

## **Towards a Decision Support System for environmental emergencies management in poor settlements in the Kathmandu Valley (Nepal)\***

Marta Giambelli<sup>1</sup>, Alfonso Vitti<sup>2</sup>, Marco Bezzi<sup>3</sup>

<sup>1,2,3</sup> Dept. of Civil, Environmental and Mechanical Engineering  
University of Trento – Italy, [ma.giambelli@gmail.com](mailto:ma.giambelli@gmail.com); [alfonso.vitti@unitn.it](mailto:alfonso.vitti@unitn.it);  
[marco.bezzi@unitn.it](mailto:marco.bezzi@unitn.it)

### **Abstract**

The output of the collaboration among ASIA Onlus and the University of Trento (Department of Civil, Environmental and Mechanical Engineering) in the analysis of environmental risk occurrences in the Kathmandu Valley is presented. Aim of the study was to design and implement a prototype of a practical Decision Support System for environmental emergencies management for the informal poor settlements in Kathmandu. Intensive fieldwork and analysis have been carried out to collect the necessary input data for the application. The population of informal urbanized areas has been involved with a participatory approach to discover perception and behaviors during environmental emergency occurrences and to share knowledge and procedures in risk management. The study focuses on one poor-area in the Kathmandu Valley considering flooding, earthquake and fire as environmental risks and aims to be extended to the entire city with the direct involvement of local authorities.

**Keywords:** Decision Support System, environmental emergencies management, Kathmandu Valley, poor settlements, network analysis, FOSS4G.

---

\*This work is licensed under the Creative Commons Attribution-Non commercial Works 3.0 License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-nd/3.0/> or send a letter to Creative Commons, 543 Howard Street, 5<sup>th</sup> Floor, San Francisco, California, 94105, USA.

DOI: 10.2902/1725-0463.2016.11.art4

## 1. INTRODUCTION

In many parts of the world, especially in developing countries, processes such as badly planned and managed urban development, environmental degradation, poverty and inequality along with weak governance are driving levels of disaster risk to new heights (United Nations International Strategy for Disaster Reduction [UNISDR], 2010). Since 2005, countries have been addressing this challenge through the Hyogo Framework for Action (HFA)<sup>1</sup> which aims to achieve a substantial reduction of disaster losses, in terms of lives, social, economic and environmental assets of countries and communities by 2015 (UNISDR, 2014). Moreover, the Bangkok Declaration on Disaster Risk Reduction (DRR) in Asia and the Pacific (2014) included the objectives of enhancing resilience at local levels, promoting further use of science and technology and innovation in DRR, and building coherence between HFA and current processes on the sustainable development goals and climate change arrangements (Asian Ministerial Conference on Disaster Risk Reduction [AMCDRR], 2014).

Nepal is in the early stages of disaster management planning. In order to address the HFA, the project "Mainstreaming Disaster Risk Reduction in Megacities: a pilot application in metro Kathmandu", led by Earthquakes and Megacities Initiatives (EMI, 2010), has been started in Kathmandu, as fast-growing metropolis. It defined a structure and the implementation of a Competent Disaster Risk Management Function for Kathmandu Metropolitan City (KMC). A new unit called the Disaster Management Section was created, structured for preparing and responding to all types of emergencies, from major disasters to the "every-day" risks (EMI, 2010). Currently the process is ongoing and the project is so far limited to KMC although the city is geographically and politically connected and integrated with the rest of the Kathmandu Valley.

The present study, carried out by the University of Trento and ASIA Onlus, was conceived to extend the focus of Kathmandu Valley disaster management planning even on informal settlements (or slums). Therefore, embracing the objective of enhancing resilience at local level, special focus was given to community's capacity building, in particular in poor settlements not recognized by the government and in which vulnerable groups of people live. Main objective of the study was to understand social and environmental contexts of these settlements, through local community participation and fieldwork, as first phase. Additional objective was to create the bases of a Decision Support System (DSS) for environmental emergencies management through the creation of new geographical information layers, the application of network analysis in the case of

---

<sup>1</sup> [http://www.unisdr.org/files/1037\\_hyogoframeworkforactionenglish.pdf](http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf)

emergency and research on local capacity of reaction, using data collected in the first phase of knowledge.

For this purpose, the prototype DSS has been implemented using a GIS (Geographic Information System), addressing the suggested action of using technology and innovation in DRR. In order to make the software accessible, available and affordable to national governments and local communities, the solution was based on open source software. Moreover, in order to create a data set as large as possible both government and open data, such as OpenStreetMap (OSM), have been adopted.

A first joint action by UniTN, ASIA Onlus and the local NGO INCLUDED was the launch of the Migrant Mapping Initiative (see Section 3). The aim was to develop a mapping tool to understand the context of migrant urban settlements across different levels of poverty. The methodology was tested in the informal settlement Balkhu, Kathmandu, during August 2014. The study reported in this paper focused on informal settlements where migrants are expected to live in poor or very poor conditions. This initiative allowed the collection of data and the possibility for understanding and being familiar with the informal settlements' and city's contexts. Therefore, the case study of Balkhu, presented in this paper, provides an application of the analysis and emphasizes the efforts that should be done in order to understand social and demographic features of the settlement and community perceptions on environmental vulnerabilities in a spatially aware approach.

For the poor settlement considered during the project spatial data were essentially not available. A fieldwork was set up and carried out in order to make up for the lack of data. The settlement population participated in the mapping activities, with an experimental and limited involvement of some slum's inhabitants. At the same time, socio economics aspects and environmental risk perceptions were collected by interviews. The use of crowdsourced geospatial data for humanitarian applications has nowadays become very popular, starting from the Humanitarian OpenStreetMap Team (HOT), which applies the principles of open source and open data sharing for humanitarian response and economic development. In case of natural disasters, for example, OSM volunteers from around the world rapidly digitize satellite imagery to provide maps and data, supporting humanitarian organizations and rescue services deployed to the affected countries, such as for Nepal 2015 Earthquake. On the other hand, community development projects have been followed, including the participative mapping of the Kibera slum (Nairobi, Kenya), in which the HOT has been involved, helping other local organizations<sup>2</sup>.

---

<sup>2</sup> Map Kibera: [mapkibera.org](http://mapkibera.org)

At this stage of the project the adopted technologies and procedures were chosen according to prior knowledge. Preliminary works on mapping and socio-economic study were carried out using known tool (e.g. GRASS GIS). Several difficulties about the use of available and known technology on the field had been faced, difficulties arise also from the interaction with the slum community, both from the technical and the socio-cultural point of views.

After the end of the first stage, aims were to exploit the gathered experience to:

- define a standard procedure for data-related activities, such as collection, validation, analysis and management;
- refine the selection of FOSS (Free Open Source Software) to be used in any of the above mentioned data-related activities;
- increase the level of public participation, also by presenting results to the people living in the settlements and involve them directly in some mapping activities (Public Participation GIS [PPGIS]);
- present results to the local government agencies so to drive an improvement of the management practices and living condition of people.

It is necessary to state that this study started just few months before the earthquakes of April and May 2015. After those events the project came to a stop, remaining in a sort of stand-by state and facing found difficulties. Many of the expected outcomes, in particular those that should have led the developments of second stage actions, have not yet been achieved.

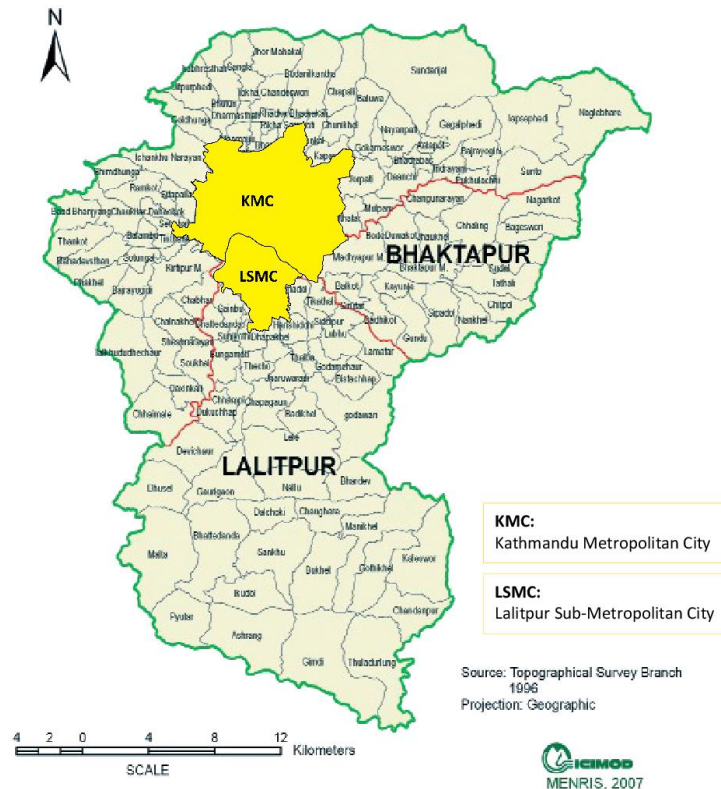
## **2. STUDY AREA: NEPAL AND THE KATHMANDU VALLEY**

Nepal is a small country landlocked between China and India. Its population numbered approximately 26.5 million, with almost 80% of people living in rural areas. The Kathmandu Valley is the political, commercial and cultural hub of Nepal, and it is located in the Central Development Region. Spread across an area of 665 km<sup>2</sup> and at a mean altitude of about 1300 m, the Valley encloses parts of three district: Kathmandu, Lalitpur and Bhaktapur (Figure 1). This area had the highest population density in 2011, reaching the maximum in Kathmandu Metropolitan City, characterized by a value of 4408 people/km<sup>2</sup>.

Nepal's development challenges need to be appreciated against the political backdrop of the last two decades. In 1995 the Maoist rebels started an armed conflict, which lasted for ten years. In 2008 the monarchy was abolished and the country became a Federal Democratic Republic. Nevertheless, currently major

political parties were focused on finding common ground for the creation of an inclusive Constitution until September 2015.

**Figure 1: Map of Kathmandu Valley: The Focus of This Study is on KMC and LSMC, Depicted in Yellow.**



Source: ICIMOD, 2007

Moreover, Nepal is classified as a least developed country with a large fraction of population under poverty level. The extent of poverty in Nepal has dropped to 25% in 2010/2011, but this is an overall figure of progress and not all groups have shared equally in poverty reduction (UN Country Team in Nepal, 2013). Social development indicators in fact reveal unequal progress in gender, ethnic, religious and caste groups, and geographical regions.

Agriculture is the mainstay of the economy, providing a livelihood for more than 70% of the population. Moreover, Nepal has considerable scope for accelerating economic growth by exploiting its potential in tourism, as area of recent foreign investment interest. However, a heavy reliance on tourism and farming makes Nepal's economy very sensitive to climate variability and natural disasters.

## 2.1. Urban Vulnerabilities

Unplanned urban development lead to an increased variety of vulnerabilities. In the Kathmandu Valley urban areas are characterized by the lack of appropriate infrastructure such as water supply and sewerage systems (Toffin, 2010). Moreover, the urban population in the Valley is increasing, with migration as one of the most important factors for rapid growth (Pradhan, 2010). Main push factors are natural disasters, such as soil erosion or deforestation, shortage of inherited land and lack of alternative land. On the other hand, the main pull factors are employment opportunities, access to health care facilities and schooling (Tanaka, 2009).

This steady urbanization led to negative impacts, such as traffic congestion, atmospheric pollution and a total collapse of the former fragile ecological equilibrium between man and his environment (Toffin, 2010). The rivers have also undergone tremendous pressure from the increase in demographic growth and in economic activities. This situation converges to numerous urban vulnerabilities, such as (Bhattarai and Dennis, 2010):

1. lack of emergency vehicular access and vulnerable infrastructures;
2. lack of open spaces;
3. uncontrolled solid waste management, like open dumping practice;
4. unhygienic conditions.

Moreover, property and land prices are increasing, making most housing unaffordable to the common Nepalese and leaving some of them with no other alternative but to squat on open lands, creating the so-called slums. In addition, it is estimated that over the 90% of houses are built by masons, still only the 10% of them are supervised by engineers.

In terms of emergency, rapid urbanization and haphazard development activities have exposed an increasing percentage of population to seismic and other natural risks, while simultaneously decreasing the capacity of emergency services to face disasters (Bhattarai et al., 2010).

### 2.1.1. Slums

The local NGO Lumanti (2008) defines slum communities in Nepal as areas of "poverty, low income, inadequate living conditions and sub-standard facilities". Moreover, these settlements in the Kathmandu Valley are mostly located on

marginalized land: the majority is established on the floodplain of rivers and along dangerous or untenable flooding areas. In fact, rivers' banks do not belong to the Municipality, but to the State (Toffin, 2010), thus a possible reaction time of threat could be slower. Most of the remaining settlements are in areas prone to landslides and on ghats<sup>3</sup>.

The communities are usually inhabited by socially disadvantaged people, with no formal title paper to prove the land ownership. Therefore, those settlements are mostly not recognized by the Government as residential areas.

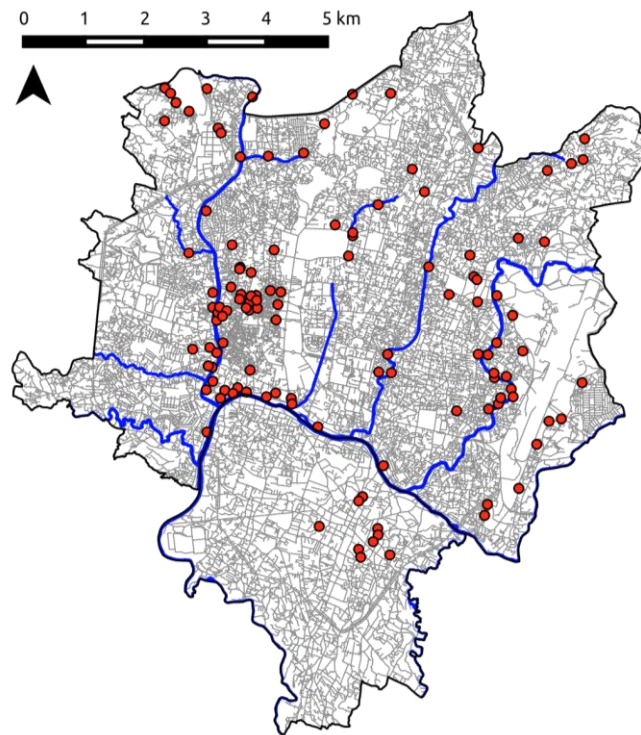
Slum settlements are expanding in size and number along with the expansion of urban areas, reaching the number of 40 settlements and more than 2700 households (Lumanti NGO, 2008) in the Kathmandu Valley. According to the KVTDC (Kathmandu Valley Town Development Committee) map, the slums are even larger, as depicted in Figure 2.

As a consequence of the ongoing political crisis, attempts at addressing these ongoing problems are passed on to NGOs and activists are fighting to inscribe housing rights in the future constitution (Toffin, 2010).

---

<sup>3</sup> Stretches of riverbank protected for cultural and religious purposes, where traditional public buildings are on the verge to collapse (UN Country Team in Nepal, 2013).

**Figure 1: Official Map of Slums and Squatter Settlements in KMC and LSMC. The Rivers are depicted in Blue.**



### 2.1.2. Environmental Hazards

Nepal experiences natural disasters every year, occupying the second position among least developed countries in terms of annual frequency of large-scale disasters since 1985 (Department for International Development [DFID], 2006). Furthermore, according to the Bureau of Crisis Prevention and Recovery at the UNDP, Nepal is the eleventh most at risk country in terms of earthquakes and the thirtieth most at risk for floods. In the Kathmandu Valley, the major natural and anthropic hazards are flooding, fire and earthquakes.

The major rivers flowing through the Kathmandu Valley are Bagmati, Bishnumati and Manohara. The occasional torrential rains, mostly during monsoon period, have caused flooding problems in the core areas of the city, inducing loss of life and damage to private properties, especially in the floodplain.



Fire is another common hazard in the Valley. The most vulnerable area is the central core, where houses are old and made with timbers and closely attached to each other and often characterized by a mixed use, which can worsen the risk. Finally, earthquakes are potentially the greatest threat, as most of Nepal lies in a high-risk seismic zone. According to seismic records, the Country faces one earthquake of magnitude 7 or greater every 75 years, on average (EMI, 2010).

#### Risks for informal settlements

Due to their position and circumstances, informal settlements are highly vulnerable and exposed to natural risks. In fact, the risk of damage has also been increased because of rapid growth of settlements near the river banks and encroachment of the rivers' floodplain. In the final recommendation of the report "Bagmati: Issues, Challenges and Prospects" (2009), the Nepal Water Conservation Foundation (NWCF) suggested the relocation of slum areas from the river bank and floodplain to reduce the risk level and possibly even to reduce the intensity of illegal sand mining (NWCF, 2009). Most of the newcomers to the river banks are in fact unaware of past floods and probably have faced no floods in recent years.

Furthermore, houses in slums are susceptible to fire, due to their low construction standards, in terms of materials and structure, the cooking methods and the overcrowded area, which may accelerate the fire propagation process.

Finally, regarding earthquake, wealthy people are not necessarily better positioned than the poor.

### **3. THE PROJECT "MIGRANT MAPPING INITIATIVE"**

As first part of the study, the "Migrant Mapping Initiative" was launched. The general objective was to develop a mapping tool to understand the context of migrant urban settlements across different levels of poverty. The project has been developed with a multidisciplinary approach, involving a Nepal sociologist, from INCLUDED NGO, and an Italian environmental psychologist, from ASIA Onlus, in addition to the authors of this paper. After understanding the size and scale of internal migrant areas within the Kathmandu Valley, the methodology was tested in one middle-sized settlement, requiring three months of work in total.

The whole process followed four phases:

1. preliminary phase;
2. identification of the community;
3. settlement mapping and collection of information on houses' features;

#### 4. community data collection.

In the first phase, the aim was to make INCLUDED stakeholders aware of the potentiality of using a GIS, after understanding the project's needs. Therefore, the objectives, methodology, database creation, and finally the existing data needed were defined. Regarding the mapping software, the choice has been driven by the necessity of a simple open source tool, that could be operative offline and online, and could address participative methodologies. Our choice fell on QGIS<sup>4</sup>.

Identification of the community was challenging, as not all the communities visited were willing to participate in a research that would not benefit them directly and immediately.

After being accepted by the community, the mapping fieldwork started and continued for three days, with two people working in the settlement. Mapping has been performed by drawing polygons of households and lines of paths directly on zoomed satellite images, as the accuracy of customer GPS receivers was not good enough to map the overcrowded unit buildings. With the help of the community leader and residents, it was easier to understand and to move inside the intricate network of household structures and to orient inside the settlement. Moreover, notes on the structures typology (toilet, school, church,..), building material and other field observations have been taken. A database of drinking water tanks and toilets has been created, getting information on the capacity of them, typology and position relative to the ground. All the elements were then digitalized through the QGIS software, which provides an OpenLayers plugin, allowing the visualization of aerial imagery and data from the most well known mapping applications on the web. It made easier and more consistent the digitalization process.

Finally, the community data collection phase was addressed with particular attention to the community participation within the project. The process included a Focus Group Discussion and questionnaires, held by both community youths and other volunteers from local NGOs. In this phase a training to orient each enumerator with the survey was organized.

---

<sup>4</sup> <http://www.qgis.org/en/site/>

## **4. RESULTS FROM THE “MIGRANT MAPPING INITIATIVE”**

### **4.1. Map and Location of Balkhu Settlement**

Balkhu settlement is located in the 14th ward of Kathmandu District, along the Bagmati River, in the south-western part of the city. The community came into existence about 9 years ago and there are roughly 350 households living in the area and approximately 1400 people. In the municipality map, the area appears as “Shahid Smarak Park”. This means that the settlement is not recognized by the Government and the community is not entitled to basic services, such as water, electricity and sanitation. As consequence, the entity in charge of this has a misleading picture of the situation. In terms of emergency management, identifying a slum as an open space could lead to serious problems: in case of disasters, an open area is likely to be chosen as a place for evacuation or vehicle unloading sites.

The settlement is divided in four sectors, defined by the timeline of the overall growth of the community, and it is characterized by poor housing conditions and materials vulnerable to fire. It is possible to distinguish permanent (and semi-permanent) houses characterized by masonry walls with concrete roof (or temporary roof), and the most lacking ones, made by reused materials such as plastics, metals, bamboos and woods. Furthermore, the internal paths are narrow and labyrinthine, making it difficult to rescue people and save their belongings during a disaster situation.

The area is exposed to different vulnerabilities due to its location, as depicted in Figure 3. On the West side of the community, there is a very busy road, crossed by big trucks, bringing in fruits for loading and unloading, as the proximity of a fruit market in the North. Furthermore, according to the community, the soil where houses are built on is packed with plastic waste, hence it rumbles when the big vehicles pass through and community has problems with sinking soil. With the fruit market on one side, and waste dump in the North side of the community, the area has many waste hazards due to the garbage dump and problems with foul smell, with potential airborne diseases related. Moreover, there are also industrial waste and toxic fumes from a factory that produces utensils, located in front of the settlement. In terms of emergency management, the fuel station and the factory could be considered vulnerable in the case of fire, and the presence of the fruit market makes the area crowded with people and trucks.

**Figure 3: Map of Balkhu Settlement**



#### **4.2. Focus Group Discussion and questionnaires**

One section of the Focus Group Discussion was dedicated to environmental hazards. It took place on Saturday morning, giving to most of the slum's dwellers the possibility to participate. The aim was to collect information on past flood data, community's response to events, frequency and occurrence of disasters, in order to understand the vulnerability of Balkhu community and its perception around the issue. The discussion of this section has been supported by a expeditious participatory maps drawing, to explore different classes of vulnerable areas inside the settlement and to understand the entity of past floods. This map can be considered only as a first merely qualitative information and cannot serve as the flooding risk map or reference information. Further careful studies need to be undertaken to analyze the flow risk on the area in an appropriate way.

In particular, between fire, flooding, earthquake and bank erosion, the community stressed flooding and fire as major concerns. They pointed that homes located in the river proximity have been under direct threat of flooding from the river, as

themselves drawn in a map created for the occasion. However, every year during monsoon and heavy rainfall, the community experienced material loss and damage, but no human casualties have occurred thus far. One leader estimated about 50 houses get affected every year by flood water entering in houses and, at worse, the water comes up to about 0.6-0.9 m. Furthermore, they stressed that there are no organizations supporting them for design of emergency plans, hence they did not know how to escape and where to meet. The community's way to respond to these risks is for the youth group to be alert and warn the community when water level rises, but there are no formal precaution measures.

Despite obtaining these results, even if the community perceived its high vulnerability to environmental hazards, people did not stress them as a priority. Their most important concern was in fact about negotiating a policy with the local governance body to issues house numbers so that they can pay taxes and, at the same time, gain some respite from the evictions threats. Then, the second priority was toilets and sanitation, both the physical structures and also need for awareness on hygiene maintenance.

From questionnaires, demographic and sociological data were collected, useful in order to consider an eventual relocation, as solution to the vulnerable area and status of illegality of the settlement.

## **5. NETWORK ANALYSIS**

The network analysis is a key part of this Decision Support System for the emergency preparedness and response in the Kathmandu Valley. The analysis is here applied into two environments, involving different stakeholders: the first one is related to the arrival of rescuers in the emergency place (EM\_CITY), while the second one is relevant to the evacuation of people from the settlement to reach safe areas (EM\_SLUM).

The procedure followed for the network analysis is the one suggested by the GRASS Tutorial developed by the University of Trento (2010). The network analysis has been applied in the open source software GRASS GIS<sup>5</sup>, which is currently mainly used in universities and research entities. It has powerful capabilities and can be integrated into QGIS. The latter is one of the most used software in International Cooperation applications, as it is highly flexible and easy to use. In this manner the academic world would be linked to a more user friendly world, making results more affordable to the Municipality of Kathmandu or to other final users. Anyway, in both the cases, a training on these two GIS software would be necessary.

---

<sup>5</sup> <https://grass.osgeo.org/>

Regarding the application EM\_CITY, the analysis included:

1. data set up and creation of the network (v.net);
2. allocation across the network to a competence area based on distance and on transit time (v.net.alloc);
3. search for the shortest and fastest routes to reach the settlement (v.net.path).

For the application EM\_SLUM, the procedure was:

1. preparation of data and creation of the network (v.net);
2. search for the fastest path to reach the assembly areas (v.net.path).

In the above lists, the GRASS modules names appear between the parentheses.

The time considered in the analysis is referred only to the transit phase, while event call and preparedness times should be added. The road network used for the study covers the Kathmandu Metropolitan City and the Lalitpur Sub-Metropolitan City, connected to the points which represent the rescue services, while the destination is the studied slum of Balkhu. In the second application, the network consists of the settlement's internal paths, connected to the urban road network and then to specific points, representing the safe areas.

### **5.1. Input Data**

The Kathmandu Valley's data collected for this study come from the Kathmandu Valley Town Development Committee (KVTDC, 2008), OpenStreetMap (OSM, 2014) and fieldwork. The layers used in the analysis are reported in Table 1 along with the related source.

As described by Ravan (2012), some typical challenges experienced during an evaluation of the use of space-based information for disaster management in several countries are:

1. non availability of baseline and thematic spatial data in the framework of GIS;
2. baseline and thematic spatial data available, but scattered at different locations with non-uniform data standards that limit data integration;
3. baseline and thematic spatial data well organized centrally, but not integrated with risk related data.

Some of these situations have been faced in this study. The data collected were scattered at different reference systems, therefore an *ad hoc* Helmert transformation from Everest Modified to WGS84 was performed. Moreover, there was incoherence between data sources (OSM and KVTDC), such as different numbers of rescue services, and non-uniform information, due to different attribute table. For these reasons a web research phase was required in order to get the right and updated information. Then the OSM map had some metadata missed, while the KVTDC map was not updated. Therefore, at least in the settlement area, a data validation by groundtruthing was directed. Moreover, disaster specific data, such as hazards maps related to the three environmental risks considered, were not available. However, they should be considered, especially in the planning and preparedness phase in order to create an effective general system of response, based on a multi-risk analysis.

**Table 1: Maps and Sources Used in the Analysis.**

Application	Maps	Source
EM_CITY	Road network	OSM
	Hospitals	KVTDC
	Fire stations	OSM
	Army barracks	KVTDC
EM_SLUM	Balkhu	Fieldwork

#### 5.1.1. Data for the application EM\_CITY

##### Nepal road status and classification

Before applying the GIS network analysis, it has been important to understand the Nepal road status and standards, in order to make reasonable assumptions. The main road network inside the Valley consists of corridors, one from North to South and one from East to West, along with a Ring Road surrounding the cities of Kathmandu and Patan (Lalitpur). Moreover, there are several radial roads, some originating from the city core area and others from the Ring Road. Apart from these, there are urban roads, most of which are narrow and heavy built-up on both sides, fostering a condition of almost every day jammed roads, which affects the travel time of emergency vehicles and increases response time of emergency services.

The OSM roads layer has been chosen for the analysis; the KVTDC map was in fact not usable, as segments were not connected. The OSM tags for the road type are several, thus they were reclassified in primary, secondary and tertiary roads in order to facilitate the analysis. Furthermore, the topology of the vector was checked and corrected, using the GRASS module *v.clean*, in order to fix the arc-node topology and to adjust the connectivity problems. Moreover, the

maximum speed of roads was missed and the information regarding the access way was useless. Therefore all the roads were considered accessible from both the ways and, from the type, the maximum speed was assumed. As no traffic data was available, the urban speed of 40 km/h has been supposed to be the maximum one in primary links. Even if road rules are not binding for rescuers' vehicles in an emergency situation, the everyday traffic jam has to be taken into account. Finally, a maximum speed of 20 km/h was assumed for secondary roads, along with 10 km/h for tertiary links.

### Rescue services

The rescue services included in the analysis are hospitals, fire brigade stations and armed police barracks. According to JICA and MOHA (2002), in the Valley there are 47 hospitals and only three fire stations, located in Kathmandu, Lalitpur and Bhaktapur Municipality. The third rescue service considered is the Nepal armed police, which has been actively participating in disaster management and leading some emergency operations. It is involved in the collection of information, resource identification, emergency response task assignment, communication with the public, coordination with other security forces, first aid and medical assistance and damage assessment (United Nations Development Programme [UNDP], 2012). However, in the analysis only the location of rescue services was considered, as there was no information available on actual vehicles and equipment.

#### *5.1.2. Data for the application EM\_SLUM*

##### Open spaces as assembly areas

One important concern of strategies to improve preparedness for response is the identification of suitable assembly areas before disasters unfold. Especially in urban contexts, the availability of such areas is often limited and there is an increasing demand for risk sensitive land use planning. Moreover, the evacuation problem is a complex issue, as there are heterogeneous aspects to deal with, like the psychological component of people and their behavior in a stress situation.

Open spaces should be chosen taking into account the proximity to the evacuated settlement and they should be easily and safely reachable by both dwellers and rescuers, without hampering the access to the settlement. Moreover, regarding the extent, for the safety of an individual a 2 m<sup>2</sup> of open space is needed (Bhattarai et al., 2010). This value could be effective: a standing man occupies 0.27 m<sup>2</sup>, still in an emergency situation it should be enlarged, to account for the likely presence of tired or injured people. Furthermore, the choice of the open place depends on the kind of environmental emergency under consideration requiring different and specific reasoning. However, a unique



indication of assembly areas should be given to the community, suitable for all the risks considered.

In order to mitigate the psychological aspect in a stress situation and to make the process of evacuation easier for the slum's dwellers, the plan has been structured by sectors. These areas were identified using a satellite image and through the knowledge acquired thanks to the fieldwork, considering an average household size of 4 people. The data related to these assembly areas are reported in Table 2. However, the current physical status of these areas has to be improved in order to respond efficiently to an emergency situation. For example, assembly areas 1 and 4 have drainage problems during monsoon periods, including slippery mud.

**Table 2: Assembly Areas of Each Sector of Balkhu Settlement.**

No. sector	No. households	Area (m <sup>2</sup> )
1	62	496
2	146	1168
3	99	792
4	40	320

#### Internal paths as evacuation routes

The internal paths of the settlement, mapped through the fieldwork, were classified in primary and secondary, according to their width. The paths orthogonal to the main road are in fact larger than the others, therefore two different speeds were associated to them. In particular, for primary paths a speed of 4 km/h was considered, while for secondary paths a speed of 2 km/h was assumed.

## **5.2. Application**

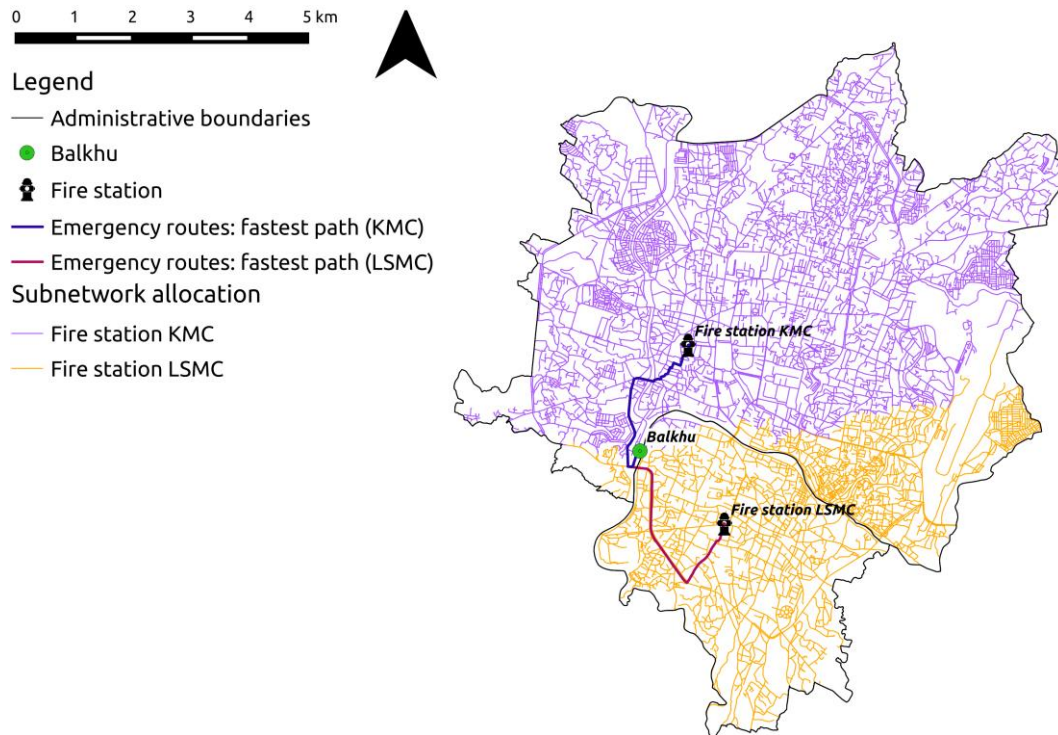
### *5.2.1. EM\_CITY*

From the allocation of sub-network to a competence area results that hospitals are homogeneously dislocated, such as army barracks, while fire brigades suffer from a lack of resources and appropriate spatial distribution. In this paper, only the fire brigades' results are reported, as an explicative example of the analysis. There are in fact only two fire stations, which have to cover an extended area, as shown in Figure 4.

As Balkhu falls in the middle of the two sub-networks, both of them were considered in the analysis. Results that in maximum time of 5 min the LSMC fire fighters could arrive in the area, although located farther from the settlement. In

Table 3, information about the fastest paths for each rescue service is reported. It is worth to notice that in maximum 6 min of transit time, all the rescue services would reach the settlement.

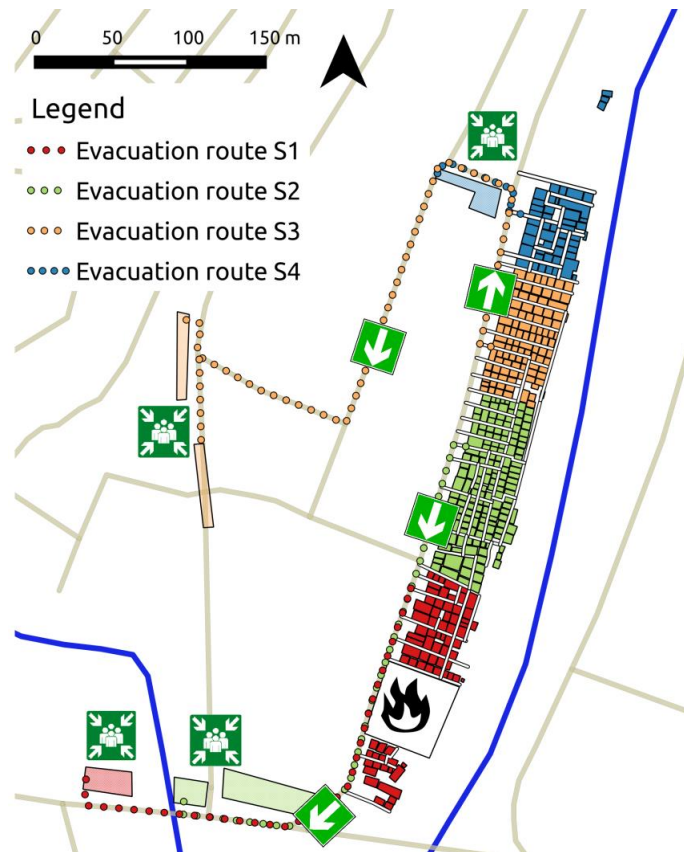
**Figure 4: Fire Brigades Sub-Networks Allocation Based on Time, and Emergency Routes Calculated as Fastest Paths.**



### 5.2.2. EM\_SLUM

The evacuation plan for Balkhu settlement, depicted in Figure 5, has been organized per sectors: this choice makes the escape easier and faster, as people know the sectors' division of the settlement and where friends and relatives live. In this manner, the psychological aspect would be mitigated. The evacuation plan and the emergency routes for the slum's dwellers have been evaluated in favor of security from the farthest point of each sector to the open space related to it. In this regard, results are reported in Table 3. Furthermore, in the network analysis, the main road southward was closed for Sector 3 in order not to overcrowd the way. From the analysis on rescue services, it results in fact to be the entrance road for fire engines: therefore, in this case, a longer path is considered preferable in order to facilitate rescuers action.

**Figure 5: Evacuation Plan for the Settlement: Evacuation Routes and Assembly Areas for each Sector are depicted.**



**Table 3: Information about Emergency Routes for Rescue Services and Evacuation Routes for Each Sector of Balkhu, Calculated as Fastest Paths.**

Emergency routes for rescue services responsible for Balkhu			Evacuation routes for Balkhu's dwellers		
Rescue service	Time (min)	Length (km)	No Sector	Time (min)	Length (m)
Hospital	4	1.5	1	5	385
Fire brigade KMC	6	3.5	2	6	455
Fire brigade LSMC	5	4	3	7	550
Army barrack	5	4	4	2	150

## 6. DISCUSSION AND PERSPECTIVES

As stated by Van Westen (2013), the use of GIS has become “an integrated, well developed and successful tool in disaster risk management”. Hazard assessment, elements-at-risk mapping, vulnerability and risk assessments all have important spatial components (Van Westen, 2013). Therefore, GIS has been chosen as frame for the realization of a prototype Decision Support System.

The objective of the study presented in this paper was to begin the development of a Decision Support System, trying to define a procedural path to identify key elements of emergency plans, with a human face, as suggested by the UN Country Team in Nepal (2013). People in fact have to be at the centre of development planning and awareness generation activities should be carried out. The final objective should include the improvement of the community's resilience, giving them the necessary resources and capacity of organization both prior to and during times of need.

An emergency application in Balkhu settlement, as pilot area, has been reported. The network analysis has been applied exploiting the maps collected or created after fieldwork. The effectiveness of the analysis as emergency support tool has been shown, considering rescue services and slums' dwellers as stakeholders and operating into two different spatial scales. The knowledge of the fastest paths for reaching the settlement and slums' community in the evacuation of the area should support the rescuers in their activities.

This work represents the first approach for an integrated emergency management in the Kathmandu Valley and it defines a methodology which can be extended potentially to the whole poor settlements in the Valley, or in other similar areas. However, it is recognized that more comprehensive knowledge of the Valley is needed. In fact, although the transit time of rescue services results comparable with the evacuation of people in Balkhu settlement, time for the call and preparedness of rescuers should be evaluated, along with other emergency related issues. In case of fire, for example, position of hydrants should be assessed, as well as the location of water sources available. Additionally, a better roads network map is necessary, in order to fill missing information, like speed and accessible roads in terms of width and ways. As traffic jam is a common problem in the Kathmandu Valley, connecting this information with the analysis would make it more efficient and realistic. Furthermore, especially regarding emergency issue, the data collected should be validated in the field, in order to understand the effective resources available and their spatial distribution within the Valley. In this regard, all the collected information should be open and continuously updated, in order to record changes in terms of infrastructures and viability.

A future prospective could also include a climate data updating, in order to improve rescuers reaction and people mobilization. Moreover, environmental hazards maps are needed in order to create risks maps, crossing the information with vulnerability. Furthermore, this tool could be integrated with participative almost real-time damages mapping, creating and digitalizing new post-event layers from fieldwork and via crowdsourcing. Another effective integration could be with the almost real-time collection of remote sensing data and images, used for example for damage assessment activities during the first days after the Haiti earthquake (January 2010). This case demonstrated the value of optical remote sensing as damage assessment tool and the capabilities of satellite and aerial data providers to timely start image acquisition and to make the data available to the humanitarian community (Ajmar et al., 2012).

Despite the project came to an early halt and many expected outcomes had not been achieved, further efforts have been made in the form of proposing other projects so to exploit gathered experience and knowledge. One of the project was aimed to the development of a municipal participatory GIS-based activity to support the post-seismic reconstruction of poor settlements in areas associated with low-levels of environmental risk.

In conclusion, in order to reduce disaster losses, more efforts should be done on Disaster Risk Management and on the identification of the cognitive elements of a territory, developing a flexible and sustainable response model in case of emergency. While in the past decades more emphasis was given to disaster relief, recovery and reconstruction, in the last few years prevention and preparedness have been recognized as central phases in order to address DRR. The improvement of response capacity of territorial systems to adverse shocks and the risk reduction are in fact widely accepted as drivers for the sustainable urban development. Nepal situation is critical and without improving housing spatial distribution and the transportation network, urban vulnerabilities are likely to increase (Bhattarai et al, 2010).

Moreover, the adoption of open data and FOSS, in particular the availability of the OSM, and PPGIS initiatives certainly will remain strategic in the future. Beside the economical aspects, the “open” paradigm permits easy access to information and technologies and it provides an invaluable opportunity for gaining and spreading knowledge. On the other side, the participatory approach is indispensable for the understanding of the social context, for acquiring information otherwise inaccessible, and for leading to more conscious designs and managements of complex societies living in complex environments. Local authorities, with the support of NGOs, should initiate a focus on poor settlements, as these communities are still unseen, unheard and abandoned by the State, even if located in visible places.

## ACKNOWLEDGEMENTS

The authors wish to thank the reviewers for their painstaking reading of the text and the interest in our work shown by their careful and never trivial recommendations. After considering the reviewers' comments and suggestions, this work has been greatly improved. We are also grateful to the chairmen of the FOSS4G-Europe Conference for having selected this paper from the Academic Track session.

## 7. REFERENCES

- Ajmar, A., P. Boccoardo, F.G., Tonolo and C. Veloso (2012). "Earthquake damage assessment using remote sensing imagery. The Haiti case study". *Geoinformation for Disaster and Risk Management. Examples and Best Practices*. Joint Board of Geospatial Information Societies, United Nations Office for Outer Space Affairs, pp. 31-37.
- AMCDRR (2014). *Bangkok declaration on disaster risk reduction in Asia and the Pacific 2014*, Kingdom of Thailand 22-26 June 2014, at [http://www.pacificdisaster.net/pdnadmin/data/original/6AMCDRR\\_2014\\_Bangkok\\_Declaration.pdf](http://www.pacificdisaster.net/pdnadmin/data/original/6AMCDRR_2014_Bangkok_Declaration.pdf), [accessed 08 July 2016].
- ASIA Onlus, <http://www.asia-ngo.org/en/> [accessed 08 July 2016].
- Bhattarai, K. and C. Dennis (2010). Urban Vulnerabilities in the Kathmandu Valley, Nepal: Visualizations of Human/Hazard Interactions, *Journal of Geographic Information System*, 2010, 2: 63-84.
- DFID (2006). *Reducing the Risk of Disasters - Helping to Achieve Sustainable Poverty Reduction in a Vulnerable World*. A DFID Policy Paper, DFID, London, at [http://www.fsnnetwork.org/sites/default/files/dfid\\_disaster-risk-reduction-policy.pdf](http://www.fsnnetwork.org/sites/default/files/dfid_disaster-risk-reduction-policy.pdf), [accessed 08 July 2016].
- Dixit, K. (2015). Preparing to be prepared, *Nepali Times*, (9-15 January 2015), at <http://nepalitimes.com/page/preparing-for-the-next-big-earthquake-in-nepal>, [accessed 06 November 2015].
- EMI, NSET-N and German Federal Foreign Affairs Office (2010). *Structuring and Implementing a Competent Disaster Risk Management Function*. Kathmandu Metropolitan City, Nepal, February 2010, at [http://emi-megacities.org/wp-content/uploads/2015/05/KMC\\_DRM.pdf](http://emi-megacities.org/wp-content/uploads/2015/05/KMC_DRM.pdf), [accessed 08 July 2016].

- GRASS GIS, <https://grass.osgeo.org/>, [accessed 08 July 2016].
- INCLUDED, <http://included.org/>, [accessed 08 July 2016].
- ICIMOD, UNEP and MoEST (2007). *Kathmandu Valley Environment Outlook*, at <http://www.unep.org/pdf/KathmanduValleyOutlook.pdf>, [accessed 08 July 2016].
- JICA and MOHA (2002). *The study on Earthquake Disaster Mitigation in the Kathmandu Valley*, Kingdom of Nepal.
- KVTDC (2008). *Digital Land Use Map of Municipalities of Kathmandu Valley*.
- Lumanti NGO (2008). *Status of Squatter Communities in the Kathmandu Valley*, unpublished.
- Map Kibera, <http://mapkibera.org/> , [accessed 08 July 2016].
- NWCF (2009). *The Bagmati: Issues, Challenges and Prospects*, Kathmandu.
- Pradhan, P.K. (2010). Population Growth, Migration and Urbanisation. Environmental Consequences in Kathmandu Valley, Nepal. *Environmental Change and its Implications for Population*, Vol 20 of the series Advances in Global Change Research: pp 177-199.
- QGIS, <http://www.qgis.org/en/site/>, [accessed 08 July 2016].
- Raj Arjal, K. (2011). *Revisiting disasters responses in Nepal*, at <http://www.icimod.org/?q=6153>, [accessed 08 July 2016].
- Ravan, S. (2012). "Spatial data to complement the use of space-based information for disaster management", *Geoinformation for Disaster and Risk Management. Examples and Best Practices*. Joint Board of Geospatial Information Societies, United Nations Office for Outer Space Affairs, pp. 19-23.
- Tanaka, M. (2009). From confrontation to collaboration: a decade in the work of the squatter's movement in Nepal, *Environment and urbanization*, Vol 21(1): 143-159.
- Toffin, G. (2010). Urban fringes: squatter and slum settlements in the Kathmandu Valley, *CNAS Journal*, Vol.37, No.2.

- UN Country Team in Nepal (2013). *A country Analysis With a Human Face 2011, updated in February 2013*, at <http://un.org.np/reports/country-analysis-2011>, [accessed 08 July 2016].
- UNDP (2012). *Capacity Assessment for Nepal. Urban Search and Rescue, Sustainable Training and Resilient Disaster Management*, at <http://www.flagship2.nrrc.org.np/sites/default/files/knowledge/Nepal%20Capacity%20Assessment%20Final%20Report%20.pdf>, [accessed 08 July 2016].
- UNISDR (2010). *Disaster through a different lens. Behind every effect there is a cause.*
- UNISDR (2014). *Progress and Challenges in Disaster Risk Reduction: A contribution towards the development of policy indicators for the Post-2015 Framework on Disaster Risk Reduction*, at [http://www.unisdr.org/files/40967\\_40967progressandchallengesindisaste.pdf](http://www.unisdr.org/files/40967_40967progressandchallengesindisaste.pdf), [accessed 08 July 2016].
- University of Trento. (2010). *GRASS Tutorial – ver 6.4.0.* at [http://www.ing.unitn.it/~grass/docs/tutorial\\_64\\_en/index.html](http://www.ing.unitn.it/~grass/docs/tutorial_64_en/index.html), [accessed 08 July 2016].
- Van Westen, C. J. (2013). Remote sensing and GIS for natural hazards assessment and disaster risk management. *Treatise on Geomorphology, Vol.3, Remote Sensing and GIScience in Geomorphology: 259-298*, 2013.