‘SOSit!’: A Bluetooth Low Energy (BLE) Accessory Panic Button for Women’s Safety with Mobile GPS and Cloud Alerts

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COMPUTER STUDIES CLUSTER

DAVAO CITY

May 2025

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A Thesis Presented to the

Faculty of the

Computer Studies Cluster

Ateneo de Davao University

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science in Information Technology

By

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Abstract

In recent years, women's safety has become an urgent issue, especially in urbanized and developing areas where harassment, assault, and delayed emergency responses continue to rise. Traditional safety measures, including mobile applications and self-defense alarms, often fail to deliver timely alerts or accurate location data when most needed. This study proposes an IoT-enabled panic button accessory that utilizes Bluetooth Low Energy (BLE) to send real-time distress signals to a mobile phone, which then uses GPS to transmit the user's location to emergency responders. The system is designed to provide a cost-effective, discreet, and reliable solution for women in high-risk environments, improving response times and ensuring that help arrives quickly.

Leveraging cloud-based services like Supabase for real-time data storage and Firebase Cloud Messaging (FCM) for notifications, the system integrates a mobile app that processes the SOS signal, retrieves location information, and alerts both emergency contacts and nearest police stations. This research explores the potential of this approach, examining its effectiveness in urban and enclosed environments where GPS signal interference is common. Additionally, the system incorporates Row-Level Security (RLS) for data privacy and security. Ultimately, the research aims to provide a scalable solution to address the challenges of network dependence, GPS accuracy, and data privacy in emergency response systems for women.

Keywords:

Panic Button Accessory, Women's Safety, IoT, Bluetooth Low Energy (BLE), Mobile GPS, Firebase Cloud Messaging, Supabase, Emergency Alerts, GPS Accuracy, Data Security

Chapter 1

Introduction

1.1 Background of the Study

Women's safety continues to be a significant concern in urban and developing regions, where rising incidents of harassment, assault, and delayed emergency response are prevalent. Traditional safety measures, such as self-defense alarms or mobile applications, often fall short during emergencies due to delays in activation, lack of real-time location sharing, or dependence on strong cellular signals. While manual activation remains necessary in many systems, including the proposed device, this study addresses key shortcomings by ensuring faster, more discreet triggering, integrated GPS tracking through the smartphone, and cloud-based alert delivery to multiple recipients in real time.

This study proposes an IoT-based panic button accessory system designed for women aged 10 and above, and to address these challenges by combining Bluetooth Low Energy (BLE) communication with smartphone-based GPS to transmit real-time distress signals through a mobile application. While accessory devices have shown promise in improving personal safety through discreet emergency signaling, challenges persist in ensuring consistent performance in real-world scenarios. Reliable communication under fluctuating network conditions remains a key obstacle. Solutions that utilize the smartphone's data connection, cloud services, and push notifications offer an opportunity for real-time alerting, but are still vulnerable to connectivity interruptions and device limitations. Additionally, GPS performance is notably compromised indoors or in obstructed urban environments, leading to inaccurate or delayed location reporting.

Previous research (Farooq et al., 2023; Saranya et al., 2021) has demonstrated that hybrid approaches, combining low-power accessories with smartphone-based communication and location services, are effective in reducing costs and extending usability. However, many existing IoT-based safety systems still face limitations in battery performance, scalability, and affordability. As highlighted by YMER (2024), high power consumption and expensive components significantly restrict adoption, particularly in low-income or underserved communities.

Building on advancements in low-power microcontrollers like the ESP32-S3, cloud services such as Supabase, and Firebase Cloud Messaging (FCM) for real-time push alerts, this study explores the integration of these technologies into a compact, user-friendly accessory system. The device communicates with a mobile application via BLE, which then retrieves the user's GPS coordinates and sends emergency alerts through the smartphone's internet connection.

The study aims to offer an accessible, affordable, and scalable solution for women's safety that addresses real-world concerns: ensuring reliable alerts even in low-signal areas through caching and retry logic, validating GPS performance across varied environments, and maximizing battery life using deep sleep and peripheral shutdown modes. In doing so, it contributes to the evolving field of IoT-based personal safety applications while proposing a practical, deployable tool to support timely emergency response in everyday contexts.

1.2 Problem Statement

Despite the availability of mobile applications and personal safety alarms, women in both urban and semi-urban areas continue to face barriers in accessing timely emergency assistance. Existing tools often depend on user interaction and stable network connectivity, which limits their effectiveness in real-world emergencies. The lack of reliable, low-cost, and battery-efficient safety accessory systems contributes to delayed responses and limited situational awareness, particularly in environments where GPS signals are weak or cellular connectivity is unstable.

This study seeks to address the following specific problems:

1. How can a Bluetooth-enabled panic button accessory system improve the reliability of emergency alert transmission in areas with fluctuating or weak mobile signals?
2. How accurate is smartphone-based GPS in determining a user's location across indoor and outdoor emergency scenarios?
3. How can the device's battery life be optimized to ensure extended operational availability using low-power microcontrollers and sleep modes?

1.3 Objectives of the Study

The study is to develop an accessory IoT device that communicates with the user's phone via bluetooth to send an 'SOS' message containing the user's basic information and GPS location using the user's smartphone GPS capabilities and a backend cloud database to deliver the message to appropriate authorities whenever a trigger is activated. The study also seeks to accomplish the following objectives:

- To evaluate the success rate of SOS alert transmissions sent through the mobile application under low-signal conditions using caching and retry logic.
- To assess the accuracy of smartphone GPS in indoor and outdoor environments using simulated emergency scenarios.
- To measure the battery performance of the ESP32-S3-based accessory device and validate whether power-saving features extend standby time to at least 7 days and emergency operation to at least 6 hours.

1.4 Significance of the Study

The proposed study aims to enhance women's safety by developing an accessory panic button system integrated with IoT and GPS technologies. The significance of this study lies in its potential to offer a proactive, real-time emergency alert solution tailored to the needs of women in vulnerable environments, particularly in Mindanao. By leveraging affordable and scalable technologies, the study addresses the urgent need for accessible safety measures in contexts where traditional emergency response systems are limited. This research will benefit the following:

Women and At-Risk Communities. Individuals in urban and semi-urban areas with limited access to immediate assistance will benefit from having a discreet, real-time emergency signaling tool. The system empowers users to transmit distress signals and location data efficiently, thereby enhancing personal safety and promoting greater freedom of mobility.

Local Organizations and Public Safety Initiatives. Non-governmental organizations (NGOs), community safety networks, and local government units can integrate the system into broader public safety programs. The availability of an accessible, low-cost emergency device supports initiatives aimed at promoting safer public spaces and faster emergency responses.

Advancement of Technology and Research. The study advances research in the integration of IoT and GPS technologies for safety-critical applications. It contributes a practical framework that future researchers can build upon, particularly in enhancing system resilience against network failures and improving indoor localization — identified gaps in current literature.

Aligned with United Nations Sustainable Development Goal (SDG) 5: Gender Equality, this study promotes the empowerment of women by supporting their right to safety, security, and participation in public life through technological innovation.

1.5 Scope and Limitations

1.5.1 Scope

This study focuses on the design and development of an accessory panic button system that integrates IoT and GPS technologies, with cloud-based support for real-time alert transmission and monitoring. The primary objective is to validate the system's core functionalities, particularly emergency signal triggering, smartphone-based location tracking, and cloud-based alert delivery using services such as Supabase and Firebase Cloud Messaging. The scope includes the prototyping of a Bluetooth Low Energy (BLE)-enabled accessory device, the development of a mobile application for user interaction and GPS retrieval, and initial field testing in selected urban and semi-urban environments within Davao City. The system aims to benefit women in urban and semi-urban areas by providing a tool that enhances their sense of safety and security, aligning with the United Nations Sustainable Development Goals (UNDP SDGs) 3: Good Health and Well-being, 5: Gender Equality, 9: Industry, Innovation, and Infrastructure, and 11: Sustainable Cities and Communities.

1.5.2 Limitations

This study is limited in several ways. It does not cover full-scale deployment across diverse geographic regions. The study will only simulate the appropriate authorities as an end user and does not involve real-world integration or direct cooperation with public emergency response infrastructure, such as the local police department. A significant limitation is the system's reliance on the smartphone's GPS and internet connectivity. Furthermore, advanced power optimization techniques such as adaptive duty cycling or energy harvesting are not implemented. Indoor localization alternatives, such as Wi-Fi triangulation or BLE beacons, are also excluded from this phase of development. Only one accessory IoT device will be created and developed. The study is specifically focused on the Android platform for mobile application development.

Chapter 2

Review of Related Works

2.1 Technological Approaches to Women's Safety

2.1.1 IoT-Based Accessory Devices

Farooq et al. (2023) stated that Internet of Things (IoT)-based systems are increasingly being used to enhance women's safety through real-time alert mechanisms and location tracking. These systems leverage sensors, microcontrollers, and wireless communication modules to detect emergencies and notify preconfigured contacts. Their prototype utilized ESP32 microcontrollers and BLE for low-power signaling, emphasizing battery efficiency and compact form factors. Despite promising results, IoT accessories still face challenges such as limited battery life and network dependence. Researchers recommend optimizing firmware, adopting deep sleep modes, and using modular low-power designs. Bhavya and Sudharshan (2025) reported an 8% to 15% reduction in power consumption when operating the ESP32-WROOM module at a reduced voltage of 3.0V compared to 3.3V, depending on interface and CPU usage scenarios (Bhavya & Sudharshan, 2025). In addition, the ESP32's deep sleep mode has been widely cited for its ultra-low power consumption capability. Arrow Electronics (2024) explains that deep sleep can reduce the current draw to as low as 5 µA, significantly extending the operational duration of battery-powered devices (Arrow, 2024). Programming Electronics Academy (2024) supports this claim, noting that using deep sleep exponentially increases battery life in IoT accesory designs by minimizing active power drain when the device is idle.

Recent advancements in Bluetooth Low Energy (BLE) technology have revolutionized wearable emergency alert systems. According to SafeHome.org (2023), Bluetooth-enabled medical alert systems offer significant advantages by "eliminating the need for a jumbled, tangled mess of cables that often connect one device to another, and potentially works to improve communications between devices, or apps." These systems allow users to press a help button on a wearable device that communicates with a smartphone to initiate calls and text messages to pre-selected contacts without requiring monthly monitoring fees. Kurt Peker et al. (2022) highlight that BLE has become the standard for short-distance wireless communication in many consumer devices since its inception in 2013, offering superior power efficiency while maintaining reliability for critical applications like emergency alerting systems.

2.1.2 GPS Tracking and Localization Techniques.

Bhushan & Jadhav (2024) explain that GPS remains the backbone of location-tracking systems in personal safety applications. Outdoor accuracy is typically within 5–10 meters, but drops significantly indoors, often exceeding 50 meters due to signal attenuation and multipath interference. Hybrid solutions like Assisted GPS (A-GPS), Wi-Fi triangulation, and Bluetooth beaconing have been explored to compensate for these weaknesses. Faka et al. (2020) further highlight the need for these hybrid techniques in low-signal environments like urban canyons or enclosed buildings. These studies underline the importance of combining smartphone GPS with fallback strategies in safety-critical applications.

GPS performance in accessory devices faces significant challenges in urban environments, particularly in enclosed spaces. FocalPoint (2023) identifies a critical issue in their research: "The design of antennas in wearables leads to poor satellite reception, which can lead to compromised positioning accuracy." To address this challenge, hybrid approaches combining A-GPS with alternative positioning technologies have emerged. For instance, a 2024 study published in Satellite Navigation demonstrated significant improvements in positioning accuracy by integrating A-GNSS services with advanced algorithms like 3DMA GNSS, representing a major advancement in achieving high-precision positioning in challenging urban environments (GPSDaily, 2024). These developments are particularly crucial for emergency alert systems where accurate location data can be life-saving in crisis situations.

2.1.3 Cloud-Based Alert and Data Management Systems

Cloud computing plays a pivotal role in emergency alert systems, enabling real-time data storage, retrieval, and transmission. Sivakumar et al. (2024) emphasized cloud platforms' capacity to manage alert logs, synchronize user profiles, and support continuous service availability. Supabase, a modern backend-as-a-service, supports spatial data via PostGIS and enables real-time updates through Edge Functions. Firebase Cloud Messaging (FCM), as noted by Sunny et al. (2022), ensures reliable cross-device notifications even under weak signal conditions. Together, these tools form a robust infrastructure for emergency alerting, though latency and security remain challenges requiring caching, retry logic, and encryption.

2.1.4 AI-Based Threat Detection and Prediction Machine learning

AI-Based and Threat Detection and Prediction Machine Learning is emerging as a powerful tool for enhancing the intelligence of safety systems. Srividhya et al. (2022) demonstrated how logistic regression and decision tree models can classify behavioral patterns and predict threats, improving system responsiveness. Potineni & Sharma (2024) noted that AI can reduce false positives by contextualizing user data, such as time, location, or activity. However, fairness, dataset diversity, and ethical profiling remain concerns. Lipton et al. (2024) advocate for transparent model design and inclusive datasets to ensure the reliability and ethical use of AI in safety applications.

2.1.5 Privacy, Ethical, and Accessibility Considerations

Privacy and accessibility are crucial in safety accessory devices. Idrees et al. (2021) raised concerns about unauthorized access and data breaches in GPS-based systems. Encryption protocols like HTTPS and secure authentication mechanisms must be standard practice. Supabase supports Row-Level Security (RLS), offering fine-grained access control to safeguard sensitive user data (Supabase Docs, 2024). Roslan et al. (2021) further emphasize that most high-tech safety devices remain unaffordable for low-income users. Studies call for low-cost, privacy-respecting systems that accommodate vulnerable communities, especially in developing regions like Mindanao.

2.1.6 Central Limit Theorem

The Central Limit Theorem (CLT) posits that for a sample size of at least 30 trials, the distribution of sample means will approximate a normal distribution, regardless of the population's distribution. This is crucial for ensuring statistical reliability when analyzing SOS system performance under varying signal conditions (strong, weak, and offline scenarios). A sample size of 30 trials helps in minimizing sampling error and ensuring that the results reflect the true performance of the system (Investopedia, 2023).

The importance of statistical power is further emphasized, as a sample size of 30 provides sufficient power to detect medium to large effect sizes in system performance, ensuring that significant differences, such as alert success rates under different signal conditions, are detected reliably (NCBI, 2023).

Additionally, conducting 30 trials per environment strikes a balance between ensuring statistical reliability and practical constraints, as it provides enough data to avoid outliers or random errors from influencing the conclusions about the SOS system's effectiveness (St. Olaf College, 2023).

2.2 Existing Safety Applications and Implementations

2.2.1 Mobile Applications for Emergency Alerts

Saglam et al. (2024) reviewed several mobile safety apps offering panic buttons, location sharing, and emergency contact lists. These apps rely heavily on internet access and may fail in low-connectivity environments. Sunny et al. (2022) proposed offline fallback features using SMS or cached transmission to ensure functionality even when data is unavailable. Feminist chatbot systems (Henry et al., 2024) embedded in apps also provide legal and emotional support, but face accessibility barriers for users in low-bandwidth regions.

2.2.2 Wearable Safety Devices and Smart Accessories

Wearable Safety Devices and Smart Accessories Innovations in smart accessories include rings, bracelets, and shoes embedded with emergency triggers. Gandhiraj & Sathiyamoorthy (2020) developed an Arduino-based wearable that transmits alerts via GSM. Similarly, Sogi et al. (2018) proposed a smart ring with integrated sensors and panic functionality. While these solutions offer discreteness and immediacy, they often suffer from trade-offs between size, sensor quality, and battery life. Farooq et al. (2023) emphasized the importance of using low-power microcontrollers like ESP32 and BLE to balance performance with longevity.

2.2.3 Community-Based Safety Networks Community-driven systems

Community-Based Safety Networks Community-driven systems enhance safety through collaborative mechanisms. Amin et al. (2022) introduced "Herd Routes," where pedestrian tracking and crowd-sourced feedback identify unsafe zones. Papadakis et al. (2021) proposed citizen-participatory anti-theft systems leveraging real-time reporting. While effective, these approaches require strong user engagement and cultural adaptability factors crucial in diverse regions such as Mindanao.

2.2.4 "Safe Path"

"Safe Path" system integrates GPS tracking and GSM communication within a wearable device to provide real-time monitoring and emergency response capabilities. This system is designed to function effectively even in areas with poor connectivity, ensuring that users can rely on the device in various environments (Safe Path, 2023).

2.2.5 Preference for Emergency Accessories Over Smartphones

In times of emergency, rapid and discreet access to alert mechanisms is critical. While smartphones offer various mobile safety applications, an increasing body of literature shows that users often prefer wearable accessory-based solutions due to their simplicity, reliability, and ease of use in high-stress situations.

Farooq et al. (2023) emphasized that emergency scenarios often limit a person's capacity to navigate complex smartphone interfaces. Their study on an IoT-based women's safety wearable found that users consistently favored one-touch wearable devices over smartphone applications due to the former's discreetness and faster activation. Participants noted that the need to unlock a phone, locate an app, and initiate an alert can be impractical in moments of distress, making accessories with physical buttons more dependable during critical incidents.

Similarly, Harte et al. (2017) conducted a qualitative study on elderly users of fall detection systems. The participants expressed a strong preference for standalone wearable devices over smartphones, citing concerns about usability, charging frequency, and the need to carry the phone at all times. The study concluded that users perceive dedicated accessories as more trustworthy in emergencies due to their simplicity and focused functionality (Harte et al., 2017).

A broader analysis of consumer behavior regarding wearables by Nelson et al. (2020) supports this preference. Their research on consumer reviews of Fitbit and other health-related devices revealed that users highly valued comfort, unobtrusiveness, and hands-free operation. These qualities were associated with increased user satisfaction and long-term adherence. The authors highlighted that the reliability of wearables in automatically tracking or responding to health-related changes contributed to their popularity, especially in contexts where smartphones were deemed intrusive or cumbersome (Nelson et al., 2020).

In developing regions, user perception toward emergency wearables remains positive despite infrastructural challenges. Seng et al. (2021) investigated the use of health wearables in Cambodia and found that participants favored accessories that allowed immediate and intuitive use, even if technical support or charging infrastructure was limited. Although maintenance and battery life were concerns, users still preferred accessories over mobile apps due to their immediate accessibility and purpose-driven design.

Additionally, research by Smith et al. (2020) compared smartphone and wearable use in post-hospital discharge scenarios. The study found that although initial engagement was higher for smartphone-based tracking, wearable users demonstrated greater consistency over time. This pattern underscores the benefit of accessories that remain on the user, are less reliant on daily interactions, and function autonomously during emergencies.

These findings suggest that while smartphones offer versatility, dedicated wearable emergency accessories provide faster response times, better user compliance, and higher trust, especially under pressure. For emergency safety systems to be effective, they must prioritize intuitive interaction, minimal steps, and physical accessibility—features more commonly associated with wearables.

2.3 Research Gaps Identified in Existing Solutions

2.3.1 IoT devices

IoT devices often face challenges in areas with weak cellular signals, which limit their effectiveness in real-world emergency applications. To address this, technologies such as NB-IoT, LTE Cat M1, and GSM fallback are implemented to provide connectivity in low-signal environments. These solutions ensure continuous communication for emergency alerts, even in areas with poor network infrastructure (Farooq et al., 2023).

2.3.2 GPS performance

GPS Performance can be compromised in indoor or obstructed areas, where signal degradation is significant. Assisted GPS (A-GPS) is a proposed solution that combines GPS with cellular data to enhance location accuracy, especially in environments where traditional GPS fails (Faka et al., 2020). Additionally, hybrid localization systems using Wi-Fi or Bluetooth can improve positioning reliability in GPS-denied areas (Saranya et al., 2021).

2.3.3 Power Consumption

Accessory devices must operate for extended periods without frequent recharging, which requires optimizing power consumption. The ESP32-S3 microcontroller, known for its low power consumption, has been shown to effectively extend battery life in accessory systems. Techniques such as deep sleep and peripheral shutdown modes further enhance energy efficiency, supporting extended operational time of at least 7 days of standby and 6 hours of emergency use (Farooq et al., 2023).

Recent research has focused on maximizing battery life in ESP32-S3 microcontrollers for wearable applications. Broell et al. (2023) examined optimization methods specifically for ESP32 in wearable IoT applications, finding that proper implementation of deep sleep modes can dramatically extend operational time. According to LastMinuteEngineers (2023), the ESP32 offers multiple sleep modes with different power consumption profiles, allowing developers to balance functionality with battery conservation. Agent Angie Homes (2025) confirms that while the ESP32-S3 has slightly higher deep sleep current than some alternatives (around 15 µA), it remains highly suitable for "low-power IoT devices, wearables, and smart sensors" due to its excellent power management system that can selectively disable power-hungry components when not in use.

2.4 Theoretical Framework

This theoretical framework underscores the multidisciplinary nature of developing an effective panic button accessory system for women's safety. By integrating insights from IoT, smartphone location services, cloud computing, data security, and human-centered design, researchers can create holistic solutions that address critical challenges in emergency response and situational awareness. The proposed study builds upon this foundation, leveraging low-power ESP32 microcontrollers, BLE communication, and Supabase backend services to develop a reliable, real-time panic button system that prioritizes user privacy and accessibility. Through rigorous evaluation of location accuracy, power efficiency, and alert reliability, this research aims to contribute novel insights and practical solutions to the growing field of IoT-based personal safety applications, ultimately empowering women and vulnerable communities in diverse contexts.

2.4.1 IoT Accessory Devices for Personal Safety

The rapid advancement of Internet of Things (IoT) technologies has paved the way for innovative solutions in personal safety. Accessory devices, in particular, have emerged as promising tools for enhancing emergency response and situational awareness. These devices leverage low-power microcontrollers, such as the ESP32, to enable compact, battery-efficient designs that can be easily integrated into everyday accessories like keychains or bracelets (Farooq et al., 2023). This form factor not only improves discreteness and user compliance but also allows for seamless communication with smartphones via Bluetooth Low Energy (BLE) protocols.

The integration of panic buttons into these accessories has been a key focus in recent studies. Gandhiraj & Sathiyamoorthy (2020) demonstrated the effectiveness of a smart safety device embedded with an Arduino microcontroller, which could transmit the user's location and trigger alerts through a connected mobile application. Similarly, Sogi et al. (2018) proposed a smart ring with an embedded panic button, highlighting the importance of designing inconspicuous yet easily accessible triggers for emergency situations.

ESP32-S3 DevKit Mini (Microcontroller Unit)

The ESP32-S3 DevKit Mini serves as the central controller of the panic button accessory device system. Selected for its affordability, compact size, and low power consumption, it supports Bluetooth Low Energy (BLE), which enables seamless communication with nearby mobile phones. The ESP32 does not handle GPS or network transmission directly in this system. Instead, it broadcasts BLE signals upon panic button activation, which are then received and processed by the mobile app. According to Farooq et al. (2023), low-power MCUs with on-device logic are ideal for accessories that need long-lasting battery life and secure offline processing.

2.4.2 Smartphone-based Location Services

Accurate and reliable location tracking is crucial for effective emergency response. Modern smartphones are equipped with a range of positioning technologies, including GPS, Wi-Fi, and cellular networks, which can be leveraged to provide multi-layered location services. GPS, in particular, has been widely used in personal safety applications due to its global coverage and high accuracy in outdoor environments. However, its performance can be limited in dense urban areas or indoors, where signal obstruction and multipath effects are common.

To address these challenges, researchers have explored techniques like Assisted GPS (A-GPS), which utilizes cellular network information to improve satellite fix times and location accuracy (Faka et al., 2020). Additionally, Bhushan & Jadhav (2024) recommend combining GPS with other indoor localization techniques to mitigate positioning errors.

2.4.3 Cloud Backend and Real-time Communication

Cloud computing has revolutionized the way data is stored, processed, and shared in modern applications. For personal safety systems, cloud backends offer scalable infrastructure, real-time data synchronization, and seamless integration with IoT devices and mobile applications. Supabase, an open-source alternative to Firebase, has gained popularity due to its PostgreSQL foundation and support for real-time features (StudyRaid, 2024).

One of the key advantages of using Supabase in location-based services is its built-in support for PostGIS, a spatial database extender that enables efficient storage, indexing, and querying of geographical data. This allows for complex geospatial operations, such as proximity searches or geofence calculations, to be performed directly in the database, reducing latency and improving application performance.

In addition to data storage and processing, cloud platforms also facilitate real-time communication between devices and users. Edge Functions, serverless compute services that run close to the data source, enable low-latency processing of IoT events and trigger notifications or other actions based on predefined rules. For cross-platform push notifications, Firebase Cloud Messaging (FCM) has been widely adopted due to its reliability and ease of integration with mobile applications (Sunny et al., 2022).

Supabase (Cloud Backend with Geospatial Capabilities)

Supabase acts as the main cloud backend for the system, providing a PostgreSQL database with support for PostGIS. It receives SOS alert data from the mobile app and stores user information, location, and timestamps. PostGIS enables geospatial operations such as identifying the nearest police station using spatial queries like ST_DWithin or ST_Distance (Bhushan & Jadhav, 2024).

Firebase Cloud Messaging (FCM) for Push Notifications

Firebase Cloud Messaging (FCM) sends real-time alerts to both emergency contacts and the nearest police station identified by the system. The alert is formatted by the Edge Function and transmitted securely using FCM tokens without exposing user data or granting direct access to the database. Peña et al. (2023) emphasize the importance of secure, real-time messaging systems in improving safety outcomes, especially for vulnerable individuals in unpredictable environments.

2.4.4 Data Security and Privacy

As personal safety applications often deal with sensitive user information, such as real-time location data, ensuring data security and privacy is of utmost importance. End-to-end encryption and secure communication protocols, such as HTTPS and SSL/TLS, are essential to protect data in transit and prevent unauthorized access (Papadakis et al., 2021). Additionally, implementing role-based access control (RBAC) and robust authentication mechanisms can help restrict data visibility and prevent misuse.

Supabase (Row-Level Security)

Supabase offers built-in security features, such as Row-Level Security (RLS), which allows fine-grained access control based on user roles and attributes (Supabase Docs, 2024). This ensures that sensitive data is only accessible to authorized users, reducing the risk of data breaches and Privacy Rights Act violations.

Supabase's Row-Level Security (RLS) offers a robust solution for protecting sensitive user data in emergency alert systems. SlashDev (2023) explains that RLS enables "policy-based access control" through SQL rules that determine data access at a granular level, allowing developers to "create policies that enforce the desired level of access control without inadvertently exposing sensitive data." Lynch (2023) further elaborates that RLS shifts security enforcement from the application level to the database level, making it particularly valuable for applications where data is owned by individual users. For emergency response systems collecting sensitive location and personal data, implementing RLS policies ensures that information is only accessible to authorized individuals, maintaining privacy while still enabling critical emergency functionality.

2.4.5 Battery Performance and Energy Conservation

One of the key challenges in designing accessory IoT devices for personal safety is ensuring long battery life while maintaining reliable performance. Farooq et al. (2023) emphasize the importance of using budget-conscious, energy-efficient components to optimize power consumption and extend device uptime. Low-power microcontrollers, such as the ESP32, offer various sleep modes and peripheral control options to minimize energy usage during idle periods.

Researchers have explored various techniques to optimize power efficiency in IoT devices. For instance, using low-power communication protocols like NB-IoT or LTE Cat M1 can significantly reduce energy consumption compared to traditional cellular networks (Faka et al., 2020). Additionally, implementing smart power management algorithms and duty cycling can help prolong battery life without compromising device responsiveness.

TP4056 Charging Module + 3.7V Li-Po Battery

A rechargeable 3.7V lithium-polymer battery powers the accessory device, managed via a TP4056 charging circuit. This setup supports safety and portability while maintaining sufficient uptime for daily wear.

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Chapter 3

Methodology

This chapter outlines the methods, frameworks, and procedures employed in the design, development, and evaluation of the panic button accessory system for women's safety. It integrates both hardware and software components, and is structured to ensure the system's feasibility, reliability, and usability in real-world emergency scenarios.

3.1 Conceptual Framework

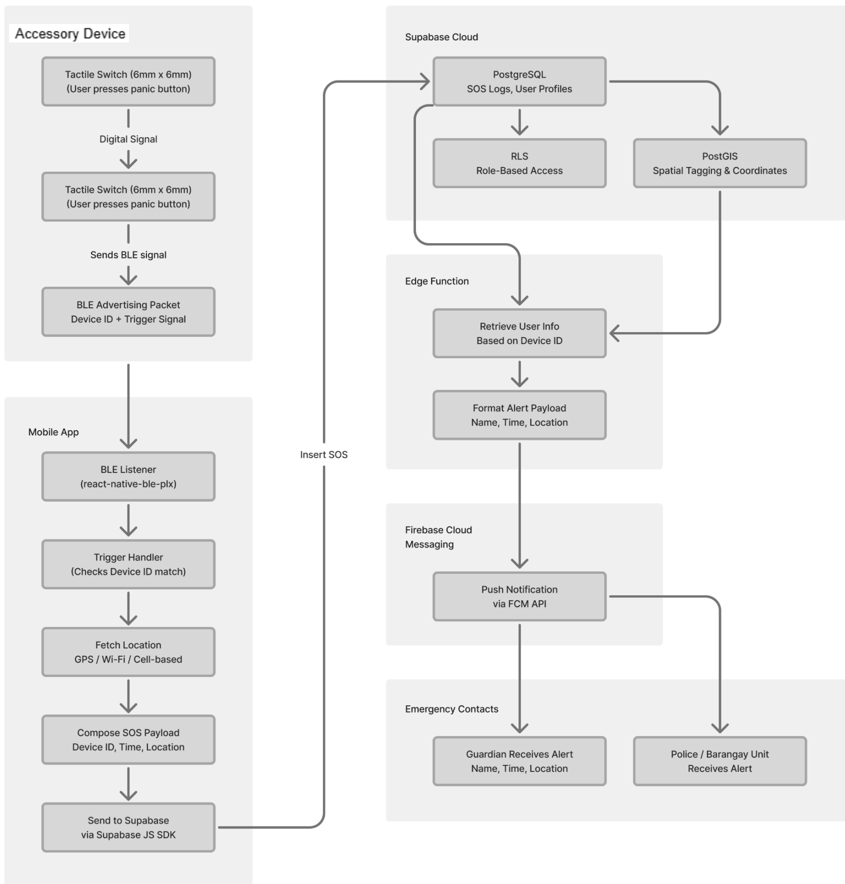


Figure 1: Conceptual Framework

The framework begins with the accessory device, which emits a BLE signal upon button press. This is detected by the mobile app, which verifies the Device ID and immediately collects the user's geo-location via GPS, Wi-Fi, or cellular data. An SOS payload is then sent to Supabase, where user and location data are stored in PostgreSQL and spatially tagged via PostGIS.

The Edge Function hosted in Supabase retrieves corresponding user info, formats the alert, and triggers Firebase Cloud Messaging (FCM) to send notifications to registered guardians and authorities (e.g., barangay uni). Role-based access and real-time notification delivery ensure privacy, responsiveness, and accountability during distress events.

3.2 Research Design

This study adopts a Design Science Research (DSR) methodology, paired with a quantitative experimental design to develop and evaluate an IoT-based accessory panic button system for women's safety. The DSR approach provides a structured framework for identifying the problem—delays in emergency response and unreliable location tracking—and systematically designing, building, and testing a technology-based solution that addresses these gaps. The artifact under development includes a Bluetooth Low Energy (BLE)-enabled accessory device, a mobile application for location retrieval, and a cloud-based backend for alert transmission.

Following the development phase, the system undergoes a series of controlled experiments to quantitatively assess its technical performance. These include measurements of GPS location accuracy (using error distance in meters), success rate of SOS transmission under various signal conditions (expressed as a percentage of successful alert deliveries), and battery performance (in hours/days across active and standby modes). The focus of this design is to validate whether the system meets performance benchmarks related to real-time alerting, energy efficiency, and location precision.

By using an experimental research design within the DSR framework, the study ensures that the final prototype is not only functional but also rigorously evaluated against measurable criteria, thereby contributing both a practical solution and empirical findings to the field of IoT-based personal safety systems.

3.3 Data Collection

This study employs a quantitative, experimental approach to collect data on the performance and reliability of the proposed BLE-based panic button accessory system. A series of controlled experiments will be conducted to evaluate three key components of the system: (1) SOS transmission success rate under varying signal conditions, (2) GPS accuracy in indoor and outdoor environments, and (3) battery performance of the ESP32-S3 device under real-world usage conditions.

For SOS testing, multiple activation trials (minimum of 30 per environment) will be performed in different signal conditions—strong signal, weak signal, and offline scenarios (with retry/caching logic active). Each activation will be logged to determine whether the alert was successfully received in Supabase and whether Firebase Cloud Messaging (FCM) notifications were triggered and received on a secondary test device. Timestamps will be recorded at each stage: button press, app receipt, cloud storage, and recipient notification.

GPS accuracy will be tested by comparing the coordinates retrieved by the mobile app against reference locations (e.g., Google Maps-pinned coordinates). Testing will be done across multiple locations, including open fields, dense urban areas, and indoor structures. Each location will involve 10–15 trials. The positional error will be measured in meters using the haversine formula to calculate the distance between reported and actual coordinates.

Battery life evaluation will involve continuous operation of the ESP32-S3 device in simulated idle (deep sleep) and active (alert) states. Current consumption will be monitored using a digital multimeter, and results will be used to estimate daily power consumption. Tests will be repeated over multiple days using a 1000mAh Li-ion battery, measuring time to full discharge under both active and standby conditions.

All collected data, including timestamps, transmission outcomes, GPS values, and power readings, will be systematically recorded in spreadsheets and application logs for analysis in the following section.

3.4 Data Analysis

The data analysis will focus on quantifying the system's technical performance based on experimental results. For SOS success rate, the percentage of successful transmissions will be calculated using the following formula:

$$Success\ Rate\ (\%) = \left(\frac{Number\ of\ Successful\ SOS\ Alerts}{Total\ SOS\ Activations}\right) \times\ 100$$

This will be computed for each environment type (e.g., high signal, low signal, offline) to assess reliability under varying conditions.

For GPS accuracy, the haversine formula will be used to compute the great-circle distance between the actual reference location and the GPS-reported location:

$$d = 2r \cdot arcsin\left(\sqrt{sin^2\left(\frac{\Delta\phi}{2}\right) + cos\left(\phi_1\right) \cdot cos\left(\phi_2\right) \cdot sin^2\left(\frac{\Delta\lambda}{2}\right)}\right)$$

Where:

- ϕ and $\lambda$are the latitude and longitude in radians,
- $\Delta\phi$ and $\Delta\lambda$ are the differences in latitude and longitude,
- r is the Earth's radius (≈ 6371 km).

The average positional error (in meters) will be reported per location type (indoor, outdoor, obstructed).

Battery life analysis will involve computing the average current consumption in both deep sleep and active modes. These values will be used to estimate projected battery life:

$$Battery\ life\ (hours) = \frac{Battery\ Capacity\ (mAh)}{Average\ Current\ Draw\ (mA)}$$

This will help determine whether the system meets the design goals of ≥7 days standby and ≥6 hours active use.

All results will be presented using tables and charts to visualize performance trends across conditions. Insights will be discussed in relation to the study’s objectives and the gaps identified in the literature.

3.5 Ethical Consideration

This study does not involve human participants outside of the research team, and therefore does not require formal ethics clearance for participant recruitment or personal data handling. All testing procedures will be conducted solely by the authors of the study, who will trigger the panic button accessory system under controlled and predetermined real-world scenarios. These include indoor environments (e.g., buildings, rooms) and outdoor spaces (e.g., open fields, urban streets) within the bounds of public safety and university regulations.

The system will collect GPS coordinates, timestamps, and pre-programmed user information (e.g., name and user ID) for each SOS trigger. These values will be stored in a Supabase PostgreSQL database with Row-Level Security (RLS) to ensure data segregation and protection. No sensitive personal data (e.g., actual names of private individuals, contact numbers, or addresses) will be stored or shared with third parties.

All test records will be generated for research purposes only, and no live emergency contacts will be involved during development. Firebase Cloud Messaging (FCM) will be configured to send alerts solely to the researchers' test accounts. Data generated during experiments will be anonymized and securely stored. After system validation, all stored logs will be cleared from the database to prevent misuse or data persistence beyond the research timeline.

The project upholds the core ethical principles of safety, privacy, and responsible technology deployment, aligned with the Philippine Data Privacy Act of 2012 (RA 10173) and Ateneo de Davao University's research conduct guidelines.

3.6 Operational Framework

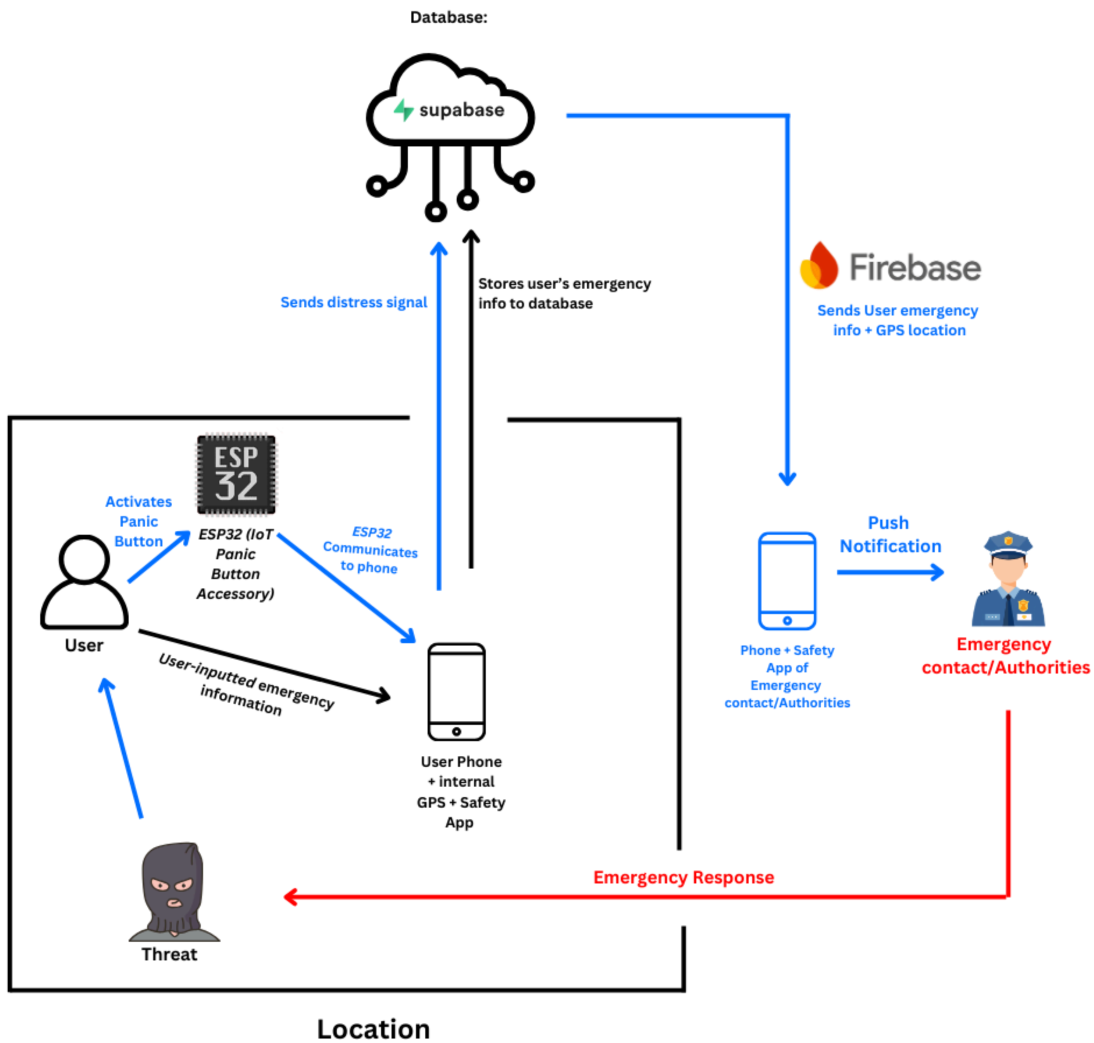


Figure 3: Operational Framework

The operational framework outlines the functional steps involved in using the accessory panic button system for women's safety. The framework describes how the system, which combines the BLE-enabled accessory device, mobile application, cloud backend, and GPS functionality, works to trigger alerts during emergency situations.

1. User Action and Panic Button Activation
    - When the user is in distress, they press the panic button accessory, which communicates with the mobile phone via Bluetooth Low Energy (BLE).
    - Upon activation, the mobile app receives the signal, and the user's information (location, user ID, and pre-programmed emergency message) is gathered by the mobile application using the GPS and transmitted to the cloud server (Supabase).

2. Backend Data Processing
    - The backend, hosted on Supabase, stores the user's emergency data in real-time, along with the timestamp and GPS coordinates.
    - Using the PostGIS extension, geospatial data (GPS coordinates) are processed to ensure the most accurate location information is available.

3. Real-time Notification to Emergency Contacts and Authorities
    - Once the SOS signal is stored in Supabase, Firebase Cloud Messaging (FCM) is triggered, which sends an immediate push notification to emergency contacts and, optionally, local authorities (e.g., barangay or police).
    - The notifications include the user's ID, emergency message, and GPS location, enabling rapid response from nearby emergency services or pre-designated contacts.

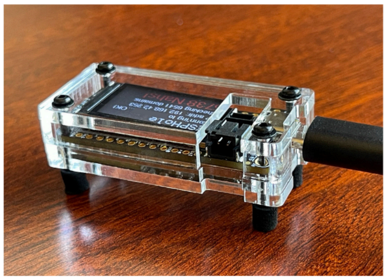
4. Role-Based Access Control (RBAC)
    - Data access is controlled using role-based security measures to ensure that only authorized individuals (emergency contacts, authorities, and system administrators) can view sensitive user data.
    - Emergency responders and contacts will receive real-time updates, while other users can only access certain parts of the system based on their permissions.

5. Geospatial Data Integrity and Privacy
    - All user data, including emergency alerts and GPS coordinates, is securely encrypted and stored in the Supabase database.
    - The use of Row-Level Security (RLS) ensures that only authorized users can access the stored data, providing privacy and compliance with data protection standards.

6. System Activation and Resilience
    - In case of network failure or weak signal areas, the system uses retry mechanisms to ensure the emergency data is transmitted reliably. The app uses caching for situations where there is an unstable internet connection, retrying until the transmission is successful.
    - The system is designed to continue functioning in low-signal areas, ensuring that alerts are always transmitted, even under challenging conditions.

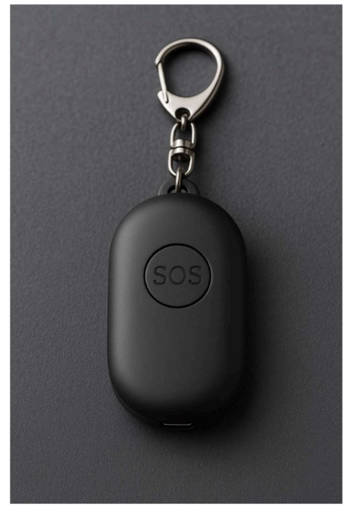
By mapping out this sequence, the operational framework ensures that the panic button accessory system provides a reliable, user-friendly, and secure means of communicating distress during emergencies. The framework also addresses critical challenges like network resilience, geolocation accuracy, and emergency response integration, while ensuring that user privacy is maintained through encrypted data handling and access controls.

3.7 Technical Output Prototype



- **Acrylic Case**

- **3D Printed Case**



AI-Generated Design

Figure 4: Hardware Prototype

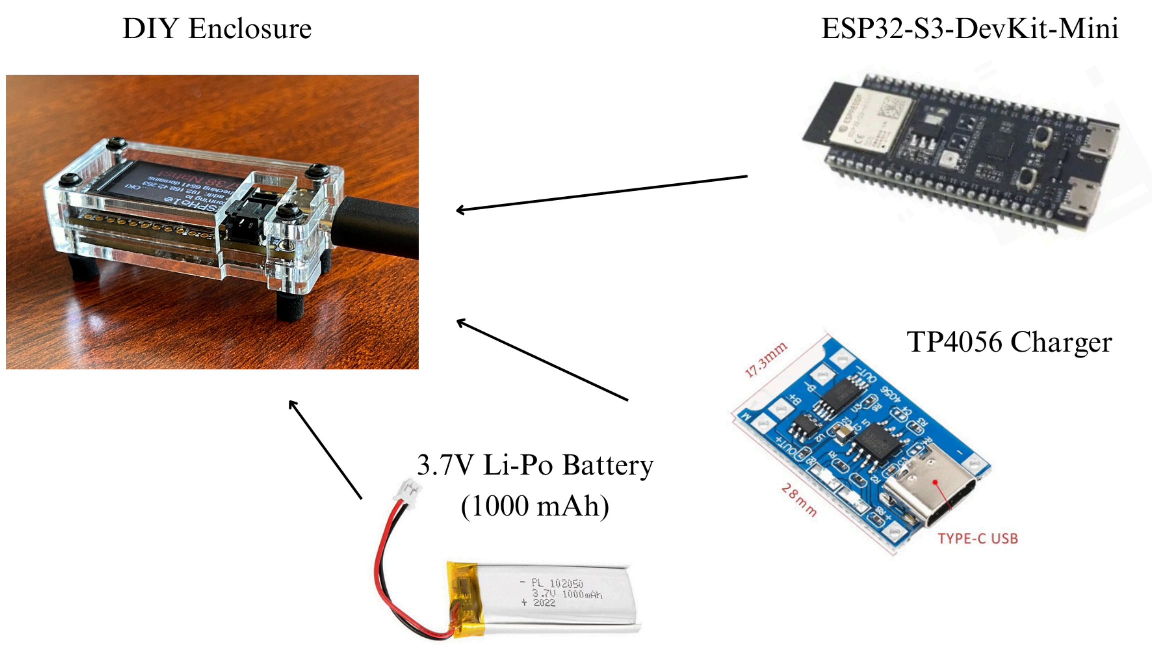
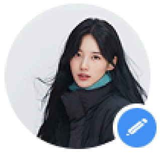


Figure 5: Exploded View of Hardware

9:30

User Information



Personal Details

Full Name

Suzy Bae Suarez

Date of Birth

07/15/2000

Phone Number

+63 939 7263 904

Email Address

suzybae@gmail.com

Emergency Contact

Emergency Contact Name

Joshua Suarez

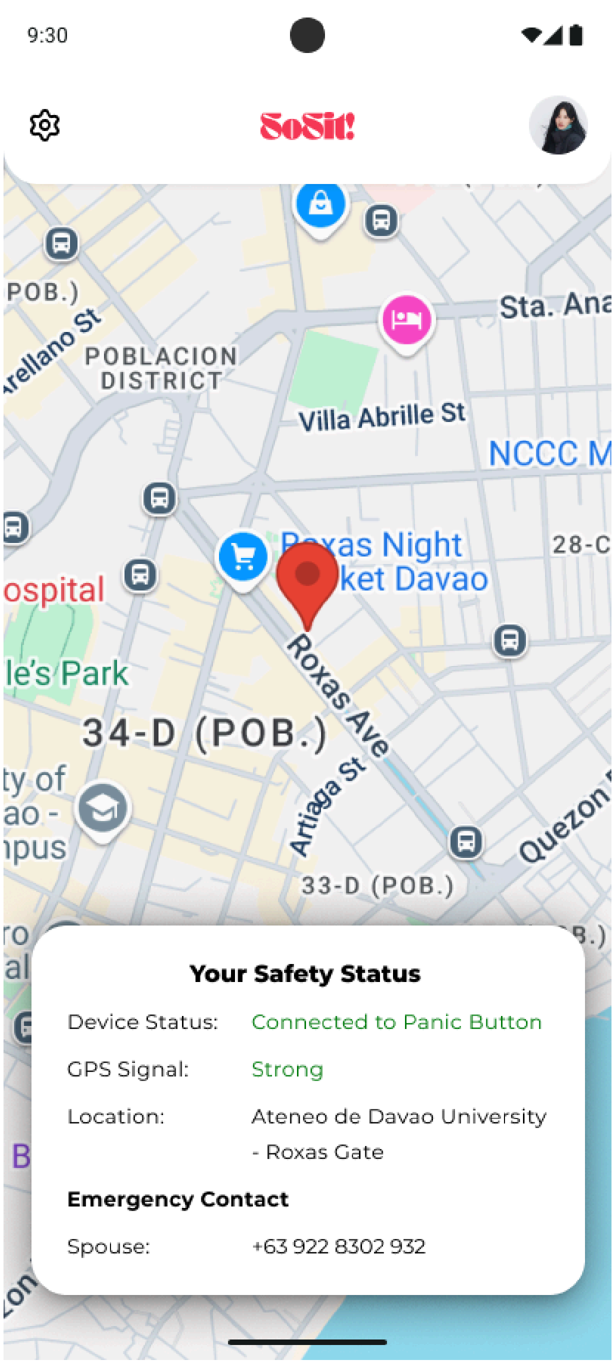
Relationship to User

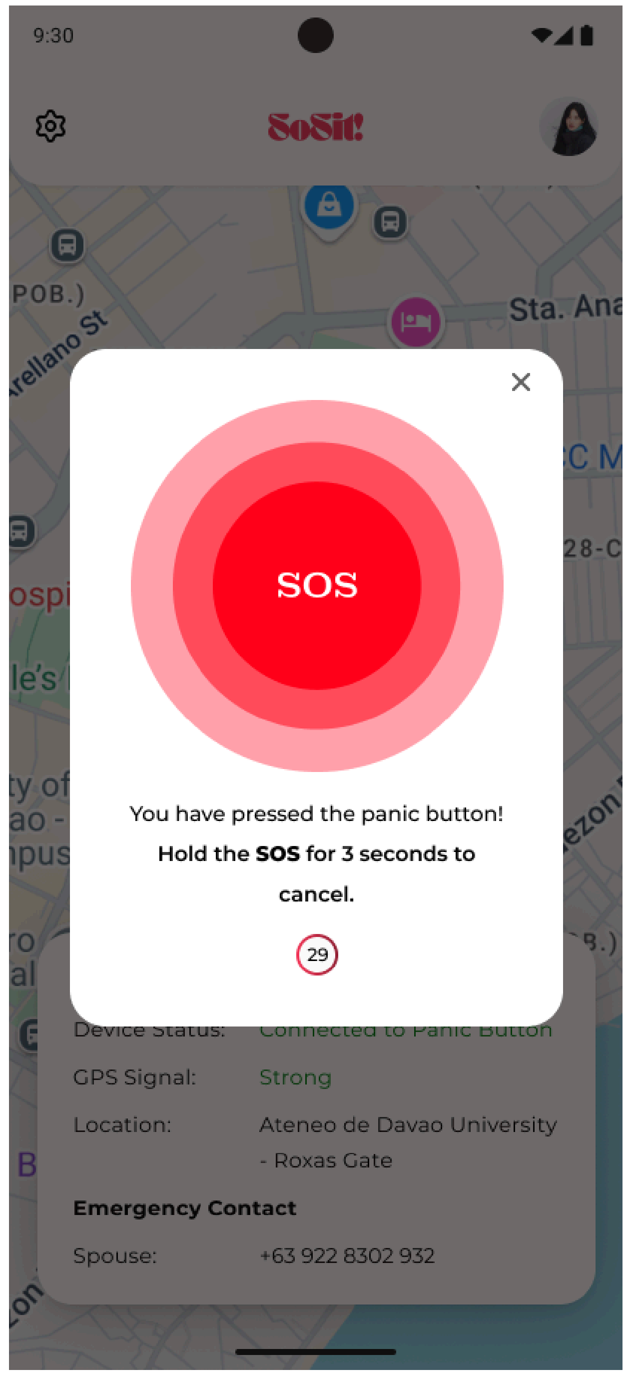
Spouse

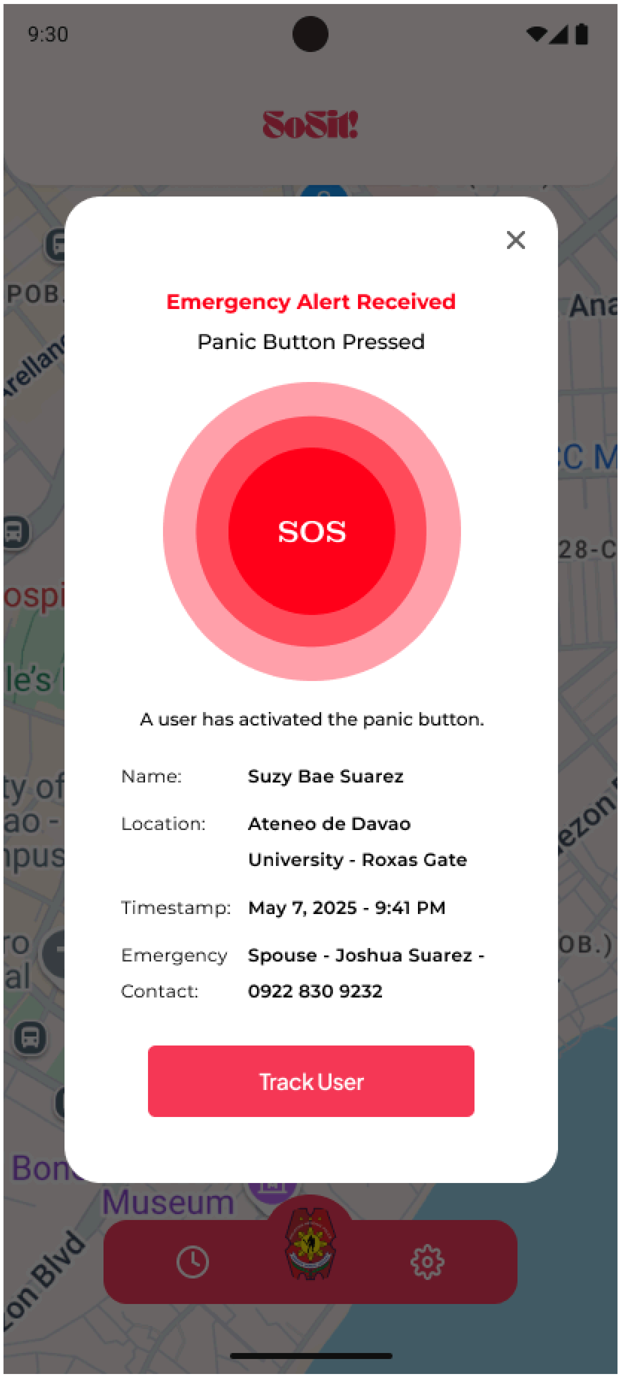
Emergency Contact's Phone Number

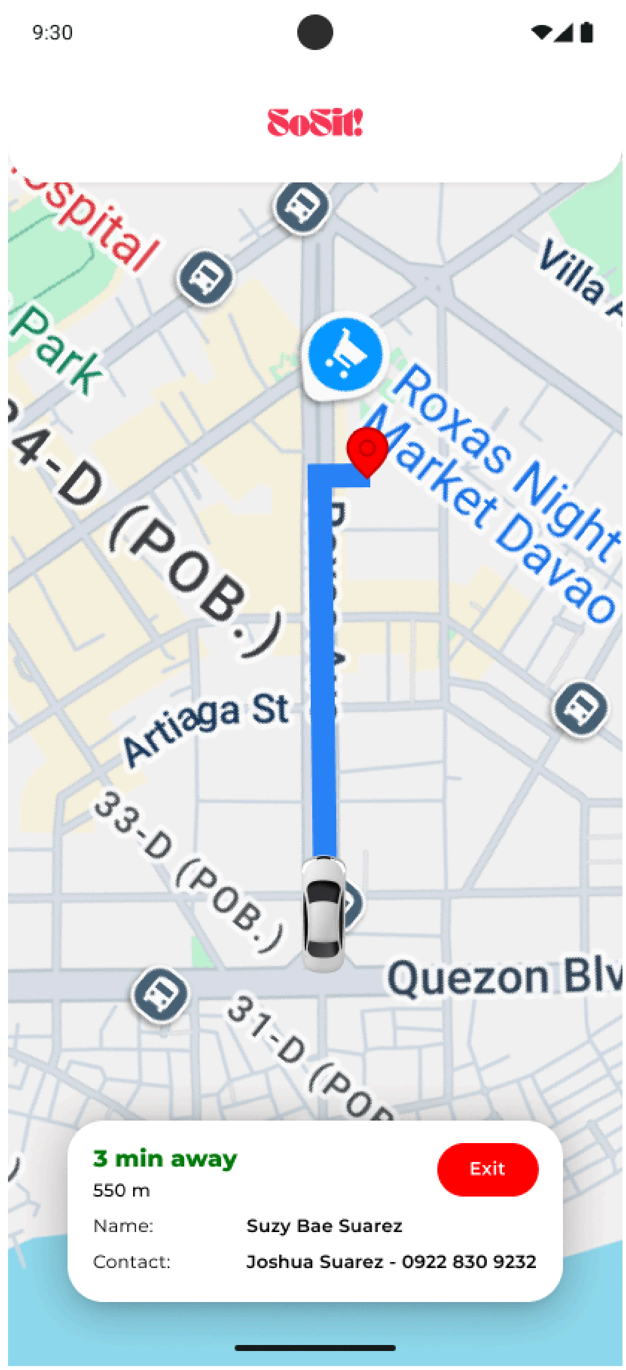
+63 922 8302 932

Save


9:30
SoSit!
Sta. Ana
POBLACION DISTRICT
Villa Abrille St
Roxas Ave
Artiaga St
34-D (POB.)
33-D (POB.)
Your Safety Status
Device Status: Connected to Panic Button
GPS Signal: Strong
Location: Ateneo de Davao University - Roxas Gate
Emergency Contact
Spouse: +63 922 8302 932


9:30
SoSit!
SOS
You have pressed the panic button!
Hold the SOS for 3 seconds to cancel.
29
GPS Signal: Strong
Location: Ateneo de Davao University - Roxas Gate
Emergency Contact
Spouse: +63 922 8302 932


9:30
SoSit!
Emergency Alert Received
Panic Button Pressed
SOS
A user has activated the panic button.
Name: Suzy Bae Suarez
Location: Ateneo de Davao University - Roxas Gate
Timestamp: May 7, 2025 - 9:41 PM
Emergency Contact: Spouse - Joshua Suarez - 0922 830 9232
Track User
Museum


9:30
SoSit!
Park
Roxas Night Market Davao
Artiaga St
3 min away
550 m
Exit
Name: Suzy Bae Suarez
Contact: Joshua Suarez - 0922 830 9232

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