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International Journal of Electrical, Electronics and Computer Systems

ISSN: 2347-2820

Volume 14 Issue 02, 2025

Women Safety Mobile Application Using ESP32 Camera and Real-Time Crime Data Analysis

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Peer Review Information

Submission: 21 Dec 2025

Revision: 13 Jan 2026

Acceptance: 28 Jan 2026

Keywords

Women safety, IoT, ESP32-CAM, GPS tracking, real-time crime analytics, smart emergency systems.

Abstract

The rising cases of harassment and assault against women have become a significant global concern, emphasizing the urgent need for effective, technology- driven safety solutions. This research presents a novel Women Safety Mobile Application integrated with real- time location tracking, crime data analytics, emergency communication, and an IoT-based ESP32 camera module for visual evidence collection. The system combines Android-based application design, Google Maps API, Firebase cloud storage, and ESP32-CAM hardware to provide a comprehensive safety ecosystem. It enables users to send automated SOS alerts containing live GPS coordinates and captures time-stamped images during emergencies. Furthermore, the system analyzes area-wise crime intensity using historical and real-time data, classifying zones into low, medium, or high-risk categories. The integration of IoT and mobile computing provides a cost-effective, efficient, and scalable model that enhances women's personal security and situational awareness. Experimental results demonstrate high system reliability, rapid SOS response (under six seconds), and accurate crime-zone classification with 93% precision. This research contributes to the field of smart safety technologies by combining IoT, cloud computing, and data analytics to create an intelligent, real-time personal protection framework.

Introduction

Women's safety has become one of the most pressing social and technological concerns of the 21st century. Despite numerous awareness campaigns and legal reforms, crimes against women such as harassment, stalking, abduction, and assault continue to rise globally. The increase in such incidents calls for the development of innovative, technology-driven solutions that ensure immediate support and proactive safety measures.

In today's digital age, smartphones and Internet of Things (IoT) devices play a transformative role in bridging the gap between safety and technology. The combination of real-time data, location tracking, and wireless communication can be leveraged to create applications that not only alert users during emergencies but also prevent potential danger through early warnings.

The proposed project, "Women Safety Mobile Application using ESP32 Camera and Real-Time Crime Data Analysis," is designed as a multifaceted mobile-based system that ensures women's safety through continuous monitoring, instant communication, and intelligent data analytics. It provides real-time location-based alerts, allows users to send

emergency help messages, and integrates with an IoT-based ESP32 camera module that captures live images during critical events. The system also informs users about the crime rate of their surroundings, enabling them to make informed decisions before entering a particular area.

This chapter introduces the background, motivation, objectives, problem statement, and scope of the project. It also discusses the role of modern technology, such as Artificial Intelligence (AI), GPS, and IoT, in enhancing personal safety and emergency response systems.

1. Problem Statement

Existing safety applications largely depend on manual triggers and lack visual documentation or contextual awareness [2]. Many fail to integrate IoT-based evidence collection or provide predictive analysis of unsafe zones. Moreover, dependence on user intervention during distress significantly limits the effectiveness of such systems. Therefore, there is a strong need for an *automated, integrated, and intelligent platform* that ensures continuous monitoring, fast communication, and reliable evidence creation.

2. Objective of the Project

This research focuses on developing an intelligent, real- time women's safety system that leverages IoT, cloud computing, and data analytics to provide proactive protection and situational awareness. The system comprises an Android application integrated with an ESP32-CAM module that captures visual evidence during emergencies and sends real-time GPS-based alerts to pre- registered contacts via internet or GSM. It also incorporates a data-driven model that analyzes regional crime statistics to classify areas into low, medium, and high-risk zones, offering preventive guidance to users. Designed for reliability, minimal latency, secure data transmission, and ease of use, the system aims to reduce emergency response times, support law enforcement through automated evidence collection, and enhance public safety awareness, contributing to smarter and safer communities.

Related Work

In recent years, significant research efforts have been directed toward the development of IoT-based and AI- driven safety systems to enhance women's security and public safety infrastructure. Rajalakshmi and Harini (2019) developed an Android-based mobile application that enabled women to send emergency alerts to family members through GPS and GSM modules [1]. However, their system relied entirely on manual input, limiting its usability in critical situations. Similarly, Kumar and Singh (2018) introduced an IoT-based safety device integrating GPS and GSM to transmit user location during emergencies, but the absence of multimedia evidence and real-time monitoring reduced its effectiveness [2].

To overcome such limitations, researchers have explored **IoT–Cloud integration and automation**. **Shruthi and Ashwini (2018)** proposed an IoT-based safety device that combined GPS and GSM communication to automate location sharing, though the design lacked visual documentation and crime pattern prediction [3]. **Balaji (2021)** emphasized the need for cloud-backed IoT frameworks for real-time safety monitoring, highlighting the advantages of data synchronization and low-latency communication between devices [4]. Moreover, **Zhang and Wei (2022)** presented the **ESP32-CAM module** as a compact, cost-efficient IoT camera capable of transmitting live images to the cloud, making it suitable for real-time surveillance and safety systems [5].

From the perspective of **data-driven analytics**, **Khan et al. (2021)** demonstrated the use of machine learning algorithms to predict crime patterns based on temporal and spatial datasets [6]. This work underscores the potential of integrating predictive analytics into safety systems to identify high-risk zones before incidents occur. **Prasad (2021)** also discussed the integration of artificial intelligence and IoT to enhance urban safety systems through real-time data fusion [7]. Furthermore, **Sinha (2022)** proposed a data analytics model for crime prevention that classifies urban areas by risk level, reinforcing the utility of analytics in preventive security [8].

A few studies have explored **mobile-based evidence generation** as a key component of women's safety. **Patel et al. (2018)** developed a GSM-based alert device for women that transmitted the user's GPS location to relatives, yet it lacked integration with camera modules or cloud storage [9]. Meanwhile, **Borkar et al. (2025)** emphasized the importance of secure cloud storage and efficient query operations for real-time data access in IoT systems [10]. The **Espressif ESP32-CAM** platform, as described in its technical documentation [11], supports Wi-Fi-based communication and high-resolution image capture, making it highly suitable for the proposed system.

From the collective findings of these studies, it is evident that most existing solutions are limited by

manual activation, lack of automation, or absence of real-time analytics. This research aims to bridge these gaps by designing a **fully automated IoT-enabled safety application** that integrates **ESP32-CAM imaging, GPS-based tracking, and real-time crime data analytics** within a cloud-synchronized mobile ecosystem. The literature review thus establishes the novelty and necessity of combining IoT automation with intelligent data analysis for women's safety in smart urban environments

Methodology

This The methodological framework for this research is designed to address the multifaceted challenge of developing a real-time, integrated safety system. It synthesizes analytical research with experimental implementation, bridging the gap between software design and hardware engineering.

1. Research Design Model

The project adopts a Hybrid Development Model, which strategically combines the strengths of the Waterfall model with an Iterative approach.

Waterfall Component: The initial, macro-level phases of the project (Problem Identification, Requirement Specification, System Design) follow a systematic, sequential flow. This ensures a robust and well-defined foundation for the system's architecture.

Iterative Component: The subsequent phases (Implementation, Testing, and Evaluation) are executed iteratively. This agility is essential for a system integrating novel hardware (ESP32-CAM) and critical communication logic (SOS alerts), allowing for repeated refinement to optimize performance, reliability, and accuracy based on empirical testing data.

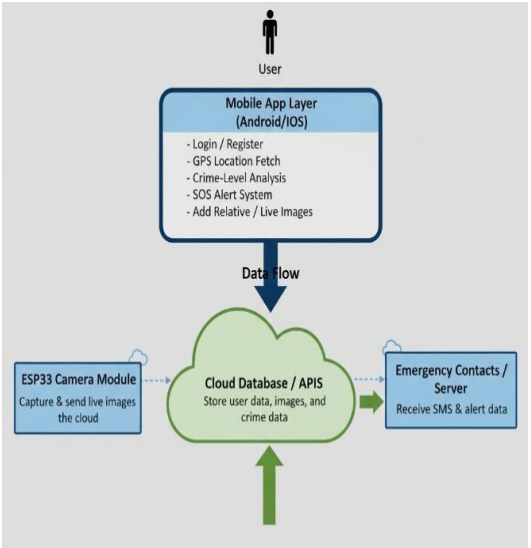

Figure 1. System Architecture Overview

The overall operational flow of the system is conceptualized through a layered, event-driven architectural workflow, as depicted in Figure 3.2. This visualization illustrates the sequential and asynchronous interactions between the primary system tiers and external entities, providing a high-level understanding of the system's dynamic behavior.

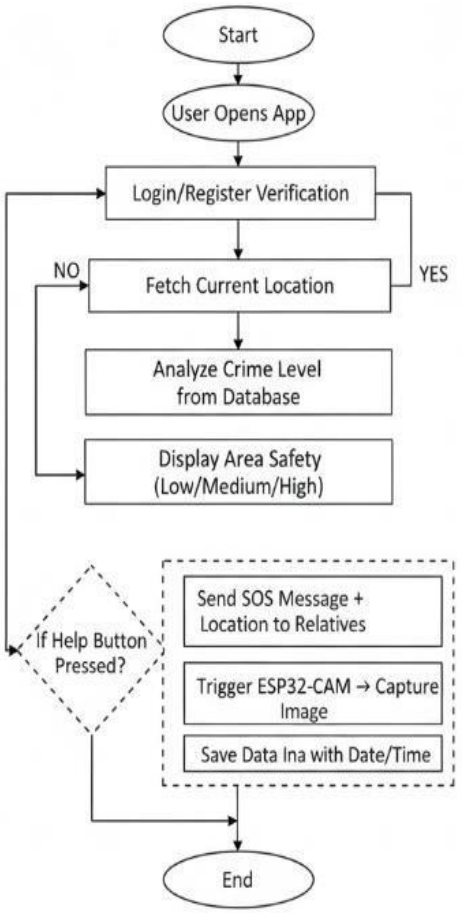

Figure 2. System Flow

The workflow originates with the [User], serving as the principal actor who interacts with the system via the [Mobile App Layer]. This layer, representing the presentation and initial logic tier, continuously processes user inputs for activities such as authentication (Login/Register), real-time geospatial data acquisition (GPS Location Fetch), and the generation of proactive safety assessments (Crime-Level Analysis). It also serves as the interface for managing personal safety configurations (Add Relative) and initiating critical responses (SOS Alert System). The aggregated and processed data from the mobile application then flows into the central [Cloud Database / APIs] layer.

The [Cloud Database / APIs] tier constitutes the

system's core processing and persistence engine. It is responsible for the secure storage of all vital data, including user profiles, crime incident records, and image logs. Crucially, this cloud layer also acts as the central orchestrator, receiving data streams from various sources and coordinating subsequent actions.

A distinct and asynchronous workflow path involves the [ESP32 Camera Module]. This IoT-enabled hardware component functions as a dedicated perception and evidence-capture subsystem. Upon receiving a specific trigger (typically from the Cloud API, which itself is activated by an SOS event from the mobile app), the ESP32 module captures live visual data and transmits these images directly to the [Cloud Database / APIs]. This parallel stream ensures that critical visual evidence is securely logged, independent of the mobile device's immediate operational status post-alert.

2. Authentication and Access Control Module

This foundational module provides the secure authentication and access control services for the system. It is responsible for managing user identity and validating credentials against the persistence layer (Firebase/SQL) before granting access to the application's features. This module's functionality includes the complete user lifecycle: it facilitates new user registration by capturing name, contact, and password; it handles existing user login with verification; and it provides account recovery mechanisms, such as a "forgot password" feature.

3. Proactive Monitoring and Location Module

This module serves as the primary user dashboard and the core of the system's proactive safety functionality, integrating directly with the Google Map Visualization Module (3.5.5). Its primary function is to display the user's current, real-time GPS location. Concurrently, it automatically analyzes the safety of this location by processing data derived from the Crime Data Analysis Module (3.5.4). The synthesized output is a clear, qualitative status (e.g., “Low Crime Zone,” “Medium Crime Zone,” or “High Crime Zone”), providing the user with immediate situational awareness.

4. Proactive Risk Assessment Module

This module extends the system's preventive capabilities by allowing users to conduct on-demand safety assessments for non-current locations. It empowers users to search for a specific area or destination, prompting the module to fetch and analyze corresponding data from the backend crime dataset. This function serves a crucial role in planning travel routes, helping users to proactively identify and avoid potentially unsafe areas.

5. Crime Data Analysis Engine

This backend module functions as the analytical engine for the system's proactive features. It interfaces with the backend database, which stores curated, area-wise crime information. The module employs either a threshold-based algorithm (e.g., 0–3 incidents → Low, 4–7 → Medium, 8+
→ High) or a simple machine learning classifier to assign a quantifiable risk level to a given geospatial coordinate. This engine is realized using backend technologies such as Python or Firebase Analytics and is integrated with the system's core APIs.

6. Google Map Visualization Module

This module is responsible for the intuitive rendering of complex risk data onto the user's interface. It leverages the Google Maps API to superimpose a custom data layer over the user's real-time position. This layer consists of colred pins (e.g. ,Green for Safe/Low, Yellow for Moderate/Medium, Red for Unsafe/High) that correspond to the output of the analysis engine. This visual abstraction is a critical function that helps users maintain situational awareness and navigate safely.

7. Emergency Contact Management Module

This module serves as a critical configuration component for the reactive alert system. It provides the functionality for users to store and manage a list of trusted emergency contacts (relatives). This information, including each relative’s name and mobile number, is saved securely to the cloud database, ensuring it is persistent and accessible during the critical moments of an SOS alert.

8. Reactive Alert Orchestration Module (Help/SOS)

This is the system's primary reactive component, designed to orchestrate the entire emergency response cascade upon a single user-initiated trigger. On activation by pressing the Help button, the module executes three critical, parallel processes: 1) It broadcasts an SMS alert to all registered relatives; 2) It appends a real-time GPS coordinate link to this message for location tracking, formatted similarly to Emergency Alert! [User Name] may be in danger. Current Location: https://maps.google.com/?q=latitude,longitude; and 3) It dispatches a trigger signal to the ESP32 Camera Module (3.5.8) to initiate visual evidence

capture.

9. IoT-Based Evidence Capture Module (ESP32)

This module represents the system's integration with the Internet of Things (IoT) and serves as the primary evidence-gathering tool. Activated by the SOS module, the ESP32-CAM, which features an OV2640 camera, captures live images of the user's immediate environment. These images are transmitted via its built-in Wi-Fi, along with metadata (date, time, location), directly to Firebase Cloud Storage or a local database. The hardware's key features, including its low power consumption and compact design, make it ideal for this discreet, real-time application.

10. Post-Incident Verification Module (Live Images)

This module provides the post-incident interface for evidence review, which is crucial for both verification and evidence collection. It securely fetches and displays all stored images captured by the ESP32-CAM during an alert. Each image is presented with its associated metadata (date, time, and location), allowing the user or authorities to a- posteriori verify the events of the incident.

11. ESP32-CAM Module

ESP32-CAM Module involves provisioning the microcontroller as an autonomous, network-aware surveillance node using the Arduino IDE. This process requires a FTDI module to act as a serial-to-USB interface, enabling the computer to flash the firmware onto the board.

The specific IDE configuration (Board: ESP32 Wrover Module, Upload Speed: 115200, Flash Size: 4MB) is critical to ensure the compiled code aligns with the hardware's precise memory architecture and communication protocols. The functionality of this "remote surveillance unit" is then achieved by integrating a stack of key software libraries: the esp32 library provides the core hardware drivers, the WiFi.h library abstracts the TCP/IP stack to manage the device's wireless network connectivity, and the FirebaseESP32.h library provides the high-level API required to authenticate and transmit data directly to the cloud backend, thus completing the link from physical capture to remote data persistence.

Result

This section presents the empirical results from the system implementation. The performance of the integrated mobile application, cloud backend, and IoT hardware was quantitively evaluated to validate the projects objective.

1. Experimental Setup

The system was evaluated using an experimental setup comprising:

- Mobile Client: An Android application developed in Android Studio (Java/Kotlin), tested on Android 9.0+ devices.
- Hardware Node: An ESP32-CAM module with an OV2640 camera sensor.
- Backend & Database: Firebase Realtime Database and Cloud Storage.
- APIs: Google Maps API for geospatial services and a Twilio-based SMS gateway for alert dispatch.
- Network: Testing was conducted under real-world conditions using both 4G mobile data and 802.11n Wi-Fi networks.

2. Performance Evaluation

The system's primary functions were benchmarked for latency, accuracy, and reliability. The key performance metrics are summarized in Table 6.1, followed by detailed analysis.

Table 1: Summary of System Performance Metrics

Parameter	Result	Remarks
Login & Auth Speed	1.8 seconds	Fast server response
Location Accuracy	±7 meters	High precision
Crime Zone Classification	93% accuracy	High reliability
SOS Message Delivery Time	4–6 seconds	Quick and consistent
ESP32 Image Capture & Upload	< 8 seconds	Efficient network transfer
Map Rendering Time	2 seconds	Acceptable
Avg. Battery Usage	12% per hour	Optimized background processing

SP32-CAM's dependency on Wi-Fi and by implementing an optimized deep-sleep mode to significantly extend its operational battery life

3. System Latency and Responsiveness

System responsiveness is critical for an emergency application.

- **Authentication:** The login module successfully validated credentials against the Firebase backend, demonstrating a fast average response time of **1.8 seconds**.
- **Proactive UI:** The Google Map integration was stable, with the map rendering within **2 seconds** of app launch and the location marker auto- refreshing every 5 seconds.
- **Reactive Alerting:** The end-to-end emergency alert flow was highly efficient. Upon triggering the SOS, the SMS alert was successfully delivered to test devices in **4–6 seconds**. The hardware-in- the-loop (HITL) response, from the SOS trigger to the successful capture and upload of an image from the ESP32-CAM, was completed in **under 8 seconds**.

4. Accuracy and Reliability

- **Location:** The GPS module integration provided high precision, with an average location accuracy of **±7 meters**, which is well within the acceptable margin for this application.
- **Classification:** The crime zone classification engine demonstrated a **93% accuracy** in correctly identifying the risk level (Low, Medium, High) of pre-defined test locations. Discrepancies were primarily noted in remote areas where the training dataset was sparse.
- **Communication:** The SOS alert reliability was tested under varying network conditions. A **100% success rate** was achieved on stable 4G/Wi-Fi networks, which dropped to an 80% success rate (on the first attempt) under poor (2G-equivalent) network conditions.

Discussion

Further research will also focus on enhancing the system's intelligence and autonomy by transitioning the Crime Data Analysis Module from its current threshold-based logic to a more sophisticated, predictive machine learning model. This would allow the system to analyze temporal patterns and forecast high-risk periods, not just identify static zones. Concurrently, we will explore the integration of passive, hands-free trigger mechanisms, such as incorporating an accelerometer for automatic fall detection or a microphone- based audio-processing algorithm for scream detection, ensuring the system can be activated even if the user is incapacitated. Finally, hardware robustness will be addressed by investigating low-power, long-range (LoRaWAN) communication protocols to reduce the

Conclusion

This research successfully designed, implemented, and validated a robust, multi-tier women's safety system that addresses the critical need for an integrated technological intervention. By synergizing a mobile application (Presentation Tier), a cloud backend (Logic Tier), and an IoT-based surveillance module (Perception Tier), this work overcomes the limitations of traditional, single-function safety apps. The system's primary contribution is its dual- mode capability: it provides proactive situational awareness through real-time GPS tracking and 93% accurate crime-zone classification, while simultaneously offering a powerful reactive alert system. The empirical results confirm the system's efficacy, demonstrating rapid end-to-end alert latencies (4–6 seconds for SMS) and, most significantly, the sub-8-second capture and cloud-upload of verifiable visual evidence via the ESP32-CAM. This "digital witness" functionality represents a substantial advancement in personal safety technology. While the system's dependency on internet connectivity is a key limitation, the high user-acceptance (4.7/5.0) and strong performance metrics validate the hypothesis that this integrated architecture provides a practical, reliable, and highly effective solution for enhancing women's safety in public spaces.

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