SMRP: A MOBILE APPLICATION FOR EARTHQUAKE PERSONAL RISK ALARMS

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ABSTRACT

Digital technologies come across almost all aspects of daily life of institutions, communities and individuals. The uncountable applications range from entertainment to medical assistance or life preserving equipment. This scope touches a field that has been calling the attention of industry, government and academia: natural disasters and risk recovery.

Due to the challenging nature of natural disasters, they are a multidisciplinary challenging area that requires the use of a full range of technologies and scientific studies for data analytics in the interest of decision-making at different levels of responsibility for the sake of avoiding human and material damage and mitigation of such events.

We present a mobile application called Semáforo Móvil de Riesgo Personal (SMRP) focused on framing individuals accordingly to their own features during a disastrous event, taking earthquakes as a case of study. The system is unique in its type as it considers three elements for situating people within the context of the seismic situation, i.e., risk, vulnerability, and personal features, using a traffic light-based alerting system with one of three colors (green, red, and yellow), and a set of suitable voice-based recommendations to help users to reach safety conditions.

The traffic light-based alert proposed in this work estimates a metric called Personal Risk Index as a personalized calculation to assess the degree of risk in a given situation. Such index enriches the official information of official seismic systems by considering user physiological, sensory, and geographical conditions. All that configures a cutting-edge alerting system.

KEYWORDS

Application for mobile devices (App), Earthquake, Natural Disaster, Personal Risk Rate, Risk Traffic Light, Vulnerability.

1. INTRODUCTION

Natural Disaster represents a challenging domain of application for humanities and sciences. A vast variety of social and technological studies need to be done to cope with the diverse phases of a given disaster. The previous one advocated mostly for prevention, the time when the event is happening; and recovery, where damages must be repaired if possible. That human casualties are one of the most undesirable consequences of such events.

Digital technologies can be extremely useful in the disaster phases with different levels of effectiveness and possibilities. For instance, mobile applications are an interesting source of possibilities for facing natural disasters due to mobile phones being widespread in many countries and virtually in all the societies around.

In such a context, we advocated to develop an application for Android-based mobile devices to provide an alerting tool in the case of earthquakes. This application improves the calculation of the Personal Risk Index (PRI) presented in (Vázquez-Espino et al., 2021) by using the built-in sensors of mobile devices. Then, based on the PRI calculation, users are alerted by means of a three colored traffic light system to represent the level of vulnerability they are exposed to give their own conditions under an earthquake situation.

The application presented in this research is composed of a module for setting user's personal data: disability (visual and hearing) and mobility; ii) a graphical representation (traffic light) of its vulnerability, the colored corresponding to its PRI calculation; and iii) voice recommendations taken from official sources of earthquakes in Mexico City such as CENAPRED (Centro Nacional de Prevención de Desastres, s. f.) and SSN (Servicio Sismológico Nacional, s. f.).

The paper is organized as follows: Section 2 presents the related work; Section 3 provides the foundations of the traffic light-based alerting systems; Section 4 gives some details of the mobile application development; Section 5 is devoted to tests and results; and Section 6 ends the paper with conclusions and future work.

2. RELATED WORK

Mobile technology has offered a sort of solutions related to earthquakes. Then, there are some applications helpful in the event of a natural disaster. For instance, notifications in advance and messaging between devices even under no network connection conditions. However, none of these applications consider user customization accordingly with the features of the user such as physical capabilities, which may represent an obstacle when facing an earthquake. Additionally, taking into account other criteria, such as the user's real-time location and its allocation within a building, can be helpful to estimate the level of vulnerability users are exposed to in an emergency caused by an earthquake. Unfortunately, to the best of our knowledge based on the search of applications for current mobile devices operating both in Mexico and some Latin American countries (SkyAlert, s. f.) (SASSLA: Monitoreo y Registro Sísmico, s. f.) (quakeRisk

- Apps on Google Play, s. f.) (Earthquake Network, 2022), there is no application or web system focused on indicating to a user the vulnerability he/she is exposed when an earthquake is in progress, considering his/her physical and sensory capabilities, as the application in question intends to do (Vázquez-Espino et al., 2021). In the following paragraphs, a brief review of the earthquake related applications is presented.

- **SkyAlert:** It is an application for mobile devices with Android and iOS operating systems. It has coverage in Mexico City, State of Mexico, Puebla, Morelos, Michoacán, Guerrero, Tlaxcala, Jalisco, Colima, Oaxaca, and Chiapas. It sends alerts up to 120 seconds before an earthquake occurs, according to the epicenter detected (SkyAlert, s. f.). SkyAlert launches alerts based on earthquakes' intensity, using the Mercalli scale, and it does assign a color label accordingly.
- **SASSLA:** It is an alternative to SkyAlert that detects earthquakes and sends alerts to mobiles up to 120 seconds before a strong earthquake occurs, it uses information from the Mexican seismic monitoring and registering service SASMEX, and it is available for both iOS and Android (SASSLA: Monitoreo y Registro Sísmico, s. f.). Unlike SkyAlert, SASSLA has mobile notifications with a higher priority with respect to other applications, so they can: Interrupt any current mobile activity or notification (calls, music, apps, etc.). Play audio alerts at maximum volume even when the phone is in silent and/or do not disturb mode. It also sets the screen brightness to the maximum level to facilitate readability of the alert information. Finally, it continuously activates the device vibration and led light, so the user notices the alert even in noisy situations.
- **Sismo Detector:** It is an Android and iOS-based application for mobile devices and it is part of the Earthquake Network research project that seeks to develop an early warning system based on smartphones (Earthquake Network, 2022). The application works as follows: once a device detects earthquake waves, a server is notified along with the geographic position of the event. Then the server determines whether an earthquake is occurring in such a case all application's users are alerted in real time.
- **QuakeRisk**: It is an application for mobile devices with Android and iOS systems and tablets with Windows. It allows the user to enter the address of the building, its characteristics such as construction date, number of floors and type of construction, between others with the purpose of evaluating earthquakes of different magnitudes (quakeRisk - Apps on Google Play, s. f.). The app's algorithm, created by engineer Mario Ordaz Schroeder, gives a risk percentage for each building (not particular users), and can be used to determine economic losses in up to one million buildings in the city. QuakeRisk is the result of more than 25 years of work on algorithms for estimating building damage from natural disasters.

2.1.1 Earthquake apps functionality comparison

In Table 1, a comparison between the applications is shown. Last column presents the characteristics of SMRP (our proposal) in contrast with the others.

Table 1. Comparison of applications for mobile devices in the current market with respect to the proposed SMRP application.

Comparison of current seismic warning apps in contrast with the Mobile Personal Risk Traffic Light (SMRP)

Feature/App	SkyAlert	Earthquake Detector	QuakeRisk	SASSLA	SMRP
System	Android and iOS	Android	Android	Android and iOS	Android
OS version required	Android 5.0+ iOS 11+	Android 5.0+	Android 9.0+	Android 4.4+ iOS 15+	Android 5.0+
App target	Smartphone user	Smartphone user	Real estate and insurance companies	Smartphone user	Smartphone user
Earthquake information source	Owner's Network	Owner's Network	N/A (is a building risk simulator)	SASMEX	Domestic server
Does the application have a web version with the same function?	✗	✗	✗	✗	✓
Consider the user´s features?	✗	✗	✗	✗	✓
Consider the user's location in buildings?	✗	✗	✗	✗	✓

In the case of SkyAlert and SASSLA, although it detects when there is an earthquake in a certain location of Mexico and distributes it in alerts to other locations near the epicenter, it is a large-scale alert dissemination.

On the other hand, users of the Earthquake Detector application can send a report as soon as they perceive an earthquake and a map with the affected area will be available in less than a minute. Depending on the intensity shown on the map, civil protection, and all other agencies responsible for people's safety can send emergency assistance and emergency teams where it is a priority. As for QuakeRisk, it is mainly based on a simulation of how catastrophic an earthquake would be in each house or building.

The SMRP app will be in one of those apps which will receive the alert propagated by the media in case of an earthquake similarly to SkyAlert and SASSLA, with the additional feature that it will be based on personalized parameters for each user of the application and will give a personalized result to represent the Risk Index of each one of them and also gives sound recommendations on how the user should act during and after the seismic event. This is the main feature of this application that differentiates it from the rest.

3. FOUNDATIONS OF THE TRAFFIC LIGHT ALERT

3.1 Data for Risk Assessment

The following input data are used to calculate the earthquake Risk Index: the danger represented with P and the vulnerability represented by V. For the calculation of P, a relationship between magnitude and danger of the earthquake inspired by the Mercalli scale is proposed and can be seen in Table 2.

Table 2. Relationship between earthquake magnitude (*n*) in Mercalli scale based and Danger (*P*).

Magnitude (*n*)	**Danger (*P*)**
$n < 4$	1
$4 \leq n < 5$	2
$5 \leq n < 6$	4
$6 \leq n < 6.5$	5
$6.5 \leq n < 7$	6
$7 \leq n < 7.5$	7
$7.5 \leq n < 8$	8
$8 \geq n$	10

For the calculation of V, two feature vectors are created that represent both the data obtained from the seismic monitoring system and the user's personal data. These are denoted as V1 and V2, respectively, where:

- V1: is the user's location in a build represented as U and the distance between the epicenter of the earthquake and the current user's location represented as D.
- V2: is the user's physical capabilities, represented with dfis and the sensory capabilities of the user, as well as the hearing and visual impairments, represented as dAuditiva and dVisual, respectively.

In the case of the V1 vector, the weighting of these elements can be seen in Table 3

Table 3. Weightings for user's location and locations of the earthquake used in *V1*.

Radius of distance between earthquake and user (km)	Value (D)
n < 80	2.5
80 ≤ n < 140	2
140 ≤ n < 200	1.5
200 ≤ n < 300	1
300 ≤ n < 400	0.5

User location on a build	Value (U)
From the sixth floor and up	2.5
Fifth floor	2
Between the fourth and second floor	1.5
First floor	1
Clear area	0.5

The purpose of the weightings shown in Table 3 is to obtain a quantifiable value based on the user's environment to have an estimate of how affected the user may be given an earthquake with a specific magnitude. As for the physical and sensory capabilities of the users, they are required to calculate V so a weighting of these is also needed. Table 4 below shows this conversion.

Table 4. Weightings for user data such as physical and sensory capabilities used in *V2*.

Physical user capabilities	Value (*dfis*)
Cannot move	2.5
Depends on the help of others to move around	2
Use wheelchair or crutches to move around	1.5
It can move with slight complications, without the need for assistance	1
Can evacuate in case of emergency without assistance	0.5

Hearing user impairment	Value (*dAuditiva*)
Cannot hear	2.5
It is difficult to listen	1.5
It can listen without complications	0.5

Visual user impairment	Value (*dVisual*)
Cannot see	2.5
It is difficult to see	1.5
It can see without complications	0.5

On the other hand, the purpose of the weightings in Table 4 is to obtain a quantifiable value of the user's capabilities which may affect his actions in the event of a possible evacuation of the building at the time of an earthquake.

4.2 The Personal Risk Index

The sum of the values calculated in Tables 3 and 4 will result in V as shown in Formula 1.

$$\begin{aligned} V &= V1 + V2 \\ V1 &= D + U \\ V2 &= dfis + dsen \end{aligned} \tag{1}$$

Where:
V: the vulnerability of the user represented with a numeric value.
V1: the vector of the characteristics of the earthquake according to the user’s location.
V2: the vector of the personal characteristics of the user.
D: the weighting of the distance between the user and the earthquake.
U: the weighting of the user's intramural location.
dfis: the weighting of the user's physical capabilities.
dsen: the weighting of the user's sensory capabilities.

The dsen value is calculated with a simple division by two, considering that this value is the sum of the user's visual and hearing capabilities represented with a numerical value. The Formula 2 shows this :

$$dSen = \frac{dAuditiva + dVisual}{2} \tag{2}$$

Where:
dsen: weighted value of sensory impairment.
dAuditiva: weighted value for hearing impairment
dVisual: weighted value of visual impairment

After weighting, the values of V and P are introduced in Formula 3 to get the Risk Index.

$$IR = a_0 + a_1P + a_2V + a_3P^2 + a_4V^2 + a_5PV (3)$$

Where:
IR is the Risk Index calculated.
P is the danger of the seismic event.
V is the vulnerability of the user under his/her own conditions.

To tune the ai coefficients, we perform regression against a set of hypothetical or theoretical cases for representing the (P, V, IR) values. As the parameter configure a set of boundaries of acceptability to be used to determine the color of the signal provided to the user, these parameters need to be adjusted, we take experimentally the following values according to the Formula 4:

$$\begin{aligned} P_1 &= (P_{min} + 0.5, V_{max}, 5) \\ P_2 &= (P_{max}, V_{min} + 0.5,5) \\ P_3 &= \left(P_{min} + 0.35P_{ptp}, V_{min} + 0.35V_{ptp}, 5\right) \end{aligned} \tag{4}$$

$$P_4 = \left(P_{min} + 0.6P_{ptp}, V_{min} + 0.6V_{ptp}, 7\right)$$

Where:
$P_{min} = 1$
$P_{max} = 10$
$V_{min} = 1.5$
$V_{max} = 10$
$P_{ptp} = P_{max} - P_{min}$
$V_{ptp} = V_{max} - V_{min}$

The values obtained for the coefficients using these points are:
$a0$ = 0.23698655
$a1$ = 0.59396298
$a2$ = 0.63429914
$a3$ = -0.02897832
$a4$ = -0.02830087
$a5$ = 0.02829105

Finally, the IR value is considered in Table 5 according to the result of the application of Formula 3 considering the pondered P and V values with Tables 2-4. As shown, if the IR is less than or equal to five, it corresponds to a green traffic light, if it is greater than five and less than seven it corresponds to a yellow traffic light, and if the IR value is greater than seven the traffic light will be red.

Table 5. Relationship of the Risk Index to a phase of the traffic light.

Phase	Risk Index (IR)
Green	IR ≤ 5
Yellow	5.1 < IR ≤ 6.9
Red	IR ≥ 7

4.3 Statistical features of the used earthquake data

A data set with 3803400 synthetic cases was generated to evaluate some statistical features of the IR calculation (c.f., Equation 2). To produce such data, we take historical seismic measures from the National Seismological Service (SSN, n.d.) monitoring center. This service provides real-time monitoring due to its 61 seismic monitoring stations scattered throughout the country. Furthermore, the traffic light system considers demographic data of Mexico City accordingly with official data from population census such as percentages of disability in population, and features of houses and promises (INEGI, 2017; INEGI, 2021). Fig. 1, shows the distribution of variable V in the data set, which can be approximated to a Gumbel distribution, a well-known function to model seismic periodicity and intensity (Gumbel, 1954).

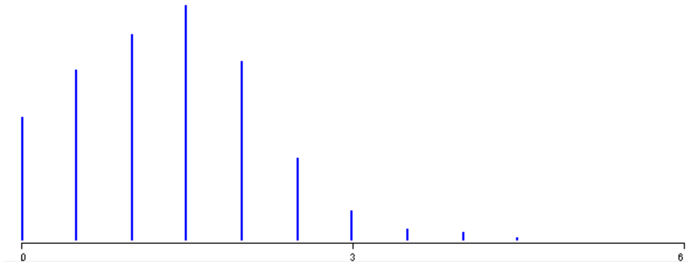
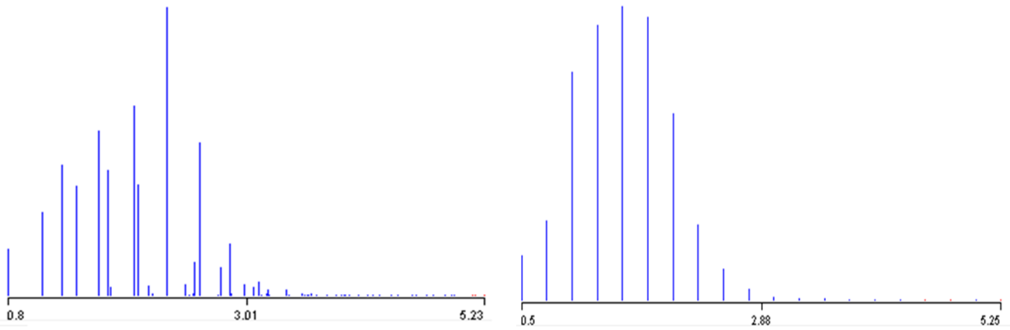


Fig 1. Distribution of vulnerability index (V).

A comparison between the calculation of the polynomial personal risk index which improves the linear calculation (both presented in Luna-Ramírez, 2021) in the data set, can be shown in Fig. 2. As can be seen, the polynomial approach shows more sensitivity, and it tends to rank with higher values of risk than its linear version. It can be explained by component V, which takes into consideration vulnerability caused from sensorial and physical disabilities.



Polynomial Risk Index   Linear Risk Index

Fig 2. Distribution of two Risk Index calculations: polynomial and linear.

4. IMPLEMENTATION OF THE SMRP MOBILE APPLICATION

For the development of the application, the OpenUP model was used, which is a minimally sufficient agile software development process, meaning that only the fundamental content for the construction of a system is included (Balduino, 2007) and the type of application to be developed will be native because it allows the use of all the hardware components of a cell phone such as GPS, accelerometer, among others (Gill, 2022) (Descripción general de sensores. Desarrolladores de Android, s. f.). The implementation of the application is based on the following deployment diagram shown in Figure 3.

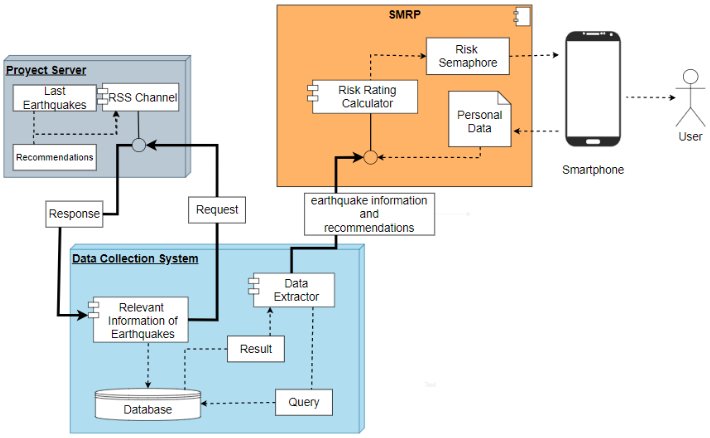


Fig 3. Deployment chart of the SMRP application.

The following is a brief explanation of the function of each component shown in the deployment diagram above.

- Project server (http://bdi-dr.cua.uam.mx/srpersonal/): this is the project server to make consultations about information on earthquakes to be shown to the user.
- Data collection system: this component runs on the project server and constantly consults the official earthquake monitoring media in our country (CENAPRED and SSN) in order to obtain the latest earthquake data captured to be stored in a database and, subsequently, debugged with an information extractor to be collected, both by the mobile application and the web system.
- SMRP: is the component corresponding to the PRI estimation where the user will enter his personal data and, in case of an earthquake, will receive the details of it from the information collection system hosted on the university's server. This earthquake data together with the user's personal data will be used to calculate the risk index, which will be displayed to the user as a risk traffic light.

In addition, this component contains the following parameters:

- Risk index calculator: this subcomponent will obtain the data required to perform the calculation of the risk index, such as the magnitude of the earthquake and the user's personal data, to obtain a numerical parameter that can be represented in a color range according to the risk traffic light.
- Personal data: corresponds to the user's physical and sensory characteristics, as well as his or her current location.
- Risk traffic light: it is the graphic representation of the risk index obtained from the calculator. It consists of the image of a traffic light with 3 colors which are red, yellow and green.

Diagram 1 shows the operation of the application and the interaction with users. For instance, it can be seen how the SMRP shows a simulation of its main function, through the collection of user data, and thus calculate its risk index taking as a starting point a series of data related to earthquakes that have occurred previously in Mexico.

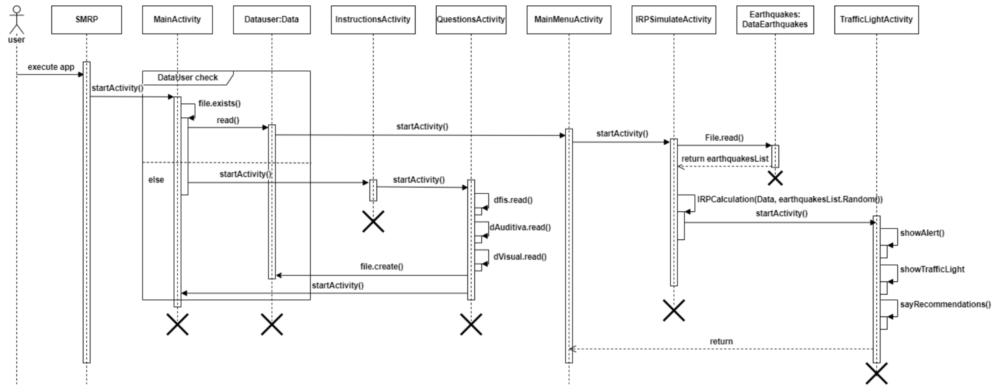


Diagram 1. Sequence of the simulation of the main SMRP function.

The components of the Diagram 1 are the following:

- *SMRP*.- it is the personal risk mobile traffic light application installed on the user's smartphone.
- *MainActivity*.- it is the main module of the application which execute the function of collecting user information and the main menu.
- *DataUser:Data*.- it is a programming entity (class) in which the user's data and some methods that allow to perform calculations corresponding to IR are stored.
- *InstructionsActivity*.- module of the application in charge of showing the user details of the operation and the collection of information.
- *QuestionsActivity*.- module responsible for collecting user data through a set of questions for subsequent saving.
- *MainMenuActivity*.- it is the module in charge of showing the user the different actions that the user can do such as modify his data, change permissions, see a list of previous earthquakes and make a simulation of his IR with his stored data and data from a random earthquake.
- *IRPSimulateActivity*.- module in charge of showing a simulation of the application operation. It retrieves the user's information and generates the data referring to a hypothetical earthquake for the sake of alerting and giving indications on how to act in case of such an event considering the user's capabilities.
- *Earthquakes:DataEarthaquake*.- It is a class like *DataUser* but in this case it is for storing earthquake data.
- *TrafficLightActivity*.- It is the module where a risk traffic light is displayed based on the seismic danger in relation to the user's capabilities, i.e., the calculated PRI.

In a brief description of how the application works, when the user opens the SMRP app installed on his smartphone, if it is the first time it is used then it displays some screens with information about the app and the PRI calculation and then starts the test to identify and locally store the user's personal information, otherwise it goes directly to the main menu.

As for the simulation of the main function of the app, what the *IRPSimulateActivity* does is to obtain the user's previously stored data and randomly select values for a hypothetical earthquake such as intensity, latitude, longitude and location within a building, all this to introduce the values in the IR calculation formula.

Finally, this data is passed to *TrafficLightActivity* via the *startActivity* method to display a colored traffic light depending on the result of the IR calculation.

In the next section, the results of the application testing are provided.

5. TESTING AND RESULTS

Figure 4 shows the result of the implementation of the risk traffic light in the mobile application for android devices. It shows a screen with the data entered by the user. The representation of the PRI in a traffic light given the simulation of an earthquake. In the case of an alarm, the app will trigger sound alerts according to the color determined by the PRI and it also will display a traffic light accordingly. Additionally, the user is guided by auditive directions about how to act during and after the earthquake. Finally, the details of such a natural disaster event are displayed on a screen in the app.

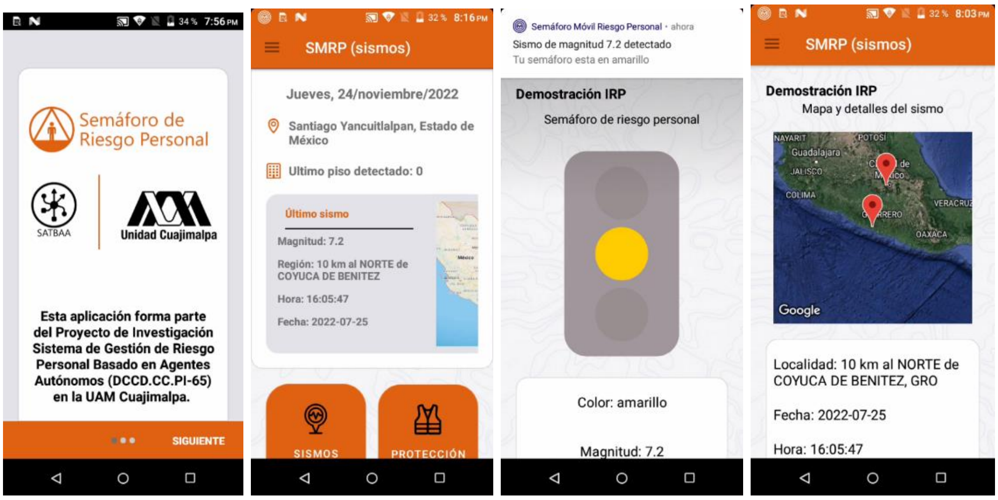


Fig 4. Demonstration of the app for the Personal Risk Index calculation and the associated traffic light with details of the earthquake (in Spanish). It goes from the profiling of the user to the geospatial identification of the seismic event on a map.

In addition, the app was evaluated with thirteen users who subsequently answered a test about the functionality, usability, design, and usefulness of the app. The results obtained from the test will be analyzed to determine which aspects of the application need to be improved and will be included in a future work. Results are shown below in Chart 1.

According to the results obtained by applying the user test to each of the five users, in the usability aspect there are aspects that still need to be worked on, although the users reported a satisfactory performance of the application now of its use, which is also reflected in the reliability that it produced in the users.

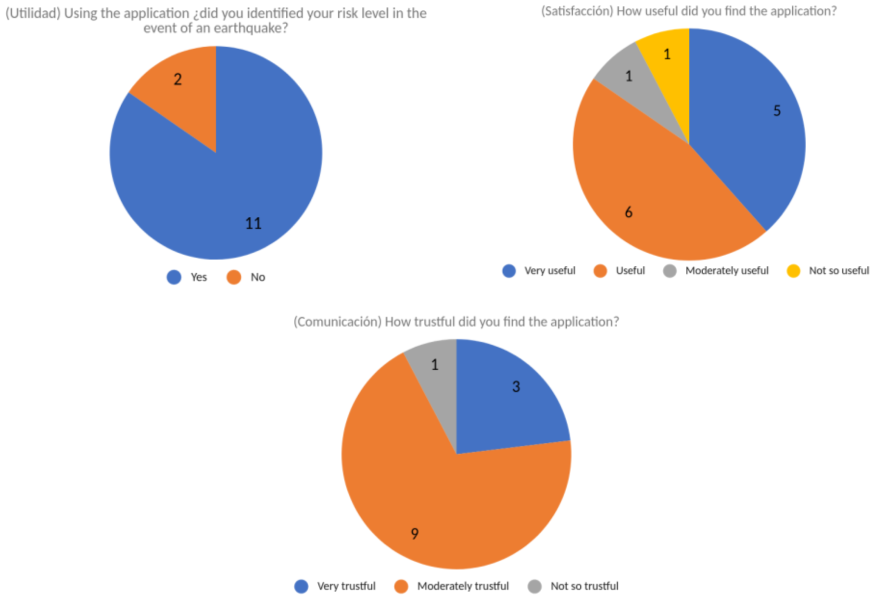


Chart 1. User's opinion about Usefulness, Satisfaction, and Communication of SMRP app.

6. CONCLUSION AND FUTURE WORK

In this work, a traffic light-based application is successfully developed to alert the user and display his Personal Risk Index. A specific contribution of this calculation is the inclusion of user's personal data related to the Risk Index such as disability (visual and hearing) and mobility, which are considered in the graphic representation (traffic light) with the data obtained from the analysis of the Personal Risk Index. Additionally, the user is provided with audio safety guidelines based on the official sources of earthquakes in Mexico. All this according to the usability and accessibility standards for mobile applications.

Additionally, the following aspects should be addressed to improve the application in the future:

- Implement intramural localization, e.g., using BLE devices.
- Include new sections to determine user vulnerability more accurately, in addition to physical and sensory impairments. These can be with emotional issues, i.e., how a person acts in an emergency, and the user's environment, i.e., what are the characteristics of the place where he/she is. Other measures can be taken from

wearables to increase the Personal Risk Index, e.g., pulse, temperature, or blood pressure.
- Implement accessibility issues for blind and deaf users.
- Improve the test sets based on the results obtained from the first test round to modify aspects like the user interface.
- It may be possible the app automatically delivers a message and calls for help to the rescue staff and/or other authorities.

Finally, the general model of SMRP app can be extended to other natural disasters by integrating its particularities and introducing an adjusted Personal Risk Index calculation ad hoc to the particularities of the danger and threat in question.

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