Chapter 1

1 Introduction

1.1 General Scope

In this research, the general scope is centered in the occurrence of earthquakes and its consequences over populated regions of the earth. The earthquakes are natural phenomena consisting in movements of the soils, mostly generated by tectonic phenomena based in the permanent movement of, and interaction between, the tectonic plates which constitute the earth's crust. The consequences of earthquakes are primarily the physical degradations generated over the built environment where the population is settled, which also lead to other results, such as: how these damages impact adversely over the population generating life losses and injuries, with adverse consequences on economic and social activities of populated centres, and even how it may affect psychologically the population instantly, or in the future after the earthquake. These effects may altogether cripple an entire city or region for a period of time, where the recovery of operability close to a normal state may take great amounts of human and budgetary efforts in a society, and even surpass the society's capability to cope with the consequences, becoming what it is called a Natural Disaster. These kinds of disasters may affect not only a country but also a region, as an example, the recent earthquake occurred in the West Coast of Sumatra on December 26th 2004, with a moment magnitude M = 9, affecting 19 countries in total, and generating 283,100 casualties, where the greatest number of victims occurred in Indonesia with a total of 108,100 casualties and 127,700 missing/presumed dead (Figure 1.1). The number of displaced people raised up to 1,126,900 persons in the region.

The several aspects outlined previously, however eloquent, need more precision to understand the scope's approach. The occurrence of earthquakes as natural phenomena is not avoidable, and it is understood as the *seismic hazard* of the premises where it is likely to occur. The physical damage affecting the built environment, as a consequence of earthquake action, is the result of the inherent susceptibility of this environment to seismic action through seismic behaviour, and it is understood as the *seismic vulnerability*; which is avoidable at some extent, as the process of building is in man's hands. The prediction of the possible effects of earthquakes over a built environment is called *seismic risk*, which is a strategy to obtain information of how the damage may be distributed over the built environment due to the occurrence of an earthquake, which allows measuring its possible consequences.

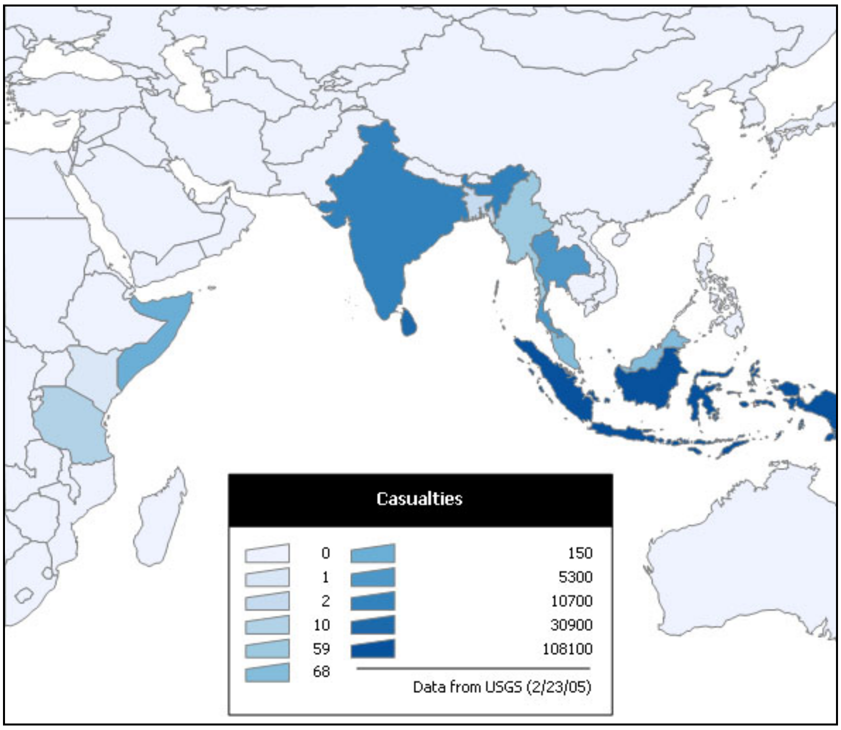

Figure 1.1: Casualties map for the December 26th 2004 earthquake [EERI, 2005].

In the document: *Countering Disasters, Targeting Vulnerability*, from the United Nation's International Secretariat for Disaster Reduction [ISDR, 2001], it is explained how vulnerability is a key element in natural disasters occurrence, as vulnerability depends "… *on the condition of human settlements and their infrastructure, the way in which public policy and administration are engaged in disaster management, the level of information and education available about hazards, and how to deal with them* …".

Observing the trends for earthquake disasters and their impact in the last two decades shown in Table 1.1 (the earthquakes accounted for are those with magnitudes greater than M = 6.0), it is evident how the number of earthquakes although decreasing from the 1990's to the half of the 2000's decade in around a 50%, the number of people killed almost doubles the number in the last decade. This leads to think in a growing vulnerability, in spite the unfavourable impact of lesser earthquakes, which might result from the expansion of urban settlements in the world, characterized mostly by the inability to withstand the action of earthquakes. The increase in vulnerability is a major problem in developing countries, where population concentration and growth over urban areas is mainly uncontrolled, and the physical status of the buildings is very poor, mostly informal non-engineered buildings not considering any code (building, seismic, sanitary), and built over very hazardous sites such as the urban lands left without occupation because of high slopes, soft soils, landsliding hazard, proximity to rivers, etc. This configures earthquake disaster-prone areas, which in many cases contain great percentages of the total population of a city, or even of an entire country.

1990-1999		2000-2005	
Number of Earthquakes	Number killed	Number of Earthquakes	Number killed
1,486	196,782	802	341,600

Table 1.1: Distribution of earthquakes and mortality from year 1999 to year 2005, after [USGS, 2005].

The problem, seen in a wider scope, not only consists in how to assess the different aspects governing risk (hazard-vulnerability), where this risk assessment leads to a forecast of the possible adverse effects, but also in the planning of different strategies and measures to cope with, avoid, or reduce to some extent, these possible adverse effects; this reduction is in the hands of policy-makers by means of planning and legislation, with the co-responsible action of the governmental institutions and authorities that must ensure and enforce the observation of the respective plans and legislations.

The Seismic Risk Analyses require great quantity of high quality information coming from the assessments of seismic hazard and seismic vulnerability, which configure datasets for the different descriptions of the site (pertinent to seismic hazard) and of the built environment (pertinent to seismic vulnerability). Treatment and operations must be performed in these datasets, with the possibility of visualising the data in different manners. The latter leads to the implementation of data administration and visualization tools such as the Geographical Information Systems (GIS) for risk assessments.

1.2 Objectives

In the scope of risk assessment of populated areas, objectives outlined for this research are:

- Review the state of the art of Seismic Risk Assessment.
- Perform a Seismic Hazard analysis for the city of Mérida, with possible local effects.
- Implement a Geographical Information System (ArcView®) for the Seismic Risk Assessment.
- Update building classification for the city of Mérida through the assessment by the WP4-LM1 Methodology; and assess a particular building type (non-engineered housing with RC frame and hollow clay block infill walls) by means of the Italian vulnerability index method, detect patterns in seismic damage and establish a qualitative approach to seismic damage for this particular building type.
- Build and use of the Damage Probability Matrices obtained from the application of the WP4-LM1 Methodology, to obtain the seismic damage distribution in the building stock assessed.
- Perform a Seismic Risk assessment through seismic damage scenarios for the city of Mérida, Venezuela.

1.3 Contents of the dissertation

The dissertation is divided in seven chapters, in which the problem is outlined and developed sequentially applying the different methodologies for Seismic Risk Assessment; the aspects contained in chapters 2 to 7 are described in the following:

- Chapter 2 (State of the Art): a review of different methodologies available to assess Seismic Risk is performed, with the respective definitions, core concepts and applications.
- Chapter 3 (Vulnerability Assessment Methods): from the methodologies used for seismic vulnerability assessment of buildings, a review of three different approaches is performed: the RISK-UE WP4 LM1 and LM2 methods and the Italian Vulnerability Index Method. Features like the identification of the buildings, the vulnerability

descriptors, the nature of the vulnerability functions, and the quality and quantity of the building's information required, are key features studied in this chapter.

- Chapter 4 (Mérida, the City): this chapter describes the geographical and physical context of Mérida City, introducing with a brief history of the city and its evolution from its foundation to the present days, and following with a description of the present state of the city by means of its physical structure, political division, population distribution, general infrastructure, and facilities.
- Chapter 5 (Seismic Hazard for Mérida): in this chapter, the methodology chosen for Seismic Hazard Assessment is explained and applied through the different stages in hazard assessment (seismicity analysis, Probability of Occurrence and Return Periods, Attenuation Laws, and Local Amplification due to soil conditions). The possible induced effects (Landslide and Liquefaction) are also evaluated by means of the HAZUS® methodology application, and the consequent implementation of the information in a Geographical Information System (ArcView® software).
- Chapter 6 (Seismic Vulnerability for Mérida): this chapter uses two different methods for seismic vulnerability assessment of buildings, the WP4-LM1 methodology applied to most of the buildings in the city, and the Italian Vulnerability Index method applied in a building typology homogeneous settlement inside the city. For the European Macroseismic Scale based LM1 Methodology, Damage Probability Matrices are obtained through the application of the approach; for the Italian Vulnerability Index some qualitative appreciations for a specific building type are inferred, based in a code-type analysis for representative buildings prototypes and observed earthquake damage in two different countries in the world for similar building types. Implementation of the data for both approaches in a GIS (ArcView® software) is performed.
- Chapter 7 (Construction and Strengthening Recommendations): a preliminary draft for strengthening existing vulnerable buildings, and improving new constructions is presented, a cost-benefit analysis of seismic retrofit for the vulnerable buildings is carried out.
- Chapter 8 (Seismic Damage Scenarios): based in the vulnerability functions obtained from the WP4-LM1 Methodology, an estimation of the physical damage to buildings is performed in Mérida city, for each of the scenario events, with an implementation of the damage data in ArcView® software.
- Conclusions (Summary, Conclusions and Further Research): this last chapter accounts for the analysis of the results, with the consequent conclusions, and the recommendations for the use of these results. Future research based in the conclusions is also outlined.