Development of a mobile application for Early Warning Systems and risk management in Cuba

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Abstract. Information and communication technologies (ICT) play a determining role in tackling climate change. ICTs are increasingly used in surveillance, prediction and support actions in adapting to these environmental risks. The archipelago of Cuba is one of the most vulnerable due to the negative effects of climate change. The island nation adopts the benefits offered by ICTs, in order to promote risk reduction due to the impact of natural and anthropogenic threats. The article presents the design of a computer tool called SATEMóvil, which was conceived as a mobile phone application for receiving early alerts in the face of extreme threats. The research exposes the operation of the Early Warning Systems and mobile applications in Cuba and the process of design and creation of the SATEMóvil App. The application contributes to adequate integrated risk management in Cuba, by favoring the identification and continuous monitoring of natural hazards, through textual reports and dynamic graphics. Its use optimizes the existing relationship, between social vulnerability indices and the level of uncertainty in the population, in the six identified threats. The result obtained enhances the country's preparedness to reduce and confront risk.

Keywords. Threats, risk reduction, climate change, adaptation, mobile telephony, App.

1. Introduction

The Republic of Cuba is geographically located in the Caribbean Sea, very close to the coasts of the United States and Mexico. It constitutes an archipelago made up of the largest island in the Antilles, the Isla de la Juventud, and more than 4,195 cays and islets [1]. In Cuba, natural threats such as hurricanes and earthquakes have been analyzed as the most extreme in the country [2]. The central and western regions of the Cuban archipelago are always the most impacted by hydrometeorological events, not so the eastern region, reported with the lowest historically reported impacts. In the eastern zone, high seismic activity is the most dangerous [1,3], (See Figure 1).
One of the ways used to guide communities in case of extreme events is the Early Warning System (EWS). These warning systems are in place in the country to address various types of threats [4, 5]. The EWSs is based on maintaining a sustained exchange of information and data analysis, between the center or system that intervenes in the detection and monitoring of threats with the relevant authorities, who finally make the appropriate decisions and guide the management of the country and the population on the various types of measures to be implemented.

In Cuba, for the information to be processed, the participation of a group of institutions involved in the EWS is required. These are: the National Institute of Hydraulic Resources - INRH (www.hidro.gob.cu/es), Cuban Institute of Radio and Television-ICRT (www.icrt.gob.cu), Institute of Meteorology-INSMET (www.insmet.cu) and the Civil Defense- DC (www.cubadefensa.cu), as well as the highest government bodies. Sometimes this information arrives late to the directors of each institution, due to failures in the electrical network or in the email servers through which these alerts are sent, this may result in a delay in transmitting the information to the decision-makers and these in turn to the population, who transmit the information using radio or television or by other means of broadcasting. In the country, there is a poor use of information technologies for risk management and therefore information is not always received in a sagacious way.

In most of the provinces of Cuba, different types of EWS have been carried out, as is the case of the Local System of Environmental Early Warning [1]. Another example is the EWS of the Bahía de Santiago de Cuba ecosystem, created in 2008 [6]. This EWS requests that the population report the various contingencies found in the land, air, and marine media in the aforementioned bay. This EWS required back then, that the citizen have a nearby landline to make the incident report. This was rarely done, either because of the absence of this transmission equipment, or because of the high costs of cellular telephony at that time. The aforementioned limitations show how little access there is to information by mobile phone.

Currently in Cuba, obtaining credits has been achieved with rapid growth in the application of mobile telephony [7, 8]. This constitutes an opportunity that should be seized today by Cuban communities. The gradual decrease in the prices of calls and the free reception of messaging, as well as the increase in the use of smartphones that can manage mobile applications for access to information in an easy way and wherever the user is. find, constitute other advantages [9]. However, it is of utmost importance to continue looking for options that allow the population to access this information using these new communication alternatives, without the need for internet access by mobile telephony, which to date has not been implemented on the island. Due to this situation, the research question arises: How to design a mobile application for the EWS, which allows information from alerts to natural threats to reach the population in a faster and more efficient way?

2. Materials and methods

Since an integrated approach is required to understand the early warning systems (EWS), it was necessary to analyze aspects relative to this term in the Cuban context. This section describes the methodological framework carried out to analyze the factors in relationship with EWS and the App SATEMóvil.

2.1. Creation of SATEMóvil

The Early Warning System in Mobile Telephony SATEMóvil is a tool that contributes to adequate integrated risk management, which favors the identification, dynamics, and monitoring of different threats, which allows monitoring forecasts on the probabilities and magnitudes of impacts, reducing the uncertainties in the population about the identified threats and promote less social vulnerability, by enhancing the
population's preparation for their confrontation [10]. In the SATEmovil system, 3 types of ways of accessing the information of the alerts are defined, they are: SMS (Short Message Service); MMS (Multimedia Messaging System) and Correo Nauta. The latter is part of a strategy that tries to seek convergence in the use of ETECSA. This company offers the possibility of checking the email inbox from cell phones.

Among the conditions established for the use of SATEMovil are: a) having access to data transmission services; b) have enabled, the mail access service called NAUTA on the mobile network (activation that is only carried out by personal request in ETECSA's business units); c) have configured the NAUTA mail, attending to the parameters that guarantee the correct operation of this email application. In this case it is important to clarify that when it is used as a modem it is not necessary to make the configuration. Users can receive the information from any of these variants, always as a choice and that suits their needs. But it is worth noting the use of SMS at present because to date it is the one with the fewest errors in our country, in addition to the fact that reception is free at no cost, unlike MMS, and Correo Nauta, which generates expenses on the balance of the user when accessing the GPRS.

2.2. SATEmovil requirements and functionalities

One of the main elements for the definition of the SATEMovil functionalities and the achievement of the proposed objective, was the analysis of the information needs of the clients, translated into requirements, both in characteristics and functions, which is known within of software engineering as the lifting of functional and non-functional demands of the application. The following were considered as functional requirements or requirements (RF):

- RF1: Show Introduction in the Application: this requirement when the user opens the application for the first time will be shown a short introduction about the functionalities that the application will have.
- RF2: Sign up for Alerts: It will allow users to sign up for the arrival of alert information via SMS, MMS, or Email.
- RF3 Unsubscribe from an Alert: The user can at any time unsubscribe from any alert to which he is already registered, this will allow him to no longer receive information on that particular alert.
- RF4: Show Alerts Information: This will allow displaying the information of each type of alert, for this the application will automatically access each access path of information that the user has registered, that is, if the user registered to an SMS alert, the application will access your SMS mailbox to obtain the information.
- RF5: Show Geographic Location of the Alert: Depending on the type of alert, the user will be able to see on a geographic map the location of the event that generated the alert.
- RF6: Reports: Here the user can contribute to the entities that manage the alerts, sending them some type of information that provides these institutions with important information for their investigations. In this case a survey.
- RF7: Locate on the Map: The user will be able to locate the map of the application the sites that he frequents the most, which will allow him to send this information in the reports that are generated.
- RF8: Configuration: In this requirement, the user will be able to configure the application if a change in the information reception infrastructure is necessary. For this you can configure the mobile number where the alerts will arrive, among other important values for the correct operation of the application.

As part of the non-functional requirements of SATEMovil are the following:

1. Appearance or external interface: It will have a simple and friendly interface with colors that are pleasing to the user with different shades of reds and whites. It will make use of discreet icons allowing easy navigation between the different views in a comfortable way for the user.
2. Usability: The application can be used by users who do not need advanced computer skills, therefore, the application must be flexible and easy to use. It will be possible to visualize in the different types of existing screen sizes, in addition, containers and filtering of the content types are used.
3. Performance: The application must implement several transactions per second to give a quick response to the user and avoid unnecessary delays, also depending on the availability of the infrastructure created. The response times and speed of information processing will be faster, as well as how the application is running in the background will not affect the performance of the mobile device.
4. Reliability: The information stored, processed and read by the application will be reliable, since it will have managers who will allow the manipulated information to be reliable, it must also have mechanisms that allow rapid recovery from any failure that has occurred.
5. Security: The information handled by the application must be carefully protected against corruption and states of inconsistency and the personal information of users within their devices must be found safe from any leak, which is why the application only access the information for which it was created.
6. Support: Possible semi-annual updates.
7. Software: Android 4.4 or higher.
8. Legal: The application must be adjusted and governed by the stipulated laws to comply with the related processes. In this case, the application will be patented to avoid plagiarism.
9. Efficiency: It must ensure quick responses, as well as allow access to information effectively, efficiently and with great dynamism in order to capture customer attention.

2.3 Development methodology of the SATEMovil App

For the creation of the SATEMovil App, the agile methodology of application development Extreme Programing (XP) was used [18]. Among the practices that this methodology proposes, the following were adopted: 1) Development of adaptable solutions instead of foresight, in the face of constantly changing customer requirements, 2) Simplicity in design, allowing speedy construction of parts of the application and the ease of its maintenance and 3) High level of feedback to improve the functional capabilities of the software, by enhancing customer-project member communication in the various phases of its development.

Pressman (2010) states that “Software engineering includes processes, methodological approaches, and tools that allow complex and computer-based systems to be developed on time and with quality. The software process incorporates five structural activities: communication, planning, modeling, construction, and deployment that are applicable to all software projects” [11]. The SATEMovil App offers support for 5 types of alerts, which are: 1) Severe Local Storms; 2) Droughts; 3) Threat to Livestock; 4) Hurricanes or Tropical Cyclones and 5) Earthquakes. Its development does not yet contemplate the threats derived from the anthropogenic origin.

This methodology of software development or, software engineering, as it is also called, is supported by diagrams. The sequence diagram defined in the Unified Modeling Language (UML), is one of the most used methods to identify the behavior of a system [19]. Represents the objects on the stage and the sequence of messages exchanged between them, to carry out the functionality described by a transaction system. Furthermore, it is frequently used to validate use cases and to appreciate design logic dynamically [20, 21]. Figures 2-A and B show the sequence and case use diagrams of SATEMovil.

![Figure 2-A. Methodological diagram of sequence for App SATEMovil.](image-url)
Figure 2B. Methodological diagram of use case for App SATEMovil

Figure 2A shows the graphic representation that is made between the different messages that are exchanged within the SATEMovil application, which the end-user does not perceive. Everything is executed correctly for the optimal operation of the project. Figure 2-B shows the sequence diagram of an activity when earthquake alerts are recorded. Similarly, other sequence diagrams can be made for the remaining alerts. Each use case tells a stylized story of how an end-user (who has a number of possible roles) interacts with the system and in specific circumstances. The story can be a narrative text, a guideline for tasks or interactions, a description based on a format, or a diagrammatic representation. Regardless of form, a use case illustrates the software or system from the end-user point of view [19]. Therefore, the diagram of use cases of the EWSMOVIL App symbolizes in a general way the different actions that the user will be able to carry out on the application allowing them to understand its operation.

2.4 Data sources and selection of tools and variables for the implementation of the SATEMovil.

The data sources that support the mobile application were collected through surveys of managers and support staff of the institutions that work on early warning systems, including Civil Defense and the Provincial Meteorological Center, as entities fundamental in the generation of Hydrometeorological alerts. The National Seismological Research Center (CENAIS), in charge of issuing seismic alerts among other entities with jurisdiction in Cuban territory, was also consulted.

For the development of the application, an analysis was made of all the existing technologies, paying special attention to those that are free. Considering the number of applications, the two leading operating systems or mobile platforms in the market, both by revenue and by the number of applications, are the Apple system and Google's Android [12].

For the creation of SATEMovil, the Android platform is selected for its versatility for the design of applications and for being the most prevalent on mobile devices within Cuba. Likewise, it provides greater transparency in its programming, since it is open-source, with countless examples, tutorials, available resources, and a wide and growing community of developers.

The Java language that is used in the development of mobile applications for the previously exposed platform is used, as well as the use of XML Markup Language that allows modeling the different user interfaces that the application will have.

The persistence of the data is managed using the own storage mechanisms of the information within the mobile devices such as the use of the SQLITE database and the use of the SharedPreferences class in the Java language to store the configurations that are executed within the application. In addition, our own algorithms
for the treatment of character strings were implemented, which allowed us to interpret the formats of incoming messages and display them to the user in readable text. For the representation of the alerts, geographically, the geographic data obtained from the OpenStreetMap project and the MapsForge programming library were used for the use of offline and free maps.

3. Results and discussion

3.1 Early Warning Systems (EWS) in mobile applications

With the rapid growth of the world population, mobile phones and networks derived from this technology are being used more to communicate alert and coordinate preparedness and response actions [10]. At the same time, alerts through electronic messaging are widely used in the dissemination of mass messages. In the Google Play application stores for devices with Android platform, as well as the App Store for devices with iOS platform, there are countless free applications that implement early warning systems for different types of alerts, among them the following can be mentioned:

- **Earthquake Alert**: The application is capable of reporting earthquakes worldwide, thanks to the fact that it gathers the data network of seismology entities and you can share the information on social networks.
- **Seismic Detector**: It is an application that reports on temblor movements and can give warnings seconds before it is perceived. According to the description of the application, "the Seismic Detector research project is aimed at developing an open collaboration early warning system, based on smartphones, to detect earthquakes in real-time and generate alerts for the population" [12].
- **MyShake**: This new application that turns a smartphone into a mobile seismometer is being tested by scientists in California [13].
- **SkyAlert**: This multiplatform application emits the alarm signal with a time frame of 60 seconds before any event occurs [14,15].

All these applications, regardless of whether they show and perform the alerts EWSisfactorily, have the limitation that they need continuous access to the Internet or EWSellite use to access the information. In developed countries, this is not a problem, but in the case of Cuba, the infrastructure created to access the Network of Networks from mobile phones does not yet exist, so these applications do not work correctly in our country. In response to this problem, it is vitally important to have a mobile application to obtain alerts in the Cuban nation, using available technologies.

3.2. Deployment of SATEMovil

SATEMovil is made up of several elements that ensure its correct operation [15], the different elements and the details of their interaction are shown in Figure 3.

![Figure 3. Deployment Diagram](image)

Among the elements of the system is a computer where the computer system that processes the information and sends it manually or automatically will be found. To issue and send the information, the GSM mobile network is used. The General Packet Radio Service (GPRS) or general packet service via radio is also used, which is an extension of this system and allows the transmission of non-switched (or packet) data.
This technology is also used in Cuba for the MMS multimedia messaging service and the @nauta service [16]. This is a new service that has been in use for several years. Each one with a configuration defined by the supplier of the aforementioned Cuban company ETECSA S.A. According to the current price list for the different services, the cost of using the GPRS is 1.00 CUC x 50 MB of data transferred for the NAUTA mail [17, 18]. Furthermore, it should be noted that not all mobile devices in our country have the ability to use email [22-24].

All the institutions involved in sending the information have this system deployed and therefore the information will be successfully distributed with the SATEMovil application. It mainly opts for the use of SMS since its reception is free for the Cuban population.

3.2.1. SATEMovil Design and Functionalities and information to process

For this, the first time the user accesses the EWSEMóvil mobile application, the application will display a loading screen with the application's logo where it will quickly initialize itself for use (See Figure 2). Likewise, as the application is initialized, the different resources available on mobile devices to obtain or send the information is shown, in this case, SMS, MMS or Email [25-27], as well as the map report of the occurrence of the event in real-time (see Figure 4 AC).

Figure 4-A Figure: 4-B Figure: 4-C

Figure 4. Different environments of the EWSEMóvil App. 4-A. Presentation of the App; 4-B. Data collection format: 4-C. Location on the map of the application of some events. (Source: Modification from Ravelo and Milanés 2018 [15]).

When the application runs, the user, by selecting the icon with three horizontal lines, displays a menu where the different types of alerts to which he can subscribe and begin to receive notifications of these are displayed (see Figure 5). By selecting an alert type, the user will be able to subscribe and receive the information through different channels that they need: SMS, MMS or Email, the first being the most recommended for users (See Figure 6).

1 The figures and screenshots of the App are placed in Spanish because it is the official language in which the tool was designed.
3.2.2. Alerts in SATMóvil for Earthquakes

In the case of earthquakes, a message is received every time an earthquake is generated, it is sent to a list of users that are defined in CENAIS, mainly for the researchers of the highest hierarchy in the center and some decision-makers within the provincial government and municipalities. The message that is sent arrives in a reduced format in acronyms, so that the application is able to process it and display it in a more understandable format (see Figure 7). With this information, the user can access the location of the earthquake that was generated (See Figure 8).

3.2.3. SATEMóvil Alerts for Hurricanes

For hurricane alerts, INSMET is proposed to use a specific format to be sent in messages, which allows it to send a single message and not several in one, thus avoiding the over-EROSuration of the communication channel and that the information reaches quickly to the various recipients. For this, the proposed example format is: Hurricane. Nom: Irma, Cat: 5, Lat: 18.23N, Lon: 75.05 W, Vmax: 650 km / h, Pat: 1004 hPa, Date: 09/27/2017, Time: 05:00 [20].

From here the application gets the category, being able, in addition, in case the category is not sent, to be able to know it by the speed of the winds, as well as if it is a hurricane or a tropical storm. The information is analyzed by SATEMóvil and is shown as in Figure 9 to later be located on the map (see Figure 10).
3.2.4. Alerts on SATEMovil for Droughts

The Institute of Meteorology of Cuba, by its acronym INSMET (www.insmet.cu), prepares a monthly Climate Surveillance Bulletin that reports on the behavior of the climate. To do this, different variables extracted from meteorological stations located in strategic locations are analyzed. These variables are: the oceanic and atmospheric conditions, the behavior of the main meteorological variables of the month that ends where the different temperature ranges are analyzed (average, minimum average, maximum average) as well as the relative humidity, rainfall, the thermal sensation between others. The proposed format to send by would be: Sequia.CM: -10, -1.6; GM: -20,1.7; JAM: -10, -1.7; PS: -15, -1.9; SL: 13.4; STGO: 23, 1.4; SF: 7.2.3; SLM: -18, -1.9; TF: 8, -0.3; PRO: Drought expected; Date: 09/27/2017; Time: 05:00

In this processed message (see Figure 11), the first value displayed is defined for each province as a value such as the Standardized Precipitation Index (ISP), to show the behavior of drought in each region of the province. In addition, the amount of rainfall made per cubic millimeters will be received for each municipality. The user clicking on the received message EWSMovil gives the possibility to graph this information for a better understanding of it in two different ways (see Figure 12).

A pie chart for the ISP is shown are calculated in general percentages of each province of the country (see Figure 13A-C), which can be Extreme, Severe, Moderate or Weak depends on its values and bar graphs for rainfall for each municipality in each province that may be Deficit or Excess (see Figure 13 BC). It is also possible to save such graphics within the mobile device as an image for later use by the user.
3.2.5. Alerts in SATEMovil to threaten comfort for livestock

For this type of alert, the INSMET generates an Agrometeorological Bulletin that is, every 10 days for each month in progress, addressed to the main producers in the province. Here are different information such as: the phases of the moon in the behavior of vegetable crops and the influence it has on animals, monitoring agricultural drought, vegetation conditions, behavior of forest fires, behavior of pests and diseases in crops, among others. Special attention to Cattle Comfort is also featured within this app. This type of comfort is defined as the area with a temperature range, within which the animal can be without it being necessary to activate its thermal self-regulation mechanism.

It is then when the center specialist calculates the Humidity Temperature Index, which is used to know the degree of caloric stress present in cattle [28, 29]). This information needs to be sent to the producers, as well as some advice on what to do in case of stress or not. This is why the message format is proposed: Threat to livestock. Descen: 1, DS: GL: NE, GC: EL, GP: EM, ES: GL: NE, GC: EL, GP: EM, Month: September, Time: 05: 00 PM. With this information, the producer or user within SATEMovil receives it better processed (see Figure 14) and is informed of the recommendations that must be taken into account to achieve greater livestock production (Figure 15).
3.2.6. Alerts on SATEMovil for Floods and Local Storms

For floods, the INSMET accesses various resources such as radar tables and identifies the most extensive and significant floods due to intense rains, located mainly in municipalities with surfaces of wide plains, low land inclination, and poorly permeable soils.

The type of message to be proposed is in the following format: Flood. Place: Guamá, Lat: 19.97N, Lon: 76.40 W, Date: 09/27/2017, Time: 05:00. This is processed (see Figure 16) and will allow you to see the location of the event on the application map [30, 31] (Figure 17).

Severe local storms usually occur at any time of the year. Generally, these can occur in the months of March to September with greater frequency, being May the month with the highest probability of occurrence. These local storms are characterized by the appearance of electrical discharges and heavy rainfall in the form of showers[32]. The validity period of a storm cloud is short, lasting around one or two hours. In this topic, the proposed message is: TLS. Type: Hail, Reg: Guamá, Lat: 19.96N, Lon: 76.32W, Date: 09/27/2017, Time: 05:00, in the same way as with floods, information is handled by EWSEmóvil (see Figure 18) and can be located on the map as well (Figure 19).

3.3. Management of information security from SATEMovil

All the information accessed by the SATEMovil application of the device is confidential, so the user can have the guarantee that their information is safe at all times. The objective of the application will always be to obtain, through the different routes used in Cuba, the information about the early alerts and represent it to the user in the appropriate format. The application will always be running, so if the user is taking any other action on their device and an alert is received, they will be notified of this alert. If the user wants to access it for more details, it will automatically redirect them to the application.

4. Conclusions

The Republic of Cuba has achieved great development in the implementation of Early Warning Systems. These EWSs allow surveillance and monitoring of various threats of natural origin that represent a danger to the population and the economy. Despite this development achieved in the EWS of conventional origin, in the country, there is some evidence of the use of tools linked to the use of mobile telephony. The development of a mobile application in Cuba like SATEMovil, allows the reception of early alerts on six different types of extreme natural threats. The success in its development will depend on the level at which this App is socialized with the entire population. SATEMovil becomes an innovative software for Cuban society on the subject of computerization on disaster risk management. This application is of great importance as it will ensure that the population and decision-makers can be informed before, during, or after the occurrence of any threat that may affect civil society.
The limitation of the use of EWSEMol only focuses on those people who use another type of mobile phone with a platform that is not Android, say iOS, Symbian, or another system. Identifying this weakness allows, over time, to consider creating a new version for each of these platforms or operating systems. To guarantee this, it is necessary to think about incorporating new functionalities that make it a primary application in all Cuban mobile devices.

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