View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by ScholarWorks@UMass Amherst

Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings

Volume 15 *Seoul, South Korea* Article 44

2015

An Open-Source WebGIS Platform for Rapid Disaster Impact Assessment

Roya Olyazadeh
Institute of Earth Sciences, University of Lausanne

Zar Chi Aye
Institute of Earth Sciences, University of Lausanne

Michel Jaboyedoff
Institute of Earth Sciences, University of Lausanne

Marc-Henri Derron
Institute of Earth Sciences, University of Lausanne

Follow this and additional works at: https://scholarworks.umass.edu/foss4g

Part of the Geography Commons

Recommended Citation

Olyazadeh, Roya; Aye, Zar Chi; Jaboyedoff, Michel; and Derron, Marc-Henri (2015) "An Open-Source WebGIS Platform for Rapid Disaster Impact Assessment," *Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings*: Vol. 15 , Article 44.
DOI: https://doi.org/10.7275/R5V1230N
Available at: https://scholarworks.umass.edu/foss4g/vol15/iss1/44

This Paper is brought to you for free and open access by ScholarWorks@UMass Amherst. It has been accepted for inclusion in Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings by an authorized editor of ScholarWorks@UMass Amherst. For more information, please contact scholarworks@library.umass.edu.

AT6-04

An Open-Source WebGIS Platform for Rapid Disaster Impact Assessment

Roya Olyazadeh, Zar Chi Aye, Michel Jaboyedoff and Marc-Henri Derron

Institute of Earth Sciences, University of Lausanne
Géopolis, UNIL-Mouline, 1015 Lausanne, Switzerland
Email: roya.olyazadeh@unil.ch; zarchi.aye@unil.ch; marc-henri.derron@unil.ch; michel.jaboyedoff@unil.ch

ABSTRACT

Natural disaster impacts have increased worldwide in the past decades. Earthquake is one of the disasters that have been studied for real-time analysis and crisis management. Disaster-related losses have been examined by the damage extent of the houses, infrastructures, fatalities and injuries converted to financial losses. WebGIS technologies provide a wide range of solutions to map those damages, analyse data and publish the results. Open-Source tools and data have been widely used today because they stay free and facilitate access to data especially significant in developing countries. This research presents a WebGIS prototype using Open-Source Geo-Spatial technologies such as PostGIS, Geoserver, Geoexplorer and OpenStreetMap (OSM) to evaluate the rapid impact of naturally produced disasters for the total damages. For this purpose, expert knowledge, such as earthquake intensities and vulnerability inputs are imported into the system and the loss of the damage is rapidly estimated. This work is part of a project for catastrophe modeling based on Open-Source data and software. We hope that applying Open-Source knowledge and solutions will decrease the time and efforts needed for rapid disaster and catastrophe management.

1. INTRODUCTION

Generally, disaster crisis happened with a complete mixture of human actions and natural hazards that directly result in a vital change during a short period of time such as death, disease, displacement including damage to infrastructure and economic loss (Wisner, et al. 2003). During the past decades, hazard events, namely as earthquakes, droughts, floods, storms and fires have produced significant loss of people, properties and environmental damage. By understanding the past hazards and anticipating the future events, the risk disasters can be minimized. As a result, disaster assessment should be a repetitive and remaining process (International Federation of Red Cross 2000) including underlying causes, dynamic pressures and unsafe conditions; this refers to a relationship between disaster, hazard and vulnerability (Blaikie, et al. 1994). Different types of assessment are based on different type of disasters and available resources. The initial assessment can be carried out quickly, and when more information are available, this can be improved (International Federation of Red Cross 2000).

During the past years, more than 1,100 dense earthquakes have occurred, causing more than 1,500,000 casualties and collapsing buildings of more than 90% (Lantada, Pujades and d Barbat 2009). Recently, the available fundamental information immediately after an earthquake is its magnitude, depth and epicenter provided by U.S. Geological Survey (USGS) data (http://earthquake.usgs.gov). However, the damage patterns are not an easy process and it requires more detailed information on-site (James and Pascale 2012). Besides, hazard map production has long process and include lots of efforts, and therefore, they cannot be available quickly and freely. Besides building and vulnerability information need a huge database. As a regard, open data, such as OpenStreetMap (OSM) and USGS data, including shake maps can be integrated directly in the Web-GIS application and will decrease the time and efforts needed for the analysis. This data will be used to estimate damage and loss of the event.

The WebGIS platforms, spatial data infrastructures, Geo visualization tools and GUI (Graphical User Interface) in the field of risk management have been applied in numerous related works (see (James and Pascale 2012), (van Westen, et al. 2014), (Aye, et al. 2015), (FEMA 2008) and (Open Quake 2015) among others). The web-GIS systems can support disaster assessment of an earthquake immediately and facilitate the analysis. In addition, different GIS prototype systems ((James and Pascale 2012) and commercial technologies ((FEMA 2008), (Esri White Paper 2008), (Open Quake 2015) and (InaSAFE 2015) have been proposed. Despite the variety of systems, there is no system which challenges the application of open data like OSM in planning of rapid disaster assessment, combined with loss and risk estimation based on available risk information, through the application of a web-GIS platform.

In this work, web-GIS technologies play a fundamental role both in rapid disaster assessment and loss estimation mainly for earthquake. This prototype application calculates loss of damage by importing data from OSM and adding other information such as earthquake intensity, vulnerability and the value of the buildings. The application is implemented based on the open source framework, namely OpenGeo (Boundless).

Section 2 of this paper begins with the methodology for rapid disaster assessment and conceptual framework of the system. In section 3, the background architecture and implementation are proposed, and section 4 is devoted to describing the data that has been used to test the application and discuss an initial result of the development. In the last part, the conclusion of this study and future works for the catastrophe management and modeling platform are reported.

2 The Conceptual Framework

The central goal of this study is to develop an integrated system for catastrophe management in case of an earthquake, focusing on rapid disaster impact assessment. The entire system plans to improve rapid assessment when there is a lack of information and data. The functions of the system are related to four main phases:

1. Hazard
2. Elements-at-risk
3. Vulnerability
4. Loss.

Intensity can be defined as a major disturbance created by a disaster. Dealing with earthquake, general information does not give an indication about the frequency. Generally, the hazard is stated in terms of the incidence rates of intensity values (Cardona, Ordaz and Marula 2008). Additionally, vulnerability is the characteristics in terms of the ability to resist and improve the effect of a hazard (Blaikie, et al. 1994). Vulnerability functions are extremely hazard related. For example, some buildings can be very vulnerable to earthquake and less to other hazards like floods (Cardona, Ordaz and Marula 2008). Likewise, the loss computation for events like earthquake is problematic, because of the lacking vulnerability information of buildings (objects at risk) or hazard intensity. Due to the uncertainties of this process, loss can be known as a probabilistic distribution in the shaking area. This methodology contains modules that permit building information such as area and prices to be added for object at risk (i), to estimate damage and loss, primarily using the shaking intensity ($I(x_i)$) at the location of the object i within the database. Using a probabilistic approach the loss of the i^{th} object for one simulation is defined by:

$$Loss_i = P(0/1)_i \times fV_i(I(x_i, RND)) \times W_i \qquad (1)$$

P(0/1): Probability of an object i to be affected (yes or no) depending on the knowledge
$fV_i()$: Vulnerability function of the considered object depending on the intensity I
$I(x_i, RND)$:Intensity function depending on the location x_i and a random value RND [0-1]
W_i: Value of the object at risk (mainly buildings)

The total loss:

$$TL = \sum Loss_i \qquad (2)$$

Figure 1 (The loss assessment flowchart) allows the end users to visualize and understand an integrated rapid disaster assessment framework.

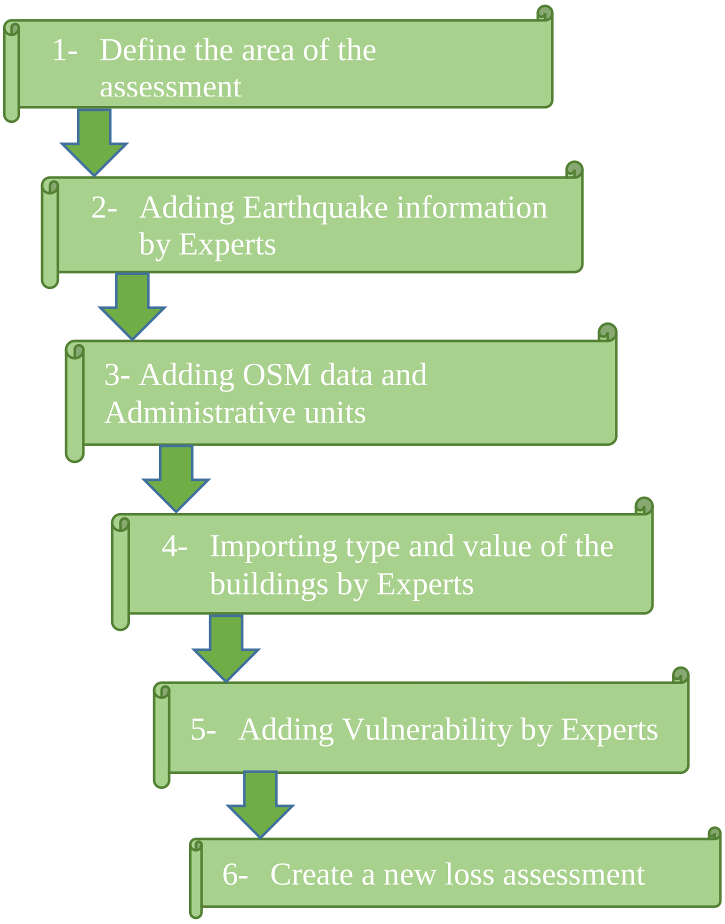


Figure 1: The loss assessment process

3. Implementation

The main features of the platform (Figure 2), containing: 1. Top panel that focuses on user management and documentation. The *user management* module is used for creating, assigning and managing user accounts and permissions. 2. Main panel that is divided to Map view, Layer view, Legend and Data view in a table format. The map view panel is located in the center with tools for zooming, searching locations, styling, drawing and editing features, etc.; and Data view panel is located in the south to visualize feature information about the particular (vector) layer on the map. The main features of the *loss calculation* module are added to the top bar of Map view for adding a new shake map layer as well as for calculating loss.

The GIS system is designed to process multiple events with different magnitudes for different epicenters. Considering the spatial data stored in the Geodatabase component, the system has been structured to obtain earthquake information such as magnitude, epicenter, intensity, vulnerability tables and OSM data. In this way, it is possible to have a preliminary assessment of the damage. For this reason, the vulnerability has been imported in terms of probabilistic percentage or damage function for different buildings.

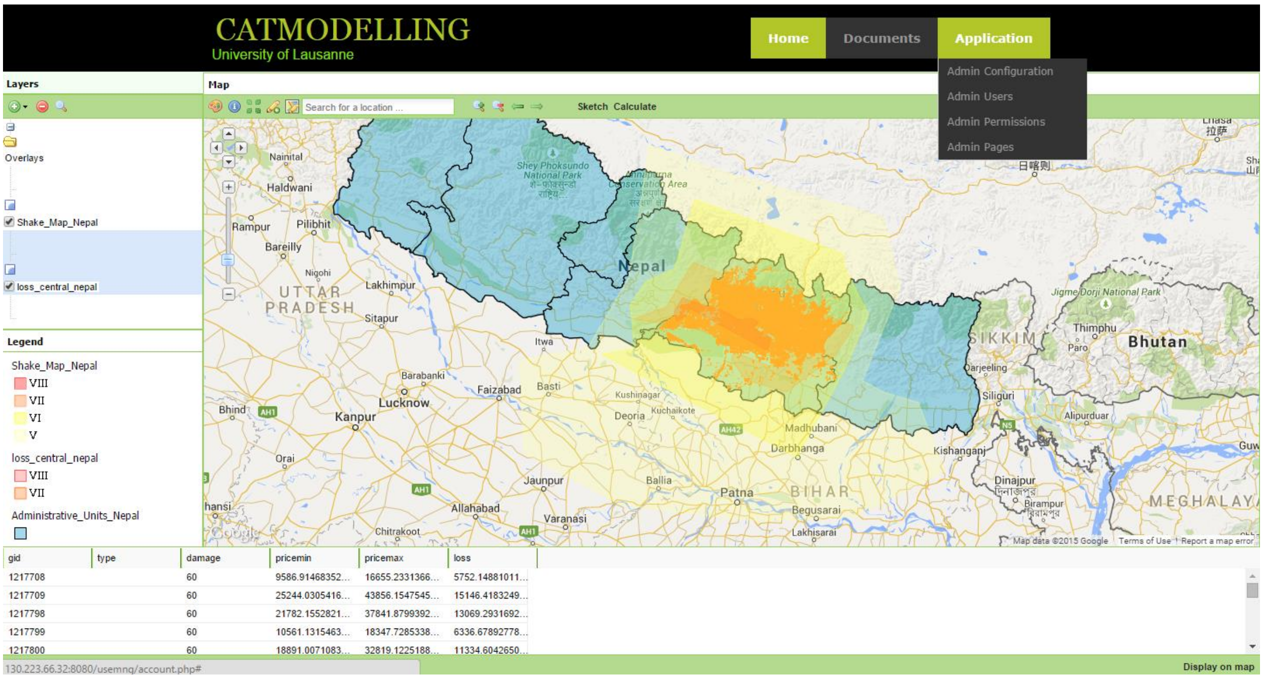


Figure 2: The main view of the platform with admin login

3.1 Architecture

The GeoSpatial analysis and visualization plays a fundamental role in disaster and post-event management. For this purpose, the GeoSpatial technologies have been combined into the architecture as a Geo-Visualization interface. The information and maps are stored and managed within a GeoSpatial database, therefore, it is possible to visualize and request the data by a map viewer. The designed global architect (Figure 3) is implemented by using free open source software (FOSS). The platform consists of the following components:

1. Geo-database (PostgreSQL and PostGIS);
2. Geographic user interface, including maps (Extjs, OpenLayers and GXP)
3. Web-GIS server (Geoserver)
4. User management with SQL (UserCake: http://usercake.com/)
5. Data analysis and process in PHP

The user sends a request login to the Apache web server using the user interface of the web browser. The request passes through the PHP to SQL server and login is succeeding. Afterwards, the requests to the Geoserver are being handled (e.g. Layer query, overlay of different layers, etc.). The data are being analyzed and processed on the web server and sending back to the format into HTML pages. Lastly, the results are displayed in the forms of maps and tables by using OpenLayers.

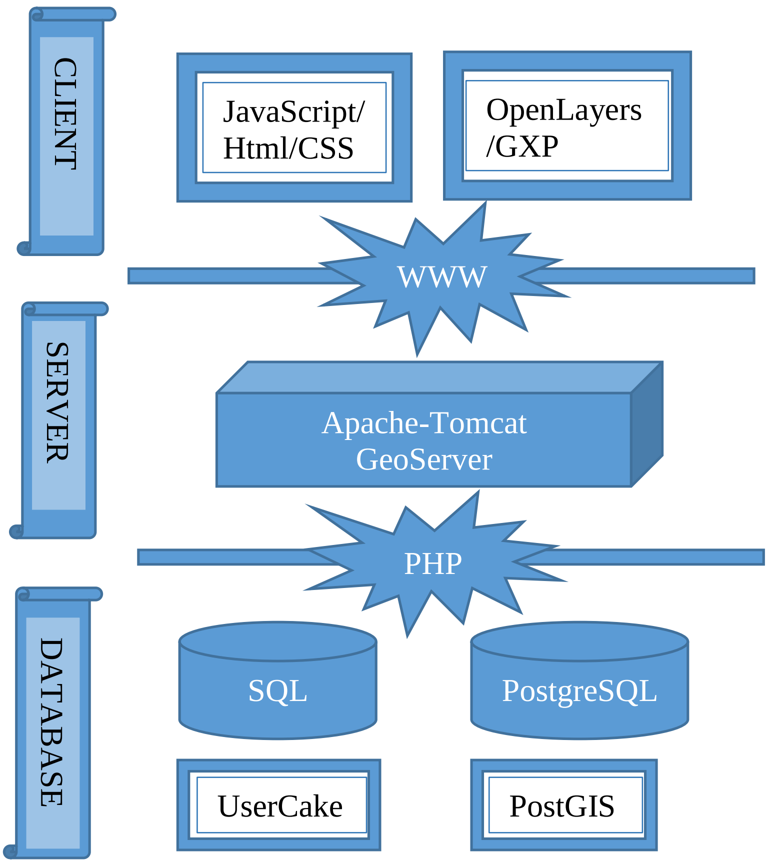
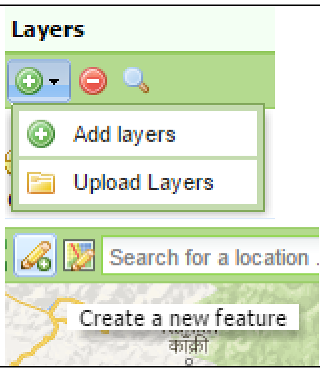
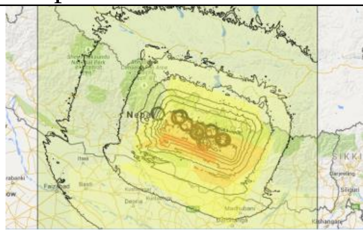


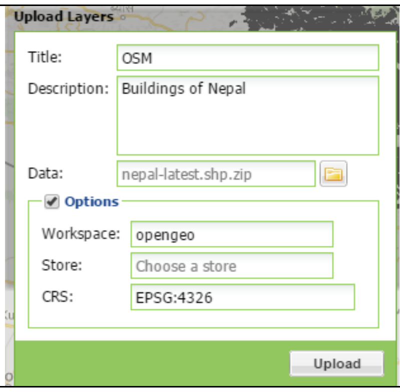
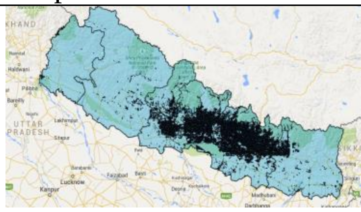
Figure 3: Architecture of the WebGIS platform

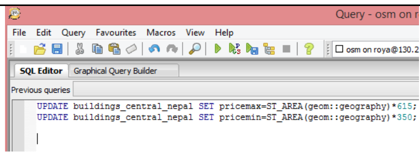
3.2 Procedures

The disaster assessment method includes four main phases (Table 1). Once the user enters into the system, the first phase is to fill the information about earthquake, importantly epicenter, depth and Magnitude. Then, the expert will update the intensity of each earthquake by uploading a SHP file or drawing on the map canvas. Following, the OSM data will be uploaded to the system as a SHP file layer. This data can be generated in QGIS and imported as spatial database.

<table>
<tr><td colspan="3">Phase 1: Earthquake data</td></tr>
<tr><td>Input Data</td><td>Tools</td><td>Output</td></tr>
<tr><td>Upload or Draw

1. Shake Map
2. Earthquake information</td><td>
</td><td></td></tr>
<tr><td colspan="3">Phase 2: Building Data</td></tr>
<tr><td>Input Data</td><td>Tools</td><td>Output</td></tr>
<tr><td>Upload

1. OSM building
2. Administrative Units</td><td>
</td><td></td></tr>
<tr><td colspan="3">Phase 3: Vulnerability</td></tr>
<tr><td>Input Data</td><td>Tools</td><td>Output</td></tr>
<tr><td>CSV file

1. Value of building
2. Damage probability in the affected area</td><td>

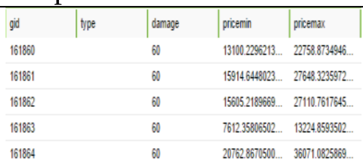
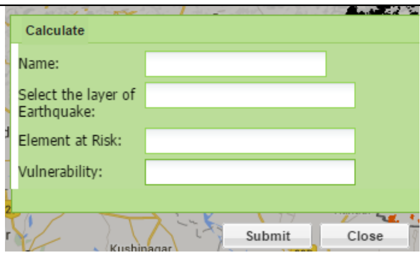
PostGIS</td><td>
<table><tr><th>gid</th><th>type</th><th>damage</th><th>pricemin</th><th>pricemax</th></tr>
<tr><td>161860</td><td></td><td>60</td><td>13100.2296213...</td><td>22758.8734946...</td></tr>
<tr><td>161861</td><td></td><td>60</td><td>15914.6448023...</td><td>27648.3235972...</td></tr>
<tr><td>161862</td><td></td><td>60</td><td>15605.2189669...</td><td>27110.7617645...</td></tr>
<tr><td>161863</td><td></td><td>60</td><td>7612.35806502...</td><td>13224.8593502...</td></tr>
<tr><td>161864</td><td></td><td>60</td><td>20762.8670500...</td><td>36071.0825869...</td></tr></table></td></tr>
<tr><td colspan="3">Phase 4: Loss estimation</td></tr>
<tr><td>Input Data</td><td>Tools</td><td>Output</td></tr>
<tr><td>1. Earthquake
2. Buildings
3. Type of damage</td><td>
</td><td></td></tr>
</table>

Table 1: The main steps of the loss calculation in the platform

Before moving into the calculation phase, vulnerability information is required to be linked to the building data. This data derive from a table in CSV file mentioning the type of the building and damage probability or defining the probability of the damage area. The value of each building is being calculated and added to the system for the final phase (Area multiply to price per square meter). Consequently, the user can select earthquake layer, building layer and vulnerability type after naming the calculation process. As a result, the loss is computed for each building and in overall. Besides, the computed loss can be shown as a map layer in the system. These procedures are the basic steps in the existing system, however, it is planned to enhance more detailed data and information on how the system can simulate and estimate intensity and vulnerability information for an improved analysis.

3.3 Data Model and GeoServer

Geodatabase is designed to integrate and incorporate Geo-spatial data delivered as an input to the system, including the data linked to Earthquake (e.g., magnitude, epicenter and intensity) and specific data connected to the area of interest (Building information, OSM data, vulnerability tables). The FOSS technologies chosen to develop this component were PostgreSQL/PostGIS (www.postgresql.org and http://postgis.net/).

The GeoServer component, in connection with Geodatabase (PostGIS), is provided to process spatial analysis and visualization. This module delivers a complete and up-to-date description of the different layers like earthquake layer, building layer and, as a result, the maps of expected financial loss in that area. Consequently, the results are stored and visualized through GeoServer WMS and WFS features (http://geoserver.org/)

4. Study Data and Results

As an example, the 2015 Nepal earthquake, which is the largest occurred during the last 50 years in this country, is applied to this study (Earthquake Track 2015). In April 2015, a massive earthquake of 7.8 M happened in Nepal as a result of faulting between the India plate and Eurasia plate. At least 8,702 people were killed, 22,493 injured (UNHCR 2015) 500,717 buildings were destroyed and 269,190 damaged in this earthquake and the M 7.3 aftershock on May (USGS National Earthquake Information Center 2015). Despite Nepal is one of the countries in the world with the lowest economy, the main source of economy is agriculture and tourism. However, reports demonstrate that the loss affected by recent earthquakes could considerably set back the economy of Nepal (Grossi 2015).
Figure 4 displays the location of the recent earthquake and the aftershocks in Nepal (Robertson and Koontz 2015). The shake map of data for earthquake of 7.8 M was imported into the system by drawing the area in a polygon format. This data can also be downloaded from USGS website as different formats such as vector or raster (USGS 2015).

Figure 5 indicates the shaking intensity affected by the Earthquake of 7.8 M (Grossi 2015).

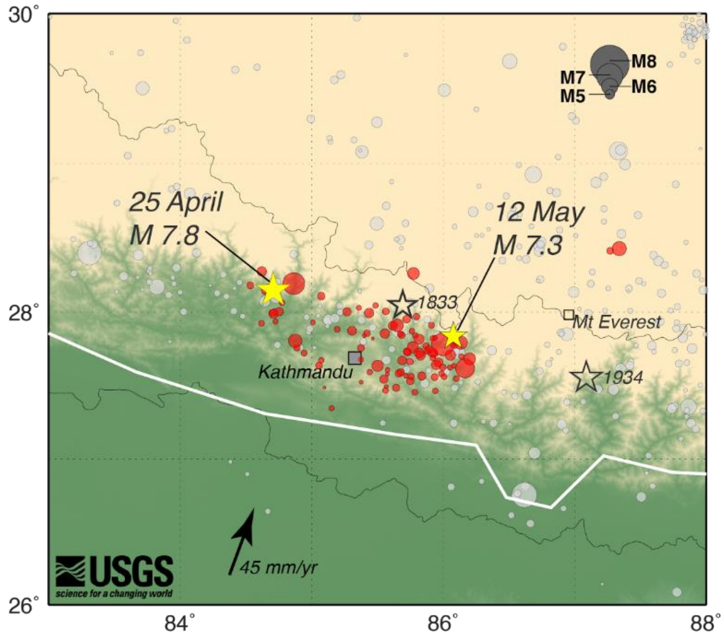


Figure 4 . Magnitude 7.8 Earthquake in Nepal & Aftershocks (from (Robertson and Koontz 2015))

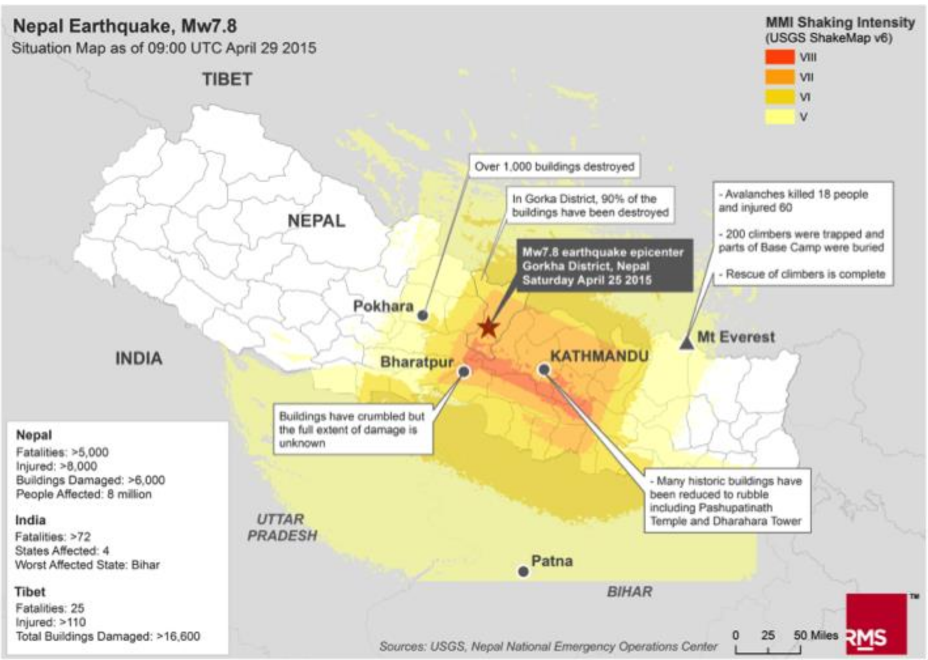


Figure 5: Shaking intensity map of Earthquake 7.8 M (from (Grossi 2015))

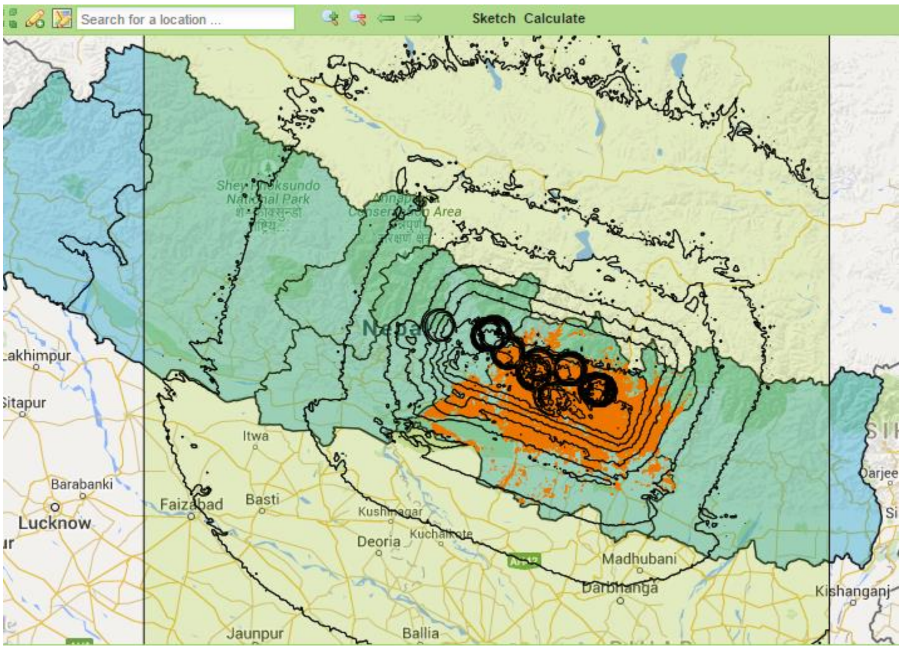


Figure 6: Shake map of Earthquake 7.8 M imported to the system

Figure 7 shows the shake intensity map has been sketched in the system and the building layer of the country has been uploaded as a SHP file to the system (GeoFabrik 2015). The building information is a huge file, hence, we decided to limit the study on a specific administrative unit of Nepal that is affected mostly by the earthquake called as Central. The administrative units' map of Nepal was downloaded as a vector layer (Administrative units: GADM database http://www.gadm.org/).

Figure 7 demonstrates the buildings that are overlaid with the central administrative unit.

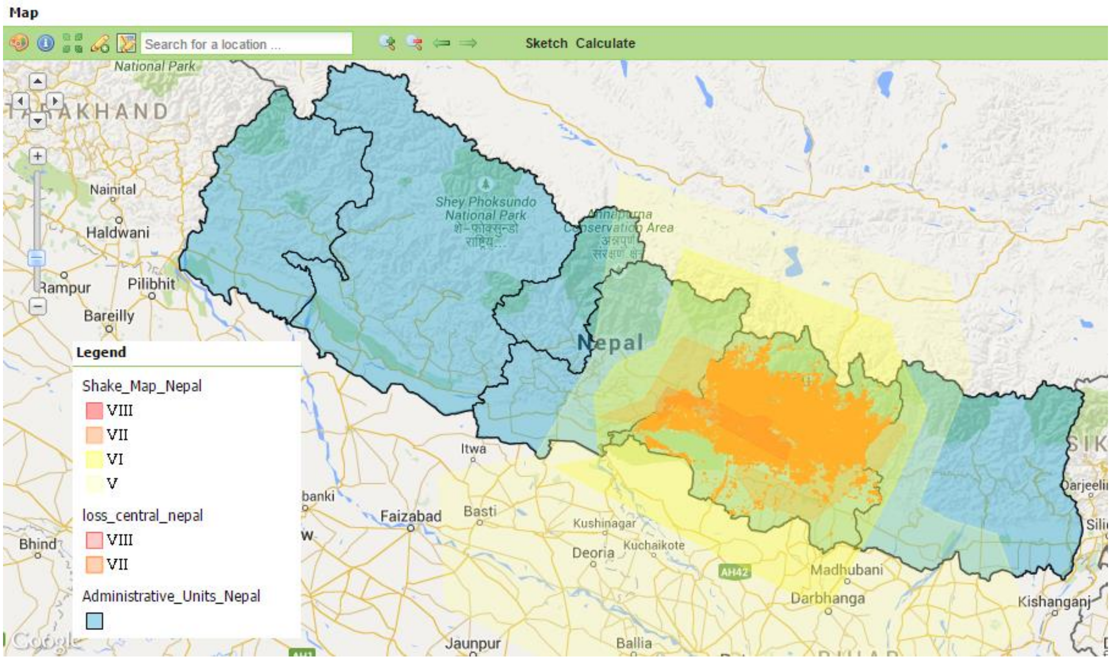


Figure 7: Overlay of buildings with central administrative unit in the map view of the system

After adding all the layer maps, there is a requirement for the update of the building information. The price per square meter in Nepal is estimated between 350 to 615 US dollars (Numbeo 2015). By having the area of each building in the database, the price of each house can be estimated roughly. Finally, the loss of each building and overall loss for the whole region are calculated. Table 2 indicates the total number of houses that are exposed in the event as well as the overall loss. This result is the preliminary result of the system based on open data and expert knowledge. The authors, therefore do not recommend others to use this result. According to the government, the earthquake destroyed 160,786 houses and more than 3 million houses were damaged (UN 2015). The result of this study shows that 3.1 million houses were exposed in the earthquake and 124,000 of the houses were exposed to the higher risk or in the absence of other information, the maximum loss shows 124 000 buildings were destroyed.

Intensity Zones	Number of Houses Exposed in the area	Loss Price: Minimum cost per square meter 350 $	Loss Price: Maximum cost per square meter 615 $
VIII	124 000	2.1	3.6
VII	957 000	12.2	21.3
V and VI	2 000 000	13.3	23.3
Overall	3 100 000	27.6 Billions	48.2 Billions

Table 2: Overall Loss for different intensity layers of the shake map

5. Conclusion

Even though different tools have evolved in this field, their practice is restricted due to the complex design of the systems, flexibility and usability. There are many challenges in developing a WebGIS system. The most important ones are the lack of information and data. In order to utilize GIS and other Geo-Spatial technologies, a variety of spatial data is required. The elements-at-risk information is critical for disaster impact assessment and in this study, OSM data are used. Though this data is not a complete set, it provides a basic and more information can be added based on expert and local knowledge. Besides the estimation of loss by using open data (e.g., OSM, USGS, Numbeo and GADM database) do not involve extensive collection and can be performed fast with a modest budget. The more accurate loss estimation requires an extensive inventory at additional cost to the end user and can be employed in future works. To be mentioned, stories of the house, lifelines like water supply and transportations were not considered in this study and will be applied in further stages of this system. This paper presented the initial implementation and the background framework of a web-based GIS system for rapid impact assessment and demonstrated a preliminary result of the case study area in Central Nepal for the recent earthquake on April 2015. The full functional system is still under development in order to fulfill the lack of information, the user requirements and skilled knowledge of the earthquake experts.

References

Aye, Zar Chi, Michel Jaboyedoff, M. H Derron, C. J van Westen , H. Y Hussin, R. L Ciurean, S Frigerio, and A Pasuto. 2015. "An interactive web-GIS tool for risk analysis: a case study in the Fella River Basin, Italy." *Nat. Hazards Earth Syst. Sci. Discuss* 4007-4057.

Blaikie, P, T Cannon, I Davis, and B Wisner. 1994. *At Risk: Natural Hazards, People’s Vulnerability, and Disasters.* London: Routledge.

Cardona, Omar D, Mario G Ordaz, and Mabel C Marula. 2008. "Estimation of Probabilistic Seismic Losses and the Public Economic Resilience—An Approach for a Macroeconomic Impact Evaluation." *Journal of Earthquake Engineering* 60-71.

Earthquake Track. 2015. *Biggest Earthquakes Near Nepal.* Accessed July 2015. http://earthquaketrack.com/p/nepal/biggest.

Esri White Paper. 2008. "Geographic Information Systems Providing the Platform for Comprehensive Emergency Management."

FEMA. 2008. *HAZUS-MH Estimated Annualized Earthquake Losses for the United States* .

GeoFabrik. 2015. *OpenStreetMap Data Extracts.* http://download.geofabrik.de/.

Grossi, Patricia. 2015. "The Nepal Earthquake: What We Know So Far." *The RMS blog.* April 29. Accessed July 15, 2015. http://www.rms.com/blog/2015/04/29/the-nepal-earthquake-what-we-know-so-far/.

InaSAFE. 2015. . http://inasafe.org/en/.

International Federation of Red Cross. 2000. *Disaster Emergency Needs Assessment.* Disaster Preparedness Training Programme.

James, Valentina, and Carmine Pascale. 2012. "Emergency, Open source GIS Tools to Map Earthquake Damage Scenarios and to Support." *The Fourth International Conference on Advanced Geographic Information Systems, Applications, and Services.* GEOProcessing. 152-157.

Lantada, N, L. G Pujades, and A. H d Barbat . 2009. "Vulnerability index and capacity spectrum based methods for urban seismic risk evaluation." *Nat Hazards* 501-524.

Numbeo. 2015. *Cost of Living in Nepal.* July. http://www.numbeo.com/cost-of-living/country_result.jsp?country=Nepal.

Open Quake. 2015. *GLOBAL EARTHQUAKE MODEL.* January 21. Accessed July 15, 2015. http://www.globalquakemodel.org/openquake/about/platform/.

Robertson, Jessica, and Heidi Koontz. 2015. *Magnitude 7.8 Earthquake in Nepal & Aftershocks (USGS).* May. Accessed July 2015. http://www.usgs.gov/blogs/features/usgs_top_story/magnitude-7-8-earthquake-in-nepal/.

UN. 2015. *Nepal earthquake: More than 3,00,000 houses damaged, says UN report.* May. http://www.firstpost.com/world/nepal-earthquake-more-than-300000-houses-damaged-says-un-report-2224632.html.

UNHCR. 2015. *Nepal: 2015 Earthquakes.* June. Accessed July , 2015. http://data.unhcr.org/nepal/.

USGS. 2015. *Earthquake Hazards Program: Shake map.* Accessed July 2015. http://earthquake.usgs.gov/earthquakes/shakemap/global/shake/20002926/.

USGS National Earthquake Information Center. 2015. *USGS.* April. Accessed July 2015. http://earthquake.usgs.gov/earthquakes/eventpage/us20002926#general_summary.

van Westen, C.J, W.H Bakker, V Andrejchenko, K Zhang, J Berlin, I Cristal, and R Olyazadeh. 2014. "User Guide: RiskChanges: a Spatial Decision Support System for analysing changing hydro-meteorological risk." Accessed 2015. http://www.changes-itn.eu/RiskChanges/UserGuide/tabid/159/Default.aspx.

Wisner, Ben, Piers Blaikie, Terry Cannon, and Ian Davis. 2003. *At Risk: natural hazards, people’s vulnerability and disasters (Second Edition).* UNDP.