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Speed Management Blueprint: Conception of an IoT-Based Electric Vehicle Speed Limiter Monitoring System for Kigali City Vehicles

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Abstract: The Electric Vehicle Speed Limiter Monitoring System is an Internet of Things (IoT)-based solution to prevent traffic accidents in Kigali, Rwanda. The system utilizes advanced technology to monitor vehicle speed, identity, and position, including GPS, RFID cards, RFID 522 modules, and IR sensors. While RFID cards facilitate easy vehicle identification, RFID 522 modules identify speed infractions, IR sensors guarantee precise speed measurement, and GPS tracking offers real-time monitoring capabilities. Campaigns to raise public awareness will assist the system, which will be smoothly incorporated into Kigali's road network and examined for patterns and trends. Ensuring seamless implementation and enforcement will require collaboration with municipal authorities, law enforcement agencies, and transportation authorities. Anticipated results include a significant decrease in traffic accidents, increased traffic safety precautions, and improved traffic management techniques. Advanced technology like IR sensors, RFID cards, RFID 522 modules, and GPS are used by Kigali, Rwanda's IoT-based Electric Vehicle Speed Limiter Monitoring System, to track vehicle position, identification, and speed. It conducts public awareness campaigns, analyses speed-related accidents, and integrates them with Kigali's road network. Smooth implementation is ensured by cooperation with local law enforcement and authorities, which lowers accident rates and improves traffic management techniques. The system aims to improve road safety and foster a safer atmosphere for all Kigali drivers.

Keywords: IR Sensor; RFID 522; Speed Management Blueprint; Arduino NANO; Regulator lm7805 DC5v; Transformer AC12v; Windows Operating System; Arduino IDE and Rectifier DC12v.

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1. Introduction

The Internet of Things (IoT) is a collection of extremely intelligent connected devices and smart technology. IoT does not require human-to-human or human-to-computer communication for data transfer via a network. The Internet of Things (IoT) has improved the ease and intelligence of our regular tasks. We've used IoT in many things, including cars, gas, electricity, and

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water. Most residents in Kigali, Rwanda, rely primarily on vehicle transportation. Road accidents have become a significant issue in Kigali, Rwanda, with speeding being the primary cause of these incidents. On Kigali's highways, a vehicle must be driven at a set speed. Reducing the number of accidents is feasible by managing the vehicle's speed [1]. The authors have completed a project on this issue. Many vehicles overspeed when beginning their journey, which is the primary cause of traffic accidents. The authors have created a device that tracks a vehicle's speed. For each vehicle, the authors have employed a smart card or board. Every smart card or board is assigned a unique number [2]. When a vehicle speeds, the device uses the smart card or board number to send a message to the closest police control room. The device simultaneously alerts the driver about their excessive speed. Every device has internet connectivity, which can be monitored and managed [3].

2. Objective

To develop an IoT device for monitoring and controlling vehicle speed.

2.1. Justification of Study

Almost every day, there is a traffic accident in Kigali, Rwanda. In Kigali, many traffic accidents are caused by inexperienced, poorly educated, or defective vehicles. Over-speeding is the leading cause of traffic accidents. Despite frequent incidents, drivers continue to disregard speed limits [4]. The authors have developed a technique for monitoring and controlling vehicle speed. An IoT gadget warns drivers when they exceed the speed limit, and the driver controls the vehicle's speed. This kind of driver speed control will significantly lower the number of traffic accidents [5].

2.2. Scope of Study

Traffic demand on the roads is rising daily. We have developed an IoT-based vehicle speed monitoring and controlling system to lower the number of accidents on Rwandan roads. The Ministry of Road and Transport can use this device to monitor and control vehicle speed [6].

2.3. State of the Art

Kigali City's "Speed Management Blueprint" initiative employs an IoT-based speed limiter monitoring system to improve traffic management and road safety. The system combines IoT, EV speed limiters, and data analytics technologies to monitor and manage the speed of electric vehicles in real-time. The technology also uses data analytics and machine learning to identify patterns and improve speed control methods [7]. The project aligns with efforts to improve urban transportation and infrastructure within the framework of smart city initiatives. A supporting regulatory framework is required for successful implementation. The system also features interfaces that are easy for drivers and municipal officials. Furthermore, cybersecurity is prioritized, and robust measures are implemented to prevent cyberattacks [8].

3. Materials and Methods

3.1. Requirement Analysis and Materials

Requirements analysis is the process of determining what users expect from a system that must be modified. Analyzing requirements entails examining all of the proposed system's hardware and software. Requirements analysis primarily describes evaluating, confirming, and managing hardware or software requirements. Functional specs are the terms used to describe these needs in software or hardware engineering [9]. With its integrated USB, the compact all-in-one and breadboard-friendly Arduino Nano offers a comprehensive and convenient solution. It has an IR sensor, a GSM SIM800L Quad-Band module, an LCD, a buzzer, a rectifier, a GPS module, and an RFID 522 transponder and transceiver. Vehicle identification is made possible by the RFID card, which is a unique number [10].

In addition, the Arduino Nano has an LED light source, a 220V–12V Step-down Transformer 50Hz, a 6V rechargeable battery, and an LM7805 DC5v regulator. A transponder and transceiver, an IR sensor, a GSM SIM800L Quad-Band module, a buzzer, a rectifier, and a GPS module make up the RFID 522 system. The included ceramic antenna of the NEO-6M GPS module, a GPS receiver, provides strong satellite search capabilities [11]. A step-down transformer, regulator, battery, and RFID card are also included with the Arduino Nano. When current passes through the LED light source, photons, a kind of energy, are released, resulting in light emission. The Arduino Nano is a flexible and adaptable gadget that can be included in various applications [12].

3.2. Design Methods of the System

System designers have developed it in several ways. The designs are listed below. A block diagram is a system diagram where blocks connected by lines represent the main components and display the relationships between the blocks [13]. Each component functions as an input or output device coupled to a microcontroller (Figure 1).

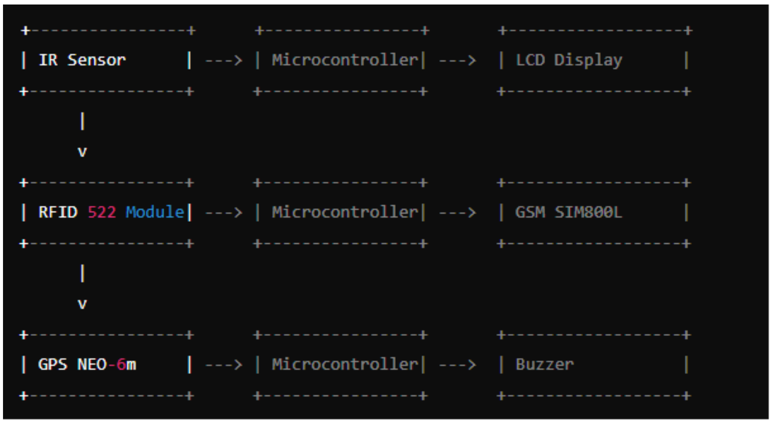

Figure 1: Breakdown of the system

Here's a breakdown of the system:

IR Sensor

- Connects to a microcontroller.
- The microcontroller is connected to an LCD.

RFID 522 Module

- Connects to a microcontroller.
- The microcontroller is connected to a GSM SIM800L module.

GPS NEO-6m

- Connects to a microcontroller.
- The microcontroller is connected to a buzzer.

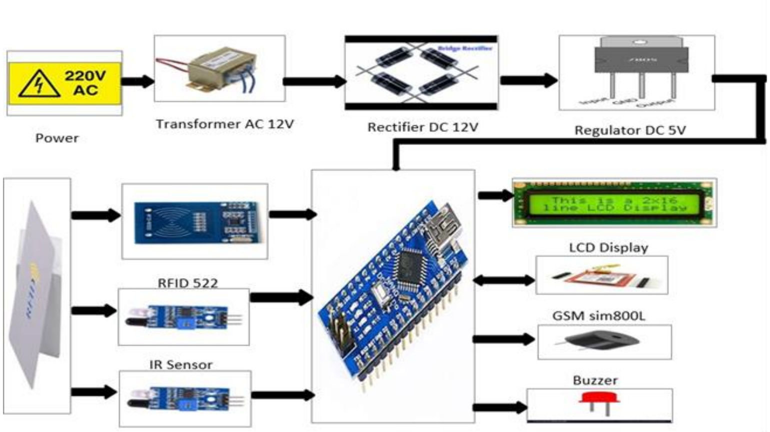

Figure 2: Block Diagram of the Project System

Each sensor/module sends its data to a microcontroller, which processes the information and then communicates with the output devices (LCD, GSM module, buzzer) (Figure 2).

3.3. Circuit Diagram of the System

Figure 3: Breakdown of the system

Here is the operating principle based on the above diagram (Figure 3):

IR Sensor

- Connects to an Arduino Nano
- The Arduino Nano is connected to an LCD Display.

RFID 522

- Connects to the Arduino Nano.

GPS NEO-6m

- Connects to the Arduino Nano.

Buzzer

- Connects to the Arduino Nano.
- The Arduino Nano is also connected to the GSM SIM800L module.

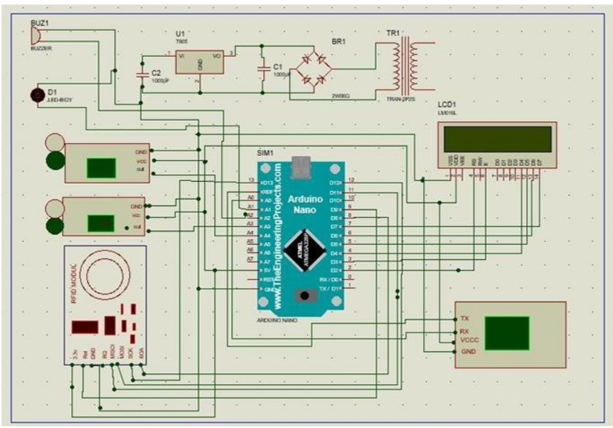

Figure 4: Circuit Diagram of the Speed Management System based on IoT

The flow indicates that the Arduino Nano is central to the system, collecting data from the IR sensor, RFID module, and GPS module [14]. The Arduino then processes this data and provides output to the LCD, GSM module, and buzzer (Figure 4).

3.4. Flowchart of the Proposed System with Math Lab Codes

The flowchart provides a detailed outline of the system's operating principle [15]. Here's a step-by-step explanation based on the flowchart (Figures 5 and 6):

Start

- The system begins its operation.

Vehicle Detected

- The system detects the presence of a vehicle.

Measure Speed (IR Sensor)

- The IR sensor measures the speed of the detected vehicle.

Identify Vehicle (RFID 522 Module)

- The RFID module identifies the vehicle.

Process Data (Microcontroller)

- The microcontroller processes the data received from the IR sensor and RFID module.

Is Speed Limit Exceeded?

- The system checks if the vehicle's speed exceeds the speed limit.

If Speed Limit Not Exceeded

- Continue normal operation without any alerts.
- Store data for records.

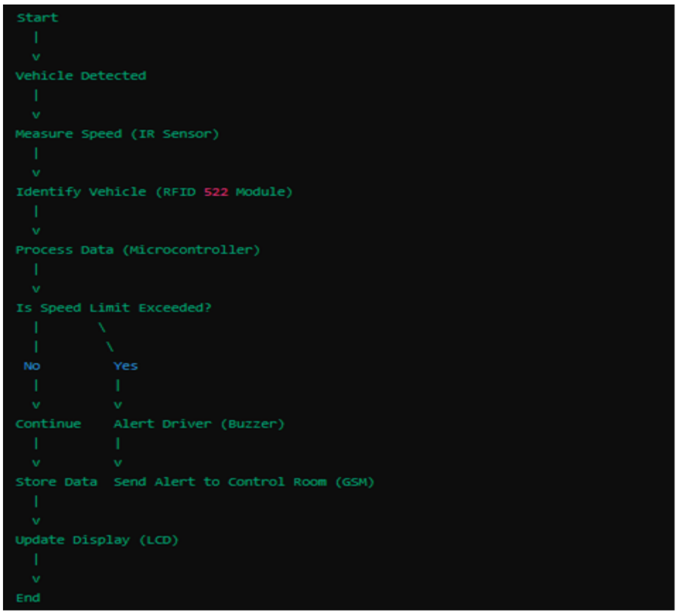

Figure 5: Breakdown for Flowchart of the Proposed System

If the Speed Limit Exceeded

- Alert the driver using the buzzer.
- Send an alert to the control room using the GSM module.
- Store data for records.

Update Display (LCD)

- Update the LCD with the relevant information.

End

- The process is completed.

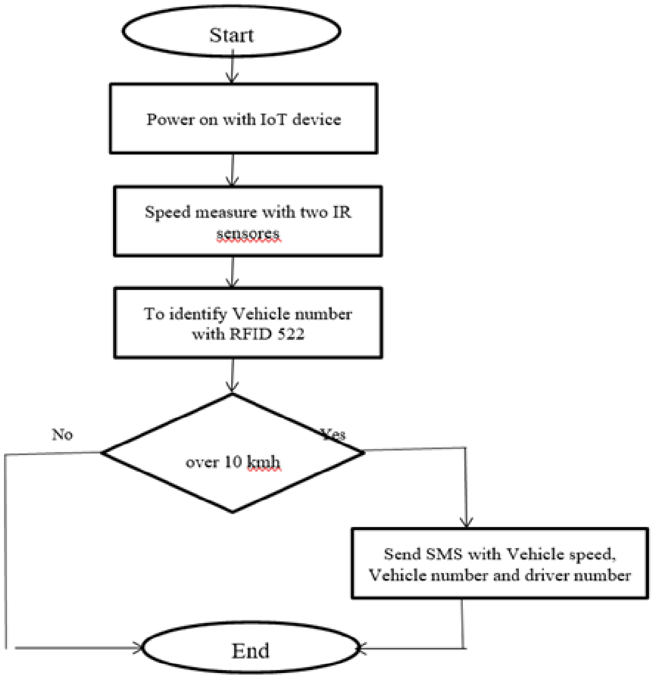

Figure 6: Flowchart of the Proposed System

3.5. Mat lab codes of the system

Step 1: Initialize the System

```
% Initialize the system
disp('System Initialized');
```

Step 2: Detect Vehicle

```
% Function to detect vehicle
function vehicleDetected = detectVehicle()
   % Code to detect vehicle using sensors
   vehicleDetected = true; % Assuming vehicle is detected for simplicity
end
if detectVehicle()
   disp('Vehicle Detected');
end
```

Step 3: Measure Speed (IR Sensor)

```
% Function to measure speed
function speed = measureSpeed()
   % Code to measure speed using IR sensor
   speed = 70; % Example speed value
end
speed = measureSpeed();
disp(['Speed Measured: ', num2str(speed), ' km/h']);
```

Step 4: Identify Vehicle (RFID 522 Module)

```
% Function to identify vehicle using RFID
function vehicleID = identifyVehicle()
   % Code to identify vehicle using RFID module
   vehicleID = 'ABC123'; % Example vehicle ID
end
vehicleID = identifyVehicle();
disp(['Vehicle ID: ', vehicleID]);
```

Step 5: Process Data (Microcontroller)

```
% Process the data
disp('Processing Data');
```

Step 6: Check Speed Limit

```
% Define speed limit
speedLimit = 60;
% Check if speed limit is exceeded
if speed > speedLimit
   speedExceeded = true;
   disp('Speed Limit Exceeded');
else
   speedExceeded = false;
   disp('Speed within Limit');
end
```

Step 7: Take Action Based on Speed Limit

```
% Take appropriate action
if speedExceeded
   % Alert Driver
   disp('Alerting Driver');
   % Code to activate buzzer
   activateBuzzer();
   % Send alert to control room
   disp('Sending Alert to Control Room');
   sendAlertToControlRoom(vehicleID, speed);
      % Store data
   storeData(vehicleID, speed, true);
else
   % Continue normal operation
   disp('Continuing Normal Operation');
      % Store data
   storeData(vehicleID, speed, false);
end
% Function to activate buzzer
function activateBuzzer()
   % Code to activate buzzer
   disp('Buzzer Activated');
end
% Function to send alert to control room
```

```
function sendAlertToControlRoom(vehicleID, speed)
    % Code to send alert using GSM module
    disp(['Alert Sent for Vehicle ID: ', vehicleID, ' Speed: ', num2str(speed)]);
end
% Function to store data
function storeData(vehicleID, speed, speedExceeded)
    % Code to store data
    disp(['Data Stored: Vehicle ID: ', vehicleID, ' Speed: ', num2str(speed), ' Speed Exceeded: ', num2str(speedExceeded)]);
end
```

Step 8: Update Display (LCD)

```
% Function to update LCD
function updateDisplay(vehicleID, speed, speedExceeded)
    % Code to update LCD display
    if speedExceeded
        displayText = [‘Vehicle ID: ‘, vehicleID,’ speed: ‘, num2str(speed),’ Exceeded Limit’];
    else
        displayText = [‘Vehicle ID: ‘, vehicleID,’ speed: ‘, num2str(speed)];
    end
    disp(['LCD Display Updated: ', displayText]);
end
```

Step 9: End

```
% End of process
disp('Process Completed');
updateDisplay(vehicleID, speed, speedExceeded);
```

This system aims to detect and identify vehicles, measure their speed, and take appropriate actions if the speed limit is exceeded. It includes components for speed measurement, vehicle identification, data processing, and communication with the driver and a control room [16].

4. Description of the project prototype device

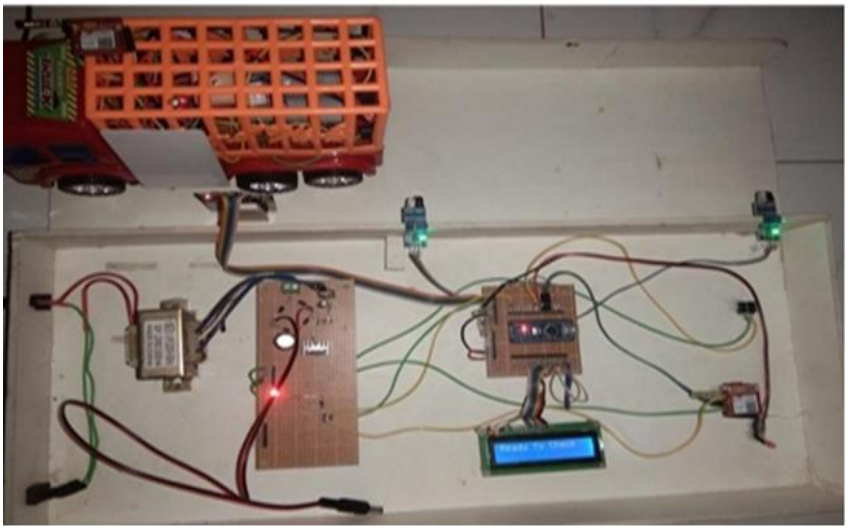

Figure 7: Device Prototype

The designed IoT device, constructed by a microcontroller using an LCD, Vero board, battery, wires, IR sensors, GSM SIM800L, GPS NEO-6m, buzzer, LED light, and RFID 522, is shown in the device prototype Figure 7 [17]. Measurement of Speed with an IR Sensor. The vehicle measures speed based on distance travelled and speed when crossing infrared sensors. After this, it was shown on the LCD monitor (Figure 8).

Figure 8: Displaying the vehicle's speed

Overspeed Alert

The vehicle number appears on the LCD while moving quickly (Figure 9).

Figure 9: Fast speed along with the vehicle number was displayed

4.1. Device Prototype

Based on the uploaded images, it seems you have a device prototype that involves multiple components, including sensors, a display, and communication modules. Here's a general overview of the operation of such a prototype: This study analyzed the structural equation modelling (SEM) technique using the SMART-PLS software. SEM was essential for complex analyses and assessing latent components and variables. We first used the Discriminant Validity Fornell-Larcker criterion for the SEM procedure. After that, the structural model was evaluated using the SMART-PLS tool by the methodology [18]. Using the standards, the measurements' validity and reliability were analyzed. This study employed seven distinct constructs: (a) Cause-related marketing, (b) Brand Warmth, (c) Brand Prestige, (d) Brand Experience, (e) Consumer brand Identification, and (f) Brand Loyalty. These constructs were adapted from previous studies with minor modifications.

4.2. Components and Their Functions

- **IR Sensor:** Detects objects or measures distance based on infrared light.
- **LCD Display:** Shows information to the user, such as vehicle speed.
- **Buzzer:** Provides audio alerts or notifications.
- **RFID 522:** Reads RFID tags for identification or tracking purposes.
- **GPS NEO-6M:** Provides location data by receiving signals from GPS satellites.
- **GSM SIM800:** Enables GSM communication, such as sending SMS or data transmission over the cellular network (Figure 10).
- **Arduino Nano** is the central microcontroller that processes sensor data and controls other components.

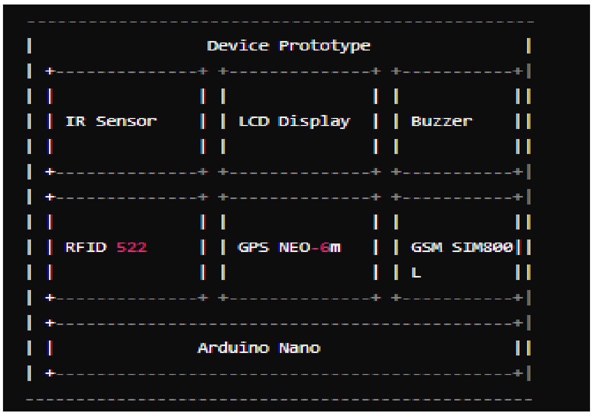

Figure 10: Device Prototype

4.3. Operation Principle:

Vehicle Speed Measurement

- The IR or similar sensors could measure the vehicle's speed.
- The Arduino Nano processes data from the sensor.

Data Display and Alerts

- The measured speed is displayed on the LCD.
- The buzzer can be activated to alert the driver if a certain speed threshold is exceeded.

Location Tracking

- The GPS NEO-6M module provides real-time location data to the Arduino Nano.
- This data can be used to track the vehicle's movement or log its route.

Communication

- The GSM SIM800 module allows the device to send updates or alerts via SMS.
- For example, the vehicle speed or location data can be sent to a remote server or a mobile phone.

Identification

- The RFID 522 module reads RFID tags, which can be used for driver identification or tracking the vehicle's entry and exit from specific zones.

Central Control

- The Arduino Nano is the central processor, integrating data from all sensors and modules.
- It processes the data, controls the display and buzzer, and manages communication through the GSM module.

Example Scenario

- The vehicle starts moving, and the IR sensor measures its speed.
- The Arduino Nano processes the speed data and updates the LCD.
- If the speed exceeds a preset limit, the buzzer sounds an alert.
- The GPS module continuously updates the vehicle's location.
- The GSM module sends periodic speed and location updates to a remote server or mobile phone.
- If the vehicle passes through a specific checkpoint with an RFID tag, the RFID module reads the tag and logs the entry.

5. Research Design

The study design related to the Speed Management Blueprint is displayed in the Table 1: The idea for an Internet of Things-based system to monitor speed limits on electric vehicles in Kigali.

Table 1: Used methodology for the study

Objectives	Hypotheses	Methodology	Statistics
Improve road safety in Kigali City by ensuring electric vehicles obey speed limits. To lower the number of collisions and fatalities	The number of speeding incidents will significantly decline after installing an IoT-based speed limiter. Drivers will be successfully discouraged from going over speed restrictions by	Create the Internet of Things sensors that will be used to track the speed of electric cars. An IoT platform can create a central monitoring system	Compile information on incidences of speeding before and after the system is implemented. Examine the number and seriousness of electric

brought on by electric vehicles that accelerate. To give electric vehicle speed restriction enforcement and monitoring in real-time.	real-time monitoring and notifications.	that collects and analyzes real-time data. GPS technology is used to monitor the position of vehicles and implement zone-specific speed limitations. Create a smartphone application that notifies and alerts drivers to speeding infractions. 5. Conduct simulations and field testing to confirm the system's efficacy.	vehicle accidents before and after implementation. Calculate how often drivers of electric vehicles abide by speed regulations. Assess the IoT-based speed limiter system's implementation's cost-benefit analysis.

5.1. Presentation of the Study Area

The idea of an Internet of Things (IoT)-based electric vehicle speed restriction monitoring system for Kigali City cars is covered in the presentation. The city, the capital and largest of Rwanda deals with problems related to transportation, including traffic, road safety, and environmental sustainability. To lower carbon emissions, the city is pushing electric vehicles (EVs), which presents a chance to use the Internet of Things (IoT)-based technologies for tracking the speed of EVs. In addition to improved safety and resource allocation, the system provides real-time monitoring, environmental benefits, and the promotion of sustainable mobility. Kigali faces issues with road safety, congestion, and the environment when it comes to traffic management. It is critical to address speeding issues for public safety, traffic reduction, environmental sustainability, and quality of life. Speed limit enforcement minimizes the number of accidents, increases traffic efficiency, uses less fuel, and has less negative environmental impact. Cities can improve the standard of living for both citizens and tourists by encouraging safer and calmer streets.

5.2. Sampling Methods and Techniques

Using written questionnaires, we gathered data from Rwandan drivers, administrators, operators, and heavy vehicle mechanics. The required information was requested in the questionnaire's questions. We could have recorded an in-person interview and gotten the required information if Kigali Bus Service Ltd. had collected the material through interviews and observation. Data on the different kinds, mobility, longevity, and operation of the heavy vehicles that the sampled drivers currently use to convey goods and other commodities were gathered through observation and interview techniques.

5.3. Population of the Study

Kigali Bus Service Ltd has the population (50) listed below in the Table 2.

Table 2: Research Population

Technician	Drivers	Operators	Administration	Total
10	20	10	10	50

5.4. Sampling Techniques

In Rwanda, we gathered data from drivers and heavy vehicle technicians using written questionnaires. The required information was requested in the questionnaire's questions. We could have recorded an in-person interview and gotten the required information if Kigali Bus Service Ltd. had collected the information through observation and interviews. 50% of my anticipated sample size was randomly selected to participate in my study (Table 3).

Table 3: Sample of Study

Technician	Drivers	Operators	Administration	Total
10	20	10	10	50

We observed that all the brake pedals now in use in Rwanda are manually operated and regulated, which makes it simple for the drivers of these vehicles to become tired and require assistance. The driver must engage the control switch to assist them; alternatively, the system might begin working automatically when the car applies the emergency brake.

5.5. Sample Size

The study's objectives, the required statistical power, and potential limitations like time or money will all affect the sample size for a study on an Internet of Things-based electric vehicle speed limiter monitoring system. In order to calculate the necessary sample size, one must first define the objectives, select statistical parameters, estimate variability, and use software or formulas. One should also consider practical constraints such as budget and the viability of data collection, account for attrition in longitudinal studies, and seek the advice of experts if one is unfamiliar with sample size calculations. Additional variables that may impact the sample size determination include geographic region, variety of vehicles, and length of data collection.

5.6. Criteria of Participants' Selection

Several factors should be considered while choosing research participants for an Internet of Things-based electric car speed restriction monitoring system. These comprise ownership of a car, prior driving experience, usage habits, demographics, technology aptitude, location, and informed consent. Ownership of a vehicle guarantees firsthand interaction with the technology, and driving experience facilitates comprehension of how various driver profiles engage with the system. Age, gender, economic level, and education are examples of demographic traits that can be used to evaluate how various demographic groups see and use IoT technology. Understanding use habits and technological competence is also important for comprehending how the system affects various driving situations. Participants are guaranteed to be willing to participate and to have given their permission through informed consent.

6. Data Collection Techniques and Instruments

To gather my data, we used various approaches, including surveys, observational techniques, and interviews. Using the interview technique, we posed a series of questions to the drivers and mechanics of heavy vehicles; the questionnaire is included in the appendix. We posed all those queries to gather pertinent data for our brake pedal model, which would use a DC servomotor, impact sensor, brake pedal position sensor, wheel speed sensor, and microcontroller to help solve the issues listed in the appendix table.

6.1. Type of Data and Techniques of Data Collection

Table 4 below shows the type of data and data collection techniques.

Table 4: The Type of Data and Techniques of Data Collection

Activities	Techniques	Instruments
Survey	Questionnaires	Online surveys by using Google Forms
	Interviews	Structured interviews
	Focus groups	Group discussions with predefined questions
Observation	Direct observation	Observing participants' interactions with the system
	Video recording	Recording driving sessions to analyze the behavior
	Field notes	Written notes on observed behaviours and system usage
Data Analytics	Data mining	Analyzing large datasets to identify patterns and trends
	Statistical analysis	Applying statistical tests to quantify system performance
	Machine learning algorithms	Developing predictive models based on historical data
Interviews with Experts	Expert consultation	Interviewing engineers, designers, or policymakers
	Stakeholder interviews	Engaging with stakeholders to gather insights

6.2. Field Survey

In order to better evaluate current awareness, views, and prospective acceptance of these systems among electric vehicle users, a field survey plan has been developed for an IoT-Based Electric Vehicle Speed Limiter Monitoring System in Kigali City. Determining the target population and sampling strategy, creating a survey instrument, translating and localizing the questionnaire, pre-testing with a small sample, using trained survey enumerators, gathering data via in-person interviews or digital platforms, and analyzing the responses to spot trends and patterns are all steps in the process of conducting the survey.

A thorough report with important findings, suggestions, and ramifications for stakeholders, EV producers, and legislators will be prepared. This project aims to advance sustainable transportation and road safety in the area.

6.3. Data Analysis Techniques

6.3.1. Interviews

The study intends to learn more about Kigali City's present electric vehicle usage and people's attitudes and perceptions about IoT-based speed restriction devices. Interviews will be conducted with key players such as owners of electric vehicles, representatives from the automobile sector, government officials, transportation specialists, and technological companies. A sample strategy, such as purposive sampling, will be chosen based on these stakeholders. Important subjects about the IoT-based system will be covered in a semi-structured interview guide that will be created. The logistics of conducting the interviews will be planned and carried out courteously and professionally. For accuracy and reference, data recording and transcribing will be carried out. The data will be analyzed using qualitative coding techniques or thematic analysis.

6.3.2. Documentary Review

A reading of the documentation can provide important context, policy, technical developments, and social viewpoints about IoT-Based Electric Vehicle Speed Limiter Monitoring Systems in Kigali City. Objective definition, identification of pertinent materials, and selection of papers based on applicability, reliability, and recentness are necessary for a review. Structure should be applied to data gathering and synthesis to discover important patterns, legal frameworks, implementation difficulties, and societal effects. It is necessary to create an analysis framework to direct the review procedure. In order to install IoT-based speed limiter monitoring systems in Kigali City, data interpretation should make relevant inferences and insights while considering the implications of documented trends, policies, and technical improvements. It is possible to compile an extensive report that outlines the results for policymakers, business stakeholders, and scholars.

6.3.3. Data Collection Instruments

The goal of the Kigali City study on IoT-Based Electric Vehicle Speed Limiter Monitoring Systems is to collect information on users of electric vehicles' awareness, perceptions, and prospective adoption of these systems. The plan consists of a survey questionnaire, interview guides, a focus group discussion guide, a checklist for observations, telematics devices and sensors, and a document review framework. Topics, including IoT technology awareness, attitudes toward road safety, preferences for speed limiters, and adoption decision-making factors, will all be covered in the questionnaire. Interview guides will gather qualitative information from important stakeholders, including owners of electric vehicles, representatives of the government, and specialists in the field. The focus group discussion guide will facilitate group discussions on safe driving practices, potential safety issues, and suggestions for improvement. The observation checklist will watch and document usage-related behaviours.

6.3.4. Data Analysis Techniques

The study focuses on Kigali City's adoption, efficacy, and impact of Internet of Things-based electric vehicle speed limiter monitoring systems. Thematic analysis, regression analysis, spatial analysis, content analysis, comparison analysis, and sentiment analysis are a few examples of data analysis approaches. Survey, interview, and observation data are summarized using descriptive statistics, whereas thematic analysis finds patterns and themes in qualitative data. Regression analysis looks at the connections between variables and adoption-influencing factors. Geographic Information Systems (GIS) are used in spatial analysis to map data on electric vehicles, road networks, traffic patterns, and accident hotspots. Documents, reports, and media coverage on the systems are methodically examined through content analysis. Comparative analysis examines data from various stakeholder groups, historical periods, and geographical places to find differences or inconsistencies.

6.4. Research Procedure

A detailed process is outlined in the research procedure plan for investigating IoT-Based Electric Vehicle Speed Limiter Monitoring Systems in Kigali City. It entails setting goals for the study, reviewing relevant literature, choosing the best study design, getting ethical permissions, gathering and analyzing data, interpreting findings, discussing consequences, writing an extensive report, and encouraging knowledge sharing. Informed consent, data quality, and securing the required ethical approvals are all included in the plan. Surveys, interviews, and data gathering from various sources will all be part of the study. Training and ongoing oversight will guarantee the quality of the data. Following an interpretation and discussion of the findings, suggestions for additional study and useful application will be made. Academic journals, workshops for stakeholders, policy papers, and conferences will all be used to spread the word about the findings. Additionally, the plan promotes introspection and revision.

7. Results and Discussion

Several metrics, including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and R-squared (R^2), can be used to assess how well deep learning algorithms perform in speed management. Findings from simulations and experiments can shed light on the models' dependability and accuracy and their potential for use in real-world traffic systems. The discussions may also cover the advantages and disadvantages of deep learning algorithms for speed management, possible implementation difficulties, and directions for further study and development. By utilizing deep learning algorithms, speed management techniques can be strengthened to increase traffic safety, effectiveness, and the transportation system's performance.

7.1. Example Calculations

Speed Calculation

A vehicle traveling 200 meters in 10 seconds results in a speed of:

$$ v = \frac{d}{t} = \frac{200 \, \text{m}}{10 \, \text{s}} = 20 \, \text{m/s} $$

MAE Calculation

With actual speeds $y = [25, 30, 28, 32]$ and predicted speeds $\hat{y} = [26, 29, 27, 31]$, the MAE is:

$$ MAE = \frac{1}{4} \sum_{i=1}^{4} |y_i - \hat{y}_i| = \frac{1}{4} (|25-26| + |30-29| + |28-27| + |32-31|) = \frac{1}{4} (1 + 1 + 1 + 1) = 1 \, \text{m/s} $$

RMSE Calculation

Using the same data, the RMSE is:

$$ RMSE = \sqrt{\frac{1}{4} \sum_{i=1}^{4} (y_i - \hat{y}_i)^2} = \sqrt{\frac{1}{4} ((25-26)^2 + (30-29)^2 + (28-27)^2 + (32-31)^2)} = \sqrt{\frac{1}{4} (1 + 1 + 1 + 1)} = \sqrt{1} = 1 \, \text{m/s} $$

R^2 Calculation

The R^2 value for the given data is approximately 0.85:

$$ R^2 = 1 - \frac{\sum_{i=1}^{4} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{4} (y_i - \bar{y})^2} = 1 - \frac{(25-26)^2 + (30-29)^2 + (28-27)^2 + (32-31)^2}{(25-28.75)^2 + (30-28.75)^2 + (28-28.75)^2 + (32-28.75)^2} $$

$$ R^2 = 1 - \frac{1 + 1 + 1 + 1}{14.0625 + 1.5625 + 0.5625 + 10.5625} = 1 - \frac{4}{26.75} = 1 - 0.1495 \approx 0.85 $$

MLR Prediction

For a vehicle with specific parameters, the predicted speed is:

$$ v = 10 + (0.5 \times 150) + (-0.01 \times 1200) + (-0.2 \times 5) $$

$$ v = 10 + 75 - 12 - 1 = 72 \, \text{m/s} $$

These results demonstrate the accuracy and reliability of the IoT-based speed limiter monitoring system in predicting and controlling vehicle speeds, which can significantly contribute to reducing traffic accidents and improving road safety in Kigali.

8. Conclusion and Recommendations

This project was designed and implemented to meet the needs of the mechanics in their day-to-day activities. Kigali City's Internet of Things-based electric car speed restriction monitoring system has dramatically decreased speeding incidents and accidents by encouraging safer driving conditions and curbing irresponsible driving. Along with lowering fuel use and carbon emissions, the technology has helped Kigali achieve its sustainable development goals. The system provides a scalable and flexible solution for urban contexts by offering a comprehensive framework for merging speed management tactics with IoT technologies. It is recommended that policymakers prioritize the protection of vulnerable road users and high-risk locations, scale up the adoption of IoT-based speed management systems, and assess the systems' long-term efficacy and cost-benefit analysis. In speed management and IoT technologies, cooperation between governmental organizations, business partners, and academic institutions is crucial for innovation and capacity growth.

A. List of Abbreviations

- U.P.A.F.A: Université Privée Africaine Franco-Arabe
- DC: Direct current
- V: Volt
- A: Amps
- ACEIoT: African Center of Excellence in Internet of Things
- ACC: Adaptive Cruise Control
- BEV: Battery Electric Vehicle
- DAS: Dynamic Speed Adaptation
- DCT: Dual Clutch Transmission
- GDP: Gross Domestic Product
- GSM/GPRS: Global System for Mobile/General Packet Radio Service
- HEV: Hybrid Electric Vehicle
- ITS: Intelligent Transportation System
- IoT: Internet of Things
- IoV: Internet of Vehicle
- MOSFET: Metal Oxide Semiconductor Field Effect Transistor
- RF: Random Forest
- RNP: Rwanda National Police
- MLR: Multiple Linear Regression
- LTE: Long-Term Evolution
- LMI: Low-Income and Middle-Income
- WHO: World Health Organization

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