor value to the serial monitor
  Serial.print("Gas Sensor Value: ");
  Serial.println(gasValue);

  // Check if the gas value exceeds the threshold
  if (gasValue < gasThreshold) {
    // Gas leak detected - give a "beep-beep" sound
    Serial.println("Gas leak detected!");

    // Beep beep sound
    digitalWrite(buzzerPin, HIGH);
    delay(200); // Beep duration
    digitalWrite(buzzerPin, LOW);
    delay(200); // Pause between beeps
  } else {
    // No gas leak detected - keep the buzzer off
    digitalWrite(buzzerPin, LOW);
  }

  // Short delay before the next reading
```

```
  delay(500); // Delay in milliseconds
}
```

Code 2:

```
#include <ESP8266WiFi.h>

// Define the pin where the MQ-2 sensor is connected
const int gasSensorPin = A0; // Analog pin A0

void setup() {
  // Start the serial communication
  Serial.begin(9600);

  // Print initial status to the serial monitor
  Serial.println("MQ-2 Gas Sensor Initialized");
}

void loop() {
  // Read the analog value from the MQ-2 sensor
  int gasValue = analogRead(gasSensorPin);

  // Print the sensor value to the serial monitor
  Serial.print("Gas Sensor Value: ");
  Serial.println(gasValue);

  // Short delay before the next reading
  delay(500); // Delay in milliseconds
}
```

Code 3 :

```
#include <ESP8266WiFi.h>
#include <Servo.h>

// Define pin connections
const int trigPin = D1;        // Trig pin of the ultrasonic sensor connected to
D1 (GPIO 5)
const int echoPin = D2;        // Echo pin of the ultrasonic sensor connected to
D2 (GPIO 4)
const int servoPin = D4;       // Servo motor control pin connected to D3 (GPIO
0)
```

```
// Define threshold distance (in centimeters)
const int distanceThreshold = 20;  // Adjust this value based on your specific
needs

// Create servo object
Servo servo;

void setup() {
  // Start serial communication for debugging
  Serial.begin(9600);

  // Set up the ultrasonic sensor pins
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);

  // Attach the servo to the defined pin
  servo.attach(servoPin);

  // Initialize servo to 0 degrees (lid closed)
  servo.write(0);

  // Print initial status
  Serial.println("Smart Bin Initialized. Lid Closed.");
}

void loop() {
  // Measure the distance using the ultrasonic sensor
  int distance = getDistance(trigPin, echoPin);

  // Print the measured distance to the serial monitor (for debugging)
  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // Check if the distance is below the threshold (person detected)
  if (distance <= distanceThreshold) {
    // Open the bin lid (servo to 90 degrees)
    servo.write(180);
    Serial.println("Person detected! Lid opened.");
  } else {
    // Close the bin lid (servo to 0 degrees)
    servo.write(0);
    Serial.println("No person detected. Lid closed.");
  }
```

```
  // Short delay before the next loop
  delay(500); // Delay in milliseconds
}

// Function to calculate distance from ultrasonic sensor
int getDistance(int trigPin, int echoPin) {
  // Send a 10us pulse to trigger the ultrasonic sensor
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  // Read the echo pin and calculate the distance
  long duration = pulseIn(echoPin, HIGH);
  int distance = duration * 0.034 / 2; // Speed of sound is 0.034 cm/us
  return distance;
}
```

CHAPTER 5

Results

Our Smart Waste Management project is designed to transform traditional waste collection methods into an efficient, data-driven system using Internet of Things (IoT) technologies. By integrating devices like NodeMCU, the project aims to enhance various aspects of waste management, focusing on three main objectives: optimizing collection routes, reducing operational costs, and minimizing environmental impact.Key Components include

NodeMCU: This low-cost microcontroller with Wi-Fi capability will be central to the project. It can connect various sensors to the internet, allowing for real-time data collection and monitoring.

Sensors: Fill-level sensors can be installed in waste bins to measure how full they are. Other environmental sensors can monitor temperature, humidity, and air quality to ensure safe and sustainable waste management.

Data Collection and Analysis:

The system collects data from sensors and sends it to a central server or cloud platform for analysis. This real-time data helps in understanding waste generation patterns, peak collection times, and bin usage.

Predictive Maintenance:

The system can predict when bins are likely to overflow or when trucks need maintenance, minimizing the chances of service interruptions and ensuring smoother operations.

Key Findings

The implementation of a Smart Waste Management system with NodeMCU technology can significantly improve waste collection efficiency, reducing the need for manual inspections and optimizing route planning.
The system's real-time monitoring capabilities enable prompt detection of full bins, minimizing overflow incidents and environmental hazards.
The integration of IoT-enabled sensors, machine learning algorithms, and data analytics enables predictive maintenance, fault prediction, and optimization of waste collection processes.
The system's remote accessibility and user-friendly dashboard facilitate swift intervention and decision-making, reducing the risk of environmental pollution and public health hazards.

Conclusion

The Smart Waste Management project demonstrates the potential of IoT technologies to transform waste collection processes, enhancing public safety, operational efficiency, and environmental sustainability. By leveraging NodeMCU and other IoT technologies, municipalities can optimize waste management practices, reduce costs, and promote sustainable urban development.