Geo Web Services for Transport Crisis Management in Alpine Region

Eszter Gálicz, Md. Imran Hossain, Wolfgang Reinhardt

Institute of Applied Computer Science, University of the Bundeswehr, Munich, Germany

Abstract. The authors of this paper have been working in a research and development project called TranSAFE-Alp under the EU Alpine Space Program since 20111. JITES (Joint Integrated ICT-Technology service for Emergency and Security management) is one of the main outputs of the TranSAFE-Alp project. The main goal of JITES is to facilitate the coordination and management of transnational actions to be undertaken when a catastrophe (natural or manmade) event take place in the transport network of alpine region. This paper demonstrates a significant part (hereafter referred as JITES-Geo) of the JITES system which has been developed solely for transport crisis management with a goal to improve the management of transport emergency cases. The main concern while developing JITES-Geo was to explore the prospects of Geo Web Services (GWS) (section 2) technologies especially the Web Processing Service (WPS) and with a basic question: whether it is possible to make a system like JITES-Geo mainly using GWS or not? The authors, at this stage, successfully designed and implemented some WPS which in combination with other GWS like Web Map Service (WMS), Web Feature Service (WFS), and Transactional Web Feature Service (WFS-T) form the base of the JITES system. Therefore, the main aim of this paper is to express JITES-Geo covering the aspects like system design, architecture, transport disaster scenarios and last but not least some use cases of the system. The paper is therefore structured in the way that the next sections after introduction include a short discussion of GWS followed by state of the art of GWS in disaster management. Thereafter, some disaster scenarios in alpine transport network are revealed in short and finally the JITES is demonstrated followed by some conclusions.

Keywords: Geo Web Services, Transport Crisis Management, Routing

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[1] http://www.transafe-alp.eu/ (last accessed on April 2, 2013)

1. Introduction

Geographic Information Systems (GIS) have been used in various domains of disaster management for many years and already been proved as valuable tools for decision support and management of disaster events (Konecny & Reinhardt 2010). Geo Web Services (GWS), which are relatively new extents of GIS, are making their headway faster than ever, allowing us to use various type of geo-data and geo-processing functionalities from different sources in a system independent environment, in a standard way and with low cost and resources. These remarkable features of GWS embolden the authors to build a GWS based prototype application (JITES-Geo[2]) for transport emergency management. JITES-Geo is in fact a major part of the JITES system which is a prime output of the project TranSAFE-Alp. The present paper demonstrates the development of JITES-Geo based on Geo Web Services for transport crisis management with a goal to improve the management of transport emergency cases within the frame of a project "TranSAFE-Alp" under Alpine Space Program. The objectives of the project as well as the requirements for Geo Web Services are outlined in Reinhardt et al. (2013).

The intention was to use open-source software only, and to create a browser-based application which can be accessed from anywhere using a standard browser. JITES-Geo is merely a prototype application, purposively developed to examine tools that are available to use in a disaster management system under the above mentioned circumstances. The application is, therefore, built with different geo web services like Web Map Service (WMS), Web Feature Service (WFS), Transactional Web Feature Service (WFS-T) and Web Processing Service (WPS) in combination with the OpenLayers library. However, it is especially the Web Processing Service (WPS) which obtains a great importance in our work, as it allows us to call geospatial operations as a service. JITES-Geo introduces a new form of routing geo-processing function which differs from the traditional routing processes in a way that it allows routing considering the safest, fastest or shortest path. Routing in combination e.g. safest and fastest or safest and shortest is also possible in JITES-Geo.

The foremost purpose of this paper is to describe some basic features of the JITES as well as details of JITES-Geo covering the aspects like system design, architecture, transport disaster scenarios and last but not least some use cases of the system.

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[2] In this paper the authors tried to reveal a major part of the JITES which is mostly GWS based.The authors select a pseudo name: JITES-Geo to refer that part of JITES in this paper.

2. Related Works

There have been a couple of implementations of GWS already in crisis management. For example, Maiyo et al. (2010) examined the importance of GWS in post disaster mapping, as tool collaboration not only for disaster management agencies, but also for user generated content. They have developed a prototype system where all these information are delivered and integrated via GWS. Their system has two components, the first one is the thin client, which is based on OpenLayers API just like our client, and it is used for adding geotagged notes, pictures, etc. and is available for every user. The other component, the thick client is used for more complex tasks such as the production of post disaster maps.

Advantages of the GWS are also well represented in the study "Decision Support for Tsunami Early Warning in Indonesia" (Raape et al. 2010). The authors of that study showed that GWS can provide a unified access to spatial data, which can be used in any kind of clients. This interoperability is also used in another early warning system study (Casola et al. 2010), where two main aspects of the Geo Web Services are used: the ability to elaborate data from heterogeneous sources and to manage data sources.

The WPS technology has been also used in crisis management, for example in the study "Multi-Criteria Evaluation for Emergency Management" (Müller et al. 2010). The authors have developed and implemented OpenGIS web service architecture for multi criteria evaluation (MCE). The spatially enabled MCE service is implemented as a WPS to ensure the potential for integration with other frameworks for spatial decision support.

3. Geo Web Services

Geo Web Services are a special form of Web Service, which are specially designed for spatial data. They provide access to geographic information and enable calculations for spatial content. GWS provide the ability to perform complex calculations on geometry of the spatial objects. GWS connect information, data and functionality from different resources in a platform independent way.

3.1. About OGC Geo Web Services

The Open Geospatial Consortium (OGC) as widely known in our community is an international consortium of 480 members with the aim to develop different interface standards in the geo-enabled web[3]. The OGC develops

[3] http://www.opengeospatial.org/ogc (last accessed on April 2, 2013)

different standards for Geo Web Service. Three major standard services of OGC that related to this paper are shortly described in the following:

WMS (Web Map Service): renders maps with spatial content dynamically from geographic information. Map is understood as the portrayal of geographic information as a digital image file which is suitable to be displayed on a computer screen. The maps produced by a WMS are generally rendered in a raster graphic format like PNG, JPEG or GeoTiff as well as in a vector based format such as SVG (Open Geospatial Consortium Inc. 2006)

WFS (Web Feature Service): The OGC Web Feature Service allows a client to retrieve and update geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services. While the basic version of WFS solely provides data, the WFS-T (Web Feature Service Transactional) also allows the modification (insert, update, delete) of vector data (Open Geospatial Consortium Inc. 2005).

WPS (Web Processing Service): All the web service standards presented so far are dedicated to the provision of data, the WPS however has the aim to define different processes and use them to process geodata online (Open Geospatial Consortium Inc. 2007).

4. Transport Emergency Scenarios in Alpine Region

The probability of a natural hazard and its severity is growing nowadays due to the growth of the population, especially in urban areas, and the susceptibility of the modern technologies (Berz 2009). It is especially significant in the alpine region, where in the past landslides and avalanches affected mostly agricultural areas, whereas nowadays settlements are found everywhere and also important infrastructures are at risk (Greminger 2003). Among the infrastructures transport network is one of the significant one since interruption of a transport network triggers cascading effects on the economy and lifestyle. The growing number and severity of catastrophes (both natural and manmade) on transport network point out a need of very well organized, also at a cross-border scale interoperable monitoring and management system to be able to organize effective rescue, damage control and management operations.

The JITES has been designed in a way that it offers guidelines of control and management of any disaster event in the transport network to the respective authority (most of the time transport control center). In order to implement this functionality, some real disaster scenarios including the disaster events and its management procedure have been collected from different transport control centers. The aim was to integrate best available

emergency plans in the systems. As an initial attempt, scenarios for some major real disaster events (e.g. fire in tunnel, flood etc.) have been collected and integrated into the JITES for the pilot actions. *Figure 1* shows a gross overview of a fire event scenario in a tunnel.

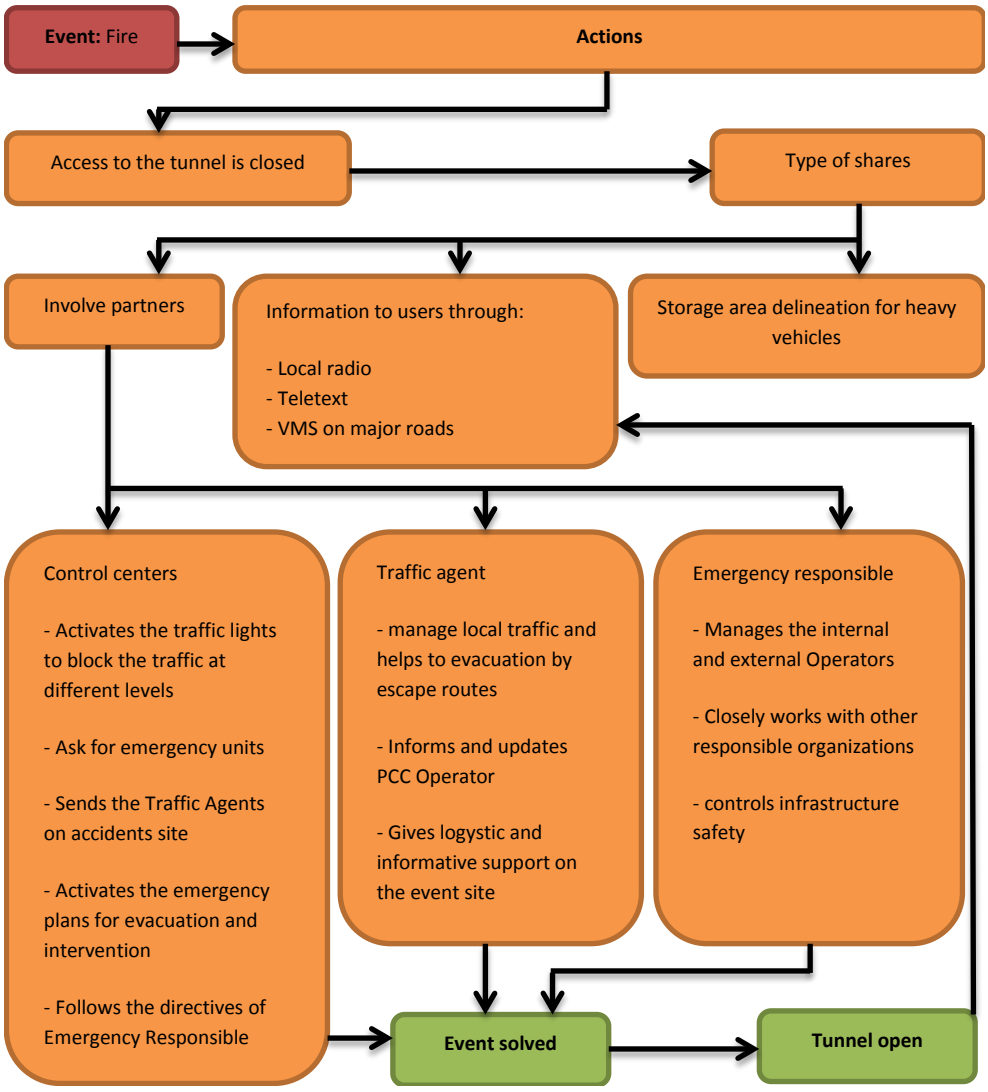

Figure 1. Scenario of a fire event in Frejus tunnel

The scenario shown in fig.1 is defined (presented in an internal meeting of TranSAFE-Alp project) by one of the partner in TranSAFE-Alp project called SITAF-spa together with Province of Turin, Turin Civil Protection

and Polytecnique University of Turin. The scenario is based on a fire event in Frejus tunnel (a tunnel between Italy and France). *Figure 1* shows that access to the tunnel get closed by the authority immediately after a fire event occurs. Thereafter, different partners get involved to solve the event and in parallel users are notified and guided through different media. Once the event is solved the tunnel gets open and users are notified.

5. The JITES-Geo

The JITES-Geo which is a prime part of JITES can be seen as a web based application capable of doing geo-editing, geo-processing and geo-visualization in the domain of transport emergency management.

5.1. Some pre-requisites

JITES-Geo should be based on GWS with special emphasis on the WPS. The intention was to use open-source software only, and to create a browser-based application which can be accessed from anywhere using a standard browser. Another important issue was to ensure the capability of data retrieval from various sources via internet so that the transport control centers do not have to wait for the data and can avoid data conversion processes. This pre-requisite ensures the necessary data to be available automatically to the control center in case of emergency so that they can begin to act immediately. Another prerequisite was to provide guidance to the control centers in the form of 'tasks to do' in case of emergency. Also a spatial representation of the emergency units with the ability to find the nearest ones was needed. And the final important demand was a routing function capable of calculating alternative fastest, shortest and safest routes.

5.2. System design

The application is based solely on open source software, such as PostgreSQL, GeoServer and OpenLayers. The architecture (fig.2) of the application can be compared with the typical three tier web architecture consisting of a data tier, a business logic tier and a client tier.

The data tier consists of databases, in this case spatial database. The database software PostgreSQL[4] and its spatial extension PostGIS[5] has been used to store the geo-spatial data. The raw data (transport network, vulner-

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[4] PostgreSQL website: http://www.postgresql.org/ (last accessed on February 6, 2013).

[5] PostGIS website: http://postgis.net/ (Last accessed on February 6, 2013).

ability information etc.), which was originally in shape file format, is loaded in this database system, and later on accessed with the help of GeoServer.

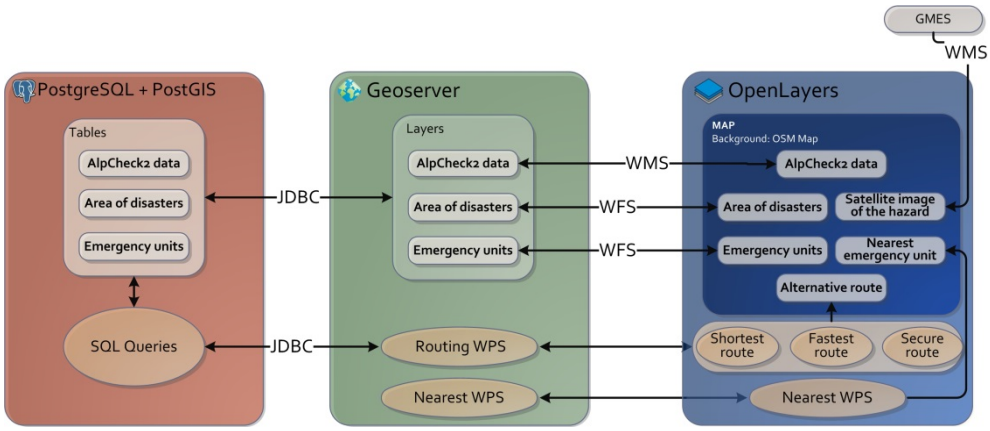

Figure 2. Architecture of JITES-Geo

GeoServer[6] has been used in the business logic tier since it is free and offers WMS, WFS and some basic WPS. The main function of GeoServer is to receive requests from the client, process the request through a connection with the data store and finally send back the results to the client. The GeoServer processes different request for the different Geo Web Services (WMS, WFS, etc.) within it.

The last tier is the browser based client tier, which is accomplished by OpenLayers[7], an open-source library designed to easily visualize geospatial data. Service requests are made with the client and sent to the GeoServer. The browser based client is also used for visualizing the results sent by GeoServer and the data editing.

5.3. Data

Datasets from different sources (fig.2) have been used, demonstrating one of the biggest advantages of a web service based application. The road network which is the main dataset, that composes the PostgreSQL database, is provided by the EU project: Alpcheck2[8]. The data contains road network with traffic information.

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[6] GeoServer website: http://geoserver.org/ (last accessed on February 6, 2013).

[7] OpenLayers website: http://openlayers.org/ (Last accessed on February 6, 2013).

[8] For more information, go to: http://www.alpcheck2.eu/ (Last accessed on April 2, 2013)

The vulnerability (with reference to natural hazards) information was gathered and processed by a project partner called AISCAT[9]. The vulnerability information is divided into seven different categories. The probability of each category of natural disaster is assigned to each segment of the road. As real data was not yet available for demonstrating the emergency units, we have randomly generated some arbitrary locations. The locations are point feature and considered as helicopter rescue units.

6. Use Cases

JITES is designed to make the work of the operator easier. It provides guidance for each step needed to be undertaken in order to manage any disaster event in the road transport network. The main responsible project partner for the development of JITES is Fondazione Bruno Kessler (FBK)[10] whereas JITES-Geo part is developed by the authors. The following flow chart (fig. 3) (some parts of this flow chart are collected from a presentation of FBK in an internal project meeting) shows the main steps of this workflow whereas figure 4 shows the background system processes of JITES-Geo. The following sections describe each steps of the workflow of JITES (fig. 3) with cross reference to the background system processes (fig. 4) where applicable.

6.1. Emergency scenario selection

When a disaster occurs, the first step is to determine the type of the disaster. JITES contains a knowledge base about almost every possible emergency scenario in road transport network including their management techniques and phases (section 3). Therefore, JITES is able to provide the best protocol a certain disaster event to the disaster management authority within a couple of seconds. This is important, because when a disaster really occurs; there is no time to figure out which protocol to use. First the general type of disaster has to be decided, i.e. whether it is an accident, a fire or a natural hazard (fig.3 B). In the next step the type of this event has to be determined more precisely, e.g. if it is a fire, is it in a tunnel, in an open road or in the surrounding? Though it has been tried to cover all possible disaster scenarios in JITES knowledgebase but there are always chances that something could happen which exceed the knowledgebase. Therefore, options for defining new disaster scenarios are also integrated in JITES.

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[9] More information of the partner can be found in the web link: http://www.aiscat.it/english/index.htm (Last accessed on April 2, 2013)

[10] http://www.fbk.eu/ for more information. (Last accessed on April 2, 2013)

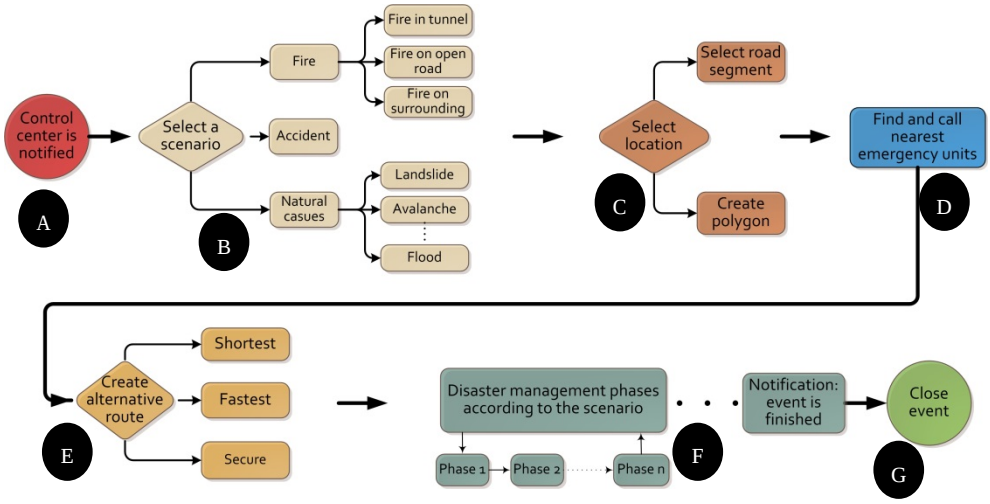

Figure 3. Workflow for managing a disaster event through JITES

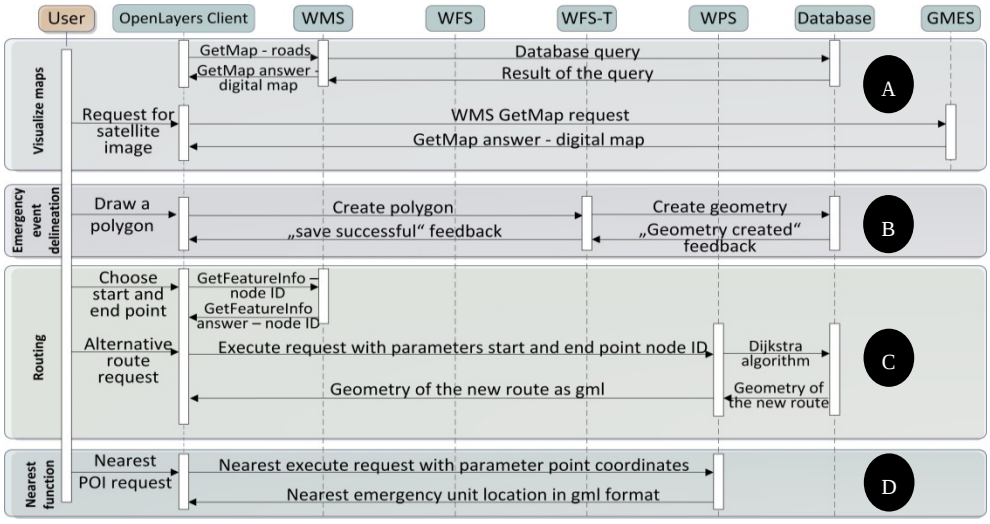

Figure 4. Sequence diagram of JITES-Geo

6.2. Affected area determination

Depending on the type of the disaster there are two possibilities to mark the affected area. If it is a local event, the control center sets the location of the event as a point (fig.3 C and fig.4 B). If it is a bigger area expanded disaster, such as flood, it is possible to request current aerial or satellite images from the GMES[11] program. This image is embedded in the system via WMS ser-

[11] GMES is an earth observation program headed by European Commission (EC). More detail can be found in: http://www.copernicus.eu/index.php (Last accessed on April 4, 2013)

vice, which makes the process easier and faster. The operator locates the disaster on the satellite image and draws its boundaries in the JITES-Geo. This is then saved with WFS-T in the database for further processing and is deleted when the event is over. At both methods the road network is intersected with the event location and the underlying roads are marked as unavailable. This is important for the rescue units and for traffic rerouting.

6.3. Finding nearest emergency units

The emergency units have to be notified once the disaster event is located. A nearest emergency unit finder function is therefore included in the JITES-Geo. The function enables the user to locate any emergency unit closest to the disaster area (fig.3 D and fig.4 D). For this a pre-programmed WPS (gs:Nearest) offered by the GeoServer is called. The nearest emergency unit finder function works in a way that when one of the disaster areas is selected, it calculates the center point of this area and then finds the nearest emergency unit to it (fig. 5). These units then are notified with the coordinates of the disaster location.

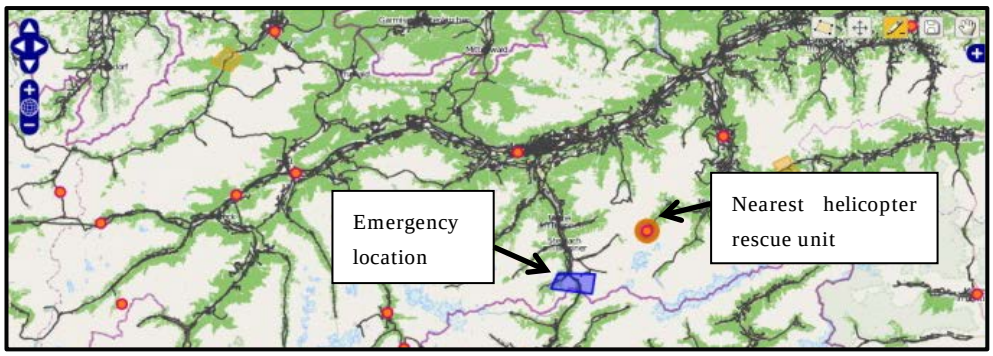

Figure 5. The nearest emergency unit is highlighted

6.4. Alternative route generation

One of the main tasks in emergency traffic management is to provide alternative routes for traffic when a disaster occurs and a road becomes unavailable (fig.3 E). To accomplish this in JITES-Geo, the authors have implemented the Dijkstra algorithm, provided by pgRouting[12] (fig.4 C). The Dijkstra algorithm calculates the most economic path between two nodes considering the cost of the path (fig.6).

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[12] pgRouting extends the PostGIS/PostgreSQL database to provide geospatial routing functionality. More detail can be found in: http://pgrouting.org/((Last accessed on April 4, 2013)

Figure 6. Alternative route considering the cost of path is shortest

The cost of the path can be generated from various type of weights allocated to each edge of the road e.g. length of edge or travel time. JITES-Geo offers three different options to from a route between two points of interest using three different weightage methods. The first option is the shortest route which is calculated simply by considering the edge length as weight. The disadvantage of this method is it does not consider the quality of the roads.

The second option is based on travel time means a route could be formed considering the minimum required time of travel. In this case weightage is assigned to each edge according to the travel time. The travel time for each edge is calculated from the length of the edge and the maximum allowed speed on that road segment. We chose the maximum speed because there were no data available regarding the average speed. Nevertheless, the maximum speed is just as sufficient as the average speed, because we only need this information to be able to compare the roads with each other. This option is more sufficient for rerouting the traffic, because in a situation where traffic jams have to be avoided time is a crucial factor (fig.7).

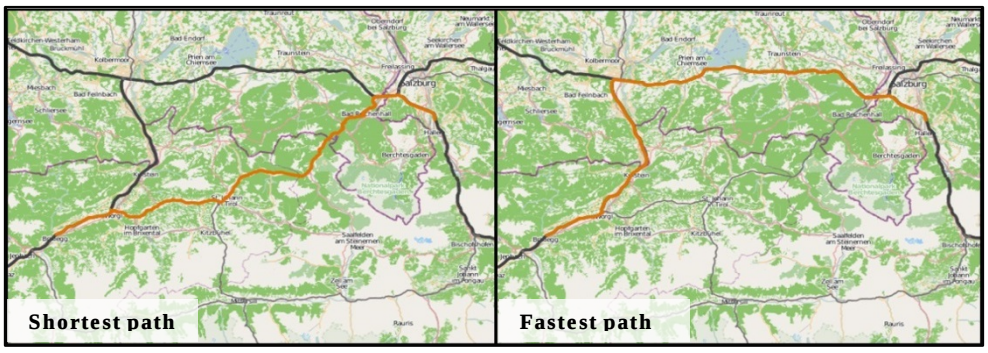

Figure 7. Difference between the shortest and fastest path

The third option is called the most secure path. This method is considering the vulnerability information which was available to us. It is developed to be able to avoid the roads which are less vulnerable to natural hazards. It is mainly used for the rerouting of vehicles carrying dangerous goods. The operator chooses the type of the hazards that should be avoided (fig.8).

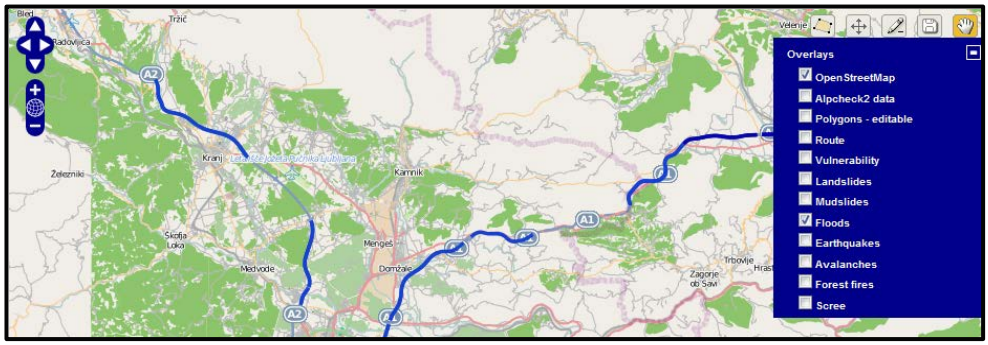

Figure 8. Routes which would be affected by flood

6.5. On-site problem solvation and status update in JITES

At this stage the responsible control center along with the responsible active partners i.e. police department, fire brigade etc. take initiatives according to the instruction provided by JITES to resolve the disaster event in site (fig.3 F). The instructions are retrieved from the disaster scenario knowledgebase and structured in different phases. Once a certain phase is accomplished the control center updates the status of that phase through the JITES to share the information to all active partners.

6.6. Close of event and notification

Once the disaster event is resolved, the responsible control center should close the event in JITES and notify all the relative partners (fig.3 G). In addition an activity log could be saved in the system for future reference.

7. Conclusion

We have presented an example how transport crisis management tools can be developed with geo web services and a browser-based client. We have tested a few functionalities, but our work reveals that the opportunity is even much higher. A wide range of geo-processing functions related to disaster management particularly transport disaster management can be implemented with the help of web processing services. The WPS has the advantage that the functionalities can be accessed from remote servers; they

do not need to be installed in the local system. Another advantage is that if the functionalities offered by a WPS provider are not sufficient, the desired function can be added from another provider or could be extended by programming.

The JITES-Geo could be further extended by developing more functions useful for disaster and transport emergency management control centers. For example, future development might be carried out in the direction of route classification to be able to make difference between roads that are available for heavy vehicles and light vehicles. The risk of transporting dangerous goods would also have to be considered in routing process. Moreover, more complex functionalities could be accomplished through chaining of web processing services or Business Process Execution Language (BPEL) (Juric et al. 2006) for example searching the suitable location for vehicle parking in emergency case could not be served by one single WPS.

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