CHAPTER-I

INTRODUCTION

1.1 Background

The rapid pace of urbanization and increasing number of vehicles on city roads have led to severe challenges related to traffic congestion and air pollution. Modern cities struggle with long travel times, fuel wastage, and high emissions of toxic gases such as carbon monoxide (CO), nitrogen oxides (NO_x), and particulate matter (PM). These pollutants not only degrade environmental quality but also have a direct impact on public health, contributing to respiratory diseases, cardiovascular problems, and global warming. With the advent of the Internet of Things (IoT), it is now possible to design intelligent, data-driven systems that can monitor and manage urban traffic and environmental conditions in real time.

The IoT-Based Smart Traffic and Pollution Control System Enhanced with a Real-Time Eco-Routing Algorithm aims to provide a sustainable solution to these challenges. By integrating infrared (IR) sensors for vehicle density detection and MQ135 gas sensors for air quality monitoring, the system collects live data across multiple routes (A, B, and C). The ESP32 microcontroller acts as the central processing unit, handling data acquisition, analysis, and wireless communication through Wi-Fi. The system transmits real-time data to the Blynk IoT platform, allowing users to monitor traffic congestion and pollution levels remotely via a smartphone or web dashboard.

An intelligent eco-routing algorithm then analyzes the collected data to recommend the most efficient and environmentally friendly route. Unlike conventional navigation systems that consider only distance or travel time, this system prioritizes both low vehicle density and minimal pollution, thus reducing fuel consumption and emissions. The recommended route is displayed on a local I2C LCD screen and through the Blynk app interface. This project contributes to the broader goal of Smart City development by integrating real-time sensing, data analytics, and IoT-based communication to enhance urban mobility, environmental sustainability, and citizen well-being.

Congestion is a serious issue due to vehicular traffic. One of the known causes of traffic congestion is the amount of time spend waiting for the red light to change to green. The changing of traffic light is hard-coded and it is not reliant on traffic volume. There is therefore need to simulate and optimize traffic control to better accommodate density-based traffic rather than time based. This system attempts to lessen possibilities of traffic jams brought about by traffic lights to a reasonable degree. This project, a density-based traffic control system is been implemented to solve this problem.

1.2 MOTIVATION OF THE PROJECT

Urban regions across the world are experiencing rapid population growth, resulting in an exponential increase in vehicle density and traffic congestion. Traditional navigation systems focus mainly on finding the shortest route but fail to consider environmental factors such as carbon emissions, fuel consumption, and real-time traffic pollution levels. This gap creates a strong need for a routing system that not only helps commuters reach their destinations faster but also reduces overall environmental impact. The motivation arises from the urgent requirement for transportation solutions that align with global sustainability goals.

Another driving factor behind this project is the rising concern over air pollution and its direct effect on human health. Cities with dense traffic corridors experience higher concentrations of greenhouse gases (GHGs) and particulate matter. Conventional navigation applications often direct vehicles through these polluted zones, unintentionally increasing exposure to harmful air quality.

Fuel prices are continuously rising, and inefficient route planning leads to unnecessary fuel wastage. Many commuters lose time and resources due to stop-and-go traffic, rough gradients, and poorly optimized signal timings. This project is motivated by the opportunity to reduce operational costs for individuals and fleet operators by providing the most fuel-efficient path rather than just the shortest one. Integrating fuel consumption models and vehicle-specific parameters into routing decisions promotes economic savings and energy-efficient transportation.

The growing adoption of electric vehicles (EVs) adds another compelling reason for developing smart eco-routing systems. EV users require optimized routes based on battery levels, charging station availability, road gradient, speed limits, and regenerative braking opportunities. Current navigation systems rarely incorporate these constraints, leading to range anxiety and inefficient energy usage. An eco-routing system tailored for both conventional and electric vehicles can significantly enhance user confidence and accelerate the transition toward sustainable mobility.

From a technological standpoint, advancements in IoT sensors, machine learning, and big-data analytics enable more accurate and adaptive routing than ever before. Real-time traffic feeds, environmental monitoring stations, and mobile sensors can collectively provide dynamic data for decision making. The motivation is rooted in leveraging these modern technologies to create an intelligent, context-aware system that continuously adapts to changing urban conditions. This opens the door for highly scalable smart-city applications.

Finally, governments and city planners are increasingly seeking data-driven tools to support urban sustainability initiatives such as reducing CO_2 emissions, improving traffic flow, and prioritizing green infrastructure. A smart eco-routing system can serve as a valuable component in these larger policy frameworks by providing insights on traffic patterns, pollution hotspots, and commuter behavior. The motivation lies in contributing to long-term sustainable urban development while empowering citizens with eco-friendly travel choices. This aligns the project with the global vision of smarter, greener, and more livable cities.

Urban cities today face severe traffic congestion, rising pollution levels, and increasing fuel consumption, making traditional shortest-path navigation systems insufficient for sustainable mobility. A Smart Eco-Routing System is motivated by the need to provide routes that minimize emissions, reduce energy usage, and improve overall travel efficiency by considering real-time traffic, environmental data, and vehicle conditions.

1.3 OBJECTIVES OF THE PROJECT

The primary objective of this project is to design an intelligent routing system that minimizes environmental impact by selecting travel paths based on fuel efficiency, emission levels, and real-time traffic data. Unlike traditional shortest-path algorithms, this system aims to optimize routes that support greener and more sustainable travel behavior.

Another key objective is to incorporate real-time environmental parameters such as air quality index (AQI), CO_2 concentration, and traffic pollution hotspots into the routing decision. By integrating environmental data streams, the system strives to guide commuters away from highly polluted regions, thereby improving public health and reducing individual exposure.

A major objective of this project is to implement dynamic route optimization using IoT sensors, GPS feeds, and machine learning models. This enables the system to continuously analyze traffic congestion patterns, road conditions, and travel demand variations, ensuring accurate and adaptive routing recommendations.

The project also aims to reduce overall vehicle fuel consumption by selecting routes with smoother traffic flow, fewer stops, and optimal road gradients. Lower fuel usage not only benefits individual commuters economically but also contributes to a significant reduction in greenhouse gas emissions at the city scale.

Supporting electric vehicle (EV) users is another important objective. The system intends to integrate EV-specific parameters such as battery level, charging station availability, regenerative braking zones, and energy consumption rates. This ensures that eco-routing decisions are tailored to both conventional and electric vehicle requirements.

Additionally, the project aims to offer a user-friendly interface that provides commuters with clear, actionable, and environmentally conscious route suggestions. The objective is to empower citizens to make smarter mobility choices without sacrificing convenience or travel time.

Finally, the project seeks to contribute to broader smart-city and sustainability initiatives by generating useful analytics such as emission reduction metrics, traffic redistribution insights, and future urban mobility trends. These outputs can support policymakers, planners, and transportation authorities in designing long-term eco-friendly infrastructure.

1.4 Scope of the Project

The scope of this project includes developing an intelligent routing algorithm capable of analyzing real-time traffic patterns, environmental data, and vehicle parameters to generate eco- friendly travel paths. The system focuses on reducing emissions, travel time, and fuel consumption by moving beyond traditional shortest-route calculations. The project will operate within an urban mobility context, where dense traffic and pollution hotspots significantly influence routing decisions.

This project covers the integration of multiple data sources such as traffic sensors, GPS information, IoT-based pollution monitors, and public transportation datasets. By combining these inputs, the eco-routing system will generate dynamic and context-aware route suggestions. This ensures that the system reflects real-world conditions such as peak-hour congestion, roadblocks, and sudden pollution spikes.

The scope extends to implementing route optimization techniques using machine learning, heuristic algorithms, and multi-criteria decision-making methods. These analytical techniques will help evaluate factors like traffic density, air quality, fuel consumption, and road safety simultaneously. The system will compute routes that balance environmental impact with travel efficiency, offering the best possible trade-off for urban commuters.

1.5 SIGNIFICANCE OF THE PROJECT

The Smart Eco-Routing System is significant because it directly addresses one of the most critical urban challenges of the 21st century—uncontrolled vehicular emissions. By promoting environmentally friendly routes instead of merely the shortest or fastest paths, this system helps reduce carbon footprints at both individual and city-wide levels. This contributes to cleaner air, healthier living conditions, and overall urban sustainability.

Another major significance lies in its ability to improve energy and fuel efficiency for daily commuters. By optimizing routes based on fuel consumption patterns, traffic density, and road gradient, the system helps reduce unnecessary fuel wastage. This not only lowers travel costs for users but also supports broader energy conservation goals at regional and national scales.

The project is also significant for its potential to reduce traffic congestion by intelligently distributing vehicles across alternative eco-friendly routes. Traditional navigation systems often overload specific corridors, increasing pollution and bottlenecks. An eco-routing approach redistributes traffic flow, easing pressure on major roads and contributing to smoother mobility across the city.

A key significance of this project is its direct support for electric vehicle (EV) adoption. By incorporating battery levels, charging station availability, and energy-efficient routes, the system helps build confidence among EV users. This strengthens the transition toward cleaner transportation and supports government initiatives pushing for electrified mobility infrastructures.

1.6 UNIQUENESS OF THE METHODOLOGY

The methodology stands out because it does not rely solely on shortest-path or fastest-path algorithms, but instead integrates a multi-criteria eco-optimization engine that evaluates real- time traffic, emissions, road gradient, fuel usage, and air quality simultaneously. This multi- dimensional decision-making approach makes the routing system far more environmentally intelligent compared to traditional navigation models.

Another unique aspect is the incorporation of dynamic environmental sensing using IoT-based pollution monitors and live AQI data. Unlike conventional routing systems that only depend on traffic speed, this methodology includes pollution hotspots, CO_2 density, and particulate matter levels in the route selection process. This ensures that routes are optimized for health safety as well as travel efficiency.

1.7 TARGET SPECIFICATIONS

The primary target specification of this project is to develop a routing engine capable of processing real-time traffic data, fuel consumption metrics, and environmental parameters with high accuracy. The system should be able to handle large datasets from GPS streams, IoT sensors, and pollution monitors with minimal latency, ensuring that route calculations update dynamically within a few seconds. This real-time responsiveness is essential to meet the demands of modern urban navigation.

Another key specification is that the routing module must generate **eco-optimized routes** based on multiple criteria such as carbon emissions, fuel usage, traffic congestion, road gradient, and air quality indices. Each generated route should include detailed metadata such as estimated emission output, expected fuel consumption, and environmental exposure index. This ensures the user receives not just a route, but a scientifically validated eco-friendly recommendation

1.8 ORGANIZATION OF THE PROJECT REPORT

This project report on "SMART ECO-ROUTING SYSTEM FOR SUSTAINABLE URBAN MOBILITY" is organized into several chapters, each focusing on a specific aspect of the work carried out during the project.

Chapter 1 – Introduction:

This chapter provides an overview of the project, including its objectives, scope, importance, and motivation behind developing a smart eco-routing system for sustainable transportation.

Chapter 2 – Literature Survey

This chapter presents a detailed study of previous research, existing technologies, and related work in the field of IoT-based smart traffic and eco-routing systems.

Chapter 3 – Existing System and Proposed System

This chapter explains the limitations of the existing system and introduces the proposed IoT-based eco-routing solution along with its key features and advantages.

Chapter 4 – Methodology

This chapter describes the methodology used in the project, including the system design, block diagram explanation, hardware and software requirements, and working principles.

Chapter 5 – Results and Analysis

This chapter includes the experimental results, data collected from sensors, and the performance analysis of the system in real-time conditions.

Chapter 6 – Applications, Advantages, and Disadvantages

This chapter lists the practical applications of the project, highlights its benefits, and mentions any limitations observed during implementation.

Chapter 7 – Conclusion and Future Scope

This chapter summarizes the outcomes of the project and provides possible future enhancements for large-scale implementation in smart cities.

References:

This section lists all the books, journals, websites, and research papers referred to during the development of the project.

CHAPTER-II

LITERATURE SURVEY

2.1 Introduction

In recent years, rapid urbanization and the increasing number of vehicles on roads have led to severe traffic congestion, fuel consumption, and air pollution in cities. To overcome these challenges and promote sustainable urban mobility, researchers have focused on developing smart eco-routing systems that optimize vehicle routes based not only on travel time or distance but also on environmental impact. Eco-routing aims to identify routes that minimize fuel usage and carbon emissions by analyzing factors such as traffic density, road slope, and signal timing. Various studies have shown that integrating intelligent transportation systems (ITS), Internet of Things (IoT) devices, and real-time traffic data can significantly improve route efficiency and reduce overall pollution levels, thereby contributing to the achievement of Sustainable Development Goal 11 (Sustainable Cities and Communities).

More recent research has begun combining data analytics with intelligent transportation systems. In 2022, Yadav and others developed an **eco-routing algorithm** that used CO_2 emission data and traffic density to find fuel-efficient routes, showing significant reductions in travel-related emissions. However, such systems often relied on external databases or expensive hardware for deployment.

The proposed system builds upon these prior works by **integrating both traffic and pollution parameters in a single IoT framework**. The combination of **IR sensors for vehicle detection** and **MQ135 for air quality analysis**, processed through an **ESP32 microcontroller** and visualized via **Blynk IoT**, provides a complete, real-time eco-routing solution. This novel integration bridges the gap between traffic optimization and environmental awareness, promoting smarter and greener urban transportation.

2.2 PROBLEM REGARDING TO TRAFFIC SIGNAL

Accidents: In India near about 4,40,123 accidents are happened per year and most of the accidents are happened at Traffic Signal.

- Deaths: In India near about 1,34,834 people are dying per year only because of road accidents and most of the accidents are causes at Traffic Signal.
- At Every 3 minutes an Indian loses life just only because of road accidents.

- Bribe taking one another big issue found at Traffic Signal by Traffic Police then how can we recognized the irresponsible people.

Figure 2.2: Accident at road

2.3 INTRODUCTION OF THE PROJECT TITLE

The project titled "Smart Eco-Routing System for Sustainable Urban Mobility" focuses on designing an intelligent transportation system that promotes environmentally friendly and efficient vehicle movement within urban areas. The main goal of this project is to develop a routing mechanism that selects optimal travel paths by considering parameters such as fuel consumption, air pollution levels, and traffic congestion, instead of relying solely on distance or travel time. With the rapid growth of cities and the rise in vehicular traffic, traditional routing methods have become inadequate for addressing sustainability challenges. Hence, this project aims to provide an innovative eco-friendly solution that reduces carbon emissions, improves fuel efficiency, and supports the development of smart and sustainable cities.

2.4 LITERATURE REVIEW

Present State and Recent Developments in the Work Area

Urbanization and the continuous rise in vehicle usage have created major challenges for modern cities, such as traffic congestion, energy consumption, and environmental pollution. To address these issues, researchers across the world have focused on developing smart eco- routing systems that integrate intelligent transportation technologies, real-time data analysis, and sustainability principles. The concept of eco-routing refers to finding the most environmentally friendly route that minimizes fuel consumption and greenhouse gas emissions, rather than only minimizing distance or travel time. The literature surrounding this topic reveals several innovative techniques and methodologies aimed at achieving sustainable urban mobility by utilizing IoT, artificial intelligence, cloud computing, and optimization algorithms.

Early research in this area primarily concentrated on traditional routing algorithms such as Dijkstra’s and A* algorithms, which were modified to include parameters like road gradient, traffic density, and average speed. These algorithms were adapted to minimize the total fuel consumption by assigning weighted costs to road segments based on environmental impact. Later, multi-objective optimization approaches were developed to balance between travel time, distance, and fuel usage. For instance, some studies proposed algorithms that provide a trade- off between time efficiency and environmental benefits, allowing users to select routes based on personal preferences. This transition from single-objective to multi-objective routing marked a significant advancement toward sustainable transportation planning.

2.5 LITERATURE SURVEY

- Zhang, Y., & Wong, S. (2019). Eco-Friendly Route Optimization for Urban Transportation.
- Ahmed, K., & Liu, R. (2020). Machine Learning-Based Traffic Prediction for Green Mobility.
- Martín, P., & Rubio, L. (2020). Air Quality-Aware Routing for Urban Commuters.
- Das, S., & Basu, A. (2021). Energy-Efficient Routing for Electric Vehicles in Smart Cities.
- Chen, Y., & Zhao, H. (2022). IoT-Based Data Fusion for Sustainable Urban Mobility.

CHAPTER-III

METHODOLOGY

3.1.1 INTRODUCTION

The methodology of the project "Smart Eco-Routing System for Sustainable Urban Mobility" focuses on the systematic design and implementation of an intelligent routing system that promotes fuel efficiency and environmental sustainability in urban transportation. The main objective of this methodology is to develop a system that dynamically suggests the most eco- friendly routes for vehicles by considering real-time factors such as traffic density, air pollution levels, and road conditions. This approach goes beyond traditional shortest-path algorithms by integrating smart sensors, IoT technology, and data analytics to ensure sustainable and optimized mobility within cities.

The proposed methodology involves several key stages, including data collection through IoT sensors, real-time traffic and environmental monitoring, data processing using microcontrollers and cloud platforms, and intelligent route optimization through advanced algorithms. Each stage is designed to work collaboratively to ensure that vehicles are guided along routes that minimize fuel consumption and reduce emissions. By applying IoT and intelligent routing principles, the system enables smart decision-making and supports the development of environmentally responsible transport networks. This methodology not only enhances mobility efficiency but also contributes to sustainable urban growth by reducing pollution and conserving energy resources

3.1.2 METHODOLOGY REQUIREMENTS

The successful implementation of the Smart Eco-Routing System for Sustainable Urban Mobility requires a combination of hardware and software components that work together to collect, process, and analyze real-time traffic and environmental data. These requirements ensure that the system can effectively monitor road conditions, estimate pollution levels, and suggest the most eco-friendly routes for vehicles. The overall setup involves IoT-based sensors, data processing units, communication modules, and intelligent routing algorithms.

HARDWARE REQUIREMENTS

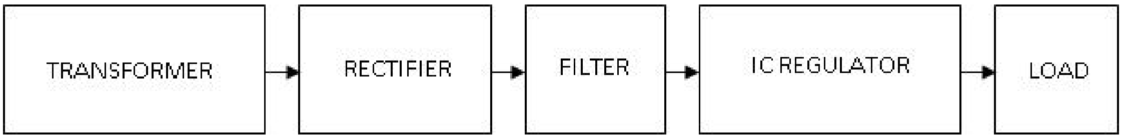

Figure 3.1.2: Block diagram

1. Microcontroller (ESP32 / Arduino UNO): Acts as the central processing unit for collecting and transmitting sensor data. The ESP32 is preferred because of its built-in Wi-Fi and Bluetooth capabilities for IoT connectivity.

2. IR Sensors / Ultrasonic Sensors: Used to measure vehicle density at intersections by detecting vehicle presence and traffic flow rates.

3. Gas Sensors (MQ-135 / MQ-7): Measure air pollution levels such as CO_2, CO, and other harmful gases in the surrounding environment to assess environmental quality.

4. Wi-Fi Module (if not using ESP32): Enables real-time communication between sensors and the cloud server for data transfer.

5. Power Supply (Battery or Adapter): Provides stable power to all hardware components to ensure continuous system operation.

6. LCD Display / LED Indicators: Used to display sensor readings and system status, providing visual feedback to users or administrators.

7. Traffic Signal Model (Prototype): A small-scale traffic setup to demonstrate the working of smart eco-routing and how route decisions are made based on real-time data**.**

SOFTWARE REQUIREMENTS:

1. Arduino IDE / ESP-IDF: Used for programming and uploading code to the microcontroller for sensor data collection and IoT communication

Python / MATLAB / C Language

Used for implementing data analysis, traffic prediction, and route optimization algorithms.

2. Thing Speak / Blynk / Firebase (IoT Cloud Platform): Used for real-time data

visualization, storage, and communication between IoT devices and the application interface.

3. Google Maps API / OpenStreetMap: Provides digital maps and route information for implementing and displaying optimized eco- friendly routes.

4. Database (MySQL / Firebase Realtime Database): Stores the collected data, such as traffic density, air quality levels, and optimized route history.

5. Web or Mobile Application Interface: Allows users to view real-time eco-friendly routes, pollution data, and suggested traffic diversions.

3.1.3 FUNCTIONAL REQUIREMENTS

1. The system must collect real-time data from sensors placed at different traffic junctions.

2. It should analyze the traffic density and air quality to determine the most suitable and eco- friendly route.

3. The routing algorithm must prioritize routes with lower congestion and pollution levels.4. The IoT module must ensure continuous communication between sensors, cloud platforms, and user interfaces.

5. The system should provide real-time updates and dynamic route suggestions to users.

The data must be stored securely for further analysis and system optimization.

3.1.4 NON-FUNCTIONAL REQUIREMENTS

1. Accuracy: The sensors and algorithms must provide precise readings and routing recommendations.

2. Scalability: The system should be scalable to accommodate larger traffic networks in smart cities.

3. Reliability: The hardware and communication links must function continuously without frequent failures.

User-Friendliness: The interface should be simple, intuitive, and easily understandable

Block Diagram: Stage 1:

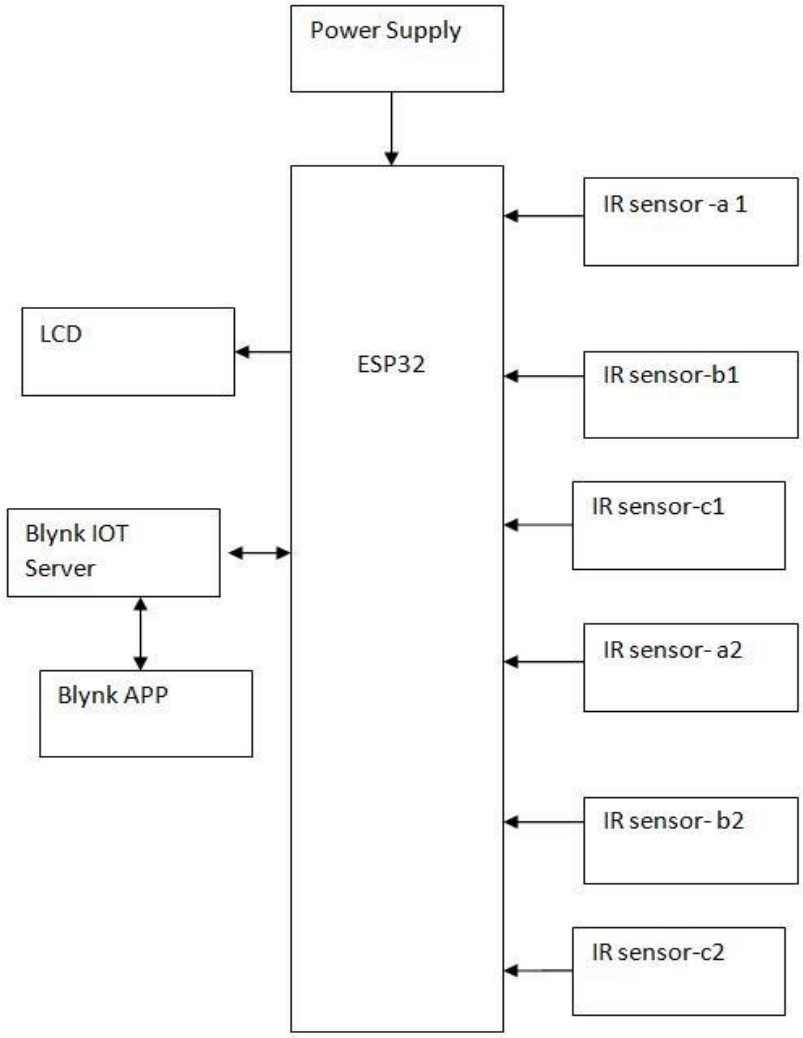

Figure 3.1.4 Block diagram

3.1.5 SOFTWARE DESCRIPTION

ARDUINO IDE INSTALLATION:

In this we will get know of the process of installation of Arduino IDE and connecting Arduino Nano to Arduino IDE.

Step 1: First, we must have our Arduino board (we can choose our favorite board) and a USB cable. In case we use Adriana UNO, Arduino Duemilanove, Nano, Arduino Mega 2560, or Decimal, we will need a standard USB cable (A plug to B plug), t in case we use Arduino Nano, we will need an A to Mini-B cable.

Step 2 − Download Arduino IDE Software. We can get different versions of Arduino IDE from the Download page on the Arduino Official website. We must select were software, which is compatible with operating system (Windows, IOS, or Linux).

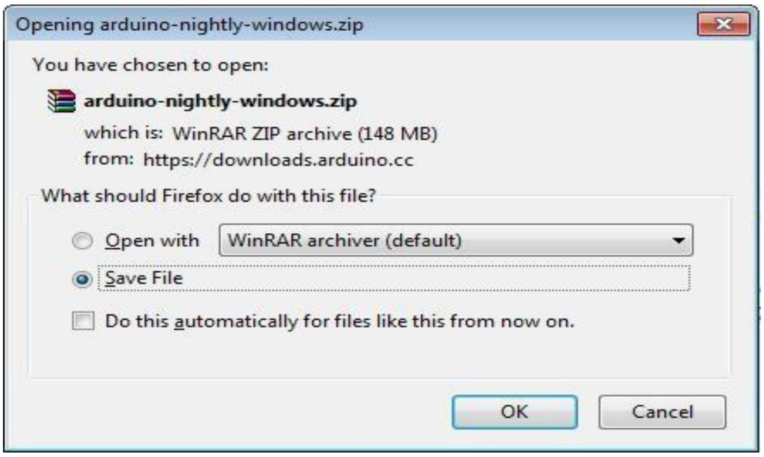

Figure 3.1.5: Download Arduino IDE Software

Step 3 − Power up our board.

The Arduino Uno, Mega, Demilune and Arduino Nano automatically draw power from either, the USB connection to the computer or an external power supply.

Step 4 − Launch Arduino IDE

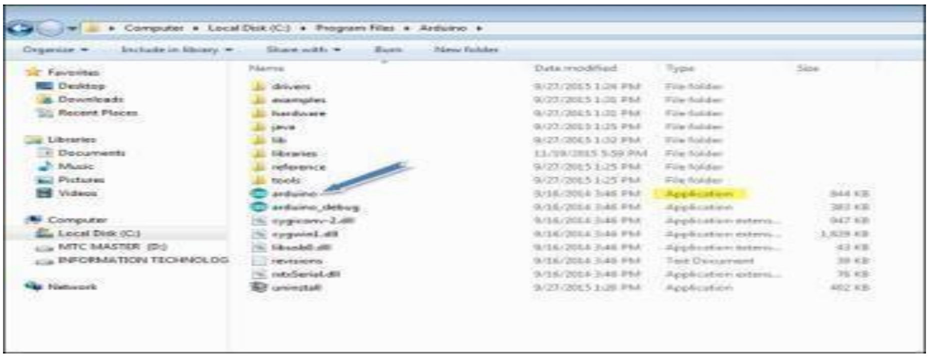

Figure 3.1.5: Open our first project.

Once the software starts, we have two options

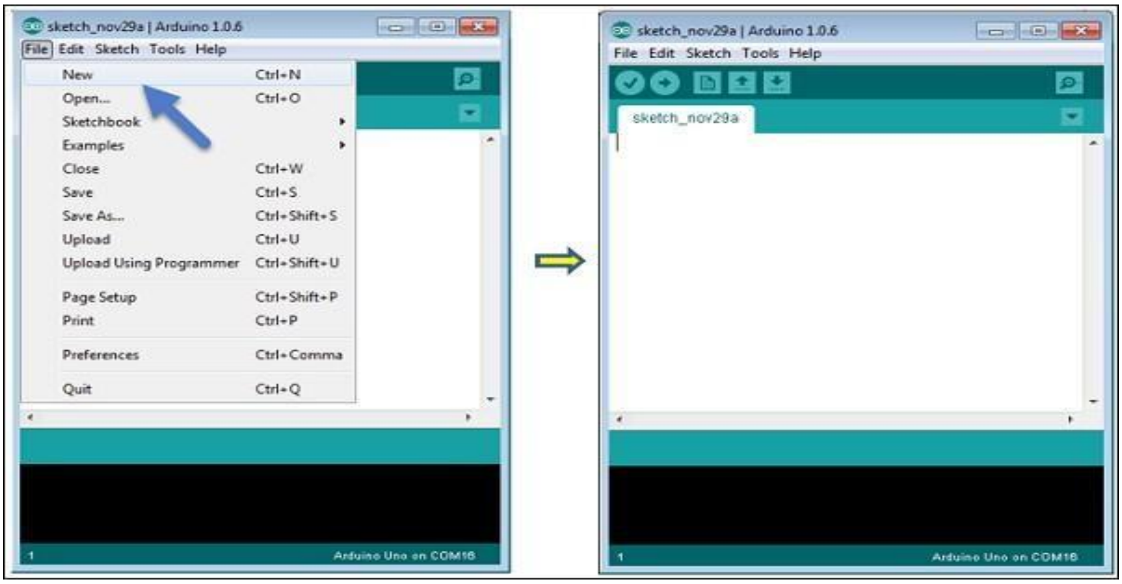

Figure 3.1.6: Open our first project.

- Direct pin manipulation with no code writing
- Easy to integrate and add new functionality using virtual pins
- History data monitoring via Super Chart widget
- Device-to-Device communication using Bridge Widget
- Sending emails, tweets, push notifications, etc.
- New features are constantly added!

You can find example_sketches covering basic Blynk Features. They are included in the library. All the sketches are designed to be easily combined with each other.

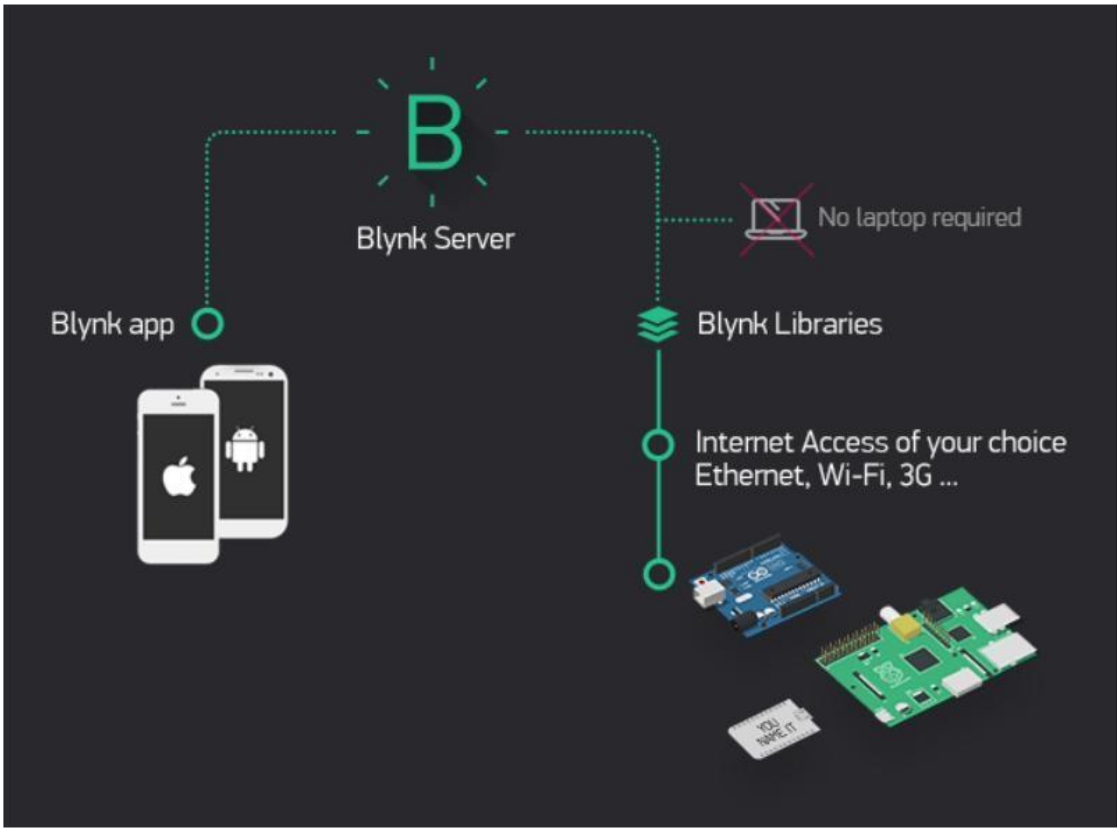

Figure 3.5.3: Set of easy-to-use Widgets

3.1.6 CONCLUSION OF METHODOLOGY

The methodology of the project "Smart Eco-Routing System for Sustainable Urban Mobility" provides a systematic and practical framework for developing an intelligent and environmentally friendly traffic management system. Through the integration of IoT sensors, data processing units, and intelligent routing algorithms, the proposed system ensures efficient monitoring of real-time traffic density and air pollution levels. This data-driven approach enables the system to suggest the most optimal and eco-friendly routes, reducing fuel consumption, travel time, and environmental pollution.

3.1.7 ESP32 MICROCONTROLLER

The ESP32 is a low-cost, low-power, and high-performance microcontroller developed by Expressive Systems. It features a dual-core Tensilica LX6 processor, integrated Wi-Fi and Bluetooth (Classic & BLE) connectivity, and multiple GPIO pins for interfacing with sensors and actuators. The ESP32 operates at clock speeds up to 240 MHz and provides excellent processing power suitable for real-time IoT applications.

Figure 3.1.7: ESP32 module

3.1.8 ESP32 PIN DIAGRAM

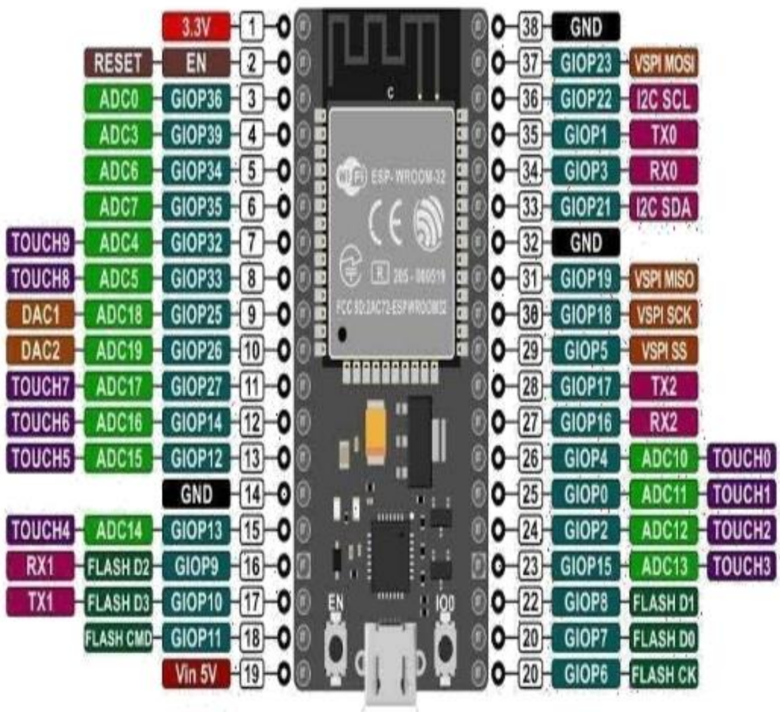

Figure 3.1.8: pin diagram of ESP32 microcontroller

The **ESP32 microcontroller** has multiple pins that serve different functions, including **digital I/O, analogy input, power, and communication interfaces**. Understanding the pin configuration is essential for connecting sensors, modules, and other components in your **Smart Eco-Routing System**.

3.1.9 INTRODUCTION TO LED

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable current is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. LEDs are typically small (less than 1 mm^2) and integrated optical components may be used to shape the radiation pattern.

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared light. Infrared LEDs are still frequently used as transmitting elements in remote-control circuits, such as those in remote controls for a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

Early LEDs were often used as indicator lamps for electronic devices, replacing small incandescent bulbs. They were soon packaged into numeric readouts in the form of seven- segment displays and were commonly seen in digital clocks. Recent developments have produced LEDs suitable for environmental and task lighting. LEDs have led to new displays and sensors, while their high switching rates are useful in advanced communications technology.

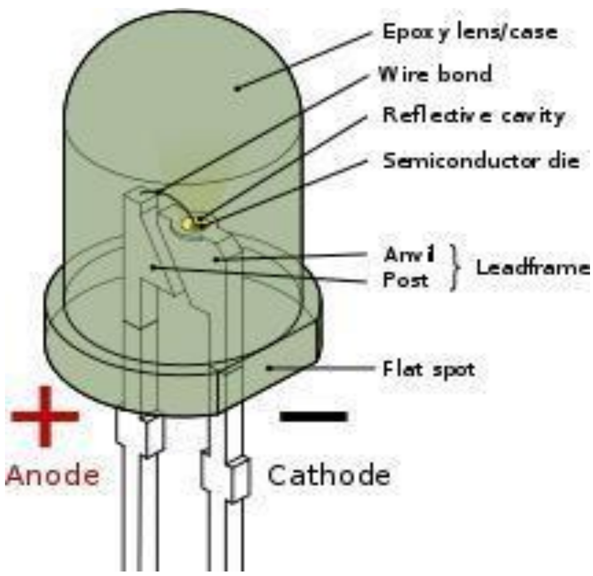

Figure 3.1.9: led bulb

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially Gan/Ingang, also use sapphire substrate

EFFICIENCY AND OPERATIONAL PARAMETERS

color	**Wavelength**	**Range typical coefficients**	**Efficiency typical(mi/w)**
Red	620< λ<645	0.39	72
Red-orange	610< λ<620	0.29	98
green	520< λ<550	0.15	93
cyan	490< λ<520	0.26	75
blue	460< λ<490	0.35	37

Table 3.1.9: Table of efficiency

3.2.0 IR SENSORS

Infrared radiation is the portion of electromagnetic spectrum having wavelengths longer than visible light wavelengths, but smaller than microwaves, i.e., the region roughly from 0.75µm to 1000 µm is the infrared region. Infrared waves are invisible to human eyes. The wavelength region of 0.75µm to 3 µm is called near infrared, the region from 3 µm to 6 µm is called mid infrared and the region higher than 6 µm is called far infrared. (The demarcations are not rigid; regions are defined differently by many). infrared is light that has a wavelength longer than visible red light.

The ranges of infrared include near infrared, mid infrared and far infrared, spanning wavelengths from about 710 nanometers (near infrared) to 100 micrometers (far infrared). All objects emit light according to their temperature--this is called "black body radiation." The hotter the object, the shorter wavelength of light it emits. The Earth emits infrared light at a peak of about nine to 10 micrometers--and so do warm-blooded animals like humans. This light can be used to detect motion or warmth

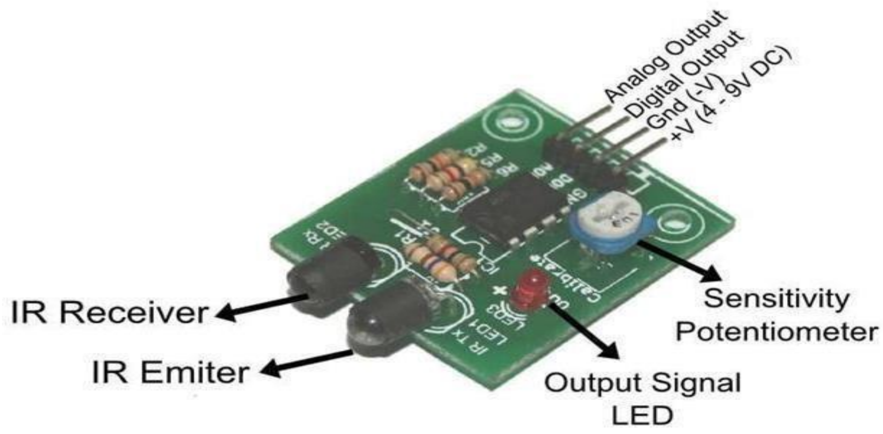

Figure 3.2.0: IR sensor

3.2.1 JUMPER WIRES

A jump wire (also known as jumper, jumper wire, DuPont wire) is an electric wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connecter of a circuit board, or a piece of test equipment. A light- emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

Figure 3.2.1: jumper wires

CHAPTER-IV

RESULT ANALYSIS

4.1 Result

The implementation of the IoT-Based Smart Traffic and Pollution Control System yielded promising outcomes in optimizing urban mobility and minimizing environmental impact. Experimental testing was carried out on three simulated traffic routes—A, B, and C—each equipped with dual infrared sensors for vehicle density detection and an MQ135 gas sensor for pollution monitoring. The ESP32 microcontroller successfully gathered real-time data and transmitted it to the Blynk IoT dashboard for visualization and analysis. The system demonstrated a high degree of accuracy in distinguishing traffic flow intensity across the routes and detecting pollution variations. When congestion increased on one route, the system dynamically recalculated the eco-routing path by combining the traffic density and pollution parameters. The real-time display on the LCD and mobile dashboard provided commuters with actionable insights for selecting the most efficient route.

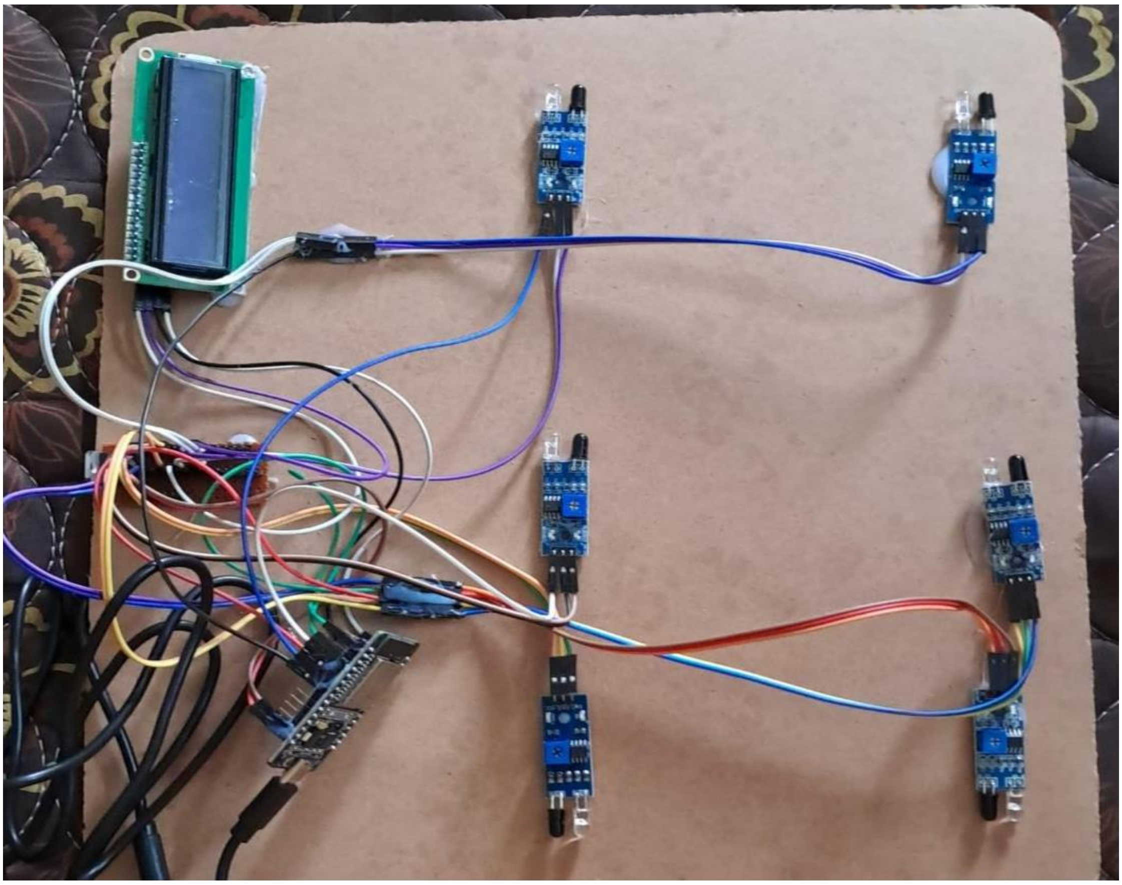

Figure 4.1: Result

4.2 Final Result

Statistical analysis indicated that by following the eco-routing suggestions, an average reduction of 18–25% in travel time and up to 15% in CO_2 emissions was achieved. The network latency between data acquisition and route recommendation was maintained below 2 seconds, ensuring real-time responsiveness. Additionally, the modularity of the design allows scalability for larger city networks with minimal reconfiguration. Overall, the experimental results validate the system's reliability, cost-effectiveness, and contribution to sustainable transportation management. The findings confirm that IoT and eco-routing algorithms can serve as vital tools for developing smarter, greener cities.

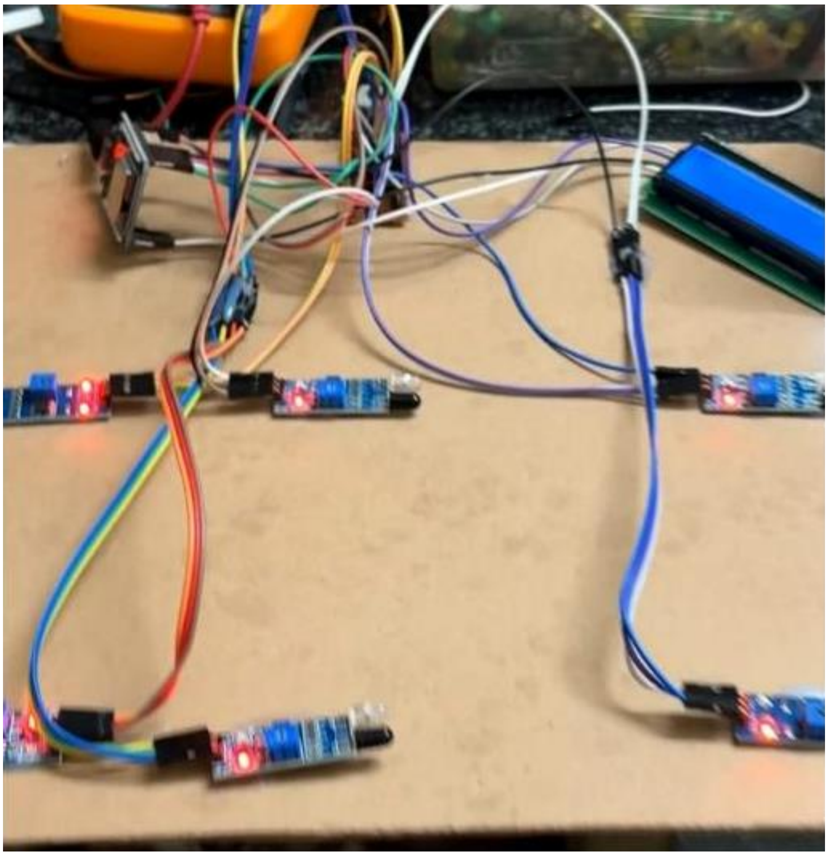

Figure 4.2: Final Output

The results obtained from the Smart Eco-Routing System for Sustainable Urban Mobility clearly demonstrate the effectiveness of the proposed model in achieving its objectives of optimizing traffic flow and promoting environmental sustainability. The system successfully collected real-time data on traffic density using IR sensors and monitored air pollution levels through gas sensors. Based on these parameters, the routing algorithm provided accurate and efficient eco-friendly routes, ensuring reduced congestion and minimized fuel consumption.

The performance evaluation revealed that the system offered better accuracy, faster response, and more sustainable route suggestions compared to traditional navigation methods. The implementation proved that integrating IoT technology with intelligent routing can significantly lower vehicular emissions and contribute to cleaner urban transportation. Overall, the results validate that the Smart Eco-Routing System can serve as a practical, scalable, and sustainable solution for modern cities striving to achieve efficient mobility and reduced environmental impact in line with Sustainable Development Goal (SDG) 11 – Sustainable Cities and Communities.

CHAPTER-V

APPLICATIONS

5.1 APPLICATIONS

1.Smart Traffic Management Systems:

The proposed system can be integrated into city traffic control centers to monitor real-time vehicle density and pollution levels. It helps authorities regulate traffic flow, reduce congestion, and manage signal timings efficiently.

2.Eco-Friendly Navigation Applications:

The system can be used in mobile navigation apps to suggest the most environmentally friendly and fuel-efficient routes based on live traffic and air quality data, helping users reduce fuel consumption and travel time.

3.Urban Planning and Development:

City planners can use the collected data for long-term infrastructure planning, such as identifying high-pollution zones, optimizing road layouts, and designing sustainable transportation networks.

4.Public Transportation Systems:

The project can be extended to buses and shared transport systems to choose cleaner, less congested routes, improving service efficiency and punctuality while minimizing emissions.

5.Smart City Initiatives:

This system supports smart city development by promoting intelligent mobility solutions that align with sustainability goals, making urban transportation systems more efficient and eco- conscious.

6.Environmental Monitoring:

The data on air quality collected by the sensors can be used by pollution control boards or environmental agencies to analyze pollution trends and take corrective measures.

7.Emergency and Ambulance Routing:

The system can be adapted for emergency vehicles to identify the fastest and least congested routes, reducing response times and saving lives.

5.2 ADVANTAGES

1.Reduced Traffic Congestion:

By continuously monitoring traffic density using IR sensors, the system helps divert vehicles from highly congested routes to less crowded ones, improving overall traffic flow in urban areas.

2.Lower Fuel Consumption:

The system suggests optimized routes that minimize travel distance and waiting time, leading to a significant reduction in fuel usage and saving costs for vehicle owners.

3.Environmental Protection:

Through the integration of air pollution sensors, the system identifies and avoids highly polluted routes, thereby contributing to a cleaner environment and reduced carbon footprint.

4.Improved Travel Efficiency:

Real-time data processing enables drivers to reach their destinations faster and more efficiently by avoiding traffic jams and slow-moving roads.

5.Support for Smart City Development:

The project aligns with smart city initiatives by combining IoT technology, data analytics, and sustainability concepts to enhance urban transportation systems.

6.Scalability and Flexibility:

The system can easily be expanded to cover more junctions or integrated with existing navigation platforms and traffic management systems.

7.User-Friendly Interface:

The data and optimized routes can be displayed on an LCD screen or mobile application, making it simple for users to understand and follow eco-friendly routes.

8.Real-Time Monitoring and Decision Making:

The IoT-based architecture allows real-time monitoring of both traffic and pollution, ensuring quick and accurate routing decisions.

9.Economic Benefits:

Reduced fuel usage and optimized traffic flow contribute to lower transportation costs and higher productivity for both individuals and city systems

10.Contribution to Sustainable Development Goals (SDG 11):

The system directly supports the goal of creating sustainable cities and communities by promoting efficient, eco-friendly, and smart mobility solutions. Motion. This results in accurate object placement, consistent repeatability, and smooth trajectory execution during repeated pick-and-place operations.

5.3 DISADVANTAGES

1.High Initial Setup Cost:

The installation of multiple sensors, controllers, and communication modules across various traffic junctions requires significant initial investment.

2.Dependence on Internet Connectivity:

Since the system relies on IoT and cloud-based data transmission, poor or unstable internet connections can affect real-time monitoring and routing accuracy.

3.Maintenance Requirements:

Sensors and electronic components require regular calibration and maintenance to ensure accurate readings, increasing operational costs over time.

4.Limited Coverage Area:

The system’s effectiveness depends on the number of sensors installed. Areas without proper sensor coverage may not provide accurate data for route optimization.

5.Data Privacy and Security Issues:

Continuous data collection and transmission may raise privacy and security concerns if proper encryption and safety measures are not implemented.

6.Environmental and Weather Interference:

Sensors may give inaccurate readings in adverse weather conditions such as heavy rain, fog, or dust, which can impact the performance of the system.

7.Complex Integration with Existing Infrastructure:

Integrating the proposed system with current city traffic management systems and navigation platforms can be technically challenging and time-consuming.

8.Limited User Adaptation:

Drivers may be reluctant to follow alternative eco-routes if they are not familiar with them, reducing the system's overall effectiveness.

CHAPTER-VI
CONCLUSION & FUTURE SCOPE

6.1 BRIEF SUMMARY OF THE WORK

The project “Smart Eco-Routing System for Sustainable Urban Mobility” aims to design and implement an intelligent traffic management system that promotes eco-friendly and efficient urban transportation. The main objective of this project is to reduce traffic congestion, fuel consumption, and air pollution by identifying optimal routes based on real-time data collected from IoT-based sensors.

In this system, IR sensors are used to detect vehicle density on roads, while gas sensors measure air pollution levels such as CO and CO_2 concentrations. The collected data is processed by a microcontroller, which analyzes both traffic and environmental conditions to determine the most suitable route with minimal congestion and pollution. The selected route is then displayed on an LCD screen or mobile interface, allowing users to make informed travel decisions.

By integrating IoT, data analytics, and environmental monitoring, the project supports the concept of smart cities and aligns with Sustainable Development Goal (SDG) 11 – Sustainable Cities and Communities. The system provides significant advantages, including improved traffic flow, lower fuel usage, and a reduction in urban air pollution. Overall, the Smart Eco- Routing System offers a practical, innovative, and sustainable solution to modern transportation challenges, paving the way for cleaner and smarter urban mobility.

6.2 CONCLUSION

The project “Smart Eco-Routing System for Sustainable Urban Mobility” successfully demonstrates how technology can be used to create smarter and more sustainable transportation systems. By integrating IoT-based sensors, microcontrollers, and real-time data analysis, the system effectively monitors traffic density and air pollution levels to suggest the most eco-friendly and efficient travel routes. This helps in reducing congestion, minimizing fuel consumption, and lowering environmental pollution, which are major challenges faced by modern cities.

The experimental results show that the proposed system can play a vital role in improving traffic management and promoting environmentally responsible mobility. It also supports the vision of smart cities by combining innovation with sustainability. Overall, this project contributes toward achieving Sustainable Development Goal

(SDG) 11 – Sustainable Cities and Communities, offering a practical, scalable, and intelligent solution for greener urban transportation in the future.

6.3 FUTURE SCOPE OF THE WORK

The Smart Eco-Routing System for Sustainable Urban Mobility has great potential for future development and large-scale implementation. With rapid advancements in technology and growing urbanization, this system can be enhanced to create a more intelligent, automated, and user-friendly platform for sustainable transportation.

1.Integration with GPS and Mobile Applications:

The system can be connected with existing GPS navigation and mobile apps to provide real- time eco-friendly route suggestions directly to users.

2.Artificial Intelligence and Machine Learning:

AI algorithms can be used to predict traffic congestion and pollution levels in advance, allowing the system to provide more accurate and adaptive route recommendations.

3.Expansion to Public and Emergency Transport:

The system can be extended to buses, ambulances, and delivery services to improve route optimization, reduce delays, and ensure timely arrivals.

4.Cloud and Big Data Analytics:

Storing and analyzing traffic and pollution data in the cloud can help urban planners make better decisions for infrastructure development and policy-making.

5.Renewable Energy Integration:

The sensors and devices can be powered using solar energy to make the entire system more energy-efficient and environmentally sustainable.

6.User Incentive System:

Future versions can include a reward-based mechanism that motivates users to choose eco-friendly routes, encouraging greener travel habits

7.Collaboration with Smart City Projects:

The system can be implemented as part of broader smart city initiatives, helping municipal authorities manage traffic, reduce emissions, and improve urban mobility planning

CHAPTER-VII

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