Geo-Intelligent Road Safety Voice Alert System (GIRS-VAS)

Research Plan

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ABSTRACT

Road safety remains a pressing global issue, with the World Health Organization (WHO, 2023) reporting that approximately 1.19 million people die each year as a result of road traffic accidents. Developing nations like India are disproportionately affected due to dense traffic, poor infrastructure, and limited enforcement of safety measures. Despite the presence of traffic signs, signals, and occasional manual warnings, these conventional approaches often fail in hazardous zones such as unmanned railway crossings, narrow bridges, blind curves, and poorly lit roads. Factors such as driver distraction, poor weather, low visibility, and language barriers further reduce the effectiveness of traditional signage-based systems.

To address these gaps, this study introduces the **Geo-Intelligent Road Safety Voice Alert System (GIRS-VAS)**, an innovative embedded solution that leverages **Global Positioning System (GPS) technology and geofencing** to provide real-time, context-aware, and bilingual voice alerts to drivers approaching hazardous zones. Unlike visual signboards that require drivers to divert attention from the road, GIRS-VAS delivers **hands-free auditory guidance**, enabling drivers to stay focused while receiving critical warnings.

The system is built around an **ESP32 microcontroller** that integrates with a **NEO-6M GPS module** for precise location detection and a **DFPlayer Mini MP3 module** connected to a speaker for audio output. Predefined latitude and longitude coordinates of danger-prone locations are stored in the system's database. As a vehicle enters a geofenced radius of 200–300 meters around these coordinates, the system automatically plays a pre-recorded voice message in **English and Tamil**, ensuring accessibility to both local and general users. The alerts are delivered only once per entry to avoid redundancy and are reset upon exiting the danger zone.

During testing, GIRS-VAS successfully provided timely alerts before railway crossings and bridges, with no false alarms recorded in open, hazard-free areas. Drivers reported **increased awareness, reduced speed, and enhanced confidence** in navigating critical zones, even during low visibility conditions such as fog and nighttime driving. The compact, low-cost, and scalable design makes the system highly suitable for large-scale deployment across rural, semi-urban, and urban road networks.

Ultimately, GIRS-VAS demonstrates that embedding **geo-intelligence and proactive voice-based safety mechanisms** in vehicles can significantly reduce road accidents, particularly in areas where traditional measures fail. The proposed system is a step toward **smarter, safer, and more inclusive transportation infrastructure**, aligning with the vision of Intelligent Transportation Systems (ITS) and Smart Cities initiatives.

INTRODUCTION

Road accidents are one of the most significant causes of injury and death worldwide. According to the WHO (2023), traffic collisions are now the **eighth leading cause of death globally**, and the burden falls heavily on low- and middle-income countries. India, in particular, records over **150,000 fatalities annually** due to road accidents, many of which occur at unmanned railway crossings, accident-prone curves, bridges, and rural roads. While governments have attempted to mitigate risks by installing signboards, signals, and awareness campaigns, the accident rate remains alarmingly high.

A timeline of major railway accidents in India (2015–2025) with date, location, causes and casualties.

Date	Location	Train(s) Involved	Cause	Casualties
19 Jun 2025	Jalgaon, Maharashtra	Goods train	Derailment	No deaths, disruption only
21 May 2025	Eluru, Andhra Pradesh	Passenger train	Track issue, derailment	Several injured
29 Oct 2023	Vizianagaram, Andhra Pradesh	2 Passenger trains	Signal error, collision	14 dead, 50+ injured
2 Jun 2023	Balasore, Odisha	Coromandel Express, SMVT-HWH Express, Goods train	Signal failure, collision	~296 dead, 1000+ injured
29 Oct 2018	Amritsar, Punjab	Dussehra crowd hit by train	People standing on track	~59 dead
10 Nov 2016	Kanpur Dehat, UP	Indore–Patna Express	Track fracture, derailment	150+ dead, 200 injured
4 May 2014	Gorakhdham Express, UP	Collision with stationary train	Overshooting signal	25 dead, 50+ injured

Recent News: Three school children were killed and two others including the driver sustained serious injuries after a school van carrying four students was rammed by a passenger train at a manned gate at Semmankuppam in Cuddalore district on Tuesday (July 8, 2025) around 7.45 a.m.

The van belonging to school, attempted to cross the railway level crossing gate no. 170, (a non-interlocked manned gate) between Cuddalore and Alappakkam, when it was hit by train no. 56813 Villupuram–Mayiladuthurai passenger. One other student has been injured and admitted to the Government Hospital, Cuddalore.

Advancements in IoT, GPS, and embedded systems, it is now possible to provide proactive, voice-based safety alerts directly inside vehicles. This project integrates location tracking and audio guidance to create a simple, affordable, and effective solution for both private and public transport. By alerting drivers in advance, the system minimizes reaction time, prevents over speeding, and ensures safer navigation through critical zones.

Conventional road safety measures face several limitations. Road signs may be obscured by fog, rain, or poor lighting, and many drivers either overlook them or are unable to interpret them in time. In rural and semi-urban regions, signage may be missing altogether, leaving drivers unaware of approaching hazards. Even when present, visual warnings require the driver to momentarily divert attention from the road, introducing potential risks. Additionally, India's linguistic diversity poses another challenge—warnings in one language may not be understood by drivers from another region.

In this context, **emerging technologies such as IoT, GPS, and embedded systems** present new opportunities for road safety. GPS enables continuous tracking of vehicle positions with high accuracy, while microcontrollers can process these inputs to trigger location-specific alerts. Combining these capabilities, **geofencing** allows virtual perimeters to be created around danger-prone areas. When a vehicle enters such a zone, the system can initiate a predefined action—such as an audio alert—to warn the driver.

The **Geo-Intelligent Road Safety Voice Alert System (GIRS-VAS)** leverages these technologies to provide **proactive, real-time, and bilingual voice alerts** to drivers. Instead of relying solely on visual cues, the system delivers auditory guidance, which is hands-free and does not require visual confirmation. This makes it particularly useful in conditions of poor visibility, heavy traffic, or driver fatigue.

The proposed solution is simple yet powerful: an **ESP32 microcontroller** acts as the brain of the system, interfacing with a **GPS module** for real-time positioning and a **DFPlayer Mini MP3 module** to play pre-recorded audio messages. When the GPS indicates that the vehicle has entered within 200–300 meters of a hazardous zone, the ESP32 triggers the DFPlayer to play a bilingual voice warning (English and Tamil). This not only informs drivers of the upcoming hazard but also reduces their reaction time, encouraging safer driving practices.

The project aligns with global trends in **Intelligent Transportation Systems (ITS)**, where vehicles and infrastructure are becoming interconnected to improve safety and efficiency. By focusing on **cost-effectiveness, simplicity, and scalability**, GIRS-VAS demonstrates that advanced road safety mechanisms can be implemented even in resource-constrained environments, ultimately saving lives and reducing injuries.

STATEMENT OF THE PROBLEM

Road accidents remain one of the leading causes of death and injury worldwide, with a significant proportion occurring in **hazardous zones such as railway crossings, narrow bridges, accident-prone curves, and poorly maintained roads**. In countries like India, these risks are further amplified due to high traffic density, lack of advanced safety infrastructure, and limited driver awareness of danger-prone areas.

Conventional safety measures such as **traffic signboards, signal lights, and manual warnings** are often ineffective because:

- Drivers may **fail to notice signboards** due to distractions, poor visibility, or high-speed driving.
- Many **hazard-prone areas lack proper signage or electronic warning systems**, particularly in rural and semi-urban regions.
- Visual warnings require drivers to **divert their attention from the road**, increasing the risk of accidents.
- Existing navigation systems provide directions but **do not deliver localized, bilingual safety alerts** for specific danger zones.

As a result, there is a pressing need for a **real-time, automated, and non-intrusive alert mechanism** that can effectively warn drivers in advance, regardless of visibility or language barriers.

"How can a low-cost GPS-based system provide real-time bilingual voice alerts to drivers approaching hazardous zones such as railway crossings and bridges to improve road safety?"

OBJECTIVES

1. **To design and implement a GPS-based embedded system** that provides proactive voice alerts to drivers when approaching hazardous zones.
2. **To enhance driver awareness and response time** by replacing conventional visual cues with hands-free auditory warnings.
3. **To ensure inclusivity** by delivering alerts in bilingual format (English and Tamil), making the system accessible to diverse drivers.
4. **To maintain low-cost, compact, and energy-efficient design** suitable for large-scale deployment in rural, semi-urban, and urban environments.
5. **To evaluate system performance** under real-world conditions and measure its effectiveness in reducing risks.
6. **To establish scalability for future integration** with IoT platforms, cloud-based traffic management, and Intelligent Transportation Systems (ITS).

HYPOTHESIS

"**Vehicles are equipped with a Geo-Intelligent Road Safety Voice Alert System**, then drivers will receive timely warnings at hazardous zones, which will **enhance awareness, promote safer driving, and reduce the likelihood of accidents.**"

EXPERIMENTAL PROCEDURE

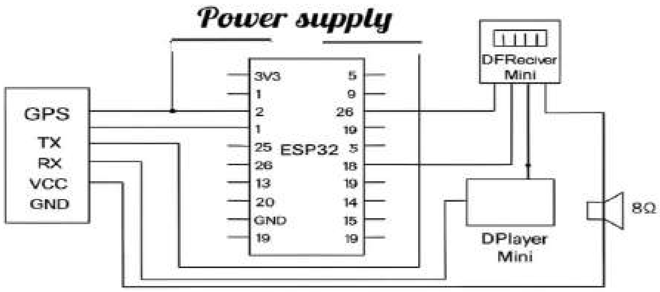
Components Needed:

S. No	Component	Function
1	ESP32 Devkit V1	Main controller
2	GPS Module (NEO-6M)	Position detection
3	DF Player Mini	Audio playback
4	microSD card (≤32GB)	MP3 files
5	8Ω 3W Speaker	Audio output
6	Buck Converter (12V→5V)	power supply
8	Jumper Wires	Connections

Experimental Procedure:

The project design is based on an embedded IoT system consisting of:

Circuit Connections:



GPS → ESP32:

The **TX pin of the GPS module** is connected to the **RX2 pin (GPIO 16) of the ESP32**, while the **RX pin of the GPS module** is connected to the **TX2 pin (GPIO 17) of the ESP32**. The **VCC pin of the GPS module** is connected to the **3.3 V (or 5 V, depending on the module)** power supply of the ESP32, and the **GND pin of the GPS module** is connected to the **GND of the ESP32**.

DF Player Mini → ESP32:

The RX pin of the DF Player is connected to GPIO 25 of the ESP32 through a 1 kΩ resistor, while the TX pin of the DF Player is connected directly to GPIO 26 of the ESP32. The VCC pin of the DF Player is connected to the 5 V supply of the ESP32, and the GND pin of the DF Player is connected to the GND of the ESP32. Finally, the speaker is connected to the SPK+ and SPK− pins of the DF Player.

Power:

The **vehicle's 12 V supply** is connected through a **1 A fuse** to a **buck converter**, whose **5 V output** powers both the **ESP32** and the **DF Player module**.

Software :

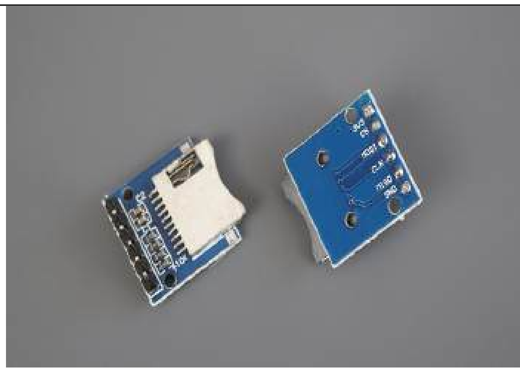
The **TinyGPS++ library** is used on the ESP32 to **parse and process GPS data** from the NEO-6M GPS module, while the **DFRobot DFPlayer Mini library** is used to **control audio playback** on the DF Player module.

Code:

```
#include <TinyGPSPlus.h>

#include <HardwareSerial.h>

#include <DFRobotDFPlayerMini.h>



HardwareSerial GPS(2);  // RX2/TX2 pins 16,17

TinyGPSPlus gps;
```

```
HardwareSerial mp3Serial(1);
DFRobotDFPlayerMini mp3;

struct Zone { double lat, lon, radius; int type; bool played; };
Zone zones[] = {
  {10.123456, 78.123456, 250, 2, false}, // Railway crossing
  {10.234567, 78.234567, 200, 3, false}, // Bridge
};

double haversine(double lat1, double lon1, double lat2, double lon2) {
  const double R = 6371000; // Earth radius
  double dLat = radians(lat2-lat1), dLon = radians(lon2-lon1);
  double a = sin(dLat/2)*sin(dLat/2)+cos(radians(lat1))*cos(radians(lat2))*sin(dLon/2)*sin(dLon/2);
  return 2*R*asin(sqrt(a));
}

void setup() {
  Serial.begin(115200);
  GPS.begin(9600, SERIAL_8N1, 16, 17);
  mp3Serial.begin(9600, SERIAL_8N1, 26, 25);
  if (mp3.begin(mp3Serial)) mp3.volume(25);
}

void loop() {
  while (GPS.available()) gps.encode(GPS.read());

  if (gps.location.isUpdated()) {
    double lat = gps.location.lat();
    double lon = gps.location.lng();
    for (auto &z : zones) {
```

```
    double d = haversine(lat, lon, z.lat, z.lon);

    if (d < z.radius && !z.played) {

      if (z.type == 2) mp3.playMp3Folder(20); // Railway crossing alert

      if (z.type == 3) mp3.playMp3Folder(30); // Bridge alert

      z.played = true;

    }

    if (d > z.radius + 50) z.played = false; // reset on exit

  }
```



ESP32 DF Mini player

Block Diagram

```
              +-----------------------+
              |      Vehicle 12V      |
              +----------+------------+
                         |
              Buck Converter (12V→5V)
                         |
              +-----------+------------+
                 |                  |
         ESP32 MCU            DF Player Mini
                 |                  |
          +----+----+          +-----+-----+
          | GPS Mod |          |  Speaker  |
          +----+----+          +-----------+
```

|

Latitude/Longitude

|

Geofence Calculation

|

Alerts: Railway / Bridge / Zones

|

Play Audio via DF Player

Working Principle:

1. Vehicle continuously receives GPS coordinates.

2. Predefined geofence coordinates of railway crossings and bridges are stored.

3. When the vehicle enters the geofence (200–300m radius), ESP32 triggers the DF Player to play the corresponding voice alert.

4. The alert is played once, and resets only after the vehicle exits the zone.

RISK AND SAFETY

- **Electrical hazards**: Short circuits or overheating of components. Mitigated by using fuses, regulated power supply, and insulated wiring.
- **GPS inaccuracies**: Possible false alerts due to weak satellite signals. Mitigated by defining tolerance ranges and resetting alerts outside zones.
- **Driver distraction**: Excessive or unclear alerts may confuse drivers. Controlled by ensuring short, clear bilingual messages and preventing repetitive alerts.
- **Mounting and stability**: Improper installation could cause components to shift during driving. Secure enclosures and vibration-resistant mounting were used.
- **Data privacy**: If future integration with IoT is implemented, location privacy must be ensured through secure communication.

DATA ANALYSIS

TABULATION

Test Zone	**Radius Defined (m)**	**Alert Trigger Distance (m)**	**Alert Accuracy**	**Driver Feedback**
Railway Crossing				
Bridge				
Open Road (control)				
Fog Condition				

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