Development of early warning systems suited to single risk management

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Abstract

This deliverable elaborates the implementation of early warning system based on single-hazard exposure of the Kaštela study area. The early warning system is developed for sea flooding in the study area. The work has clearly shown that today level of ICT allows fast and effective development of early warning systems. As the result, the Waves – seafront monitoring mobile application is developed to demonstrate the usability of mobile application as an early warning mechanism.

1 Introduction

One of the purpose of PMO-GATE 5.1 Activity "Improved early warning systems for single risks" is to show how the basic ITC technology can be integrated into early warning system for a single risk. Herein, the sea flooding risk has been chosen to demonstrate the usability of mobile application as an early warning mechanism for the most frequent threat in the study area (Figure 1).

Figure 1. Flood risk at the study area [1]

United Nation International Strategy for Disaster Reduction (UN ISDR) defines the four elements of an effective early warning system (Figure 2). With the aim to achieve people-centred early warning systems, the system should encompass a risk knowledge; technical monitoring and warning service; communication and dissemination of warnings; and community response capability [2]. The four elements are briefly explained in the following paragraphs.

Risk knowledge

As a first step, it is necessary to perform risk assessments, for which it is necessary to know the characteristics of hazards, vulnerabilities and exposures of people and assets. Risk has a dynamic characteristics, it changes over time, depending on the development of the hazard itself, but also the vulnerability and exposure of people and assets that change (i.e. urbanization, deforestation, etc.). It is common to make risk maps, so risk maps were prepared for the pilot area of Kaštel Kambelovac.

Technical monitoring and warning services

For an early warning system to be effective, there must be a scientifically based model for predicting hazards and their characteristics (i.e. propagation, intensity etc.), based on the systematic measurements of various parameters via network of sensors (24 hours a day, sufficiently dense and reliable sensor networks, etc.). The result of this element is accurate and timely warnings.

Certain types of hazards is not possible or difficult to predict such as an earthquake, but once it happened it is possible to model its propagation and possible cascading events (i.e. a tsunami caused by an earthquake) and generate warnings.

Dissemination and communication services

The goal of this element is for the warning to reach all those at risk and those who need to act to save lives and assets. Therefore, warnings should be easy to understand and recognised as credible (received from a source identified as competent to issue such warnings). In order for alerts to reach as many people as possible, it is necessary to use various communication channels (i.e. radio or television, sirens, electronic media, web and mobile applications) to ensure that alerts will reach even in the event of interruption of some of the channels. In addition, there is a need to use both, video and audio warnings, to reach people with hearing or vision impairment.

Community response capability

In order to achieve the best possible response, the local community should be informed in advance about possible risks and ways of acting, as well as about the responsible response agencies and their services. Therefore, emergency response plans are necessary for various disasters and regularly performed exercises and tests of actions, evacuation routes and measures for damage reduction.

Figure 2. Four Elements of People-centred Early Warning Systems defined by UN ISDR [3]

The following chapters describe the design of the early warning system for sea flooding. First, a brief overview of ICT technologies and ICT system architecture is given, followed by an information flow design and a description of the developed application for the pilot area, in case of sea flooding. At the end, a conclusion and a list of references are given.

2 Design of the Early Warning System for sea flooding risk

From the information and communication technology (ICT) point of view, an early warning system integrates all the ICT's tools supporting the four elements: risk assessment, monitoring and prediction, communication services and processes of response.

State of the art technologies such as Internet of Things, Cloud Computing and Artificial Intelligence are used in building elements of early warning systems. For example: various sensors are sensing parameters such as water level and velocity, communication networks are transmitting large volume of data in near real time, fast computing provided by powerful processors and effective algorithms are modelling hazards and their propagation, artificial intelligence algorithms integrates information and support generation of accurate warnings, and finally public internet and smart phones are broadcasting timely warnings (Figure 3). An overview of ICT advanced tools and particular early warning systems architecture based on Internet of Things is given by Esposito et al in [4].

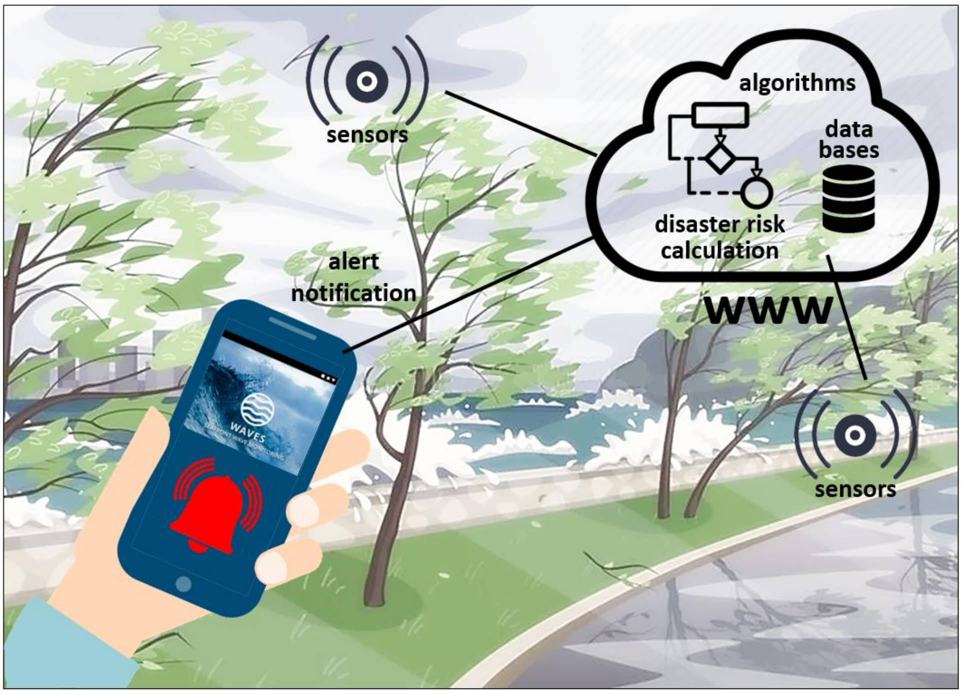


Figure 3. ICT's tools supporting an effective early warning system

Authors Dongxin B. et al in [5] explains an ICT architecture for early warning system. The architecture consists of four layers (Figure 4). Perceptual layer includes various sensors monitoring hazard parameters and supporting sensors infrastructure for energy supply, communication and protection equipment. The second layer is data layer including data receiving and parsing, data storage and data access interfaces. Various services are realised inside the Service layer. Here, data management and complex data analysis is performed (including artificial intelligence and decision support algorithms for storing and using knowledge of risks, detection of false alarms, creation of messages, etc.) as well as standards services such as user and project management. The last layer is the Terminal layer. It represents IT devices for warning dissemination mainly web and mobile applications.

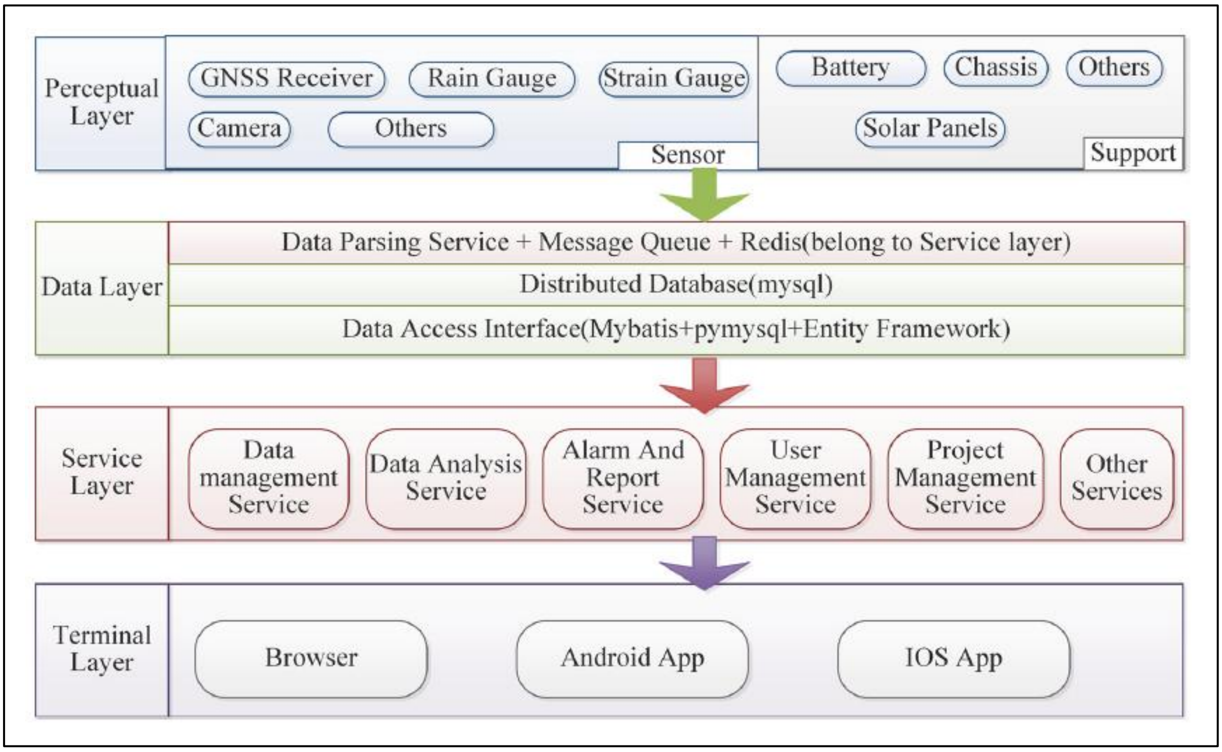


Figure 4. The architecture of early warning system [5]

The following chapters elaborate design of the information flow for sea flooding early warning system implemented in the pilot area and design of the mobile application.

2.1 Design of information flow

Information flow diagram shows how information is communicated from server feeding mobile app, which inform citizens about the flood threat. We use the process or activity model as a basis for description of the information flow. It describes operational activities, input and output flows between different actors, as well as input and output flows to/from concepts within organisation. Herein, the purpose of the process model is to:

- Define activities related to the use of sensors, models and the mobile app to alert citizens about flood threat,
- Identify information flows to be implemented in both server and mobile apps,
- Define citizens’ activities and roles while using the mobile app.

For this purpose, the Business Process Model and Notation (BPMN) 2.0 notation [6] is used, but limited to the subset which fits the project's purpose (Table 1). Therefore, the activity model is depicted in BPMN notation implemented in Camunda Modeler [7].

Figure 5 shows the information flow diagram for the early warning system developed for sea flooding. Mobile application alerts and informs citizens about the potential emergency due to sea level-rising, which may be caused by three different phenomena acting together: exchanging of low and high tide, atmospheric pressure and waves. Information about threats is being generated on a server using data from the sensors and algorithms. Sensors provide wind's velocity and direction, as well as atmospheric pressure. The data are processed by the algorithm for the assessment of an absolute sea-level. The results are combined with results from the algorithm for definition of sea level caused by exchanging of low and high tide and the algorithm for prediction of the wave height generated by winds along the coastline. The study area is divided in ten emergency zones (Figure 6), which are defined taking into account type of coast and wave reflection. The threat is calculated as a difference between predicted sea and terrain-level for each zone.

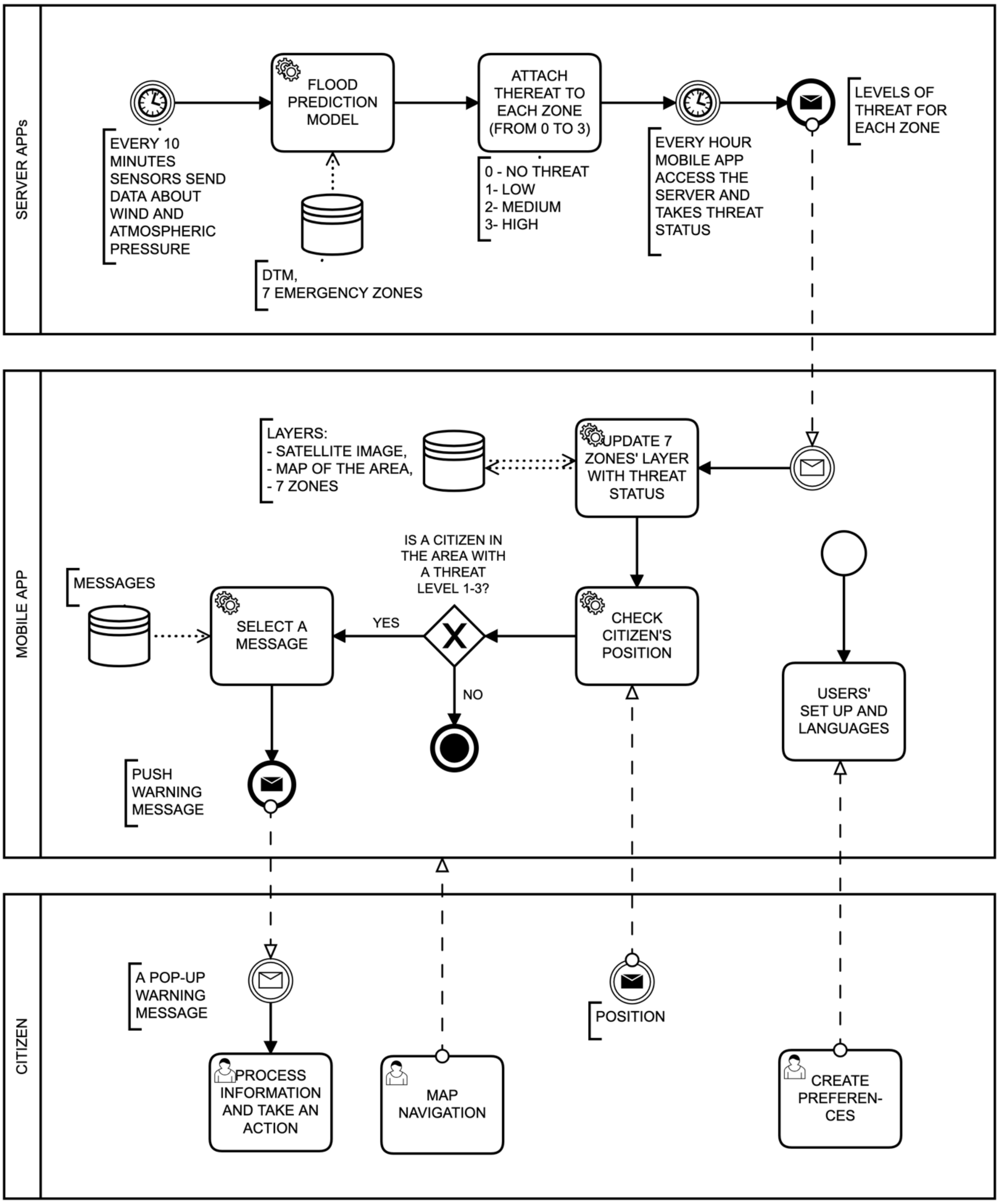
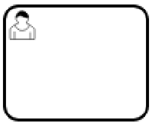
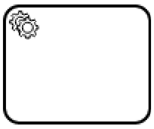
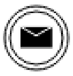
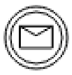
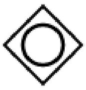
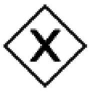
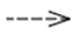


Figure 5. Information flow diagram for the early warning system for sea flooding

Table 1. Legend of used BPMN symbols

Symbol	Meaning
	User task
	Service task
	Data storage
	Signal start event
	Message start event
	Message intermediate throw event
	Message intermediate catch event
	Inclusive gateway (inclusive OR)
	Exclusive gateway (exclusive OR)
	Sequence flow
	Association flow
	Message flow

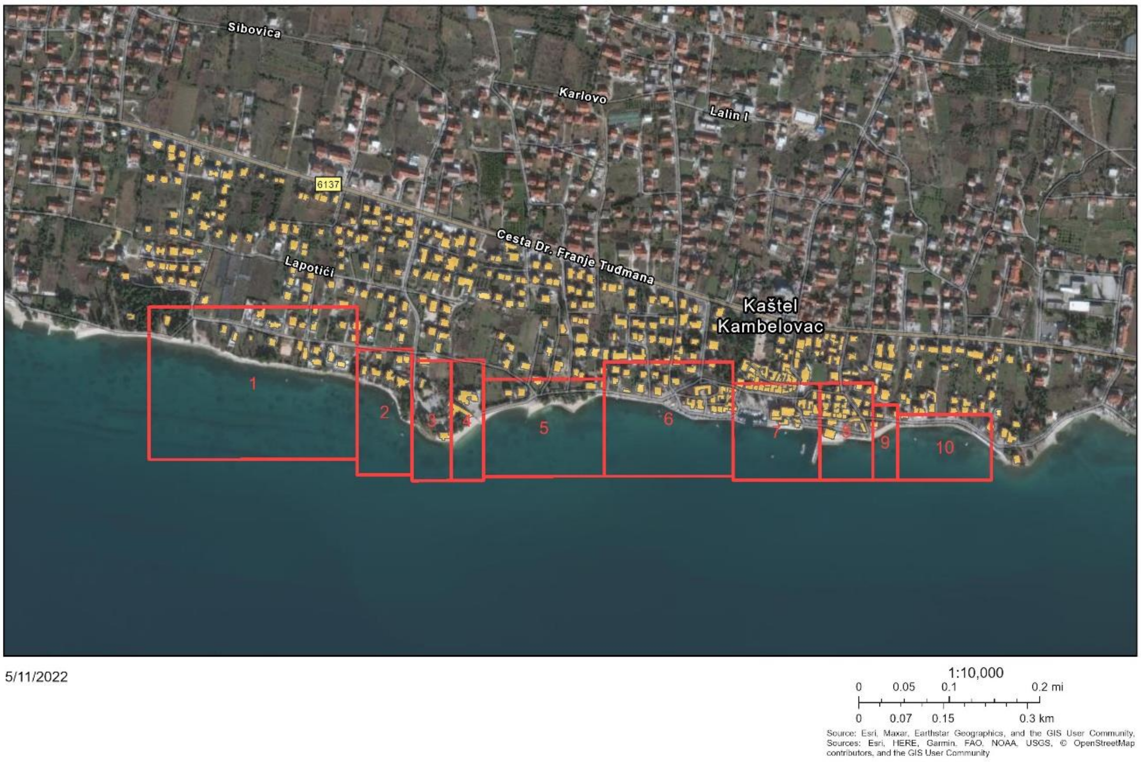


Figure 6. The ten emergency zones in the study area

There are three levels of threat defined as an average predicted flood level for a zone: low, medium and high.

The sensors send the data every 10 minutes and the mobile application accesses the updated threat status every hour.

The mobile application access information about threats and process is further towards citizens. It contains the following layers:

- A satellite image with scales,
- A map of the area (Kaštel Kambelovac, from dr. Franje Tuđman street southward),
- A transparent map with ten emergency zones.

A user can navigate the maps i.e., zoom in and out and move around the study area.

The mobile application contains adequate messages for each threat level. The messages contain warning about the actual situation and prediction and suggest the action. The application processes the data about the threats in the zones and if the threat is identified it chooses the appropriate messages and sends it to citizens in the corresponding zones. The messages are being sent as a push notification and appears on the mobile phone screen. The notification also includes sound, so blind and visually impaired people can also use it.

The application also allows users to set up their functional preferences and choose the language (Croatian, English, Italian).

Flood hazard classification is defined based on the threat level for potentially exposed citizens located within the endangered area. For each threat level, a flood hazard class is assigned followed with the corresponding warnings. These warnings are primarily focused on preventing citizens' safety so each threat level is defined in relation to water depth and potential human instability in floodwater. Flood hazard classification is based on the research of Xia et al in [8], which conducted different tests to obtain the conditions for the instability of a human body in floodwater. As a result, different stability thresholds are derived for adults and children. The presence of any floodwater in combination with high velocity typical for extreme coastal waves can be dangerous for children due to possible sliding, so the first hazard class is defined as 0 – 0.2 m. As soon as water depth exceeds 0.2 m (second hazard class) it becomes dangerous for adults as well, while exceedance of 0.5 m (third hazard class) can cause severe injuries or even casualties.

Yellow warning (threat level: low)

The sea can penetrate into objects having entrance sills lower than 20 cm. Children aged up to 7 years could be endangered. Road traffic can be disrupted in road depressions.

Orange warning (threat level: medium)

The sea can penetrate objects having openings less than 50 cm from the ground. Persons with limited mobility and children could be endangered. Road traffic can be disrupted.

Red warning (threat level: high)

The sea can penetrate objects, the sea level is higher than 50 cm. All citizens could be endangered. Road traffic is disrupted. There is a possibility of pollution.

2.2 Description of the mobile application

For the pilot area of Kaštel Kambelovac, a digital sea level monitoring system is developed under the name "Waves – seafront monitoring". It also includes location service for the positioning of the user. Short description of the system is summarized from Šolić [9] and given below.
The three parts are as follows:

1. Mobile application

It allows user to locate yourself on the map and get informed of the current sea level.

2. Google Firebase server component

It provides services of estimating sea levels based on sensor data and user authentication.

3. Integration of data from the sensors

Collecting sensors data that is published on TheThingsNetwork (TTN) cloud (data on air pressure, wind speed and direction).

The application user interface (Figure 7) contains three main parts:
1. Login interface with user login details (Figure 7, number 1) and project logo (Figure 76, number 2);
2. Registration interface for creating access account;
3. Map interface: the central part of the application contains the following functionalities:

   a. Drop down menu where the user has a choice between three languages: Croatian, English and Italian (Figure 7, number 3);
   b. Log out button from the application (Figure 7, number 4);
   c. Values read from the sensor and total sea height calculated by the algorithm based on tide, speed and wind direction, and atmospheric pressure (Figure 7, number 5);
   d. Google maps with coastline mapped respectively to heights, flood risk zones (green - safe; yellow - warning; orange – dangerous; red – flooded; Figure 7, number 6);
   e. Zone maps showing the names and photos of coastal zones (Figure 7, number 7);
   f. Notification button (Figure 7, number 8).

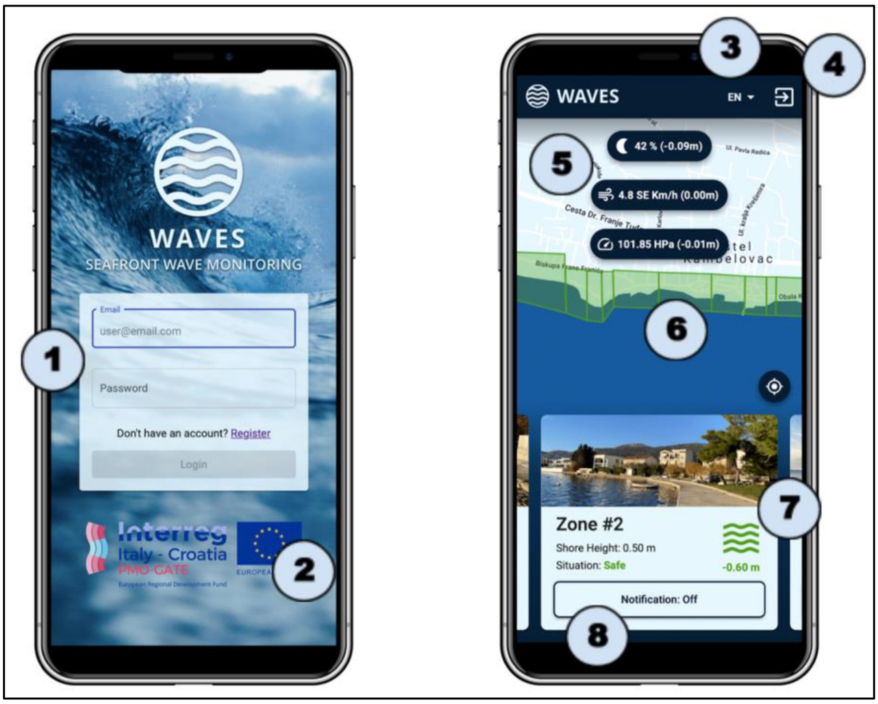


Figure 7. “Waves – seafront monitoring” user interface [9]

3 Conclusion

This report elaborates the design and development of an early warning system for sea flooding in the pilot area. The work has clearly shown that today level of ICT allows fast and effective development of early warning systems. As the result, the Waves – seafront monitoring mobile application is developed to demonstrate the usability of mobile application as an early warning mechanism.

As more sensors and data would become available, the models for hazard and risk modelling could be enhanced and warnings more accurate. By development of fast and large capacity communication networks such as 5G, allowing transmitting huge volumes of data in near real time, the new prospects for development of early warning systems would arise.

4 References

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[6] https://camunda.com/bpmn/reference/ (last access May, 2022).

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[9] Šolić P. Report on WAVES SEAFRONT MONITORING APPLICATION, 2022.