Towards Improving Urban Mobility With Crowdsourcing Incident Data

Carlos V. Chavez
Department of Computer Science
The University of Texas at El Paso
El Paso, Texas, USA
cvchavez2@miners.utep.edu

Emiliano Ruiz
Department of Civil Engineering
The University of Texas at El Paso
El Paso, Texas, USA
eruiz37@miners.utep.edu

Adrian Gomez Rodriguez
Department of Computer Science
The University of Texas at El Paso
El Paso, Texas, USA
agomezrodr@miners.utep.edu

Itzel Rivas Pena
Department of Computer Science
The University of Texas at El Paso
El Paso, Texas, USA
ierivaspena@miners.utep.edu

Sandra Barba
Department of Computer Science
The University of Texas at El Paso
El Paso, TX, USA
ssbarba@miners.utep.edu

Victor M. Larios
Smart Cities Innovation Center
CUCEA, Universidad de Guadalajara
Guadalajara, Jalisco, Mexico
victor.m.lariosrosillo@ieee.org

Natalia Villanueva-Rosales
Department of Computer Science
The University of Texas at El Paso
El Paso, Texas, USA
nvillanuevarosales@utep.edu

Oscar Mondragon
IMSE Department
The University of Texas at El Paso
El Paso, Texa, USA
oamondragon@utep.edu

Ruey Long Cheu
Department of Civil Engineering
The University of Texas at El Paso
El Paso, Texa, USA
rcheu@utep.edu

***Abstract*— This paper describes our efforts towards improving commuter safety in urban areas by using both historical and real-time crowdsourced data about safety incidents. Our goal is to better understand (personal) mobility safety by enabling the collection of data through IoT devices as well as by informing commuters about at-risk areas and providing alternative commuting routes. The implementation of this project includes the creation of a mobile device application that informs residents of the occurrence of incidents in their proximity. The user-provided information serves the function of not only alerting users about these occurrences, but additionally to assist residents in the making of safe mobility decisions. The current prototype is capable of collecting data involving emergency alerts and user-provided reports. The collected reports are organized into three different categories: (1) criminal activity, (2) perceived danger, and/or (3) suspicious activities. In the next iteration, the plan is to integrate the historical occurrences of a variety and multiple events into a composite mobility index. Users of the application can then make use of this index to determine the safest routes. Our approach aligns with the concept of Smart Cities, in particular with Smart Mobility, where solutions consider the use of technology and data to improve the quality of life of city residents. We believe that efforts towards providing different perspectives and reuse of data are important to address new demands in urban environments and convert them into Smart Cities.**

Keywords—safety, security, mobility, crowdsourcing, Smart Cities

I. Introduction

Research and application in transportation routing and mobility traditionally consider elements typical to the transportation domain including efficiency, resiliency, and level of service. However, due to increased danger, safety and security concerns relevant to mobility must also be taken into consideration [1]. During the urbanization period of the Guadalajara Metropolitan Area (GMA) in the Mexican state of Jalisco, the composition of the municipalities of Guadalajara, Tonala, San Pedro Tlaquepaque, El Salto, Tlajomulco de Zuniga, and Zapopan has resulted in an amounting population close to 4.4 million. This rapid settlement, in addition to the unique location and socioeconomic context, has contributed to the overcrowding of the urban area. Along with this comes security concerns to which government institutions are finding difficulty in providing comprehensive solutions. The National Survey on Victimization and Perception of Public Security (ENVIPE) conducted by the Institute of National Statistics and Geography (INEGI) [2], found that in the State of Jalisco the percentage of the adult population feeling unsafe has been maintained between the extremes of 61.5% and 75.9% in 2012 and 2013, respectively (See Fig. 1). However, events reported in 2018 established an insecurity perception of 73.6% with projections to increase in the following years.

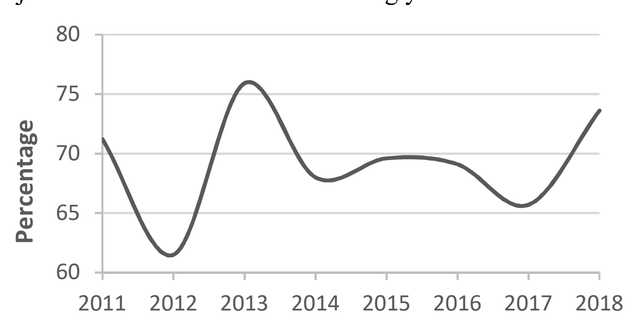

Figure 1 Jalisco ENVIPE results

As of September 2013, INEGI conducted the National Survey of Urban Public Security (ENSU). In comparison to ENVIPE, the objective of this survey involves obtaining information for the derivation of representative estimations on the perception of public insecurity, specifically within an urban environment. Additionally, ENSU is responsible for the identification of the public spaces with higher perceptions of insecurity, the quantification of the most common experienced/witnessed criminal occurrences, the determination of the level of performance of public authorities, and the estimation of habitual changes due to fear of crime victimization. These additional statistics are obtained with the purpose of collecting information fundamental in the making of public policy. Authorized by the State of Jalisco, the Institute of Statistical and Geographical Information (IIEG) has analyzed the 2018 data provided by ENSU, and has summarized the findings for the GMA, as listed below [2].

- 77.1% of the adult population feel unsafe, representing an increment of 3.5% compared to the percentage of Jalisco in general.
- 55.3% of the population found themselves obligated to stop carrying valuable items.
- 50.0% prevented minors from leaving their personal residences.
- 47.3% avoided walking at night.
- 29.6% stopped visiting friends or relatives outside their familiar zones.
- 46.7% of the population opinioned that in the following 12 months (December 2019) the crime rate will remain the same or intensify.
- 71.9% consider the government as a limited or inefficient source in the resolution of the challenges affecting the GMA.
- 82.9% of women perceive the city as insecure, while 70.1% of men feel the same sentiment.
- 53.4% of the population 18 years of age and older experienced at least one altercation.

These statistics demonstrate that an alarming paradigm exists between the quality of life and the existing services provided to safeguard that quality. To mitigate this paradigm, the government of the State of Jalisco initiated a program focusing on the student population, as a result of the increasing crime susceptibility in the vicinity of educational institutions. The plan, presented under the solicitation of the Federation of University Students (FEU) from the University of Guadalajara (UDG), proposes the incorporation of "*senderos seguros (safe corridors)*" in the municipalities composing the GMA. A *safe corridor* may be defined as a corridor that is protected and guarded by the community through an established synergy composed by neighbors, merchants, parents, faculty, and authorities, in order for students to attend and return from their institutions without becoming victims of violence and delinquency during their mobility. The solicitation was deemed necessary after encountering that the type of delinquent events to which these individuals are more vulnerable include assault, sexual harassment, homicide, rape, kidnapping, physical aggravation, femicide, and sale and abuse of substances [3].

A field visit to the community within the corridor incorporated in the municipality of Guadalajara referred to as *"Unidad Modelo (Model Unity),"* provided the authors with an additional tool in the understanding of the societal context to be addressed. The visit, in addition to an open discussion between stakeholders including students, government institutions, neighborhood representatives, school officials, and the police resonated that although a sense of community has been acquired through programs designed to instill trust in these government initiatives, significant progress has to be made to safeguard the security within the municipality. The combination of insufficient security personnel, low-income households, inadequate street and pedestrian infrastructure, limited transportation options and inadequate alarm systems represent only a few of the factors that influence the persistence of delinquency events in *Unidad Modelo*.

The first use case of this project includes the selection of *Unidad Modelo* corridor as a testbed for a mobile application that uses the smart city concept of IoT to facilitate the collection and sharing of data among stakeholders. Our team is to work with the stakeholders to transform *Unidad Modelo* into a safe corridor as part of the contribution to make the GMA a Smart City. In this research, Smart Cities is defined as the integration of technology and humans to enhance the productivity, sustainability, and efficiency of services and resources for the improved quality of life of its residents. Under this normative, the proposed Safe Commuting System (SCS), utilizing people as sensors, takes crowdsourcing as an advantage for the acquisition of information regarding incident occurrences. Our project aims to the following research questions:

1. ***How can IoT devices contribute to understanding (personal) mobility safety?***
2. ***How can mobility safety risks be modelled with crowd-sourced data?***
3. ***How does personal mobility information of crowd-sourced, and public agency data, contribute to mobility safety metrics?***

The data entries stored in the system, will in the future, serve as input for an algorithm for the generation of a safety index which may then be used to calculate the safest routes. The remainder of the article is separated into the following sections: literature review, methodology, discussions, future work, and conclusion.

II. Literature Review

One of the biggest concerns regarding Smart Cities involves Smart Mobility. Although this domain primarily involves the transportation of people and goods, as the expansion of the world's urbanization continues and people change their lifestyles to reside in these sprawling environments, safety has evolved into an additional Smart Mobility component that has yet to be well-integrated into the solutions proposed to better the quality of life. Some cities have moved forward into providing adequate technology and transportation infrastructure to safeguard commuter safety. As a result, this has created a clearer notion that the main threats posed against mobility in the remaining cities include security, and the lack thereof. In practice, there are numerous systems and mobile applications used as tools for the generation of secure routes and the provision of safety tips or criminal incident reports. The main problem is that there is not a single one that incorporates all services into the same platform. As noted in the comparison of application services in Table 1, different from SCS, the maximum services provided by competing models are only two capabilities. It is noted that the asterisk (*) represents a feature to be introduced in the next iteration. The main distinguishing feature of our proposed system compared to the current systems in Table 1, is the data collection process and the purpose of collecting such data.

Table 1 Application services comparison

Service	System				
	SCS	***SP***	***Avisora***	***Waze***	***IPN***
Panic Alert	X				
Event Report	X		X	X	
Route Generation	*	X		X	X

For example, in the United States, the open government and data initiative articulated under President Barack Obama's administration provided public access to datasets for the contribution of innovative solutions. Such is the case of a case study using crime datasets from Chicago, Illinois and Philadelphia, Pennsylvania for the generation of safe, urban navigation. Safe Paths (SP), the developed system, through a risk analysis model, calculates the probability that a crime will occur again. An algorithm then generates a route based on the calculated risk [4]. In Mexico, a similar study from researchers at the National Polytechnic Institute (IPN) predicts the safety of routes by integrating both historical data and crowdsourcing information, and semantically classifying them utilizing Bayes Algorithm [5]. Although both of these systems generate safe routes generation, only IPN incorporates crowdsourcing information. One problem associated with crowdsourcing is the validation of the information compiled from social media because there is no way to verify the veracity of the reports. In addition, the government is unable to provide real-time data. The above shortcomings affect the perception of safety within the route.

In comparison to these systems, Avisora and Waze represent two crowdsourcing mobile applications which have already been implemented in large scales and are currently publicly available for download in multiple operating systems. Avisora is a tool that in spite of providing the platform to report a variety of incidents, users mostly report infrastructure necessities such as public lighting, potholes, and obstruction of the public right of way. On the other hand, Waze utilizes solely the reporting of traffic events from users for the generation of faster rather than the safest routes. While both applications make use of user-reported information, they are designed for a specific purpose different from providing users with safety information for making rational and informed mobility decisions.

III. Methodology

This section provides details on the progress towards the creation of the SCS system as well as anticipated features.

A. Prototype Architecture

The prototype architecture of the SCS involves three distinct stages composed by both the backend and frontend development of the mobile application. These stages are separated into *data collection*, *storage*, and *visualization*. The stages and their relationships are illustrated by the system description diagram in Fig. 2.

The *data collection* stage of the system is the gathering of data via crowdsourcing, which as previously mentioned, involves the use of individuals as sensors to collect valuable information in the generation of innovative solutions. This crowdsourced data is collected directly from individuals using the prototype application as a mean of providing insight into a particular situation or event. It is noted that to create a pleasant user experience during this stage, a feature of the application includes the ability to operate in different languages. Based on the user's mobile device language preferences, the application is currently automatically translated into either Spanish or English. Developed with *Android Studio*, a platform utilized for the making of mobile applications for devices compatible with Android operating systems, the prototype uses *Java* as the main programming language. *Java* is a static-typed programming language that is class-based, object-oriented and designed to have as few implementation dependencies as possible.

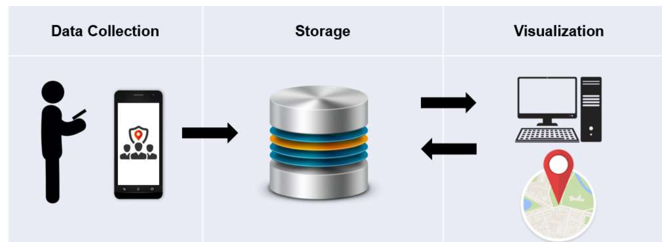

Figure 2 SCS architectural system diagram

Once the user-provided information is collected in the *data collection* stage, the information is then received in the *storage* stage. In this section of the system architecture, all data is stored in a cloud server utilizing *MongoDB*, a cross-platform document-oriented database program. In this location, the data entries are stored in flexible, *JSON*-like documents that allow fields to vary from document to document, in addition to the data structure to change over time. To achieve the connection between *MongoDB* and *Android Studio*, the system uses *NodeJS*, an open source server environment that can run on various platforms like Windows, Linux, Mac, etc. In comparison to the *data collection* stage, the *storage* stage uses *JavaScript*, a dynamic-typed rather than a static-typed programming language.

During the *visualization* stage, the stored data in *MongoDB* is sent back and forth between the backend and frontend components of the application to visually display the entries in a map. To retrieve the data, the system uses Python, a dynamic-typed programming language allowing for run-time modification.

B. Use Case Diagram

In this subsection, we illustrate the main features of the SCS through a use case diagram. A use case diagram provides a graphical representation to define the extent of a system. This is done by describing the possible usage scenarios and by depicting what a system is intended to provide without addressing technical details. By incorporating a representation of users and services, the diagram provides guidance during and after the design process to demonstrate the interactions that exist between the different actors and services that interact with the functionality of the prototype. As seen in Fig. 3, this functionality is represented by three actors, and five services distinct to each actor. In the current and functional SCS prototype, the actors involved are *resident*, *authority*, and *administrator*. In the case of *Unidad Modelo*, a *resident* is identified as a student, inhabitant, or merchant within the safe path established in the community, an *authority* as the security personnel of the safe path (school personnel), police, or neighborhood representatives, and an *administrator* as security personnel of the safe path. Under the same case, the services allocated to these actors include user registration, send an alert, send report, show event in the map, and manage the event.

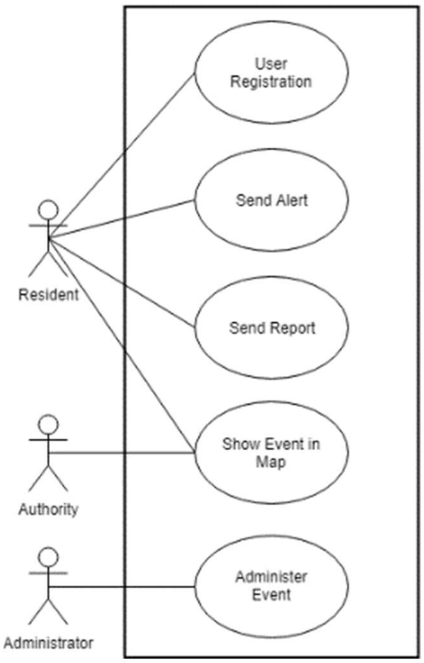

Figure 3 SCS use case diagram

The user registration service provides the advantage of registering every *resident* using SCS to validate accounts and obtain only factual alerts and reports. Additionally, this validity metric allows for the termination of accounts in the event the reported incidents are deemed false or misleading by the *administrator*. Additionally, the *resident* has the option to report an incident based on two different events: (1) in the event of an emergency, and (2) in the instance in which the actor's integrity is not compromised. In the first event, *residents* have the advantage of sending a georeferenced and time-stamped emergency alert via a panic button incorporated within the application. In the second scenario, *residents* provide a detailed description of the event either witnessed or experienced in order to provide other users with information to make them aware of the occurrences happening within their community and their mobility route. These scenarios, combined with the third service provided by SCS to *residents*, allows these actors to avoid possible altercations posing a threat to their personal wellbeing by a direct visualization of the crowdsourced-obtained emergency alerts and incident reports in a map. This visualization is represented in the use case diagram as show event in the map, and both the *resident* and *authority* have access within their personal mobile devices.

The last service representing the functionality of the prototype involves the administration of events. This service managed directly by the *administrator*, allows for an emergency alert to obtain immediate assistance and follow-up procedures. Additionally intended as an internal security system for UDG security personnel, this feature also allows for the allocation of resources (personnel) to procure the emergency while providing an alert status.

C. Mobile Application

The two types of events described in *Subsection B* are illustrated in Fig. 4. An emergency alert is demonstrated by a *red* icon, while a *blue* icon signifies that a report has been submitted. As seen in the same figure, upon reviewing the icons, the latitude and longitude coordinates are displayed to show the exact location where the events occur. By clicking the report icon, further information is shown based on user's description. This information may contain not only the type of incident occurrence but also a picture or video to better articulate the context of the scenario submitted. We believe that the use of graphical artifacts will foster a better understanding of the current situation by the user.

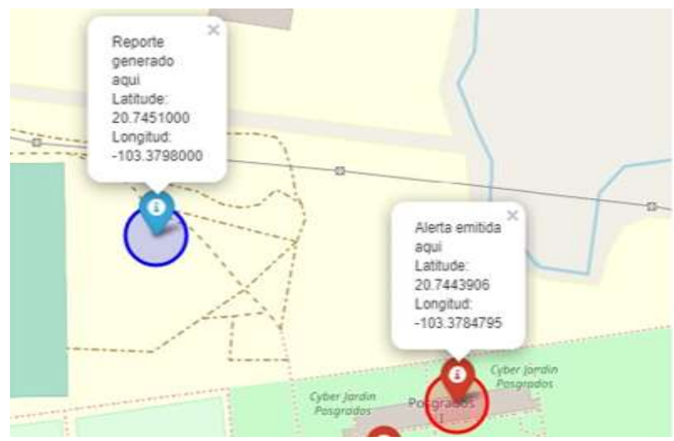

Figure 4 Reported events map visualization

In the Home Screen menu where all services are available for use, a red square symbolizes the emergency alert button, and it is strategically placed for users to press and send georeferenced coordinates instantly in a case of an alarming situation. For the second type of event, the user interface (UI) provides the user with the capability to classify their crowdsourced contribution into three different categories: criminal activity, perceived danger, and suspicious activities. An additional option includes selecting "other" to enable the user to report an incident tht is not classified in any of the previous categories. Based on the incidents listed to which students are most vulnerable, these categories were deemed necessary to provide an accurate representation of the events happening in their immediate surroundings. As seen in Fig. 4, the UI provides convenient access for the classification of a specific report. As noted in the same figure, if the criminal activity category were selected by the user, some of the events listed include theft, assault, burglary, etc. It is noted, that the take picture functionality is optional and is only intended to provide a visual of the reports submitted. The last functionality provided by the prototype includes the provision of an applied internal security system. From a remote location, and external to the mobile application, the *administrator* has access to a web page where the same map provided to *residents* is shown. From this location, the security personnel (if available) are given the status of the emergency alert and the capability to specify the person to whom the emergency has been assigned to.

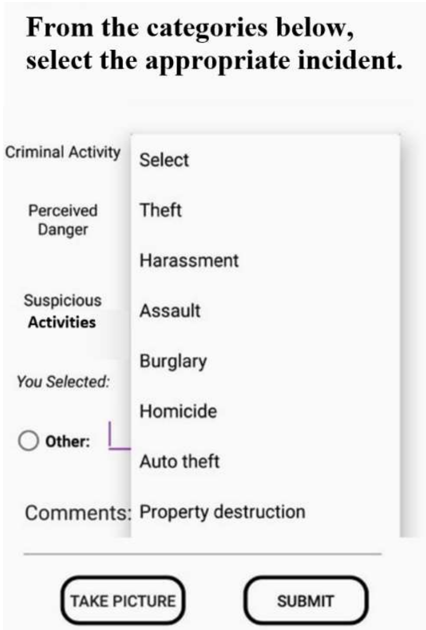

Figure 5 Report generation UI

The status is represented by colors in the map, *red* represents the report has been received, *yellow* the assignation of resources, and *green* the closing of the emergency alert.

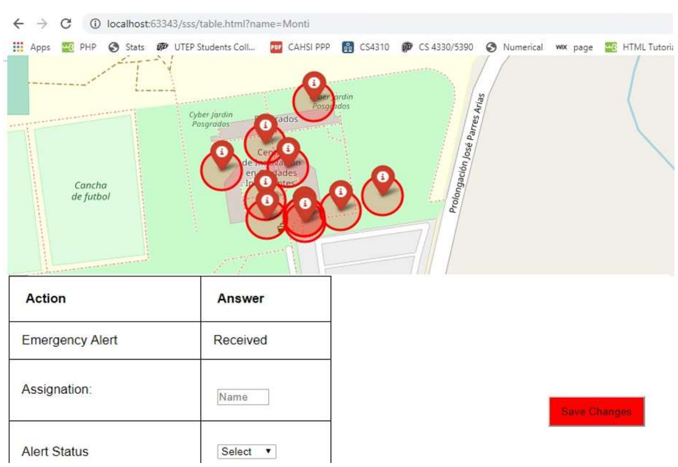

Figure 6 SCS emergency alert follow up platform

D. Data Model

The SCS App requires users to create a username and password to be able to login from multiple devices. Additionally, users may provide information such as first name, last name, age range, and gender. Information is transferred to the SCS server and stored in MongoDB. When reporting an incident, the SCS App will provide the location for the device for the user to confirm (in terms of address) and will send the specific coordinates to the server. The event will be identified with a unique, autogenerated number. Fig. 8 presented below provides a representation of the information collected and stored by the SCS App.


_id: ObjectId("5d03cbebf0aeb220442d818d")
firtsName: "John"
lastName: "Doe"
ageRange: "25-29"
gender: "male"
password: "2721e914d139b407a444afc8ec2b4b39ac3e50c1202509ac439f958559e0684c7f3168..."
salt: "00bbc9ac44b4fcb4"
username: "jdoe"
_id: ObjectId("5cfec317c7218517aca920b1")
latitude: "20.74406178"
longitude: "-103.37890547"
timeStamp: "1560199954096"

Figure 7 An excerpt of a file stores on the SCS backend

IV. Discussion

To measure the functionality and applicability of the developed prototype specifically as a Smart Cities solution, we believe that that the technology must meet the following core principles for Smart Cities solutions: *resiliency*, *security*, *scalability*, *interoperability*, and *modularity*.

Resiliency: This refers to the ability of any system to recover within a reasonable amount of time after a failure. In a city, there are critical infrastructures requiring highly resilient architectures such as traffic systems, security systems, healthcare services, among others, all composed of components ranging from sensors/actuators, telecommunications, and software hosted in a private cloud. The SCS architecture is designed in such a way that in the event that the resident does not have an active service connection with the server, the user can still create a report really quick specifying the details where the incident occurs. The solution is the use of a wearable device like a bracelet, necklace or any item that may pass unperceived. That device can be connected to the phone via Bluetooth. The wearable device will have a small button that will send the alert in case of panic. The alert will specify the location and information about the user. This can be a better option for many residents since even when they do not have connection they can be helped by someone else, and finally in case there is big emergency and the resident does not have time to get the mobile device or someone is trying to steal their items, they can send the alert to receive help as soon as possible.

Security: This refers to the measure of the system to prevent unauthorized access. This also includes the prevention of any attempt to access data, to modify data, and attempts to deny service to legitimate users [6]. Components of mobile application solution must be compliant with appropriate security protocols and mechanisms. The reason why we are implementing this is that even if many people report the same incident, it is difficult for the system to follow up all of them. In the SCS, passwords are encrypted when stored in the database. This is done through the module Crypto located in NodeJS that deals with encryption and decryption of an algorithm, in our case the password of the user. To ensure even more security a Salt Hash technique was also utilized to prevent attacks. The Salt Hash technique takes the password and a random string, and it combines them through an algorithm. This makes it more difficult for the attacker to crack because this technique reduces the possibilities of having duplicates.

Scalability: This refers to the ability of a system to handle a growing amount of work by adding resources to the system [7]. It is imperative to develop a solution based on the current needs of its residents but also considering the limitations and growing capacities in the influx of data coming by such. As it was mentioned before, the prototype was made using the resources and tools we had on hand to deploy something functional in a short amount of time. At the same time, we are keeping scalability concerns in mind since we intend to expand the usage of our application throughout the GMA. Our system was initially developed for devices using the Android operating system. In order to tackle iOS, we are migrating our application to Flutter which is an open-source mobile application development framework created by Google. Flutter provides a platform for developing real native applications for Android and iOS. We want to make sure we cover the two main operating systems for mobile devices.

Interoperability: This refers to the ability of different systems to exchange data between each other, in an effective and secure way. SCS compiles with the principle of interoperability because the system requires to share data between two interfaces. It is composed by an Android mobile application and an interface that displays a map with markers, both to retrieve and visualize data. However, to be able to exchange the data from one to another they need to be connected to a database like MongoDB where all the information is stored. Once connected to MongoDB the system can post and retrieve data between both interfaces.

Modularity: This refers to the decoupling of a program into independent, interchangeable modules, such that one does not depend on the other. SCS complies with this principle since its front-end services developed for Android operating system is completely separated from the platforms used for our backend services such as NodeJS and MongoDB. Modularity feature builds on scalable and interoperable architectures. Our system architecture follows the Model-View-Control architectural pattern, meaning that the user interfaces are not connected to the model and controller classes. This allows the system to have Model classes that can later be reutilized with minimal changes to the code when migrating the system to Flutter. Although the Android platform ties the UI with the control of the application, its model classes are not.

V. Future Work

As for future work, a prototype refinement is expected to provide the development of a composite safety index and use it to generate safe routes. Having the functional service running in *Unidad Modelo*, valuable data entries are expected to be stored in the database. This will provide the opportunity of implementing in our system the ability to generate different routes by taking into consideration that the resident is looking to be safe, we will be showing to the user the different options that they can use and then we will be advising the best option.

After the historical occurrences obtained from multiple events are integrated into a composite mobility index, the combination of the Dijkstra Algorithm and the Critical Path Algorithm may be applied to obtain the safest alternative routes. Dijkstra is an algorithm for finding the shortest path between an origin and destination (nodes) distribution. On the other hand, a Critical Path is an algorithm that through the summation of sequences, or events, generates a route to take. After assigning statistical weights based on an event's likelihood to influence commuting decisions, the combination of both algorithms is expected to provide the safest route, while also selecting the shortest available route from the options provided to SCS users.

To evaluate the functionality of the Safe Commuting System (SCS), a user usability survey implementation has been planned. This is expected to be distributed to the different actors within the system after proper IRB approval is obtained. The survey questions are intended to obtain information about the user's perception of the following aspects of the application: user interface, functions, impact on mobility, and the overall perception of safety.

VI. Conclusion

This paper described the development of Safe Commuting System (SCS), a mobile application designed for the improvement of commuter safety in urban areas. The current functional prototype is capable of collecting data involving emergency alerts and user provided- reports about the occurrence of incidents in their surroundings. The work is expected to continue with the integration of historical occurrences to generate a composite mobility index to assist in the generation of safe routes. This is the first time that these functionalities have been incorporated as a Smart City application to better the quality of life of city residents.

VII. Acknowledgments

The authors would like to thank members of the previous cohort of the IRES: US-Mexico Interdisciplinary Collaboration for Smart Cities, in particular to Daniel Mejia, for the initial conceptualization of the project as well as members of the Universidad de Guadalajara including Dr. Rocio Maciel Arellano, Dr. Jesus Raul Beltran Ramirez, Dr. Jose Antonio Orizaga Trejo, and Emmanuel Aceves for their insightful feedback. The IRES program is funded by NSF Award #1658733. In addition, they also appreciate the support of the CUCEA Campus from UDG, faculty, and students for hosting them during the five weeks they spent in Guadalajara.

VIII. References

[1] C. Tingvall, and N. Haworth, "Vision Zero – An ethical approach to safety and mobility." The 6th Int'l. Conf. on Road Safety & Traffic Enforcement,. *FHWA. Adm. Int. Technol. Exch. PROGRAM, Sept.* 6-7, 1999.

[2] "Instituto Nacional de Estadística y Geografía. INEGI."

[3] "100 dias Senderos Seguros | FEU," 2019. www.feu.mx /100diasdesenderos/. [Accessed: 14-Jun-2019].

[4] E. Galbrun, K. Pelechrinis, and E. Terzi, "Urban navigation beyond shortest route: The case of safe paths," *Inf. Syst.*, vol. 57, pp. 160–171, Apr. 2016.

[5] F. Mata *et al.*, "A Mobile Information System Based on Crowd-Sensed and Official Crime Data for Finding Safe Routes: A Case Study of Mexico City," *Mob. Inf. Syst.*, vol. 2016, pp. 1–11, Mar. 2016.

[6] L. Bass *et al.*, "Software Architecture in Practice Third Edition," 2013.

[7] A. B. Bondi, "Characteristics of Scalability and Their Impact on Performance," 2000.