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# Improvement of Emergency Situation Management through an Integrated System Using Mobile Alerts

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**Abstract:** The capacity to act as quickly as possible in the event of an emergency is a major concern for all those involved in providing first aid. Responses in due time are crucial for efficient alarm and event management. Currently, in most systems, notifications regarding alarms and events are sent to a list of recipients. The recipients can be operators, workstations, and/or formations. For a more effective response, it would be advantageous for an alarm or event to be announced to the operators, workstations, and/or the mobile formations closest to the location where the alarm or event occurred. The authors present an innovative solution—an integrated system consisting of a mobile application intended for users and a web application for dispatchers—which aims to reduce the response time and to facilitate the identification of the emergency situation. The proposed applications are validated through usability tests, the results of which demonstrate the ease of use and acceptance of the application by users and dispatchers. It is shown that this tool can have benefits at a large scale, but depends on the involvement of governmental decision-makers for implementation.

**Keywords:** event management; emergency situation; mobile emergency application; mobile alerts; PSAP



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## 1. Introduction

The absence of immediate medical attention at the scene of an accident can increase the possibility of death. This is due to the fact that emergency operators do not receive vital information in due course, and analysis has shown that if the response time of emergency teams decreases by 1 min, the chances of saving an individual's life increase by up to 6% [1].

Scientific studies have demonstrated that evolution in the field of information and communication technology offers new opportunities for early warnings and faster response times. The latest technologies facilitate collaboration among legally established institutions in order to act in emergency situations through the identification of potential risks, the mitigation of those risks, and the coordination of public warning activities regarding impending disasters [2].

According to the EENA (European Emergency Number Association), mobile devices are currently the main form of communication; 70% of calls to the emergency number "112" are from these devices [3]. Advances in mobile technology have turned mobile applications into a powerful tool for communication in emergency situations [4–8].

An increased focus has been given to emergency response research, with several scientific reports and articles on disaster communication and disaster management published. Studies conducted by the EENA (European Emergency Number Association) concluded that emergency mobile applications are necessary and should operate in the same way as a telephone call to "112". In 2016, the European Commission published a universal directive

establishing an electronic means of communication in emergency situations, inviting all EU member states to guarantee equivalent access to emergency services for all users, including citizens with disabilities. The EENA has promoted the development of adequate means of communication in emergency situations, meaning that people in a crisis situation have the opportunity to select the optimal communication solution, depending on their needs [8].

The EENA confirmed the need to develop an emergency mobile application that is regulated and made available throughout the European Union. In the near future, the EENA's goal is to create an emergency mobile application that is useable within the EU and beyond, and to promote its widespread use. To date, the EENA has officially recognized 28 mobile emergency applications developed in 13 states [8]. In order to reduce the response time, it is necessary to implement a system of communication between the citizens involved in an emergency situation and the necessary rescue teams that is as automated as possible, which can contribute to reducing response times and, consequently, to reducing casualties.

The main objective of this study is to design a mobile emergency system that uses smartphones to announce emergency situations and report them to the nearest available dispatch centres. The designed system aims to reduce the intervention time of rescue teams, thus contributing to the reduction in casualties.

By developing an integrated emergency system, the persons involved can help by quickly transmitting critical information to emergency dispatchers. Information can be quickly and clearly conveyed in a text form rather than orally, which can be interrupted or difficult due to emotions, noises, or language barriers.

The emergency system proposed for development consists of two parts:

- The mobile application for victims: designed to allow users to alert emergency dispatchers;
- The web application for dispatchers: designed to allow PSAP (Public Safety Answering Point) operators to manage reported events.

This paper presents the developed integrated system (mobile emergency alert system named SASU) to be used in the case of emergency situations (mobile and web application) and outlines its working methodology. To test the integrated system, a simulated scenario of a real case fire was used. The system's usability and process times were evaluated and a survey was conducted among participants to assess their opinions, and to identify the system's strengths and weaknesses.

The secondary objective of this paper is to propose a working method for developing emergency mobile applications, which can be used to support developers and share lessons learned from the experience and the research conducted. Thus, based on an analysis of the current literature, the experience gained while designing the system, the reflections on the obtained results of the evaluation phase, as well as from interviews with university experts, several findings are formulated for the improvement of the system's design and necessary functions; thus, the emergency mobile application can be made as efficient as possible.

## 2. Theoretical Background

Scientometric research was carried out, in which an extensive review of the literature in the field of mobile applications for emergency situations is presented; we analysed scientometric methods using 1393 published articles indexed in the Web of Science database from January 2016 to August 2022.

The key questions of the current research are:

Q1: Which are the most productive authors, institutions, and countries?
Q2: Which are the most cited papers and how are they related to each other?

The primary data were downloaded as plain text files from the Web of Science (WoS) database. The results were analysed using VOSviewer version 1.6.16 (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands), which offers scientific mapping in order to analyse the content of titles and abstracts of scientific publications. Thus, the term identification function of the VOSviewer program was used to carry out

a systematic identification of the key terms from the database (citations) and to organize the large quantities of text in a semantic map, while ignoring the elements related to the structure of summaries and statements regarding the copyright that might be included. Out of a total of 1393 documents, 920 had at least one citation. The results obtained using the VOSviewer software are shown in Figure 1.

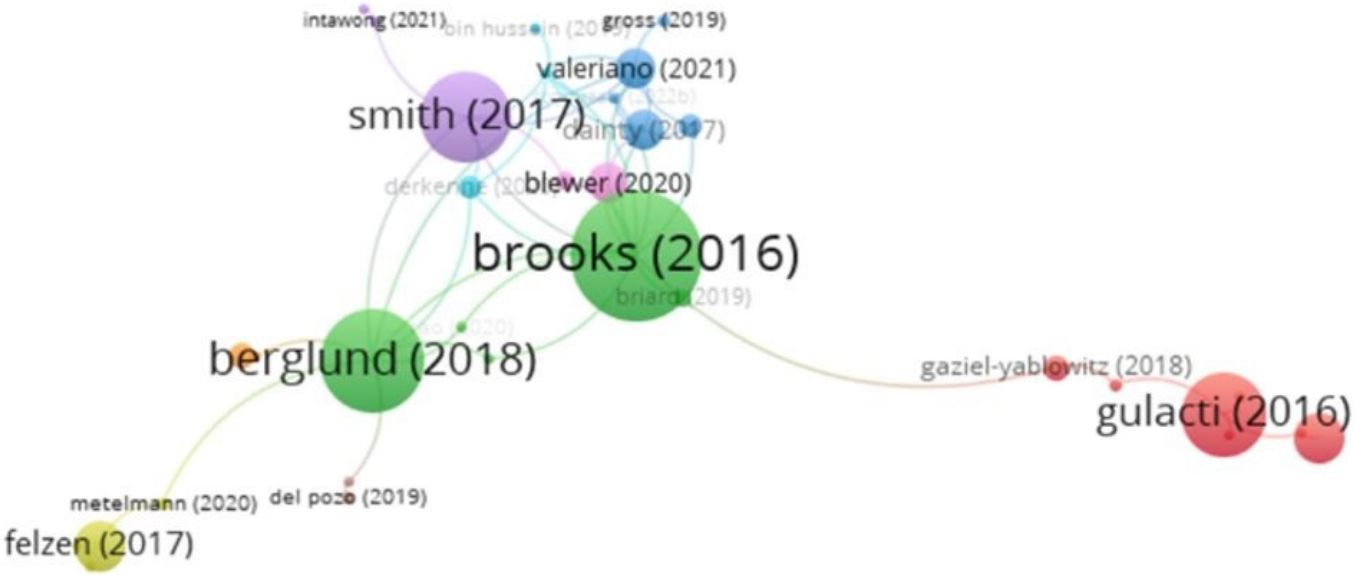


**Figure 1.** The most cited articles in the researched field.

Of 1016 journals which published articles in the researched field, only 25 journals published articles with more than 5 citations (Figure 2). The most cited articles, according to the scientometric map, are the references [9–18].

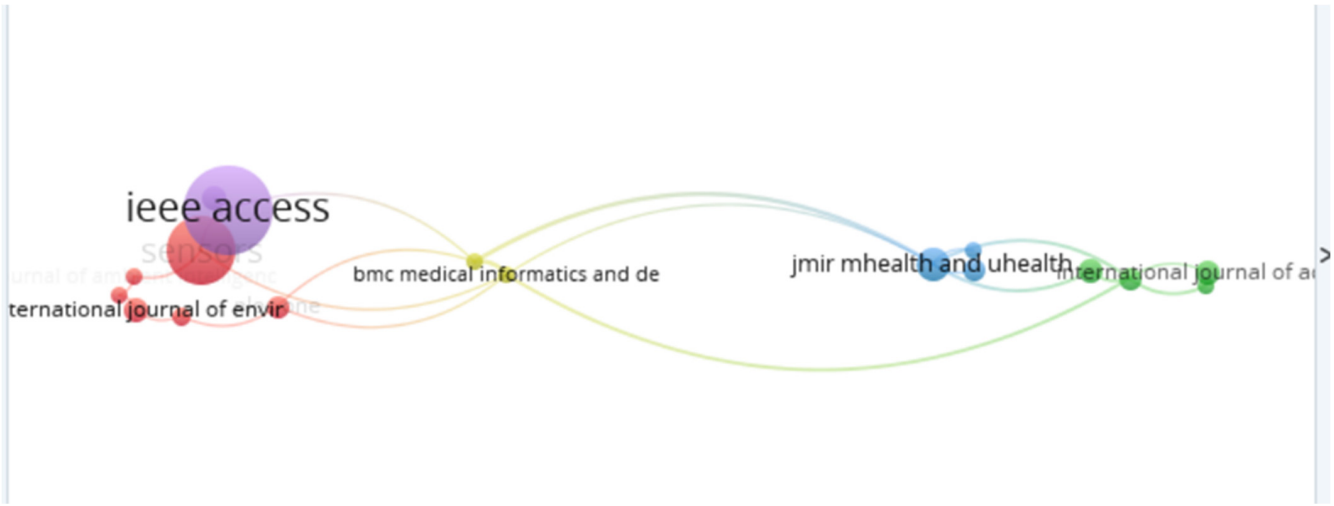


**Figure 2.** Journals that have published articles in the field.

In order to eliminate the use of mobile applications in the field of health, the research was redefined by searching in the predefined Web of Science domains: industrial engineering, multidisciplinary engineering, green sustainable science technology, management and multidisciplinary sciences. Therefore, only five nonmedical papers were obtained from the new analysis [11,16].

The main finding from this extensive review is that the literature investigating the adoption and use of crisis informatics, including disaster apps, is still at a relatively early

stage; thus, this paper intends to bring value to the field. On the other hand, apps such as those for mobile banking, payments, financial services, health services, data services, games, and learning are becoming more popular, as people have become more willing to use mobile apps in their daily life due to their ease of use and efficiency.

Currently, one of the most problematic aspects in the field of emergency management is notification systems in emergency situations, especially in terms of obtaining accurate information in the first stages of the event and notifying the affected people. Researchers have noted that, in order to improvement crisis event management, rescue specialists should particularly rely on the collaboration of citizens directly involved in the event, considering that they can act as "human sensors" during an emergency [19]. Romano et al. (2016) developed a mobile application to be used in cases of small-scale emergency situations, using people as human sensors [20]; the same idea is also applied by Astarita et al. (2018), who propose the addition of the concept of bidirectional communication: from users to rescue operators and from operators to users [21].

Researchers have observed that in the immediate aftermath of a disaster, online activities increase around the world as the population seeks out up-to-date news, and emergency response agencies and rescue crews use the Internet to coordinate activities and resources for rescue, raising funds, expressing points of view, and also, for finding missing persons [22].

To improve emergency responses, the most common approach is to establish a two-way channel between emergency management operators and citizens. This channel is used to transmit real-time information through an emergency communication system [23]. Such systems are called "Emergency Notification Systems", which are mainly used in emergency situations [24].

In small-scale events where the number of participants is reduced, social media communication is low; these events are generally the type of events that emergency responders deal with on a daily basis.

Real-time citizen participation could be of great help in crisis management. Witnesses or victims, through their involvement, can provide useful information from the scene of the event, thus facilitating the intervention of law enforcement or rescuers. In order to achieve citizen involvement, researchers, agencies that provide emergency services, governments, the European Union, and mobile application developers have worked intensively in recent years to provide reliable mobile solutions that collect information from the disaster site, and also notify citizens of impending events [25,26].

There are several emergency management applications with different aims, methods of use, and recipients of the message. Some applications send the gathered information only to a contact list of friends and family or to a list of city halls; others work as an exchange platform for citizens; whereas a limited number send data to a specific security department or to emergency operation centres [20].

Some research has been dedicated to developing applications to be used by dispatchers, such as the one proposed by Delaney et al. (2022) which notifies the rescue teams based on their location so that the lay first responder closest to the event location can reply and confirm their intervention [27]. This type of application can be valuable in low- and middle-income countries where the cost aspect of emergency systems is significant.

On the other side, there are available applications targeting a specific group of users, such as opioid overdose victims [28], people with diabetic hypoglycaemia [29], or people with heart-threatening conditions [30].

Other available apps propose complicated interactions, which require filling in long and complex forms. Further, there are mobile applications which offer a chat bot [31], a feature which can replace some of the human interaction, but has proved to not be very effective in emergency cases. As a common function, the most available mobile applications allow for the sharing of one's geolocation, but only a limited number share multimedia messages.

An alternative to emergency voice calls is necessary for people with disabilities or people in situations when calling is not an option [32]. The study of Repanovici and Nedelcu (2021) assessed the three options for emergency communication, voice calls, SMS, and mobile apps, by using a multicriteria analysis based on the following criteria: manufacturing and maintenance cost; utility; quantities of information; accuracy of information; data monitoring; user perception; usability; and time of response. The results showed that the mobile app is the best option for communication during an emergency [32].

An analysis of the literature revealed that there are very few mobile apps which can effectively replace a call to the emergency number 112 by using communication through text messages and other app functionalities, especially in cases of small-scale events. Therefore, the research presented in this study aims to fill this gap and proposes a useful application, which can easily be by people to alert rescue operators. Moreover, as a lack of a centralized system was identified, the study includes a second application to be used by dispatchers in order to optimize the emergency alerting process.

According to Romano, the apps available on the market have an interface design which negatively affects the user's interaction [20]. Therefore, the applications presented in this study aim to offer a very intuitive and easy-to-use interface, even for use by citizens without prior training.

## 3. Methods and Materials

### *3.1. Research Methodology*

The present research consisted of two parts: the first part was the development of the integrated alert system and the second part was testing the usability of the application.

The development of an emergency alert system implies developing two applications: the mobile application for victims and the web application for dispatchers. The approach used in the development process is the Rapid Application Development (RAD) methodology, which is an adaptive and agile approach for software development that focuses more on achieving a product that meets clients' needs (or potential users' needs in this case) than on strict planning. The main objective of this approach is to deliver high-quality systems with fast development times and low costs [33]. This approach is especially suitable for the present research because it involves a small development (research) team and low costs. Another aspect taken into consideration is the focus on delivery rather than on having numerous requirements [33].

The four stages in the RAD model are: requirement planning, user design, rapid construction, and transition [34].

In the first stage, the authors conducted a study to identify similar applications and their functionalities, followed by a survey on the desired usability and a focus group session with the aim to establish the objectives of the proposed tool.

Once the desired characteristics of the system were defined, the authors moved on to the next stage: developing the first prototype of the two applications. Several cycles of testing, collecting feedback, and developing followed until the applications reached a final version.

In the last stage (product finalization), the applications were tested in real life, using a fire scenario with 49 participants. In this phase, the usability (easiness, utilization time, and response times) was evaluated, and afterwards, a survey was conducted among the participants to assess how they interacted with the applications.

The method proposed in this research also implies an iterative process: the first working model is developed, which is presented and tested in a small group of persons; then, feedback is gathered and the prototype is improved based on the input. This cycle is repeated until the last phase of testing, which is the usability test.

The results obtained by means of this methodology can clarify potential design issues, allowing researchers to learn from the experiment in order to develop a product that meets the needs of the end users as well as possible.

The research phases are described in detail in the next sections.

### *3.2. Description of the Emergency Alert System*

The first step of the research was to conduct a study of the literature and an assessment of existing applications in order to identify the requirements for the emergency alert system. Before starting the development of the mobile application, in order to meet user expectations, a survey was conducted on the desired usability. A set of statements from five categories regarding the usability of an emergency mobile application was distributed to 27 respondents who participated in the design phase of the emergency mobile application for victims. According to ISO/IEC 9241, usability, or the degree of usefulness, is referred to as, "the way in which a product can be used by specific users in order to achieve the specified objectives effectively, efficiently and satisfactorily in a specific context" [35]. Afterwards, a focus group consisting of the authors and two other collaborators took place to analyse the responses and to establish the research objectives and the main characteristics of the tool.

Thus, in order to ensure the ease of use of the developed mobile applications, the following principles of use specific to smart mobile devices were taken into account [36]:

- Visibility of system status;
- Concordance between the system and the real situation;
- User control and freedom;
- Application consistency;
- Compliance with security standards;
- Error prevention;
- Easy identification of main functions;
- Flexibility and efficiency of application use;
- Application design;
- User guidance for recognizing and diagnosing errors in the application;
- Application documentation (user manual).

The emergency alert system was developed with the main objective of offering complementary functionalities to existing systems on the market, such as:

- The possibility to create an emergency alert without sound;
- The possibility to request multidisciplinary help, simultaneously, in a single notification;
- The possibility to select the appropriate response provider for the reported situation;
- The possibility to create an alert in a limited amount of time, with a short and concise textual description composed of predefined keywords;
- The possibility to inform simultaneously the emergency dispatcher regarding a major event in which several people are involved, and for which, individual calls prove to be ineffective to describe the extent of the event (correlation of the alerts depends on the users' location);
- The possibility to create silent emergency alerts, which are necessary in situations such as terrorist attacks, deprivation of liberty, etc., in which a phone call could endanger the caller's life;
- The possibility to notify the nearest available dispatcher;
- The possibility to collect and share a user's personal details in a very short time.

The most complex case that the application takes into account is when multiple alerts are transmitted from the same location, allowing the PSAP operator to deduce the extent of the event and act before it escalates. However, although the application does not consider single-victim emergencies, words such as "rape" or "kidnapped" have been added to the keyword list to cover such events when the victim cannot alert the emergency dispatcher through a voice call because any noise could endanger his/her safety.

Regarding the minimum information required to create an emergency alert, the user's position combined with the user's profile (phone number and full name), which are data that are automatically retrieved; the selection of providers able to respond; and the associated keywords have demonstrated to be sufficient. Storage of personal information and the automatic retrieval of a device's position allow the sending of an emergency notification in

just two steps, with the users being able to select the response provider (police, fire brigade, or ambulance) and the keywords associated with the emergency event.

In an emergency situation, the users of the mobile app intended for victims will be able to alert the nearest emergency dispatcher to quickly transmit the specific details of the situation, as well as essential information such as: exact location, identification data of the user (name and phone number), requested response provider, and words associated with the event produced.

The information received from the mobile application intended for victims will be transmitted to the web application intended for dispatchers, which allows the operators from the emergency command to view the respective information. Thus, the operator from the emergency dispatcher will be able to analyse the alert and the needs of the caller in real time, allowing them to intervene and provide the required assistance at the scene.

As soon as an emergency alert is initiated by means of the victim mobile application, a notification will reach the nearest emergency dispatcher. The operator in the emergency command centre analyses the alert received, the user's request, and the identification data. An emergency alert can contain only one type of request, depending on the event, as follows:

- In the case of an accident where a pedestrian was hit on a pedestrian crossing, the alert sent by the user can contain only one type of request:
    - "Ambulance".
- In the case of more serious events, or where several persons are involved, such as a terrorist attack, a fire, or a car accident with victims, the notification may contain two or even three simultaneous requests:
    - "Police";
    - "Fire brigade/SMURD" (Mobile Emergency Service for Resuscitation and Extrication);
    - "Ambulance"

After analysing the alert, the operator initiates the rescue operation by sending the request to the qualified rescue teams: police, firefighters/SMURD, and/or ambulance.

As soon as the emergency alert has been redirected to the rescue teams qualified to intervene at the scene of the event, the PSAP operator transmits to the user, by means of the application, the estimated time in which the rescue teams will arrive at the scene of the reported incident. Similarly, in the web application intended for dispatchers, the operator can visualize with the map, in real time, the intervention of the teams.

The flow of the alerting process, where the notification is transmitted from the victim mobile application to the web application intended for the PSAP dispatcher, is illustrated in Figure 3.

In order to send an emergency mobile alert, users must execute the following steps, which could take an average of 10 s:

1. Authentication in the mobile application intended for victims.
2. Creation of emergency alert:
    a. Identification of the response provider according to reported incident (police, firefighters/SMURD, or ambulance)
    b. Selection of keywords specific to the incident (for example: casualties, terrorism, injured, accident, crowd, rape, weapons, kidnapping, or avalanche).
3. Sending the notification.

As soon as the user has completed the previous steps and the alert has been launched from the mobile application intended for the victims, the notification can be sent to the database of the emergency dispatchers, which is later redirected to the nearest PSAP.

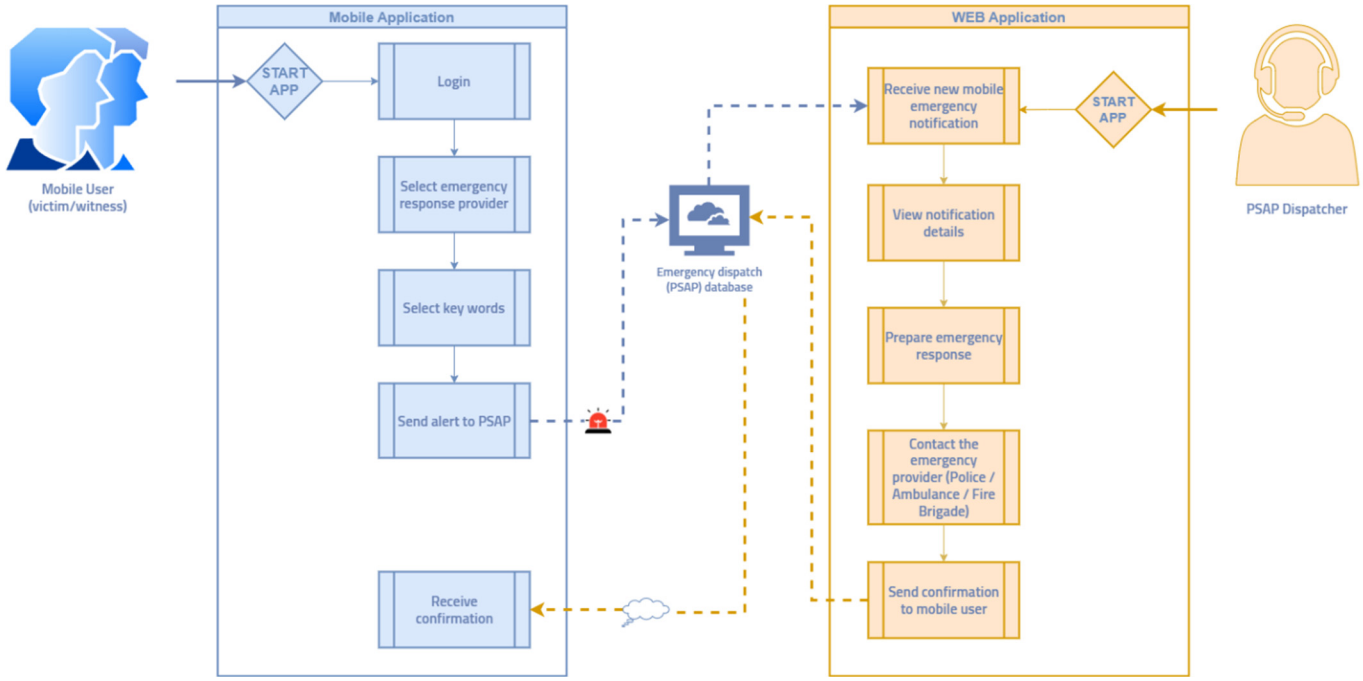


**Figure 3.** Alert process flow.

Next, when the dispatcher web application receives a new alert, the PSAP operator in the dispatcher where the notification arrived takes the following steps to analyse and handle the received emergency alert:

1. Display the emergency alert received.
2. Analyse the alert and initiate the rescue operation:
    - Contact the response provider according to the reported incident (police, fire-fighters/SMURD, or ambulance);
    - Inform the user about the estimated intervention time.

### *3.3. Victim Mobile Application*

In order to use the emergency mobile application for victims, users must first install the application on a smart mobile device equipped with an Android operating system. The application can be installed on any mobile device running Android 9.0 or a newer version.

The mobile emergency system developed within this project is not intended to be used in the context of a real emergency situation. Therefore, users did not have access to a dedicated application in the application store provided by Google; thus, to install the mobile application on a smart mobile device, they needed to copy the apk file of the application to the "Downloads" folder of the device to launch the installation.

After the analysis was carried out, ten use cases (UC) were identified for the mobile application intended for victims, of which six are main cases and four are secondary cases:

- UC01: application launch.
- UC02: new user registration.
- UC03: login.
- UC04: view personal data.
    - UC041: edit profile.
- UC05: create emergency alert.
    - UC051: emergency alert transmission.
    - UC052: cancellation of emergency alert.
    - UC053: view emergency alert status.

- UC06: disconnect.

To access the services provided by the emergency mobile application for victims, the user must, firstly, install the mobile application on his/her device, create a user account, and allow the application to access all requested data (e.g., device location).

Based on the use cases described in the previous section, the following six screens were designed:

- SCR_REG_001—registration screen;
- SCR_LOG_001—login screen;
- SCR_EMG_001—screen for selecting the response provider appropriate for the emergency situation;
- SCR_EMG_002—emergency-specific keyword selection screen;
- SCR_WFC_001—PSAP confirmation waiting screen;
- EMG_CFM_001—emergency alert confirmation screen.

After installation, when opening the application for the first time, the user will see the registration screen, called SCR_REG_001. At this stage, to create a new profile, the user must provide personal details for personal identification. An emergency alert containing all this personal information increases credibility, giving the user the chance to shorten the response time of rescue teams. After the account has been created, the user can use the application to send emergency alerts to PSAP, log out, or change their personal information. The user can view and update his/her profile at any time after login.

Immediately after installation, or the next time when the application is opened, the user will enter a login screen, called SCR_LOG_001. Thus, if the device used by the user already has an account created, the login screen will be the first screen displayed when opening the application.

After authentication, the application will show the user the screen for selecting the rescue team(s) (Eng. Get Help From), named SCR_EMG_001. This screen presents three buttons with visual icons that allow for a quick and easy selection of the emergency provider appropriate to the victim's situation. Each button represents one of the three main emergency response providers available in Romania:

- "Police": stands for police service;
- "Ambulance": stands for ambulance service;
- "Fire brigade": stands for SMURD fire and rescue service.

Once the user has validated the selection of the response provider appropriate for the respective emergency situation, the mobile application will show the user the screen for selecting the words that describe this situation (details), called SCR_EMG_002. This screen is composed of ten buttons that allow the victim to quickly and easily describe the crisis event. Each button represents a keyword that can describe a specific situation.

After the user selects the keywords specific to the current event on the SCR_EMG_002 screen and validates the action by pressing the validate button, the mobile application will display the PSAP confirmation waiting screen, named SCR_WFC_001. The purpose of this screen is to notify the user through both a text message and an animation that the request has been forwarded to the emergency dispatcher and will be picked up by a PSAP operator as soon as possible.

After the PSAP operator sends the emergency request to the rescue teams qualified to intervene in the situation described by the mobile user, the system will notify the user about the estimated time of the arrival of the rescue team. Thus, the mobile application will display the emergency alert confirmation screen (Eng. "Help is on the way"), called SCR_CFM_001, by which the user is notified that his request has been processed and the rescue team is on the way.

The flow of the emergency mobile application is illustrated in Figure 4.

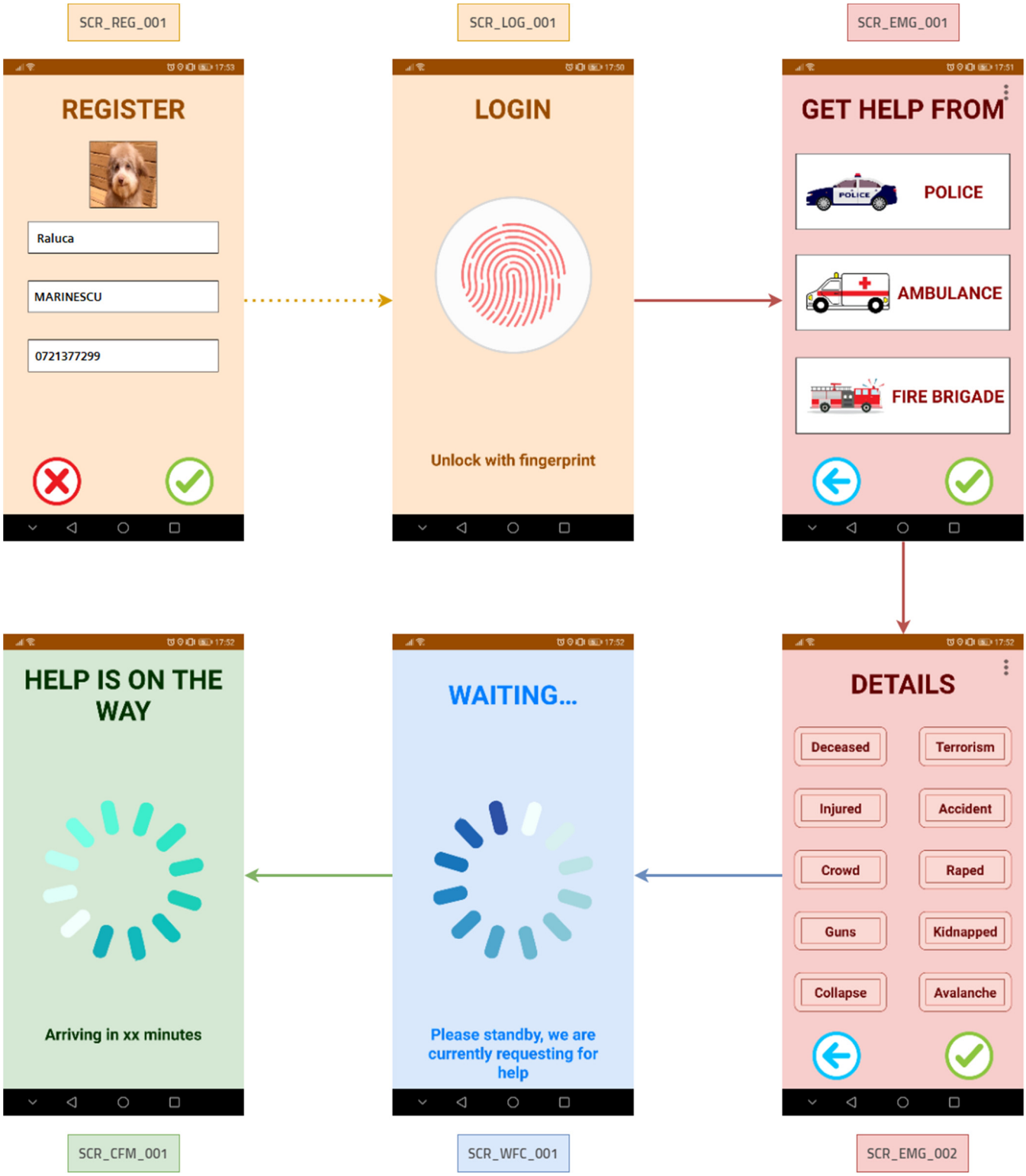


**Figure 4.** Emergency mobile application for victims: usage flow.

As it can be seen from the usage flow (Figure 4), in order to send an emergency alert through the victim mobile application, the user needs to follow these steps:

1. Authentication.
2. Create notification:

a. Identification of the response provider adequate for the reported incident (police/ambulance/firefighters);
b. Selection of keywords specific to the incident (for example: casualties, terrorism, injured, accident, crowd, rape, weapons, kidnapping, or avalanche).

3. Notification validation.

Once the user has completed the previous steps, the created alert, together with all identification data (entered by the user during the registration process) and the user's location, is transmitted to the database of emergency dispatchers and is visible in the web application intended for dispatchers.

### *3.4. Web Application for Dispatchers*

As it has been developed for experimental purposes only, the web application for dispatchers is not available at a public web address. Thus, to access the services offered by the web application for dispatchers, the user must launch the web application on a laptop or computer with Internet access by accessing the localhost port: 70.34.207.151:3000. The web application was developed to receive the alerts sent by victims via the mobile application. Therefore, it was developed in a simplistic way, and is composed of three screens where the emergency dispatch users can view the location of the emergency alert, the total number of alerts received from the same location, and also, the details of the users (name and phone number). Afterwards, after analysing an alert, the PSAP operator can select to send the service requested by the user to the victim's location. To test the system, a random hardcoded location was used, which was assumed to be the location of the dispatcher. To calculate the appropriate route and the estimated time of arrival of rescue vehicles at the location indicated by the victim, the web application for dispatchers uses the Google Directions API.

Following the analysis, a total of four use cases (UCs) were identified for the web application intended for dispatchers:

- UC01: application launch;
- UC02: emergency alert reception;
- UC03: emergency alert analysis;
- UC04: starting rescue operation.

Considering the fact that the web application was developed exclusively for the experimental testing of the system, it was not intended to be used simultaneously by several users. Therefore, functionalities such as user profile creation, user registration/logout, profile editing, accessibility, and system administration were not implemented at this time.

Based on the use cases described in the previous section, the following three screens were designed:

- SCR_WEB_001—main screen;
- SCR_WEB_002—alert reception screen;
- SCR_WEB_003—emergency analysis screen.

After launching the application, the user will be shown the main screen, called SCR_WEB_001. At the moment of receiving an emergency alert, the data transmitted by the mobile users will be automatically retrieved and displayed in the web application intended for dispatchers, and can be viewed later by the PSAP operator.

When an emergency alert is received, the user of the emergency dispatcher will be shown the alert reception screen, named SCR_WEB_002. When one or more alerts are sent via the mobile application, the data of the mobile users will be automatically retrieved by the web application intended for dispatchers. Thus, when the system receives a new notification, the web application will display the message, "New request".

To view the details of the received alert, the PSAP operator must open the notification in the SCR_WEB_002 screen by clicking on the "New Alert" message displayed in the alerts section. In this step, the web application will display the alert analysis screen, named SCR_WEB_003. Now, the user has the possibility to analyse the received alerts, and later

on, can send the request to the appropriate command centre. For example, if the received notifications contain the keywords "fire", "crowd", or "injured", the PSAP operator will forward the request to all three command centres of police, firefighters, and ambulance, according to the established protocol for such situations. Finally, after selecting the relevant provider and in order to transmit the notification to the requested command, the PSAP operator must press the "Begin Operation" (dispatch resources) button. At this point, the user of the mobile application is informed of the estimated time in which the rescue team will arrive at the scene of the event.

The web application flow is illustrated in Figure 5.

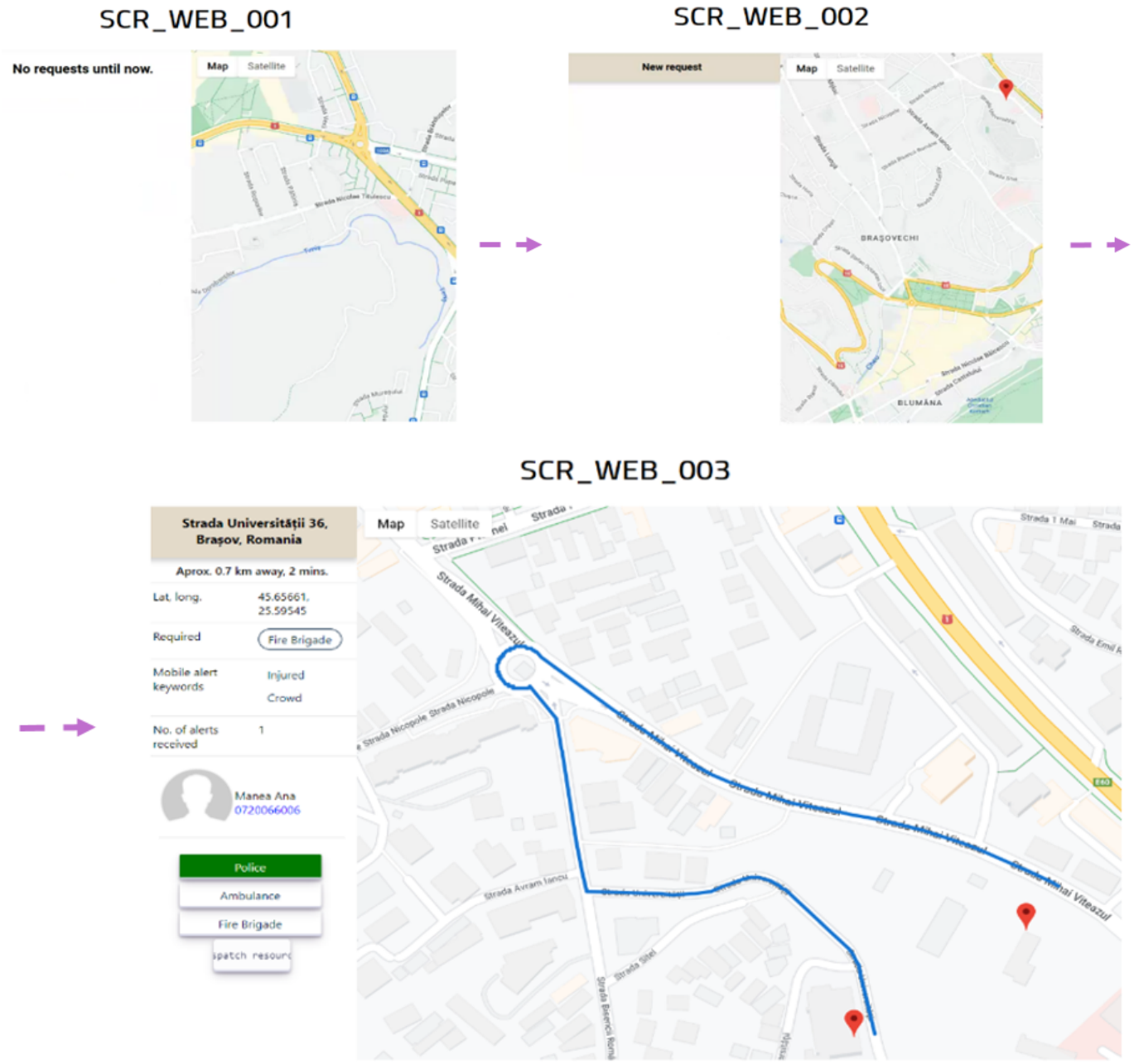


**Figure 5.** Web application for dispatchers: usage flow.

### *3.5. Used Technologies*

This section lists the technologies used for developing the mobile emergency system, including both the emergency mobile application for victims and the web application for dispatchers, and also illustrates a short section of the written code.

Android is an operating system developed by Google for open-source smart mobile devices [37,38].

Android Studio is the main Android IDE (integrated development environment) and provides an Android developer with all the tools needed to develop an Android mobile application. More specifically, it facilitates code writing via autocompletion tools, debugging, testing, and running code on a physical or virtual device, in addition to allowing for setting programming or visual preferences. Java and XML are the only programming languages needed to create applications using Android Studio [37,38].

Google Play Services provides mobile application developers with a full set of useful features, such as maps and a connection to the Google+ platform. The services include the Google Play Services Client Library and the Android Package Kit for Google Play Services. Other important functionalities, such as viewing a map and obtaining a user's location, also rely on these services provided by Google [39].

API Google Location is a part of Google Play Services, and it provides a more robust framework that automates the selection of a location provider and operation management. Mobile application developers intending to use location techniques should consider using Google's location services if they use the API framework [40].

Google Maps Library (API Android Google Map) is also a service that is a part of the Google Play Services Library. It facilitates accessing the Google Maps server automatically, displaying the map, downloading data, and interacting with the map. It also allows adding map markers, polygons, and basic overlays, as well as user transit between map areas [40].

Google Places Library (API Google Places Web Service) is a service that returns geographic information about locations, units, and prominent points of interest using HTTP requests. In the free version, Google Places allows over 150,000 queries per day [40].

API Google Directions is a service that uses HTTP requests to calculate the distance between two or more queried locations. When calculating the directions, the library returns the most suitable route in addition to its alternatives, with the ability to highlight the most efficient route based on the required travel time or on the distance to be covered [40].

Developed by the Django Software Foundation, Django is an open-source web framework that observes a "model-template-view" architectural pattern. Using Django, web developers have the ability to create complex websites with database connections [41,42]. Django version 3.2.9 (Django Software Foundation, Atlanta, GA, USA) was used to create the emergency mobile application for victims.

Used preponderantly for Python computer programming, the PyCharm IDE provides its users with the necessary tools for code analysis, graphical debugging, unitary testing, and version control systems. Created by the Czech founders of JetBrains, PyCharm supports web developers that use Django by also providing support for data analysis with Anaconda [43].

Ranked as the most popular tool for developers, Visual Studio Code is a code editor for Windows, Linux, and macOS developed by Microsoft. As it can be used as a free alternative for web development on any platform, in any location, Visual Studio Code can be integrated with a multitude of programming languages such as C++, Node.js, Java/JavaScript, and Python [44].

In order to illustrate the code written and the programming language used (Java), a short section of code from the login screen is presented in Figure 6. As soon as the user opens the login screen, the authentication.enableBiometricLogin(this) function is automatically called. Depending on how the user interacts with the authentication module, the onActivityResult function receives a response code.

```
@Override
public void onResume(){
    super.onResume();
    // enable biometrics whenever this activity is resumed
    authentication.enableBiometricLogin( activity: this);
}

@Override
protected void onActivityResult(int requestCode, int resultCode, Intent data) {
    super.onActivityResult(requestCode, resultCode, data);
    switch (requestCode) {
        case Authentication.LOCK_REQUEST_CODE:
            if (resultCode == RESULT_OK) {
                System.out.println("SUCCESS");
                Authentication.markUserAsLoggedIn( value: true);
                ActivityUtil.moveToGeneralHelpActivity(this);
            } else {
                //If screen lock authentication is failed update text
                // re-enable the fingerprint sensor if the user canceled the process
                authentication.enableBiometricLogin( activity: this);
            }
            break;
        case Authentication.SECURITY_SETTING_REQUEST_CODE:
            //When user has enabled Security settings then we don't get any kind of RESULT_OK
            //So we need to check whether device has enabled screen lock or not
            if (authentication.isDeviceSecure()) {
                //If screen lock enabled show toast and start intent to authenticate user
                authentication.enableBiometricLogin( activity: this);
            } else {
                //If screen lock is not enabled just update text
                Logger.LOGGER.log(Level.SEVERE,  msg: "Screen lock is not enabled");
            }
            break;
    }
}
```

**Figure 6.** Authentication screen—the enableBiometricLogin function.

## 4. Research Description

### *4.1. Experimental Testing of the Emergency Alert System*

The assessment of the conceived emergency alert system consists of two parts: the first part is the experimental testing of the mobile application for victims and of the web application for dispatchers, and the second one is the evaluation of users' satisfaction.

The objective of the experimental testing is to analyse the SASU emergency alert system, which is composed of an emergency mobile application for victims and a web application for dispatchers, in order to understand its real utility, potential benefits, and limitations. The ultimate goal of the testing was to assess the benefits and drawbacks of using the victims' emergency mobile application in a real-world setting.

In order to test the validity and usability of the application, an emergency scenario was chosen. This was selected during a group brainstorming session where the researchers discussed different possibilities. As a starting discussion point, the Bataclan (Paris, France) and Colectiv (Bucharest, Romania) events that took place in 2015 were considered. Such scenarios took place in locations with crowds of people, and the purpose of the proposed mobile application is to facilitate the intervention of rescue teams in such situations. During the discussion, it was also highlighted that in the case of a common emergency scenario (e.g., car accident or injured pedestrian), the mobile application cannot provide real help, as the PSAP operator can be misled by the information coming from a single alert. The cases that the application target are when multiple alerts are sent from the same location, and the PSAP operator can deduce the extent of the event and act before the situation escalates. For

this reason, it was decided to simulate a fire at Transilvania University of Brașov, Brașov, Romania.

The experimental testing of the SASU emergency alert system took place between June and July 2022. The experiment took place at the Transilvania University of Brașov's Faculty of Sociology and Communication over the course of two rounds, with participation from the students and professors of the following specializations: digital media, and communication and public relations.

As the purpose of this testing phase was to assess if the applications developed can easily be used by citizens in real-life situations, and also, if the working methodology proposed could be useful in similar research, it was decided that although the sample chosen is not representative, it fulfils the intended scope. Moreover, this mobile emergency system may be implemented in the future on the university campus.

Thus, two groups of participants participated in the testing and validation of the emergency mobile application for victims, as follows:

- Group I:
    - Twenty-two first-year students at Transilvania University in Brașov, Faculty of Sociology and Communication, majoring in digital media;
    - Two university professors;
    - One teaching assistant.
- Group II
    - Twenty-two first-year students at Transilvania University in Brașov, Faculty of Sociology and Communication, majoring in Communication and Public Relations;
    - One university professor;
    - One teaching assistant.

The age groups of the respondents were as follows:

- Forty-four respondents were under 21 years old (students);
- Two respondents were aged between 31 and 40 (teaching assistants);
- Three respondents were aged over 50 (university professors).

Each test session lasted for approximately 25 min: the participants were introduced to the SASU emergency alert system, the mobile application was installed on compatible phones, the users interacted with the application at the time of the simulated emergency event, and subsequently, they answered a usability questionnaire whose results are presented in the following sections.

During the presentation of the SASU emergency alert system, the participants were informed about the purpose of the assessment, but not about the process itself, being instructed to perform certain tasks with the mobile application. This choice is due to the fact that this experience was intended to simulate the stress felt during an emergency situation in order to validate the usability of the mobile application in an unusual situation.

Before starting the experiment, the emergency mobile application for victims was installed on the participants' phones. Only the mobile devices with an Android operating system that include fingerprint authentication or facial recognition were chosen. To install the mobile application, the users copied the apk file of the application to the "Downloads" folder of the device and launched the application. The participants had the application manually installed on their phones, as it is not available in the application store offered by Google since the SASU emergency alert system was developed exclusively for research purposes.

Afterwards, the necessary settings and permissions were configured by the users. After configuring the required permissions, the users created a user account to use the emergency mobile application for victims.

The experiment started without preliminary preparation, as the main purpose was to observe the degree of users' understanding regarding the mobile application, the screens, and also, the designed flow of use.

Afterwards, the participants were faced with the emergency scenario: the fire alarm was triggered, and they were asked to alert the emergency dispatcher via the mobile application installed on their phones. The actions required to create a mobile emergency alert are displayed in Table 1, where the average time needed to carry out each of the described actions is shown.

**Table 1.** Mobile application usability test actions.

| Action | | Average Time |
|---|---|---|
| 1.1 | Application installation | 0:20 |
| 1.2 | Account creation | 0:30 |
| 1.3 | Response provider selection | 0:09 |
| 1.4 | Keyword selection | 0:15 |
| 1.5 | Alert release | 0:05 |
| 1.6 | PSAP response | 0:02 |

Research has shown that alerting an emergency incident via a voice call to the European emergency number "112" takes between 30 and 278 s, with an overall average of 90 s [5,45–48]. Comparatively, the average time it took to send an emergency alert via the mobile application for victims was about 30 s, which included the time needed for users to select the appropriate response provider and the keywords associated with the event. Among the options offered by the mobile application when creating the emergency alert, the users chose:

- The response provider appropriate to the situation:
  - Ambulance.
  - Fire Brigade.
- Keywords associated with the event:
  - Injured.
  - Crowd.
  - Accident.

The benefits that the emergency mobile application for victims offers are obvious. In cases of simultaneous calls coming from the same location, the PSAP emergency dispatcher needs a PSAP operator for each caller, and if they are not available, call response times are extended and victims must wait to be able to communicate the problems they face. Using the mobile application, information can be aggregated and monitored automatically, requiring only one PSAP operator that manages data from the same location.

### *4.2. Evaluation of User Satisfaction*

To assess the level of satisfaction among end users, a satisfaction survey using multiple choice questions was conducted for the two emergency applications developed: the mobile application for victims and the web application for dispatchers. A set of 19 questions regarding the use of the emergency mobile application was distributed to the 49 respondents who participated in the testing phase of the emergency mobile application for victims: the first group of 22 digital media students; the second group of 22 communication and public relations students; and the third group of 5 professors and teaching assistants. Afterwards, to test and validate the emergency web application intended for dispatchers, the five members of the teaching staff, including professors, and teaching assistants, from Transilvania University in Brașov were asked to answer a set of 15 questions regarding the use of the emergency web application.

The results of the questionnaires are presented in detail in Sections 4.2.1 and 4.2.2.

4.2.1. Survey on User Satisfaction of the Emergency Mobile Application for Victims

All 49 participants who took part in the testing of the SASU emergency alert system were later asked to evaluate the mobile application for victims. During the experiment, the five members of the teaching staff were asked to interact mainly with the web application intended for dispatchers, but they also actively participated in the testing of the mobile application.

The questionnaire was divided into two parts, where the first 18 questions referred to the current state of the mobile application and the last 1 was for suggestions and recommendations. For these questions, the respondents had the following options:

1. Totally Disagree;
2. Disagree;
3. Don't Know;
4. Agree;
5. Totally Agree.

The responses collected from the three groups of respondents were combined, as shown in Figure 7, in order to represent the results obtained using a random sampling technique.

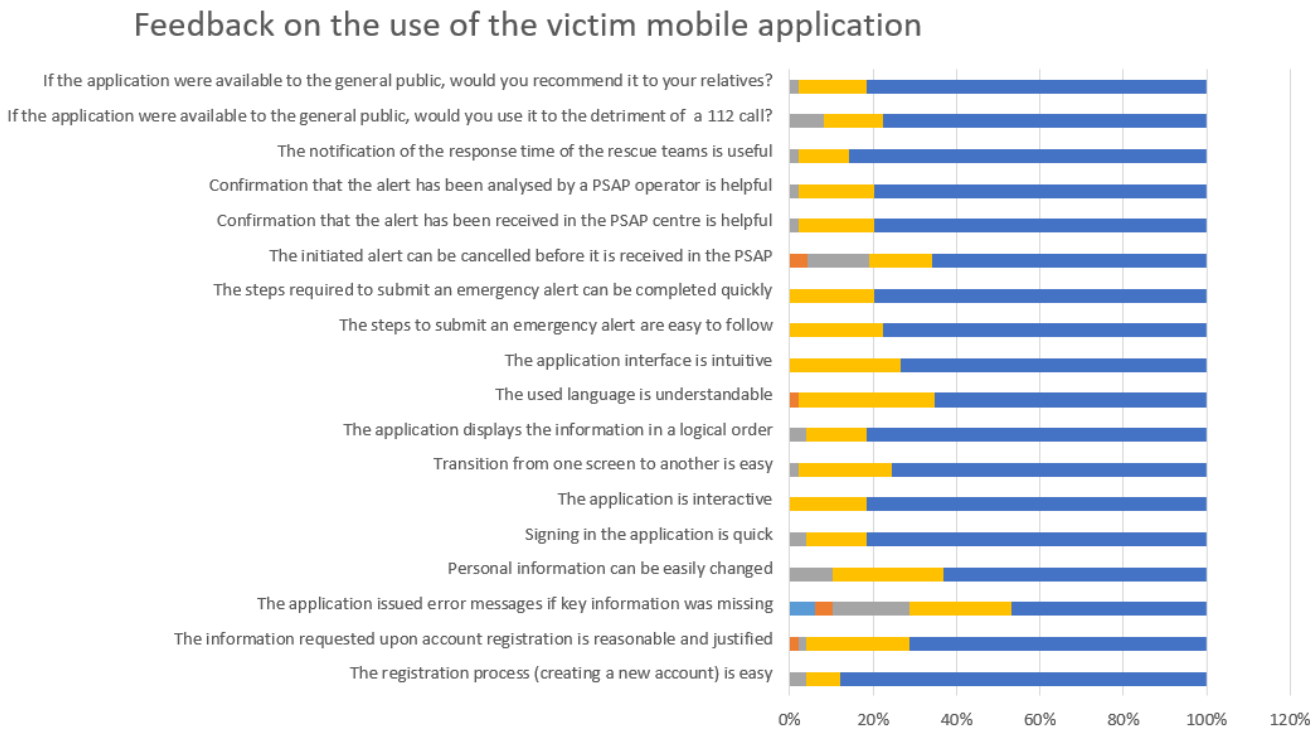


**Figure 7.** The mobile application for victims: results of the satisfaction questionnaire.

The highest score for the fifth answer option: Totally Agree was obtained for the question, "The registration process (creating a new account) is easy" (87.76%, representing 43 answers out of a total of 49); the question, "The notification of the response time of the rescue teams is useful", came in second, as it obtained 42 responses out of a total of 49, scoring 85.71%.

The questions regarding the process of registering a new user, "The registration process (new account creation) is easy" and "The information requested during account registration is reasonable and justified", scored well, both receiving the answer options of 4: Agree and 5: Totally Agree at a rate of 95.92%.

Similarly, the questions related to user interaction with the emergency mobile application intended for victims obtained very good results, being evaluated mostly with the

answer options of 4: Agree and 5: Totally Agree. Of these, the best scores for the answer options of 4 and 5 were obtained for the following questions:

- The application is interactive; with a score of 100%.
- The application interface is intuitive; with a score of 100%.
- The steps required to submit an emergency alert are easy to follow; with a score of 100%.
- The steps required to submit an emergency alert can be completed quickly; with a score of 100%.
- The transition from one screen to another is easy; with a score of 97.96%.
- The language used is understandable; with a score of 97.96%.
- The confirmation that the alert was received in the PSAP centre is useful; with a score of 97.96%.
- The confirmation that the alert has been analysed by a PSAP operator is helpful; with a score of 97.96%.
- The notification of the response time of rescue teams is useful; with a score of 97.96%.
- The authentication in the application is fast; with a score of 95.92%.
- The application displays the information in a logical order; with a score of 95.92%.

The question regarding the use of the application over the use a voice call to 112 received 7 answers (14.29%) for the answer option 4: Agree and 38 answers (77.55%) for the answer option 5: Totally Agree.

It should be noted that 3 users omitted to answer the questions, "The interface of the application is intuitive" and "The notification about the intervention time of the rescue teams is useful". Similarly, of the 18 questions, only 4 were scored with the answer options 1: Totally Disagree and 2: Disagree, as follows:

- "The information requested during account registration is reasonable and justified".
    - Option 1—Totally Disagree: zero answers (0%).
    - Option 2—Disagree: one answer (2.04%).
- "The application issued error messages if key information was missing".
    - Option 1—Totally Disagree: three answers (6.12%).
    - Option 2—Disagree: two answers (4.08%).
- "The language used is understandable".
    - Option 1—Totally Disagree: zero answers (0%).
    - Option 2—Disagree: one answer (2.04%).
- "The initiated alert can be cancelled before it is received in the PSAP".
    - Option 1—Totally Disagree: zero answers (0%).
    - Option 2—Disagree: two answers (4.26%).

Thus, the results obtained reflect the success of the emergency mobile application for victims and the degree of acceptance among most of the users.

The last question, "Suggestions, proposals, comments", was formulated in order to obtain suggestions for further development, and the respondents had the possibility to answer according to their personal experience when testing the application. In this regard, 19 suggestions, proposals, and comments were collected, most of them referring to:

- The utility of the application;
- The need to develop the application in Romanian;
- The need to develop the iOS application (for iPhone);
- Keyword expansion;
- Public testing, promotion, and sale.

The suggestions and proposals offered by the respondents to the last question in the questionnaire regarding the degree of satisfaction using the emergency mobile application intended for victims reveal the fact that the participants had a positive opinion, as the

suggestions for improvement were mainly regarding its development in Romanian and to the development of a version for the mobile devices running iOS.

#### 4.2.2. Survey on User Satisfaction of the Emergency Web Application for Dispatchers

After developing and testing the SASU emergency alert system, in order to assess the level of satisfaction among the end users, a satisfaction survey was conducted regarding the web application for dispatchers.

To test and validate the web application intended for dispatchers, a group consisting of five members of the teaching staff, including professors and teaching assistants, from Transilvania University of Brașov was selected.

During the experiment, the five participants were asked to interact mainly with the web application for dispatchers, and later, they were given the questionnaire on the degree of user satisfaction with regard to the web application for dispatchers.

Thus, a set of 15 questions regarding the use of the emergency web application was distributed to the five respondents who participated in the test phase of the emergency web application intended for dispatchers.

The questionnaire was divided into two parts, with eight questions referring to the current state of the web application, and the remaining seven questions being asked for the purpose of further development. The respondents had the following options:

1. Totally Disagree;
2. Disagree;
3. Don't Know;
4. Agree;
5. Totally Agree.

The results obtained are shown in Figure 8. As for the questions in the second part of the questionnaire regarding the potential development of the web application for dispatchers, the highest score for answer option 5: Totally Agree was 100%, which was obtained for the following three questions:

- "Users should be able to view on the map, in real time, the intervention of rescue teams";
- "Users should be able to view the intervention in real time";
- "Users should be given a training course before using the application".

Two other questions, namely, "The application should provide visual aid to guide the user", and "Users should have access to a guide for using the application", were answered with the options 4: Agree (20%) and 5: Totally Agree (80%), which reflects the need for the further development of the system in order to achieve a better performance in real emergency situations.

It should be mentioned that no question was marked with the answer options 1: Totally Disagree, 2: Disagree, or 3: Don't Know. The results reflect the success of the web application for dispatchers and the degree of acceptance among the untrained users in the field of emergency situations. Thus, in the light of the obtained results, it can be considered that the web application intended for dispatchers has been validated.

The first validation of the developed integrated system consisted of the actual completion of the conducted simulation. Secondly, the satisfaction surveys showed good acceptance from the users.

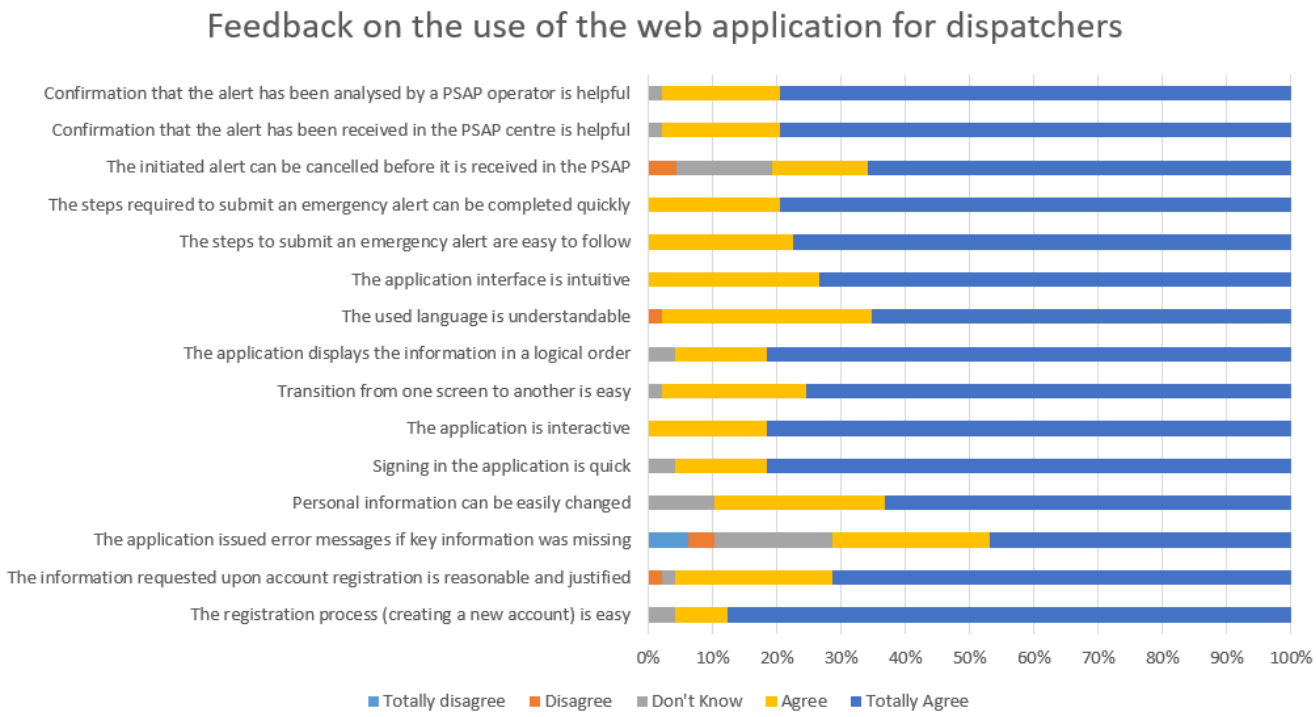


**Figure 8.** The Web application for dispatcher: results of the satisfaction questionnaire.

## 5. Discussion and Conclusions

The experimental testing of the SASU alert system in emergency situations highlighted some interesting elements regarding the usefulness of the system, its acceptance among users, and its ability to be used through an emergency mobile application intended for victims.

Case studies on the sequence of steps in emergency situations have demonstrated that the speed of reactions and interactions with rescue forces is crucial. Reducing the time from the onset of the intervention is the most important feature. The processing procedure of an emergency call depends on the average time to answer the call; the average duration of the call, which is reported to be approximately 2 min; and the ideal duration of a call, which is estimated to be a maximum of 30 s. A critical analysis of existing mobile emergency applications on the market revealed that mobile emergency alerts can reduce the overall call duration by reducing the time for making the call, the period of time until the call is answered, and the time required to obtain personal information, address details, and an event description.

There are several applications available for target alerting in cases of emergency situations, but as the analysis concluded, these have flaws in terms of content and interactions [20]. Most of the mobile applications that allow sending an alert through a text message provide the user position through the embedded GPS, which is a function that the application presented in this study offers too. Other applications allow for the gathering of data in the form of photos, videos, or audio, which could be a feature to be added in the future to the mobile app presented here.

What this study proposes that could not be identified in the literature is an integrated emergency system which includes a mobile app for citizens to send alerts about emergencies through text messages and a web app for dispatchers to deal efficiently with the messages received.

The main contribution of this research is the development of an emergency system which integrates two applications, a mobile app for citizens and a web-based app for dispatchers. Both of them proved their usability within a test scenario. The most valued features besides the general intuitive flow include: the possibility to process more notifications simultaneously; the accuracy of personal information provided; the transmission

of the exact location; the accessible language; and the sending of a confirmation message. These ideas could enrich the current knowledge around mobile applications for emergency situations.

First of all, it was discovered from this research that the emergency mobile application for victims can have a positive impact on the current mechanisms used to inform about exceptional events. Although the average time for sending a message via the application is significantly lower compared to a voice call to 112, its real utility lies in the fact that an operator at the emergency dispatch centre can handle several notifications at the same time. This represents one of the advantages of using the tool: the time until the alert is registered and actions are taken is shortened. In addition, the content of the notification is accurate, and the provided information is sufficient to deal with the event. Furthermore, the dispatchers can quickly identify if the event is a collective one, implying that there are more victims, and they can compile data gathered from more users.

Moreover, the application can prove to have further utilities in situations when the victim is not able to make a call, but instead can use their phone to create an alert.

Further, the application seemed to be accepted by potential users. In the light of the results obtained from the surveys, it can be considered that the mobile application was validated. The vast majority of the respondents stated that they would use this application over a voice call to 112. However, the developed application is not intended to replace traditional phone calls, but only to provide citizens with another official channel.

In terms of usability, the experiment demonstrated that the application can be easily used, and the answers from the questionnaires show a good level of acceptance. Moreover, the experiment revealed that the participants showed no hesitation in handling the phone and in gathering the necessary information, thus proving that the application is intuitive.

The accuracy level of the GPS built into smart mobile devices is considered adequate by both experts and users. By automatically retrieving the location, further interactions such as using a map or describing an address are avoided. Regarding the minimum information required to create an emergency alert, the user's position combined with the user's profile (e.g., the phone number and the full name) and the selection of the response provider together with the associated keywords proved to be sufficient. Storing personal information and automatically retrieving the device's position allow for sending an emergency notification in just two steps, as users only have to select the response provider (police, fire brigade, or ambulance) and the keywords associated with the emergency event.

It was also found that short and direct interactions were suitable, being preferred by the users over voice calls. Moreover, the language used and the short descriptions (the keywords) were easily understood, giving the participants the opportunity to reach the dispatcher in a short time. Finally, the confirmation that the alert was received and analysed by the operator in the emergency dispatch reassured the users of the mobile application's effectiveness. It was, therefore, discovered that an emergency mobile application must be able to provide a confirmation message regarding the receipt of the alert by the emergency dispatcher, that the request has been evaluated, and that the rescue teams have been sent to the scene of the incident.

Following the second objective of the present research, another contribution of the study is the proposed methodology for developing applications. The working method described proved to achieve its scope: to quickly develop a useful app with reduced costs which meets the clients' (users') needs. Furthermore, an iterative process was proposed: repeating a cycle of testing, feedback gathering, and improving the application until it reaches an acceptable version that includes the best compromise between cost, time, and quality. The abovementioned findings could support other researchers and developers in their demarche of developing similar applications, especially practitioners with less experience and limited resources. Other researchers have also adopted the Rapid Application Development (RAD) approach [49] to develop their solutions, but there are also other similar agile approaches such as the Design Science Research (DSR) methodology by Hevner and Chatterjee [20].

One limitation of the application is, of course, an Internet connection, as without one the mobile application cannot work. Further, the mobile devices must be equipped with the Android operating system. However, this impediment could be overcome by future developments and the extension of the application for other operating systems.

The present study included a relatively small number of respondents and showed a reduced representativeness of the respondents, which could be one of the study's limitations, but for the purpose of this research the sample proved to be enough to test the application's validity and usability. The scope was to test the application and to gather feedback about it, which could happen with more iterations. Other similar mobile apps were also tested on a limited number of participants in other studies: 10 trained lay first responders equipped with an emergency medical dispatch system utilizing a mobile application participated in an emergency simulation-based study [27], and 35 respondents tested the usability of an emergency accident alert mobile application developed by Sarlan et al. (2016) [49].

Thus, future research could focus on more extensive testing (with more participants, in various scenarios, etc.), while also involving people working as emergency operators or rescue teams, such as the research conducted by Romano et al. (2016) [20].

Future complementary studies could explore the behavioural aspect of the topic, focusing on the influencing factors that determine why people use mobile applications for emergency situations.

Through analysing the specialized literature and testing the application made by the authors of this article, it was identified that the success of these applications is fundamentally dependent of interactivity, quality of information, and ability to increase the speed of response, as well as their integration with other innovative technologies. Future studies will need to test different combinations of these elements. Furthermore, future research can assess the factors that contribute to the large-scale use of the application by potential users.

Similarly, the development and promotion of mobile systems for alerting and responding to emergency situations require international and interdisciplinary collaboration and the involvement of key decision-making governmental factors [3,10,11]. In the end, such an application is not intended to replace phone calls to the emergency number, but to create a small contribution to the improvement of emergency event management. The working method proposed in this research can represent a model for other researchers who intend to design and develop applications for emergency situation management.

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