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Prototype design for a Web-GIS disaster management system: enhancement of flood management systems by integration of crowdsourcing data

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Cover photograph: Meester van de Heilige Elisabeth-Panelen, anoniem, c. 1490 - c. 1495. *The Saint Elizabeth's Day Flood* (Painting). Amsterdam, Rijksmuseum. Retrieved from: https://www.rijksmuseum.nl/en/collection/SK-A-3147-B

ABSTRACT

The objective of the present research project is the design of a software architecture for a web-based platform that uses GIS technologies to function as a tool for decision support system (DSS) in case of disasters. When disaster arises, the unpredictability and dynamics of the situation makes the phase of response challenging, hindering the decision-making processes. The possibility to collect information from different sources, official (e.g. sensor networks monitoring environmental variables, emergency resources availability and location) and non-official (volunteered geographic information), in a one-stop platform allows a better understanding of the situation and supports the decision making of the different actors involved (i.e. crisis managers, emergency response organizations, general citizens).

Following the cycle of user-centred design (UCD), the study first identifies the user requirements of a tool for DSS in case of disasters. Literature review on related projects generates a background of the user needs tackled by the different initiatives. Then, Personas method and generation of scenarios helps to get a more thorough and concise knowledge of the user requirements. These requirements together with the analysis on suitable software architectures and components are the base of the software architecture design of the aimed tool for DSS in case of disasters. The last step in the process is the evaluation of that software architecture design, what is achieved by two approaches: (1) a functional evaluation to test the design feasibility by developing a prototype to tackle selected functionalities (derived from the user requirements); and (2) assessing the usability of the designed tool by testing a mock-up version of a smartphone app based on the proposed design by the Personas using the think-aloud method. This way the study goes once through the cycle of UCD, developing a solution that addresses the identified user requirements.

Going through the method the identified user requirements of a tool for DSS in case of disasters are related with the notification of alerts, information on the spatio-temporal evolution of the disaster, suggestion on routes to reach safer destinations, and information about the status of users' families and friends. The solution proposed to address these requirements is a Geoweb, which exploiting the advantages of the technologies Web 2.0, allows the integration of official and non-official data sources, and also the visualization and analysis of the information that is required for the potential users. Based on a client-server structure and aiming the interoperability between the diverse data and also between the multiple actors, the Geoweb design is formed by open source components and the use of the recognized OGC protocols. Basically the design components are: PostgreSQL/PostGIS as the spatial object-relational database management system for the collection and integration of the multi-source information; GeoServer as application server to load, publish and share the information by internet; and OpenLayers as the mapping application.

The feasibility of the Geoweb is tested for the routing and flood mapping functionalities by developing a prototype following the designed software architecture with open source components. Integrating information about the flood status and information collected by citizens to the road network provides different alternatives at the routing calculation results, supporting the users' decision-making process. Besides the use of the think-aloud method with the defined Personas reveals that the routing functionality and the flood evolution visualization are the best considered functionalities of the system. In addition, the combination with other information like shelters location or citizens' reports enlarge the effectiveness of the information offered by the tool. Despite of that, the messaging functionally was not found helpful but confusing, maybe due to the mock-up design. Moreover, even though the integration of multi-source information seems to be gladly received by most of participants, it can also generate more difficulties in some occasions when different sources point to different information.

This study can be used as a guideline and framework for further developments of tools for DSS in case of disasters, even though further research may address issues such as the integration of the information and the assimilation of big data volumes from citizens.

Keywords: FOSS4G, crisis management, VGI, Geoweb, Web 2.0.

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List of Acronyms

AHN	Actueel Hoogtebestand Nederland
AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
CA	Cellular Automata
CBS	Centraal Bureau voor de Statistiek
CGI	Common Gateway Interface
DMS	Disaster Management Systems
DSS	Decision Support System
EM	Emergency Management
ERiskA	European Risk Atlas
FEMA	Federal Emergency Management Agency
FEWS	Flood Early Warning System
FLIWAS	Flood Information & Warning System
FOSS4G	Free and Open Source Software for GIS
FWC	Flood Warning Communicator
GDI4DM	Geographical Data Infrastructure for Disaster Management
Geo-ICT	Geographical Information & Communication Technology
GIS	Geographical Information Science
GMM	Google Map Maker
GNSS	Global Navigation Satellite System
IFIS	Iowa Flood Information System
InaSAFE	Indonesia Scenario Assessment For Emergencies
ISO	International Organization for Standardization
KNMI	Koninklijk Nederlands Meteorologisch Instituut
NAP	Normaal Amsterdams Peil
OGC	Open Geospatial Consortium
ORDBMS	Object-Relational DataBase Management System
OSGeo	Open Source Geospatial Foundation
OSM	Open Street Map

PGIS	Participatory GIS
PPGIS	Public Participatory GIS
POI	Point Of Interest
RSS	Rich Site Summary (or Really Simple Syndication)
SDI	Spatial Data Infrastructure
SMS	Short Message Service
SWE	Sensor Web Enablement
UCD	User-Centred Design
VGI	Volunteered Geographic Information
W3C	World Wide Web Consortium
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
XML	Extensible Markup Language

1 INTRODUCTION

1.1 Background

The Geographic Information Systems (GIS) domain has broken the barriers of its more classical utilization in research and institutional field to more diverse disciplines. The power of GIS on analysing, visualizing and processing spatial information is proven in subjects as environmental sciences, logistics and urban planning, among others (Maliene, Grigonis, Palevičius, & Griffiths, 2011).

The advantages of GIS application for a better understanding of the world play a crucial role in a field such as disaster management, where in combination with communication technologies GIS applications can provide priceless help. When disaster arises, the unpredictability and dynamics of the situation makes the phase of response challenging (Sisi Zlatanova & Fabbri, 2009). The management of these crisis situations requires the procurement of reliable and up-dated information that can be eased by the use of GIS applications.

In risk and disaster management, numerous examples of GIS technology exist providing essential information for predicting risks, modelling disasters, and supporting the making decision process (Kamel Boulos et al., 2011; Sisi Zlatanova & Fabbri, 2009). Recent disasters like hurricane Katrina or the Haiti earthquake are clear examples of the importance of GIS in crisis situations (Goodchild & Glennon, 2010; Roche, Propeck-Zimmermann, & Mericskay, 2011). In those cases the implementation of GIS techniques through initiatives such as Open Street Map (OSM)[1] or Google Map Maker (GMM)[2] contributed successfully to the risk management efforts, providing structured map-based information and an immediate visualization (Ortmann, Limbu, Wang, & Kauppinen, 2010).

This kind of initiatives also acts as tools for instantaneous communication between stakeholders, allow the dissemination of extensive information and the networking of remote communities. These are relevant aspects for organizational interoperability, connecting the different stakeholders involved in crisis management.

Additionally, these unfortunate disasters demonstrated the potential of crowdsourcing information, providing current field information and enhancing the understanding of the situations (Roche et al. 2011). Through the use of web-based social networks, citizens were able to disseminate information, communicate personal situations, or reveal locations where urgent assistance was needed.

For instance, Terpstra et al. (2012) analysed the possibilities of using automated filtering of information posted at Twitter during a disaster. The research, based on the storm event of Pukkelpop 2011, demonstrated the valuable use of crowd-sourced information for the operational response and crisis communication.

In these crisis situations, citizens play a new role becoming “sensing devices”. This is possible due to the accessibility and availability of mobile devices that are interned-enabled, location-aware and include multiple sensors (Kamel Boulos et al., 2011).

The valuable information acquired by the citizens in combination with authoritative data leads to an evolution of the traditional information chain used in crisis management (Roche et al., 2011). This participative approach turns citizens into a more active role, getting involved in their own decision-making for risk reduction (Burke et al., 2006; White, Kingston, & Barker, 2010).

[1] http://www.openstreetmap.org
[2] http://www.google.com/mapmaker

Moreover, from the perspective of crisis managers and decision-makers, crowdsourcing information adds meaningful value to the crisis management systems, as real-time data could lead to a more effective use and distribution of services and resources.

Recent risk analyses show that, in the case of the Netherlands, floods could cause the most extreme and tragic consequences, even if they are highly unlikely (Kolen & Helsloot, 2012). Developed projects for flood management systems, as for instance FLIWAS (Flood Information & Warning System), show a strong technological focus (Langkamp et al., 2007). However, crisis management also requires flexible plans that can adapt to the unpredictability of the situation and offer room for improvisation (ten Brinke, Kolen, Dollee, van Waveren, & Wouters, 2010). In this way, the collaboration between politicians, emergency services, safety organizations and citizens could lead to a more effective management of crisis.

1.2 Problem definition

The relevance of Geo-ICT in disaster management has been proven during recent crisis events and its efficiency has been confirmed (Sisi Zlatanova & Fabbri, 2009). With the purpose to reduce risk, manage the crisis or coordinate emergency services when a disaster occurs, different initiatives have arisen involving communities, experts and non-experts. Some of these initiatives, like for instance Ushahidi[3] or Humanitarian Open Street Map[4], are based on the collective use of geoinformation systems, spatial databases and satellite imagery.

Technological advances lead to possibilities of enhancement. The possibility of connecting to GNSS and internet through user-held mobile devices (i.e. smartphones, tablets) enables the citizens' engagement by collecting potentially useful real-time data.

However, the integration and sharing of information from multiple sources is still an issue that needs to be improved (Kamel Boulos et al., 2011). Gathering official (static or real-time) data with crowdsourcing information, and other data offered by different involved organizations could lead to more effective crisis management systems, with improved coordination and a higher citizens' trust.

The challenge now is how to address the connection of information that increases in quantity and diversity of formats and sources. An initiative with similar purposes is the plugin for Quantum-GIS InaSAFE[5] (Indonesia Scenario Assessment For Emergencies). This free application is an example of how to combine data from scientists, local governments and communities to produce realistic natural hazard scenarios for better planning, preparedness and response activities.

Nevertheless, InaSAFE is still a tool meant to help in the preparedness phase of a disaster. Besides, different challenges arise for crisis management when a disaster emerges. In those situations, the generation of a web platform hosting real-time information could allow the collection and sharing of information and a better inter-communication between stakeholders (Roche et al., 2011).

For instance, crowdsourcing initiatives exist to help individuals to select the most appropriate route for reaching their destinations by informing them on the traffic density (Kanhere, 2013). However, in a crisis situation, the decision-making process requires considering additional information as the location and availability of shelters or the situation of hazard areas and the special resources provided to handle the crisis.

[3] http://www.ushahidi.com/
[4] http://hot.openstreetmap.org/
[5] http://inasafe.org/en/

Another factor to take into account is the reliability of the information offered. Official information does not always mean a higher level of credibility by citizens, as De Jong & Ira Helsloot (2010) found in the analysis of the participants' response during the National Dutch flooding exercise 'Waterproef'. In this regard, a wider range of sources of information could allow a more confident decision making process to citizens.

The challenge now is to integrate the information from different sources, with diverse acquisition processes, data formats and time steps.

1.3 Research objectives

The general objective of the research is the definition of a Web-based GIS software architecture to function as a tool for decision support system (DSS) in case of disasters that allows the use and integration of diverse multi-source data.

To tackle this general objective, the following sub-objectives will be addressed:

Sub-objective 1. Definition of the requirements in terms of data for a risk management system (particularly focusing on a flood case) and data collection.

Sub-objective 2. Design of a software architecture for a web-based GIS platform for risk management that addresses the previously defined requirements.

Sub-objective 3. Evaluation of the software architecture in a specific case study.

1.4 Structure of the Report

The thesis report is organized in eight major sections. Chapter 2 explains the methodology followed to conduct the research objectives. Then, the obtained results per sub-objective are included in different chapters. This way, Chapter 3 includes the results of the analysis on the requirements (content-wise) for a thorough system of risk management. The design of the software architecture is offered in Chapter 4. Then, Chapter 5 includes the results of that software architecture evaluation from two approaches: a technical assessment by building a prototype based on the proposed design; and from the users' perspective. The methods and results are discussed in the Chapter 6. Finally, Chapter 7 addresses the main conclusions and Chapter 8 presents the recommendations for further studies, projects and research.

2 METHODOLOGY

This chapter addresses the methods followed to accomplish the defined research objectives.

The central objective of this research requires understanding of designing a tool for decision support system (DSS) in case of disasters. With this objective, the development of the research follows the sequence of activities for a user-centred design project. The standard ISO 9241-210[6] (former ISO 13407 User centred design process for interactive systems) explains how to achieve quality in use (the extent to which the software meets the needs of the users) by incorporating user centred design activities (Bevan, 1999).

According to that standard, the development of computer software projects includes an iterative cycle of the following activities:

1) specification of the context of use;
2) specification of the user and organizational requirements;
3) production of design solutions;
4) evaluation of designs against user requirements.

The cycle iteration of those activities (Figure 1) ensures the satisfaction of the objectives (Bevan, 1999). These activities guide the steps of the methodology in this project.

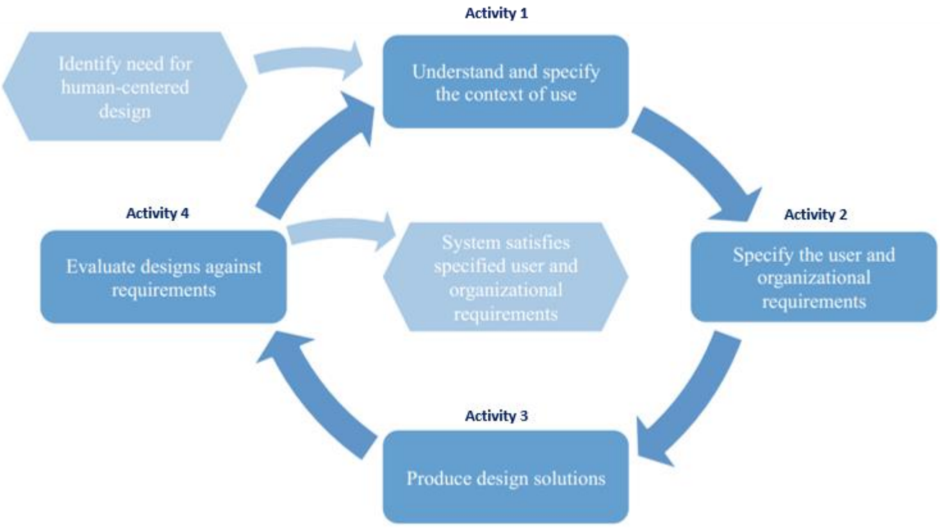


Figure 1. Cycle of user centred design activities (adapted from ISO 9241-210:2010).

The first of the activities establishes the definition of the context of use. The following part of the chapter (2.1) address the specifications of the context of use in this project, which generates the framework to focus the analysis process. Thereafter, section 2.2 details the methodology followed to attain the research (sub)objectives.

[6] ISO 9241-210:2010. International Organization for Standardization

2.1 Context of use definition

A potential flood in the Netherlands is selected as context of use for the aimed tool for disaster DSS. The selection is made due to the expected availability of information/data, as well as projects and initiatives related with flood control in The Netherlands.

The fact that about two thirds of the territory of The Netherlands is vulnerable to flooding (see Figure 2) has driven the development of different techniques for floods prevention in Dutch history. Large construction works reducing the influence of the sea, river dikes and intensive systems of ditches, canals and pumping stations (some examples in Figure 3) control the level of water, preventing the occurrence of floods and aiming to provide safety to citizens.

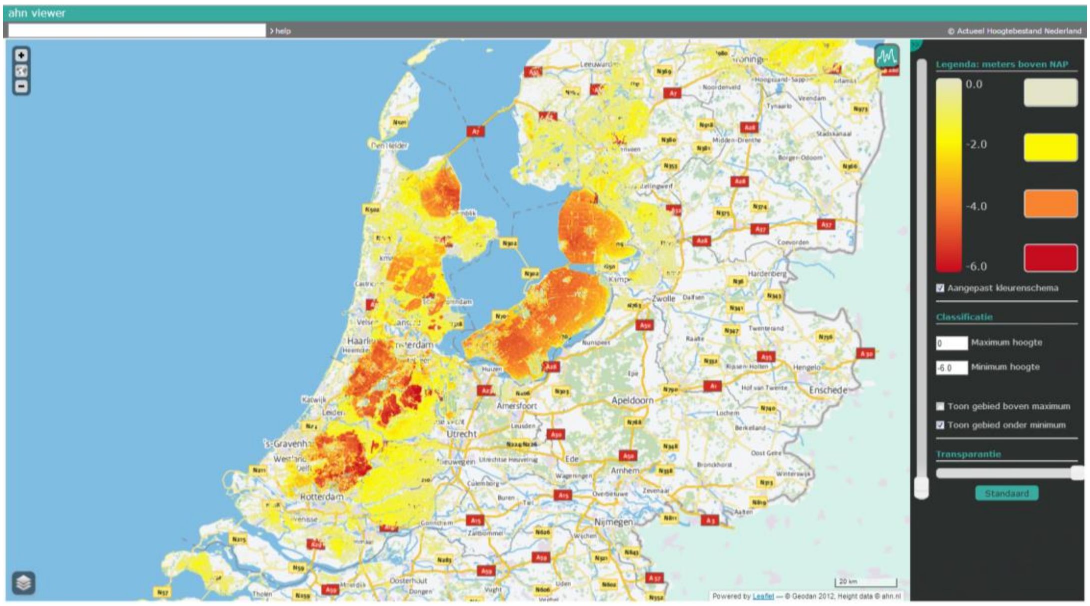


Figure 2. Current elevation in The Netherlands. Source: ANH[2] The Netherlands[7]. Areas below sea level are shown in colours from yellow (below 0 m NAP) to red, the lowest parts (below 6 m NAP).

Even though the current sea defences and other flood control techniques are stronger and more sophisticated than ever, experts suggest staying aware of the risks potentials. These aspects make the potential flood in The Netherlands an interesting scenario for the purpose of the present study.

Figure 3. Examples of flood control architectures in the Netherlands. From left to right: dike at the Nederrijn, windmills in Kinderdijk and the Oosterscheldekering dam. Source: http://en.wikipedia.org/wiki/Flood_control_in_the_Netherlands

[7] http://ahn.geodan.nl/ahn/

2.2 Methodology

According to the cycle of activities for a user centred design project (Figure 1), once the context of use is defined, the next steps are:

- the user requirements specifications;
- the design of a software architecture solution;
- and the evaluation of the design against requirements.

The development of these activities allows the achievement of the research (sub)objectives of the present project. The methods conducted to develop those activities are detailed below.

2.2.1 Analysis of users' data requirements

In relation with the research (sub)objective 1 (*Definition of the requirements (content-wise) for a thorough and useful risk management system and data collection*), the analysis is executed by two different approaches, including literature review and the use of Personas method.

- **RESEARCH LITERATURE REVIEW**

  A review of projects and initiatives on risk management systems in general, and about floods in particular, offers the overall overview of the state-of-the-art on related projects. Additionally, an analysis of documentation about Dutch initiatives on flood control provides a closer view of what is going on in the selected context of use. The review focus on analysing what are the objectives of the projects and to what extent those projects achieve the expectations from users.

  Chapter 3 presents the results of the analysis, including the most relevant information obtained.

- **PERSONAS METHOD**

  For a more thorough idea and precise definition of what users will require from the tool for DSS in case of floods, the Personas Method (Pruitt & Grudin, 2003) is used.

  The method consists of the generation of the Personas, fictional profiles representative of a segment of the potential users group. These Personas are widely used in the marketing and user-centred design fields to improve the understanding of the goals, desires and limitations of users (Pruitt & Grudin, 2003).

  Within this project, Personas are used to get a better insight on the data requirements of the potential users of the tool, identifying user goals and tasks for the system.

  The method includes the following steps:

  - Establishment of the potential user groups;

- Detailed definition of the Personas as representatives of those user groups. The Personas are described by their age, gender, ethnic group, level of education, location, type of residence, type of family, job, computer skills, etc.;
- After that, scenarios are generated, placing the Personas in context. The scenarios help to get an idea of how the tool might be used:
- The analysis of the Personas' needs through the scenarios, lets identify which are the requirements of information in those situations. Thus, the design of the application will be guided by those identified requirements in order to fulfil the expectations from the user.

2.2.2 Design of a software architecture solution

This activity addresses the research (sub)objective 2 (*Design of a software architecture for a web-based GIS platform for risk management that addresses the identified users' requirements*).

The method includes:

- First, a literature review is conducted to get an insight on what kind of architecture designs have been adopted in other related projects. A study on the advantages and weakness of the different systems allow to consider a preferred structure for this project;
- Then, to generate the selected architecture a revision of the potential software is done to know which components are more suitable for the project purpose;
- Finally, the proposed software architecture design is defined and explained, describing the selected components of the application.

2.2.3 Evaluation of the software architecture

Once the software architecture is designed, the assessment of the prototype is developed considering two different approaches:

- **THE FEASIBILITY OF GENERATING A SOFTWARE-BASED TOOL ACCORDING TO THE DESIGNED ARCHITECTURE.**

  An experimental exercise is developed to build a tool for decision support system in case of floods in The Netherlands covering some of the pretended functionalities of the system. The exercise is thought as a kind of throwaway prototype as a simple working model to detect problems in the architecture design and to show the users how the intended tool may work.

- **THE USER REQUIREMENTS, CONCERNING THE INFORMATION OFFERED BY THE TOOL.**

  The assessment of the prototype design regarding the users' requirements is conducted following the think-aloud protocol (Ericsson & Simon, 1980). The method, used in product design and development, consists on involving participants thinking aloud while they perform specific tasks. This method for data collection is recognised as a valid method for researching cognitive processes (Ericsson & Simon, 1980).

  The practical approach of the method is developed by collecting data in real-time, asking subjects to think aloud while they perform the experiment.

In this project, the experiment is developed to evaluate how the suggested prototype design fulfils the requirements of the potential users. The exercise is focused on the content offered by that prototype and to what extent the information offered helps participants to structure it in order to make a decision.

Consequently, the method of this project, integrated by the diverse activities explained above, completes once the cycle for user-centred design (Figure 1). Summarizing, first the context of use (Figure 1, Activity 1) is defined as the focus of the project, a potential flood in the Netherlands is used in this case. Then to obtain the specifications of the user needs (Figure 1, Activity 2) an overall overview of other projects related is done by a literature review, and more concise requirements are achieved by using the Personas method.

The next step in the cycle concerning the design of the solution (Figure 1, Activity 3) includes the review of the software architectures used in other related projects, to have an overview of the possibilities to select the most appropriate for the aim of the project. Then the components to form the architecture are selected and the final proposed design of the solution can be formulated.

The cycle ends with the assessment of the produced solution (Figure 1, Activity 4). The feasibility to produce the solution is tested by building a prototype covering some of the identified user needs. Then the fulfilment of the users requirements by the offered solution is tested by using the think-aloud method.

The present project includes these four activities that complete one cycle of the user-centred design process. Moreover, a further development of the tool for DSS in case of floods will need the iteration of the cycle till the system satisfies the specified user requirements.

3 USER REQUIREMENTS IN TERMS OF CONTENT OF A PLATFORM FOR DECISION SUPPORT SYSTEM IN CASE OF DISASTERS

The method in this research follows a user-centred design (UCD) approach to ensure the usefulness of the aimed platform for decision support system (DSS) in case of disasters. As described in the previous Chapter 2 (Methodology), an analysis of the user requirements precedes the design of that platform, to get a better understanding on what information and functionalities are expected from the potential users.

The objective of the thesis is the design of a multi-user platform that attempts to fulfil the requirements of the heterogeneous actors, i.e. citizen, authorities, crisis staff and rescue forces. In this regard, a new challenge is added for the system design as the diverse actors are involved in different ways within the crisis situation, thus their decision making process may need different kind of information.

This Chapter 3 comprises the results of the analysis on data user requirements in relation with that tool for disaster DSS. Aiming to achieve the first of the research objectives established in this thesis (the understanding of the user expectations of this kind of systems), two approaches are considered. As defined in the methodology section of the document (Chapter 2), first a review of related projects and initiatives is conducted to learn from these experiences. The result of the analysis provides information on what are the settings of other related projects, what kind of useful information has been offered/shared and by which means that information was made available, what problems were found and what those experiences recommend.

The review is developed by analysing the information offered by literature and documents about:

- risk management systems in general, and about floods in particular;
- Dutch initiatives related with flood management systems;
- and experiences with crowdsourcing information on disasters.

Thereafter, the following section includes the procedure and results from the Personas method. The method is conducted as a way to get a deeper insight into the requirements of information from the different users in case of disasters.

3.1 Literature Review on Risk Management Systems

The Federal Emergency Management Agency (FEMA) of the USA defines Emergency Management [8] (EM) as the function to provide communities with frameworks to reduce vulnerability to hazards and cope with disasters (FEMA, 2007).

Risk management is a cycle that presents four different phases depending on the moment on time regarding the event (Figure 4). The present thesis focuses on the phase of response, just right after the emergence of the event. In that phase, the Emergency Management aims the coordination and integration of the necessary activities to improve the communities' capabilities on responding to the arise disaster.

Aspects that characterize the emergency response to a disaster are the critical role of time, the dynamism of the situations, the ample number of people involved, the play of emotions and the obstruction or elimination

[8] Along this present report, other related terms as *crisis, disaster or risk* are used as synonyms.

of infrastructures, ways of communication and access to information (Sisi Zlatanova & Fabbri, 2009). All those characteristics make the response to disasters a challenging phase.

Figure 4. Risk and need of management in terms of geographic information (Roche et al., 2011).

A non-comprehensive literature review of projects and initiatives dealing with EM shows that capabilities of GIS technologies play a vital role allowing the analysis, exchange and visualization of the information needed for the decision-making process in this kind of situations. Below some examples on literature are given for a better understanding on what are the requirements from the different potential users of an EM system.

Zlatanova & Fabbri (2009) found in their review of EM studies that information awareness is designated as one of the more important factors for a successful emergency response. Frequent asked questions during crisis are related to the location of rescue teams and shelters, the status and forecast of the disaster magnitude and extension or the accessibility of transport networks. The continuous update of changes in these circumstances is also considered needed, due to the unpredictability of the situations during disasters.

The study of Zlatanova & Fabbri (2009) also shows the results from a large user investigation performed in the Netherlands in 2007 among different actors related with disaster management. The study finds the provision of exhaustive information with location of responders and in situ sensor data as one of the more important issues to be improved in emergency response systems.

An example of initiative within the European Union framework dealing with flood management by using GIS capabilities is the European Risk Atlas (ERiskA)[9]. The project is one of the application data models derived from the European project HUMBOLDT[10]. It aims to create a harmonized spatial information infrastructure for floods in the cross-border region of Lake Constance (including Swiss, German and Austrian territories) to facilitate the cooperation between agencies for risk management. Its development was based, among others, on user requirements, including static data sets (harmonized information on infrastructure like roads, railways or hydrographic features) and dynamic data (water level measurements and precalculated flood extensions from models).

Focused on floods, in the UK and Wales, the Environmental Agency initiated the project FloodAlert as a way to extend the reach of their flood warning services. The flood section at the Environmental Agency[11] website provides extended information about the current status of rivers and sea, forecasts, recommendations for the different phases of the disaster (mitigation, preparedness, response and recovery), links to get updated information about the official weather forecast and traffic information. Then, FloodAlert application is a multi-layered map that extends the website services by providing information on flood warnings to the users through

[9] http://www.esdi-humboldt.eu/scenarios/european_risk_atlas.html
[10] http://www.esdi-humboldt.eu/home.html
[11] http://www.environment-agency.gov.uk/homeandleisure/floods/

the social networks, such as Facebook and Twitter (Figure 5). It provides information about the alerts in points of interest (POI) established by the user, and also allows keeping updated with the information from the Environmental Agency and from local authorities.

Figure 5. FloodAlert application user interface for Facebook. Examples of live flood warning map (left) and details of an alert (right). Source: https://apps.facebook.com/FloodAlerts/

Similarly, the Iowa Flood Information System[12] (IFIS) is an ambitious web-platform to access flood conditions, forecasts, visualizations, inundation maps and flood-related data, information, and applications at watershed level. IFIS provides a user-friendly and interactive environment to access real-time and historical data of water levels, gauge heights, and rainfall conditions from automated sensors, stream gauges, radars and forecasts (Figure 6). Under continuous development, the platform helps general public, researchers and decision makers accessing valuable information to make better-informed decisions on the emergence of a flood and minimize the damages alerting in advance.

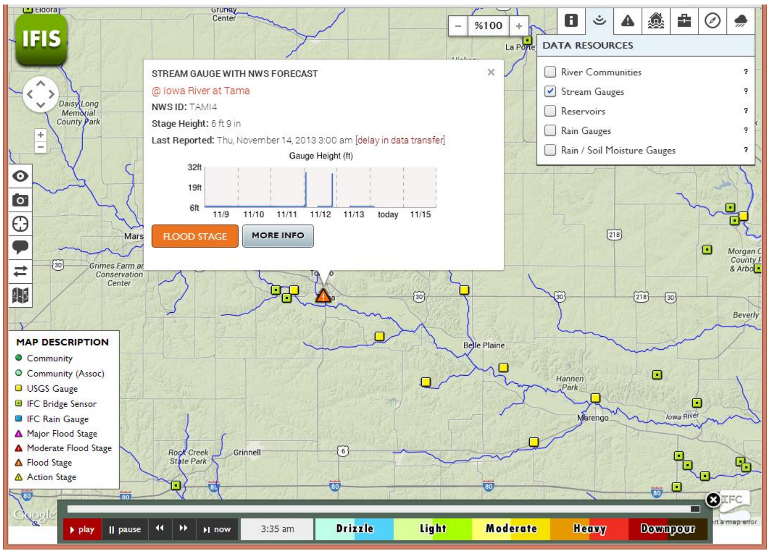


Figure 6. IFIS user interface showing filtering options and providing real-time and historical data from bridge sensors, rain gauges, and other data sources. Source: http://ifis.iowafloodcenter.org/ifis/main/?v=b

[12] http://ifis.iowafloodcenter.org/

An example of initiatives for the preparedness phase of a disaster is InaSAFE[13] (Indonesian Scenario Assessment For Emergencies). It is a free software that produces realistic scenarios for better planning, by a rigorous combination of information provided by scientists, local governments and communities. InaSAFE allows the preparation of contingency plans, giving answer to the emergency managers to questions like what facilities could be used in case of disasters (hospitals, shelters, schools and others), what areas and roads will be affected or how many people will need to be evacuated.

Also mobile applications are developed to facilitate the exchange of information in the phase of recovery. For instance in USA, FloodMap™ Mobile[14] offers to homeowners, real estate agents, and insurance agents information on demand gathered from official sources to ease property decisions.

Overall, the review on literature and projects reveals wide variety of initiatives for risk management systems that take advantage of GIS capabilities to better collect, visualize and analyse information of interest in case of disasters. These kind of initiatives are mainly GIS-based web-platforms that gather information from multiple sources with the aim to help users in their decision-making process. Different aspects considered in the design of the platforms are:

- Multi-hazard (e.g. InaSAFE) or disaster-specific (e.g. IFIS for floods), what may influence the level of detail of the information gathered;
- Assisting on different phases of the disaster (e.g. ERiskA) or centred on only one phase (e.g. FloodAlert on preparedness);
- Multi-users (e.g. IFIS) or focus on a specific group of users (e.g. InaSAFE for crisis managers);
- Collecting information from only official sources (e.g. FloodAlert in UK) or considering also information gathered by the citizens (initiatives commented in the next section of this chapter).

Despite these differences in the aim and design of the analysed initiatives, most of them present similar kind of information. The content of the information offered by these initiatives serves as an indicator of the user requirements that they try to fulfil. The offered information is related to:

- Notifications of emerging risk situations (alerts);
- Location of points of interest (shelters, help points, hospitals and others);
- Current status and forecast of the disaster;
- Real-time data from sensors and updates from official sources.

Next section goes through initiatives for flood management developed in the Netherlands to get a better insight into the Dutch particularities regarding this topic.

3.1.1 Dutch initiatives related with flood management systems

The Netherlands present a sophisticated and strong infrastructure for defence against floods. Situated on the deltas of the River Rhine, Meuse and Scheldt, the main water management efforts aim to protect this low-lying territories against flooding by building vast defences. The feeling of protection leads to a low awareness of citizens about the risk of floods (Kellens, Terpstra, & De Maeyer, 2013; Teun Terpstra, 2010), which can affect the community's response when actions need to be executed (Velotti, Trainor, Engel, Torres, & Myamoto, 2013). A better understanding of the problem could lead to better decisions when a crisis arises (Helsloot & Ruitenberg, 2004).

[13] http://inasafe.org/
[14] https://itunes.apple.com/ca/app/floodmap-mobile/id392069902?mt=8

The success of the Dutch flood management policy so far is not only based on large-scale flood defence construction projects, but on the adaptation of the legislation, policy and organizational structures to new perspectives (Rijkswaterstraat, 2012). In the Netherlands flood risk management and water management are integrated. Nevertheless, the need of improvements for crisis communication between water managers and crisis managers from the emergency services led to the national disaster exercise "Waterproof" in 2008 (Rijkswaterstraat, 2012).

De Jong & Ira Helsloot (2010) analysed the citizens response during that national exercise "Waterproef" (Remkes, 2006), focusing on the link of the responses and the provided information and communication during the exercise. The study shows that communication indeed has an effect on the response of individuals but not always in the expected way. Offering detailed information seems to generate higher credibility among citizens. Then people wait for government instructions to act. However the trust of citizens on the offered information was low during the whole exercise.

Helsloot & Ruitenberg (2004) performed a survey of literature about citizen response to disasters and concluded that authorities need to take into account citizen response. The fact that disaster management was originally controlled by military forces still affects the way the authorities cope with citizen response. However, in order to make better decisions, citizens need access to the information about the circumstances and alternative actions to be taken. Also the authorities should consider the value of citizens' help, especially when actions from emergency services are limited. The document "Flood Risk and Water Management in the Netherlands. A 2012 update" (Rijkswaterstraat, 2012) also mentions the need of mind shift between the different organizations involved in flood management. A better communication to the public is necessary in order to enhance the effective use of the general public.

However, new approaches are detected in the National Water Plan (2009-2015), paying attention to the mitigation of floods effects by considering spatial planning and risk management including citizens' participation (Teun Terpstra & Vreugdenhil, 2011). It considers a more realistic and pragmatic view, taking into account the inherent uncertainty of flood events, shifting towards the exploration of more natural and sustainable methods.

An interesting initiative is the software tool Flood Warning Communicator (FWC). Included in the innovation programme Flood Control 2015[15], FWC allows authorities to generate effective flood-warning messages by using a database with parts of predesigned phrases established beforehand (Teun Terpstra & Vreugdenhil, 2011). That way prevents authorities from lacking elements and content when the chaotic circumstances emerge. Furthermore, this structured way of communication improve the consistency between messages, while reduces the time to generate them.

This Flood Control 2015 programme is one example of the complex and sophisticated solutions related with flood management developed in the Netherlands. This integrated forecasting system has been developed by a consortium of Dutch companies and knowledge institutes, in conjunction with public bodies. The objective is to ease the communication between the variety of actors involved in order to prevent disasters and mitigate damages (Vermeer, de Bruijne, Heynert, & Nijhof, 2012). With that aim a Dashboard Water Safety is being developed to give a common picture about the actual situation of the threat, the society and its possible consequences. The input data sources of the dashboard are FEWS (Flood Early Warning System) for flood forecasting, and FLIWAS[16] (FLood Information & WArning System) for data exchange and crisis communication. The latter is a multilingual web-based system that, consisting of different independently usable modules, provides and communicates information about floods to help authorities, water managers and other involved

[15] http://www.floodcontrol2015.com/

[16] http://www.hkv.nl/page.asp?id=244119&pid=3430&mid=4160

parties in their decision-making process (de Gooijer & Reuter, n.d.). Through this tool, all involved organisations share the same data from one common source. So all decisions are based on the same information.

On the same subject but with a focus on cross-border cooperation, the project VICKING II[17] aims to enhance the cooperation and tasks division of disaster response by improving the information provision between authorities from the Dutch province of Gelderland and the German federal state of Nordrhein-Westfalen.

Recently the Digital Delta[18] project was announced to be launched with the idea of finding smarter ways of exchanging information in the water sector and the re-use of ICT applications for water management in the Netherlands. The idea is to make data publicly available and legible, so that new solutions and applications can be developed by all interested actors.

The reviewed projects and initiatives developed in the Netherlands show the awareness of the relevance of information exchange between the different actors involved in flood management. Even though the complexity and thoroughness of the projects, still the involvement of general public in the management process is needed, what requires their access to the flood-related information.

In this regard, next section analyses the advangtages and disadvantages of integrating information gathered by the general pulic ("the crowd") by analysing initiatives for emergency response that considers crowdsourced information.

3.1.2 Experiences with crowdsourcing information on disasters

As commented previously, the uncertainty, dynamism and chaos characterise the situations when disasters emerge. A better understanding of the evolution requires updated and reliable information (Poser, Kreibich, & Dransch, 2009).

In these circumstances the integration of information collected by the citizens could be highly valuable covering the gap of information that occurs at the emergence of a disaster (Wang, 2012). The difference between the high demand of information that follows the emergence of such a risky event and the information that is offered originates that gap (Figure 7). However, that low availability of information does not necessary means that it does not exist, rather usually happens not to be accessible when it is needed. Additionally, in disaster circumstances, communication failures or even destruction of sensors could interrupt the collection of information from sensors (Poser et al., 2009).

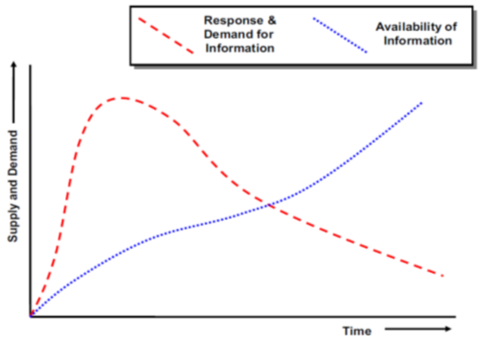


Figure 7. The Information Demand-Provision Gap following an emergency event (based on work by Peter Power, Visor Consultants, 2004).

[17] http://www.programmaviking.nl
[18] http://goo.gl/G4hdVZ

The idea of involving citizens in environmental monitoring and spatial planning has been proved as an useful addition (Poser et al., 2009). However, the recent affordability and widespread use of devices as tablets or smartphones has changed the way citizens can collect and participate in the collection of information. These location-aware sensor-enabled devices offer the capability of collecting real-time information and spread it instantly through the network by using the capabilities of the Web 2.0. This term Web 2.0 covers the idea of a new way of using the World Wide Web, where contents and applications are created and modified by all users in a participative and collaborative way (Kaplan & Haenlein, 2010). Examples of technologies with this new approach are social networking, blogs, wikis, mashups and web applications, among others (http://en.wikipedia.org/wiki/Web_2.0).

These technologies Web 2.0 together with the advances on GIS technologies allow the occurrence of Volunteered geographic information (VGI). Goodchild (2007) embraced the term VGI to express the use of tools for generating, collecting and distributing geographic data provided voluntarily by individuals. WikiMapia, OpenStreetMap, and Google Map Maker are well-known examples of VGI. These kind of initiatives redefine the role of traditional mapping from expert cartographers to every interested individual connected to the Internet network.

Other terms such as crowdsourcing or participatory GIS are used along this report as synonyms of VGI. Crowdsourcing implies the idea that information obtained by a crowd is likely to be closer to the truth than when offered by only one observer (Goodchild, 2007; Kanhere, 2013; Roche et al., 2011). Along the same line, participatory GIS (PGI) or public PGIS (PPGIS) considers the role of VGI in empowering individuals and communities (Goodchild, 2007; White et al., 2010).

Between the advantages of using crowdsourcing information for disaster response are: the availability of real-time information, the possibilities of improving both spatial and temporal resolution and the availability of tools for collecting information via multiple sources (SMS, email, tweets, etc.).

An example of initiatives developed for the adoption of crowdsourcing information in emergency response is the web platform Ushahidi[19]. This is an open source project for information collection, visualisation, and interactive mapping that enables local observers to collect reports by using internet or mobile phones. The initiative includes tools for analysing the information, i.e. SwiftRiver[20], which allows the filtering and verification of real-time data from channels like Twitter, SMS, email or RSS feeds. Through this tool, relief organizations get updated information that helps them to better coordinate and organize their resources.

Based on the use of Ushahidi the Australian public broadcaster ABC launched Queensland Flood Crisis Map (Figure 8), developed as an attempt to centralize the information gathered from official and non-official sources (VGI) during serious floods occurred in Queensland on 2011.

Queensland Flood Crisis Map offers categorized information, distinguishing between validated and non-validated information. This initiative seemed to be successful collecting many contributions from citizens. The content of the contributions showed the process of the flood along the days, changing from issues related with the response to the flood (roads impassable, flooded streets, shelters and sandbagging locations, etc.), towards contents related with the recovery phase (volunteers wanted and available, lost and found pets, vaccinations, locations for bottled water drops, etc.) (Potts, n.d.).

[19] www.ushahidi.com
[20] www.ushahidi.com/products/swiftriver-platform

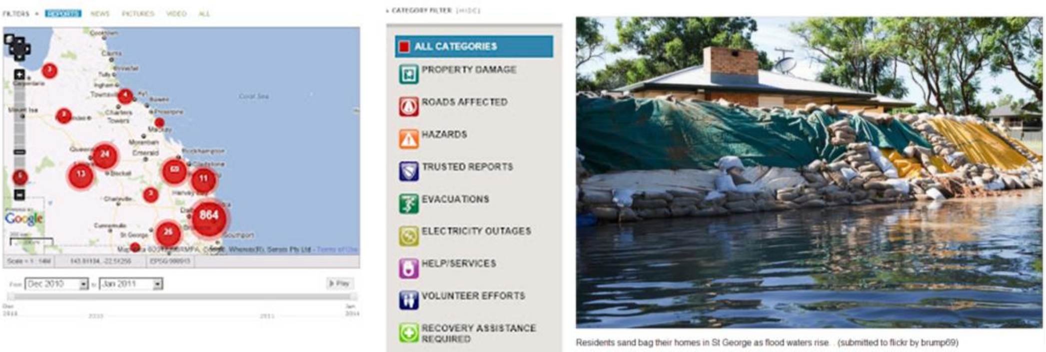


Figure 8. Queensland Flood Crisis Map, based on Ushahidi (left) and example of information gathered from VGI (right).

Another example of initiatives developed to use crowdsourced information for risk management is Twitcident. This Web-based system automatically filters, searches and analyses tweets related to an specific event in the Netherlands (Teun Terpstra et al., 2012). The high level of interaction and speed of communication allowed by Twitter, makes it a valuable source of real-time information. According to a survey conducted to the emergency services in the Netherlands, they showed to be positively in favour of using Twitter as a source of information in case of disasters (T Terpstra, Hartman, De Vries, & Paradies, 2011).

Despite the value of crowdsourcing information for disasters relief, there are still challenges or issues to improve. Difficulties on the integration of VGI into disaster management systems are related with the lack of structure, validation and documentation of the information collected (Schade, Luraschi, De Longueville, Cox, & Diaz Sanchez, 2010).

In addition, the availability of information gathered by citizens is not guaranteed and cannot be planned beforehand. Thus, in a situation of disaster VGI needs to be considered as supplementary information to the official sources (Poser et al., 2009).

Gao et al. (2011) stated that applications for crowdsourcing information still do not provide a common platform for exchanging the information between the different organizations for emergency response. Also the accuracy of the information is not completely guaranteed. Another issue mentioned in their study is the lack of security from the crowdsourcing applications. In some occasions, sharing publicly controversial information could endanger the activity of the organizations.

Solutions for problems in relation with the data reliability and usefulness could be solved by the establishment of protocols and institutions for control (Goodchild, 2007). In this regard, Schade et al. (2010) propose the use of the standard for Sensor Web Enablement (SWE)[21] to convert VGI in “timely, cost-effective and valuable source of information for spatial data infrastructures (SDIs)”. SWE is an Open Geospatial Consortium (OGC) standard that offers a well-structured framework for integration of information and communication for the heterogeneous potential sensors (Botts, Percivall, Reed, & Davidson, 2008). In the study conducted by Schade et al. (2010), the possibilities of SWE technologies to VGI are presented. Even promising (Kamel Boulos et al., 2011), still research needs to be done in this aspect (de Longueville, Annoni, Schade, Ostlaender, & Whitmore, 2010).

Many other projects and initiatives are taking place nowadays in relation to this topic, researching on the integration possibilities of VGI into spatial data infrastructures, to convert it in a source of structured, valid and documented information.

[21] www.opengeospatial.org/projects/groups/sensorwebdwg

In summary, the review of projects and initiatives on risk management systems shows the tendency to benefit from GIS capabilities for the collection, visualization and analysis of useful information in case of disasters. In addition the development of new technologies allows a better exchange of information between the different actors involved, what is shown as one of the main issues to enhance in risk management systems. Despite the differences in the aim and design of the analysed initiatives, they usually try to offer answers to, what seems to be, common questions. Thus, the information offered is in general related with alerts, location of points of interest, the evolution of the disaster, and updates from official sources.

Initiatives with sophisticated solutions for flood monitoring in the Netherlands aim also the exchange of information between different sources of flood-related data. However, for a better management of the risk the involvement of citizens still needs to be addressed. The added value of the information gathered by the general public is proved in the emerging initiatives that use crowdsourcing information in risk management.

The review offers an overall idea on what kind of information is collected, analysed, offered and distributed by existing initiatives of risk management. This serves as an indicator of what are the requirements of information that these platforms try to fulfil. However, the design of a useful and thorough tool for DSS in case of floods requires a closer view of what are the expectations of the potential users.

3.2 Personas

The previous literature review offers a broad idea about what the different actors (i.e. authorities, crisis managers, emergency services and citizens) require, in terms of information, in the phase of response of a crisis situation. Nevertheless, the Personas Method offers the possibility to get a more thorough understanding and precise definition of what these actors specifically will require from the tool for DSS in case of floods.

The method consist on the generation of the Personas, fictional profiles representative of a segment of the potential users group (U.S. Dept. of Health and Human Services, 2013). These Personas are widely used in the marketing and user-centred design fields to improve the understanding of the goals, desires and limitations of users (Pruitt & Grudin, 2003), and to facilitate the communication among designers.

Commonly Personas are built by conducting a series of interviews with a wide number of potential users, identifying groups of similar respondents and also extremes in user behaviour (O'Connor, 2011). Due to the time consuming of the activity, in this project a market research about the smartphones ownership in the Netherlands is used as a base to identify the groups of interest.

According to the statistics from CBS[22] (Dutch acronym for Centraal Bureau voor de Statistiek), The Netherlands presents high rates on use of internet and mobile internet. In 2012, the Netherlands presented the highest percentage of online users of the European Union (Figure 9) and a rate much higher than the European average on the use of mobile internet.

[22] www.cbs.nl

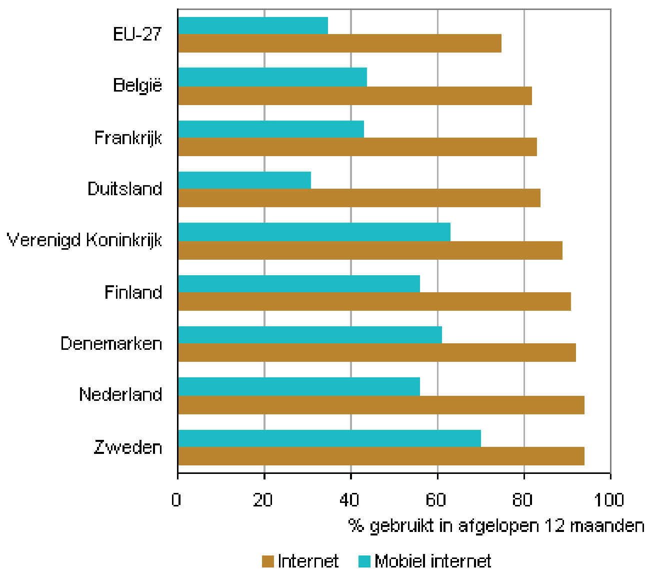


Figure 9. Use of (mobile) internet by 16 - to 75-year olds in some EU countries, 2012. Source: Eurostat.

The table "Profile of smartphone owners in the Netherlands" (Bouwman & Heerschap, 2012) includes interesting aspects of user profiles that can be extracted for this analysis. According to the statistics (Table 1) men show a slightly higher rate on smartphones ownership than women. In addition, more than 80% of the owners are below 50 years old and with a level of education medium/high.

		Target smartphone bezit in Nederland %
	Geslacht	
-	Man	62
-	Vrouw	38
	Leeftijd	
-	15-34 jaar	50
-	35-49 jaar	33
-	50+	18
	Opleiding	
-	Hoog	46
-	Midden	41
-	Laag	12
	Regio	
-	3 grote gemeenten	15
-	Noord	9
-	Oost	20
-	Zuid	22
-	Randgemeenten	5
	Gezinsgrootte	
-	1 persoon	18
-	2 personen	29
-	3 personen	21
-	4 personen	21
-	5 of meer personen	11

Table 1. Profile of smartphone owners in the Netherlands by age, education, region and family size. Adapted from: Bouwman & Heerschap (2012).

Volunteers invited to participate in this project generated Personas profiles using those statistics as a framework and considering the different actors to be represented as potential users, i.e. authorities, emergency services, crisis managers and general citizens. The generated profiles offer detailed description of a specific representative for each group of interest.

The findings of the extensive literature review conducted by Kellens et al. (2013) on the perception of citizens about flood risk, give an idea of what are the characteristics to consider when describing the Personas profiles in detail. Their study reveals the most important socio-demographic characteristics correlated with citizens' risk perception, i.e. age, gender, education, income and home ownership.

Through this way of proceeding four persona profiles are generated. Robert, Henk and Rosa are used as representatives of citizens as potential users, while Katherine is the Persona representative of emergency services. Following is a brief description of the Persona profiles (the detailed information is included in *Persona profiles and Scenarios*):

- Robert – bank employee, 40 years old, married with 2 children, high level of education, owns a house located in an area with low risk of flooding (according to his local knowledge)
- Henk – single researcher, 28 years old, geo-geek, high level of education, doesn't own a house/flat
- Rosa – retired, 67 years old, medium level of education, owns a farm in an area of high risk with horses and other animals
- Katherine – police of 28 years old, married with 2 children, owns an apartment on a 2nd floor in the city centre

All of them are aware of new technologies, and own at least a smartphone as mobile internet device. However they have different habits in their day life, also they differ in the way they commute and how they communicate with their family and friends (use of email, telephone call, SMS, social networks or others).

Once the Persona profiles are generated, they are embedded into specific scenarios (Figure 10) where they have to attempt some goals/tasks (Smith, 2003). Within those scenarios, activities take place while the Personas make use of a product in order to achieve their goals. In this research, the scenarios for all of them start with the warning of a flood situation. Therefore, they need to take decisions based on the information they obtain from the tool to be designed (app for smartphones) in order to keep safe and take care of their families/friends, if that is the case. Appendix 1 includes the whole description of the scenarios for each of the personas.

The analysis and interpretation of the scenarios reveals what are the capabilities that the user expects from the product to be designed. Figure 10 shows an example of the requirements identification through the scenario analysis. That example shows an excerpt from Rosa's Persona with annotations in the parts of the scenario description where user needs can be identified. The analysis helps finding what issues need to be solved in those scenarios. For instance, in the example at Figure 10, Rosa's concerns about how much time could she spend on taking her horses to a safest place, implies the updated information of the flood areas evolution and its forecast for the next hours as information requirements. Then, decisions need to be taken on which of the issues will be answered by the product to design and which of the issues will not be included, at least in a first version of the product (Smith, 2003).

The technical functions that the product should present to achieve the user expectations define the system requirements. This thesis focus on the requirements of the users regarding the information that the system should offer to them to support their decision-making process. Even though this method allows learning about data requirements, functional requirements, and technical requirements, the analysis focuses just in the requirements of information. Thus, Table 2 shows the user requirements in terms of content obtained as a result of the Personas method in this research. The variety of requirements obtained is organized into the following groups:

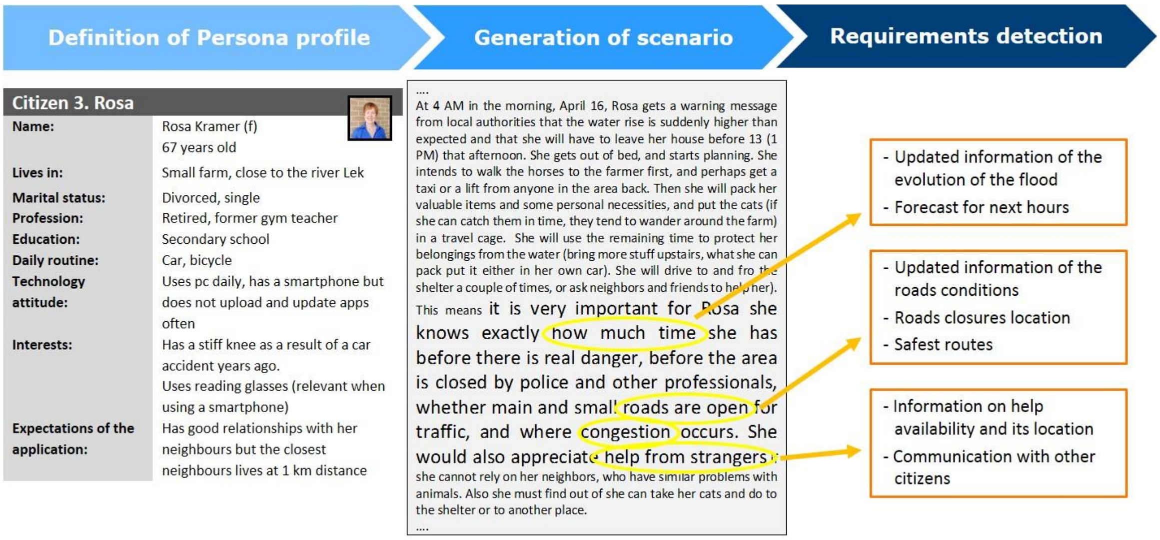


Figure 10. Process for user requirements detection through the use of Personas. Excerpt of the analysis as an example.

- Alerts: related with the users' need to be notified when a flood is occurring or it is expected to occur. General public (represented by Henk, Robert and Rosa) require these notifications in order to be able to anticipate, reducing their exposure to the coming risk. Citizens with family present an added requirement in this sense, wishing also alerts from different points of interest, e.g. their children's school or their mate's working place. This requirement is not that explicit for Katherine (the emergency service representative) as she expects to be personally notified by the specific emergency protocol at the police station where she works.

- Maps: including the information that presenting a spatial component is better understood by visualizing it on a map. All the Personas agree in this requirement. In the occurrence of a flood users require to know the current and forecasted location and extension of the flooded areas and roads, where there are traffic congestions, helping points, shelters, etc. From the emergency services is also important to know the geolocation and the status of the citizens for a better management of the resources.

- Graphs: present the need of information about the temporal evolution of the water level in a particular location. Again this is a requirement identified for all the Personas.

- Routing: information on the level of safety of the roads to reach a specific destination. This is a requirement identified from the general public, even Henk requires the consideration of different means of transportation. In contrast, emergency services do not require this functionality, what could be due to their possibilities to use other means of transport resistant to those situations.

- Messaging: includes the communication with other citizens or with emergency services. Citizens need to express their wills to help others or, by contrast, that they require help. Locating people that require help is one of the main concerns for Katherine.

- Suggestions: referred to information on how to act in those risky circumstances. Two out of the three Personas representing citizens, required this kind of information.

- Links: related to connection with other sources of information, like news, local government, comments from social networks, etc… Unless Robert, is a requirement identified for the rest of Personas.

Requirements		Persona			
		Henk	Robert	Rosa	Katherine
Alerts	Establishment of alerts on fixed coordinates		X	X	
	Establishment of alerts on the actual location (mobile device location)	X	X	X	
	Establishment of varios "Points of Interest" (POI)		X	X	X
	Alerts establishing alerts, warnings, severe warnings	X	X	X	X
	Alerts from different sources (goverment, meteorological organizations, news...)	X	X		X
	Received by email or social networks	X	X		
Maps	Actual flood extension	X	X	X	X
	Forecasted flood extension during next hours	X	X	X	X
	Location of shelters, help points,		X	X	X
	Traffic density, obstacles	X	X	X	X
	Geolocation of people with FloodApp activated				X
Graphs	Water level at a POI: actual and forecasted for the next hours	X	X	X	X
Routing	From actual location to:				
	available shelters		X	X	
	help points	X	X	X	
	an address	X	X	X	
	by different transport means (car, bike, walking, public transport)	X			
Messages	To announce abilities:				
	to help	X	X		
	to give a lift	X	X		
	to host people				
	To require:				
	help (moving stufs, ...)	X		X	X
	to get a ride to a safe place	X		X	X
	a place where to stay			X	X
Suggestions	Suggested activities to reduce the risk considering the situation	X		X	
Links	News related	X		X	X
	Water board, government, NGOs,	X		X	X
	Images from flickr (filtered)	X			X
	Posts on Facebook, Twitter (filtered)	X			

Table 2. User requirements by Persona.

This list of user requirements in terms of content is the base for the functionalities to be addressed by the aimed tool. The capabilities included in the prototype of the tool will be finally based on these requirements together with the results of the analysis on the components of the software architecture.

The findings of the analysis by the Personas method are in line with the requirements derived from the functionalities of the reviewed initiatives (explained above in section 3.1). All of the requirements for information identified by using the Personas method are, to some extent, answered by the functionalities presented in the analysed initiatives commented in the previous section. However, none of those projects include functionalities to tackle all the requirements presented by the Personas.

4 Analysis of software architecture of disaster management systems (DMS) and Geoweb design

This chapter includes the design of the software architecture solution, related with the second (sub)objective of the project (see section 2.2.2). Once the user requirements are identified, the next step in the user-centred design cycle is the design of a solution capable to answer those requirements. With this aim, first this chapter includes an overview of some basic concepts on software architecture and literature review on related projects designs, what helps to identify trends, advantages and disadvantages of existing designs.

Next, a review on the potential components to form the software architecture is developed to evaluate the most appropriate for the study. Finally the proposed software architecture design as a tool for DSS in case of disasters is defined and explained, describing the selected components of the application.

4.1 Analysis of software architecture of disaster management systems (DMS)

The exchange and integration of information for emergencies response is possible through the service of a Geoweb. This is a web-based platform that integrates GIS tools allowing the sharing of information generated collectively (Roche et al., 2011). Relying on the Web 2.0 infrastructure, a Geoweb offers dynamic and interactive maps, the possibility of integrating and disseminate real-time information and the access to distributed resources and data services (Karnatak, Shukla, Sharma, Murthy, & Bhanumurthy, 2012).

The interoperability among the components to exchange data and services is essential when generating a multi-user application. In this regard, Geowebs ensure that exchange and communication by using recognised standards as ISO/TC 211[23] (ISO standard for digital geographical information) and OGC standards[24] (WMS, WFS, WCS), W3C[25] interfaces (main international standards organization for the World Wide Web) and new Web technological advances (AJAX, XML, RSS, tag, etc.) (Yamada, 2010). This framework enhances Geowebs offering a "more flexible structures (thanks to new-generation languages), more open communication protocols, as well as a more extensive interoperability (syndication via RSS, mashups and use of API—Application Programming Interface)" (Roche et al., 2011).

These capabilities of a Geoweb make it a powerful tool for emergency response, allowing the centralization of the data and services for the analysis and visualization of critical information. Moreover, offering an interactive platform, Geowebs also boost the involvement of citizens in the collection of information, i.e. VGI.

Literature review shows that Geoweb is a widely used solution for exchanging multi-source information and widely spread in risk management initiatives. In this regard, Roche et al. (2011) distinguish three kinds of projects: an extended group of projects based on a mashup approach; projects for collecting citizens reports (e.g. Ushahidi); and projects aiming to enhance base maps collectively (e.g. OpenStreetMap).

The research in this thesis is focused on the first group of projects, as map mashups represent a powerful solution for offering multi-source information. Basically a map mashup is a web page that uses content from more than one source to create a single new service displayed on a map in a single graphical interface. Hosted online or as a client application, mashups access directly raw data sources and integrate them fast and easily

[23] http://www.isotc211.org/
[24] http://www.opengeospatial.org/standards
[25] http://www.w3.org/

offering added value results. The access to the data is usually via RSS feeds or other XML marked-up language, or via an API. These APIs define the queries to call the data, enabling an easy integration of data and functions. The large amount of available APIs nowadays facilitates the mashup generation about any topic of interest.

Besides, this project considers also the second group of Geoweb projects established by Roche et al. (2011) regarding the collection of citizens' records. The evaluation of the initiative Ushahidi capabilities are also evaluated as it is gaining popularity among crisis management projects for collecting crisis reports.

An example of Geoweb generation for disaster management is found in the experiment conducted by Yamada (2010), where the software stack provided by OSGeo[26] is used to test the feasibility of a Geoweb as a tool for centralizing information in case of disasters in Japan. Even though the conceptual model could fulfil the requirements of the different potential users, some official institutions seem to be reluctant to share crucial information with the citizens.

The study of Pawlowicz et al. (2011) shows similar setting, establishing a system for dynamic data collection to address the challenge of data quality from volunteer surveys. The system is a geospatial knowledge-based solution that allows in-field data collection with real-time quality control. Based on a client-server architecture, the system is built considering a common implementation using open standards (i.e. GeoServer, PostGIS and OSM). The test conducted by the authors shows that the system allows an optimised survey system, considering spatial awareness and quality control, and at the same time, seamless outreach to wide communities.

A mashup solution is presented in the study of Karnatak et al. (2012), proving to be very useful on a disaster management case study. The study also presents the experience of other researchers (e.g. Turner 2006, Haklay et al. 2008, Battya et al. 2010, and Lee 2010) that used a mashup architecture in geospatial domain to connect various sources services, obtaining an added value product for final users.

A different approach is the one presented by Sani & Rinner (2011), that propose the use of the cloud computing platform Google App Engine to generate a participatory Geoweb tool for deliberating democracy. The scalability of the system (its "ability to accommodate increased usage levels through the addition of system resources", Sani & Rinner, 2011) was successfully tested in a local application. Still technical challenges need to be addressed. The disadvantage of this approach is that the computing time of Google App Engine is limited for free usage.

In this regard, recently, many open-source software projects have arisen for offering online maps and building online services. The research in this thesis is focused on the use of open source software to build risk management systems. Despite proprietary GIS is widely used by authorities, companies and individuals, there is an increasing interest on the use of open source software. The term "Free and Open Source Software for GIS", abbreviated as FOSS4G, denotes software that is free in the sense of freedom (not free-of-cost) and whose source code is not only accessible, but able to be modified and shared (Steiniger & Hunter, 2013). For these reasons, the utilization of FOSS4G allows a collaborative development of the system, while ensures the interoperability between the multiple sources contributions, by supporting standards and commonly used formats. Additionally, an architecture based on FOSS4G will allow an easier adaptation to the different and unexpected situations that could arise in disaster events.

The compendium of FOSS4G generated by Steiniger & Hunter (2013) offers an idea of the great variety of software developed. Appendix 2 presents that list of major software projects arranged by functional categories:

[26] The Open Source Geospatial Foundation (OSGeo) provides OSGeo4W, a binary distribution of a broad set of open source geospatial software for Win32 environments (Windows XP, Vista, etc.). OSGeo4W includes GDAL/OGR, GRASS, MapServer, OpenEV, uDig and QGIS, among others. More information is given in next section 0.

GIS desktop, remote sensing software, server GIS and WPS[27] servers, mobile GIS, exploratory spatial data analysis and software libraries for GIS.

Technologically there exist diverse practical solutions for the development of Geowebs based on FOSS4G. However, literature review in this regard reveals that most of projects are based on the use of products supported by the Open Source Geospatial Foundation[28] (OSGeo). OSGeo is created with the aim to support the collaborative development of FOSS4G and promote its widespread use.

Figure 11 shows the relationship between different clients/servers OSGeo projects and other geographical tools and their intercommunication by OGC protocols.

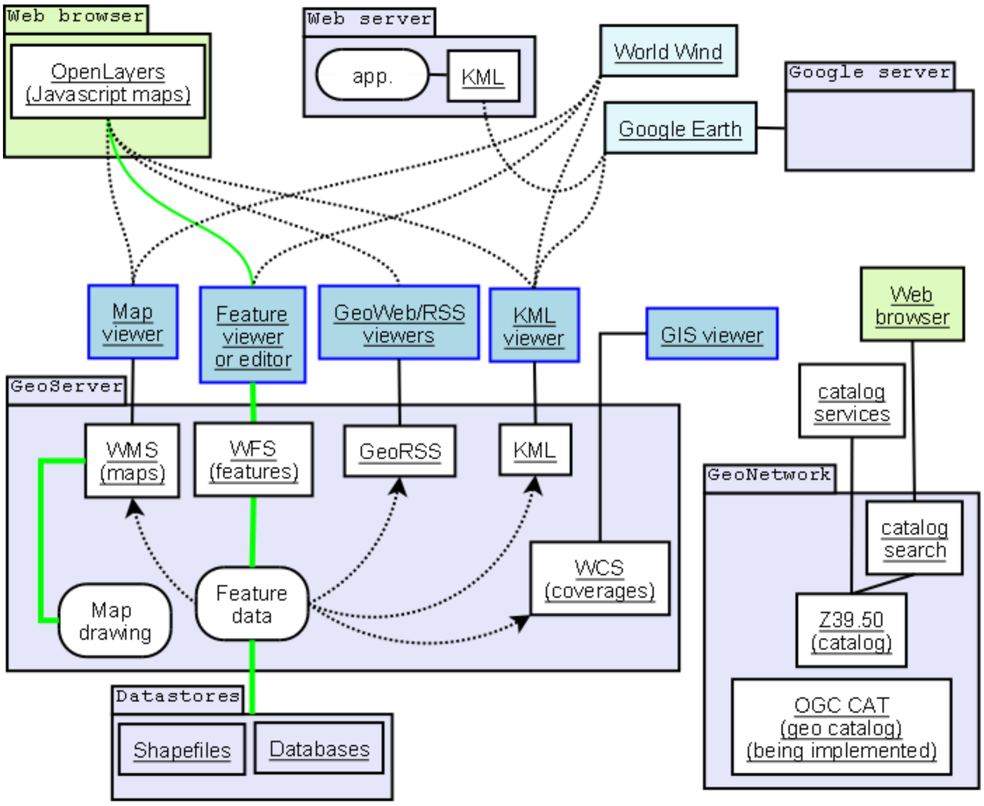


Figure 11. Communication ways and data flow between different OSGeo projects and other geographical tools. Source: http://en.wikipedia.org/wiki/File:GeoServer_GeoNetwork_with_web_app.png#filelinks

As commented previously, a crucial aspect of the Geowebs to ensure the interoperability between the different components is the use of recognized standards and protocols. In this regard the web services specified by OGC play an essential role (see Figure 11).

The Web Map Service[29] (WMS) is a standard protocol for retrieving cartographic images generated by a map server. Figure 12 shows how a WMS turns data into a map image. The map request from the client side establishes parameters that the map server considers to generate an image that will be finally return to the client.

[27] Web Processing Service (WPS) - http://www.opengeospatial.org/standards/wps
[28] http://www.osgeo.org/
[29] http://www.opengeospatial.org/standards/wms

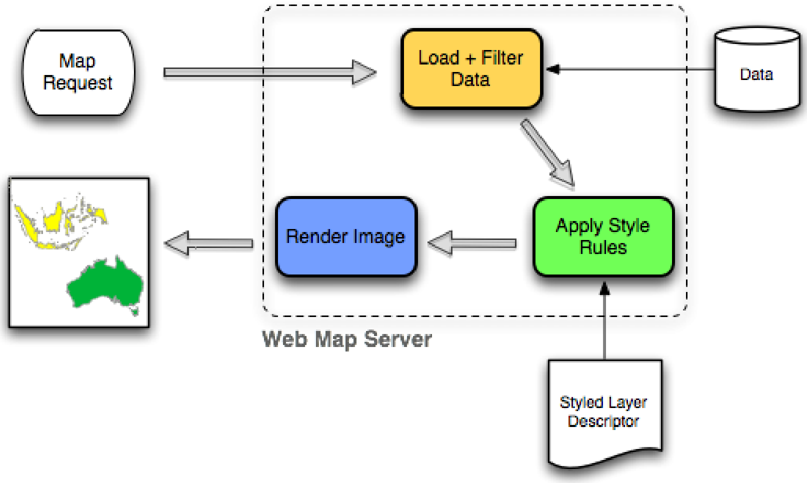


Figure 12. Diagram of systematic procedure of WMS. Source: http://workshops.opengeo.org/suiteintro/_images/wms.png

Additionally, the actual geographic data that comprise the map image can be also returned by a web mapping server. The OGC protocol used for it is Web Feature Service[30] (WFS). Through this protocol, the utilization of the data allows the users to generate their own maps and applications from it (see Figure 13).

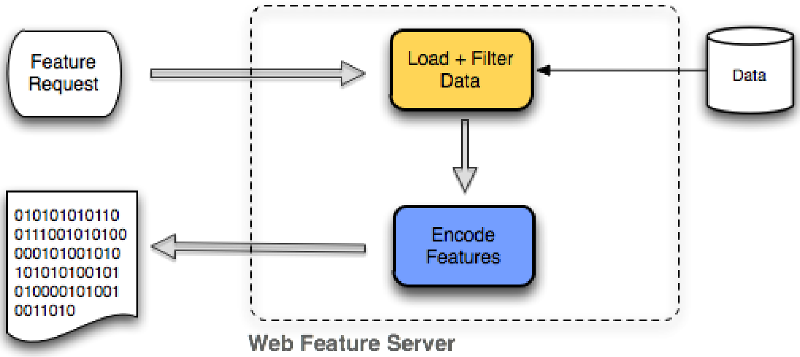


Figure 13. Diagram of WFS protocol procedure. Source: http://workshops.opengeo.org/suiteintro/geoserver/wfs.html

Besides protocols for communication, it is worth to mention that the interoperability within the system claims for the standardization on semantics. Computer systems not only need to be able to exchange the information but to automatically interpret accurately the provided information (Sani & Rinner, 2011). This challenge of systems for integrating and analysing multi-source, multi-format data, widely commented in literature, could be addressed with improved standardization of geospatial ontology and formalism of semantics (Ortmann et al., 2010; Pawlowicz et al., 2011; Rester et al., 2012; Sisi Zlatanova & Fabbri, 2009).

The paper from Zlatanova et al. (2010) on *Models of dynamic data for emergency response* analyse efforts on harmonization. With that aim, the study compares data models to manage dynamic data, developed within the projects for harmonization GDI4DM[31] (Geographical Data Infrastructure for Disaster Management) in the

[30] http://www.opengeospatial.org/standards/wfs
[31] http://www.geodan.nl/onderzoek/projecten/gdi4dm/

Netherlands and the European HUMBOLDT[32]. The analysis shows that all of the models present a good level on semantic quality. However, the harmonization between organizations in cross-border areas is still challenging. Efforts as the European INSPIRE and work groups from OGC may lead to a future global model.

The projects and initiatives review reveals the mashup solution based on a client-server structure (as shown in Figure 11) as a suitable solution for this project. Due to the vast variety of FOSS4G potentially used, a first selection considers the popularity of those open source software (Figure 14). Popular open source software ensures some beneficial aspects for the development of this project, such as the existence of a user community for support, examples of successful implementations or suggestions about their use and application. Then the preselected FOSS4G attributes must accomplish the following non-functional requirements[33]:

- Platform compatibility: must run on Microsoft Windows OS[34] as is the environment where the software architecture will be hosted;
- Interoperability: able to interoperate with other implementations as Esri, Google or Microsoft;
- Documentation: availability of documentation offering a clear overview of the software and tutorials to get started;
- Community: existence of wide community of users/developers/members. A large and active community implies better support, greater acceptance of the product and improves the likelihood that the product will endure and improve;
- Support: existence of forums or e-mail listings and information on how to get support.

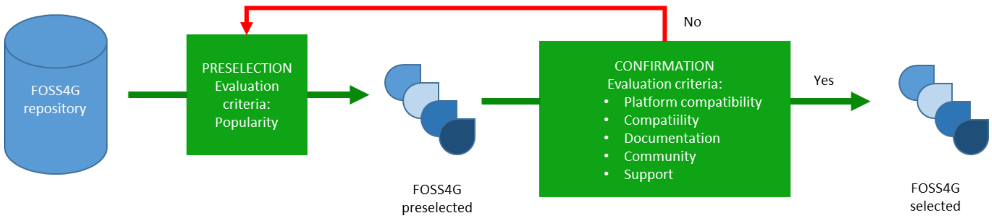


Figure 14. FOSS4G selection process based on non-functional requirements.

Following that procedure, the selected FOSS4G to form the software architecture are PostGIS, GeoServer, OpenLayers and QGIS. That is a quite common configuration as shown in the literature review. Additionally those FOSS4G projects attributes ensure the accomplishment of the established non-functional requirements for this project. The next section explains the proposed software architecture including more details about these selected components.

4.2 Software architecture of a Geoweb for DSS in case of floods

The previous analysis on software architecture trends and availability of possible components, together with the results of the analysis on users' requirements are the base of the design of the aimed web-based GIS platform for DSS in case of floods (henceforth "the Geoweb"). Consequently, the Geoweb is based on a client/server architecture built on distributed GIS technology supported by the OSGeo initiative (see Figure 11).

[32] http://www.esdi-humboldt.eu/home.html
[33] http://en.wikipedia.org/wiki/Non-functional_requirement
[34] http://windows.microsoft.com

The software architecture solution for the Geoweb, that follows the relatively generic implementation, is shown in Figure 15.

The software architecture of the Geoweb consists mainly of three components: client side, server side and data side. Each of them is covered by the following selected OSGeo projects.

4.2.1 Database: PostGIS[35]/PostgreSQL[36]

The object-relational database PostgreSQL allocates the information gathered by the different involved actors. PostgreSQL is spatially enabled by the extension PostGIS, allowing it to answer spatial queries and becoming a backend spatial database for GIS. It is certified as compliant with the OGC "Simple Features for SQL"[37] specification.

Additionally, PostGIS includes spatial functionalities for determining geospatial measurements and some geoprocessing (e.g. union, buffer, difference, etc.). Also support the storage, management by adding types and indexes (Boundless, n.d.).

4.2.2 Middleware / Web Services: GeoServer[38]

GeoServer is a Java-based GIS server application for publishing OGC web services, responsible for mediating between the database and the client layer. It allows the user to access the data by transforming the web request from the user into the specific way of requiring the information to the database or the GIS files.

GeoServer can generate multiple output formats using different standard protocols, including:

- OGC Web Map Server (WMS) for retrieving cartographic images;
- OGC Web Feature Server (WFS) for querying and retrieving vector feature collections;
- OGC Styled Layer Descriptors (SLD) for encoding cartographic styling rules;
- OGC KML for encoding feature collections for visualization in Google Earth;
- OGC Geographic Markup Language (GML) for encoding feature collections for general purpose re-use.

4.2.3 User interface (Web Browser): OpenLayers[39]

OpenLayers is a pure JavaScript library for displaying map data in web browsers, with no server-side dependencies. Designed to consume spatial data and maps from numerous sources, it is not tied to a particular map source, as it is Google Maps. Additionally, OpenLayers offers tools that allow working directly with spatial data in the browser.

[35] http://postgis.net/
[36] http://www.postgresql.org/
[37] OGC and ISO standard that specifies a common storage model of mostly two-dimensional geographical data (point, line, polygon, multi-point, multi-line, etc.)
[38] http://geoserver.org/display/GEOS/Welcome
[39] http://openlayers.org/

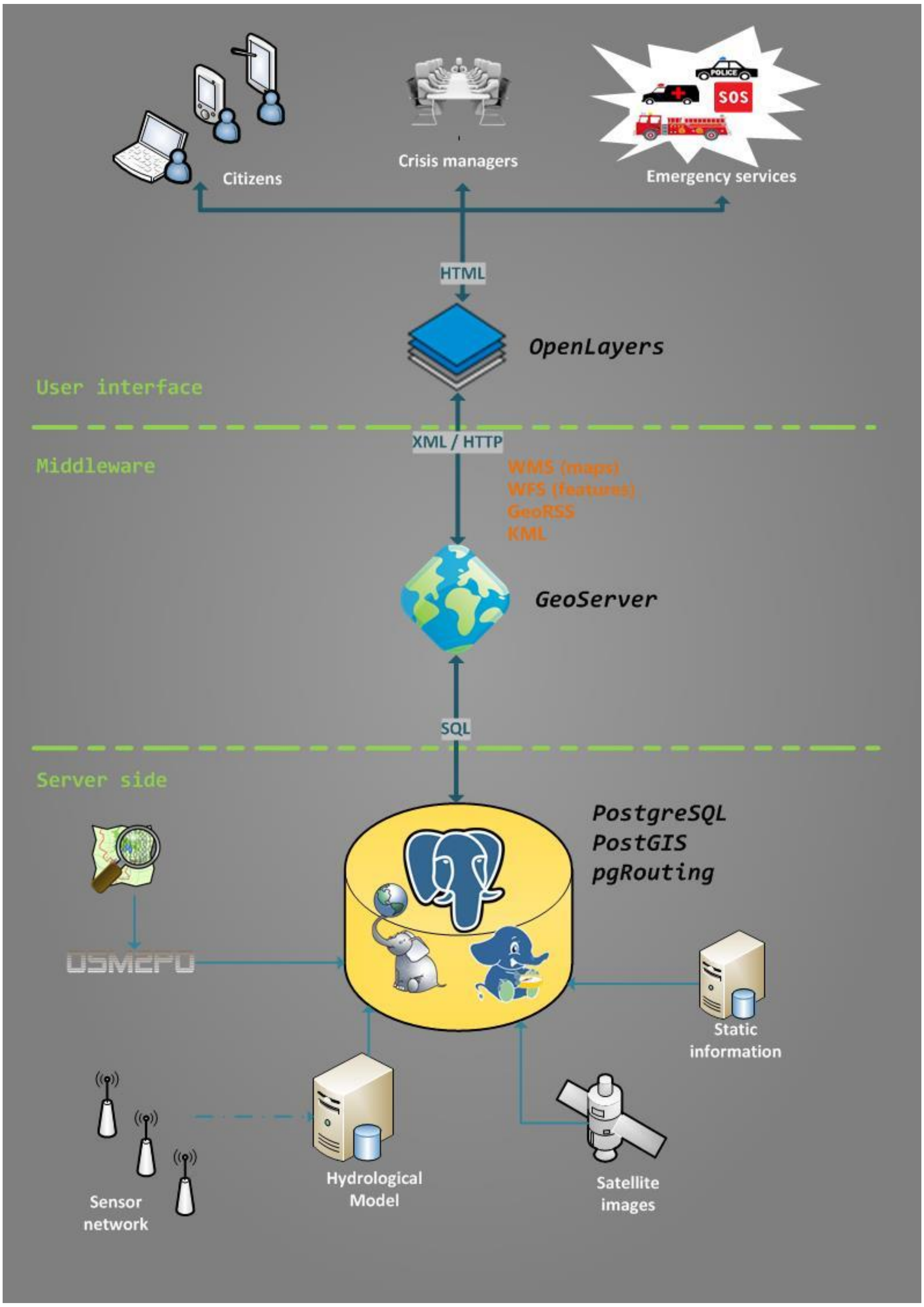


Figure 15 Software architecture solution for the Geoweb.

4.2.4 Other functionalities

Moreover, other functionalities of the Geoweb are given by the use of the following software:

- **DESKTOP APPLICATION: QGIS**[40]

QGIS (formerly known as Quantum GIS) is a desktop GIS for data viewing, editing and analysis that is used for testing the implementations on PostGIS by visualizing the results of the operations.

QGIS presents an extensible structure by plugins. Between the wide varieties of existing plugins, DB Manager[41], officially now part of QGIS (since version 2.0), add features to QGIS that enhances the communication with the database, PostgreSQL in this case. DB Manager allows executing SQL queries against your spatial database and then viewing the spatial output for queries by adding the results to QGIS as a query layer.

- **ROUTING FUNCTIONALITY: PGROUTING**[42]

pgRouting extends the PostgreSQL/PostGIS geospatial database to provide routing and other network analysis functionalities. It includes the classical functions for routing Shortest Path A*, Dijkstra and Shooting algorithm. It also includes Traveling Sales Person solution, computes travel distance and other important factors for network analysis as one-way traffic, for example.

- **DATA CONVERTER: OSM2PO**[43]

Osm2po is a data converter that parses OpenStreetMap[44] (OSM) data and makes it routable for network analysis. It generates SQL Insert scripts for PostGIS, compatible with pgRouting and Quantum GIS.

- **USHAHIDI**

This open source project, already commented in the section *3.1.2 Experiences with crowdsourcing information on disasters*, aims to create a simple and fast way to aggregate information from the public to be used for instance in crisis response. Ushahidi is a web platform for managing crowd-sourced information that allows the collection of distributed data via SMS, email, web, Twitter, Facebook and voice mail. Users can also visualise and interactively map by using internet or mobile phones. The software allows individuals and groups to collaborate in creating live multi-media maps for all kinds of projects.

The initiative includes tools for analysing the information, i.e. SwiftRiver[45] that allows the filtering and verification of real-time data from channels like Twitter, SMS, email or RSS feeds. Through this tool, relief organizations get updated information that helps them to better coordinate and organize their resources.

[40] http://www.qgis.org/en/site/
[41] http://www.qgis.org/en/docs/user_manual/plugins/plugins_db_manager.html
[42] http://pgrouting.org/
[43] http://osm2po.de/
[44] http://www.openstreetmap.org/
[45] https://swiftapp.com/

Furthermore, Ushahidi offers a fast and simple method for installation, i.e. Crowdmap[46], allowing the deployment of the Ushahidi platforms without need of installation in your own browser. Despite the installation of Ushahidi platform requires PHP knowledge, it offers more possibilities of customization than Crowdmap.

[46] https://crowdmap.com/

5 Evaluation of the Geoweb Architecture

The previous chapter described the software architecture solution to address the user requirements of a tool for DSS in case of floods. According to the established methodology based on the cycle of user-centred design, the next step is the evaluation of the solution related with the requirements. In this case, the design of the system is assessed considering two different approaches: the feasibility of generating such a system and its capability to fulfil the identified user requirements about the contents of information offered by the system.

The feasibility of generating a software-based tool according to the designed architecture is assessed by developing an experimental prototype of a part of the system. The steps followed to develop the experiment are explained below, including comments on the challenges and advantages of the system.

The second part of the Chapter explains the assessment of the system from the users' perspective. With this aim, four participants assessed the usability of a mock-up version of the Geoweb, while playing the role of one Persona (see section *3.2. Personas*). The exercise used the think-aloud protocol to evaluate how the suggested Geoweb design fulfils the requirements derived from the scenarios.

5.1 Evaluation of the Geoweb architecture, regarding the design and development

Parts of the software architecture for the Geoweb as a tool for DSS in case of floods are tested by the implementation of a functional system for some of the required functionalities of the solution. Table 3 shows the list of the identified user requirements of the system with the specification of functionalities tested by prototyping and the ones that had been tested in similar projects (literature review).

	USER REQUIREMENTS	PROPOSED SOFTWARE (TOOLS)	TECHNICAL EVALUATION BY PROTOTYPING
Alerts	Establishment of alerts on fixed coordinates	Ushahidi	
	Establishment of alerts on the actual location (mobile device)	Ushahidi	
	Establishment of varios "Points of Interest" (POI)	Ushahidi	
	Differencing between alerts, warnings, severe warnings	Ushahidi	
	Alerts from different sources (goverment, meteorological organizations, news...)	Ushahidi	
	Received by email or social networks	Ushahidi	
Maps	Actual flood extension	GeoWeb (QGIS, OpenLayers)	x
	Forecasted flood extension during next hours	GeoWeb (QGIS, OpenLayers)	x
	Location of shelters, help points,	GeoWeb (QGIS, OpenLayers)	
	Traffic density, obstacles	GeoWeb (QGIS, OpenLayers)	
	Geolocation of people with FloodApp activated	Ushahidi	
Graphs	Water level at a POI: actual and forecasted for the next hours	GeoWeb (QGIS, OpenLayers)	
Routing	From actual location to:	GeoWeb (PostGIS - pgRouting)	x
	available shelters	GeoWeb (PostGIS - pgRouting)	x
	help points	GeoWeb (PostGIS - pgRouting)	x
	an address	GeoWeb (PostGIS - pgRouting)	x
	by different transport means (car, bike, walking, public transport)	GeoWeb (PostGIS - pgRouting)	x
Messages	To announce abilities:	Ushahidi	x
	to help	Ushahidi	x
	to give a lift	Ushahidi	x
	to host people	Ushahidi	x
	To require:	Ushahidi	x
	help (moving stufs, ...)	Ushahidi	x
	to get a ride to a safe place	Ushahidi	x
	a place where to stay	Ushahidi	x
Suggestions	Suggested activities to reduce the risk considering the situation	Ushahidi	x

Table 3. List of identified user requirements of the system and specification on functionalities tested.

The exercise is considered as a throwaway prototype. A simple working model is generated to detect problems in the architecture design and to show the users how the intended system may work. Based on the results and lessons learned of the exercise, a potential revised and improved final model should be created from scratch.

Functionalities of the designed system tested in the experimental exercise are related to the geoprocessing executed in the server part, i.e. route calculations and map visualization of flood. In this regard, the exercise aims to generate a tool for calculating the safest route considering the case study of a flood in the Netherlands. In the scenario the action (flash flood) takes place in the surroundings of Wageningen area. The information from official sources (regarding the current level of water in the area and the forecasted situations), together with information gathered from un-official sources (citizens) influence the route calculation.

With this aim, and considering the software design specified in previous section 0, the exercise consists of the following steps:

- **5.1.1.** Database preparation and software installation
    - **5.1.1.1**. PostgreSQL/PostGIS installation (see previous section 4.2.1)
    - **5.1.1.2.** pgRouting installation (see previous section 4.2.4)
    - **5.1.1.3.** Data input preparation
        - **5.1.1.3.1.** Water level data
        - **5.1.1.3.2.** Road network
- **5.1.2.** Routing calculation
- **5.1.3.** Platform for Risk Management System (see previous section 4.2.4)

The next part of this section describes each of the steps, including specifications of the prototype settings and comments on the software utilization experience. Moreover, Appendix 3 includes detailed information on a criteria-based evaluation of the main software used to build the prototype up, i.e. the Relational DataBase Management System PostgreSQL/PostGIS and the platform for risk management system Ushahidi. The criteria selected to assess the software is related with the following attributes:

- Functionality:
    - Ease/complexity to use it (installation procedure, availability of guidelines to install it, level of IT skill required, among others);
    - Learnability: existence of information on how to get started and how to specifically work on Windows OS;
    - Customization: possibility of customization and way to do it;
    - Integration and interoperability: which open standards are applied and how is the integration with other programs;
    - Transportability: possibility to import/export data, and multiplatform capacity.
- Community:
    - Importance of the community within the project;
    - Support: availability of free/commercial support via different ways on how to use it the software and to fix problems;
    - Documentation: procurement of sufficient information for users and also for developers, availability of case studies.
- Licensing issues
    - License category: copyrights, open source license.

5.1.1 Database preparation and software installation

5.1.1.1 POSTGRESQL/POSTGIS INSTALLATION

As commented in the previous chapter, PostGIS is an extension of the PostgreSQL object-relational database system which allows GIS (Geographic Information Systems) objects to be stored in the database.

The latest release of PostGIS (version 2.0 as of this writing) comes packaged with the PostgreSQL DBMS installed as an optional add-on. The installation is done by following the guidelines “pgRouting 2.0 for Windows quick guide” offered in Anita Graser’s blog[47].

This way, the installer version PostgreSQL 9.2 for Windows x86-64 bits is downloaded from http://www.enterprisedb.com/products-services-training/pgdownload/. Through the installation process, the extension PostGIS 2.0 is also installed.

Once the PostgreSQL server is running, the database is accessed by the use of the tool for administration and management pgAdmin III[48]. Figure 16 shows a screenshot of the GUI of pgAdmin III enabling an easier utilization of the spatial database.

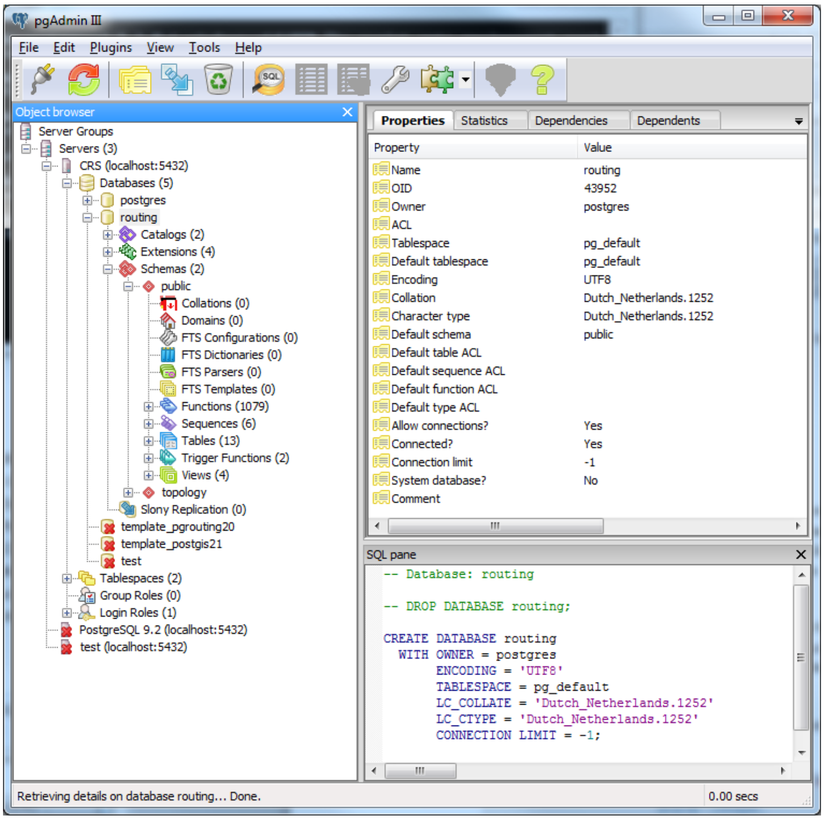


Figure 16. Interface of pgAdmin III, tool to administrate and manage the spatial database PostgreSQL/PostGIS.

[47] http://anitagraser.com/2013/07/06/pgrouting-2-0-for-windows-quick-guide/
[48] http://www.pgadmin.org/

5.1.1.2 PGROUTING INSTALLATION

The next step is then to install the extension for PostGIS and PostgreSQL pgRouting that adds routing and other analysis functionalities to the geospatial database. pgRouting offers the possibility to be used through the open source GIS desktop QGIS, which facilitates the process as the results can be directly visualized, unlike using it directly on PostGIS/PostgreSQL.

pgRouting includes different routing algorithms that could be used for the calculation, as the classical Dijkstra or A* among others. The minimum attributes required for routing are just a start point ("source"), a destination point ("target"), an unique identifier of the way ("ID") and an associated attribute "cost".

For example, a simple query for calculating a shortest path considering Dijkstra algorithm looks like this:

```
SELECT seq, id1 AS node, id2 AS edge, cost FROM pgr_dijkstra('
                SELECT gid AS id,
                         source::integer,
                         target::integer,
                         length::double precision AS cost
                         FROM ways',
                44528, 352, false, false);
```

In this example the length of an edge of the road network is used as cost, thus the route calculates the shortest path. However, cost could be whatever parameter we are interested on considering. In this case, the interest is to calculate the route that presents the minimal danger, which is the safest route.

Between the advantages of this database routing approach is the possibility of calculating the "cost" attribute dynamically through SQL, considering values that come from multiple fields or tables. In fact, this capability makes this "cost" parameter the key factor of the exercise, integrating information provided by a variety of sources, official and non-official, presenting different level of trustfulness, involvement and accuracy.

The calculation then could consider real-time information offered by different actors about the level of safety of the ways, what may add a meaningful value to the result, helping users to make decisions more confidently. Particularly the official information included is regarding the current and forecasted water level, while the unofficial information considered is reports with suggestions on the roads use suitability.

5.1.1.3 DATA INPUT PREPARATION

5.1.1.3.1 Water level data

Official information about the evolution of the flood is crucial to determine the safety levels of the roads that could be used in the defined scenario (see section 2.1), a fictional flash flood in the surroundings of Wageningen area (The Netherlands).

A first attempt was to use the outputs from hydrological models used in actual Dutch initiatives for early warning systems in case of floods. As commented in the previous Chapter 3, in these projects usually sophisticated hydrological models are developed to predict the extension of flooded areas and for a better understanding of hypothetical situations in case of a rise of water levels. Usually those

models are feed by real-time meteorology data and water level at the dikes, which makes them highly convenient tools for early warning systems.
However, difficulties were found to access the models or even just use the data outputs. Due to the fact that the exercise is developed just for technical demonstration, a less accurate and sophisticated, but feasible solution is the simulation of a flood by a Cellular Automata (CA) modelling approach. This is a grid-based simulation that allows temporal and spatial dynamics. The grid consists of regular cells that present an initial situation that will change along the time considering the state of the neighbouring cells. Based on the idea presented by Parsons & Fonstad (2007), the conservation of mass and the Manning's equations for flow velocity are coupled with an algorithm to integrate the temporal delay to simulate surface water flow.

This way, the two-dimensional lattice of cells is created from the Digital Surface Model (AHN[49] 100m) of the study area (Figure 17). Then each cell is instantiated with its spatial location and an elevation value, which the model uses to compute how much water the cell can get till reaching the water level fixed at the dike (see Figure 18). To start the simulation, the dike breach is arbitrarily located in a cell in the dike area, which water level is fixed as the river water level (parameter h in Figure 18). Then, with a fixed water influx, each time step the water is distributed by the lattice of cells, considering the water level in the neighbouring cells at the time before. For a matter of simplicity the parameters of precipitation and infiltration are not taken into account.

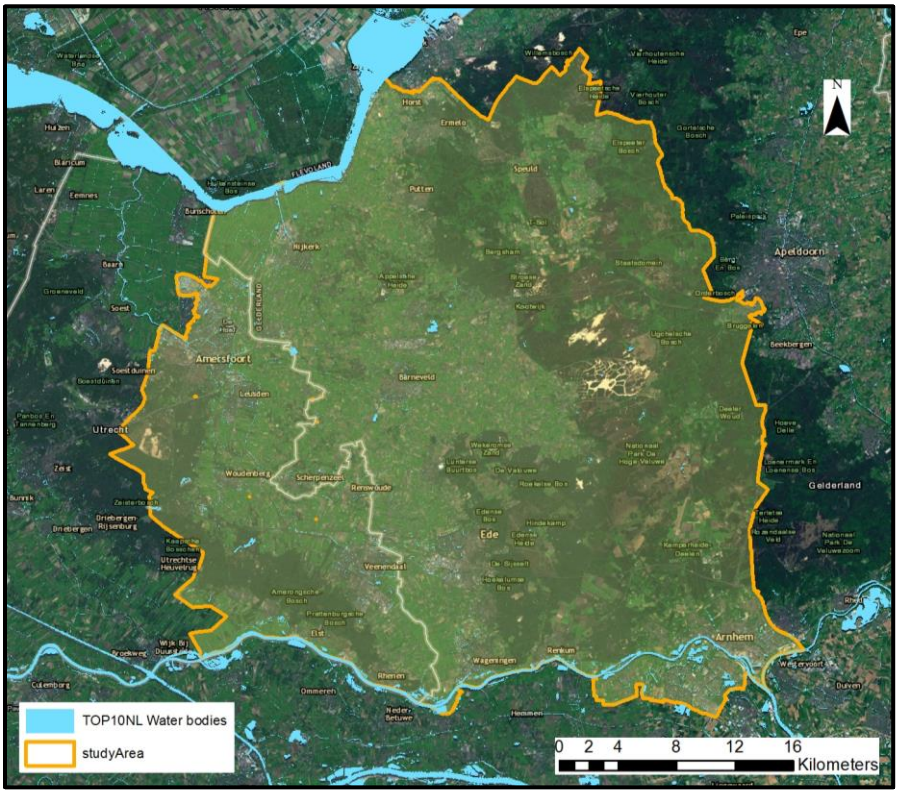


Figure 17. Delimitation of the study area – part of the water basin at the North of Wageningen.

[49] Actueel Hoogtebestand Nederland (AHN) – www.ahn.nl

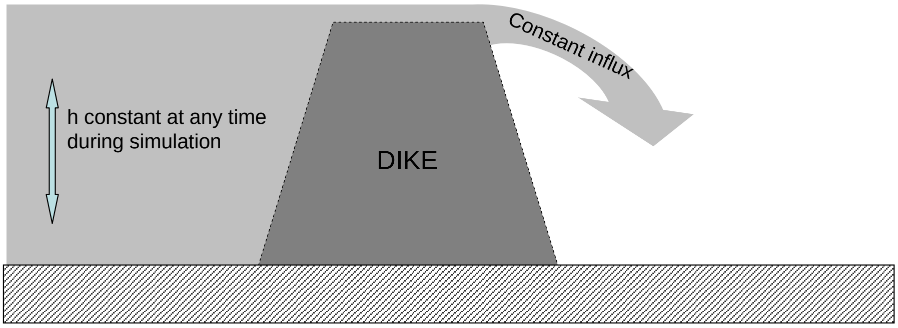


Figure 18. Schematization of the influx at the starting point (adapted from A. Ligtenberg).

The implementation of the model in NetLogo software[50] generates raster files with information on water level per cell and time step. Examples of the simulation outputs are shown in Figure 19.

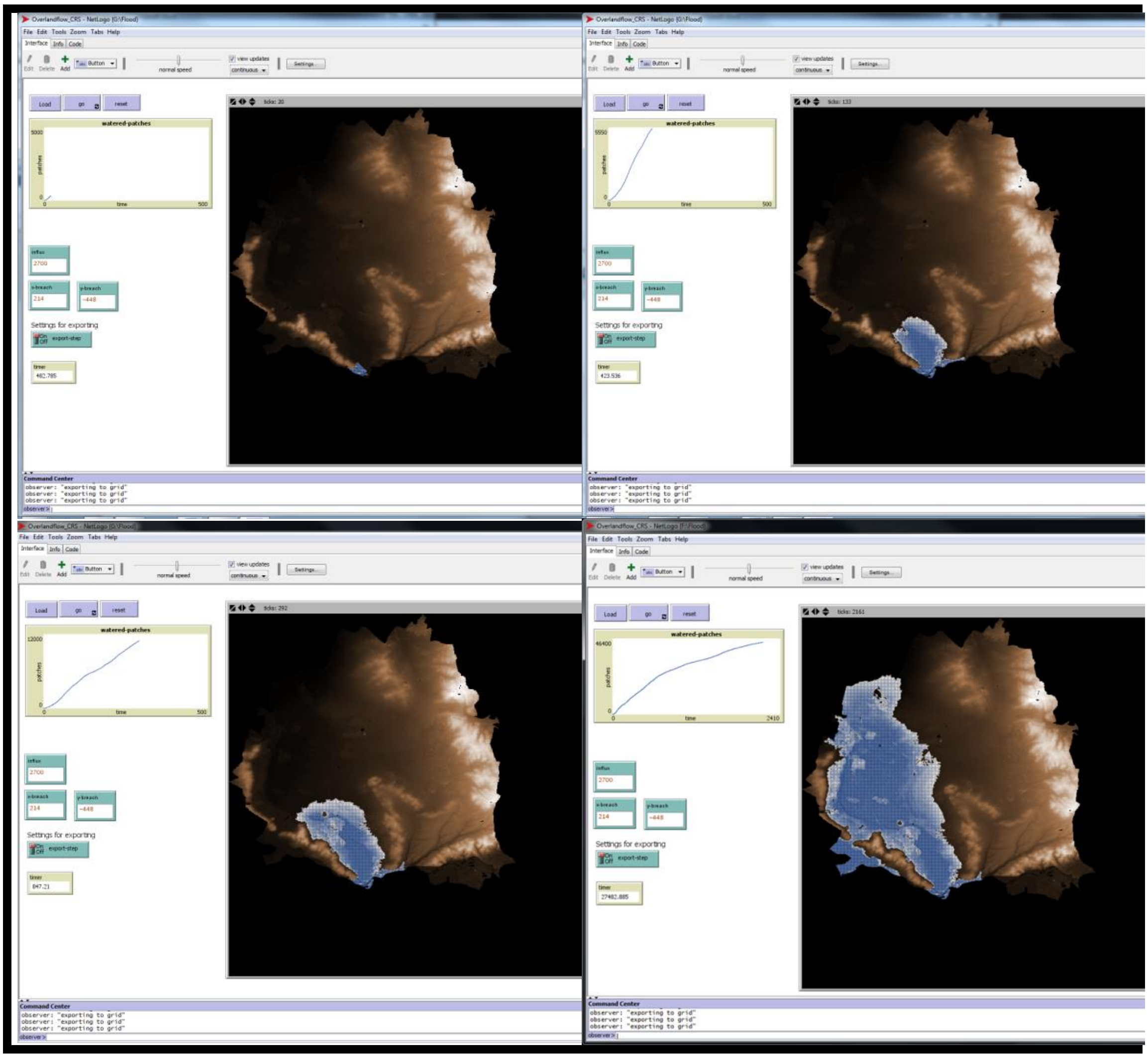


Figure 19. Screenshots of four different time steps in the evolution of the flood n the study area simulated by Cellular Automata approach in NetLogo.

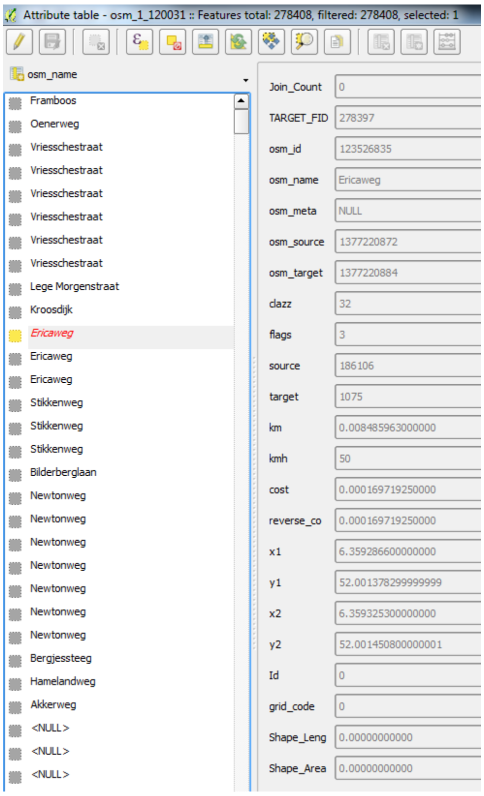
50 http://ccl.northwestern.edu/netlogo/

In PostGIS 2.0 PostGIS Raster is fully integrated, unlike in previous versions, so there is no need of extra compilation for it. The raster loader executable raster2pgsql is used to format the raster outputs of the simulation into SQL suitable for loading into a PostGIS raster table.

5.1.1.3.2 Road network

The road network data source to be used in this exercise is OpenStreetMap[51] (OSM), a collaborative project that generates free editable maps of the world. This data is compatible with pgRouting as it presents a topological data structure, with four core elements (nodes, ways, relations and tags), needed for the routing calculation.

The roads network data from OSM is imported into the PostgreSQL/PostGIS database by the use of OSM2PO[52]. Once downloaded, this tool written in Java can be started just by launching a batch script that connects with the URL where the OSM data for our study area is available. For the purpose of this exercise the OSM data for Gelderland area is downloaded from the site http://downloads.cloudmade.com/.



The OSM data offers information on what kind of transport is allowed in each road/edge of the network. Thus in this exercise the routing algorithm can be used to calculate routes whether travelling by car or by bike. Figure 20 shows an example of the available information for each of the road network edges, including among others the attribute *clazz* expressing the kind of road (motorway, primary road, secondary road and other classes); *kmh* with the maximum allowed speed information; *km* offering the length data; and *flag* for the kind of transport that supports that road.

Figure 20.Example of the data structure resulted after converting OSM road information with the tool OSM2PO.

[51] http://www.openstreetmap.org
[52] http://osm2po.de/

5.1.2 Routing calculation

Once the database integrates the information on road network and water level from the flood simulation, a classification of the roads is done considering their level of safety. In line with the guidelines suggested by Risicokaart.nl[53], the classification of the roads according to their safety.

Level of safety	Water level (wh) (cm)		Alerts
	travelling by car	travelling by bike	
Safe	wh = 0	wh = 0	Recommended
Low risk	0 < wh < 20	0 < wh < 10	Low risk
High risk	wh > 20	wh > 10	Not recommended

Table 4. Parameters considered for road classification.

These considerations need to be taken into account when calculating the safest route. With this aim, the "cost" attribute of each edge of the network needs to integrate those specific considerations.

PostGIS Raster includes the function ST_Intersect that allows locating the roads that are not safe, where the water level is higher than 20 cm. Then a very high value can be added to the attribute "cost" of those roads. Thus the access will be restricted in those ways and the routing algorithm will avoid them to generate the safest route (the one with lower cost).

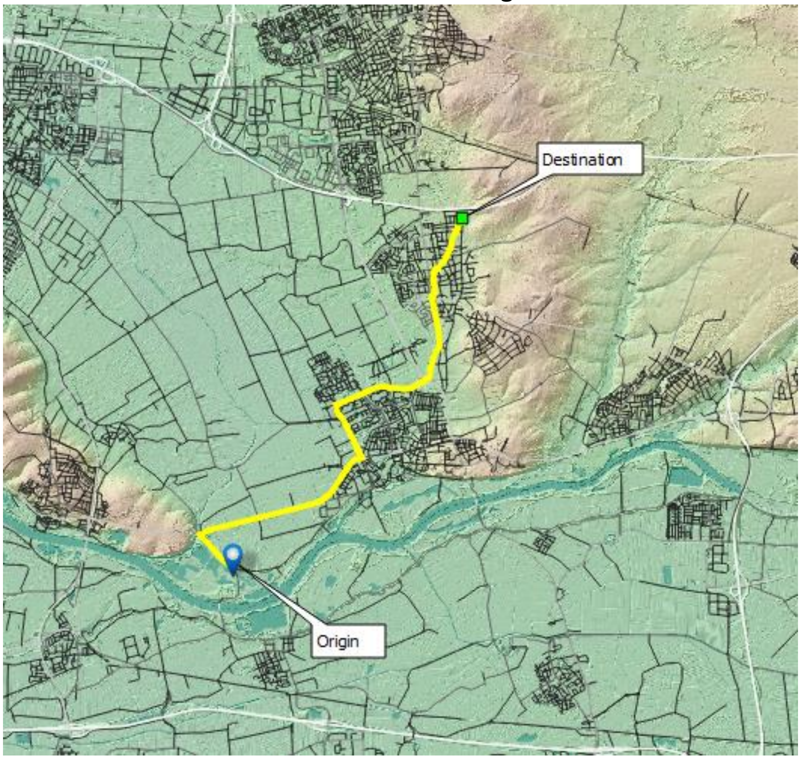
In the same way, the integration of the information offered by citizens is done by adding to the corresponding attribute cost an extra value, in case of low risk, or a very high value, when the risk is high. In this exercise the integration of VGI (what in Table 4 is shown as "Alerts") is done manually as the interaction of VGI with the database is out of the scope of this prototyping exercise.

Following are some examples of the results from the routing algorithm considering:

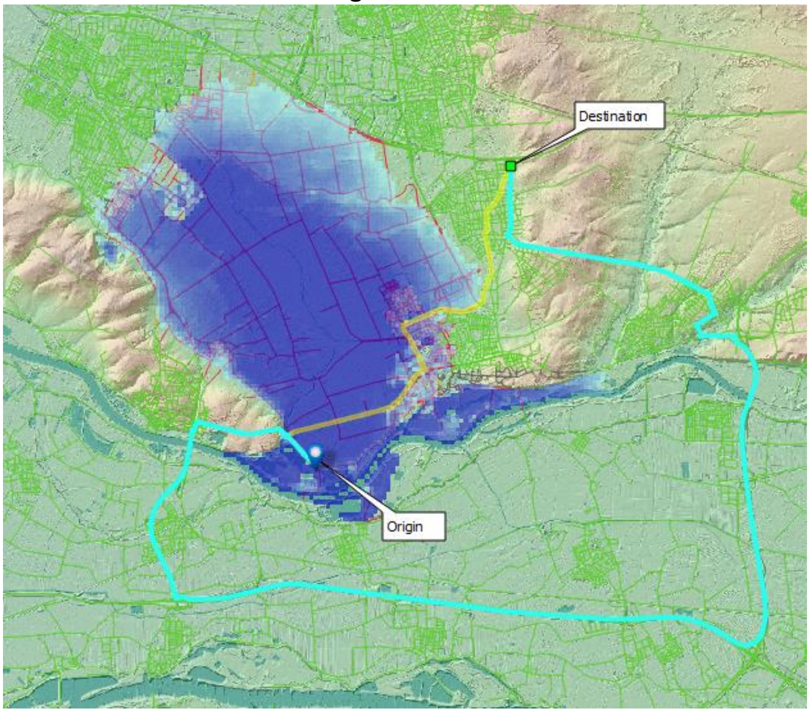
- only the length of the roads;
- the length and also the water level;
- and considering all the available information, i.e. the length plus the water level and the information gathered by VGI.

[53] http://www.risicokaart.nl/en/informatie_over_risicos/overstroming/

Route A. COST = length



Route B. COST = length + water level information



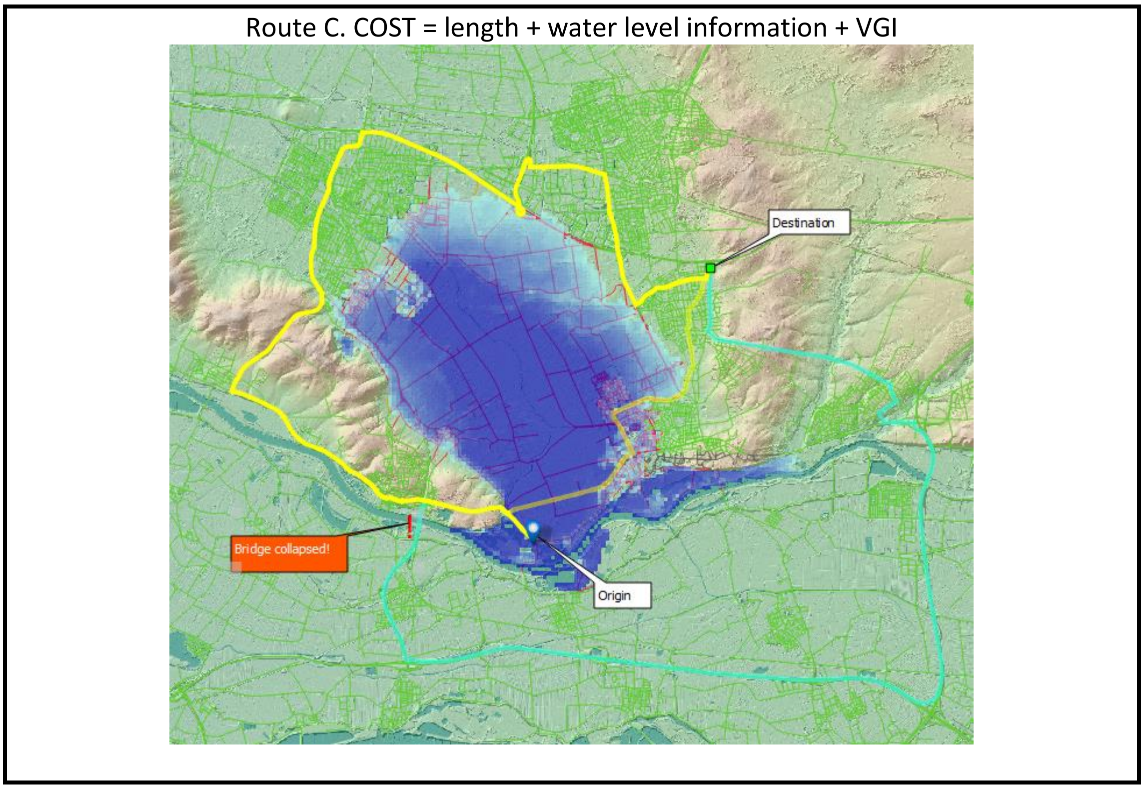


Figure 21. Safest routes calculated by pgRouting considering only the length of the roads (A); adding the information of the water level from the flood simulation (B); and taking into account information from VGI (C).

The availability of alternative routes depending on the data sources considered provides users' awareness to base their decisions on what they consider more convenient. Users looking for the shortest route may follow the route A, while considering the information about the area flooded is clear that route A is not safe thus route B may be considered. Moreover, a user that trust the information offered by other citizens and doesn't want to suffer the low speed traffic occurring at the bridge (orange sign in route C of Figure 21) will probably select the route C.

The open source software used in this exercise made the generation of a system feasible (the spatial database) that integrates information gathered from different sources in different formats. Additionally the results give an idea of the added value that integrating multi-source information can offer to users, whatever his/her role is, in a decision making process.

5.1.3 Platform for Risk Management System

A first attempt of the exercise was to seize already available and specific platforms for generating risk management systems, as the one already mentioned Ushahidi.

Ushahidi has been successfully proved in different kind of projects, and especially in case of disasters. In the present report the example of Ushahidi deployment to exchange information in case of floods in Queensland is already shown. That successful initiative demonstrates the capabilities of Ushahidi to collect, categorize and visualize official and non-official information in case of floods.

The installation of the platform on the PC is explained in detail in the Appendix 4. The appendix is attached with the aim to provide guidance to further installations in a PC with similar characteristics, i.e. Windows x64bits. This installation process requires IT knowledge related with PHP developments and command-line arguments.

Because Ushahidi is a free and open source software system, the main application can be downloaded and then modified to include other required functionalities not included in the original system. Even though Ushahidi presents a convenient and easy to customize interface for visualization, that could be used as the main interface for the Geoweb, there are functionalities like visualizing raster or the geprocessing of data that need to be addressed by the use of other software. Customizing Ushahidi to integrate new functionalities or to interact with other software require programming skills. For that reason, the platform Ushahidi is decided to be used for the collection and filtering of the real-time reports/information from the multiple sources, both official and non-official.

The Ushahidi manual (Ayala Iacucci, n.d.) offered in the Ushahidi community website is followed to customize the platform. This way some categories to filter the reports are established ("looking for help", "shelter", "help point", "trusted reports") and connections to feeds and alerts are established.

Information of interest that can be collected in Ushahidi is:

- Reports from citizens via text messages, email, twitter and web-forms;
- Static information: recommendations on how to deal the situations during a flood (example is found in the website Risicokaart.nl[54]);
- Feeds to live stream webcams, e.g. webcam.nl[55] or cammap.nl[56];
- RSS feeds from KNMI (Koninklijk Nederlands Meteorologisch Instituut) about weather conditions[57] and warnings[58], offered as standard CGI (Common Gateway Interface[59]).

Next Figure 22, Figure 23 and Figure 24 show the main interfaces of the system generated by Ushahidi.

Figure 22 shows the main interface of the generated system that includes:

- a map of the area of interest with the geolocated reports categorized;
- a list of the most recent feeds from official and mainstream news (KNMI and others);
- a list of the most recent reports;
- a graph showing the evolution on time of the number of reports collected;
- and contact information.

To submit a report the interface where to load the information is shown in Figure 23.

And Figure 24 shows the tab where alerts can be configured, giving an email address where to receive the notifications, the radius of the area of interest and the categories of the reports you are interested on.

Even though the intuitive user interface of the platform, the customization of Ushahidi requires IT skills related with PHP development, web servers, html, that need to be considered when planning the architecture design of the aimed system[60]. This way, in this project the integration of the flooded information in real-time together with the results from the routing algorithm cannot be loaded with the default settings of the platform database. Due to the time constraints intrinsic to thesis projects this issue is recommended for further research. Another

[54] http://www.risicokaart.nl/en/informatie_over_risicos/overstroming/
[55] http://hdtv.webcam.nl/website/page1/live_HD_webcams.html
[56] http://cammap.nl/
[57] http://www.knmi.nl/rssfeeds/knmi-rssweer.cgi
[58] http://www.knmi.nl/rssfeeds/knmi-rsswaarschuwingen.cgi
[59] http://en.wikipedia.org/wiki/Common_Gateway_Interface
[60] More information in this regard is given in the *Appendix 3. Software criteria-based assessment*

idea is to export the reports obtained by Ushahidi, integrate them into the database, allowing their further analysis or visualization through the web map server.

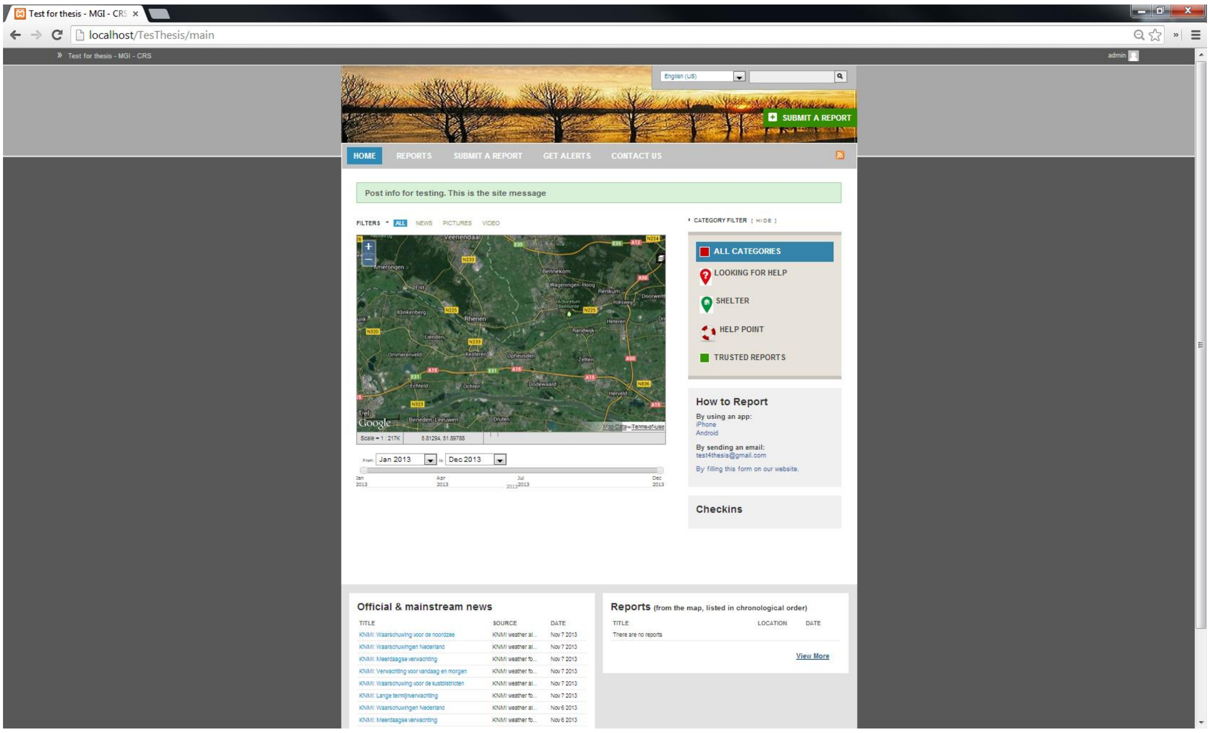


Figure 22. Screenshot of the main interface of the system based on Ushahidi platform.

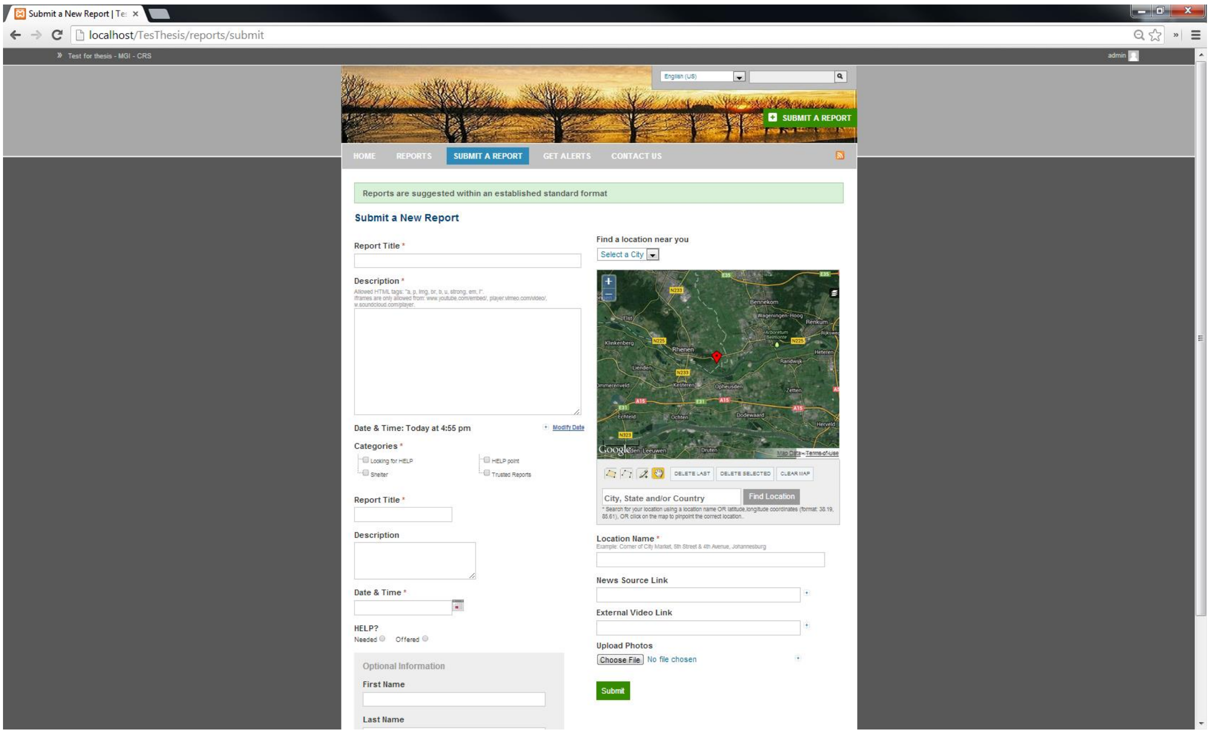


Figure 23. System interface to submit reports.

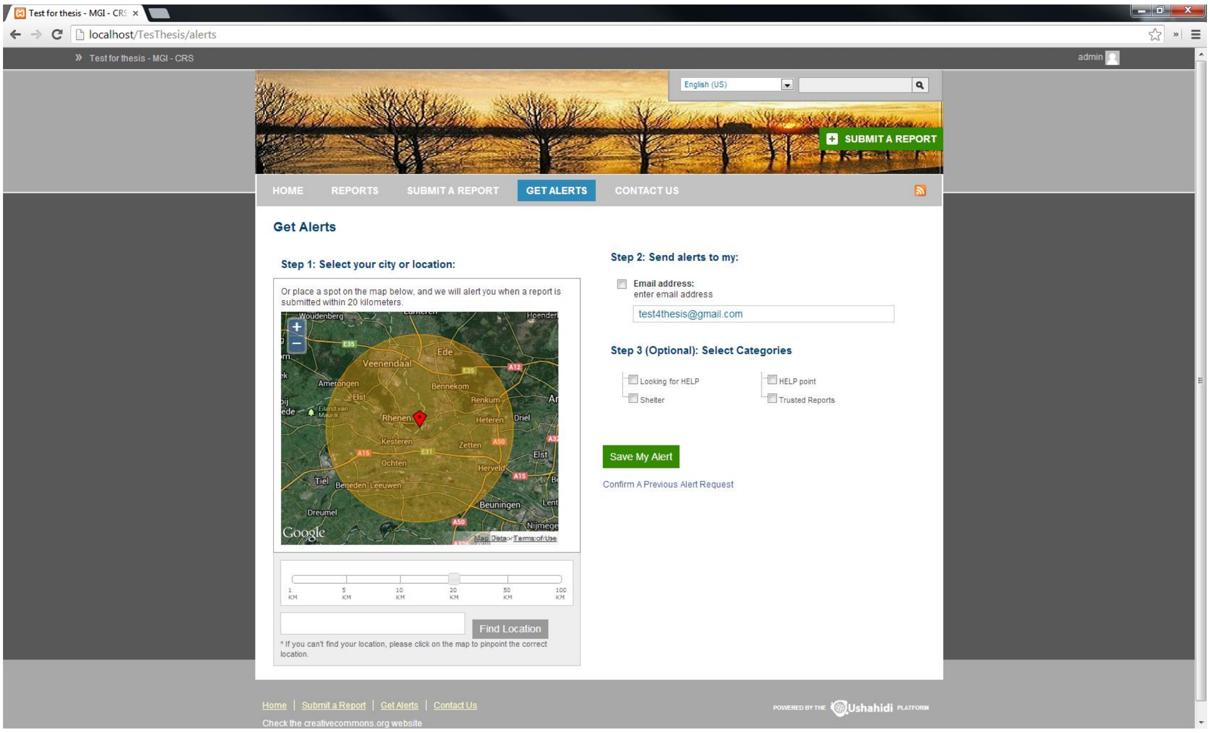


Figure 24. System interface to subscribe for alerts.

5.2 Evaluation of the Geoweb architecture, regarding the user requirements

The assessment of the Geoweb architecture regarding the user requirements is conducted following the think-aloud protocol. This method for data collection is used in product design and development and is recognised as a valid method for researching cognitive processes (Ericsson & Simon, 1980) when using an application. The practical approach of the method consists on collecting data in real-time, asking participants to think aloud while they perform specific tasks.

In this project, the experiment is developed to evaluate how the suggested architecture helps to fulfil the requirements of the potential users. The exercise is focused on the content offered by that Geoweb and how the tool helps participants to structure the information in order to make decisions.

Following the guidelines from the *User-Centred Requirements Handbook* (Maguire, Kirakowski, & Vereker, 1998), two usability goals are used for the assessment. These are the effectiveness of the tool, meaning to which degree the tool allows users to complete the tasks accurately. The second usability goal is the satisfaction from using the tool that will derive from completing the tasks successfully and quickly. It is worthy to mention that even though the exercise aims to test the usability of the designed architecture, the design is much related to the usability, what makes it difficult to separate opinions related to the design of the tool.

Four participants took part in the experiment. Three of the four participants elaborated previously the Persona's profile, thus playing the role of the Persona was quite straightforward for them. Also the fourth participant is aware of this project, so the "playing the game" was intuitive. Additionally the participants (three men and one woman) present a high level of education and expertise on GIS techniques, ages ranging from 25 to 50 years old and knowledge on emergency situations within the average of the population. This last attribute means that they are aware of the existence of warning systems and plans for risk mitigation in case of floods. One of the participants, presents a higher sensibility to floods due to the frequent occurrence of floods in his hometown.

With this aim, the experiment is conducted by providing the participants with a mock-up version of a potential app based on the suggested architecture (from now on "FloodApp", see Figure 25). The mock-up version consists of an interactive PowerPoint that presents a smartphone screen with different pages of the FloodApp. Interactively from the main page of the FloodApp (Figure 25 – 1) the user can choose among the different functionalities of the system by pressing the buttons that represent them. The functionalities that present the FloodApp are:

- Alerts: it guides the user to a screen where alerts are given, from official sources, like Waterschap Rivierenland, from the news and from social networks (Figure 25 – 2). That screen gives links to the original websites of the alerts sources, where the user can get further information (Figure 25 – 3, 4 and 8, respectively).
- Flood Forecast: shows the user a map with the current extension of the flood (Figure 25 – 5) with a temporal slider that allows seeing the evolution on the predicted flooded area in the next two hours (Figure 25 – 6) and 6 hours (Figure 25 – 7).
- Messages: guides the user to the Ushahidi main page of the project showing on the map the number of reports generated in the area and the different categories that classify the messages. The reports visualized on the map can be filtered by clicking on a selected category (guiding the user to Figure 25 – 9). From the map, clicking on a specific report, the system directs the user to the selected report contained within the list of reports in that category (Figure 25 – 10). The selected report is a picture (Figure 25 – 12) that can be accessed just by linking on that report.
- Routing: when selecting this option the user will get a map showing the route from his/her current location to the destination (the option to select start and end point is not offered in this mock-up version, although it is identified as a user requirement and a real development should consider it). That route is shown in Figure 25 – 13. From there the user has the option to recalculate the route integrating information about the flood Figure 25 – 14) and information collected by the citizens (Figure 25 – 15).

The experiment was conducted individually with each of the participants in a quite working environment (PC rooms of Wageningen University). The exercise was introduced to the participants giving some explanations about the procedure to follow, which could last around half an hour approximately. Then a random video with flood images of Europe was shown to the participants helping them to get more easily into situation. Next, each participant was asked to perform the role of one of the Persona profiles defined in section 3.2. They are asked to confront the generated scenarios (see *Appendix 1. Persona profiles and Scenarios*), by using the mock-up app. The participants were provided with a printed version of their own scenarios. They need to go through the situations and execute predefined actions, while they expressed whatever are their thoughts and impressions.

There were no scripts for follow-up questions. Rather, spontaneous questions were asked based on events that arose during the think aloud protocol (Willis, 1999). Appendix 5 includes the transcriptions of the outcomes from the think-aloud exercises. The comments are grouped into the different functionalities that are tested and offered by the mock-up version of the tool, i.e. alerts, messaging, maps, graphs, routing and overall impressions.

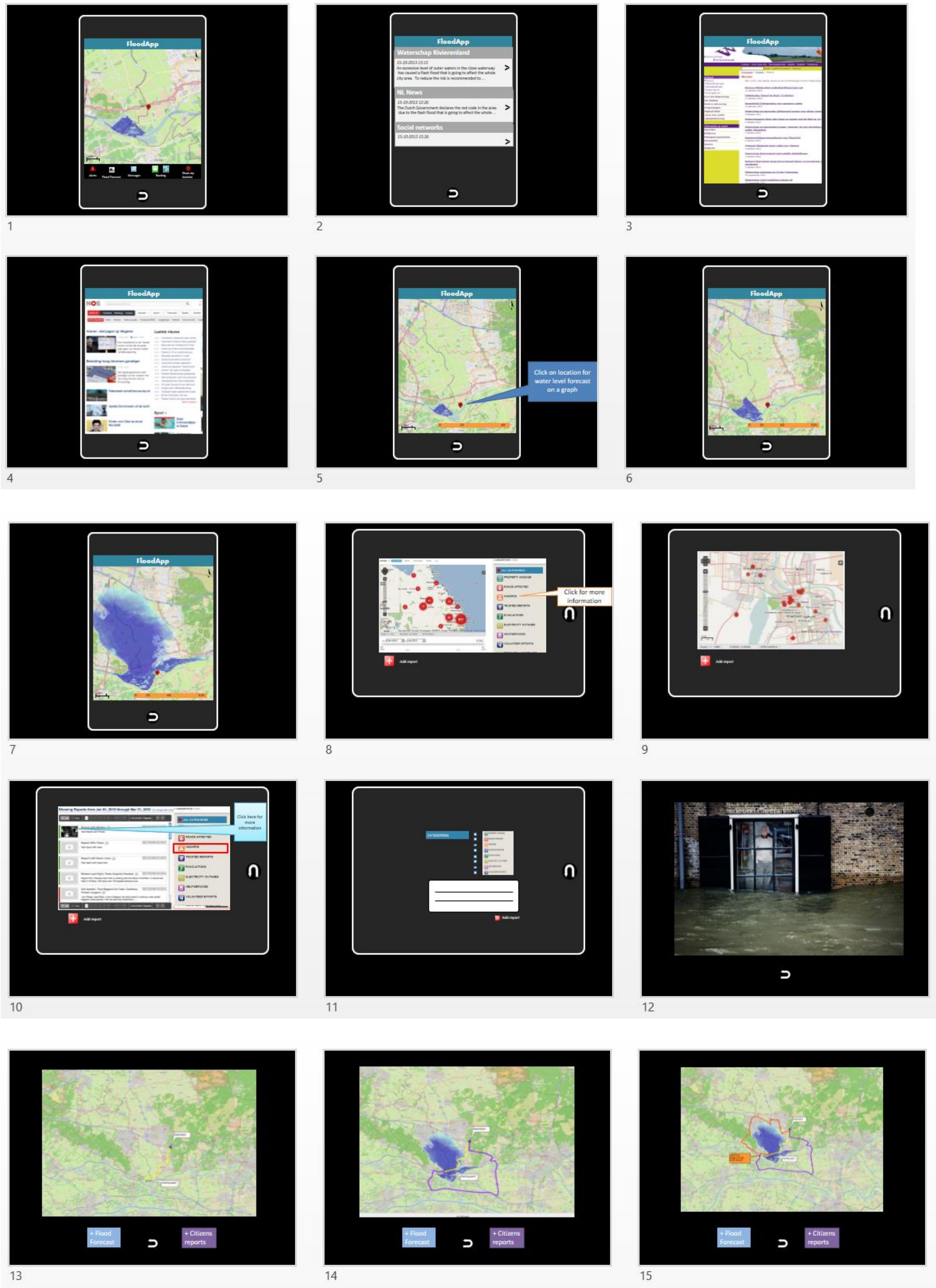


Figure 25. Screenshots of the mock-up version “FloodApp” based on the software architecture designed in Chapter 4.

The four participants went through all of the possibilities offered (buttons) in the main screen. The participants who were more organized first highlighted on the printed scenario the tasks they would need to develop. These participants looked for the functionality of the FloodApp that allows them to tackle it. Instead, other participants got a general idea of what they would need to perform and then tried to check all the offered functionalities that could be useful to solve the situation.

Following are the conclusions obtained from the participants' responses (Appendix 5).

In general, the participants' first impression from the app was favourable. The use of well-known and broadly used icons allows participants to understand easily and intuitively the information shown, as for instance the icon for location made clearly recognized the current position of the users.

The function alert includes notifications of warning for floods collected by both official and non-official sources. For all the participants this function is very handy, feeling more confident when they know that a warning message will be sent to them in case the risk of flood arises. However the links to the sources of the warning message, i.e. Waterschap Rivierenland, Dutch news and social networks, is only useful for some participants, like Rosa that seems to feel more confident when receiving more information. In contrast, Robert found the information offered by the links useless and redundant. Despite his scenario revealed his requirement of updated information from official sources (see *Table 2. User requirements by Persona*), it was not accurate enough to specify that his interest focus on more detailed information, in a local level (i.e. from local government and local groups or organizations).

An icon to access the function for messaging is included in the main screen of the app to facilitate users to load reports, either restricted to only their contacts or open to everyone. However the purpose of this option was not clear for most of the participants, which seems to be more related with the design of the tool than with the lack of usefulness. Therefore, participants prefer to use their usual ways of communication with their contacts, i.e. email, SMS, social networks.

Moreover, Katherine, as representative of the emergency services, and responsible for providing information to the citizens and other organizations involved in emergency response, shows strong concern about the difficulties of the tool to load messages.

Regarding the visualization of the flood evolution, all the participants felt satisfied with the opportunity to understand spatially the current extension of the flood and to be aware of the flooding process. This result is expected due to being an identified requirement for all of the Personas (see *Table 2*). However participants commented on aspects for improvement, such as the scale of the map, the lack of a legend and regarding the temporal indication on the map.

Moreover, the integration of the information about the flooded areas with the suggested safest routes and the VGI information increase the usefulness of the maps. The capacity to visualize this integration of information at once allows participants to contrast or verify the obtained information, what means a more robust base for their decisions.

Additionally, participants add their own previous knowledge of the area and compare it with the information obtained by the tool. Participants' self-confidence determines how strong this previous knowledge is compared with the information offered by the tool. However, disparate information given by different sources about the status of a specific area could generate confusion and difficulties at taking decisions.

Related to the VGI information, the quantity and quality of the information were the most notable issues. A higher number of reports and widely disperse all over the area enhance the trustfulness of the information. Additionally, reports offered in the format of pictures are more attractive for most of participants. Due to the pictures are geolocated, they help to visualize the circumstances in a specific location.

Evaluating the overall effectiveness and usability of the tool, the participants expressed to feel quite satisfied with the information offered by the tool. The functionalities to get alerts, visualize maps and route calculation are considered the most effective ones, as they provide useful information supporting the users to form their decisions in case of a flood. The design of the mock-up tool influenced the results of the assessment of the messaging functionality. Being recognized as a requirement of the system, the messaging function of the app does not look appealing to the participants. The rough format of the functionality together with a different design from the usual apps for messaging could be the reason that motivates participants to achieve this action by using other communication ways instead.

6 DISCUSSION

The results obtained in the different analysis and researches developed in the course of the present project are influenced by some factors that are discussed in this chapter. Particularly, the aspects concerning the following sections of the project are discussed:

- the method of Personas to analyse the requirements of the users;
- the design of the software architecture and ;
- its evaluation by prototyping and from the users' perspective.

6.1 Utilization of Personas and scenarios for the analysis on the requirements of the users

The approach of using Personas is taken from the field of user-centred design and in this project it is implemented to analyse the requirements of the potential users of the aimed tool for disaster DSS. The method, used to facilitate the communication between the members of design teams and for better understanding of the desires of potential users, has proven to offer good results for the analysis of users' needs in this project. Especially the analysis of the situations that occur when users are placed within a particular scenario, allows to get a clearer idea of what are the specific needs of the users towards the functionalities of the tool, as suggested by (Smith, 2003). This way, the use of Persona profiles within specific scenarios constitutes a straightforward process to identify users' system requirements.

The profiles of Personas and the scenarios are usually agreed by team members aiming a software design. Therefore, in this case, the assistance of participants to generate the profiles was preferred to avoid the bias of being created only by the author. Additionally, in accordance with the best practices suggested at www.usability.gov[61], it is convenient to generate one or more Persona profiles as representatives of the different groups of potential users to include different perspectives. In the research a few profiles are used covering adequately the representation of citizens (according to the demographic analysis commented on section 3.2). However, due to the time constraints and low quality (due to lack of details) in some of the profiles generated, there is only one profile to represent the emergency services and none covering the role of the crisis managers. This way, the analysis is done without considering the profile of the crisis managers, what may prompt different requirements regarding the functionalities of the tool from a managerial perspective.

Additionally, scenarios show only one level of flood magnitude. More levels of hazard are not considered in the analysis as users may require the same kind of functionalities from the tool. Only the urgency in which users will require access to the information may be different.

6.2 Design of the software architecture

The design of the software architecture is based on the use of open source software and information, which not only permits the interoperability within the different programs, but also makes the system easy to enhance by integrating other software for system optimization and to replicate for other projects with similar aims.

[61] www.usability.gov: website of the resource for user experience from U.S. government

However, the use of proprietary software could improve the developing process for some specific tasks, for which open source software has not been specifically developed. That could allow solving those tasks easily or more efficiently.

Also between the enormous amount of open source software for GIS (FOSS4G) available, the study centres primarily on the ones supported by the OSGeo Foundation, due to the wide community that is behind them enforces the possibility of getting support and guidelines through forums, tutorials or workshops. In addition, initiatives requiring less coding and programming languages skills were preferred, what conditioned the design of the system constitution.

6.3 Evaluation of the software architecture design, regarding the tool development

The development of the prototype had been designed taking into account the input data available. Limitations at finding potential useful information to feed the system are found due to the language of available documentation. Most of the official information is offered in Dutch, which hindered the search and finding of potential data.

As a first attempt, in order to have a more realistic system, the idea was to use water level data and hydrological models used in actual projects for flood monitoring in the Netherlands. However the difficulties found to access this kind of information, made the use of a basic flood simulation a better option for this project. Other encountered difficulties, apart from the language of documentation available, were the discontinuity of some of the Dutch projects for flood monitoring and restrictions due to the involvement of software licenses.

Regarding the flood simulation, a coarse grid was selected as a base to run the model to ease the use of NetLogo and speed the calculations. Even though the simulation generated this way is lacking spatial details, it does not influence the result of the prototype developed for technical demonstrations.

Many other parts of the system are interesting to be tested by developing a prototype, as for instance the integration of dynamic data, the connection to the real-time traffic information or the consideration of big amount of data collected by citizens. However they were excluded from the analysis scope, due to the time constraints and the higher requirements of computer skills to be implemented.

Also decisions on tools to be used for building the prototype were taken considering the availability of guidelines and recommendations offered by the community of users. Even though FOSS4G is usually developed for multi platforms (Mac, Linux, Windows), developers communities work mainly in Linux, that makes it more difficult when trying to develop a system on Windows operative system. In this regard, for instance, the most common tool to convert the OSM information to be used as input for pgRouting (osm2pgrouting), has only be tested on Linux. Guidelines for Widows OS are found instead for the converter osm2po, thus is the one implemented in the prototype. Even though the results of the conversion from osm2pgrouting are different from the ones of osm2po, the calculations for routing are not influenced by that.

In the prototype, the calculation of the safest route is based on the value of the attribute “cost” of the roads. The value of that attribute means how safe is to use each of the roads transect, according to the available information, official and non-official. In this prototype the values are given roughly as an indicator, just for demonstration purposes. So, when developing a functional tool for a better representation of the situations, a further analysis needs to be done about these “cost” values and how they change according to the new added information.

6.4 Evaluation of the software architecture design, regarding the user requirements

Once the system architecture was technically tested by the development of the prototype, an exercise was made with participants to assess a mock-up version of an app based on that prototype. Conducted following the think-aloud method, the exercise brought out the participants' impressions about using the app as a tool for supporting their process of decision making. The assessment not only offered clear ideas on the capabilities of the participants to fulfil their goals by using that app, but also made visible many aspects to be considered concerning the design of the tool. These are suited tasks for the method, as they are related to the cognitive process of the users that involve verbalizable contents, in line with Van Someren et al. (1994) statements.

The exercise was also successful in identifying functionalities of the tool that, being initially determined as requirements of the users, were not really demanded from the tool when performing the exercise. That was the case of the messaging functionality. Users showed preferences towards their usual tools for messaging instead of using the messaging functionality offered by the app. That may be influenced by the design of the mock-up version of the app that was roughly created and missed many of the details that smartphone users are familiar with. Regarding to this functionality for communication, the Geoweb could just present a link to the programs for messaging that users are familiar with and where the information of the users' contacts is already stored.

In that regard, that rough design of the mock-up version at some points generated confusion when trying to achieve a task, and also made the participants get distracted. That is why a fair design of mock-up versions is recommended in order to avoid these influences in the experiment.

Finally, the results of the study show that the integration of the information collected by the citizens (VGI) add value to the information offered by the designed tool for DDS in case of disasters. Specifically, in the evaluation exercise, the possibility of calculating alternative routes by considering different data sources (road network, flood models and VGI) provides users a wider vision of the situation to base their decisions. Ushahidi proves to successfully handle the collection, filtering and visualization of the reports collected in real-time by different sources, including especially from citizens. However the platform, built on MySQL/PHP, does not present spatial functionalities to combine the gathered reports with other kind of information, such as the flood data or the road network status. Moreover spatial analysis cannot be executed through it. A solution could be the migration of the reports collected by Ushahidi into the PostgreSQL/PostGIS spatial database. In this regard, further research could bring the valuable integration of the multi-source information, including especially VGI.

7 Conclusions

The objective of this research is the definition of a Web-based GIS software architecture to function as a tool for decision support systems (DSS) in case of disasters that allows the use and integration of diverse multi-source data. The results of the study can be considered as a framework for further tool developments with similar aims.

To tackle that general objective, the research has been developed accomplishing the following defined sub-objectives:

Sub-objective 1. Definition of the requirements in terms of data for a risk management system (particularly focusing on a flood case) and data collection.

The conducted research revealed that the requirements of the users regarding the content of information for a tool for disaster DSS are related to:

- Alerts: the tool should warn the user whenever a disaster is occurring or forecasted;
- Spatio-temporal evolution of the disaster: maps of the evolution of the disaster along the time helps user getting a better understanding of the actual and future situations;
- Routes: depending on the level of risk, users may decide to scape to safer areas. Taking action requires information on which are safe routes to get their destinations;
- Status of their families and friends: communication with their families and friends is essential;
- Up-date information on strategies, plans from crisis management teams, emergency services that could be helpful for users to take decisions.

Sub-objective 2. Design of a software architecture for a web-based GIS platform for risk management that addresses the previously defined requirements.

Geoweb is the functional solution for a GIS web-based software architecture to operate as a tool for disaster decision support system (DSS) that fulfils the identified user requirements. Exploiting the advantages of the technologies Web 2.0, the Geoweb allows the integration of static data with real-time information from the scene gathered by official (e.g. flood monitoring sensor network) and non-official sources (citizens' reports). Additionally, the Geoweb allows the visualization and analysis of the information that is required for the potential users.

The design of the Geoweb is based on a client-server structure. Aiming the interoperability between the diverse data and also between the multiple actors, the Geoweb design is based on open source components and the use of recognized protocols, such as OGC protocols for service (WMS, WFS, and WCS). The capabilities of the Geoweb provided by the integration of those components presents the following functionalities:

- Storage: a spatial object-relational database management system (ORDBMS) allows the collection and integration of the information. The study propose and tests the use of the objet-relational database PostgreSQL spatially enabled by PostGIS;

- Application Server: GeoServer map/feature server is proposed to load, publish and share the information by internet;
- And user interface map component: mapping application is facilitated in this study by using OpenLayers, a library for displaying and render spatial data in web browsers.

Sub-objective 3. Evaluation of the software architecture in a specific case study.

The routing and flood mapping functionalities of the Geoweb are tested by developing a prototype following the designed software architecture based on open source software for GIS. Integrating information about the flood status and information collected by citizens on the road network provides different alternatives at the routing calculation results, supporting the users' decision-making process.

Besides, the effectiveness of the Geoweb and users' satisfaction on successfully completing the tasks is tested by using the think-aloud method with the defined Personas. Using a mock-up application for a smartphone based on the software architecture proposed, four participants tested to which degree the tool allows them to complete the tasks accurately and how the tool satisfies their needs of information to support their decisions. As a result, the routing functionality and the possibility to visualize the evolution of the flood in combination with other information are considered the most useful functionalities of the tool. Additionally, the capability to get alerts and updated information from official sources is conveniently present in the tool according to the participants' perception. However, the messaging functionally was not helpful for most of the participants who found it confusing, maybe due to the mock-up design.

Moreover, even though the integration of multi-source information seems to be gladly received by most of participants, it can also generate more difficulties in some occasions when different sources point to different information.

8 Recommendations

The development of Geowebs as platforms for multisource data integration is a field in constant development. The possibilities of new technologies are continuously investigated to integrate advantages for a better collection, analysis, visualization and delivery of information. The present project reviews the state-of-art technologies to address the challenge of multisource data sharing in case of disasters.

Despite these technological advances, occurrence of disaster events show that still efforts need to be done for a better coordination and response from the different actors involved to reduce risks. In addition, interest in this topic is presented recently in related technological conferences and professional circles, foreseeing further research and development on this kind of solutions. In this regard, this study can be used as a guideline and framework for further developments. Due to the inherit time constraints of a master thesis the present study is limited. For that reason this Chapter collects suggestions for a further research on this topic.

Regarding the data input, a Geoweb for DSS in case of floods needs the results of adjusted flood models based on real-time data to offer accurate current and forecast extension of the flooded areas. Collaboration with the waterboards, institutes of research, like Deltares, or Universities involved in the research and operational monitoring of floods may lead to more realistic results.

Another enhancement of the system would be the integration of real-time traffic information from providers as NAVTEQ or TomTom. Connecting to their web services will allow the calculation of safest and fastest routes according to the current traffic status of the roads network. ESRI presents a tool for updating traffic data in ArcGIS desktop to download the live traffic data from the web services and store it in a format that its network datasets can read. The addition of an open source alternative for this data collection and further analysis and visualization will improve the system.

In regards to the routing functionality another possible enhancement is the consideration of latitude/longitude data as input of starting/ending point of the route. This will allow an easier interaction with the system, as users could just point the places of interest.

Further research needs to be done on the functionalities not tested in this project, like the alerts or the messages. In addition, the final integration of all the variety of data in a one-stand platform also needs to be addressed. The capabilities of Ushahidi for sending alerts or allowing the transfer of messages have been tested on literature, however the connection with the database to update flood information or to show the routing algorithm results will need a further research. That way Ushahidi would become the final platform for visualization of the system. Otherwise the functionalities of Ushahidi could be just used at the back of the system. That option would imply that users will interact with the system through the web services of the Geoweb, while the Geoweb make use of the Ushahidi functionalities to retrieve the required information.

Existing plugins to extend the functionalities offered by Ushahidi would also improve the system. For instance, Open GeoSMS provides the option to collect location-based information via SMS from mobile devices. Another plugin among others that could be used for a more thorough system is SwiftRiver, for filtering and verifying real-time data from channels like Facebook of Twitter.

At this point, it is worthy to mention that even though strong efforts are developed to ease the utilization of FOSS4G by users, tailoring a system to satisfy user requirements implies many technical issues that involve program coding and computational skills. Therefore technical and computational competences of the development team members need to be considered to develop this kind of initiatives. In this regard, Crowdmap[62] is a recommended alternative to Ushahidi when a project with basic functionalities and setups wants to be developed with low level of IT skills.

Another interesting research is related with the utilization of other initiatives of crowdsourcing for crisis management as Sahana. Analysis on the possibilities and constrains of these projects may bring new ideas for the design of a tool for DSS in case of disasters.

The integration of GeowebCache application within the system could improve the map server service accelerating the delivery of map tiles. The review of projects related with disaster management commented in Chapter 3, revealed the common use of GeowebCache in projects based on the same software architecture as the one proposed in this project.

Regarding the use of Personas as a method to identify user requirements, at least one Persona needs to be defined as representative of each group of users. This way, the system design can cover all the needs from the potential users.

In addition, using the Personas to test the usability of the system was not only successful to assess the contents of the system, but also revealed to be a very useful method to know the attitude of the users regarding the design of the tool. Even though the design was not the focus of the system evaluation, it is closely related to the functionality of the tool, so it is difficult to avoid assessment regarding the design of the tool. Thus it is a recommended method for design evaluation of web services. However, attention should be given when the process includes the design of a mock-up version. Confusing interfaces or the lack of details complicate the exercise, bringing inconsistent results.

[62] https://crowdmap.com

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Appendix 1. PERSONA PROFILES AND SCENARIOS

Katherine (Police woman)

Name:	Katherine (f) - 28 years old
Lives in:	Nijmegen
Marital status:	Married
Type of residence:	Owned apartment, where lives with her family: husband and 2 children (4 and 6 years old, respectively)
Profession:	Police
Education:	Bachelor of Laws
Daily routine:	Katherine works in a police station near home, so she usually goes walking. Her husband takes the children to the school and picks them up in his way back. They have a car and a van that they enjoy using during the weekends.
Technology attitude:	Owns a smartphone Internet at home
Interests:	Reading, swimming, going camping with the van and the children
Expectations of the application:	The police station receives the most up to date information about the emergency of situations. However, whenever a flood occurs, she'll use the FloodApp to: - monitor people movements, - receive notifications of alerts from individuals

Scenario:	
	During the lunch break, Kat gets an alert from the central station announcing that a flooding is expected. This is an early warning message about a possible flooding. There is time to make early preparations, however coordination between the different organizations is crucial.
	Kat has been working in the opposite side of the city from the police station and she needs to go urgently there to join the crisis management team. However before driving there, she calls her husband to inform him about the situation. He's working so he doesn't pick up the phone, then she decides to let him a message through the FloodApp. In the message, Kat suggests him to pick up the children with the van and go to her parents' house that is located in a completely safe area according to the forecasts. He could check the best routing via the FloodApp functionalities. Also, she reminds him to activate the geolocation monitoring, so that Kat will know where he is going to be along the next hours.
	Then Kat is ready to drive to the police station continue with her tasks within the crisis management team. She checks if the route she would use is safe. Once she is at her office, the tasks for emergency response are distributed. Among others, she'll be attending individual alerts sent by social networks. Additionally she'll be in charge of offering updated information through the FloodApp about: - the location of help-points and shelters, - the status of the transport network

Henk (Administrative)

Name:	Henk (m) - 35 years old
Lives in:	Wageningen.
Marital status:	Single
Type of residence:	Renting a house in a quiet neighbourhood
Profession:	Administrative at the University services (WUR)
Education:	Economic Studies
Daily routine:	Living less than 3 km away from his work he usually goes cycling. Henk only uses his car when the weather is too bad and during the weekends when he visits his sister.
Technology attitude:	Owns a smartphone Active within social networks
Interests:	He likes sporting (squash, cycling). Enjoys gardening and travelling to foreign countries to discover new cultures.
Expectations of the application:	Henk is not really worried about a possible flood. However, he'd like to be informed when an alert for floods emerge.

Scenario:
Henk has finished his work and is cycling to the squash courts (within the campus area) when he receives an alert in his smartphone. The alert announces that he's in an area where the risk of flood has increased dramatically and actions to minimise the effect of flood damage need to be taken.
So Henk checks the "FloodApp" to get information on: - What is causing that area to be risky? - What is the extension of the risky area? - Which is the prediction for the next few hours?
The "FloodApp" shows the link to a new from the Waterschap Rivierenland announcing that an excessive level of outer waters in the close waterway has caused a flash flood that is going to affect the whole city area. To reduce the risk is recommended to leave the area within the next 4 hours.
He checks whether there are images taken from others in the surroundings of the area to have a better idea of what's going on. The "FloodApp" gathers some images posted by people showing the unusual high level of the water around the riverside. Henk is now really aware of the situation so he tries to call his colleagues but the lines are busy. Thus he uses his usual social networks (Facebook, Whatsapp) to send a warning message and to look for his family and friends status. Henk's neighbour, Vincent, seems to be quite nervous. Vincent doesn't have a car and through the FloodApp he noticed he cannot reach a safer destination by bike on time. Henk decides to go home, get his most valuable stuffs and pick up Vincent. At home, Henk follows the instructions from the Flood App to keep saver his house. Then Henk is ready to drive to his sister's place that is located in a safer area. The routing option of the FloodApp shows that the usual way he takes to reach there has a high transit, so he follows the alternative route offered by the FloodApp.

Robert (Bank Employee)

Name:	Robert (m)- 40 years old
Lives in:	Nijmegen
Marital status:	Married, 2 children (2 and 4 years old)
Type of residence:	Owned house in the outside neighbourhoods of Nijmegen
Profession:	Bank employee
Education:	BSc of Economics
Daily routine:	He usually cycles to go to his office. Every morning he passes by the school to let the children there. His wife drives early in the morning to her workplace, in a small town close to Utrecht.
Technology attitude:	Robert owns a smartphone and has a laptop at home with internet connection.
Interests:	Sailing (own boat), running
Expectations of the application:	The application should offer him the following information: - Generation of alerts announcing the level of risk (threats or occurrence) and confidence of the source - Reception of alerts from different points of interest: his recent location, his house, his children's' school, his boat, his parents' place

Scenario:	
	Robert is having breakfast when he gets an alert of an imminent flood due to the heavy rain. The alert presents an 80% of confidence (source: KNMI), so Robert trust it.
	Robert check in the FloodApp: - which is the forecasted extension of the flooded area, - which is the expected height that the water will reach, - how long will the water stay, - is the supply of public utilities (water, electricity, gas) ensured
	The forecast indicates that the water will reach 1 meter height and will stay for a minimum of 3 days. They have 2 hours to move to a safer area.
	They move the most valuable stuffs to the first floor and use the FloodApp routing service to check the safest route to get to his friends place, out of the risky area.
	Robert let the children and her wife at his friends place and goes back to home to protect it better and offer his help.
	After 6 hours working in the house protection, Robert realized he cannot drive any more, as all the road connections are broken. Then Robert checks the FloodApp to know where the points of assistance to leave the city are.

Rosa (Retired)

Name:	Rosa Kramer (f)- 67 years old
Lives in:	Small farm, close to the river Lek
Marital status:	Divorced, single
Type of residence:	Owned apartment, where lives with her family: husband and 2 children (4 and 6 years old, respectively)
Profession:	Retired, former gym teacher
Education:	Secondary school
Daily routine:	Car, bicycle
Technology attitude:	She uses pc daily, has a smartphone but does not upload and update apps often
Interests:	She has a stiff knee as a result of a car accident years ago. She uses reading glasses (relevant when using a smartphone)
Expectations of the application:	She has good relationships with her neighbours but the closest neighbours lives at 1 km distance

Scenario:
Rosa lives on her own in a small farmhouse near the village of Lopik, close to the river Lek. Her farm is located on a dike, so she has beautiful views on the river and surrounding meadows and orchards. However, her house is in a vulnerable spot. The last few years the water has occasionally risen so high that her cellar was flooded and her yard and meadow became waterlogged for a couple of days. Rosa owns three horses, three cats and a dog. Sometimes the children of her neighbour (one kilometre away) help her with feeding and grooming the horses; they also ride them but only in the meadow. Two of the cats are old and almost blind.
On April 12, RWS and the local waterboards warned Rosa that a critical situation might arise within a week: the level of water of the Lek might rise to a dangerous level due to heavy rainfall in Germany in combination with melt water from the Alps. Rosa was advised to leave the area if possible, and stay with friends or family. If that would not be possible, she was advised to prepare for evacuation if necessary, after which the local council would offer a safe temporary shelter. Because Rosa had no place to take her horses and animals to, she decided to stay and prepare for high water levels. Over the next few days, she moved her furniture to the first floor of her house and asked a farmer three kilometres inland if she could bring her animals there in case of emergency. The farmer agreed, but would not be able to pick them up. Rosa would have to arrange transport herself.
At 4 AM in the morning, April 16, Rosa gets a warning message from local authorities that the water rise is suddenly higher than expected and that she will have to leave her house before 13 (1 PM) that afternoon. She gets out of bed, and starts planning. 1. She intends to walk the horses to the farmer first, and perhaps get a taxi or a lift from anyone in the area back. 2. Then she will pack her valuable items and some personal necessities, and put the cats (if she can catch them in time, they tend to wander around the farm) in a travel cage. She will use the remaining time to protect her belongings from the water (bring more stuff upstairs, what she can pack put it either in her own car).

3. She will drive to and from the shelter a couple of times, or ask neighbours and friends to help her.

   This means it is very important for Rosa to know exactly:
   - how much time she has before there is real danger, before the area is closed by police and other professionals,
   - whether main and small roads are open for traffic,
   - and where congestion occurs.

   She would also appreciate help from strangers if she cannot rely on her neighbours, who have similar problems with animals. Also she must find out if she can take her cats and do to the shelter or to another place.

   In the alarm message she receives a link to a website and an app. She starts the app and first fills in her location and requests for help.

4. It's too early to wake up her neighbours, so she lets a message through the app asking for a lift to come back after letting the horses in the other farm. Rosa doesn't want to call her neighbours till is at least 7 am. Meanwhile she starts preparing the house.

Appendix 2. PFOSS4G SOFTWARE BY FUNCTIONAL CATEGORIES (STEINIGER & HUNTER, 2013)

Desktop GIS	Spatial DBMS	Server GIS	Mobile GIS	ESDA Software	Remote Sensing software
GRASS GIS – grass.osgeo.org	PostGIS for PostgreSQL - postgis.refractions.net	52° North WPS - 52north.org	gvSIG Mobile - gvsig.org/web/projects/gv	OpenGeoDa. PySAL and STARS -	OSSIM - ossim.org
Quantum GIS – qgis.org	MySQL Spatial - forge.mysql.com/wiki/GIS	deegree3 WPS - wiki.deegree.org	Quantum GIS for Android - hub.qgis.org/projects/and	R language - r-project.org	InterImage - www.lvc.ele.puc-
ILWIS/ ILWIS Open – ilwis.org	SpatiaLite for SQLite - gaia-gis.it/spatialite/	PyWPS - pywps.wald.intevation.org	Geopaparazzi - geopaparazzi.eu/	GeoVista - geovistastudio.psu.edu	e-foto - www.efoto.eng.uerj.br
uDig – udig.refractions.net	Hibernate Spatial for Hibernate -	Zoo - zoo-project.org	gvSIG Mini – m.gvsigmini.org	HiDE - gicentre.org/hide/	Opticks - opticks.org
SAGA – saga-gis.org	Hatbox for H2 - hatbox.sourceforge.net	GeoServer - geoserver.org	tangoGPS/FoxtrotGPS – foxtrotgps.org		GNU Data Language (GDL) project -
OpenJUMP – openjump.org	INGRES - community.ingres.com/wi	WebGEN - kartographie.geo.tu-			ILWIS - 52north.org/communities
MapWindow GIS – mapwindow.org	Jaspa for PostgreSQL and H2 - jaspa.upv.es/blog/				
gvSIG – gvsig.org	CouchDB - couchdb.org				
gvSIG Community Edition - gvsigce.org	MongoDB - mongodb.org				
KOSMO - opengis.es	GeoCouch - github.com/couchbase/ge				
Kalypso - kalypso.bjoernsen.de					
Whitebox GAT - www.uoguelph.ca/~hydro					
iGeoDesktop - deegree.org					
OrbisGIS - orbisgis.org					
Software Libraries for GIS Development					
Data input/output and conversion libraries	**Geometry libraries**	**Projection libraries**	**Geographic data processing and analysis**	**Other libraries**	**General (Development) Frameworks**
GDAL and OGR- gdal.org	JTS Topology suite - tsusiatsoftware.net	Proj.4 - trac.osgeo.org/proj/	Sextante project - sextantegis.com	Java Matrix Package (JAMA) -	GeoTools - geotools.org
FDO - fdo.osgeo.org	GEOS - geos.refractions.net	Proj4J - http://trac.osgeo.org/proj	ImageJ - rsbweb.nih.gov/ij/	JMathTools - jmathtools.berlios.de	OpenMap - openmap.bbn.com
GDMS - trac.orbisgis.org/wiki/devs	NetTopologySuite - code.google.com/p/netto	GeoTools - geotools.org	ORFEO - orfeo-toolbox.org	GNU Scientific Library - www.gnu.org/software/gs	SharpMap - codeplex.com/SharpMap
GeoTools - geotools.org	CGAL - cgal.org	deegree 3 - wiki.deegree.org	TerraLib - terralib.org	JGraphT - jgrapht.sourceforge.net	DotSpatial - dotspatial.codeplex.com
SharpMap - codeplex.com/SharpMap	Boost.Geometry - geometrylibrary.geodan.nl	Proj.Net - codeplex.com/ProjNET	R - r-project.org	Boost - boost.org	GeoScript - geoscript.org
libLAS - libLAS.org		Generic Mapping Tools (GMT) -	PAL - pal.heig-vd.ch	JFreeChart - jfree.org	Puzzle GIS - puzzle-gis.codehaus.org
GeoKettle project - geokettle.org					Quantum GIS - qgis.org
JEQL - http://tsusiatsoftware.net					OpenJUMP - openjump.org
Software for Internet Mapping Applications					
Web Map Server	**Web Map Application Development Frameworks**		**Other (i.e., special thick client applications)**	**Catalogue/Metadata**	
MapServer - mapserver.org	OpenLayers - openlayers.org	i3Geo - gvsig.org/web/projects/i3	NASA WorldWind - goworldwind.org/	Geonetwork - http://geonetwork-	
GeoServer - geoserver.org	MapFish - mapfish.org	Mapbender - mapbender.org			
MapGuide Open Source - mapguide.osgeo.org	GeoExt - geoext.org	GeoMajas - geomajas.org			
deegree - wiki.deegree.org	Leaflet leaflet.cloudmade.com	MapStraction - mapstraction.com			
TinyOWS -tinyows.org	ReadyMap - readymap.com	SharpMap - codeplex.com/SharpMap			
QGIS Server - hub.qgis.org/projects/qua	OpenWebGlobe SDK - openwebglobe.org	Google Web Toolkit (GWT) -			
FeatureServer - drupal.org/project/fserver	OpenScales - openscales.org	Mapnik - mapnik.org			
GeoRest - code.google.com/p/geore	ModestMaps - modestmaps.com	MapBox/TileMill - mapbox.com/tilemill			
see also: wiki.osgeo.org/wiki/Bench	GeoMOOSE - geomoose.org				

Appendix 3. SOFTWARE CRITERIA-BASED ASSESSMENT

Criteria	PostgreSQL/PostGIS	Ushahidi
FUNCTIONALITY		
Ease of Use / Complexity		
User interfaces are intuitive	PgAdmin is the tool used for the administration and management of the spatial database. http://www.pgadmin.org/ Supporting all PostgreSQL features, makes administration easy. However, the functionality of the RDBMS is driven by SQL statements, and the use of external extensions, like for instance converters, which execution requires command-line arguments.	Ushahidi presents an intuitive user interface. The home page shows different sections given access to the different functionalities of the system, i.e. map, categories, timeline, static layers, reporting box, incidents list and official and mainstream news. The dashboard for platform administrator allows an easy project management, also with intuitive sections to access the different functionalities.
Product is downloadable in a production ready format	Yes, from PostgreSQL website selecting the OS Windows, it derives us to http://www.enterprisedb.com/ where installers for different PostgreSQL versions for Windows, Linux or Mac are offered. The PostgreSQL installer includes the Stack Builder tool (commented below) and a bundled copy of PgAdmin.	Yes, via http://download.ushahidi.com/ the last version of Ushahidi can be downloaded in a zip file containing all the needed files.
Web site has instructions for installing the software.	Yes, however specifically for Windows OS: http://www.bostongis.com/PrinterFriendly.aspx?content_name=postgis_tut01	Yes, the wiki offers an installation guide with the system requirements and guidelines for the different platforms. https://wiki.ushahidi.com/display/WIKI/Ushahidi+Installation+guide However it assumes some IT knowledge like PHP, servers, libraries installation and command-line executions. Attention also should be put at the different versions of the programs and libraries required for the interoperability between the involved software (server, database). Following those guidelines errors are found due to the PHP curl extension. The guidelines given at http://flowingmotion.jojordan.org/2010/03/11/step-3-get-ushahidi-going-in-your-community-install-the-code-about-1-hour/ complement the installation.
Easy installation of add-ons/extensions/packages	PostgreSQL includes the application Stack Builder, a download and installation wizard combined with a set of pre-configured packages to complement PostgreSQL's one-click installers on Windows, Mac and Linux. PostGIS can be downloaded from Stack Builder. Additionally, large number of extensions written by third parties is available.	http://community.ushahidi.com/plugins/ offers an extensive list of plugins that add extra functionality to a deployment of the Ushahidi platform
Web site lists all third-party dependencies that are not bundled, along with web addresses, suitable versions, licences and whether these are mandatory or optional.	Yes, PostgreSQL requirements are specified in the installation manual: http://www.postgresql.org/docs/9.1/static/install-requirements.html PostGIS requirements: http://postgis.net/docs/postgis_installation.html	https://wiki.ushahidi.com/display/WIKI/System+Requirements presents the system requirements. It also offers links to the required PHP extensions.

Tests are provided to verify the install has succeeded.	Yes, http://postgis.net/docs/postgis_installation.html (section 2.4.4)	Not found
All GUIs contain a Help menu with commands to see the project name, web site, how/where to get help, version, date, licence and copyright (or where to find this information), location of entry point into user doc.	Yes, PgAdmin presents help about pgAdmin III and PostgreSQL	No
User IT skills requirements for installing the software	SQL programming language and command-line arguments.	IT knowledge required on web servers, PHP and database management and command-line arguments.
Learnability		
A getting started guide is provided outlining a basic example of using the software	Yes, through tutorials PostgreSQL offers a getting started chapter in its manual http://www.postgresql.org/docs/9.3/interactive/tutorial-start.html, showing some query statements. To start with PostGIS the exercises and examples offered at the websites http://www.bostongis.com/?content_name=postgis_tut01 and http://workshops.boundlessgeo.com/postgis-intro/ are quite useful.	A step-by-step guide on how to use the Ushahidi platform is accessible by: http://community.ushahidi.com/uploads/documents/Ushahidi-Manual.pdf
Specific information to work on Windows OS	PostGIS: http://www.bostongis.com/PrinterFriendly.aspx?content_name=postgis_tut01	Guidelines to install the system on Windows platform and WAMP as web server is given at the community portal: https://wiki.ushahidi.com/display/WIKI/Installing+Ushahidi+on+a+WAMP+Server
Customization		
Customizable through tailoring or programming	PostgreSQL allows user-defined functions to be written in other languages besides SQL and C. Those are called procedural languages that can be loaded into the database through extensions. 3 language extensions are included with PostgreSQL to support Perl, Python and Tcl. There are external projects to add support for many other languages, including Java, JavaScript (PL/V8), R.	Customization requires a PHP developer and a designer.
Integration and Interoperability		
Uses open standards	PostgreSQL implementation strongly conforms to the ANSI-SQL:2008 standard. PostGIS is registered as "implements the specified standard" for "Simple Features for SQL" by the OGC. However it has not been certified as compliant by the OGC.	Ushahidi features are open-standards and open-source based.
Product integrates with other programs	The Wiki of PostGIS published a list of tools that support PostGIS: http://trac.osgeo.org/postgis/wiki/UsersWikiToolsSupportPostgis The list includes tools for loading, converting and extracting data (as e.g. shp2Pgsql allowing to load shapefiles into the Database), web-based GIS to display data, as GeoServer, or GIS desktop as ESRI.	Integration with other software is possible by plugins and add-ons. Plugins already available can be found at: http://community.ushahidi.com/plugins/.

Transportability		
Data is importable/exportable	Supported by a wide variety of libraries and applications, PostGIS provides many options for loading data in different formats as shapefiles, kml, CSV, GeoJSON and OSM. Also supports raster data as GeoTIFF, PNG and NetCDF. To load shapefiles PostGIS presents the PostGIS Shapefile Loader, that can be also installed through the Stack Buider application.	Ushahidi allows gathering information via email, web-forms, SMS or twitter. Static background information can be loaded as kml. Plugins and add-ons provide more opportunities to export/ import different formats.
Application can be built on and run under different platforms	PostgreSQL is available for many platforms including Linux, FreeBSD, Solaris, Microsoft Windows and Mac OS X.	Supported platforms: Windows, Mac OSX and Linux platforms

Criteria	PostgreSQL/PostGIS	Ushahidi
COMMUNITY		
Community at a Glance		
The community appears large and active as indicated by forums and a significant volume of posts	- Mailing-lists: The postgis-users mailing list is a supportive community forum to discuss issues, to learn new techniques, and to share your knowledge with other learners. For developers also exists a different mail list. - Wikis: also for users and developers. - http://planet.postgis.net/ - as a window where users can share their projects and experiences - More info at http://trac.osgeo.org/postgis/	With members of the team and our community spread around the world, we use various channels to connect with each other: - Irc://irc.freenode.net #ushahidi - Skype developer chat rooms(Contact username: "Heatherleson" or "ngelzy" to be added)) - Mailing lists - Wiki https://wiki.ushahidi.com/pages/viewpage.action?pageId=294916 - Forums https://wiki.ushahidi.com/display/forums/Ushahidi+Forums - community http://community.ushahidi.com/
Other community sites	http://gis.stackexchange.com - GIS Stack Exchange is a question and answer site for cartographers, geographers and GIS professionals where useful information about PostGIS can be found.	https://www.facebook.com/ushahidi
Support		
Support is available free of charge on how to use the product	http://postgis.net/support shows the different ways to get free support as its IRC Channel or the Mailing lists	There are different ways to get supported, the most common one is the forums: https://wiki.ushahidi.com/display/forums/Ushahidi+Forums, then also can be used the IRC Channel (Irc://irc.freenode.net #ushahidi), or the mailing lists.
Support is available free of charge on how to fix problems in the software	Yes, bugs are reported and managed in a ticket tracker. Instructions are given at http://postgis.net/support. It allows searching and reading tickets.	Bug tracker via GitHub: https://github.com/login?return_to=https%3A%2F%2Fgithub.com%2Forganizations%2Fushahidi
Website gives information on commercial support	Yes, a list of organizations is given at http://postgis.net/support	Yes, https://wiki.ushahidi.com/display/WIKI/Value-Added+Services

Documentation		
User documentation is available	Yes. Documentation about the software objectives, functionalities and rationale is available at: - http://postgis.net/documentation/ about PostGIS, and - http://www.postgresql.org/docs/9.3/interactive/index.html for PostgreSQL	Documentation is available from the home page: http://www.ushahidi.com/get-involved/resources Also in the wiki page
Partitioned into sections for users, user-developers and developers (depending on the software).	Yes, PostGIS presents also special for developers at http://postgis.net/docs/doxygen/2.2/ For PostgreSQL: http://doxygen.postgresql.org/	For developers: https://wiki.ushahidi.com/display/WIKI/Ushahidi+Developer+Guide
Case studies of use are available.	Yes. Some case studies can be found at http://www.postgresql.org/docs/. Also for PostGIS is possible to find some cases at http://postgis.net/casestudy	A collection of deployments are offered at http://community.ushahidi.com/deployments/
Lists resources for further information.	Yes, links to free and commercial support, tutorials, books and web sites are given at http://postgis.net/documentation	https://github.com/ushahidi

Criteria	PostgreSQL/PostGIS	Ushahidi
LICENSING ISSUES		
License Category		
Copyright: All rights reserved by creator	PostgreSQL Copyright © 1996-2013 The PostgreSQL Global Development Group Not for PostGIS	Copyright © 2013 Ushahidi.com.
Open source license that permits reuse and modification, as well as the inclusion of source code or the product in proprietary or commercial products	Yes, PostGIS is released under the GNU General Public License (GPLv2). PostgreSQL is released under the PostgreSQL License, a liberal Open Source license (http://opensource.org/licenses/PostgreSQL, Open Software Initiative (OSI)-recognised licence)	The Ushahidi Platform is free for you to download and use. It is released under the GNU Lesser General Public License (LGPL).

Appendix 4. Specifications of Ushahidi platform installation on Windows OS x64bits

Instructions adapted from the Community Wiki of Ushahidi[63] and from the blog of Jo Jordan[64], management consultant.

Turn your PC into a local server

Download WAMP and install it on your PC.
For my 64-bit machine, I have the 64-bit php5.3 version
http://www.wampserver.com/en/#wampserver-64-bits-apache-2-4
Because I'm using the 64-bit version, I also have to install Visual C++ libraries, e.g. "Microsoft Visual C++ 2010 SP1 Redistributable Package (x64)"
from http://www.microsoft.com/en-us/download/details.aspx?id=13523
I selected the package offering the version of php 5.4.3, as later on there is a problem to fix that can be solve for that version.
Once WAMP is running on the PC, there should be a little half-shell in your systems tray. Left click and select “Start all services” to make it work.

Download the Ushahidi code

Set up a sub-directory in your server root directory to contain all the code for the website.
Think of your domain name and create a directory
D://CRS/software/wamp/www/TesThesis
Left click the WAMP ‘shell’ icon in the system tray and go to localhost.
Select phpmyadmin.
Go to Database and there ‘Create a new database’.
Enter “yourdomainname” (TesThesis).
Check the privileges for both “root” and the “username” are granted (yes).
I created a new user CRS, password crs, host by localhost with all the privileges for TesThesis DB.
Now unzip the Ushahidi files into the directory of your project:
D://CRS/software/wamp/www/TesThesis
Check that the file config.php at application/config/config.php has the proper route in the site_comain term:
$config['site_domain'] = 'localhost/TesThesis/';
Copy everything in the sub-directory Ushahidi
D://CRS/software/wamp/www/TesThesis

Check your php extensions

Left click on the shell of the WAMP server, go to PHP settings and then PHP extensions. Go down the list and make sure the following are “on”: php_curl, php_mbstring, php_gdr, and php_mcrypt.

Fix Curl problem

This is a 64-bit issue: the Curl files that were included in WAMP don't work properly on 64-bit machines.
Go to this blogpage, look for "fixed Curl extensions" (you need this - not the Curl files above them), and find the file for your WAMP's version of PHP.
There are 2 of these: get the one without nts in its title, e.g. for my WAMP server using PHP 5.3.13, that's php_curl-5.3.13-VC9-x64.zip.
Unzip that file, and you'll see a file called "php_curl.dll" in it.

[63] https://wiki.ushahidi.com/display/WIKI/Installing+Ushahidi+on+a+WAMP+Server
[64] http://flowingmotion.jojordan.org/step-3-get-ushahidi-going-in-your-community-install-the-code-about-1-hour/

Move php_curl.dll into directory c:/wamp/bin/php/php5.3.13/ext/ (you'll overwrite the existing copy of php_curl.dll, but that's okay).
You also need to enable Curl by uncommenting a line in two WAMP files (for reference, these are c:/wamp/bin/php/php5.3.13/php.ini and c:/wamp/bin/apache/apache2.4.2/bin/php.ini in my copy of WAMP).

- open php.ini with Notepad++
- look for “curl”
- uncomment the line: ;extension=php_curl.dll

Installing Ushahidi

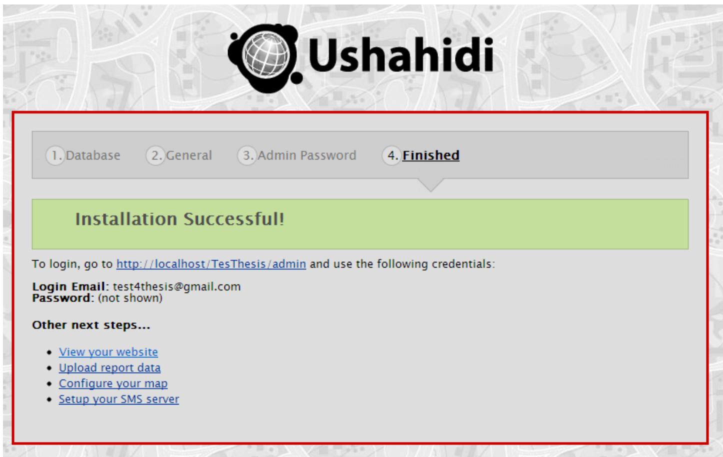
Go to your browser and type http://localhost/TesThesis/installer
Choose “basic” and we are going to fill in some information.
Enter your tagline (required).
Enter your (very) public email address.
Now enter the name of your database (that you set up above). And the username you use for databases and your database password (all set up on Step 1).
And you are done!

Getting started with Ushahidi

You should see a fresh installation of Ushahidi in your browser at http://localhost/yourdomainname.
Go to http://localhost/yourdomainname/admin (remember this for future login’s).
Enter admin for user and password (don’t forget these).
Well done! You can explore now.
It is the time to think about what your new site is for and what you want it to accomplish.

Tip for improvement on your Ushahidi domain

Make the Ushahidi URLs work. Ushahidi typically uses clean addresses like "http://www.yourushahidi.com/reports" rather than php addresses like "http://www.yourushahidi.com/index.php?kohana_uri=reports". You need to: click 'Apache' on the WAMP menu, then 'apache modules'. This gives you a list of modules. Scroll down, find "rewrite_module" and click on "rewrite_module" to get a tick next to it.



Appendix 5. Evaluation of the Geoweb architecture, regarding the user requirements. Outcomes of the think-aloud method

Rosa's profile interview

Functionality	Information expectations - organization - structure - details	Information obtained	Extra information
Alerts		Clear Useful to be updated and to be redirected by the links to the original source	
Messaging		The message task is not clear at all. She gets lost. But she finally gets the information that she needs, about her neighbours availability to pick her up.	She wants to share her plans with others. (Even she is aware that the process requires her actions. She cannot just be waiting for help)
Maps	Missing details (scale, north arrow,)	She guess about the flood information, but no details about the level of water is given. The temporal reference of what is shown is also confusing. The background map (OSM) makes confusing the distinction of the main road with the river. (Consider that her viewing capacities are not perfect)	Importance of previous knowledge (she knows the area, so she localize herself easily)
Graph	It's difficult to find	It's useful to know more detailed information (she wants to know which is exactly the level of water at her place along the time)	
Routing	Missing more information from citizens (reports, suggestions). VGI info is helpful when integrated with the routing. More pictures to have a better understanding Also info about the shelters location is of interest Missing how longs that every route will take (Time is of high importance!!)	Routes shown don't give info enough. It's confusing. Not easier to decide. Looking for other information offered by the tool to make it clearer. (The flood information offers the time info that was missing)	She takes her decision considering her previous knowledge on how the status of the roads could be affected by the water level, and the type of ways (narrow, with holes...) She needs to know that she is getting the most updated information!
Overall		Sharing her location is helpful and make her feel more calm She manages to get a decision based on the information offered, that was helpful but not enough and not organized as she expected	Clear layout with the options that the tool offers Temporal information should be better integrated in the functionalities of the system, as it is the most relevant aspect.

Robert's profile interview

Functionality	Information expectations - organization - structure - details	Information obtained	Extra information
Alerts		Useful to get alerts of floods. Information from the waterboards is essential. As well information coming from local organizations and emergency services. However, links to news are meaningless, as they offer more general information.	VGI information needs to be included in other section of the app. Doesn't seem logic at this division. VGI is more helpful when combined with flood forecast information and routing solution. A clear separation of official and non-official sources of reports is needed. Information from emergency services shouldn't be shown in the section of social network.
Messaging	Confusing part. What is it for? Not clear.		Icon of messages is misunderstood with the functionality to check the reports/messages from others.
Maps	No need to be shown apart from the routing solution. Senseless.	Easy to recognise safe areas. The time indication is useful. What is the source of the information? Important to have an idea of the quality level of the forecast results.	A forecast with small temporal resolution (outputs every 15 minutes) is desirable.
Graph		Only useful if add more temporal details to the flood forecast. Otherwise is nonsense.	
Routing	It misses the temporal indication. What time is it when the route is shown. Also the scale to show the routing is important. A scale enough to recognize the established route is preferred.	Previous knowledge of the area is used to contrast with the app results. Adding VGI is useful, but the addition of pictures will make it more trustful. Also metadata will add extra value, like time when a picture was taken.	Capabilities for zooming in and out would be desirable. The visualization of the information of the flood forecast and VGI together with the calculated route will add very valuable information.
Overall		Very useful in a local environment: local and detailed information for a problem that affects the user locally. No matters the size of the whole problem (flood), the user needs to take decisions in his/her level of scale.	First interface impression: the current location is recognised easily (DUE TO THE USE OF CONVENTIONAL ICONS/LOGOS). The indication of the flooded area is also understood from the first sight.

Katherine's profile interview[65]

Functionality	Information expectations - organization - structure - details	Information obtained	Extra information
Alerts	Not so clear. Only Waterschap information is checked. Not checked the link to news.	VGI information in categories is very useful. Being able to zoom and get from clusters to individual reports is handy. However reports are shown in a list, and I need to see them on the map. The location of the emergencies is crucial! Also the picture doesn't show a concise location. And picture shows a requirement of immediate assistance.	Seems that information gathered by people contrast the forecast. Validated information from those areas is needed. Metadata associated to VGI information is crucial. Whether to know when a picture is taken or where the help is needed
Messaging	Confusing. Messaging should differ between different groups of contacts. I would like to share some messages only with my family. Others only with my colleagues from the Police Dpt.		The main tasks on Kath's scenario are related with the exchange of messages and the mock-up version is not very suitable for this functionality. Kath doesn't find the function that allows calling to contacts. Maybe the app should share the folder of contacts with the rest of apps in her smartphone.
Maps		Enhance the awareness of the flood risk spatially and temporally also.	
Graph	Helpful for temporal awareness. It is checked when looking for more detailed information.	Many issues are not so clear: - water level expressed in meters? Problems of visualizing due to the scale; - uncertainty percentages are confusing	Desirable the option to send the graph to other contacts.
Routing		A better scale of the map is needed to allow the user recognize the recommended route. Previous knowledge is used to contrast the route calculated. Combination of route with flood forecast shows clearly an unsafe way.	Even though the previous knowledge is quite essential when taking decisions, the availability of getting alternative options is quite helpful when the stressfulness of the situation could affect the rationale. Very handy and supportive tool.
Overall		Clear, basic but including the key aspects for emergency service.	The icons presented in the first interface are conveniently simple. However, the meanings are not as clear as it is supposed at first.

[65] The Persona profile generation and the evaluation of the Geoweb by using the mock-up version are not developed by the same participant.

Henk's profile interview

Functionality	Information expectations - organization - structure - details	Information obtained	Extra information
Alerts	Useful to get alerts of floods and to keep updated from the news. Social network shouldn't be included in alerts.	Seems to be a confusing icon. The links seem to be official websites, what makes it look serious. About the pictures from VGI, can generate confusion when different from what the forecast predicts. More VGI could help to gain trustfulness.	The showed summary of the information offered by the links, influences on what source is going to be read.
Messaging	Not interested in this functionality.		
Maps	Missing temporal indicator, what makes it confusing. Also a legend is required.		
Graph	Not useful, could be even more confusing		
Routing		Confusing due to the scale, the lack of time indication and the meaning of the different alternatives. Solution contrasted with previous knowledge of the area.	It's important the scale. If I cannot see clearly the way, it's difficult to decide.
Overall	Temporal indicator is missed in many of the screenshots, and is one of the most important factors.		First interface impression: the current location is recognised easily Due to time constraints, to check social networks or to participate as VGI becomes impossible.