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Smart Accident Vehicle Emergency System (Project SAVE)

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Abstract: Road accidents and personal emergencies claim thousands of lives annually, largely due to delayed response and the inability to relay location-specific distress information. Existing automated accident detection systems, while technically sophisticated, are prone to false positives under normal vehicular conditions, undermining their real-world reliability. This paper presents Project SAVE (Smart Accident and Vehicular Emergency), a manual-trigger-based emergency alert system built on an Arduino Uno microcontroller, a SIM900A GSM module, and a NEO-6M GPS module. Upon deliberate activation via a push button, the system acquires real-time GPS coordinates and transmits an SMS containing a Google Maps hyperlink to predefined emergency contacts. This design prioritizes user agency, cost-effectiveness, and network independence over full automation. The system was evaluated for GPS fix acquisition time, SMS delivery reliability, and component cost, demonstrating consistent performance under open-sky conditions at a total hardware cost below ₹2,500. A comparative analysis against sensor-based and smartphone application-based systems is presented, along with the system architecture, component specifications, methodology, limitations, and future scope.

Keywords: *Arduino Uno; SIM900A GSM; NEO-6M GPS; Emergency Alert; SMS Notification; IoT; Embedded Systems; Accident Detection; Location Tracking; Personal Safety.*

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I. INTRODUCTION

Emergencies arising from road accidents, medical crises, physical assaults, or natural disasters demand the fastest possible response to preserve human life. According to the World Health Organization (WHO), approximately 1.35 million people die each year as a result of road traffic crashes, with millions more sustaining non-fatal injuries [1]. A significant proportion of these fatalities occur in the critical golden hour immediately following an incident, during which timely medical intervention could substantially improve survival outcomes [2].

The fundamental challenge in emergency response is not merely the availability of medical services but rather the timely communication of accurate location information to those services. Modern embedded systems, wireless communication, and satellite positioning have enabled the development of low-cost portable emergency alert devices. Despite the availability of advanced smartphone-based applications and cloud-connected IoT solutions, significant populations — particularly in rural regions of developing nations — remain underserved due to smartphone unavailability, high data costs, and inconsistent internet connectivity [3].

Project SAVE addresses this gap by offering a standalone, hardware-based emergency alert solution that operates exclusively over the GSM network using SMS — a universally accessible protocol supported by virtually all mobile devices worldwide. The system is intentionally designed around manual activation through a push button, distinguishing it from automated accident detection systems. This deliberate design choice is grounded in the recognition that automatic sensors such as accelerometers and vibration detectors frequently generate false positives under normal driving conditions, eroding trust in the system [4].

The objectives of this research are: (i) to design and implement a cost-effective hardware-level emergency alert system; (ii) to demonstrate reliable real-time GPS location transmission via SMS; (iii) to compare the proposed architecture against existing systems; and (iv) to identify avenues for future enhancement.

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II. LITERATURE REVIEW

➢ *Sensor-Based Automatic Accident Detection*

Ravi et al. [5] proposed an accident detection system using MEMS accelerometers with an ARM Cortex microcontroller. Upon detecting sudden deceleration exceeding a threshold, the system triggers a GSM alert. However, road bumps and aggressive braking generated false activations in testing. Kaur and Sharma [6] combined a vibration sensor, tilt sensor, and GPS, reporting a false positive rate of approximately 18% in urban environments. Amin et al. [7] improved reliability by using an airbag deployment signal as the primary trigger, though this limits applicability to airbag-equipped vehicles only.

Kumar et al. [8] proposed a multi-sensor fusion approach using accelerometer, gyroscope, and barometric pressure data processed on a Raspberry Pi, achieving higher detection accuracy at the cost of significantly greater hardware complexity and expense.

➢ *Smartphone and Application-Based Systems*

Warade et al. [9] developed an Android application that detects crashes using the phone's built-in accelerometer and automatically sends GPS coordinates to predefined contacts. The approach is elegant but inherits false positive challenges and requires the application to be actively running with simultaneous data access. Bhatia and Sood [11] leveraged IoT architectures to transmit emergency data to cloud servers, requiring continuous internet connectivity — a vulnerability in areas with poor data coverage.

➢ *GSM and GPS-Based Alert Systems*

Kiruthika et al. [12] described a vehicle tracking system using SIM908 with an AVR microcontroller, capable of transmitting location on demand. Nagaraja et al. [13] proposed a women's safety device using Arduino, GSM, and GPS triggered by a hidden button — architecturally the closest precedent to Project SAVE, though without systematic performance evaluation.

➢ *Research Gap*

The reviewed literature reveals a persistent tension between automation and reliability. Fully automatic systems risk unacceptable false positive rates; application-based systems depend on smartphones and internet; hardware-based manual systems offer pragmatic reliability at low cost without internet dependency. Project SAVE contributes a validated implementation and systematic comparative evaluation to this design space.

III. SYSTEM ARCHITECTURE

➢ *Architectural Overview*

Project SAVE follows a modular, event-driven embedded architecture centered on the Arduino Uno. The system is partitioned into four functional layers: Input Layer, Processing Layer, Sensing Layer, and Communication Layer. These interact in a sequential pipeline triggered by a user action, ensuring deterministic behavior.

➢ *Block Diagram Description*

The signal flow proceeds as follows:

- [INPUT LAYER] Push Button Array (Emergency Trigger)
- [PROCESSING LAYER] Arduino Uno (ATmega328P @ 16 MHz)
- [SENSING LAYER] NEO-6M GPS Module (UART, NMEA 0183)
- [COMMUNICATION LAYER] SIM900A GSM Module (UART, AT Commands)
- [OUTPUT] SMS Alert with Google Maps Link to Predefined Contacts
- [FEEDBACK] LED Indicator + Buzzer (confirmation to user)

➢ *Signal Flow Phases*

Idle/Standby: Arduino polls the push button in a continuous loop. (2) Trigger Detection: Button press detected and software-debounced. (3) GPS Acquisition: NMEA sentences parsed via TinyGPS++ library to extract latitude and longitude. (4) Message Composition: Arduino constructs SMS string embedding a Google Maps URL. (5) SMS Transmission: AT commands instruct SIM900A to deliver the message to all stored contact numbers.

IV. HARDWARE COMPONENTS

➢ *Arduino Uno (ATmega328P)*

The Arduino Uno is built around the ATmega328P 8-bit AVR microcontroller operating at 16 MHz with 32 KB Flash, 2 KB SRAM, and 1 KB EEPROM. It exposes 14 digital I/O pins and 6 analog inputs. Operating at 5V logic, it can be powered via USB or an external 7–12V DC supply. Its open-source ecosystem and extensive library support make it the ideal prototyping platform for this application.

➢ *SIM900A GSM/GPRS Module*

The SIM900A is a quad-band GSM/GPRS module operating on 850/900/1800/1900 MHz bands, providing global cellular compatibility. It communicates via UART using AT command sets. For Project SAVE, only SMS functionality is utilized. The module requires 3.4V–4.4V supply and can draw peak currents up to 2A during transmission, necessitating a dedicated regulated power supply independent of the Arduino's onboard regulator.

➢ *NEO-6M GPS Module*

The NEO-6M is a high-sensitivity 50-channel GPS receiver by u-blox AG with tracking sensitivity of -161 dBm. Under open-sky conditions, it achieves a cold-start Time to First Fix (TTFF) of approximately 27 seconds. It outputs NMEA 0183 sentences at 9600 bps via UART. The $GPRMC sentence is parsed to extract latitude, longitude, and validity status. A logic level converter is required on TX/RX lines due to the module's 3.3V logic versus the Arduino's 5V.

➢ *Push Button and Supporting Components*

The emergency trigger is a momentary tactile push button connected to a digital input configured in INPUT_PULLUP mode. Software debouncing with a 50 ms

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delay prevents spurious triggers. Supporting components include current-limiting resistors, a 5mm status LED, a 5V active buzzer, and a 9V–12V DC power adapter for standalone operation.

➢ *Component Cost Summary*

Table 1 Component Cost Summary

Component	Specification	Cost (INR)
Arduino Uno R3	ATmega328P	450–600
SIM900A Module	Quad-band GSM	400–600
NEO-6M GPS	50-channel	300–450
Push Button	Momentary tactile	10–20
LED + Buzzer	5mm, 5V active	20–40
SIM Card (2G)	Active GSM plan	50–100
Power Supply	12V/1A adapter	100–150
Misc. Components	Wires, PCB, etc.	80–150
Total (Approx.)	–	₹1,410–2,110

V. METHODOLOGY AND WORKING PRINCIPLE

➢ *System Initialization*

Upon power-on, the Arduino Uno executes setup(): (i) configures push button pin as INPUT_PULLUP; (ii) initializes hardware UART at 9600 bps for debugging; (iii) initializes two SoftwareSerial instances — pins 7/8 for SIM900A and pins 3/4 for NEO-6M, both at 9600 bps; (iv) waits for SIM900A network registration; (v) awaits first valid NMEA sentence from GPS.

➢ *Trigger Detection*

The main loop() continuously polls the push button. A LOW reading (active-low via INPUT_PULLUP) indicates activation. Software debouncing with a 50 ms delay and a second read confirmation eliminates contact bounce. Upon confirmed trigger, the system sets an alert flag, illuminates the LED, and activates the buzzer briefly for user feedback.

➢ *GPS Data Acquisition*

The NEO-6M continuously outputs NMEA 0183 sentences at 9600 bps. The Arduino assembles complete sentences and uses the TinyGPS++ library to extract latitude and longitude in decimal degrees from the $GPGGA or $GPRMC sentences. A timeout mechanism (default: 60 seconds) ensures that if a valid GPS fix is unavailable, a fallback SMS is transmitted indicating GPS unavailability while still alerting contacts of the distress event.

➢ *SMS Composition and Transmission*

Once valid coordinates are obtained, the Arduino constructs the alert message:

"EMERGENCY ALERT! I need help. My location: https://maps.google.com/?q=[LAT],[LON] – Sent via Project SAVE"

The SIM900A is commanded via the following AT command sequence: (1) AT — module check; (2) AT+CMGF=1 — set SMS text mode; (3) AT+CMGS="[number]" — specify recipient; (4) Message body followed by ASCII 26 (Ctrl+Z) to send. This sequence executes for each of up to five preconfigured contact numbers.

➢ *Firmware State Machine*

The firmware is structured as a Finite State Machine (FSM) with four states: IDLE, TRIGGERED, GPS_ACQUIRING, and SMS_SENDING. Transitions are driven by input events (button press) and data availability (GPS fix), ensuring predictable behavior under all operating conditions including GPS timeout and GSM unavailability.

VI. COMPARATIVE ANALYSIS

Table 2 presents a systematic comparison of Project SAVE against representative emergency alert architectures.

Table 2 Comparative Analysis of Emergency Alert Architectures

Parameter	Project SAVE	Sensor-Based	App-Based
Trigger	Manual (button)	Auto (sensors)	Manual (phone)
False +ve Risk	Very Low	Moderate–High	Low–Moderate
Internet Req.	No (SMS only)	Often Yes	Yes
Cost	~₹1,500	₹5,000+	Moderate
2G Dead Zone	Functional	Fails	Fails
User Incap.	Fails	Functions	Fails

The comparative analysis confirms that Project SAVE occupies a distinctive niche: highest reliability under network-constrained conditions and lowest false-positive risk, at the cost of inapplicability when the user is physically incapacitated.

VII. ADVANTAGES AND LIMITATIONS

- *Advantages*

- False-Positive Elimination: Deliberate manual activation ensures alerts are generated only through user intent, resolving the endemic false-alarm problem of sensor-based systems.
- Internet Independence: SMS-based operation over 2G GSM extends functionality to areas without data connectivity, covering underserved rural populations.
- Low Cost and Accessibility: Total hardware cost of approximately ₹1,400–2,100 enables large-scale deployment in cost-constrained environments.
- Standalone Operation: No paired smartphone or active data plan required. The system operates as a fully autonomous communication unit.
- Precise Location Sharing: GPS-derived coordinates delivered as a Google Maps link provide immediately actionable location data to responders.
- Modular Architecture: Supports straightforward addition of sensors or communication modules without fundamental redesign.

- *Limitations*

- User Incapacitation: In severe accidents rendering the user unconscious, the manual trigger cannot be activated — the fundamental trade-off of the deliberate design.
- GPS Indoor Performance: Signal attenuation indoors or in urban canyons can result in extended TTFF or fix failure, mitigated by the fallback SMS mechanism.
- 2G Network Sunset: Progressive shutdown of 2G networks by operators may require module replacement with 4G-compatible alternatives (e.g., SIM7600).
- Power Dependency: Loss of power supply disables the system; battery backup is required for vehicular or remote deployments.

VIII. APPLICATIONS

- *Vehicular Emergency Response*

A dashboard or handlebar-mounted implementation allows drivers and riders to alert emergency contacts following an accident, breakdown, or carjacking with a single button press.

- *Women's Personal Safety*

A wearable or keychain variant provides a rapid, discreet distress mechanism achieving activation with a single press even under duress — superior to multi-step application-based systems.

- *Elderly and Differently-Abled Care*

A home-installed unit provides a lifeline in the event of medical emergencies such as falls or cardiac events, operating continuously on mains power with optional battery backup.

- *Remote Area Workers*

Miners, construction workers, and agricultural laborers in areas with GSM but no data coverage can use Project SAVE as a personal distress beacon, leveraging the broader footprint of 2G SMS networks.

- *Institutional Safety*

Strategically placed alert stations within schools, hospitals, or public facilities can notify security personnel or emergency services with GPS-referenced location data upon activation.

IX. FUTURE SCOPE

- Automatic Trigger Sensors: Integrating an MPU-6050 accelerometer with intelligent threshold algorithms and machine learning-based crash signature detection can enable automatic activation for incapacitation scenarios while minimizing false positives.
- 4G/LTE Module Upgrade: Replacing the SIM900A with a 4G-capable module (e.g., SIM7600, Quectel EC21) ensures compatibility with modern networks and enables MMS and data-based notification channels.
- Cloud Integration: Connecting to an IoT platform (AWS IoT, ThingSpeak) enables real-time tracking dashboards, alert history logging, and integration with professional emergency dispatch services.
- Bidirectional Communication: Enabling emergency contacts to acknowledge receipt or initiate a voice callback substantially improves the emergency response information loop.
- Battery-Backed Solar Power: A lithium-ion battery management circuit with solar charging enables fully autonomous, continuous outdoor deployment.
- Wearable Miniaturization: Custom PCB design with a low-power microcontroller (ARM Cortex-M0) enables wristband, helmet, or clothing integration for personal safety wearables.
- Integration with National Emergency Services: Future iterations can interface with India's Dial 112 Emergency Response Support System API for direct emergency service notification [17].

X. CONCLUSION

This paper has presented Project SAVE — a Smart Accident and Emergency Alert System — as a practical, low-cost, and reliable hardware-based emergency notification solution. The architecture, centered on the Arduino Uno with SIM900A GSM and NEO-6M GPS modules, delivers accurate real-time location information via SMS upon deliberate push-button activation.

The design philosophy of manual activation, while representing a trade-off against full automation, provides a demonstrable advantage in false-positive elimination — a persistent challenge in sensor-based systems documented extensively in the reviewed literature. The comparative analysis confirms that Project SAVE occupies a unique and valuable niche: more reliable than sensor-based systems in non-incapacitation scenarios, more accessible than

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smartphone systems in data-constrained environments, and significantly more cost-effective than commercial emergency alert solutions.

At a total hardware cost below ₹2,500, the system is deployable at scale in developing-nation contexts where emergency response infrastructure is underdeveloped and financial constraints limit adoption of commercial alternatives. The proposed future roadmap envisions progressive evolution toward a cloud-connected, bidirectional emergency response node. Project SAVE demonstrates that effective, life-saving technology need not be expensive or dependent on cutting-edge infrastructure.

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