GPS-Based Emergency Response System for Disaster Risk Reduction and Management

Consumo, Lea Marie R., Lastica, Ian Rhey G., Ortiz, Jelyn E., Perez, Lancee Faith L., Sindol, Isauro Jr. S.

School of Information and Communications Technology, West Visayas State University – Lambunao Campus, Lambunao, Iloilo

Philippines

leahmarie.consumo@wvsu.edu.ph
ianrhey.lastica@wvsu.edu.ph
jelyn.ortiz@wvsu.edu.ph
lancefaith.perez@wvsu.edu.ph
isaurojr.sindol@wvsu.edu.ph

Abstract **- This study developed and evaluated a GPS-Based Emergency Response System for the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Lambunao, Iloilo, Philippines to address challenges in delayed emergency reporting, absence of real-time location tracking, and inefficient coordination between residents and responders in the municipality. The system comprises a mobile application for residents and emergency personnel, and a web-based administrative dashboard for MDRRMO authorities. The resident application enables users to submit emergency requests with incident details, images, and automatically generated GPS location data. The responder application allows emergency teams to receive real-time alerts, navigate to incident sites using GPS, and update response statuses. The administrative dashboard provides real-time monitoring of incidents, responder locations, and response progress to facilitate effective coordination and decision-making. A descriptive-developmental research design was employed, focusing on the system's design, development, and evaluation. The system was assessed by thirty-three (33) respondents, including five (5) MDRRMO staff and responders, eight (8) residents, and twenty (20) IT experts, using an adapted evaluation instrument based on the ISO/IEC 25010:2011 Software Quality Standards. The application was developed using Flutter for the mobile platform, PHP and MySQL for backend services, and HTML, CSS, JavaScript, and Bootstrap for the web interface, following an Agile software development methodology to enable iterative enhancements based on stakeholder feedback. Evaluation results yielded an overall mean rating of 4.77, interpreted as Excellent, across the criteria of Functional Suitability, Performance Efficiency, Usability, Reliability, Security, Maintainability, and Portability. The findings indicate that the proposed system significantly improved the accuracy of emergency reporting, reduced response time, and enhanced coordination among responders. The study demonstrates the potential of GPS-enabled technologies to strengthen local emergency response operations and improve public safety in the Municipality of Lambunao.**

Keywords **- GPS, Emergency Response System, Disaster Risk Management, GPS-Based Response System**

I. Introduction

Disaster Risk Reduction and Management (DRRM) has become a global priority as the frequency and intensity of natural and human-induced hazards continue to increase. In the Philippines, DRRM is institutionalized through Republic Act No. 10121, which mandates a comprehensive framework for disaster preparedness, prevention, mitigation, response, and recovery [1]. The law decentralizes disaster governance and emphasizes the critical role of Local Government Units (LGUs) in ensuring coordinated and community-based emergency response systems. Despite this strong legal foundation, operational inefficiencies remain prevalent at the municipal level, particularly in rural and semi-urban communities.

Emergency response operations in many municipalities continue to rely on conventional communication channels such as online calls, short message services (SMS), and two-way radios. These manual and fragmented systems often result in delayed reporting, inaccurate location descriptions, dispatch errors, and poor inter-agency coordination. Studies indicate that emergency response delays are frequently associated with incorrect or incomplete address information, traffic conditions, route unfamiliarity, and limited situational awareness [2], [3]. The absence of an integrated and real-time digital tracking system further compounds these challenges, reducing the overall effectiveness of disaster response operations.

The Global Positioning System (GPS), developed and maintained by the United States Department of Defense, provides precise positioning, navigation, and timing services worldwide [4]. GPS technology has been widely adopted across sectors such as transportation, logistics, agriculture, and geospatial monitoring due to its accuracy and reliability. In emergency management, GPS integration enhances operational efficiency by enabling real-time incident localization, dynamic route optimization, and live tracking of emergency units [5]. However, despite the widespread availability of GPS-enabled smartphones and digital mapping services, its systematic integration into localized DRRM systems remains limited, particularly in developing and resource-constrained municipalities.

In the Municipality of Lambunao, emergency reporting primarily depends on hotline-based communication and coordination through barangay officials. Preliminary stakeholder

consultations revealed recurring operational issues, including vague location descriptions, duplicate dispatches, cancelled missions, and delayed arrival of responders. These challenges reflect a broader research gap: while GPS-based solutions have been implemented in urban and large-scale emergency systems, few studies have focused on designing and evaluating an integrated, standards-compliant GPS-enabled emergency response platform tailored for municipal-level DRRM operations.

Existing systems often implement isolated functionalities such as call-based reporting or fleet monitoring without providing a unified architecture that integrates (1) real-time GPS-based incident reporting by residents, (2) live responder tracking and navigation, and (3) a centralized administrative dashboard for coordinated decision-making. Furthermore, limited empirical research has assessed such systems using internationally recognized software quality models such as ISO/IEC 25010:2011 [6].

The urgency of strengthening municipal emergency response systems has increased due to rising road accidents, climate-related hazards, and other localized emergencies. Simultaneously, the widespread adoption of mobile devices and advancements in cross-platform development frameworks present a timely opportunity to modernize traditional DRRM workflows. Leveraging GPS-enabled mobile technology can significantly reduce response times, enhance reporting accuracy, and improve inter-agency coordination.

This study proposes the design and development of a GPS-Based Emergency Response System for the MDRRMO of Lambunao. The system integrates a mobile application for residents and responders with a web-based administrative dashboard to support real-time incident reporting, geolocation tracking, route navigation, and centralized monitoring. By bridging the gap between national policy mandates and practical technological implementation, this research contributes to the advancement of data-driven disaster management, supports smart governance initiatives, and promotes improved public safety outcomes in resource-constrained communities.

II Literature Review

A. Disaster Risk Reduction and Management Framework in the Philippines

Disaster Risk Reduction and Management (DRRM) has evolved into a central governance priority due to the increasing frequency and severity of natural and anthropogenic hazards worldwide. The Philippines, being one of the most disaster-prone countries, institutionalized its DRRM framework through Republic Act No. 10121, also known as the *Philippine Disaster Risk Reduction and Management Act of 2010* [1]. This legislation marked a paradigm shift from reactive disaster response toward proactive risk reduction, preparedness, mitigation, and recovery planning.

Republic Act No. 10121 decentralizes disaster governance by empowering Local Government Units (LGUs) to establish Local Disaster Risk Reduction and Management Offices (LDRRMOs). The law mandates the creation of comprehensive and community-based emergency response mechanisms at provincial, municipal, and barangay levels [1]. While the legal and institutional framework is robust, several studies and field observations indicate that operational challenges persist at the municipal level, particularly in rural and semi-urban areas where technological infrastructure and technical expertise are limited.

Despite policy alignment with international DRRM standards, practical implementation often relies on conventional communication workflows. This disconnect between policy and operational capability highlights the need for technology-enabled systems that can enhance coordination, accuracy, and timeliness in emergency response operations.

B. Operational Challenges in Municipal Emergency Response Systems

Emergency response efficiency is strongly influenced by communication accuracy, dispatch coordination, and responder navigation. In many municipalities, reporting mechanisms depend heavily on hotline calls, SMS, and two-way radio communication. These manual processes frequently result in incomplete incident details, ambiguous location descriptions, and delayed response times.

A systematic review by Jafari et al. [2] identified key determinants affecting emergency medical service (EMS) response times, including inaccurate address information, traffic congestion, limited dispatcher awareness, and route unfamiliarity. These factors significantly contribute to operational delays, particularly in geographically dispersed communities. Similarly, Goh et al. [3] emphasized that fragmented communication systems and lack of integrated information platforms hinder coordinated emergency response and reduce situational awareness among agencies.

The absence of real-time tracking and centralized monitoring systems further exacerbates inefficiencies. Without digital visualization of incidents and responder locations, decision-makers rely on verbal updates, which are prone to misinterpretation and duplication of dispatch efforts. These operational gaps underscore the need for integrated digital platforms that provide accurate geolocation data and centralized oversight.

C. GPS Technology in Emergency Management Systems

The Global Positioning System (GPS), developed and maintained by the United States Department of Defense, delivers accurate positioning, navigation, and timing services globally [4]. Originally designed for military applications, GPS technology has since been widely adopted across civilian sectors, including transportation, logistics, agriculture, and geographic information systems.

In emergency management, GPS integration enables precise incident localization, real-time tracking of emergency vehicles, and dynamic route optimization. The performance standards established by the U.S. Department of Defense confirm the reliability and global coverage of GPS services [4], making it suitable for time-critical operations.

Raghu and Mala [5] highlighted that GPS-based systems significantly improve public safety operations by reducing response times, enhancing fleet monitoring, and optimizing dispatch decisions. Real-time geospatial data allows emergency responders to navigate efficiently while enabling administrators to monitor movement and adjust deployment strategies dynamically.

However, despite the widespread availability of GPS-enabled smartphones and digital mapping technologies, systematic integration of GPS into localized DRRM systems remains limited in developing municipalities. Most implementations focus on isolated functionalities—such as vehicle tracking—without integrating incident reporting, navigation, and centralized coordination within a unified architecture.

D. Integrated Information Systems for Coordinated Response

Integrated emergency information systems are essential for achieving synchronized multi-agency operations. Goh et al. [3] demonstrated that unified platforms significantly enhance situational awareness, improve communication flow, and reduce redundancy in dispatch processes. An integrated architecture typically consolidates incident reporting, responder assignment, navigation support, and administrative monitoring into a centralized digital environment.

Despite demonstrated benefits in urban and large-scale contexts, research on municipal-level implementations remains sparse. Many existing systems emphasize call-based reporting or standalone fleet monitoring tools without enabling real-time citizen reporting through geotagged mobile applications. This fragmented approach limits scalability and fails to address recurring operational inefficiencies at the grassroots level.

A comprehensive system should integrate the following components:

1. Real-time GPS-based incident reporting by residents
2. Live tracking and navigation for responders
3. A centralized web-based dashboard for monitoring and coordination

Such integration aligns with the decentralization principles mandated under Republic Act No. 10121 [1] while addressing documented response-time challenges identified in prior studies [2], [3].

E. Software Quality Evaluation and ISO/IEC 25010:2011

Beyond functionality, system quality evaluation is critical to ensure reliability, usability, security, and performance. The ISO/IEC 25010:2011 software quality model provides an internationally recognized framework for assessing system quality across characteristics such as functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability [6].

Applying ISO/IEC 25010 in evaluating DRRM systems ensures that technological solutions are not only operationally effective but also sustainable and standards-compliant. However, limited empirical research has examined GPS-enabled municipal emergency systems using this standardized evaluation model. Most studies focus primarily on technical implementation rather than comprehensive quality validation.

Integrating ISO/IEC 25010 evaluation into the development of municipal emergency response systems strengthens both academic rigor and practical reliability. It ensures that the proposed platform meets internationally recognized benchmarks for system performance and user satisfaction.

F. Research Gap and Theoretical Contribution

The reviewed literature establishes three key observations:

1. The Philippines has a strong legal DRRM framework, but operational inefficiencies persist at the municipal level [1].
2. Emergency response delays are frequently linked to inaccurate location reporting and fragmented communication systems [2], [3].
3. GPS technology significantly enhances emergency operations, yet its integration into localized DRRM workflows remains limited [4], [5].

While prior studies demonstrate the effectiveness of GPS and integrated information systems in urban or large-scale settings, there is limited research focused on designing and evaluating a standards-compliant, GPS-enabled emergency response system tailored specifically for municipal DRRM operations in resource-constrained communities.

Addressing this gap, the present study proposes the development of a GPS-Based Emergency Response System for the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Lambunao. The system integrates mobile-based real-time incident reporting, responder geolocation tracking, route navigation, and a centralized administrative dashboard. By aligning technological innovation with national DRRM mandates and international software quality standards, this research contributes to data-driven disaster governance, smart municipal management, and improved public safety outcomes.

III. Methodology

A. Research Design

This study employed a descriptive-developmental research design to design, develop, and evaluate a GPS-Based Emergency Response System for the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Lambunao, Iloilo, Philippines. The descriptive component focused on identifying the operational challenges encountered by the MDRRMO, particularly delayed reporting, lack of real-time tracking, and inefficient coordination. The developmental component involved the systematic design and implementation of a software solution to address these challenges.

The system was evaluated using an adapted instrument based on ISO/IEC 25010:2011 Software Quality Standards, covering the following criteria:

1. Functional Suitability
2. Performance Efficiency
3. Usability
4. Reliability
5. Security

6. Maintainability
7. Portability

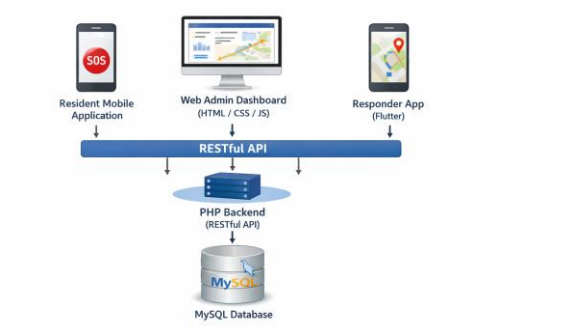
Thirty-three (33) respondents participated in the evaluation, consisting of five (5) IT experts, eight (8) MDRRMO staff and responders, and twenty (20) residents.

B. System Architecture

The proposed system follows a three-tier client–server architecture, consisting of:

1. Presentation Layer (Mobile and Web Applications)
2. Application Layer (Backend Server)
3. Data Layer (Database Server)

1) Architectural Overview



2) Mobile Application Layer

The mobile applications for residents and responders were developed using **Flutter**, enabling cross-platform deployment on Android devices.

a. *Resident Module Functions:*
   i. User registration and authentication
   ii. Emergency request submission
   iii. Image attachment
   iv. Automatic GPS coordinate acquisition
   v. Real-time status tracking
b. *Responder Module Functions:*
   i. Incident notification alerts
   ii. GPS-based navigation
   iii. Status updates (Received, En Route, Arrived, Completed)
   iv. Real-time location sharing

3) Web-Based Administrative Dashboard

The web dashboard was developed using HTML, CSS, JavaScript, and Bootstrap. It allows MDRRMO administrators to:

a. *Monitor incoming emergency reports*
b. *Track responder locations in real time*
c. *View incident details and attached images*
d. *Generate response reports*
e. *Manage user accounts*

4) Backend and Database Layer

The backend was implemented using PHP to handle API requests and business logic. The MySQL database stores:

a. *User profiles*
b. *Emergency reports*
c. *GPS coordinates*
d. *Response logs*
e. *Status updates*

RESTful API endpoints were used to ensure secure and structured communication between clients and the server.

C. Algorithms and Functional Processes

1) Emergency Reporting Algorithm

The emergency reporting process automatically captures user location and transmits incident data to the server.

Algorithm 1: Emergency Submission Process
Input: User emergency request
Output: Stored emergency report with GPS data

Step 1: User selects “Report Emergency”
Step 2: System activates GPS module
Step 3: Retrieve latitude and longitude
Step 4: User inputs incident details
Step 5: Optional image attachment
Step 6: Validate input fields
Step 7: Send data to server via REST API
Step 8: Store data in MySQL database
Step 9: Notify available responders
End

2) Responder Assignment Algorithm

The system assigns emergency cases based on availability status.

Algorithm 2: Responder Notification Process
Input: New emergency report
Output: Alert sent to available responders

Step 1: Query database for available responders
Step 2: Broadcast notification
Step 3: First responder to accept is assigned
Step 4: Update incident status to “En Route”
Step 5: Continuously update responder GPS location
Step 6: Display route navigation
End

3) Real-Time Location Tracking

The system uses periodic GPS updates from responder devices.

D. Development Methodology

The system followed the Agile Software Development Methodology, specifically an iterative and incremental approach.

Agile Phases Implemented

1. *Requirements Gathering*
2. *Sprint Planning*
3. *System Design*
4. *Development*
5. *Testing*
6. *Stakeholder Review*
7. *Iterative Refinement*

Each sprint incorporated feedback from MDRRMO personnel and IT experts to ensure alignment with operational needs.

E. Experimental Setup and Evaluation Procedure

1) Participants

8 MDRRMO staff and responders

20 Residents
5 IT Experts
Total: 33 Respondents

2) Evaluation Instrument

An adapted survey instrument based on ISO/IEC 25010:2011 was used. The rating scale employed a 5-point Likert scale:

Scale	*Description*
5	Excellent
4	Very Good
3	Good
2	Fair
1	Poor

3) Testing Environment

1. Android smartphones (Resident and Responder apps)
2. Web browser (Google Chrome) for admin dashboard
3. Local server with PHP backend
4. MySQL relational database

4) Data Analysis

Weighted mean was computed average function in spreadsheet application

F. Ethical Considerations

The participation was voluntary with consent from the respondents

Personal data were handled in compliance with applicable data privacy regulations.

IV. Results and Discussion

A. Evaluation Based on ISO/IEC 25010 Software Quality Characteristics

Table I presents the summary of the system evaluation based on the ISO/IEC 25010 software quality characteristics.

TABLE I

SUMMARY OF SYSTEM EVALUATION BASED ON SOFTWARE QUALITY CHARACTERISTICS

Software Quality Characteristic	Mean	Std. Dev.	Interpretation
Functional Suitability	4.89	0.10	Excellent
Performance Efficiency	4.78	0.11	Excellent
Portability	4.78	0.12	Excellent
Maintainability	4.77	0.11	Excellent
Usability	4.76	0.11	Excellent
Reliability	4.75	0.12	Excellent
Security	4.67	0.13	Excellent
Grand Mean	4.77	0.11	Excellent

The system obtained a **grand mean of 4.77 (SD = 0.11)**, interpreted as *Excellent*, indicating that respondents perceived the system as highly effective and reliable for emergency response operations.

Among all characteristics:

Functional Suitability (M = 4.89) received the highest rating, demonstrating that the system successfully fulfills its intended emergency management functions.

Performance Efficiency and Portability (M = 4.78) indicate that the system performs efficiently and operates consistently across multiple platforms and environments.

Maintainability (M = 4.77) reflects ease of system updates and modifications.

Usability (M = 4.76) confirms that users find the system intuitive and easy to learn.

Reliability (M = 4.75) shows stable and consistent system performance.

Security (M = 4.67), although the lowest, still falls within the *Excellent* range, suggesting strong protection mechanisms with opportunities for further enhancement.

Overall, the results demonstrate balanced excellence across all ISO/IEC 25010 dimensions, with particularly strong functional performance.

TABLE 2

SUMMARY OF SYSTEM EVALUATION PER RESPONDENT GROUP

Respondent Group	Mean	Interpretation
Residents	4.94	Excellent
MDRRMO Administrators & Staff	4.78	Excellent
IT Experts	4.59	Excellent
Grand Mean	4.77	Excellent

The results show consistent agreement among all respondent groups regarding the system's effectiveness:

Residents (M = 4.94) provided the highest rating, indicating strong acceptance and perceived usefulness for emergency reporting and monitoring.

MDRRMO Administrators and Staff (M = 4.78) rated the system highly, confirming its operational effectiveness in emergency coordination and management.

IT Experts (M = 4.59) gave slightly lower but still *Excellent* ratings, reflecting a more technical and standards-based evaluation perspective.

The slightly lower score from IT experts may indicate stricter assessment criteria related to software architecture, security enhancement, or scalability considerations. Nevertheless, their rating confirms that the system meets professional technical standards.

V. Conclusion

This study evaluated the developed emergency response system using the ISO/IEC 25010 software quality characteristics framework. The overall results indicate that the system achieved a Grand Mean of 4.77 (SD = 0.11), interpreted as *Excellent*. This demonstrates that the system is highly effective, reliable, and suitable for supporting emergency response operations.

Among the evaluated characteristics, *Functional Suitability (M = 4.89)* received the highest rating, confirming that the system effectively fulfills its intended emergency management functions. High ratings in *Performance Efficiency (M = 4.78)* and *Portability (M = 4.78)* indicate that the system operates efficiently across different platforms and environments. Likewise, strong results in *Maintainability (M = 4.77)*, *Usability (M = 4.76)*, and *Reliability (M = 4.75)* demonstrate that the system is stable, user-friendly, and adaptable for continuous improvement. Although *Security (M = 4.67)* received the lowest mean score, it remains within the Excellent range, suggesting robust protection mechanisms with room for further enhancement.

Evaluation across respondent groups further validates the system's effectiveness. Residents (M = 4.94) expressed very high acceptance and perceived usefulness, indicating strong community readiness. MDRRMO administrators and staff (M = 4.78) confirmed its operational efficiency in emergency coordination, while IT experts (M = 4.59) provided slightly more conservative but still Excellent ratings, reflecting technical rigor in system assessment. Overall, the results demonstrate balanced excellence across functional, technical, and user-centered dimensions.

REFERENCES

[1] Republic of the Philippines, "Republic Act No. 10121: Philippine Disaster Risk Reduction and Management Act of 2010," Official Gazette of the Republic of the Philippines, 2010.

[2] S. Jafari, et al., "Factors affecting emergency medical service response time: A systematic review," *Prehospital and Disaster Medicine*, vol. 36, no. 5, pp. 594–601, 2021.

[3] S. Goh, J. Zhang, and K. Lee, "Improving emergency response coordination through integrated information systems," *International Journal of Disaster Risk Reduction*, vol. 62, 2021.

[4] U.S. Department of Defense, "Global Positioning System Standard Positioning Service Performance Standard," Washington, DC, USA, 2020.

[5] R. Raghu and M. K. Mala, "Applications of GPS technology in emergency response and public safety systems," *International Journal of Advanced Research in Engineering and Technology*, vol. 14, no. 3, pp. 45–53, 2023.

[6] International Organization for Standardization, "ISO/IEC 25010:2011 Systems and software engineering—Systems and software Quality Requirements and Evaluation (SQuaRE)—System and software quality models," Geneva, Switzerland, 2011.