Smart Muni Platform: Efficient Emergency and Citizen Security Management Based on Geolocation, Technological Integration and Real Time Communication

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Abstract*—The global increase in crime across cities has led to the development and implementation of technological solutions, such as the Smart Muni platform, designed to enhance citizen security. This platform integrates geolocation, real-time notifications, and a digital panic button to optimize emergency management and coordination between citizens and authorities. Developed using a structured approach that included requirements analysis, system design, development, testing, validation, deployment, and maintenance, the platform employs advanced technologies such as Firebase, Amazon S3, and Twilio, ensuring scalability, high availability, and seamless communication. Initially implemented in two districts with high crime rates, Smart Muni registered an average of 10 daily alerts, with peaks of up to 50 alerts in a single day. The system has proven effective in managing frequent incidents like alcoholism and domestic violence, significantly reducing response times and improving coordination. Despite its success, Smart Muni faces challenges related to optimizing its resilience against potential system failures and improving its ability to handle increased data loads. In comparison to other international systems, Smart Muni's flexible and scalable architecture stands out, though future enhancements are required to further strengthen the system's reliability and expand its features. Overall, Smart Muni has proven to be a valuable tool in improving citizen security, fostering stronger relationships between citizens and authorities, and contributing to a safer community.

***Keywords*—Citizen security; geolocation; emergency management; cloud technology; alert platform**

I. Introduction

Citizen security refers to the protection of citizens' rights and freedoms, as well as the prevention and control of violence and crime in urban environment [1]. For García and Zambrano [2], this concept should be conceived from a broad perspective, involving both the perception of security by the population and the concrete actions carried out by the authorities to guarantee it.

Globally, many cities are experiencing rising crime rates and facing major challenges in emergency management. Rapid urbanization and increased population density in urban areas have aggravated these problems, highlighting the need for innovative solutions to ensure public safety. In large cities, the adoption of advanced technologies has proven to be effective in improving coordination and response to crime incidents and emergencies; to increase the effectiveness and efficiency of public safety operations, innovative strategies using the Global Positioning System (GPS) have been implemented. Cities such as New York and London have integrated geolocation systems and data analysis into their security strategies, allowing for a faster and more accurate response to emergencies. However, in Latin American countries, the integration of technology to promote the security of their citizens is lagging behind [3].

While several international systems, such as those implemented in New York and London, have successfully integrated geolocation and data analysis to improve emergency response, these solutions often focus on larger, well-resourced urban centers. In contrast, Latin American cities, particularly in Peru, face unique challenges such as fragmented communication infrastructures and limited access to technological resources. The existing systems also lack the ability to address the specific needs of local municipalities, which often operate under constrained budgets and require more adaptable solutions. Smart Muni fills this gap by providing a scalable, cost-effective platform tailored to the context of smaller cities in developing regions. Its integration of real-time communication, geolocation, and cloud-based technologies ensures that it can quickly adapt to the evolving needs of these communities, while also offering enhanced resilience in regions where emergency response systems are often under-resourced.

The problem of citizen security in Peru is complex and multifaceted; many Peruvian cities are experiencing an increase in crime rates, a situation that is affected by various social, economic and political factors. According to the National Strategic Programs Survey, nine out of 10 people believed that they would be victims of crime in the next 12 months [4]. Citizens and local authorities face difficulties in coordinating quick and effective actions to guarantee citizen security; there is a growing concern about acting in a timely manner to prevent crime or mitigate its consequences.

The lack of an integrated incident management system and the absence of adequate technological tools for the reception and management of security and emergency alerts compromises the authorities' ability to act in a timely manner and reduces community confidence in public safety, demonstrating the urgent need to implement an advanced technological solution to optimize emergency response and management, improve communication between citizens and authorities, and strengthen citizen security in the region. Sarkar [5] and Samarakkody et al. [6] suggest that technological innovations enhance disaster resilience and empower citizens, creating livable communities and improving overall quality of life. Protecting a complex environment, such as a city, is a task of enormous and increasing complexity, requiring the combination of multidisciplinary techniques and tools, the availability of very diverse skills, and the ability to correlate and explore large flows of data and information [7]. Technology plays a crucial role in smart cities, supporting the optimization of urban services and improving the quality of life of their inhabitants [8].

Several research studies explore the application of geolocation and geographic information systems (GIS) to improve citizen security and tourism safety. Alvarez [9] proposes extending Ecuador's ECU 9-1-1 system to rural areas, incorporating georeferencing and monitoring cameras to enhance emergency response. In Mexico, Espinoza-Ramirez et al. [10] developed a mobile device-based system using GIS to map crime incidents, helping citizens to identify and avoid dangerous areas. However, Gonzalez [11] raises concerns about the constitutionality of citizen geolocation through mobile applications, particularly about the rights to privacy and freedom of movement. Solano Barliza [12] suggests that combining recommender systems with geolocation technologies could improve tourism safety, pointing out the lack of existing solutions specifically focused on this aspect.

The implementation of a geolocation-based software application to detect aid points when a citizen observes or suffers a crime is crucial for a rapid and coordinated response by the authorities [13], which would significantly improve communication between citizens and authorities, strengthen trust in public safety, and empower the community to actively participate in their own protection.

For their part, Jesus et al. [14] deal with the reliability and detectability of emergency management systems, emphasizing the importance of resilience to common failures. Costa et al. [15] present a review of various emergency management systems, highlighting the diversity of technologies and approaches used. Samarakkody et al. [16] investigate technological innovations that improve disaster resilience in smart cities.

In this information context, a robust and efficient platform for the management of citizen emergencies and alerts is proposed, which will significantly improve the response and coordination capacity between citizens and authorities and allow for a more direct and real-time interaction, facilitating decision making and the mobilization of resources to efficiently respond to citizens' calls for help.

II. Methodology

A. Stages

In order to develop a robust and effective platform to improve citizen security through the use of geolocated technology, a structured methodology has been followed that includes the following stages:

1) Requirements analysis: Identification of needs and definition of functionalities.

2) System design: Definition of the technical structure and design of an intuitive and accessible interface for users.

3) Development: Identification of suitable languages and frameworks for web and mobile development.

4) Testing and validation: Performing unit and integration testing to ensure that each component works correctly and the app as a whole operates smoothly, and user testing to get feedback and make necessary adjustments.

5) Deployment and maintenance: Release, monitoring and updates to improve functionality and security.

B. Implementation Context

The proposed platform was implemented in the districts of Cayma and José Luis Bustamante y Rivero, located in the region of Arequipa, Peru; districts that face a significant increase in crime. With populations of approximately 91,935 and 82,642 inhabitants, respectively, these districts have seen an increase in crimes such as robberies, vandalism, family violence and cases of alcoholism. In 2022, more than 1290 robberies and about 1038 cases of family violence were reported [17][18].

The growing concern among citizens and authorities is due to the inadequate and delayed response to emergencies, aggravated by the absence of a unified incident management system. To deal with this problem, Smart Muni was implemented, a comprehensive platform consisting of a web application, a mobile application for the sereno (municipal security officer) and a mobile application for the citizen. This solution seeks to improve coordination and efficiency in emergency attention, facilitating communication and incident management in the districts of Cayma and José Luis Bustamante y Rivero.

III. Platform Description

The direct users of the platform are citizens, serenos and municipalities (Fig. 1). Citizens use a mobile application to report incidents and emergencies, providing details such as location and multimedia information. Additionally, they receive notifications about their reports, access security information, use the panic button in emergency situations and consult the incident history.

For their part, the serenos, members of the citizen security corps, work to maintain order and security in streets and public spaces. Employed by local governments, such as provincial and district municipalities, their main function is to prevent and control risk situations, such as robberies, aggressions or disturbances. The serenos, using the corresponding mobile application, manage the incidents reported by citizens through geolocated alerts, resolving and updating them in real time, and they are monitored to ensure their location.

The municipalities use a web application to manage the platform. This web application allows attending to alerts or incidents and assigning them to the corresponding units, analyzing data in real time through advanced analysis tools to identify patterns and improve security, and sending notifications to citizens in a timely manner. Furthermore, municipalities can manage user permissions and access, integrate the system with other government and emergency entities, and continuously monitor all activities to ensure a quick and efficient response to any incident.

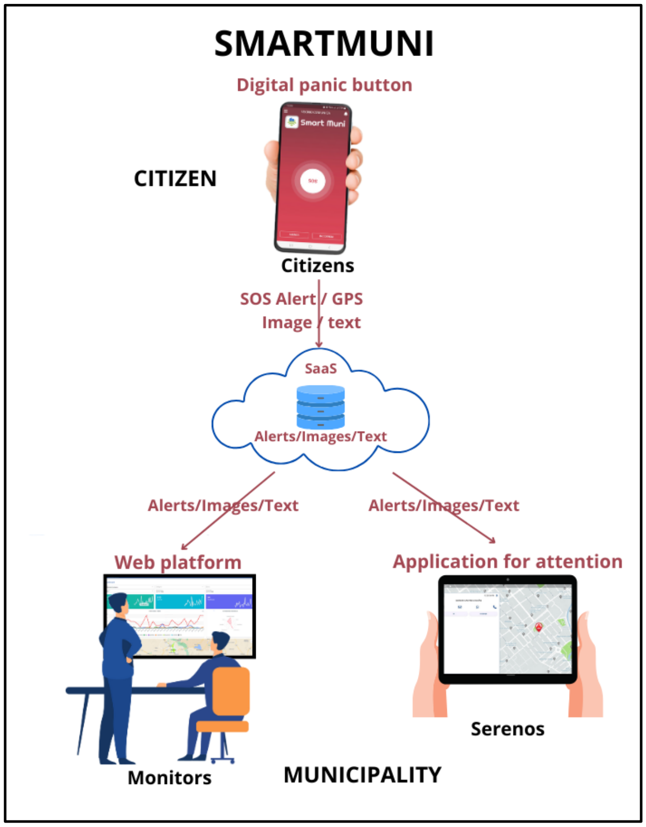

Fig. 1. Smart muni scheme.

A. Integration of Technologies

The platform architecture was designed and developed internally to ensure efficient control over the deployment and updating of the project. Fig. 2 shows the technologies employed in three key areas: data storage, message sending and deployment.

1) Data storage: For data storage, Amazon S3, PostgreSQL and Firebase Realtime Database technologies were used [19][20][21].

2) Deployment: Docker, Docker Compose and GitLab CI/CD along with GitLab Runner were used for developing, sending and executing containerized applications, facilitating continuous integration and delivery [22][23][24][25].

3) Web service providers: Web services were provided by DigitalOcean and GoDaddy, simplifying IT infrastructure and offering online tools for business [26][27].

4) Messaging: Firebase Cloud Messaging and Twilio were used for messaging and notifications, enabling communications on iOS, Android devices and web applications [28][29].

5) Development technologies: Django REST Framework, Quasar Framework and Flutter were used in the development of technologies, allowing the construction of web APIs, user interfaces and hybrid mobile applications [30][31][32].

6) Servers and middleware: Servers and middleware included Nginx, uWSGI, Let's Encrypt and Ubuntu UFW, providing high performance, security and firewall rule management on servers [33][34][35][36].

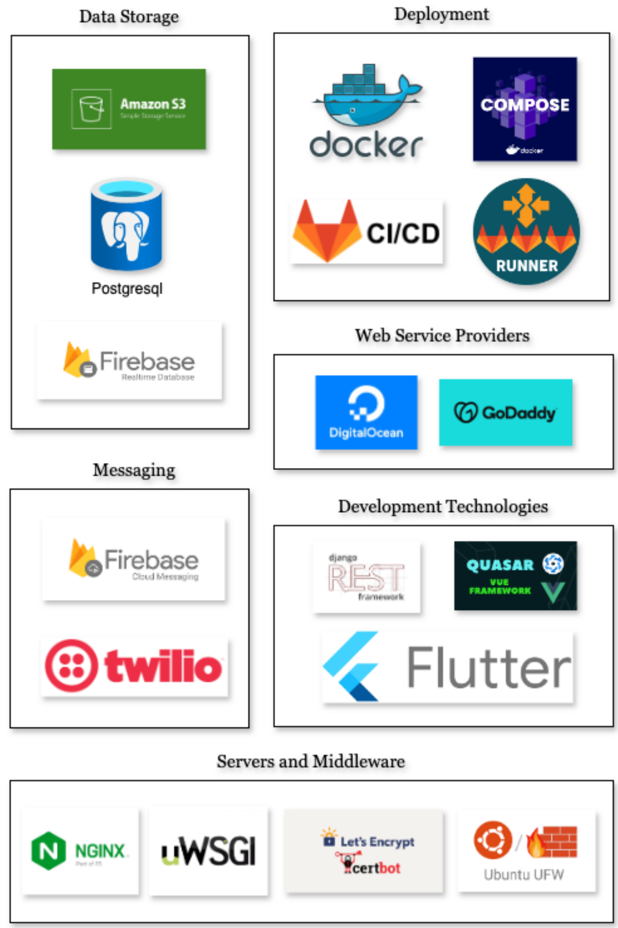

Fig. 2. Scheme of the used technologies.

B. Software Architecture

Fig. 3 shows the software architecture of the platform, integrating several external services and specialized databases.

The platform architecture is composed of the following elements:

1) Firebase services: Includes Firebase Real Time Database and Firebase Cloud Messaging for real-time storage and sending notifications to mobile devices.

2) Google service: Google Maps APIs for mapping and location functionalities.

3) Amazon service: Amazon S3 for file and data storage.

4) Twilio service: For communication and sending SMS messages.

5) GeoLite2 service: For geographic location of IP addresses.

6) PostgreSQL database: Used as the main data store.

7) Web services: This central component manages the interactions between models, controllers, views and the ORM. It is the system core that connects database and external services with the mobile applications and the website.

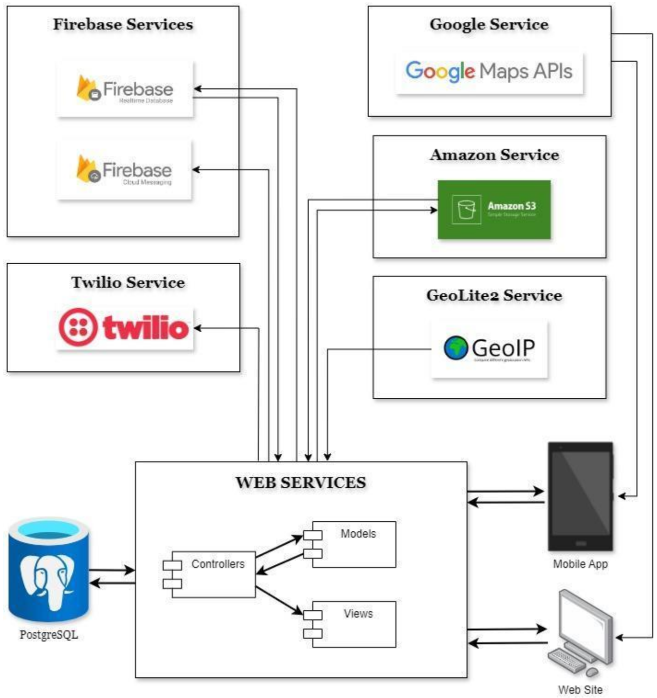

Fig. 3. Platform architecture.

This architecture allows the integration of several services and technologies providing a robust and scalable solution that supports both mobile and web applications. The web application uses Vue.js (progressive framework for building user interfaces) for client development, structured with VueRouter (library for handling navigation in Vue.js applications) for navigation and a Store (centralized solution for managing the state of an application) for state management (Fig. 4).

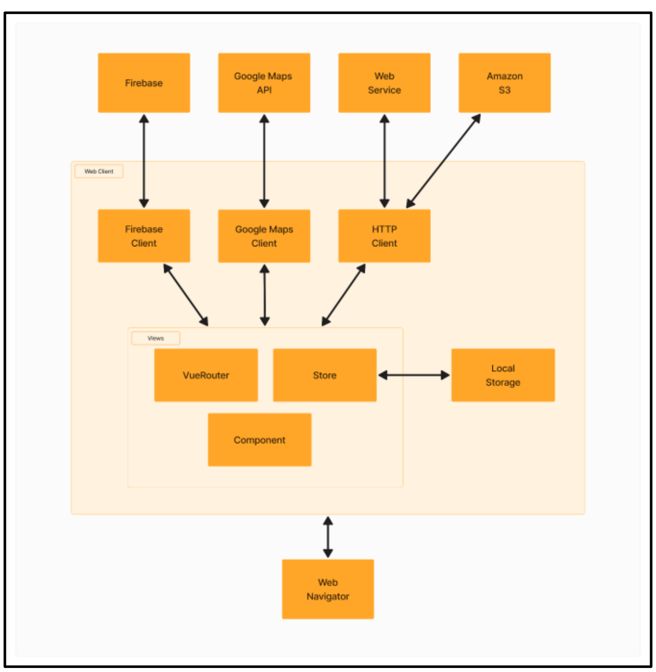

Fig. 4. Web architecture.

These components interact with Firebase for real-time databases, Google-Maps-API for maps, an API for data and Amazon S3 for file storage through specialized clients. The browser's local storage is used for session data. User interaction is performed through a web browser, communicating directly with Vue.js components for an interactive and dynamic experience.

For the mobile architecture (Fig. 5), Flutter (UI framework for creating native applications) is used with the BLoC design pattern to manage events and states. Flutter components communicate with Firebase for real-time databases, Google Maps API for maps and a web service to consume data from an API through specialized clients. The SharedPreferences library is used to persist data locally, and mobile services such as GPS and camera are integrated. The application, running on Android and iOS devices, interacts with Flutter widgets, efficiently managing resources and functionality.

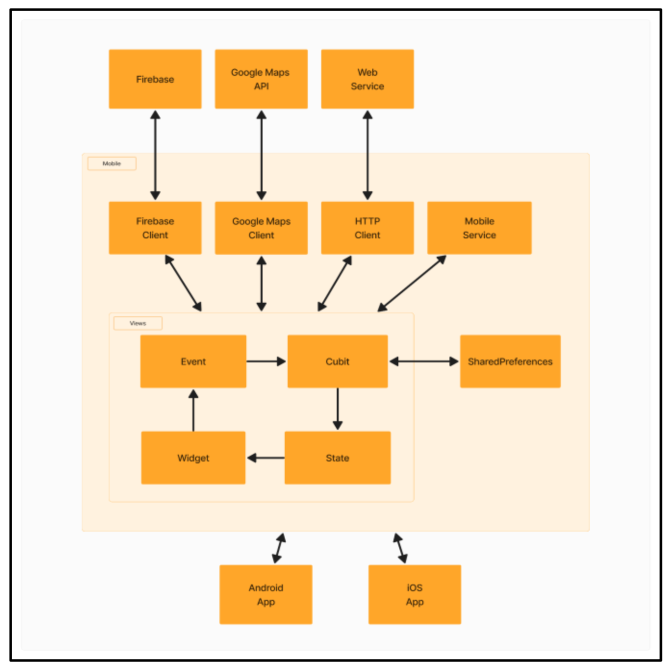

Fig. 5. Mobile architecture.

C. Navigability Diagrams

The web application allows the comprehensive management of various modules related to citizen security, including incidents, alerts, monitoring and events. Moreover, it facilitates the administration of venues, advertising, geozones and other municipal aspects, both on the part of the municipality and the administrators. The assignment of specific permissions according to account type is also considered (Fig. 6).

The mobile application for citizens (Fig. 7) allows the creation of accounts, sending alerts and generating incidents through an interactive map. Besides, configuration of profiles and the possibility of reviewing the history of alerts and incidents are also available.

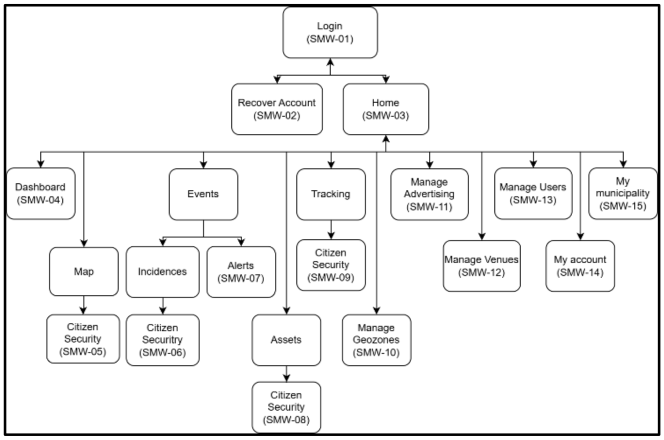

Fig. 6. Web application navigability diagram.

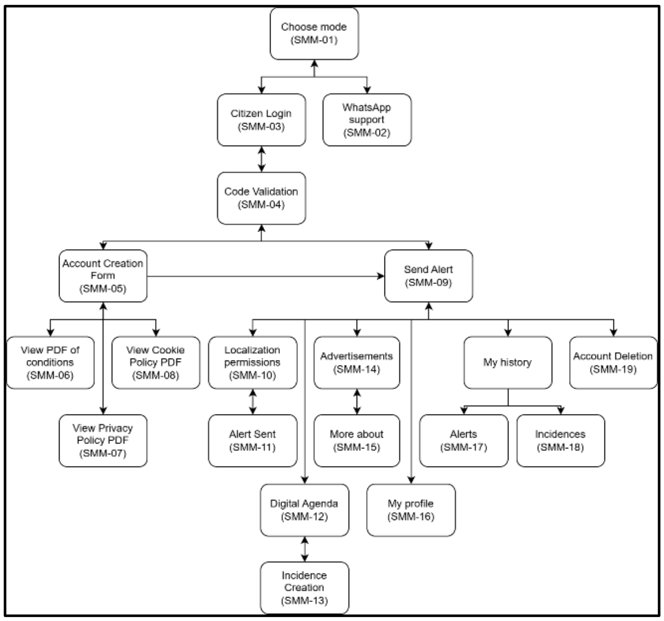

Fig. 7. Citizen's application navigability diagram.

The mobile application for serenos (Fig. 8) allows the configuration of profiles and locations, as well as the review of the history of alerts and incidents of all users. It also facilitates visualization of this information through PDF files.

D. Interfaces

The user interface is the point of human-computer interaction and communication on a device. Fig. 9 and Fig. 10 show main interfaces of the platform. Fig. 9 shows the main screen of Smart Muni web application, where an interactive map showing locations of different incidents and alerts in the city can be seen.

In this interface, alerts and incidents can be attended, as well as incidents can be filtered by their status (attended or not attended) and by type of incident (alert, family violence, alcoholism, drug addiction, robbery, vandalism, accident and others). In addition, monitoring by application is displayed, showing the number of workers, motorcycles, vans and other vehicles monitored in real time, as well as the number of cameras and sirens available.

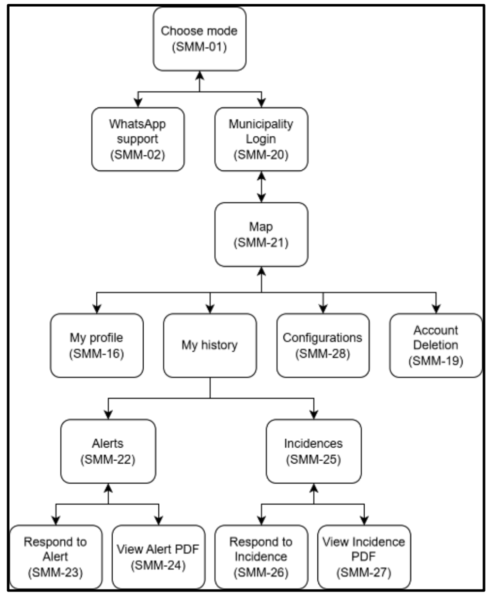

Fig. 8. Sereno's application navigability diagram.

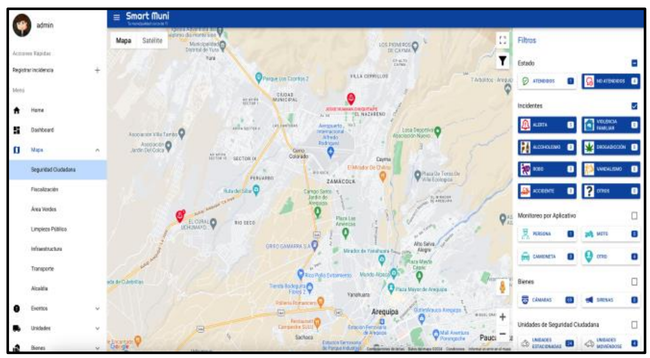

Fig. 9. Main interface of the control module and display of alerts and incidents.

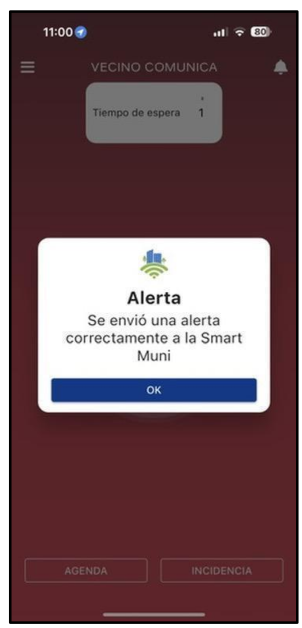

Fig. 10. Mobile app sending an alert.

Detailed interfaces can be accessed by clicking on: INTERFACES.pdf

IV. RESULTS

The implementation of Smart Muni in the districts of Cayma and José Luis Bustamante y Rivero has significantly improved citizen security, demonstrating its positive impact on management of emergencies and citizen reports.

Smart Muni in the district of José Luis Bustamante has been in operation since December 20, 2023, and in the district of Cayma since June 20, 2023.

The historical record made by the application is fundamental to evaluate the accuracy and efficiency of the system compared to the manual methods previously used, methods that, since they are not adequately regulated, have not allowed access to the historical data recorded manually. Data collection through the Smart Muni platform allows for the creation of a solid base of information to be analyzed over time. This continuous recording ensures data integrity, and also facilitates identification of patterns, trends and potential improvements in the process. The historical data collected by the application over one year (Table I) are evidence of the system's impact and evolution, emphasizing its capacity to generate accurate and consistent records that contribute to informed decision making.

TABLE I. NUMBER OF ALERTS AND INCIDENCES PER MONTH

Month / Year	Cayma	José Luis Bustamante y Rivero
August 2023	145	-
September 2023	128	-
October 2023	89	-
November 2023	93	-
December 2023	117	156
January 2024	56	99
February 2024	53	48
March 2024	117	71
April 2024	139	60
May 2024	161	68
June 2024	126	32
July 2024	209	49

Heat maps are visual tools that show data density in geographic areas. In citizen security, areas with the highest frequency of incidents are indicated using a color scale. This helps the authorities to identify “hot spots” for better allocation of resources and preventive measures. Fig. 11 and Fig. 12 heat maps identified critical areas in Cayma (La Tomilla Zone B and Señorial Urbanization) and José Luis Bustamante y Rivero (Estados Unidos Avenue and Vidaurrazaga Avenue), enabling efficient targeting of resources.

Table II presents 413 incidences received, the most common were family violence and alcoholism, with 148 and 144 cases respectively, facilitating a specific preventive approach. These results demonstrate Smart Muni's effectiveness in improving community safety and well-being through effective communication and comprehensive resource management.

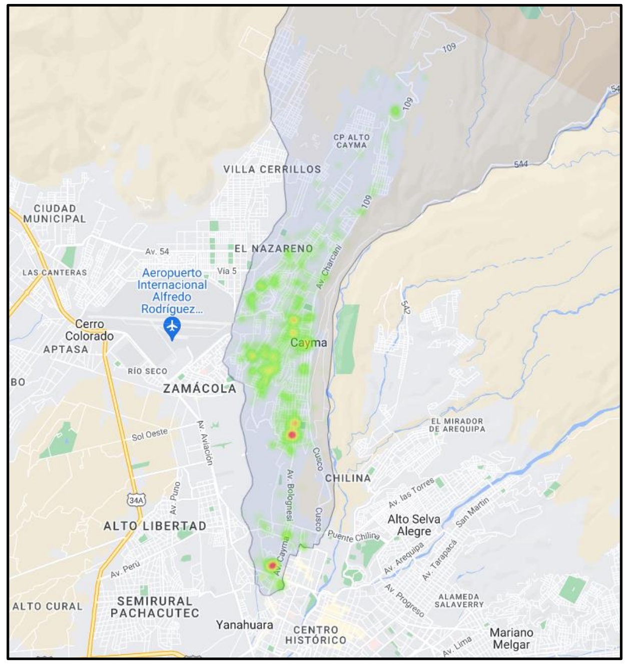

Fig. 11. Heat map of Cayma district.

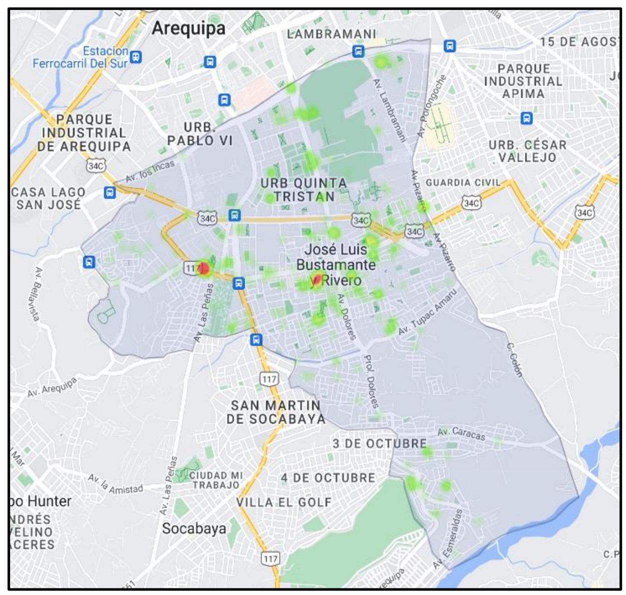

Fig. 12. Heat map of José Luis Bustamante y Rivero district.

TABLE II. NUMBER OF ALERTS AND INCIDENTS BY TYPE

Type of incident	Quantity	Percentage
Family violence	148	36%
Alcoholism	144	35%
Robbery	28	7%
Drug addiction	7	2%
Vandalism	7	2%
Accident	8	2%
Other	71	17%

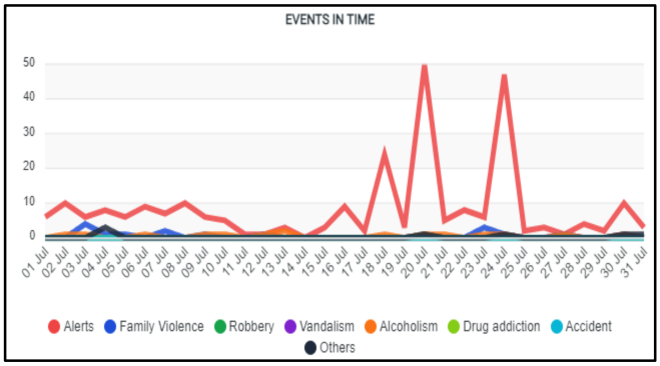

Fig. 13. Alerts and incidents graph in month with the highest activity.

Fig. 13 shows a graph illustrating the quantity of alerts and incidents recorded during the last year. The horizontal axis shows the dates, while the vertical axis shows the quantity of alerts received. Data analysis reveals the day with the highest number of recorded alerts reached a peak of 50, while the daily average number of alerts remained at 10. This graph displays trends and peaks in alert activity, providing a clear view of peak demand times and helping to plan a better response by authorities.

Fig. 14 shows a distribution graph of incident types reported through Smart Muni platform. This graph indicates that the most frequent incidence types are alcoholism and family violence, which stand out significantly over other incidence types. This information is crucial for authorities, helping to identify the areas of greatest concern and need for intervention, facilitating implementation of targeted strategies to deal more effectively with these specific problems.

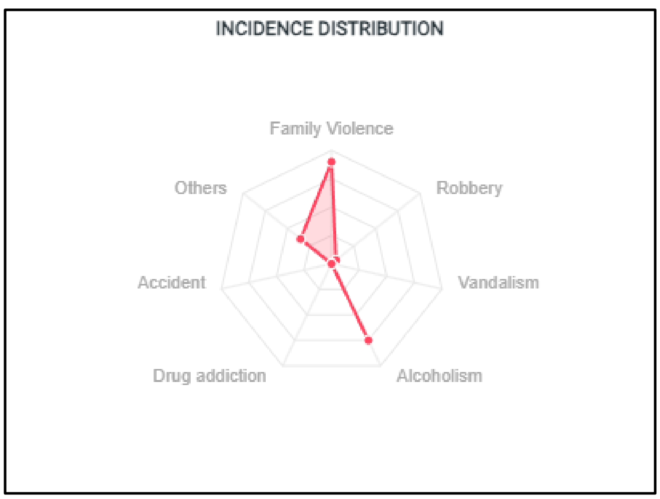

Fig. 14. Distribution of incidence types.

V. Discussion

The implementation of Smart Muni has proven to be an effective solution for emergency management and improving citizen security in the districts of Cayma and José Luis Bustamante y Rivero. The proposed platform, Smart Muni, as suggested by Liu and Li [13], uses geolocation and real-time communication technologies to enhance coordination between citizens and authorities. The implementation of tools such as the digital panic button and instant notifications has significantly reduced emergency response times, in line with recommendations of Liu and Li's study.

Smart Muni incorporates multiple layers of redundancy and uses cloud services such as Firebase and Amazon S3 to ensure data availability and reliability. Although this approach has proven to be effective, it is essential to continue to explore and improve the resilience of the system to potential failures, as suggested by Jesus et al. [14].

While Smart Muni shares similarities with several solutions reviewed by Costa et al. [15], particularly in the use of mobile applications for alert management, it offers significant advantages over existing systems. First, Smart Muni is designed to be highly scalable and flexible, making it adaptable to both large and small municipalities with varying levels of technological infrastructure. Unlike many international systems that are often cost-prohibitive for smaller cities, Smart Muni provides a cost-effective solution that is particularly suited to municipalities operating under budget constraints. Additionally, its integration of real-time communication through services such as Firebase and Twilio ensures a faster, more reliable response compared to traditional systems, which often suffer from delays due to manual processes. Moreover, the cloud-based architecture ensures high availability and data redundancy, critical for maintaining system functionality even in the face of failures, a challenge that many other systems do not adequately address. These advantages make Smart Muni an ideal solution for developing regions where emergency response systems are often underfunded and technologically underdeveloped.

One of Smart Muni's strengths is the implementation of a flexible and scalable architecture that quickly adapts to changing community needs and emerging challenges. This flexibility and adaptability are aligned with the recommendations of Samarakkody et al. [16], who emphasize the importance of dynamic and resilient systems to efficiently manage emergencies in complex urban environments.

Comparison with these previous studies has identified areas for improvement and opportunities for future research. Although Smart Muni has shown promising results in terms of efficiency and responsiveness, it is essential to continue optimizing the system's resilience to failures and exploring new technologies which can complement and enhance existing functionalities. Additionally, performing periodic evaluations and adhering to best practices identified in the literature is recommended to ensure the system remains effective and relevant.

VI. Conclusion

Smart Muni has demonstrated to be a viable and effective solution to improve citizen security through use of advanced technologies. The platform has optimized emergency management and has also strengthened the relationship between citizens and authorities, promoting a safer and more resilient community.

Smart Muni application was successfully developed and implemented, offering key functionalities such as incident reporting, geolocation, real-time notifications and digital panic button; these features have allowed for a more agile and efficient management of emergencies.

Multiple technologies were integrated, including Firebase, Amazon S3, Docker, and Twilio, among others, to guarantee a scalable and highly available system. This technological integration has permitted platform to handle large volumes of data and support fluid communication between different actors involved.

The platform has provided advanced analysis and monitoring tools, which have made it possible to identify critical areas and incidence patterns. This has facilitated a more efficient allocation of resources and implementation.

The work performed provided a solid base for future improvements and expansions of system:

1) Integration of security cameras into platform to enable real-time monitoring. This will allow authorities to view streaming cameras when a robbery is reported, ensuring a faster and more effective response.

2) Implement an option to make payments directly through the application, such as payment of municipal taxes and other municipal services. This will simplify the process for citizens and improve administrative efficiency.

3) Incorporate an intelligent chatbot to help solve users' doubts about use of application and other related issues. This will improve user experience and reduce workload for support staff.

4) Perform data analysis to evaluate security in areas within a 5 km radius, based on reports from the last 2 to 3 weeks. This will allow citizens to have a clear view of security in their area and make informed decisions.

5) Implement a function like a Facebook wall where citizens can interact anonymously, post incidents and respond to municipality publications. This will encourage greater citizen participation and improve communication between community and authorities.

6) Implement a messenger chat so the municipality can have direct communication with neighborhood councils, who are people in charge of supporting citizen security in a specific sector. This will improve coordination and response to emergency situations and security problems.

Despite its success, Smart Muni faced several challenges during its implementation. One of the main limitations was the need for continuous optimization of the system's resilience to potential failures, particularly in areas with unstable internet connectivity, which could affect real-time communication between citizens and authorities. Additionally, the platform's reliance on cloud-based services, while advantageous for scalability, also presents a challenge in terms of maintaining high availability in regions with limited infrastructure. Future improvements should focus on enhancing the system's ability to operate efficiently under these conditions and ensuring its long-term sustainability in municipalities with constrained budgets. Addressing these challenges will be critical for further expanding the platform's reach and impact in other regions.

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