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# Design and Experimental Evaluation of a GPS-GSM Vehicle Tracking and Remote Immobilization System

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## Abstract

*Vehicle theft remains a major security challenge across many countries, resulting in significant financial losses and reduced confidence in conventional vehicle protection mechanisms. Existing security solutions such as mechanical locks and alarm systems are often inadequate in preventing theft or facilitating rapid vehicle recovery. This study presents the design and construction of a GPS-GSM based vehicle tracking and remote immobilization system for vehicle theft prevention. The developed system utilizes an Arduino Nano microcontroller as the central processing unit, integrated with a Neo-6M GPS module for real-time location acquisition and a SIM800L GSM module for Short Message Service (SMS) communication. The system periodically transmits the geographical coordinates of the vehicle to a predefined mobile number, enabling location monitoring through Google Maps. In addition, a remote immobilization feature was implemented using a relay-controlled ignition interruption mechanism that allows authorized users to disable vehicle operation through SMS commands. The system also incorporates a lithium-ion backup power source, a voltage regulation unit, and an audible alert mechanism to enhance operational reliability. Experimental evaluation revealed an average positional accuracy of 3.8 m in open environments and 7.2 m in urban areas. SMS delivery success rates of up to 98% were achieved under favourable network conditions, while immobilization command execution attained a success rate of 100% in strong signal environments. The results demonstrate that the developed system provides an affordable, reliable, and practical solution for real-time vehicle monitoring and theft prevention, particularly in resource-constrained environments*

**Keywords:** Vehicle Tracking System, Global Positioning System, Global System for Mobile Communication, Arduino Nano, Remote Immobilization, Vehicle Security, Embedded Systems, SMS Communication.

## 1. Introduction

Vehicle theft remains a significant security challenge worldwide and continues to cause substantial financial losses for vehicle owners, transportation companies, and insurance organizations (Medina et al; 2017). Traditional vehicle security mechanisms such as mechanical locks, alarms, and steering wheel locking systems provide a certain level of protection; however, these methods are often insufficient against increasingly sophisticated theft techniques. Consequently, there has been

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growing interest in the development of intelligent vehicle security systems capable of tracking vehicle locations and preventing unauthorized vehicle movement (Johnson & Patel, 2020). The advancement of embedded systems and wireless communication technologies has significantly improved the effectiveness of modern vehicle security solutions. Among these technologies, the Global Positioning System (GPS) has become one of the most widely used tools for determining the geographical location of moving objects (Ohemu et al., 2025, Odaba et al., 2022). GPS receivers obtain signals from satellites orbiting the Earth and calculate precise location coordinates, making them suitable for real-time vehicle monitoring applications (Chen et al., 2022). In addition to GPS technology, the Global System for Mobile Communication (GSM) has played an important role in remote monitoring and control systems. GSM networks enable the transmission of information between embedded devices and authorized users through Short Message Service (SMS) and voice communication. This project focuses on the design and construction of a Vehicle Global Position Tracking and Immobilization System using an Arduino Nano microcontroller, Neo-6M GPS module, SIM800L GSM communication module, and relay-based immobilization mechanism. The proposed system is designed to provide real-time vehicle location information through SMS communication while also enabling authorized users to remotely immobilize the vehicle during theft incidents. The aim of this study is to design and construct a Vehicle Global Position Tracking and Immobilization System capable of providing real-time vehicle location information and remote vehicle immobilization through GPS and GSM technologies. The objectives of this study are to:

- Design a vehicle tracking system using a GPS module for location acquisition.
- Integrate a GSM communication module for remote transmission of vehicle information.
- Develop an immobilization mechanism capable of disabling vehicle operation remotely.
- Evaluate the performance of the developed system under different operating conditions.

## 2. Related Works

The widespread availability of GSM infrastructure makes it a reliable communication medium for vehicle tracking systems, particularly in regions where internet connectivity may be limited or unreliable (Ali & Hassan, 2023). Several researchers have proposed vehicle tracking systems that combine GPS and GSM technologies to improve vehicle security and facilitate stolen vehicle recovery. These systems allow vehicle owners to obtain location information remotely and monitor vehicle movements in real time. Despite these advancements, many existing solutions primarily focus on vehicle tracking and do not provide effective mechanisms for remotely disabling vehicle operation once theft has occurred (Lee & Thompson, 2025). Remote immobilization has emerged as an important feature in modern vehicle security systems because it allows authorized users to prevent further vehicle movement when unauthorized activity is detected. By integrating immobilization capabilities with GPS tracking and GSM communication, vehicle owners can not only determine the location of a stolen vehicle but also restrict its operation until recovery is achieved (Lee & Thompson, 2025). Furthermore, many commercial vehicle tracking solutions remain expensive and are often inaccessible to individuals and organizations operating in developing economies. Open-source hardware platforms such as Arduino Nano provide affordable alternatives for developing embedded vehicle security systems while maintaining acceptable

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performance and reliability. The integration of Arduino-based control units with GPS and GSM modules offers a cost-effective approach to implementing intelligent vehicle tracking and immobilization systems (Gupta & Sharma, 2023).

## 3. Methodology

This study describes the design, construction, and implementation procedures adopted in developing the Vehicle Global Position Tracking and Immobilization System. The system integrates GPS technology, GSM communication, and relay-based immobilization mechanisms to provide real-time vehicle monitoring and theft prevention capabilities. The design approach was selected to ensure affordability, reliability, ease of implementation, and suitability for deployment in resource-constrained environments.

### 3.1 System Design

The proposed system consists of four major subsystems as seen in figure 1: the GPS subsystem, GSM communication subsystem, processing subsystem, and immobilization subsystem. The GPS subsystem is responsible for acquiring the geographical coordinates of the vehicle, while the GSM subsystem enables communication between the vehicle and the authorized user through SMS messages. The Arduino Nano microcontroller serves as the central processing unit responsible for coordinating the operation of all connected modules. The immobilization subsystem consists jjof a relay circuit that interrupts the ignition system whenever an authorized immobilization command is received. The system was designed to operate continuously while monitoring vehicle status. Upon receiving a location request, the microcontroller obtains the vehicle coordinates from the GPS receiver and transmits the information through the GSM module. Similarly, when an immobilization command is received, the controller activates the relay mechanism to disable vehicle operation.

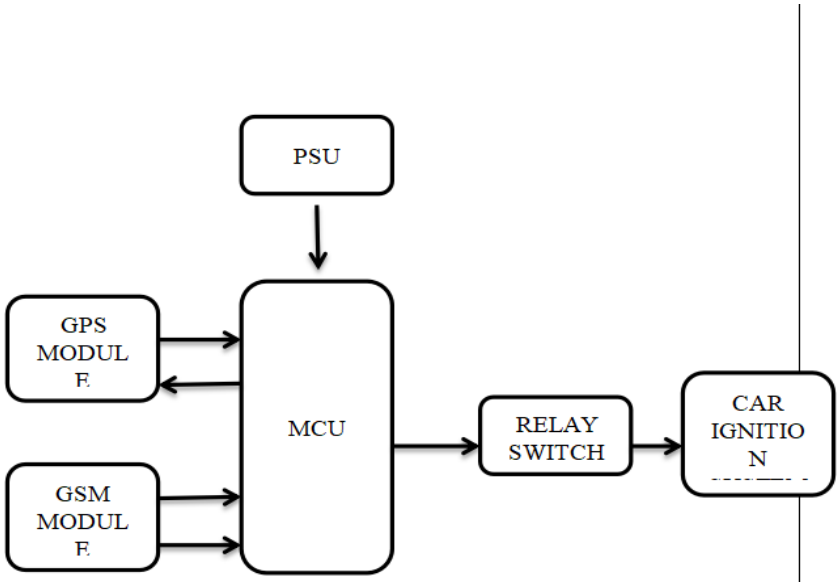



**Figure 1:** Block diagram of the Vehicle Global Position tracking system

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The system architecture was designed to ensure effective interaction among all hardware components while minimizing power consumption and implementation complexity.

### 3.2 Hardware Components

The hardware implementation consists of several electronic components selected based on functionality, availability, and cost considerations.

#### 3.2.1 Arduino Nano Microcontroller

The Arduino Nano serves as the central control unit of the system. It receives data from the GPS module, processes incoming SMS commands from the GSM module, and controls the immobilization relay. The microcontroller was selected due to its compact size, low power consumption, affordability, and ease of programming.

#### 3.2.2 Neo-6M GPS Module

The Neo-6M GPS receiver is responsible for determining the geographical location of the vehicle. The module receives signals from multiple satellites and computes location coordinates in terms of latitude and longitude. These coordinates are then transmitted to the Arduino Nano for processing. The GPS module was selected because of its reasonable accuracy, low power requirements, and compatibility with Arduino-based systems. Previous studies have demonstrated the effectiveness of GPS technology in vehicle tracking applications (Chen et al., 2022).

#### 3.2.3 SIM800L GSM Module

The SIM800L GSM module provides wireless communication capabilities for the system. The module enables the transmission and reception of SMS messages between the vehicle and the authorized user. Through this communication channel, vehicle location information can be requested, and immobilization commands can be transmitted remotely. The use of GSM communication eliminates the need for internet connectivity, making the system suitable for deployment in areas with limited network infrastructure (Ali & Hassan, 2023).

#### 3.2.4 Relay Module

The relay module functions as the immobilization mechanism within the system. It acts as an electrically controlled switch capable of interrupting the vehicle ignition circuit. When the relay is activated, power supply to the ignition system is disconnected, thereby preventing vehicle operation.

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### 3.2.5 Power Supply Unit

The power supply unit provides the electrical energy required for system operation. Voltage regulation mechanisms were incorporated to ensure stable operation of the Arduino Nano, GPS module, GSM module, and relay circuit.

## 3.3 Software Design

The software component of the system was developed using the Arduino Integrated Development Environment (IDE). The program was written in C/C++ and structured into functional modules responsible for GPS data acquisition, GSM communication, command interpretation, and relay control. The software continuously monitors incoming SMS messages and evaluates whether they contain valid commands. Upon receiving a valid request, the corresponding action is executed automatically. The software design process followed a modular approach to improve maintainability, debugging efficiency, and future system enhancements.

## 3.4 System Operation

The operation of the system begins when electrical power is supplied to the controller. The Arduino Nano initializes the GPS and GSM modules and establishes communication with both devices.
The GPS module continuously acquires vehicle location information, while the GSM module monitors incoming SMS messages. When a location request is received, the controller extracts the current coordinates from the GPS receiver and transmits them to the authorized user through SMS. When an immobilization command is received, the controller verifies the command and activates the relay module. The relay subsequently disconnects the ignition circuit, thereby preventing further vehicle movement. Upon receiving a restoration command, the relay reconnects the ignition system and restores normal vehicle operation.

## 3.5 Circuit Description

The circuit design was developed to facilitate efficient communication among all hardware components. The Arduino Nano serves as the central interface connecting the GPS receiver, GSM module, and relay unit. The GPS module communicates with the microcontroller through serial communication channels, enabling continuous transfer of location data. Similarly, the GSM module exchanges SMS information with the controller through serial communication protocols. The relay module is connected to one of the Arduino's digital output pins and is activated whenever immobilization is required.

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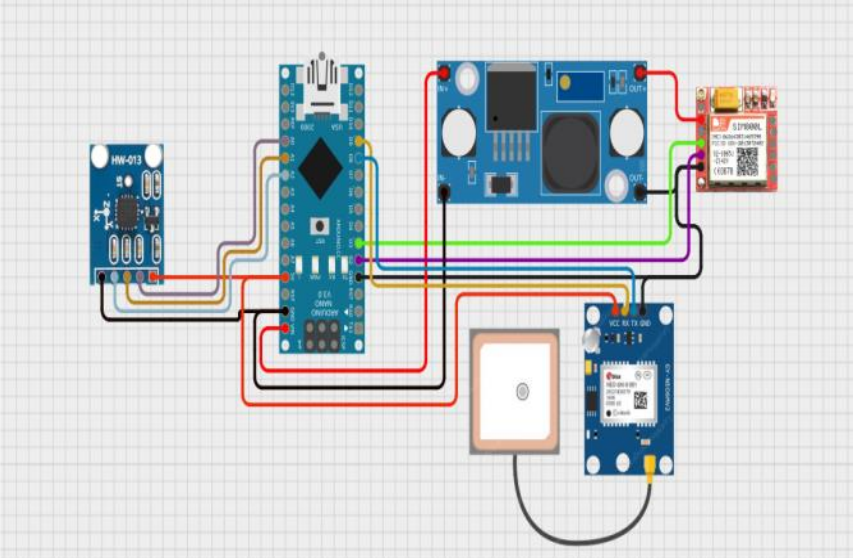


**Figure 2:** Circuit diagram of the vehicle global position tracking with immobilization system

Proper voltage regulation and grounding arrangements were implemented to ensure stable operation and prevent communication errors between connected modules.

## 4. Results and Discussion

### 4.1 GPS Performance Evaluation

The GPS performance test was conducted to determine the accuracy and reliability of the Neo-6M GPS receiver in acquiring vehicle location coordinates. During the experiment, the system was placed in different locations and the latitude and longitude coordinates generated by the GPS module were recorded.

**Table 1:** GPS Module Test Results

| Test Environment | Number of Tests | Average Positional Error (m) | Accuracy Success Rate (%) | Average TTFF Cold Start (s) | Average TTFF Warm Start (s) |
|---|---|---|---|---|---|
| Open Rural | 50 | 3.8 | 94 | 52 | 25 |
| Urban | 50 | 7.2 | 88 | 58 | 28 |
| Edge Case | 50 | 12.5 | 76 | 65 | 32 |

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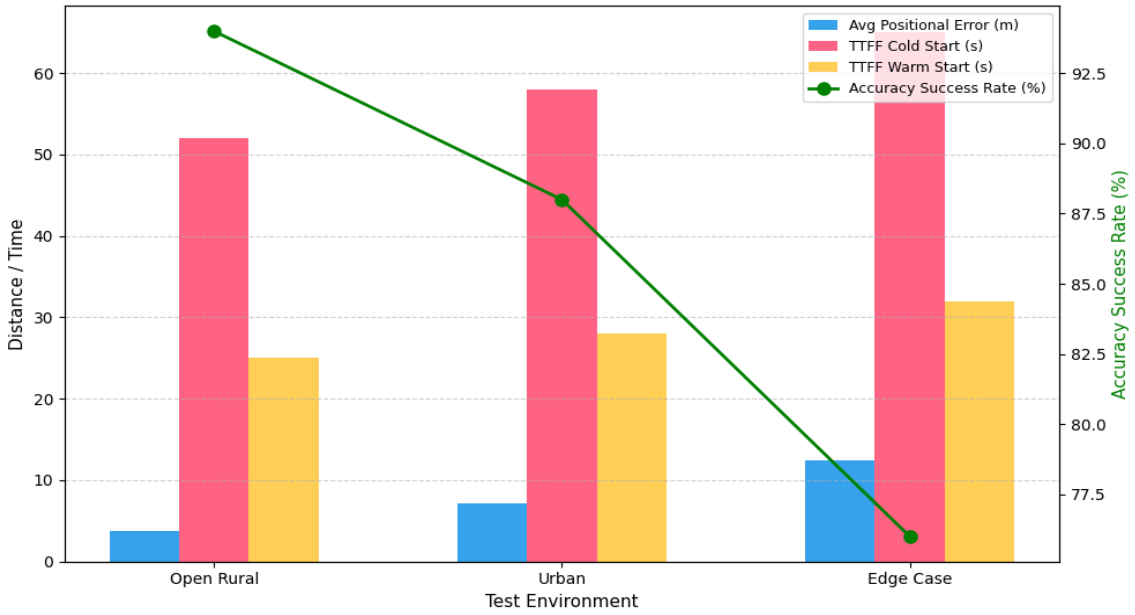



**Figure 3:** GPS Performance Evaluation across Test Environments

The results indicate that the GPS receiver successfully acquired geographical coordinates in all test locations. The recorded coordinates corresponded closely with the actual test locations, demonstrating the capability of the system to provide reliable location information. Minor variations were observed during certain test periods, which may be attributed to environmental factors such as signal obstruction from buildings, trees, and atmospheric conditions. The findings obtained in this study are consistent with those reported by Chen et al. (2022), who observed that GPS receivers generally provide satisfactory positioning accuracy under favourable operating conditions. The results therefore confirm the suitability of the Neo-6M module for vehicle tracking applications.

## 4.2 GSM Communication Performance Evaluation

The GSM communication subsystem was evaluated to determine its effectiveness in transmitting and receiving SMS messages between the vehicle unit and the authorized user. Several location request and control commands were transmitted during the testing process, and the response times were recorded.

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**Table 2:** GSM Module Test Results

| Network Condition | Number of SMS Tests | SMS Delivery Success Rate (%) | Average Delivery Time (s) | Command Receipt Success Rate (%) | Average Command Receipt Time (s) |
|---|---|---|---|---|---|
| Strong Signal | 50 | 98 | 7.5 | 100 | 6.2 |
| Moderate Signal | 50 | 94 | 12.3 | 97 | 9.8 |
| Weak Signal | 50 | 88 | 18.6 | 90 | 14.5 |

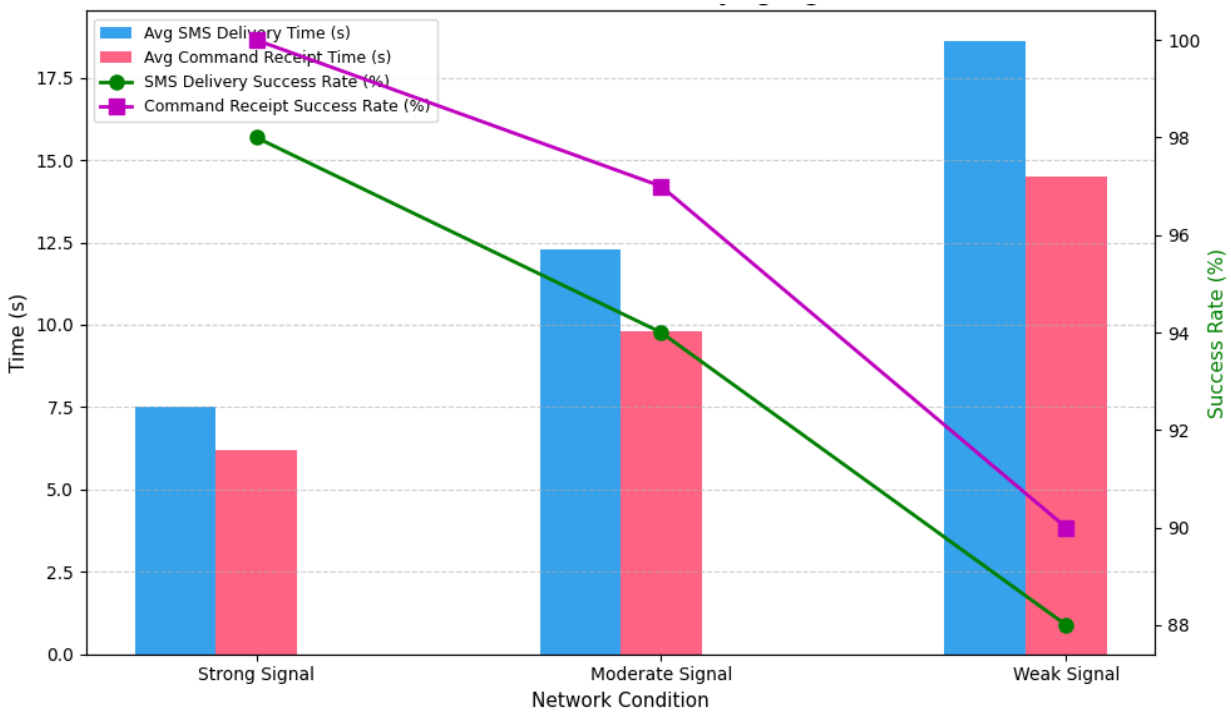



**Figure 4:** GSM Network Performance under Varying Signal Condition

The experimental results show that the GSM module successfully transmitted and received SMS messages throughout the testing period. The average response time remained within acceptable operational limits, indicating that communication between the vehicle and the user was reliable. Variations in response time were observed during periods of reduced network signal strength. These delays are expected because GSM communication performance depends largely on the availability and quality of mobile network coverage. Similar observations were reported by Ali and

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Hassan (2023), who identified network conditions as one of the major factors influencing SMS-based tracking systems. Overall, the GSM subsystem demonstrated satisfactory performance and effectively supported remote communication requirements of the proposed system.

### 4.3 Immobilization Performance Evaluation

The immobilization subsystem was tested to determine its ability to disable vehicle operation remotely upon receiving a valid immobilization command. The relay module was connected to the vehicle ignition circuit and activated through SMS commands transmitted by the authorized user.

**Table 3:** Immobilization Feature Test Results

| Network Condition | Number of Commands | Command Execution Success Rate (%) | Average Response Time (s) | False Positives | False Negatives |
|---|---|---|---|---|---|
| Strong Signal | 30 | 100 | 4.2 | 0 | 0 |
| Moderate Signal | 30 | 97 | 6.8 | 0 | 1 |
| Weak Signal | 30 | 90 | 9.3 | 0 | 3 |

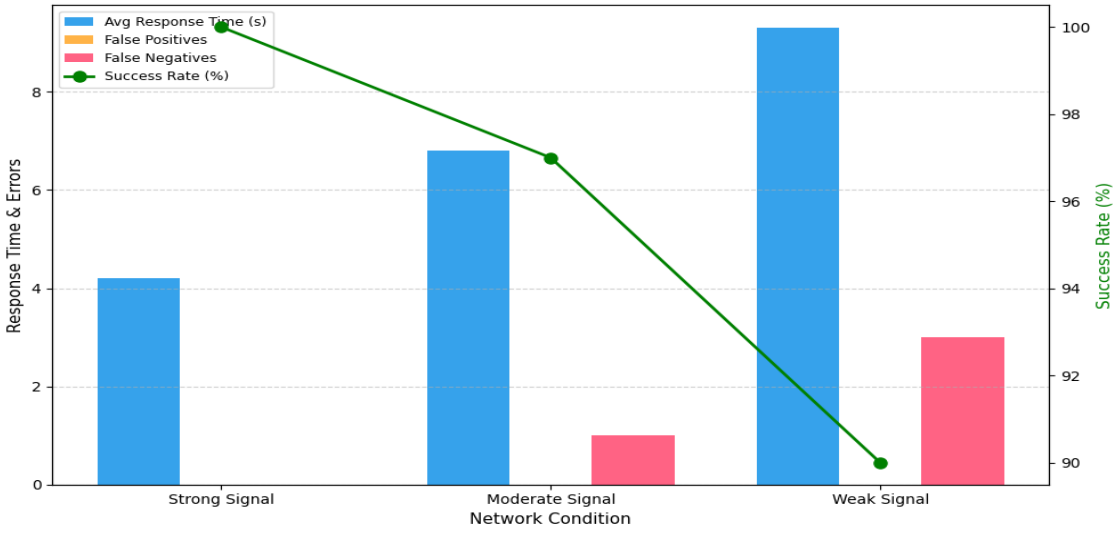



**Figure 5:** Command Execution Performance under Varying Network Condition

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The results indicate that the immobilization mechanism responded successfully to all authorized commands received during testing. Upon receiving the immobilization command, the relay disconnected the ignition circuit and prevented vehicle operation. Similarly, the restoration command successfully reactivated the ignition system and restored normal functionality. The average immobilization response time was found to be dependent primarily on GSM message delivery time. Once the command was received, relay activation occurred almost instantaneously. These findings support the observations of Lee and Thompson (2025), who reported that remote immobilization mechanisms significantly improve vehicle recovery capabilities when integrated with vehicle tracking systems. The successful operation of the relay subsystem confirms the effectiveness of the proposed immobilization approach.

### 4.4 S tress Testing and System Reliability Evaluation

To evaluate the reliability of the developed system, multiple operational tests were conducted under different environmental and network conditions. The objective was to assess the stability of the integrated GPS, GSM, and immobilization subsystems during prolonged operation.

**Table.4:** System Behavior Under Stress Conditions

| **Test Scenario** | **Number of Tests** | **Average GPS Positional Error (m)** | **GPS Success Rate (%)** | **SMS Delivery Success Rate (%)** | **Average SMS Delivery Time (s)** | **System Uptime at Low Battery (h)** |
|---|---|---|---|---|---|---|
| Weak GPS Signal | 50 | 9.8 | 82 | 92 | 12.5 | 28 |
| Weak GSM Signal | 50 | 6.5 | 90 | 86 | 19.2 | 26 |
| Low Battery (20%) | 50 | 7.1 | 88 | 89 | 14.8 | 24 |

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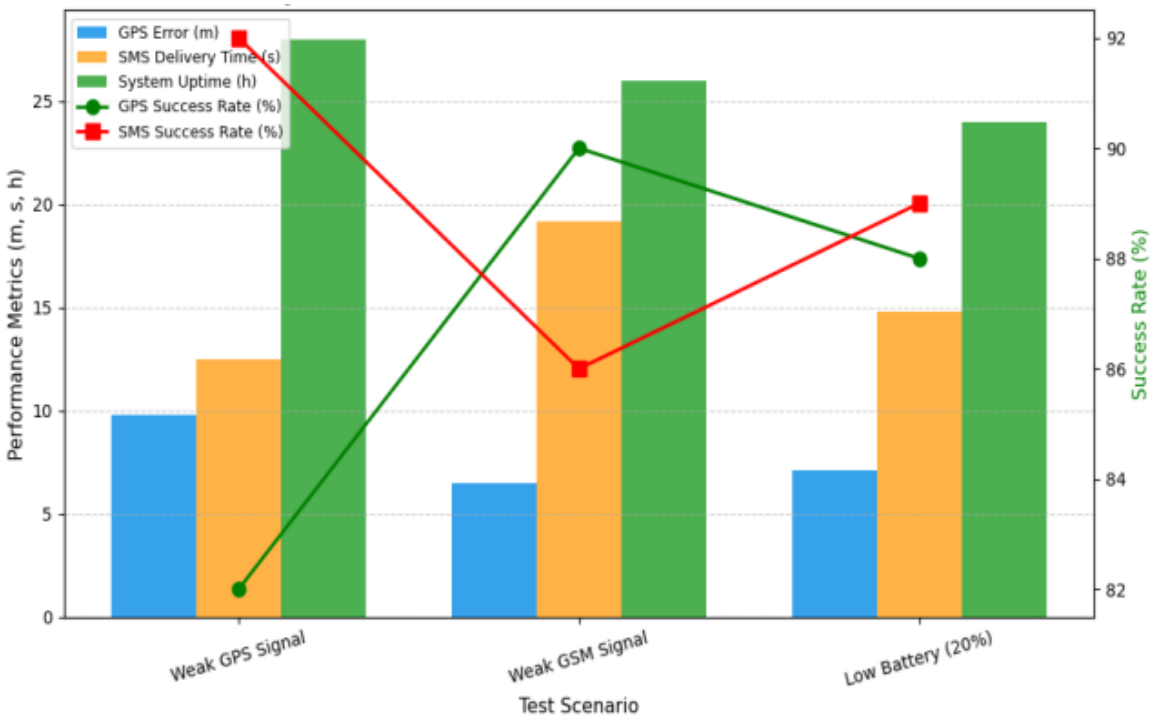



**Figure 6:** System Performance under Different Test Scenarios

The results obtained during stress testing indicate that the system maintained stable operation throughout the evaluation period. GPS location acquisition remained consistent, GSM communication was successfully maintained, and the immobilization mechanism continued to respond appropriately to user commands. Although occasional communication delays were observed due to network fluctuations, these delays did not significantly affect overall system functionality. The results demonstrate that the developed system is capable of supporting continuous vehicle monitoring and control operations. The reliability observed during testing suggests that the proposed system can be deployed effectively in practical vehicle security applications.

## 4.5 Discussion of Findings

The results obtained from this study demonstrate the successful integration of GPS tracking, GSM communication, and vehicle immobilization technologies into a single embedded system. The developed system achieved all the objectives established for the study and provided reliable vehicle monitoring and control functionality. The GPS subsystem demonstrated acceptable positioning accuracy and successfully provided real-time vehicle location information. Similarly, the GSM communication subsystem enabled efficient transmission of commands and location data through SMS communication. These findings support previous studies that identified GPS and GSM technologies as practical solutions for vehicle security applications (Smith & Johnson, 2020; Ali & Hassan, 2023). The incorporation of remote immobilization functionality distinguishes the developed system from many conventional vehicle tracking solutions. While numerous tracking systems focus solely on location monitoring, the proposed system provides an additional layer of

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security by allowing authorized users to disable vehicle operation remotely. This capability increases the likelihood of vehicle recovery and reduces opportunities for unauthorized vehicle movement. Furthermore, the use of affordable hardware components such as the Arduino Nano, Neo-6M GPS receiver, and SIM800L GSM module contributes to the cost-effectiveness of the system. This makes the proposed solution particularly suitable for deployment in developing economies where access to expensive commercial vehicle security systems may be limited (Adebayo & Ojo, 2022). Overall, the results confirm that the developed Vehicle Global Position Tracking and Immobilization System provides an effective, reliable, and affordable solution for improving vehicle security and theft prevention.

## 5. Conclusion

This study focused on the design and construction of a Vehicle Global Position Tracking and Immobilization System using an Arduino Nano microcontroller, Neo-6M GPS receiver, SIM800L GSM communication module, and relay-based immobilization mechanism. The motivation for the study arose from the increasing incidence of vehicle theft and the limitations associated with conventional vehicle security systems. The developed system successfully integrated GPS tracking, GSM communication, and remote immobilization functionalities into a single embedded platform. Experimental evaluation demonstrated that the GPS module effectively acquired and transmitted vehicle location coordinates, while the GSM module provided reliable communication between the vehicle unit and authorized users through SMS technology. Furthermore, the relay-based immobilization subsystem successfully disabled vehicle operation upon receipt of valid immobilization commands. The results obtained from the performance evaluation confirmed that the developed system achieved the objectives of the study. The GPS subsystem provided reliable location information, the GSM communication subsystem supported effective remote interaction, and the immobilization mechanism enhanced vehicle security by restricting unauthorized vehicle movement. The integration of these technologies resulted in a practical solution capable of supporting vehicle monitoring, theft prevention, and vehicle recovery operations. In addition, the use of low-cost hardware components contributed significantly to the affordability of the system. This makes the proposed solution suitable for deployment in developing economies where access to sophisticated commercial vehicle security systems may be limited. The study therefore demonstrates that effective vehicle security solutions can be developed using affordable embedded system technologies without compromising essential functionality. Overall, the developed Vehicle Global Position Tracking and Immobilization System provides an efficient, reliable, and cost-effective approach to vehicle security and represents a valuable contribution to the application of embedded systems in intelligent transportation and security management.

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