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A Systematic Review of Database-Driven Vehicle Tracking and Alerting Systems for Theft Reduction

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Abstract:

Vehicle theft continues to pose a global challenge, with millions of vehicles stolen annually and recovery rates often below 50%. Traditional tracking systems, particularly those relying on GSM and SMS communication, suffer from latency, poor scalability, and security vulnerabilities, limiting their effectiveness in preventing theft in real time. This paper presents a systematic review of vehicle tracking and alerting systems published between 2014 and 2025, focusing on database-driven architectures and modern communication technologies. This review categorizes prior studies into four thematic groups: GSM/SMS-based tracking systems, IoT and cloud-integrated platforms, biometric and advanced security systems, and AI-enhanced monitoring approaches. Comparative analysis highlights recurring limitations, including reliance on SMS with delayed alerts, weak authentication protocols, and limited scalability in multi-user contexts. Conversely, emerging solutions leveraging LTE/4G connectivity, cloud databases such as Firebase, and geofencing algorithms have demonstrated significant improvements in terms of latency, reliability, and user accessibility. The findings reveal that database-driven systems provide a robust foundation for real-time monitoring, automated alerts, and historical data analysis, offering enhanced deterrence and recovery potential. However, gaps remain in predictive analytics, advanced security hardening, and integration with fleet-scale operations. This review concludes that future research should prioritize AI-based motion prediction, multi-vehicle tracking, and secure cloud architectures to improve the effectiveness of vehicle theft reduction technologies.

Keywords — **Vehicle Tracking System, Internet of Things (IoT), ESP32, 4G LTE, Firebase, Cloud Database, Geofencing, Vehicle Theft Prevention.**

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I. INTRODUCTION

Vehicle theft remains a pervasive global problem, with millions of vehicles stolen annually and recovery rates often below 50% [1]. Despite advances in automotive security technologies, such as alarms, immobilizers, and GPS-based trackers, determined thieves continue to exploit vulnerabilities in keyless entry systems, electronic control units, and conventional tracking devices [2]. This persistent challenge underscores the need for more effective real-time solutions that can deter theft and improve the recovery outcomes.

Traditional vehicle-tracking systems, particularly those relying on the Global System for Mobile Communications (GSM) and Short Message Service (SMS), suffer from inherent limitations. These include latency delays of up to 30 s [3], susceptibility to interception, and restricted scalability [4]. These shortcomings hinder the timely detection of unauthorized movements and reduce the effectiveness of the recovery operations. Moreover, many earlier systems lack robust integration with

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modern communication technologies, resulting in poor real-time responsiveness and limited user accessibility [5].

Recent developments in the Internet of Things (IoT), cloud computing, and Long-Term Evolution (LTE/4G) networks have opened new opportunities for designing advanced vehicle-tracking and alerting systems. By leveraging microcontrollers such as ESP32, integrated LTE/GNSS modules, and cloud-hosted databases such as Firebase, low-latency, secure, and scalable solutions can now be achieved. These systems enable continuous monitoring, geofencing, and automated alerts accessible through web and mobile interfaces, thereby enhancing theft deterrence and recovery [5].

This study presents a systematic review of database-driven vehicle-tracking and alerting systems published between 2014 and 2025. This review categorizes prior studies into GSM/SMS-based solutions, IoT and cloud-integrated platforms, biometric authentication systems, and AI-enhanced monitoring approaches. Through comparative analysis, this study identifies recurring limitations, highlights emerging solutions, and outlines the future directions. The objective of this study is to demonstrate how modern database-driven architectures can significantly improve real-time monitoring, reliability, and security in combating vehicle theft.

II. Methodology

This study adopted a systematic review approach to examine vehicle tracking and alerting systems published between 2014 and 2025. The primary focus was on solutions designed to reduce theft using database-driven architecture and modern communication technologies. The scope of the review included peer-reviewed journal articles, conference proceedings, technical reports, and theses that addressed automotive security, the Internet of Things (IoT), cloud computing, and intelligent monitoring. By restricting the time frame to the past decade, this review ensured that only contemporary and relevant technologies were considered for inclusion.

The literature was retrieved from major academic databases, ResearchGate and institutional repositories. A combination of keywords was employed to capture the breadth of research in this domain, including vehicle-tracking systems, GSM/SMS, IoT, cloud databases, Firebase, geofencing, biometric authentication, AI monitoring, and theft prevention. Manual searches of the reference lists were conducted to identify additional relevant studies that may not have appeared in the initial database queries.

To ensure rigor, clear inclusion and exclusion criteria were set. Studies were included if they addressed vehicle-tracking, theft prevention, or monitoring systems using GSM/SMS, IoT/cloud, biometrics, or AI/ML approaches. Works published before 2014, studies unrelated to theft reduction, and systems that lacked database-driven components were excluded. Proprietary or commercial systems without technical documentation were excluded to maintain transparency and reproducibility.

The selected studies were organized into four thematic categories: GSM/SMS-based tracking systems, IoT and cloud-integrated platforms, biometric and advanced security systems, and AI-enhanced monitoring approaches. This categorization allowed for a systematic comparison of the strengths, limitations, and emerging opportunities of different technological paradigms.

Finally, each study was evaluated using standardized criteria. Latency was assessed in terms of alert transmission speed and responses. Scalability was examined by considering the ability of the systems to support multiple vehicles or users simultaneously. Security was evaluated based on the presence of encryption, authentication, and interception resistance. Usability was measured through the accessibility of mobile or web dashboards and the ease of operation. Predictive capability was considered when AI or machine learning was employed to detect anomalies or to forecast theft events. Together, these metrics provide a structured basis for analyzing the effectiveness of existing systems and identifying the gaps that the proposed DVTS framework aims to address.

III. REVIEW OF SIMILAR WORKS

Reviewing prior studies on vehicle-tracking and security systems is essential to understand the extent

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to which existing technologies have addressed theft prevention. By examining the methods, architectures, and challenges faced by other researchers, informed decisions can be made regarding the tools and approaches required to achieve better outcomes. The following subsections categorize relevant studies published between 2014 and 2025 into four major themes: GSM/SMS-based systems, IoT and cloud-integrated platforms, biometric and advanced security systems, and AI-enhanced monitoring approaches

A. GSM/SMS-Based Tracking Systems

Early vehicle-tracking systems relied heavily on GSM and SMS communications.

Gashi, [6] presented a real-time vehicle-tracking system that utilized GPS, GSM, and GPRS technologies. This system employs a GPS module to capture vehicle location coordinates and transmits them via GPRS to a central server and a database. In the absence of GPRS connectivity, the data were stored locally and synchronized later. A Web application displayed vehicle locations on a map using Google Maps, while sensors tracked additional data, such as fuel levels. The system aims to provide real-time monitoring to reduce vehicle misuse and maintenance costs, following a development life cycle that includes requirements gathering, development, testing, and maintenance. The Security measures involved encrypted data transfer and secure socket layer (SSL) web authentication. Despite integrating GPS tracking with wireless transmission for centralized data storage, the reliance on GSM/GPRS reflects a broader limitation of early vehicle-tracking systems, where low-cost communication methods were prioritized over responsiveness issues. This design choice consistently undermined real-time theft prevention, as scheduled data transfers delayed alerts and reduced the system's ability to provide immediate intervention. The gap identified in this study highlights the need for continuous low-latency communication channels in modern tracking systems.

Kumar *et al.* [7] designed and developed a GPS-based vehicle-tracking system to display vehicle locations on Google Maps. The system utilized an Arduino Mega microcontroller to control a Ublox NEO-6M GPS module to obtain coordinates and a SIM900A GSM module to send locations to the user's phone via text messages. Users could initiate tracking by sending a "START" message and subsequently receive SMS updates with links to view locations on Google Maps. The system aims to aid in the recovery of stolen vehicles by enabling remote location monitoring through the integration of readily available Arduino, GPS, and GSM components. However, the dependence on SMS illustrates a recurring trend in early Arduino-based tracking solutions, where simplicity and affordability outweighed security and speed considerations. While SMS enabled basic location sharing, its vulnerability to interception and transmission delays made it unsuitable for theft scenarios requiring an immediate response. This limitation underscores a broader research gap: the need to transition from SMS-based alerts to secure real-time communication technologies such as LTE or IoT protocols.

Hlaing *et al.* [8] designed and implemented a basic real-time vehicle-tracking system using an Arduino platform with GPS and GSM modules. This system provides location monitoring and alert capabilities via SMS, making it accessible through basic mobile phone. However, the reliance on SMS reflects the broader challenge of early low-cost tracking systems; while accessible to basic mobile phones, SMS inherently restricts update frequency and introduces latency. This design choice illustrates the trade-off between affordability and responsiveness but ultimately undermines the system's ability to provide continuous real-time monitoring. The simplicity of the hardware/software setup further highlights a recurring gap in scalability, showing that systems built for accessibility often fail to meet the demands of modern theft prevention. Additionally, the hardware and software setup of the system is relatively simple, potentially limiting its scalability and functionality. This study highlights the need for more advanced tracking systems that can offer continuous, real-time updates and alerts with enhanced reliability and scalability.

Nikumbh *et al.*, [9] designed and implemented an anti-theft system for vehicles using GPS, GSM, a relay module, and a microcontroller. The system employs a GPS module to track the vehicle location

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and a GSM module to relay this information to the owner through a mobile application. The microcontroller and relay module enabled the remote deactivation of the vehicle ignition as a theft deterrent. The mobile application allowed vehicle registration, location viewing on a map, and relay switch control. Although the system effectively combines available hardware and IoT capabilities to offer a low-cost security solution, it faces limitations in terms of real-time response and the reliability of relay activation. These issues highlight the need for improvements in the speed and reliability of vehicle immobilization methods to enhance the overall effectiveness of anti-theft systems.

Rajendra *et al.* [10] developed a car theft detection and monitoring system utilizing Global Positioning System (GPS) and Global System for Mobile Communications (GSM) technologies to combat the increasing problem of vehicle theft, which results in substantial financial losses. The system uses an infrared (IR) sensor to detect unauthorized motion, prompting the microcontroller to activate GPS and GSM modules. The vehicle location was then sent to the owner via Short Message Service (SMS), and the engine could be remotely disabled upon theft detection. Testing confirmed the effectiveness of the system in motion detection, location sharing, and engine control. Despite its advantages, such as low cost and real-time tracking capabilities, the system faces limitations, such as signal distortion and network issues, which can affect its reliability and speed in real-time applications. This study highlights the need for more advanced communication technologies that can mitigate these challenges and provide more reliable and faster responses in vehicle security systems.

Sudha and Kumar [11] designed an ARM-based vehicle monitoring system utilizing GPS and GSM technologies. The system employs a GPS module to obtain the location coordinates and a GSM module to send alerts via text messages. It monitored the engine temperature and automatically turned off the ignition if overheating was detected. Accident alerts with location information were sent to predefined contacts, and vibration and infrared (IR) sensors were integrated for theft detection, triggering alerts as required. The ARM microcontroller coordinates all the system functions. Despite its low-cost design and the integration of various sensors and wireless communications, the system's reliance on SMS alerts may limit its immediacy and scalability. Furthermore, the system's ability to detect and respond to complex situations, such as theft or accidents, may be constrained by the basic sensor setup, indicating a gap in its advanced detection and response capabilities.

Shukla [12] presented a smart anti-theft system for vehicle security using Global System for Mobile Communications (GSM) and Global Positioning System (GPS) technologies, incorporating a microcontroller, GSM module, and GPS to address vehicle theft. The system featured real-time vehicle-tracking and Short Message Service (SMS) alerts sent to the owner's phone, with remote engine control capabilities. Vibration and sound sensors detect unauthorized access and trigger actions using a microcontroller. GPS facilitated vehicle-tracking, whereas GSM handled communication, with alerts sent if predefined limits were exceeded. Despite demonstrating the ability to track vehicles and secure them from theft, the system relied heavily on GSM and SMS for communication, which may not be optimal for real-time alerts because of possible speed and latency issues. This study did not explore more advanced communication technologies that could provide quicker response times and enhanced security. This highlights a research gap in the utilization of more robust and faster communication networks to improve the real-time effectiveness of vehicle-security systems.

Gorret [13] developed a GPS-GSM-based real-time vehicle theft tracking system specifically designed to address the urban security challenges in Uganda, where vehicle theft is exacerbated by inadequate policing and poor digital infrastructure. The proposed system integrates a Neo-6M GPS module, SIM800L GSM transceiver, and Arduino Uno microcontroller to provide SMS-based alerts upon unauthorized access events, including an optional SMS-triggered engine immobilization feature. Unlike cloud-reliant solutions, this system functions effectively in environments with poor or no Internet connectivity, using low-cost locally available components to ensure affordability and scalability. Field tests across urban areas in Kampala

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revealed high performance, with GPS accuracy averaging 4.8 m and SMS alert latency under 4 s, achieving 95.2% GPS lock reliability and 98.6% SMS delivery success. A front-end dashboard built with React.js and backend APIs in Python/Flask enabled real-time tracking and control, with features such as alert history, map plotting and engine immobilization. Despite minor limitations, such as GPS drift in dense urban zones and reduced battery efficiency at high temperatures, the system proved to be highly viable and cost-effective, outperforming commercial alternatives in terms of adaptability and affordability. Future improvements include mobile application integration, LoRa/NB-IoT support, machine learning for predictive theft detection, and broader regional deployment studies, highlighting a meaningful contribution to ICT for development and localized smart city solutions in resource-constrained settings.

Abdirahman *et al.* [14] developed a vehicle-tracking system based on the ARM7 microcontroller platform, integrating GPS and GSM technologies to monitor vehicle location and movement in real-time. The system used a GPS module to capture positional data, which were transmitted to a central mobile number or server via a GSM modem. The setup included an ARM7 LPC2148 microcontroller, SIM300 GSM modem, GPS module, and supporting power supply and interface circuitry. The GPS continuously tracked the vehicle coordinates, and upon request or at specified intervals, the data were sent via GSM as an SMS. This allowed users to receive the vehicle location as a clickable Google Maps link. The objective of the system was to provide an efficient, low-cost vehicle monitoring solution that could help with real-time location tracking, route monitoring, and theft prevention. It targets private car owners, fleet managers, and logistics operators who require consistent oversight of vehicle location. The development methodology focused on embedded system design, software-hardware interfacing, serial communication via UART between the GPS, GSM, and ARM7 microcontroller, and SMS command response loops for position updates. Security measures were minimal because the system relied primarily on GSM text messaging without encryption or authentication layers. It also lacks a centralized, cloud-based monitoring platform or secure storage. Despite the effective use of GPS-GSM integration for vehicle-tracking, the limitations include the absence of continuous real-time monitoring due to SMS-based transmission, which restricts the update frequency. Additionally, the use of GSM-only communication poses a risk of delay or failure in areas with poor network coverage. These limitations suggest a research gap in integrating more robust wireless technologies (such as 4G/5G or LPWAN), cloud-based real-time dashboards, and enhanced security protocols into the system. Moreover, there is potential for AI-enhanced analytics, vehicle diagnostics, and automated event-based alerts in future systems.

B. IoT and Cloud-Integrated Systems

With the rise of the Internet of Things (IoT) and cloud computing, newer systems have adopted real-time databases and mobile/web interfaces.

Wijesuriya [15] developed a mobile application and Web-based system called "Route-Me" to manage vehicles and drivers for Global E Marketing Solutions, with the aim of enhancing and tracking vehicle routing to improve efficiency. The system allows employees to request trips through a web application, which transport managers can allocate to specific drivers based on their availabilities. Drivers received notifications via a mobile application and updated their trip status as needed. The system utilizes the Global Positioning System (GPS) to track locations and calculate trip distances while monitoring driver hours, vehicle usage, and routing. The Web system was developed using Hypertext Preprocessor (PHP), Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and My Structured Query Language (MySQL), and the Android mobile application was built with Java, using Representational State Transfer (REST) Application Programming Interfaces (APIs) for data access. Although testing validated the functionality of the system across devices, it faced challenges with scalability, as the system may struggle to accommodate a growing number of users and operations without significant modifications. Additional limitations include potential device compatibility issues, limited offline functionality, and security risks associated with data handling.

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These issues highlight the need for more robust solutions that address scalability and security challenges in real-time vehicle tracking systems.

Shibghatullah *et al.* [16] developed a vehicle-tracking application using GPS and Google Maps API to enhance estimated arrival time accuracy. The system employed a GPS-enabled Android device to obtain vehicle location coordinates at regular intervals and stored the data in a Firebase real-time database synchronized across users. To calculate the arrival times, the system used Google's Distance Matrix API, which considers traffic conditions and routing. The prototype was tested and refined based on the user feedback. Although the system effectively uses real-time GPS tracking and Google's traffic-aware API to improve arrival time predictions, it relies heavily on Google's services and the accuracy of the real-time traffic data. Additionally, the system's effectiveness may be limited by the availability and accuracy of GPS signals in certain areas, revealing performance gaps under challenging conditions.

Godwin [17] presented a review of GPS-based vehicle-tracking systems, highlighting their capabilities and potential applications, such as fleet management, theft prevention, accident detection, and vehicle diagnostics. This study explained the working principle of GPS and its integration with the GSM network for real-time tracking using web and mobile applications. While discussing system capabilities such as acquiring current and historical vehicle locations, setting alerts for speed and geographic limits, and monitoring movements, the review identified challenges, including ionospheric disturbances affecting GPS signal accuracy, security, and privacy concerns related to data transmission. The review primarily focused on existing technologies such as GPRS and GSM without addressing newer communication technologies such as 4G/5G networks, which offer improved performance and reliability. This gap indicates the need for further research on advanced communication technologies and security measures to enhance the robustness and effectiveness of vehicle tracking systems.

Agarwal *et al.* [18] examined a real-time Global Positioning System (GPS)-based Android application designed to improve fleet management in congested urban environments by tracking public transport vehicles such as buses, auto-rickshaws, and e-rickshaws. This system utilizes a client-server model to gather and relay vehicle location data to users to reduce waiting times and facilitate efficient commute planning. Developed using Android Studio, SQLite, and Firebase, the application offers mapping, tracking, and data transmission. Despite its benefits, the system faces challenges related to ensuring data accuracy and maintaining consistent real-time updates amidst urban GPS signal interruptions and network connectivity issues, indicating a research gap in developing more reliable solutions for real-time public transport tracking in metropolitan areas.

Bacîrea [19] presented the development of a real-time GPS tracking system using a Raspberry Pi 4 model B and a GPS-NEO-6MV2 module. The system demonstrated the applicability of GPS technology for location tracking and route monitoring, particularly in emergencies. It utilized a Raspberry Pi board, GPS module, GSM module, and other circuits to collect GPS data, transmit them via GSM, and display the location on a web interface using the Google Maps API. Although the system was effective in validating real-time tracking, it utilized GSM for communication, which may have limitations in speed and coverage compared with 4G technology. Additionally, the system proposed future enhancements, such as image and video capture, which are not included in the scope of the proposed study. This study highlights the potential of GPS tracking in various domains but does not address the benefits of advanced communication technologies, such as 4G.

Salih and Alsaedi [20] introduced an intelligent vehicle-tracking system employing GPS and GSM modem technologies. This system incorporated an Arduino microcontroller, GPS receiver, GSM modem, and various sensors to continuously capture vehicle location and speed data at 10-second intervals, transmitting this information to an IoT platform via GPRS. The system offers users the capability to remotely monitor their vehicles through an Android application, and it also includes SMS alerts for location requests and accident detection alerts. An evaluation of the GPS tracking accuracy revealed a strong performance, with a mean absolute error of 2.14986 m. Their proposed system facilitates

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real-time monitoring, tracking, and accident detection in vehicles using widely available and cost-effective components. The integration of GPS, GSM, and IoT technologies presents an efficient solution for remote vehicle monitoring. This study mainly focused on vehicle monitoring and did not explore advanced communication methods or other features. The research gap lies in the potential for integrating newer communication technologies, such as 4G, to enhance the system capabilities and improve the tracking efficiency.

Chun [21] presented the development of a Raspberry Pi-based cyber-physical system for vehicle monitoring over the Internet, utilizing a Raspberry Pi 3B+ board connected with various sensors, such as the DHT22 temperature-humidity sensor, MQ135 gas sensor, and NEO-6M GPS module. The EDA tool and EAGLE were used to design a custom PCB for component mounting. The system collected sensor data, including temperature, humidity, gas quality, and GPS coordinates, and analyzed them for abnormalities before uploading the data to a Firebase real-time database. A mobile application built using the Flutter framework retrieved and displayed the data from Firebase, showing the temperature, humidity, gas status, and vehicle location on a map, and sent notifications upon detecting abnormal values. Although the system successfully demonstrated data collection, transmission, storage, retrieval, and anomaly alerting, it focused on environmental monitoring rather than comprehensive vehicle security. The research gap lies in the potential for expanding such systems to include advanced security features and enhanced communication technologies, such as 4G, to provide more robust real-time tracking and alert capabilities.

Moumen *et al.* [22] presented a real-time GPS tracking system for connected vehicles utilizing Internet of Things (IoT) and Vehicular Ad Hoc Network (VANET) technologies. The system employed Arduino Uno R3, SIM800L module, NEO-6M GPS module, Node.js, WebSocket, and Firebase for real-time location data collection, transmission, storage, and visualization on a Web interface. These modules were interfaced with an Arduino to acquire the location data and transmit them via GPRS to a cloud server. Node.js and WebSocket facilitated efficient hardware-software integration, whereas Firebase provided real-time database capabilities, allowing for the remote monitoring of vehicle locations and movements. The system demonstrated potential applications such as dynamic routing, eco-driving feedback, smart charging stations, and fleet emissions reduction, highlighting its versatility across the transportation, logistics, and tracking sectors. The implementation process covered HTTP connections, Leaflet map integration, and web development, with results demonstrating accurate real-time tracking on an interactive map. Although the system effectively leverages IoT, VANET, and V2X communication for connectivity and data exchange among vehicles, infrastructure, and the cloud, the research primarily focuses on vehicular networks rather than vehicle theft prevention. The research gap lies in the opportunity to incorporate advanced security measures and communication technologies, such as, 4G to enhance real-time tracking and alert capabilities, specifically for anti-theft purposes.

Bhandare *et al.* [23] developed a smart vehicle-tracking and accident alert system using GPS, GSM, IoT microcontrollers (ESP32, Arduino UNO), and Firebase cloud platform. The system automatically detects accidents through accelerometers and vibration sensors, immediately sending GPS coordinates via GSM to emergency contacts. Sensor data streams to Firebase via Wi-Fi for live dashboard monitoring. Additional safety features include flame sensors, ultrasonic sensors, and relay-driven engine cutoff mechanisms. The system addresses delayed emergency responses when victims are unconscious or no witnesses are present, prioritizing affordability, easy installation, and minimal human intervention. Key limitations include GSM network dependency causing potential coverage issues in remote areas and false triggers from non-accident movements. Research gaps exist in AI-based accident classification, communication redundancy (satellite, LoRa, VANET), and enhanced cybersecurity for scalable deployment.

C. Biometric and Advanced Security Systems

Some researchers have introduced biometric authentication and multilayered security features.

Garba *et al.* [24] proposed an integrated vehicle security and tracking system addressing urban car theft. The system combines passive infrared (PIR) motion detection, surveillance cameras for theft documentation, and biometric thumbprint authentication, all managed by an ATmega328p microcontroller (Arduino Uno). Using cellular networks for cost-effective tracking and remote vehicle demobilization, the system demonstrated robust performance in validation metrics. However, significant limitations emerged. Biometric authentication complexity creates practical challenges, particularly for temporary access scenarios like mechanic servicing. The sophisticated security measures may also compromise the element of surprise in deterring thieves. The rigid authentication requirements lack flexibility for legitimate temporary users, highlighting a critical research gap: balancing robust security with practical usability. Future systems should incorporate multi-level authentication options, temporary access protocols, and context-aware security measures that maintain protection while accommodating real-world usage scenarios beyond single-owner operation.

Abdulkareem *et al.* [25] proposed an advanced vehicle security and tracking system utilizing cellular networks to address the pervasive issue of vehicle theft, especially in urban areas. The system integrates a passive infrared (PIR) motion detector, surveillance camera, and biometric thumbprint device embedded in the vehicle's steering wheel for enhanced security. An Arduino Uno module with an ATMEGA328p microcontroller was employed to facilitate communication between the software and hardware components, enabling effective car tracking using wireless technology. The proposed system is designed to detect unauthorized movements, capture images of the vehicle interior, and send real-time location data to the owner using GSM and GPS technologies. The simulation results demonstrated a reliability rate of 87%, outperforming previous methods. However, reliance on cellular networks and microcontroller-based solutions may introduce security vulnerabilities and require additional measures to ensure robustness against potential attacks.

Jeevan *et al.* [26] proposed a GPS-based vehicle-tracking system integrating two-factor authentication and IoT technologies for enhanced security and real-time monitoring. Built on Arduino Uno with NEO-6M GPS and SIM800L GSM modules, the system employs fingerprint biometric verification and relay-controlled ignition to prevent unauthorized access. A buzzer alerts failed authentication attempts. Features include remote ignition control and SMS-based location retrieval, with GPS accuracy averaging 5.4m (residential) and 2.6m (urban). The system achieved 93% success across trials, transmitting coordinates periodically to servers or mobile devices. Limitations include occasional GPS/GSM connectivity delays and message transmission lags. Despite these, the layered security approach combining biometric and mobile controls, low-power design, and cloud-compatible communication offers robust theft prevention. Future optimization should address data handling efficiency and hardware performance to reduce communication delays and enable scalable deployment.

D. AI and Machine Learning Approaches

Emerging studies have explored predictive analytics and intelligent monitoring.

Rahman [27] conducted a systematic literature review of Internet of Things (IoT)-based smart vehicle monitoring systems using GPS and cellular networks. This study aimed to uncover research methods and trends to lay the foundation for future advancements in automated driving systems. The proposed model integrated GPS tracking, General Packet Radio Service (GPRS)/Global System for Mobile Communications (GSM) communication, machine learning, and the Google Maps API for real-time vehicle-tracking and navigation. It utilized a GPS module to obtain location coordinates, and machine learning algorithms generated driving instructions and collision avoidance warnings. Data were transmitted via GPRS and displayed on an Android application. The literature review identified limitations, such as the lack of full automation and persistent security issues, indicating a research gap in developing more secure and automated vehicle monitoring systems. These gaps suggest a need for further exploration of secure, real-time data

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transmission methods and advanced automation techniques in vehicle-tracking.

Presitha Aarthi *et al.* [28] developed a cloud-based road safety system detecting rash driving using IoT sensors and Random Forest algorithms, collecting data from accelerometers, GPS, OBD-II modules, and steering sensors to identify abrupt acceleration, erratic steering, and speeding behaviors. Data transmits via ESP8266 Wi-Fi to cloud platforms (AWS/Azure IoT) for RF classifier processing, achieving 92% accuracy, 94% recall, 88% precision, and 91% F1 score in identifying rash driving while minimizing false alarms. The system provides real-time alerts to traffic authorities and nearby vehicles with continuous learning capabilities adapting to evolving conditions. However, key limitations include reduced performance in extreme weather and high-traffic scenarios, lack of comparison with alternative machine learning models, and research gaps in evaluating system robustness across diverse environments and integrating predictive capabilities into V2V/V2I safety networks for comprehensive road safety management.

Table of Summary

TABLE I
COMPARATIVE SUMMARY OF VEHICLE-TRACKING APPROACHES

Category	Representative Works	Strengths	Limitations
GSM/SMS-Based Systems	Gashi (2014), Kumar (2019), Hlaing (2019), Nikumbh (2022), Rajendra (2022), Sudha & Kumar (2022), Shukla (2022), Gorret (2025), Abdirahman (2025)	Affordable, accessible, simple design, effective in low-resource settings	High latency, poor scalability, weak security, reliance on unstable GSM networks
IoT & Cloud-Integrated	Wijesuriya (2019), Shibghatullah (2022), Godwin (2022), Access (2023), Bacîrea (2023), Salih & Alsaedi (2023), Chun (2023), Moumen (2023), Bhandare (2025)	Real-time dashboards, synchronization, improved accessibility, fleet management	Dependent on GSM/Wi-Fi, vendor lock-in (Google/Firebase), privacy risks, limited scalability
Biometric & Advanced Security	Garba (2022), Abdulkareem (2024), Jeevan (2024)	Enhanced authentication, layered security, remote ignition control	Usability challenges, cumbersome access, occasional delays, GSM dependence
AI & Machine Learning	Rahman (2021), Presitha Aarthi (2024)	Predictive analytics, driver behavior monitoring, high accuracy in detection	Narrow scope (driver focus), limited theft prevention, weak robustness in diverse conditions

IV. RESULTS OF THE REVIEW

The systematic review of vehicle-tracking and alerting systems highlights both the progress made and the persistent challenges across different technological approaches. Each category; GSM/SMS-based systems, IoT and cloud-integrated platforms, biometric security solutions, and AI-enhanced monitoring offers distinct strengths that have advanced the field; however, they also share recurring limitations that restrict their effectiveness in theft prevention. Simultaneously, emerging opportunities point toward database-driven architectures, advanced communication

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technologies, and predictive analytics as promising directions for future development. The following subsections summarize these findings in terms of their strengths, limitations, and opportunities.

A. Strengths Across Approaches

Across the reviewed works, each technological approach demonstrated notable strengths that advanced vehicle-tracking and security. GSM/SMS-based systems are affordable and accessible, particularly in low-resource environments, and their simple hardware setups make them easy to implement and maintain. IoT and cloud-integrated platforms have introduced real-time dashboards and synchronization, improving user accessibility and enabling applications such as fleet management and accident detection. Biometric systems have added layered authentication, reducing unauthorized access and achieving high reliability in controlled trials. AI and machine learning approaches have contributed to predictive analytics and intelligent monitoring, achieving high accuracy in driver behaviour detection and highlighting the potential for proactive intervention.

B. Limitations Across Approaches

Despite these strengths, recurring limitations were evident in all categories. GSM/SMS systems consistently suffer from latency, poor scalability, and weak security, undermining their effectiveness in real-time theft prevention. Although IoT and cloud-based platforms improve accessibility, they remain dependent on GSM or Wi-Fi, limiting performance in low-connectivity areas and raising concerns about privacy and vendor lock-in. Biometric systems introduce usability challenges, as complex authentication processes delay legitimate access, and they continue to rely on outdated GSM/SMS communication. Although promising, AI and machine learning approaches are narrow in scope, focusing more on driver behaviour than theft prevention, and lack robustness under diverse conditions or integration with modern LTE/cloud infrastructures.

C. Emerging Opportunities

The review also revealed several emerging opportunities that point toward the future of vehicle-tracking and theft reduction. Database-driven architectures, such as Firebase, enable low-latency, scalable, and secure real-time monitoring while supporting historical data storage for forensic analysis. Advanced communication technologies, including LTE/4G, 5G, and LPWAN, offer faster, more reliable channels compared to GSM/SMS, with potential for coverage in remote areas. Geofencing and automated alerts provide proactive theft deterrence by triggering notifications when vehicles leave predefined zones, while AI-enhanced prediction models can identify suspicious movement patterns before theft occurs. Finally, cybersecurity hardening through encryption, authentication, and intrusion detection is essential to protect sensitive vehicle data and ensure trust in large-scale deployments.

V. Proposed Framework/Conceptual Model

The proposed Database-Driven Vehicle-tracking System (DVTS) is designed to overcome the recurring limitations identified in GSM/SMS-based, IoT/cloud, biometric, and AI-driven approaches. By integrating modern communication technologies, cloud-hosted databases, geofencing, and intelligent alerting, DVTS provides a comprehensive solution for theft prevention and vehicle monitoring.

A. System Architecture

The DVTS architecture is built around three core layers:

1) ***Vehicle Layer:*** Equipped with a GPS module that continuously captures real-time location data. An LTE/4G modem transmits this data securely to the cloud, eliminating the latency and unreliability of GSM/SMS communication.

2) ***Cloud Layer:*** A Firebase cloud database serves as the central repository for all vehicle data, including location, alerts, and user activity logs. Security layers encryption, authentication, and AI-based anomaly detection ensure data integrity and protect against unauthorized access. A geofencing engine operates within the cloud, monitoring vehicle movement against predefined zones.

3) ***Client Layer:*** Web and mobile dashboards provide intuitive interfaces for owners, managers, and authorities. Real-time alerts are delivered instantly, and authorized users can trigger remote immobilization when theft is suspected.

The Fig.1 illustrates the structure of the proposed Database-Driven Vehicle-tracking System (DVTS) solution. It shows how GPS and LTE/4G modules in the vehicle transmit data to a Firebase cloud database, which applies security layers and geofencing logic. Real-time alerts and immobilization commands are sent to client dashboards for owners, managers, and authorities.

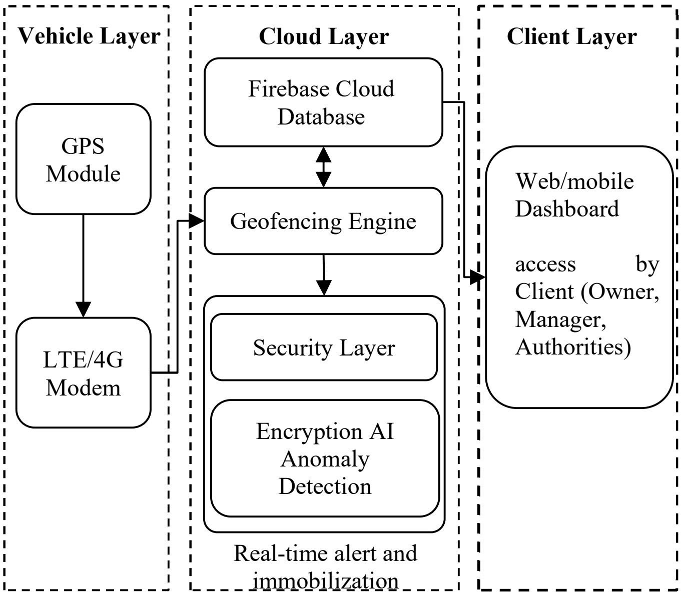

Fig. 1: DVTS System Architecture

B. *Workflow of Alerting and Monitoring*

The DVTS workflow ensures seamless communication and rapid response:

*1) **Data Capture:*** The GPS module records vehicle coordinates continuously.

*2) **Transmission:*** Data is sent via LTE/4G to the Firebase cloud database.

*3) **Processing:*** Security layers validate and encrypt the data, while the geofencing engine checks for boundary violations.

*4) **Detection:*** If unauthorized movement is detected, the system flags anomalies using AI-based detection.

*5) **Alerting***: Real-time notifications are sent to the client dashboards (mobile/web).

*6) **Response***: Users can monitor the vehicle's status and, if necessary, initiate remote immobilization.

*7) **Storage***: All events are logged in the database for forensic analysis and law enforcement support.

This flowchart in Fig. 2 outlines the step-by-step process of how DVTS detects unauthorized movement and responds. It begins with GPS location capture, followed by LTE/4G transmission to the cloud. The geofencing engine checks for boundary violations, triggering alerts and enabling remote immobilization. All events are securely logged in the cloud database.

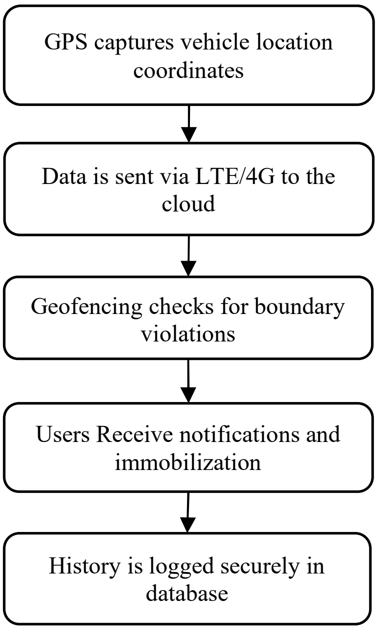

Fig. 2: Workflow of Alerting and Monitoring

C. *Advantages Over Prior Systems*

The DVTS framework offers several advantages compared to earlier approaches:

*1) **Latency Reduction:*** LTE/4G communication eliminates delays inherent in SMS-based systems, ensuring real-time monitoring.

*2) **Scalability***: Cloud-hosted databases allow seamless expansion from individual vehicles to large fleets.

*3) **Enhanced Security***: Multi-layered protection (encryption, authentication, anomaly detection) addresses vulnerabilities in GSM-only systems.

*4) **User Accessibility:*** Dashboards provide intuitive, centralized control, improving usability compared to cumbersome biometric-only systems.

*5) **Predictive Capability:*** AI integration enables proactive theft detection, moving beyond reactive driver behaviour monitoring.

*6) **Data Reliability:*** Historical logs stored in the cloud support forensic investigations and improve recovery rates.

VI. DISCUSSION

A. *Critical Analysis of Findings*

The systematic review revealed that while vehicle-tracking technologies have evolved significantly between 2014 and 2025, recurring limitations persist across different approaches. GSM/SMS-based systems, though affordable and accessible, consistently suffer from latency, poor scalability, and weak security. IoT and cloud-integrated platforms improve synchronization and accessibility but remain dependent on GSM/Wi-Fi, raising concerns about reliability and data privacy.

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Biometric systems add layered security but introduce usability challenges and still rely on outdated communication methods. AI/ML approaches show promise in predictive analytics but remain narrow in scope, focusing more on driver behaviour than theft prevention.

These findings highlight a clear research gap: the need for database-driven, LTE/4G-enabled systems that combine real-time monitoring, secure communication, and predictive analytics to deliver effective theft reduction.

B. Addressing Gaps with Database-Driven Systems (DVTS)

The proposed Database-Driven Vehicle-tracking System (DVTS) directly responds to the limitations identified in prior works:

*1) **Latency and Real-Time Monitoring:*** Unlike SMS-based systems, DVTS leverages LTE/4G communication and Firebase cloud databases to ensure continuous, low-latency updates. This eliminates delays inherent in GSM/SMS alerts.

*2) **Scalability:*** Cloud-hosted databases allow DVTS to scale seamlessly across fleets, overcoming the scalability challenges noted in systems [15].

*3) **Security:*** DVTS integrates secure authentication, ***encrypted*** data transmission, and geofencing alerts, addressing vulnerabilities highlighted in GSM-only systems [14].

*4) **Usability:*** By combining biometric authentication with mobile/web dashboards, DVTS balances robust security with practical usability, avoiding the cumbersome access issues [24].

*5) **Predictive Analytics:*** DVTS incorporates AI-based geofencing and anomaly detection, extending beyond driver behaviour monitoring to theft-specific prediction, bridging the gap left [27], [28].

C. Practical Implications for Theft Reduction

The integration of LTE/4G communication, cloud databases, and geofencing in DVTS has significant practical implications. Real-time alerts and remote immobilization increase the likelihood of preventing theft before it occurs. Continuous tracking and secure cloud storage of historical data aid law enforcement in recovering stolen vehicles and provide forensic evidence. Scalable architecture supports multi-vehicle monitoring, reducing misuse and operational inefficiencies in fleet management. User-friendly mobile and web dashboards enhance accessibility, ensuring that owners, managers, and authorities can respond quickly to theft incidents.

D. Future Directions

While DVTS addresses many of the gaps identified in prior works, further research and development are necessary to strengthen its capabilities. Integration with 5G and LPWAN technologies could enhance coverage and reduce latency beyond LTE/4G. AI-enhanced theft prediction models can be expanded to identify suspicious movement patterns and proactively prevent theft. Cybersecurity hardening through advanced encryption, intrusion detection, and blockchain-based data integrity will be critical to protect sensitive vehicle data. Finally, multi-channel communication using satellite, LoRa, or mesh networks can provide redundancy, ensuring reliability even in remote or low-connectivity areas.

VII. CONCLUSIONS

This systematic review examined vehicle-tracking and alerting systems developed between 2014 and 2025, categorizing them into GSM/SMS-based, IoT/cloud-integrated, biometric, and AI-enhanced approaches. While each category contributed meaningful advancements, recurring limitations such as latency, poor scalability, weak security, and narrow predictive scope persisted across the literature.

To address these gaps, the proposed Database-Driven Vehicle-tracking System (DVTS) integrates LTE/4G communication, cloud-hosted databases, geofencing, and intelligent alerting mechanisms. This framework offers real-time monitoring, secure data management, and proactive theft deterrence, surpassing the capabilities of earlier systems.

The DVTS model demonstrates how modern technologies can be combined to deliver scalable, secure, and responsive vehicle-tracking solutions. Its architecture supports multi-vehicle fleets, enhances user accessibility, and enables forensic data recovery. Future research should explore integration with 5G networks, AI-based theft prediction, cybersecurity hardening, and multi-channel communication to further strengthen system resilience and effectiveness.

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