Securing mobility in Bucaramanga: Road safety control based on a mobile application

Asegurando la movilidad en Bucaramanga: control de seguridad vial basado en una aplicación móvil

Garantindo a mobilidade em Bucaramanga: controle da segurança viária a partir de um aplicativo móvel

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Abstract

Introduction: The smart city paradigm is made up of a set of actors who must operate jointly to guarantee road flow. However, sometimes there are accidents, and they affect productive apparatus, cause minor or temporary injuries and sometimes death of the individuals involved.

Problem: Events occur for multiple reasons and the authorities have difficulties in implementing controls that minimize their occurrence since they do not have the necessary tools to capture and analyze timely information on the claims that have been presented.

Objective: The objective is to increase road safety control and safeguard mobility in Bucaramanga. For this, a mobile application is designed to capture accident data by implementing the Flutter framework and the Model-View design pattern methodology. Controller (MVC).

Methodology: The development of software to analyze the large amount of information on road events. A database is developed where said information is stored and processed using programming languages, coding and data hosting. Design and process factors are also considered according to the user's needs, which will determine the interface and expected performance.

Results: A structured system for data capture with the ability to integrate the general community, streamline the availability of information and facilitate decision making that deals with the problem in real time.

Conclusion: It is concluded that its implementation in the city fosters self-care for pedestrians and drivers, facilitating the design of effective control measures by territorial entities, bringing the city of Bucaramanga closer to sustainability.

Originality: This methodology for integrating events is unique in the country and is developed based on the city's own characteristics.

Limitations: The lack of information provided by the government actors.

Keywords: Road accidents, Road safety, mobility, sustainability, information / data management, App Development.

Resumen

Introducción: El paradigma de la ciudad inteligente, está conformado por un conjunto de actores que deben operar de manera conjunta para garantizar la fluidez vial, pero en ocasiones se presentan incidentes, que afectan el sistema de movilidad, ocasionando lesiones leves o temporales y en ocasiones muerte de quienes intervienen.

Problema: Los incidentes ocurren por múltiples motivos y las autoridades tienen dificultades para implementar controles que minimicen su ocurrencia ya que no cuentan con herramientas suficientes para capturar y analizar información oportuna sobre los reclamos que se han presentado.

Objetivo: El objetivo es incrementar el control de la seguridad vial y salvaguardar la movilidad en la ciudad de Bucaramanga y para ello se diseña una aplicación móvil para capturar datos de incidentes mediante la implementación del framework Flutter y la metodología de patrón de diseño Model-View. Controlador (MVC).

Metodología: El desarrollo de un software para analizar la gran cantidad de información sobre eventos viales, se desarrolla una base de datos donde se almacena y procesa dicha información utilizando lenguajes de programación, codificación y alojamiento de datos. También se consideran factores de diseño y proceso según las necesidades del usuario, lo que determinará la interfaz y el rendimiento esperado.

Resultados: Como resultado se obtuvo un sistema estructurado para la captura de datos con capacidad de integrar a la comunidad en general, agilizar la disponibilidad de información y facilitar la toma de decisiones que atiendan el problema en tiempo real.

Conclusión: Se concluye que su implementación en la ciudad de Bucaramanga fomenta el autocuidado de peatones y conductores, facilitando el diseño de medidas de control efectivas por parte de las entidades territoriales, acercando a la ciudad a la sostenibilidad.

Originalidad: Esta metodología de integración de eventos es única en el país y se desarrolla en base a las características propias de la ciudad.

Limitaciones: La falta de información proporcionada por los actores gubernamentales.

Palabras clave: Incidentes viales, Seguridad vial, movilidad, sostenibilidad, gestión de información/datos, Desarrollo de Apps.

Resumo

1. INTRODUCTION

In 2018, there were about 1.35 million deaths resulting from road accidents, of which 11%, i.e., almost 155,000 deaths, occurred in the Americas. This corresponds to a rate of 15.6% per 10,000 people, according to the WHO report submitted at the end of the aforementioned year [1]. These are similar rates to those submitted in Colombia in

2017, according to the report of road accidents in Ibero-America, where it was equal to 13.8% per 100,000 inhabitants, leading to a fourth place ranking in the list of countries with more deaths in 2017, which is led by the Dominican Republic [2]. The above figures are repeated year after year with few significant changes and this proves the problems faced by today's society in terms of mobility. Government administrations have not been able to develop policies, plans, or programs that influence the causes of the accidents that occur in the different territories due to the multiple factors such as the condition of the roads, the weather, the condition of the vehicle, the traffic rules of the area, the expertise of the driver, and the actions of the pedestrian. As one can guess, a single strategy or action is not enough to deal with all the factors influencing accidents, and if one implements any strategy without having the necessary knowledge, one risks leaving aside important and high incidence factors[3]. Furthermore, knowing the percentage of participation or the influence exerted by each factor is only possible if reliable and timely information is available. This is difficult to achieve because of the way in which the records are kept [4]–[6]. This is because with the current system it takes a long time to receive the information, given that reports are made manually by the traffic agents at the scene of the events. They are then taken on the following days to the traffic control centers where the information is received and digitalized. All these steps cause investigations to start with delays due to factors external to the incident itself, reducing the effectiveness and the efficiency of the investigative groups and other actions that may occur after the analysis of the accident, such as judicial, criminal, and governmental decisions. Therefore, the proposal is to formalize in an experimental model the conceptual framework for road safety management based on concrete data through the development of a system with a mobile application that transforms road accident data into useful information for decision making. Among its functions are the collection of relevant data from a road accident, by any citizen, for processing, analysis of the accident rate, and subsequent publication of results, facilitating decision making not only at the political-administrative level, but also by the individual when the possible results of his/her actions are disclosed. This information, generated by the implementation of the application, can also be useful for academia as, throughout its study, it will be possible to design actions that have a positive impact on society by reducing road accidents and increasing the safety of road actors, making Bucaramanga a sustainable city.

The general purpose of this article is to safeguard mobility in Bucaramanga through road safety control based on a mobile application. The specific objectives are: 1) To establish the functional requirements of the mobile subsystem for the collection of information. 2) To design the relational database of the mobile subsystem for the

collection of information. 3) To structure the mobile application system for the capture of information on road accidents in the city of Bucaramanga for the transformation of data into useful information for decision making through a mobile application. 4) To test the alpha and beta applications (real environment) for verifying its functionality and making the recommended and/or convenient adjustments.

1.1. Theoretical framework

In the following section we will find a theoretical approach to the programming for addressing the problems that many cities are currently experiencing with figures and data from the latest road accident report. In addition, ICT will be introduced as an effective tool for mobility management, showing models developed around the world with their functions and the solutions they provide, to finally end up by detailing the theoretical structure of the programming for the mobile application to be developed.

1.1.1. Road accident data

According to art. 2 of [7], road accidents are defined as "sudden and involuntary events that are mostly predictable and produce affectations in the person generating partial or permanent personal injuries and even death; regarding goods and vehicles, such events produce damages that sometimes are irreparable and on the roads they generate traffic jams and congestions causing delays when users try to reach their destinations and an increased fuel consumption by the vehicles due to the time they must operate to get out of the traffic jams." Therefore, these are events that are to be avoided at all costs, and to this end, the traffic departments of the cities have to implement several plans and programs to improve mobility. At the national level, the plans have not generated satisfactory results according to the forensic medicine report where an increase of 1.85% of injured people between 2017 and 2018 are reported; in addition, a rate of 13.8 in terms of death per 100,000 inhabitants is reported, which is lower than the average of America (15.6) and higher than the statistic for Europe (9.3) [8].

The report concludes emphasizing the importance of having performance indicators and for that end it is vital to collect and analyze data and figures on road crashes allowing the implementation of measures to improve mobility systems. In the local context, the city of Bucaramanga presents several positive results compared to the results for Colombia, since a decrease of 5% in the total number of accidents reported

for 2019 was shown, compared to the immediately previous period. This may be due to specific efforts made by the local administration and the Traffic Department [9].

1.1.2. Mobility management through ICT application

The implementation of new information technologies has helped solve specific and complex problems in different areas of a society up to the point of breaking paradigms and becoming agents of change in a community. Urban mobility topics have not been an exception. Outstanding studies of mobile applications that have enabled significant changes have been reported, such as the following series of studies that were conducted in Vietnam with the aim of knowing the incidence of factors such as unhealthy lifestyles and risky behaviors in the traffic accidents of motorcycle cab drivers based on applications [10]–[12]. The information was compiled from an online survey where the data on demographics, the work patterns, and the incidence factors of 600 drivers working in the three largest cities of Vietnam were obtained by applying a binary linear regression model. Among drivers who suffer accidents, the impact of factors was detected regarding education, distances traveled per day, unhealthy habits such as smoking or drinking, risky driving behaviors such as the use of cell phone, poor use of turn signals, lane encroachment, and others. The most outstanding aspect is the amount of information obtained from the mobile application, enabling real-time analysis, and a better understanding by the authorities, companies, and users about their behaviors and risks [13], [14].

On the other hand, Celesti et al [15], looking for an alternative to monitor traffic flow and alert notification based on OpenGTS and MongoBD, large amounts of traffic data were processed in real time, allowing users to have the possibility of receiving alert messages to avoid risks of possible accidents. Such alerts were useful for all kinds of vehicle drivers, especially rescue vehicles such as ambulances. A similar application along with a hardware prototype was developed by Ikram and Mahajan [16]. To prevent traffic accidents, a technique based on information technologies was developed. It alerts drivers with a buzzer and a message with the location of other vehicles that are within the range of the application, allowing their real-time location. It is a useful tool when maneuvers such as blind turns are required and/or when it's necessary to know whether a vehicle is traveling toward you at high speed. The main limitation of this technique is the range of coverage, and the system only detects vehicles that also have the application. Finally, in the development of the application performed by Nayak et al [17], it was found that it overcomes the previous design limitation as the application sends voice notifications when approaching or being around an accident-prone area

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using a GPS system that specifies the virtual boundary (a geofence). It has Google's opensource API (Application Programming Interface) and Firebase as the backend, which facilitates the storage of information in real-time databases. Such databases are the starting point to configure accident-prone areas in Google maps and after the areas are already configured, alerts can be sent to users who approach them. The user must have the application to receive the notification. All these developments allow us to appreciate the contributions made by the implementation of these technologies, guaranteeing the collection of information in real time, timely alerts, and even the handling of behavioral changes in users. Therefore, for this specific case we suggest the development of a mobile application to allow any user to collect information of road accidents, to centralize the information in a real- time database, analyze the common causes and patterns identifying areas more prone to accidents, and visualize the results of the investigations [18], [19].

1.1.3. Design and programming of mobile applications

Nowadays, mobile applications are creating a new style of technology, differentiated from desktop and web applications, which, although still important, have flaws in the design and adaptability issues in devices such as digital tablets and smartphones [20]. This has produced a considerable increase of device users to the extent that, by August 2017, there were more than 4 billion internet users who use mobile devices, who spend an average of 69% of their time using smartphones. This use covers more than 70% of internet consumption in the world, and 50% of that time is spent on mobile applications [21].

- Design Patterns. For the design and programming, a variety of factors such as performance, technologies, graphics, and storage must be considered, and they are aimed at providing a solution to the previously identified problem. In practice, solutions that start from scratch represent a considerable investment in economic resources and time. Therefore, selecting requirements from previous solutions is a feasible option. Taking into account the above, design patterns are introduced, which are defined as the description of a problem that repeatedly occurs in the environment, to which a solution can be applied an infinite number of times without doing the same thing twice. Patterns are described in 11 elements, namely: pattern name, purpose, applicability, structure, participants, collaborations, consequence, implementation, example code, known uses, and relational patterns [22]. The

MVC design pattern is used to build user interfaces in Smaltalk-80. It covers three aspects of a software application. Its acronym Model-View-Controller (MVC) describes the separation of the application data (Model) from the application interface (View) and the application logic (Controller) [23].

- Framework Flutter. This is a programming toolkit developed by Google. It has a single opensource code for the development of applications and from the same base and/or environments, it is compiled originally, for mobile, web, and desktop devices. It allows the use of a set of widgets and its structure is distributed in layers, allowing for a fast customization and rendering, with expressive and flexible designs [24].
- Performance. The performance of a mobile application is determined by more than one measurement because it sometimes may refer to raw speed and network speed or to UI (user interface) fluency and the lack of it. Jank term occurs when the UI is not fluently rendered. For example, a frame takes 10 times longer to be rendered, so it is discarded, and thus the animation is visibly shaken [25].

1.1.4. Design of the database

Databases are essential for the development of information systems, web applications, desktop applications, or any type of technological solution that is related to data, where the data can be a text or an image. Large databases are the foundation for the operation of applications such as Facebook, Twitter, and WhatsApp. There are two types of databases, namely relational and nonrelational. The former type is also known as SQL, which is an acronym for Structured Query Language [26]. As the demand increased, the SQL standard was extended from the relational model to include object-oriented language constructions, which is a programming methodology that defines the autonomous collections of data structures and routines that are called objects. However, with the increase of user demands, it became more noticeable that the relational language was insufficient to meet the actual demand. This reality makes data normalization a more complex process, as a result of this, nonrelational or NoSQL databases were created [27]. In fact, NoSQL DBs are characterized by having a collection of data that is similar but not the same, so there is no need to create new relationships to add attributes to the database collection objects. This allows them to be lighter and faster than relational databases [3], [28].

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1.1.5. Database management system

The database management system (DBMS) is an application that allows users to define, create, and maintain the database, as well as provide controlled access. It deals with the physical structure of data and their storage. DBMSs follow a model that is similar to the one used for program development with object-oriented languages, which makes an internal implementation of an object and a separate external specification. This means that users are not affected by internal implementation changes, as they only see the external specification [29]. Currently, there are many DBMSs that allow for the creation, the management, and the administration of databases, as well as many that specify structures used for storing data and searches. According to the management system, a certain number of tools can be used, such as serverless transactions, security system, data integrity, and consistency. Among the best known are MySQL, Baria Db, SQLite, PostgreSQL, SQL Server, and Firebase real-time databases. The first one is the most used one because it is free, and the latter is exclusive to Google, which is characterized by being opensource [30], [31]. Annex A shows a comparison of the properties of the mentioned management systems.

2. MATERIALS AND METHODS

The development of a program that manipulates a considerable amount of data requires a database where such information is stored and processed by programming languages, coding and data hosting. Additionally, design and process factors must be considered according to the user's needs, which will determine the interface and intended performance.

2.1. Design factors

The development should take into account functional design factors of the open data processing system for road safety, which will be useful for research and administrative decision making.

2.2. Process factors

A number of requirements are defined, such as power, for the system to operate on any cell phone or tablet compatible with Android or IOS. The power consumption is like the one used to check a chat application or to open Facebook. This has been

considered as a performance factor of the application. Through the Flutter application, a performance of 60 frames per second (fps) or 120 fps is provided for devices with 120 Hz refresh/updating needs. For 60 fps, frames are rendered approximately every 16 minutes.

Input requirements: a form is needed to allow user registration to the system and another one to report registrations to the database in real time.

Other requirements for the operation of the system are an arrangement or DBMS, a database server, a backend and frontend developer, a server connection, and a data hosting service to ensure the continuity in the supply. This service should be obtained, but it is not very expensive. Additionally, as part of the operation, the labor aspect must be considered, which is nothing more than users with the capacity to interact with information and communication technologies.

2.3. Methodology

Through the MVC design pattern and using the Dart package, mvc_aplication in the Google Flutter SDK, we obtain by default stocks of tools. This packaging provides a reference of applications that offer common functions and features for the design of cross-platform mobile applications. Thus, a new way is achieved for looking at applications in terms of performance, since the use of Dart as Google's application language with a Framework Flutter enables a focused approach to improve the performance of ATA time code (AOT).

In the development, an improvement between 10% and 20% in microbenchmarks can be observed with Dart 2 Common Front-End. The new language features allow for performing functions when writing the script set using literal sentences. Additionally, the load speed is improved during the execution and development process due to improved code writing. Enhanced widgets from the code facilitate a clean and native development of the application. In the application compilation, the efficiency of perfect pixel IOS and Android is appreciated to help the native application. As the coding progressed, the Dart language was applied to the set of material and Cupertino widgets to test the UI.

2.4. Database selection

According to the types of use defined in Section 2.4, the NoSQL database is selected because: It is multiplatform, it can be used in mobile devices, it allows database scaling and the decentralization of information, it performs analytical tasks, and it does

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not require a complex infrastructure. Additionally, this selection is made taking into account future adaptations that the application may have within the framework of a scaled project as it allows access to the creation, modification, and/or suppression of parts that may eventually become unusable, generating an optimal performance on the same data management.

2.5. Selection of DBMS

DBMS manipulates every aspect of the information without affecting the user, so choosing an appropriate one facilitates tasks such as triggers, user management, user authentication method and authentication recovery [32]. A review and comparison were made of some nonSQL DBMSs [32], such as MongoDB [33], Apache [34], Cassandra [35], CouchDB [36], Redis [37], Neo4j [38], and Firebase [39]. The comparative summary can be found in Annex A. After comparing their properties, Firebase was selected as the appropriate system, since Google provides all services, including tools for failure analysis, testing, statistics, and projection. In addition, it has a wide range of instructions and manuals that facilitate its implementation.

2.6. Implementation

For the design of the Road Accident Application, the users and 'the behavior that each user-role and their interactions should have' were defined. Such roles are "administrator", who acts on the application permissions; creates the agent profiles; and modifies incidents by some type of causality, and the traffic agent. The latter is an account verified by the administrator with the permissions to create the claims, assign the vehicles involved, and the penalties they can receive. The next role is accident verifier, who is an actor with permissions to follow up incidents. They are typically represented by the traffic agent verifying the process. The final role is the driver. This is a generic standard user with permissions to view the information and status of a claim assigned to a license plate. The users and their functions according to the roles are grouped in a "use case" diagram presented in Figure 1.

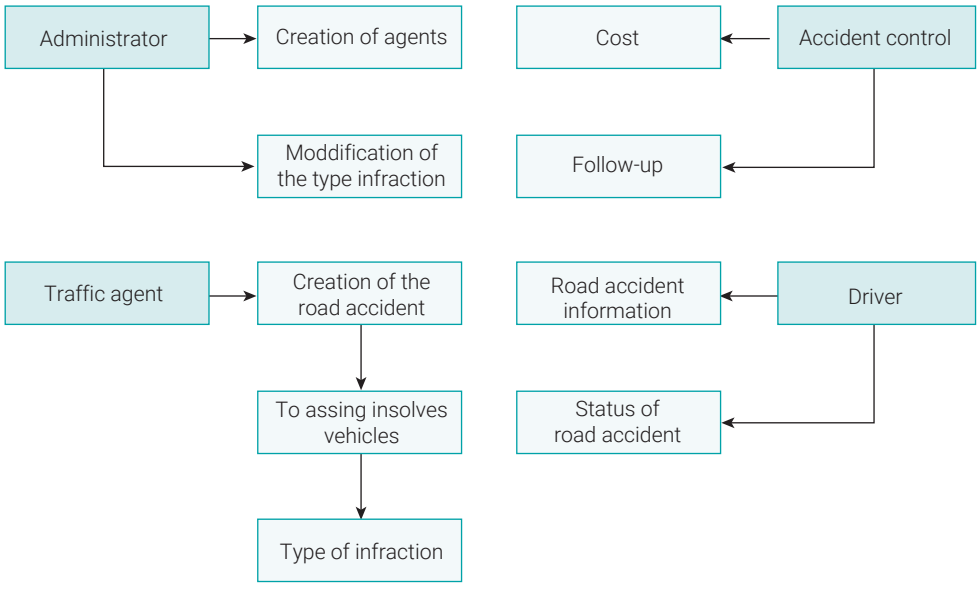

Figure 1. Diagram of the use case.
Source: own work

The initial structuring and modeling were based on a relational database, with phpMyAdmin data manager with XAMPP control panel version 3.2.2, which was later analyzed and compared with Google's Firebase NoSQL database. The latter was considered the ideal one for the development of the application, so the Realtime engine was migrated to Firebase's Cloud-Firestore. This is because it offers better scaling opportunities. It is important to highlight that the modeling of NoSQL databases is not a common practice yet. The databases are related by means of an identifier, as a JSON would do in programming having the Key=>Value. These can be dynamic data, even in Firebase itself, due to the fact that it offers predetermined data types which can be used in development. With Cloud-Firestore engines, the same document can create a new collection that in turn can have other documents thus linking the data that are necessary without the need to normalize data. Since they are within the same "source," they do not generate data redundancy.

The design of the relational model begins with the creation of the source code, which can be seen in Annex B. The indicator table or primary key is the one that has more relationships, such as the "road accidents" table as it is the one that is composed of different fields that are annexes of other tables to complete the functional process. This generates a logical order recorded in the data. Different tables that go along with the process of generating the road accident claim can be seen. One of them is the "vehicles" table. The license plate attribute is the main one of the tables, and it displays a

series of informative data such as the owner, model, vehicle type, color, and insurance (SOAT) number. This set of data is part of the information history that will be saved in the events to be recorded. Similarly, the interactions in the person and intervention tables are set up, creating an optimal set of tables so that the database management system does not display errors while performing operations. The entity-relationship model shown in Figure 2 is then created.

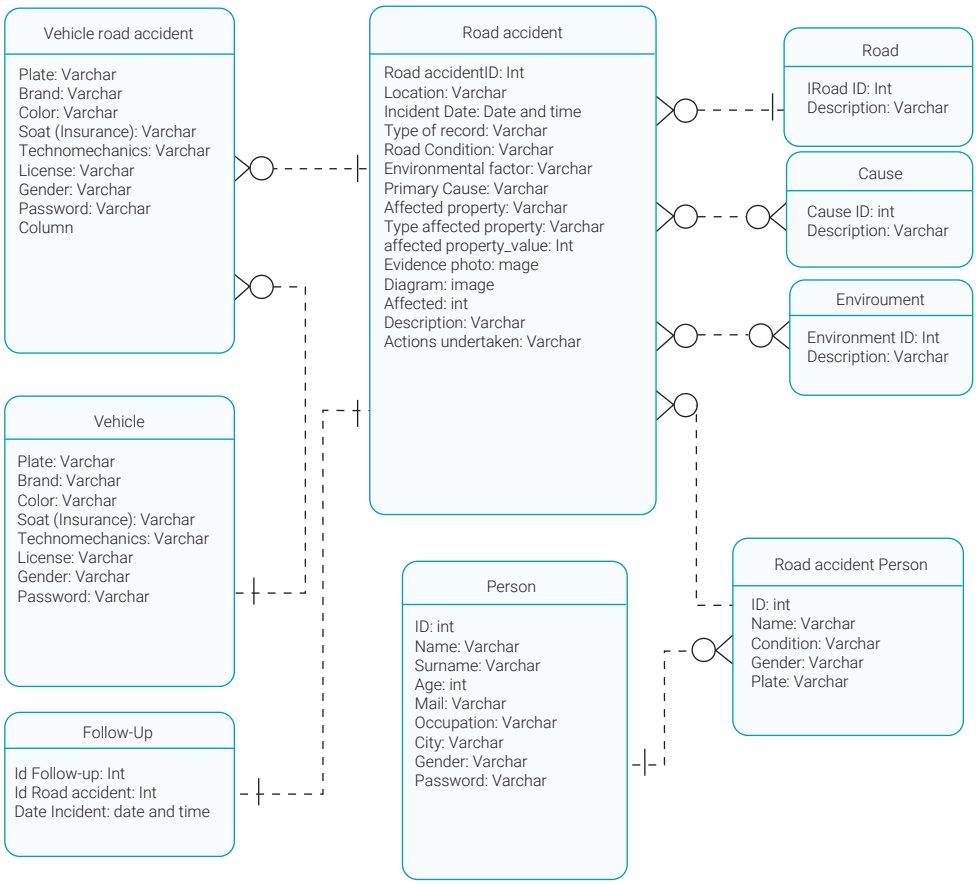

Figure 2. Entity-relationship model.
Source: own work

According to the relationships established above, the following prototype of the data collection is created:

- **ROAD ACCIDENT,**

cause_road accident city, environmental_conditions, road accident_description, path_description, road _status, date, time, road accident_ id:

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- **INJURED_PARTY/PERSON,**

type_docum_id, id_injured_party, surname1, surname2, name1, name2, age, sex, license_categoty, residence_address, education, resid_municip, ocuppation, type_actor_road,
expenses_health_by_road accident, is_hospitalized, survives_road accident, days_hospitalization, alcohol_percentage, drugs, was using_cell phone, helmet_use, seat belt_use, medicines_uses,

- **INVOLVED_VEHICLE**,

color, vehicle_condition, tires, lights

- **INSURANCES**

non-contractual_insurer, soat_ insurer, non-contractual_policy_number, soat_ policy_number, non-contractual_policy, last_review, last_oilchange, id_vehicle, brand, model, plate

- **INTERVENTION**

suggested_control, cost, review_date, intervention_id, other_accidents_ happened_insitu, post-intervention_review, road accidents_were avoided, control_was implemented, re-intervention_was implemented

With the defined entities and models, the development of the mobile subsystem of road accidents for Android devices is done following the MVC applied to mobile devices implemented in the Framework Flutter, which provides facilities for the creation of multiplatform mobile applications with high performance using the same source code, which optimizes the design time. The source code of the project logic is located in the GitHub repository, at the following link: https://github.com/fredytellor/siniestros_app

3. RESULTS

The social problem resulting from the accident rate on urban roads in cities is verified, and it produces a considerable number of injured people (39,537) and casualties (6,879) in the country[8] compared to the previous year (40,115 and 6,754, respectively), which evidences that it is a complex issue because many factors are involved as described above. Therefore, a conceptual framework was developed through the design of a mobile application for the management of road safety, which allows for

the collection of relevant data from a road accident by any citizen, to obtain, in an agile way and in real time, data on road accidents, reducing the periods of processing and the analysis of the corresponding entities. To verify its usefulness, alpha and beta functionality tests were conducted by collecting information from some road accident claims generated during the period from July 15, 2020 to July 21, 2020 to be processed in the mobile application developed [40]. The data found can be seen in Annex C.

To generate the road accident report, the data are recorded in a similar way to the traditional paper format, which facilitates the transition from the traditional method due to the knowledge of the information to be entered. The difference lies in the order of the information. The data are stored in the Firebase database together with the evidence taken from the application about the incident and, as they are saved, they are created with a unique incident code. Additionally, the application groups them by order of entry or date, which is a mechanism that facilitates the search for the incident. Upon entering the application, you will find a simple interface as shown in Figure 3, and Figure 4 presents the list of searches for road accidents.

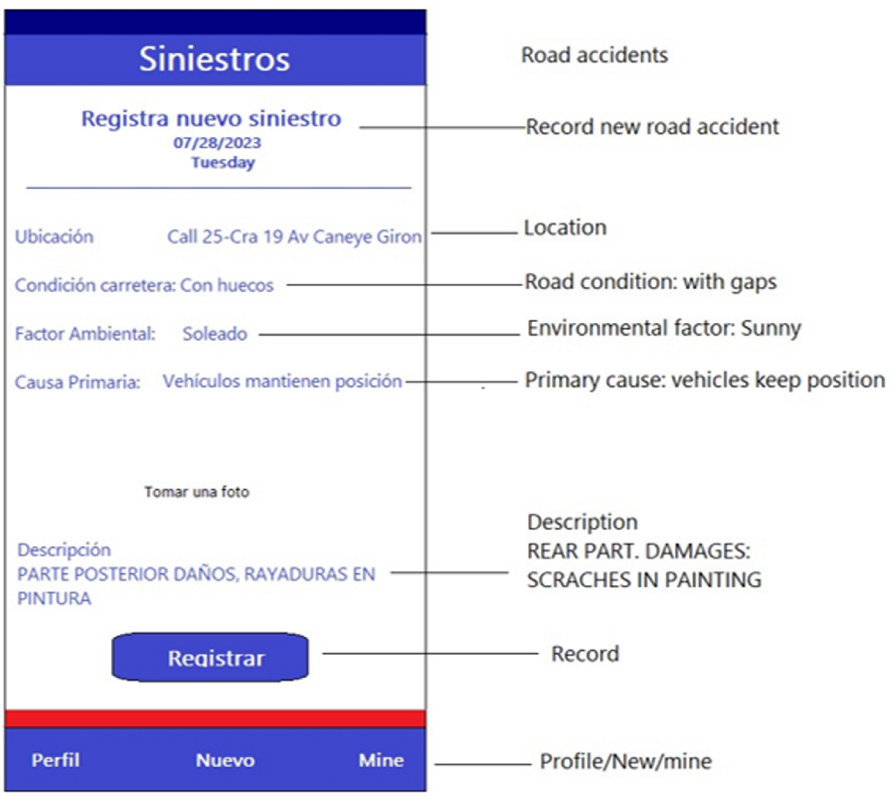

Figure 3. Interface for road accidents claims record.
Source: own work

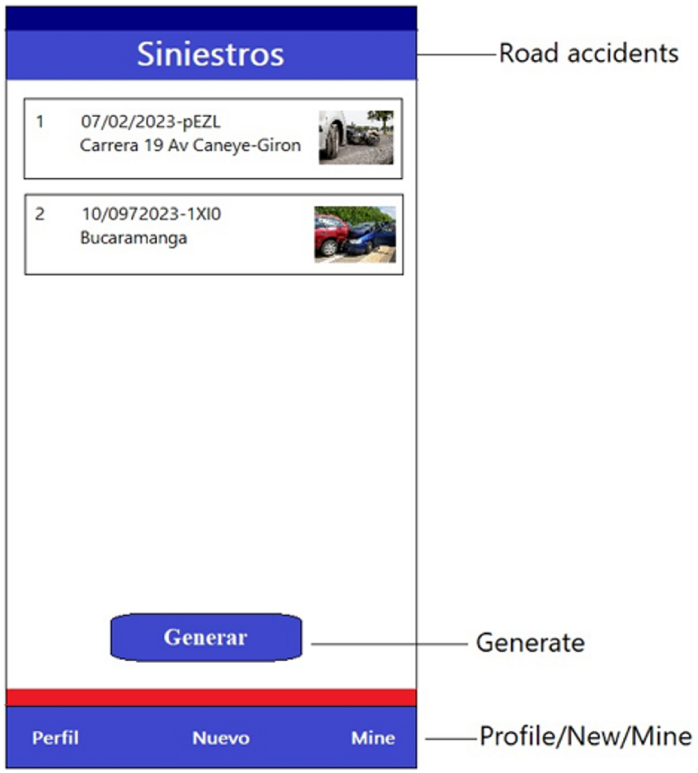

Figure 4. History of reported claims.
Source: own work

As it can be observed, the interface contains only the necessary elements for the recording of the incident, allowing the user to record each important aspect, such as license plates, people involved, their condition, status, and probable cause. Also, by including photographic entries as an integral part of the record, the user can corroborate any doubt or hypothesis based on this information. For each record it is possible for the application to create a file in PDF format together with the photographic evidence, if available, as shown in Figure 5. This file groups all the information recorded for the incident, helping the user to check its details.

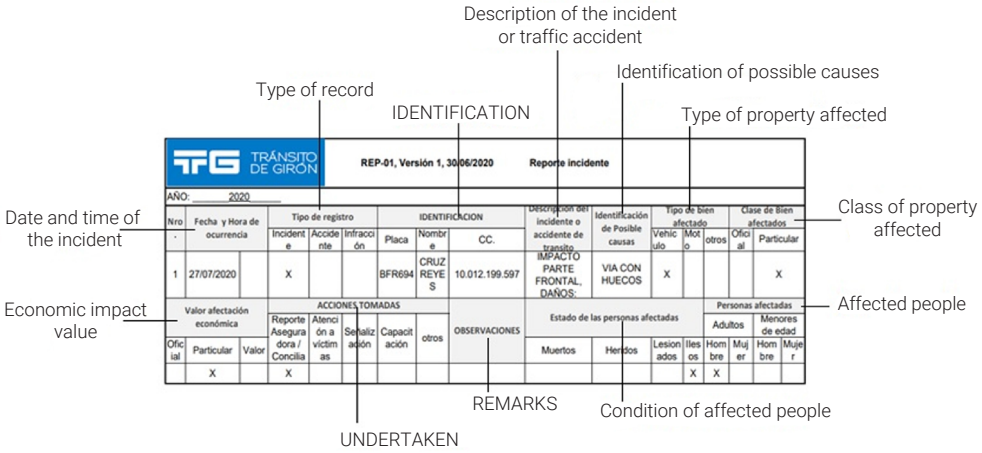

Figure 5. Road accident report.
Source: own work

The user who generates the report will be able to have, in a single file, all the information corresponding to the road accident, such as vehicle identification, road condition, affected parties, their condition, and the actions that were taken or are being taken at the moment. This way of summarizing information can streamline the report and investigation process.

4. CONCLUSIONS

The literature surveyed and cases of applications found allowed us to demonstrate the capacity of mobile applications to address the mobility problem in terms of road safety for the city of Bucaramanga.

The developed application has the capacity to provide useful and timely data, promoting the creation of effective measures and the generation of cultural changes in the community, to increase road safety controls in the city of Bucaramanga.

The requirements were established in accordance with the current regulations on accident reporting and investigation, identifying four roles for the application: administrator, traffic agent, road accident verifier, and driver.

The database was created based on the definition of different roles, with their attributes and relationships, and NoSQL databases were considered to be the most suitable for the optimal functioning of the application.

The application system was designed using the MVC design pattern that formed the basis for the development of the mobile application, which was essential

to ensure optimal operation and performance by implementing the Flutter framework and Firebase database management system.

The functionality of the application was verified by registering road accidents that occurred nearby, in the metropolitan area of Bucaramanga, within the framework of the development of alpha and beta level tests. In these, users found an intuitive system with similarities to the traditional method, something that would facilitate the transition from one method to another. Additionally, some aspects that need to be improved were identified, such as the possibility of registering two or more vehicles per road accident and the personal information of the affected persons besides the driver.

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