Identifying Elements at Risk from OpenStreetMap: The Case of Flooding

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ABSTRACT

The identification of elements at risk is an essential part in hazard risk assessment. Especially for recurring natural hazards like floods, an updated database with information about elements exposed to such hazards is fundamental to support crisis preparedness and response activities. However, acquiring and maintaining an up-to-date database with elements at risk requires both detailed local and hazard-specific knowledge, being often a challenge for local communities and risk management bodies. We present a new approach for leveraging Volunteered Geographic Information to identify elements at risk from the free and open-source mapping project OpenStreetMap. We present initial results from a case study in the city of Cologne, Germany, to validate our approach in the case of flood-hazard. Our results show that the identification of elements at flood risk from OpenStreetMap is a suitable and cost-effective alternative for supporting local governments and communities in risk assessment and emergency planning.

Keywords

Volunteered Geographic Information; VGI; Elements at Risk; Risk Assessment; Flood; OpenStreetMap; OSM

INTRODUCTION

A crisis is the consequence of the interplay of at least two factors: the probability that a harmful event takes place - e.g. natural hazards like floods or earthquakes - and the vulnerability of physical and social structures being exposed to a hazardous event. Substantial work in risk and vulnerability assessment has been conducted in the last decades (e.g. Blaikie et al. 2004; Dilley et al. 2005; Birkmann and Wisner 2006; Jongman et al. 2012; Smith 2013; Mays et al. 2013).

An essential part in methodologies for the assessment of hazard-risks and vulnerabilities of physical and social structures is the identification and valuation of an inventory of objects and assets exposed to a certain hazard. The risk of an asset or element at risk is then expressed in its tendency to get damaged (Douglas 2007: 283). However, the inventory of elements at risk is acquired in time-consuming procedures through integrated collection of data through official government data sources, land cover databases and individually gathered data (e.g. Herrmann et al. 2007). Additional challenges may arise from lacking expertise and local knowledge, time-criticalness or political constraints. Moreover, the identification of elements at risk is specific to each risk assessment approach.

The use of so-called Volunteered Geographic Information (VGI) holds potential for the evaluation and assessments of risk from natural hazards and for a rapid and comprehensive inventory of assets exposed to natural hazards. The term VGI was coined by Goodchild (2007) and describes the utilization of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals.

When official disaster risk information is lacking, extracting information from VGI can help fill the gaps, i.e. citizen-generated geodata can complement to the existing datasets available (Goodchild 2007). In addition, VGI often holds inherent local knowledge from citizens about positions of potentially vulnerable objects and thus can be a valuable resource for risk assessment. When risk management bodies work together with citizens to create VGI, this process of inclusive risk assessment can contribute to mutual understanding and increase risk awareness.

In this paper we present a new approach for leveraging the free and open-source VGI mapping project OpenStreetMap (OSM) based on well-recognized frameworks in research and practice for the identification of elements at risk for risk and vulnerability assessments. With our methodological approach we seek to make a contribution to the challenges in acquiring elements at risk by providing a generally applicable solution for the identification of hazard-exposed elements.

We present initial results from a case study in the city of Cologne, Germany to validate our approach for extracting elements at risk from OSM in the case of flood-hazard.

The remainder of this paper is structured as follows. Section 1 gives an introduction into the conceptual frame of our approach. In Section 2, we describe our approach to obtain elements at risk from the VGI source OpenStreetMap. Section 3 deals with preliminary results from a case study we conducted for the city of Cologne to identify Essential Facilities from OSM for flood hazard scenarios. In section 4, we provide a discussion of the achieved results and an overview about future work.

ELEMENTS AT RISK IN RISK ASSESSMENT

In the framework of the International Strategy for Disaster Reduction (ISDR) the term risk is defined as the "*probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions*" (ISDR 2004: 16). Consequently, risk assessment is based on a methodology to evaluate the nature and extent of risk determined by characteristics of potential hazards and conditions of vulnerability that could potentially harm people, their properties and the environment (ISDR 2004: 16).

While the general concepts of risk, hazard and vulnerability have been researched (e.g. Alexander 2000; Blaikie et al. 2004; Birkmann & Wisner 2006; Smith 2013; Mays et al. 2013), just a few works specifically refer to elements at risk or related terms. However, some authors define risk along with the term elements at risk. Alexander (2000) defines total risk as the product of the amount of elements at risk, hazard and vulnerability:

Total Risk = (amount of elements at risk) x Hazard x Vulnerability

Thus, risk is defined as the probability that loss from a natural hazard results from a series of elements exposed to a certain hazard and when the element is intrinsically characterized by certain vulnerabilities (Alexander 2000: 10).

In the evaluation of the risk that a certain element might be affected by a natural hazard, the exposure of the element has to be evaluated. The term exposure "*refers in general to the volume and concentration of elements in a given area, and is calculated combining population exposure, density of population, built area, industrial area, and Government and institutional area*" (Villagrán de León 2006b: 46). Thereby the distribution and characteristics of elements at risk can define physical exposure to natural hazards, e.g the susceptibility to be affected by natural phenomena: "*Elements at risk, an inventory of those people or artefacts that are exposed to a hazard*" (UNDP 2004: 136).

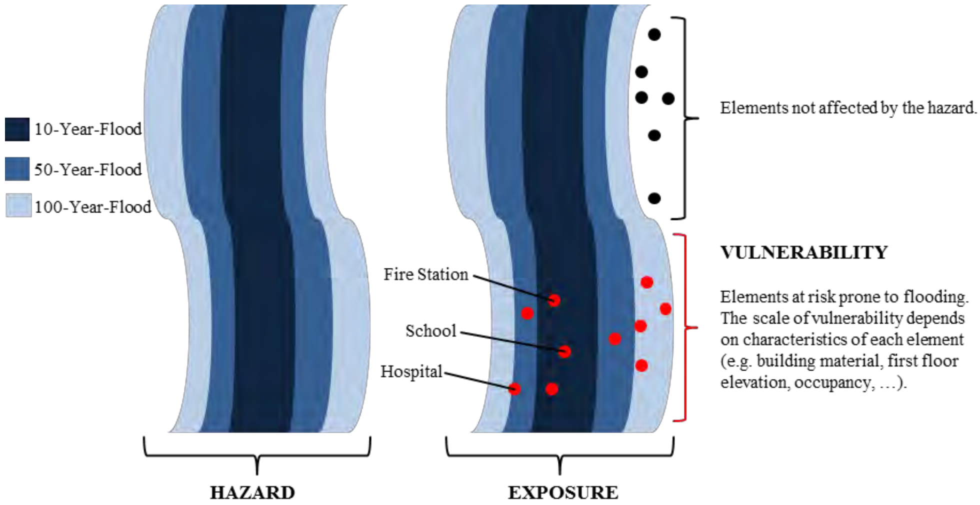

Figure 1: Flood Risk as the synergy of Hazard, Exposure and Vulnerability. Adapted from (Merz & Thieken 2004: 28).

Exposure as a term relating to elements at risk is also described by Pelling (2003), Cardona (2003) and Dilley et al. (2005). Figure 1 gives a schematic overview of the interplay of hazard, exposure and vulnerability in the case of flood-risk. Hazard levels are plotted on maps giving indication about the exposure of elements at risk and their vulnerability.

Examples of what assets elements at risk actually comprise depend on the type of hazard and risk assessment. Our literature research found that the term is used in a diverse field of risk assessments and thus it is difficult to derive a commonly applicable list. However, the categories in every publication comprise populations and communities, the built environment and infrastructures, as well as economic services (Jha et al. 2010; Dilley et al. 2005; Villagrán de León 2006a). We found the most detailed and substantial model for elements at risk in the HAZUS framework, a natural hazards loss estimation software developed by the Federal Emergency Management Agency of the United States. Elements at Risk in HAZUS are pre-defined and extensively described in FEMA (2012). In the HAZUS terminology elements at risk are considered as an "inventory" (building stock, infrastructure and population exposed). This inventory is used to estimate the damage from the potential hazard.

In general, FEMA uses the following categories: General Building Stock, Essential Facilities, Hazardous Material Facilities, High Potential Loss Facilities, Transportation Lifeline Systems, Utility Lifeline Systems, Demographics (FEMA 2004: 3-2).

OBTAINING ELEMENTS AT RISK FROM VOLUNTEERED GEOGRAPHIC INFORMATION

In our approach we follow the previously described concepts of exposure (Villagrán de León 2006b; UNDP 2004) and the definition of risk entailing the term elements at risk, (Alexander 2000), to set the conceptual frame for obtaining elements at risk from VGI.

Our overall methodology with the example of flood-hazard can be seen in Figure 2 and is further explained in the following. As a first step a literature review of common frameworks and methodologies for the classification and evaluation of elements at risk was carried out to compose a list of generally applicable categories (step 1).

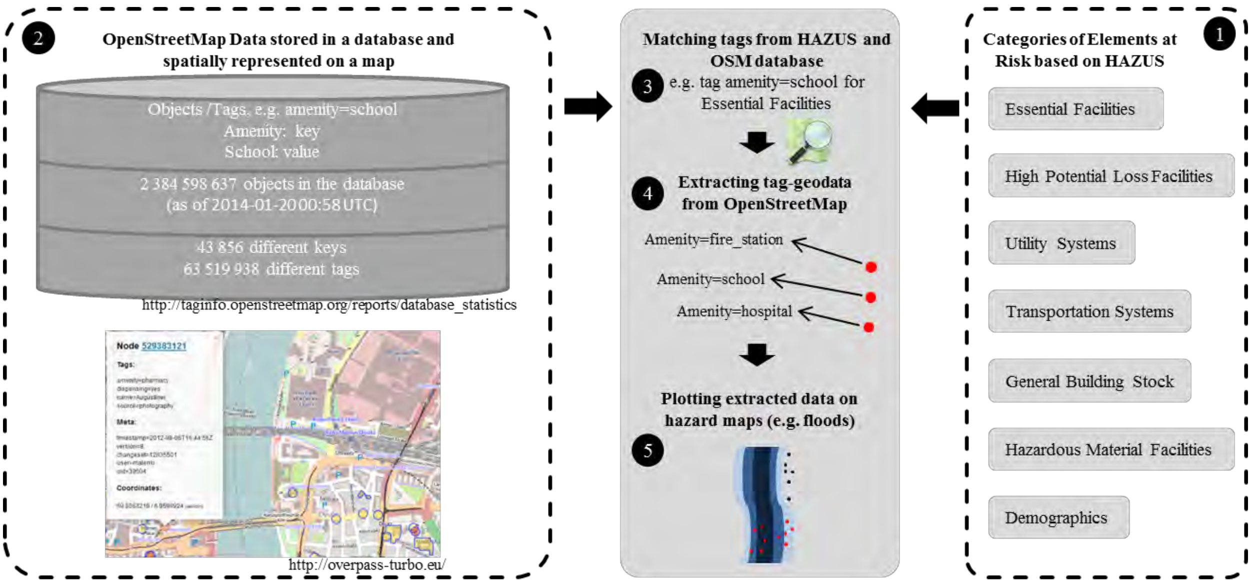

Figure 2: Research Approach and Methodology.

As we found in the HAZUS model the most comprehensive list of categories and descriptors for elements at risk, which are basically consistent with categories proposed by other authors (Jha et al. 2010; Dilley et al. 2005; Villagrán de León 2006b), we utilized the HAZUS categories as described above and in Figure 2 as a basis for this first analysis of the usefulness of VGI for identifying elements at risk. We concentrate on extracting information from OpenStreetMap as one source of VGI, a freely available database of worldwide geo-information with edited collective input by a community of over 1.3 million registered users[1] (Ramm & Topf 2010) (step 2). Based on the HAZUS' categories an examination of the OSM Data Model was carried out to identify object descriptors ("tags") that are frequently used by the OSM community to describe geo-objects. The identified OSM tags were matched to the previously defined categories of the HAZUS model describing elements at risk (step 3). An example of our data model to describe elements at risk with OSM data can be examined in Figure 3 in the case of Essential Facilities. "*Essential facilities are those facilities that provide services to the community and should be functional after a flood. Essential facilities include hospitals, police stations, fire stations and schools*" (FEMA 2012:3-33).

[1] http://wiki.openstreetmap.org/wiki/Stats

Essential Facilities							
OSM Key	**Amenity=**	**Building=**	**Landuse=**	**Historic=**	**Emergency=**	**Social Facility=**	**Aeroway=**
OSM Values	Police	Hospital	Retirement	Heritage	Ambulance Station	Shelter	Aerodrome
	Hospital	Fire Station			Fire Station		
	Doctors	Retirement Home					
	Clinic	School					
	Pharmacy	Kindergarten					
	Social Facility						
	Hospital						
	Fire Station						
	Retirement Home						
	Nursing Home						
	School						
	College						
	University						
	Kindergarten						

Figure 3: Data Model for Essential Facilities based on OSM and HAZUS.

The identified tags were then extracted from the database on a map as point-information to derive a spatial representation of the relevant objects (step 4). In the last step of our methodology, the extracted data can be intersected with hazard maps to derive an indication about the exposure of the identified elements at risk. This approach of identifying elements at risk can be the same for every hazard. Due to the hazard-specific requirements to assess the risk of certain objects, the usefulness of OSM-geodata for risk assessment needs to be further evaluated. However, for the extraction of elements at risk from OSM, our approach is generally applicable for every type of natural hazard.

CASE STUDY EXAMPLE – ESSENTIAL FACILITIES IN FLOOD PRONE AREAS IN COLOGNE, GERMANY

Based on the previously described methodology, we carried out a case-study for flood prone areas of the city of Cologne, Germany to identify elements at flood risk of the category Essential Facilities. The city of Cologne is one of the most flood-prone cities in Europe. The first recorded flood with an inundation height of over 11 meters can be traced back to 1342. Since 1965 the city experienced 42 flood events (STEB 2014). However, the city has made substantial investments in flood risk reduction programmes. Thus, it is an ideal test-bed for evaluating and improving our research approach.

Based on 25 tags (e.g. amenity=school) in the OSM data model corresponding to Essential Facilities we searched the OSM database for the city boundary of Cologne. Our search-results show that 12 out of 25 OSM-tags are used by the community in the city of Cologne representing Essential Facilities. The intersection with a flood-hazard map for Cologne resulted in a list of 168 objects of the category "Essential Facilities" exposed to flood-hazard. Interviews with flood-risk managers of Cologne revealed that our approach is time-efficient when compared to traditional approaches to identify elements at risk and that our approach would be of special interest in regions with lack of official data.

CONCLUSION

This study found out that extracting elements at risk from OSM is a suitable tool to complement to existing object inventories for flood risk assessment. The conceptual match between elements at risk and VGI results in a generally applicable framework for the identification of elements at risk. Thus, the framework can add value in the process of evaluating the exposure of assets to potential hazardous events. Moreover the rapid identification of elements at risk from an expanding database of open geodata updated by citizens can be integrated in practice to improve action planning for risk reduction and response measures, as well as to improve the decision making process of risk managers. The involvement of citizens in the process is advantageous not only for making them aware of potential risks but also because it lowers the cost of acquisition and maintenance of the database with elements at risk. For future work, we aim to further refine and evaluate the data model to include more object types in order to improve generality and applicability of the data model. Moreover, we plan to enhance the coverage of our approach by integrating other VGI sources (e.g. Wikimapia). The data model will also serve as a basis for a decision support toolbox for assisting communities in flood-risk assessment based on VGI. In addition, our research will give new insights into the applicability of VGI and its usefulness and quality for special use-cases like risk assessment.

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