EARTQUAKE VULNERABILITY INDICATORS AND VULNERABILITY ASSESSMENT USING REMOTE SENSING, ISTANBUL

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ABSTRACT

There are a number of factors that contribute to the configuration of vulnerability and thus risk in cities. The ultimate objective of this project is to develop a methodology for deriving vulnerability indicators from remote sensing in case of an earthquake and implementing them in a GIS environment for vulnerability assessment and analysis, as a decision support system for disaster management. When an earthquake strikes particularly in a mega city located in a developing country, the loss becomes greater due to high density, inadequate infrastructure and services, unauthorized building, and unbalanced socio-economic developed society. Remote sensing technology with high spatial resolution images enables adequate and up-to date data for disaster management. In this research vulnerability indicators have been defined based on spatial and non-spatial elements, which compose city structures. Spatial vulnerability indicators, so-called physical indicators, mostly have been derived from remote sensing data, whereas non-spatial vulnerability indicators, so-called social and economic indicators, have been derived from remote sensing data in an indirect way. Based on vulnerability indicators, a vulnerability assessment map has been generated. Although the methodology is primarily designed for mega cities in developing countries, the vulnerability indicators could be generalized based on their common features and could be applied in developing countries. Two districts in Istanbul, Zeytinburnu and Uskudar have been chosen as case study. [i]

1. INTRODUCTION

At the beginning of the twentieth century approximately 2 per cent of all humans lived in just 14 mega-cities. Today the portion is close to 20 per cent and it will probably rise to around 30 per cent by the year 2020 (Fellman, 1992). Mega-cities of developing countries are vulnerable to environmental hazards for a complex mixture of reasons (Eibenschutz and Puente, 1991). According to Puente (1999), these mixture of reasons are physical characteristics of the city's location; differences in the material fabric of buildings and infrastructure; variable flows of resources and wastes that shape the urban metabolism; and degrees of coordination among different social agents, especially state, and socio-economic

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[i] The research is a part of a big project called " Earthquake Istanbul project", which is in collaboration with CEDIM (Center for Disaster Management and Risk Reduction Technology), Karlsruhe and the Geo Forshungs Zentrum Potsdam. The aim of the project is estimating the vulnerability of the Istanbul region and the potential direct and indirect economic effects in case of an earthquake.

status of the population. Van Westen (1994) defines vulnerability indicators as property, essential goods and services, such as housing, safe water and food, and infrastructure, such as reliable transportation and energy. Urban vulnerability to natural hazards such as earthquakes is a function of human behavior. Several models of urban vulnerability have been proposed to address the various ways by which society becomes subject to hazard impacts (Menoni, 2001). As many factors can play a role in the occurrence of the disaster event (e.g. an earthquake), analysis of vulnerability is a complex task. In this aspect, the use of Remote Sensing and GIS are considered to be useful tools in the assessment of natural hazards (van Westen, 1994). Remote sensing data, such as satellite images and aerial photos, allow us to map the varieties of terrain properties, such as vegetation, water, geology, both in space and time (ISL, 1993).

The ultimate objective of this project is to detect vulnerability indicators of mega-cities from remote sensing. The research aims to contribute especially in the disaster prevention phase, which includes hazard analysis and assessment, vulnerability analysis and assessment, and disaster management. In this research vulnerability indicators have been defined based on spatial and non-spatial elements, which compose city structures. Spatial vulnerability indicators, so-called physical indicators, mostly have been derived from remote sensing data, whereas non-spatial vulnerability indicators, so-called social and economic indicators, have been derived from remote sensing data in an indirect way. Based on vulnerability indicators, a vulnerability assessment map has been generated. Although the methodology is primarily designed for mega cities in developing countries, the vulnerability indicators could be generalized based on their common features and could be applied in developing countries. Two districts in Istanbul, Zeytinburnu and Uskudar have been chosen as case study.

2. ISTANBUL, TEST SITE

The research was carried out on a test site in Istanbul, located in Turkey (See Figure 1). This developing country lies in one of the most active earthquake and volcano regions in the world and suffers from frequently and devastating earthquakes. More than 95 percent of the country's land area is at risk from earthquakes.

The case area of Istanbul is located near by the Northern Anatolian fault line, thus can be expected to be severely shaken about once in ever century by a destructive major earthquake that takes place in the vicinity. Beyond its closeness to the fault line, Istanbul is vulnerable due to high density, inadequate infrastructure and services, unauthorized building, and unbalanced socio-economic developed society. Moreover, new estimates suggest a yearly probability of around 0.02 of a major earthquake in Istanbul (magnitude 7), which is estimated to result 30 to 40 thousand deaths, 40 to 50 thousand injuries and affect 500,000 households (Erdik, 2000). This places Istanbul among the highest seismic risk mega-cities in the World.

Two study areas have been chosen based on availability of remote sensing data and on their differentiation in urbanization, social features, economical activities, and building development codes[ii]. Zeytinburnu is located on the European side, whereas Uskudar, is located on the Asian side (see Figure 1).

[ii] Building codes: the definition of standards for the construction of buildings and infrastructure, so that they are able to withstand a disastrous event of a certain magnitude/intensity. (Remote Sensing and Geogrphic Inforamtion Systems for Natural Disaster Management , Edited Version January 2000, International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, the Netherlands.C:J: van Westen)

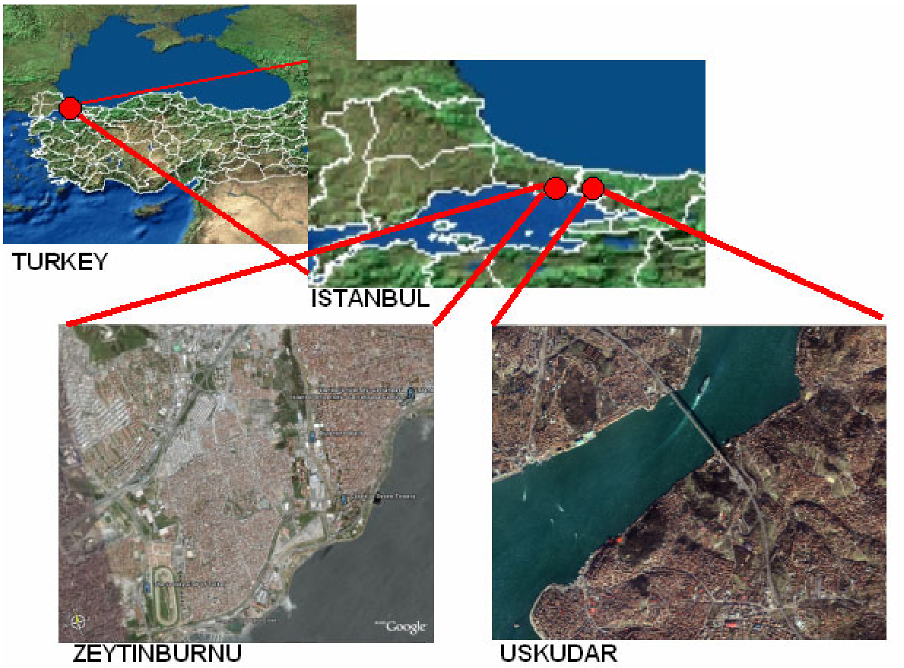

Figure 1: Location of study area, Istanbul, and study cases, Zeytinburnu and Uskudar

3. DATA

High spatial resolution satellite images enable a great potential for recognition and information gathering of urban areas. For this research, 1m resolution IKONOS imagery, taken on December 20th 2003 displaying the center of Istanbul and the central districts of the Uskudar quarter has been used. Statistical and cadastral data has been.

4. METHODOLOGY

Vulnerability indicators have been defined and classified into three classes: physical, economic and social vulnerability indicators. First, physical vulnerability indicators have been derived from remote sensing data through digitalization and visual interpretation and have been implemented in a GIS environment. Correspondence analyses have been executed to generate a homogeneous unit map based on physical vulnerability indicators, such as street pattern, building density, building alignment, open space density and land cover. Next, a questionnaire was prepared based on an aerial quadrant sampling method for fieldwork in the case studies of Zeytinburnu and Uskudar. By a questionnaire social and economical vulnerability indicators were derived as well as some physical vulnerability indicators, which could not be derived from remote sensing data such as, building height, building material, building function, land use and building age. During the fieldwork, auxiliary data for accuracy assessment was gathered particularly from municipalities and private companies. After accuracy assessment, a vulnerability-zoning map will be generated, displaying different vulnerability levels of case studies. The methodology of this research could be seen in Fig. 2.

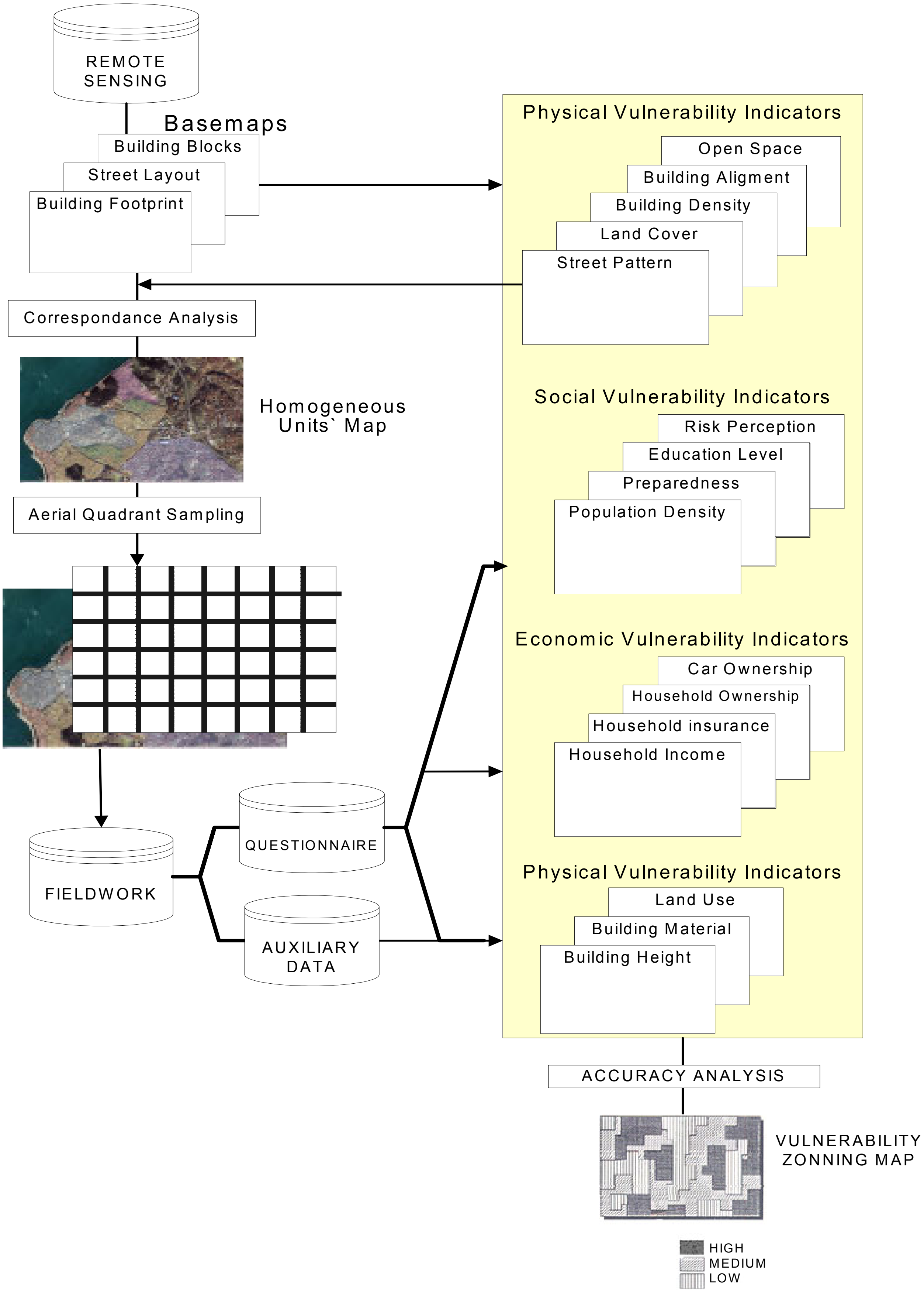

Figure 2: Methodology

4.1 Definition of the Vulnerability Indicators

Vulnerability indicators have been defined based on spatial (physical) and non-spatial (social and economic) elements that configure the urban form and have potentiality for risk. They have been classified into three classes: physical, economic and social vulnerability indicators. GIS base maps` layers were generated, such as building footprint, street layout, and building blocks. First, physical vulnerability indicators have been derived from remote sensing data through digitalization and visual interpretation. Among them is building alignment, land cover, building density, street pattern and open space. Not all of the physical indicators could be derived from remote sensing data.

4.2 Homogeneous Units Map

Correspondence analysis was applied to generate a homogeneous unit map. These analyses are statistical methods allowing to analyze and to describe graphically and synthetically big contingency tables (Greenacre, 1993). Physical vulnerability indicators, derived from remote sensing were weighed, which refers to quantify and to convert data in comparable quantitative format. Then these weighed values were implemented in tables and then a homogeneous unit map was generated. This homogeneous map was combined with an aerial quadrant sampling method, in which areas are divided into equal size of square quadrant. By the help of this combination, in which a single sampled building infer the characteristics of the whole built-up area, time and dependency on field survey was reduced.

4.3. Fieldwork, Accuracy Assessment and Vulnerability Map

Fieldwork consists of two parts, the questionnaire and the acquisition of auxiliary data. Questionnaire has been carried out during the daytime, thus most of the participant was housewife and retired people. In addition, public participation to the questionnaire, particularly in Uskudar, was below the expected number, yet it was enough to be used in the project. These questionnaires have basically been used for deriving social and economic (non-spatial) vulnerability indicators, which were later implemented in a GIS environment. Thus, social and economic vulnerability indicators have been derived through remote sensing in indirect way. Economic vulnerability indicators concentrate on economic statue of the household, in order to measure vulnerability level of household particularly in preparedness and mitigation phase of disaster management. Economic indicators are car ownership, preparedness level to earthquake, communication facilities, household ownership, household income, and insurance types. Social vulnerability indicators are mostly based on the demographic configuration of the household and risk perception. Social vulnerability indicators are density, the number of vulnerable groups of society (woman, children, elderly, and invalids in household level), age of individuals, education level, risk perception, and psychological preparedness.

The second part of the fieldwork, auxiliary data acquisition includes cartographic and statistical data gathering from institutions, interviews with academics, and municipality staff. These data has been used for two purposes. First to define physical vulnerability indicators that could not be derived from RS, such as building height, building material, building function, and land use. The second purpose is that, auxiliary data will be used for accuracy assessment of the vulnerability indicators` results. After implementing all of the vulnerability indicators in GIS environment, as point, vector, or polygon layer, overlays and interactions among the layers will be carried. Then an accuracy assessment will be carried out for these results. As a final step, vulnerability zoning map will be generated, displaying probably three layer of vulnerability in terms of high, medium and low.

5. CONCLUSION

The research is directed towards developing a methodology to derive a certain number of vulnerability indicators from remote sensing. This methodology aims to become a supportive tool in vulnerability analysis and vulnerability assessment of mega cities. Thus, it could provide an opportunity to develop disaster preparedness tools such as early warning systems, awareness raising, capacity building, disaster reduction plans, insurance policies, and construction standards particularly in developing countries.

Research has been carried out at a mega-city located in a developing country, so the indicators developed have been based on structural characteristics of Istanbul. It should be made clear that the set of vulnerability indicators that have been developed not only applicable to developing mega cities, but also for develop countries as well. Even though, mega cities are differentiating among each other, the vulnerability indicators of urban form displays similarities. Thus vulnerability indicators could be generalized and this method could be applicable to developed countries. While the methodology is applied to the other test site, it should be taken into account that, the name and the reason of indicators could remain the same, but parameters used for weighting could change in definition.

Lastly, there is a need for further research, which can overcome some limitations of space borne remote sensing in definition of vulnerability indicators. Especially combination of space-born imaginary and air-borne imagery may be become significant in definition of vulnerability indicators, particularly physical ones.

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