Geo-information for measuring vulnerability to earthquakes: a fitness for use approach

Verónica Botero Fernández

International Institute for Geo-information Science and Earth Observation, Enschede, the Netherlands

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ITC, P.O. Box 6, 7500 AA Enschede, the Netherlands

University of Utrecht

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Geo-information for measuring vulnerability to earthquakes: a fitness for use approach

Geo-informatie voor het meten van kwetsbaarheid voor aardbevingen: geschikt voor gebruik?

(met een samenvatting in het Nederlands)

Geo-información para la evaluación de la vulnerabilidad sísmica: una aproximación a la determinación de la aptitud para el uso

(con un resumen en Español)

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Promotor:

Prof. Dr. H.F.L. Ottens

Co-promotoren:

Dr. C.J. van Westen

Dr. R.V. Sliuzas

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to Ana and Raquel

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Introduction

The information you have is not the information you want.
The information you want is not the information you need.
The information you need is not the information you can obtain.
The information you can obtain costs more than you want to pay.
(Anonymous)

The opening quote is an appetizer to what is developed through out this thesis. Information, or rather the availability of useful information, is a critical element for effectively tackling vulnerability. Defining the fitness for use of municipal geo-information is the main topic of this research. In the following chapters a complete literature review on vulnerability and municipal provision of geo-information is reported on. Also the methods developed and used are presented, as well as the application in two case study cities. The objective of this introductory chapter is to describe briefly the context and approach of this research. First, a general description of the consequences of geo-hazards and the relevance of risk management for both the developed and developing world are explained. Secondly, the motivation and the research objectives, questions, and goals are defined. Finally, the thesis outline is presented.

1.1 Research Context

Between 1980 and 2003 (see Figure 1.1), geo-hazards (earthquakes, landslides, volcanic eruptions) and weather related hazards (floods, extreme temperatures and wind storms) have claimed the lives of more than 700 000 persons around the world (OFDA/CRED, 2006) and have produced an estimated damage of 740 billion US dollars. The most deadly natural hazards in the past two decades have been wind storms, earthquakes, and floods; and in terms of estimated damage, floods and wind storms account for 75% of the total, without considering the economic effects that can represent about fifteen percent of the GDP in these countries (OFDA/CRED, 2006).

Even though natural hazard threats are present in most parts of the world, according to the data collected in the International Disaster Database (OFDA/CRED, 2006) most of the natural hazards occur in developing countries, and it is estimated that over 95 percent of all deaths caused by disasters occur in developing countries (Kreimer et al., 2003).

Of the world urban population, about 70% is located in developing countries. Much attention has been centered on mega-cities (those with 10 million or more) in recent years, but they are not home to a large proportion of the world's urban population, nor are they going to absorb a significant proportion of future urban growth. Smaller cities (those with fewer than 500,000 inhabitants) still contain more than half of the world's urban population (UN/FPA, 2007).

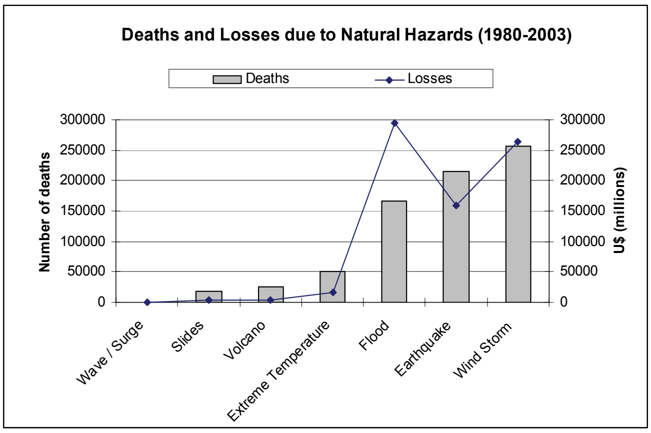

Figure 1.1. Death Toll and Estimated Damage due to Natural Hazards from 1980 to 2003 (OFDA/CRED, 2004)

The information contained in disaster databases has to be analyzed carefully in order to understand the devastating effects of natural hazards. Comparisons between different groups of countries have to be made to see the human and economic consequences of disasters. The Human Development Index (HDI) can be used for grouping of countries. The United Nations Development Program -UNDP- calculates the HDI (Human Development Report, 2003) using a Life expectancy Index, an Education Index, and a GDP Index (UNDP, 2003) and ranks the countries as follows:

Low human development	HDI < 0.50
Medium human development	0.50 <= HDI < 0.80
High human development	HDI >= 0.80

If the disaster data available at the Emergency Disasters Data Base (EM-DAT) were to be displayed differentiating countries in these three major groups, in terms of not only of lost lives but in terms of economic losses, as in Figure 1.2, one can conclude that even though economic losses are higher in the developed countries, almost 90% of the casualties are in the countries with low and medium human development.

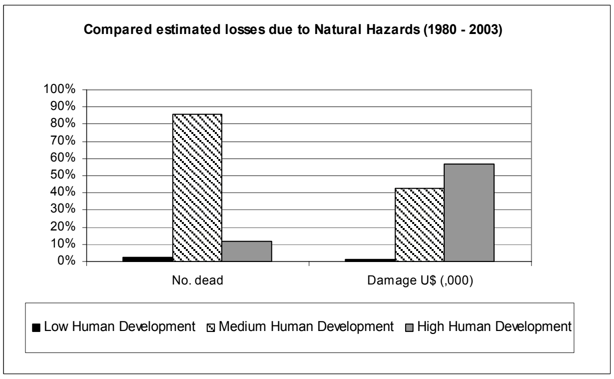

Figure 1.2. Normalized estimated losses due to natural hazards in the period 1980 – 2003 (OFDA/CRED, 2004; UNDP, 2003)

In Figure 1.3, a comparison between the economic losses due to natural hazards as percentage of the Gross Domestic Product (GDP) is presented. Although the values do not exceed 4%, it is clear that the most affected countries are the ones with medium human development. The economic losses in countries of low and medium human development delay their economic development by many years.

An increasing awareness of the effects of natural hazards lead international agencies to add up efforts in disaster reduction. In 1989, the United Nations declared the period 1990-2000 as the "International Decade for Natural Disaster Reduction - IDNDR". The purpose of the IDNDR was to organize the policies, experience, and expertise in each country to reduce loss of life, human suffering, and economic losses caused by natural hazards. In May 1994, during the World Conference on Natural Disaster Reduction, a set of guidelines for natural disaster prevention, preparedness, and mitigation were adopted and called the Yokohama Strategy and Plan of Action for a Safer World. These guidelines included a set of targets to be achieved by all countries by the year 2000. The targets can be summarized in three main topics (UNESCO, 1994):

- Complete National Risk Assessments: Identify natural hazards which pose the threat of disaster; Evaluate the geographic distribution of hazard threats and their frequency and impacts; Assess the vulnerability of populations, development, and resources.
- Implement National and/or Local Prevention Preparedness Plans
- Implement Global, Regional, National, and Local Warning Systems

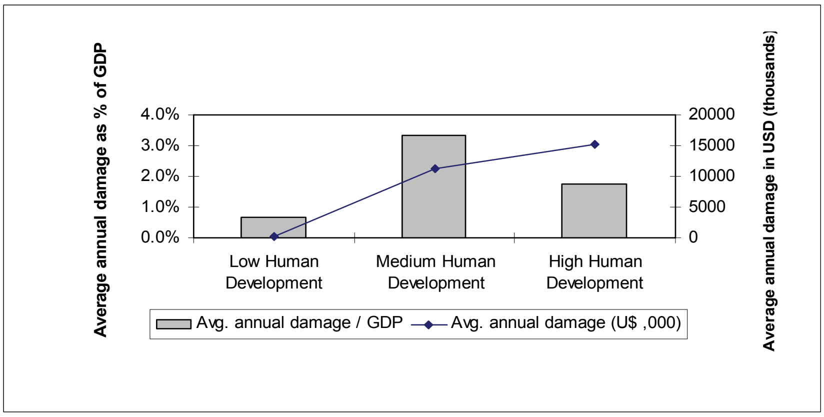

Figure 1.3. Average annual economic losses due to natural hazards for the period 1980 -2003 (OFDA/CRED, 2004; UNDP, 2003)

The targets were only partially achieved and few countries completed their national risk assessments, implemented national and/or local prevention preparedness plans, or implemented global, regional, national and local warning systems. By the end of the 1990's, the United Nations created a successor policy: the International Strategy for Disaster Reduction -ISDR- aimed at helping the communities reduce the risk of long term social and economic disruption in the face of natural disasters.

In spite of the efforts of international agencies, disasters triggered by natural hazards keep threatening development and increasing poverty worldwide. Losses due to natural disasters remain a major obstacle to sustainable development and the achievement of the Millennium Development Goals (MDG's) (United Nations, 2002). Until 2004, more than USD 1 billion have been spent in economic and infrastructure recovery due to natural disasters according to statistics recorded for the last 6 years by the Financial Tracking System of UN-OCHA (United Nations - Office for the Coordination of Humanitarian Affairs), that is without considering the tsunami in Indonesia (2005) and the last earthquake in China (2008). The World Bank and United States Geological Survey (USGS) calculated that economic losses worldwide from natural disasters in the 1990s could have been reduced by $280 billion if $40 billion would have been invested in preparedness, mitigation, and prevention strategies (World_Bank, 2004).

If the amount of money spent in recovery due to natural disasters were to be compared to the amount of money invested in risk management initiatives in developing countries, it would result in an unbalanced scenario. Risk management or disaster reduction initiatives are a small percentage of the money spent in recovery. Disaster prevention is a very attractive investment; on average, for every USD1 invested in disaster preparedness, USD7 can be saved in disaster recovery costs (Abramovitz, 2001).

The ISDR (2005) gathered at Hyogo at the beginning of 2005 to review the lessons learned and identify the gaps of the Yokohama strategy. Their conclusions indicate that these gaps and challenges are mainly in governance (organizational, legal and policy frameworks); risk identification, assessment, monitoring and early warning; knowledge management and education; reducing underlying risk factors; and preparedness for effective response and recovery. These are the key objectives for the Hyogo framework for action for the decade 2005–2015.

1.2 Motivation

During the International Decade for Natural Disaster Reduction (IDNDR), an enormous effort was dedicated to devise and promote initiatives to reduce risk due to natural hazards. At the doorstep of the new millennium, the decade ended with more disasters, resulting in more deaths, more human dislocation and suffering, and greater economic losses than when it began. The trend during the last decades shows an increase in the number of natural hazard events and their consequences.

All countries suffer after a natural hazard, but those unprepared to cope with its effects, basically due to low development, suffer the most. Local and national government offices have to manage information concerning natural hazards and vulnerability to define strategies for risk management. We cannot avoid natural hazards from happening, but we can contribute to the understanding and study of the factors that make up vulnerability as the only factor in the risk equation that we can manage. In this endeavor, information is a key factor in vulnerability reduction.

Living in a hazard prone country like Colombia, where earthquakes, volcanic eruptions, landslides, and floods are part of every day life, gives earth scientists motivation and opportunity to undertake research projects that will have an impact on decreasing the consequences of these hazards.

1.3 Problem statement

Most planning authorities rely on hazard maps to define risk management plans and projects, but these maps only depict the threat and not the whole picture of what and who can be affected by these hazards. For instance, the 1988 earthquake in Armenia and the 1989 Loma Prieta earthquake in California were of similar magnitude and affected populations of comparable size. However, the Armenian event killed 25,000 people whereas the Californian earthquake killed only 63. This difference in casualties is due to different vulnerability levels in the 2 cases. Therefore, it is not only important to understand the hazard, but to fully grasp the concept of vulnerability and measure it in all its types and for all the disaster phases. Authors such as Menoni et al (1997), point out that a comprehensive approach to assessing systemic vulnerability is needed, especially when referring to urban and regional systems.

Vulnerability assessment is a fundamental component of determining risk and planning in hazard prone environments. Urban vulnerability assessments often rely on a one-off survey, providing a snapshot of vulnerability that may quickly become outdated, more uncertain, and less useful over time. An alternative approach to assessing vulnerability is to exploit typical municipal databases. The assumption in this study is that increasingly municipalities will have access to more and better quality digital data sets. To test the idea that these information resources could be better exploited than is currently the case, an objective fitness for use assessment is developed and performed on the existing municipal data sets in this research.

As municipalities manage the built environment and typically also have a broad range of responsibilities related to the population and their well being, the local economy, and the environment, they inevitably collect and use a great amount of data that could also be of use for risk management. Considerable attention is now given to improving the organization and management of information resources at all levels, from local through to global through the establishment of Municipal or Urban Information Systems (MIS or UIS), or through Spatial Data Infrastructures (SDI - see for example www.gsdi.org). SDI's make it possible to share data between various applications, thereby adding to the value of each piece of data and offering economies in terms of its collection and maintenance. In this current work we examine the potential for doing just that for assessing vulnerability.

1.4 Research Objectives

Disasters are the unfortunate combination of a hazardous event and a vulnerable system, resulting in general disruption and destruction, loss of life, loss of livelihood, and injury. The trend during the last decades shows an increase in the number of natural hazard events and of their consequences. Therefore, we are called to invest in vulnerability reduction. This means understanding vulnerability, its types, how it can be measured, what kind of information is used to measure it, and most of all, whether municipalities use the data sets they collect for multiple purposes and assess their fitness for use for vulnerability assessments.

The main objective of this research is to develop a methodology to assess the fitness for use of municipal geo-information for earthquake vulnerability assessment. It will establish whether and to what extent the vulnerability indicators calculated using this geo-information are suitable for decision making. Based on this fitness for use assessment, a development path can be devised to enable municipal data to be better used for such assessments on a regular basis.

Other objectives are:

1. To define the indicators and information needs for the three disaster phases (impact, relief, and recovery) for the main vulnerability types (physical, socio-

cultural, economic, and political-institutional) based on an extensive literature review of vulnerability assessment methods.

2. To understand how municipalities deal with geo-information for multiple purposes in the developing world context, especially in Latin America and Asia.
3. To apply and assess the proposed methodology in two concrete contexts with different characteristics: one municipality that is data rich – capacity moderate and another municipality that is data poor and capacity deficient, both in developing countries. It is important to point out that the choice of two case studies with such context differences can help in specifying a development path for better use of municipal data for vulnerability assessment.

1.5 Research Questions and Goals

To fulfill the research objectives, several research questions were postulated:

- What are the variables that are needed to measure the vulnerability of a municipality, and which is the data needed to assess them?
- What are the typical data sets in a municipality in a developing country? Are they sufficient and adequate to measure vulnerability?
- What is the fitness for use of this data? How can this fitness for use be measured, in order to assess the overall uncertainty of the vulnerability measures?
- Can vulnerability be measured and quantified using existing municipal data sets, and if yes, how?
- How can an information strategy be developed based on local conditions?

These questions are aimed at pursuing the following research goals:

First, to generate a scientifically valid set of indicators for the three phases of a disaster (impact, relief, and recovery) for four types of vulnerability based on an extensive literature review of vulnerability assessment methodologies. Second, to design a methodology that can be used by risk experts, acquainted with a specific municipality, to determine the relative importance of these indicators and the characteristics of the data available. Third, to assess the fitness for use of the available geo-data and to establish an information priority list for vulnerability assessments that reflects other possible uses by the municipality. And finally, to assess the indicators selected for the city of Medellín, one of the case study areas, at the same time developing specific methods to calculate each of them using GIS capabilities at different intra-urban scales. The fulfillment of these goals will render more insight into the urban vulnerability assessment problem and the use of geo-information by municipalities.

1.6 Thesis outline

This first chapter introduces the thematic context of the study, the main research problem, the motivation to pursue the research, and the research objectives, questions, and goals.

Chapter 2 presents the conceptualization of vulnerability based on an extensive literature review. Paradigms of vulnerability, vulnerability types, methods to measure vulnerability, and vulnerability elements as considered by different authors are explained. The chapter ends by presenting both the most simple and most elaborate concept of vulnerability in terms of information.

Chapter 3 explains the evolution of concepts of urban management, from supply-driven to comprehensive institutional development. Some urban management models and urban management structures are presented. The Urban Information Pyramid as defined by Huxhold (1991) is explained, as well as the concept of Urban Information Systems (UIS). A general approach to spatial data infrastructures (SDI's) and geo-services is given and the vulnerability variables in the context of an UIS are indicated. Once the general concepts of urban management are explained, some concepts about quality of geographic information are discussed.

Chapter 4 describes the methods used in the research. The conceptual research model is presented. The case study selection criteria are explained and a brief description of the municipal setting and the Risk management setting -policies, institutions, projects- is presented for the two case studies (Data Rich – Capacity Moderate Case Study: Medellín, Colombia and Data Poor – Capacity Deficient Case Study: Lalitpur, Nepal).

Chapter 5 describes the selection of case studies, and a brief introduction to both settings is given.

Chapter 6 presents the results for the case study in Medellín, and in Lalitpur. A critical analysis of quality issues of the available information for each case study is given, and a development path for both municipalities is devised.

Chapter 7 presents the vulnerability analysis with the selected indicators for the case study in Medellín, explaining in detail how each of them was calculated, to illustrate the possibility of using municipal geo-information for vulnerability assessments.

Chapter 8 focuses on the conclusions, recommendations, and further research, bringing the book to a close.

Chapter 2
Vulnerability

We feel obliged to speak of missing persons or unheard voices; of 'hidden damage' and 'shadow risks' and, more severely, of 'silent' or 'quiet violence'…We identify 'voiceless' and 'invisible' presences; conditions and people ignored or marginalized.
K. Hewitt, 1995

The study of risk has inevitably ended up focusing on vulnerability as the main factor that can be changed, contrary to hazard. Researchers from varied scientific disciplines have devoted many years to the study of the variables, causes, and possible solutions to the issue of vulnerability reduction. This chapter presents an overview on vulnerability; the evolution of the term and its implications within the science of disasters are reviewed. Several models defining its progression and the factors involved are also addressed. Finally a comprehensive view from an information management perspective sums up the chapter, setting up the basis for the use of existing municipal geo-data for vulnerability assessments.

2.1 Paradigms of risk and vulnerability

The study of disaster and risk has gone through an interesting evolution during the past decades. Although this chapter deals with vulnerability, a few other concepts like risk, hazard, and capacity have to be introduced. This myriad of terms has evolved along with human understanding of the mechanisms and implications of disasters.

A set of paradigms have ruled the study of disasters and risk in the past decades, defining the usage of terminology and conditioning the importance given to all the concepts surrounding the topic of risk.

2.1.1 Technocratic paradigm

The first approaches to risk were the ones that assimilated it to hazard or focused mainly on it, carried out especially by professionals of the natural sciences (geologists, engineers, meteorologists, etc.). According to Blaikie et al (1994), until the emergence of the idea of vulnerability to explain disasters, there was a range of prevailing views, none of which really dealt with the issue of how society creates the conditions in which people face hazards differently. The first approach was unapologetically naturalistic, in which all blame was apportioned to 'the violent forces of nature' (Frazier, 1979; Foster, 1980 cited in Blaikie et al, 1994). Governments and individuals relied upon physical protection against the hazards.

2.1.2 Physical or Structural paradigm

The concept of vulnerability entered the risk scene. Protection was defined not only according to the physical protection systems built, but also according to the people's behavior. This inclusion of people's behavior led to the design and use of early warning systems and educational programs about hazards and how to protect against them.

This paradigm lasted for a couple of decades and was even used during the Yokohama Strategy and Plan of Action for a Safer World (1994), where all the efforts were aimed towards increasing our scientific knowledge about the causes and consequences of natural hazards and facilitate its wider application to reducing vulnerability of disaster-prone communities. This perspective included overall development, attacking root causes, and capacity building.

2.1.3 Complexity paradigm

A new understanding of the complex interaction between nature and society has emerged, and as such, a new complex approach to understanding risk has to be undertaken. As Hilhorst and Bankoff (2003) point out, vulnerability is not only about groups or individuals, but is also embedded in complex and social relations and processes.

2.2 Definitions

To understand better these paradigms it is important to set up a framework of terms. The following definitions are the result of a broad collection of different international sources, performed by the ISDR, responding to a need expressed in several international venues of precise definitions to avoid confusion in the terms used in risk management (UN/ISDR, 2004).

"***Risk:*** The probability of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or technological hazards and vulnerable/capable conditions. Conventionally risk is expressed by the following function:

Risk = (Hazards, Vulnerability/Capacity)"

Beyond expressing a probability of physical harm, it is crucial to appreciate that risks are always created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risks and their underlying causes.

"***Disaster:*** A serious disruption of the functioning of a community or a society causing widespread human, material, economic, or environmental losses which exceed the ability of the affected community/society to cope using its own resources. It results from the combination of hazardous events, conditions of vulnerability, and insufficient capacity or measures to reduce the potential negative consequences of risk."

"***Hazard:*** A potentially damaging physical event, phenomenon, and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) and/or induced by human processes (environmental degradation and technological hazards). Hazards can be sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability."

"Natural hazards: Natural processes or phenomena occurring in the biosphere, lithosphere, atmosphere, or hydrosphere that may constitute a damaging event. Natural hazards can be classified by origin namely: geological, hydro-meteorological, or biological. Hazardous events can vary in magnitude or intensity, frequency, duration, area of extent, speed of onset, spatial dispersion, and temporal spacing."

"Technological hazards: Danger originating from technological or industrial accidents, dangerous procedures, infrastructure failures, or certain human activities, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Some examples: industrial pollution, nuclear activities and radioactivity, toxic wastes, dam failures; transport, industrial or technological accidents (explosions, fires, spills)."

Considering that vulnerability is the main focus of this research, an extended explanation of the evolution of the definition is necessary. The term vulnerability has evolved as the understanding of disaster and risk has improved. It has evolved from terms such as condition of danger, inability to absorb, inflexibility, capability to protect, susceptibility of suffering damage, internal risk factor, propensity to damage, probability of suffering damage, and degree of loss to more positive terms, such as capacity to anticipate-cope-resist-recover and lately the ISDR (2002) has redefined the concept as conditions which increase the susceptibility to the impact of hazards.

In the following definitions, the evolution of the term vulnerability can be traced as well as the understanding of the importance of the community as an active agent in decreasing vulnerability through their capacities.

Vulnerability expressed as an intrinsic aspect of hazard. Vulnerability depends on the hazard and it cannot be changed:

- "**condition in which human settlements or buildings are in danger** due to the proximity of a hazard, the quality of the building materials or both" (Cuny, 1983).
- "**propensity** of things to be damaged by a hazard" (Coburn et al., 1994).
- "internal risk factor of a subject or exposed system to a hazard, corresponds to its **intrinsic predisposition** to be affected or susceptible of suffering a loss" (Cardona, 1993).
- "the **degree of loss** to a given element or set of elements within the area affected by a hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss)" (UNDRO, 1979).

Vulnerability expressed as the inflexibility to adapt to change. The vulnerable subject is unable to change its inherent conditions:

- "a community's **inability** to absorb, through auto-adjustment, the effects of a certain change in its' environment." Change inflexibility (Wilches-Chaux, 1988).
- "**to be susceptible** of suffering damage and having difficulties recovering from it. **Inflexibility** or inability to adapt" (Maskrey, 1993).

Vulnerability as the probability of suffering damage or being susceptible of suffering damage:

- "a community's **probability** of suffering human or material damage if exposed to a hazard, according to the **degree of fragility** of its elements (infrastructure, livelihood, production activities, organizational degree, early warning or alert systems, political and institutional development, etc.) (Caballeros et al., 2000).
- "**being prone to** or susceptible to damage or injury" (Blaikie et al., 1994).
- "**how easily** the exposed people, physical objects and activities may be affected in the short or long term" (Davidson, 1997).
- "**predisposition, susceptibility** or physical, economical, political or social feasibility of a community to be affected or of suffering damages in case a destabilizing phenomenon of natural or human origin occurs" (Cardona, 2001b).
- "**level of graveness** up to which a community, a structure, a service or a geographic area can be affected or disturbed by the impact of a certain hazard" (Chardon and González, 2002).

Vulnerability expressed as a combination of exposure and capacities:

- "the **characteristics** of a person or group in terms of their **capacity to anticipate, cope with, resist and recover** from the impact of a natural hazard" (Blaikie et al., 1994)
- "the **conditions** determined by physical, social, economic, and environmental factors or processes, which increase the **susceptibility of a community** to the impact of hazards" (UN/ISDR, 2004).

Although different classifications of vulnerability have been presented, most schools of thinking underline the fact that vulnerability should not be limited to an estimation of the direct impacts of a hazardous event. From all the definitions listed above, and considering the dynamic and complex nature of the term, the proposed working definition for vulnerability based primarily on the terminology defined by the UN/ISDR (UN/ISDR, 2004) is:

Vulnerability: conditions that make a vulnerable subject (in our case the combination of people and infrastructure entangled by social, cultural, economical, political, and institutional relationships) susceptible to the impact of a hazard and also the capacity or ability to cope, resist and recover from the impact of the hazard.

Capacity has to be understood as a combination of all the strengths and resources available within a community, society, or organization that can reduce the level of risk or the effects of a disaster. Capacity may include physical, institutional, social or economic means, as well as skilled personnel or collective attributes such as leadership and management. Capacity may also be described as capability.

Two important aspects are highlighted: existing conditions and capacities. These two aspects will be discussed in depth in the vulnerability models.

2.3 Vulnerability models

Simplistic notions about vulnerability have been overruled in the past decade as the complexity of risk has been unveiled. From a geo-information perspective, new forms of measuring the unsafe conditions and the capacities that people have should be developed in order to understand and cope with hazards. These forms of measuring these conditions and capacities have to reveal, as much as possible, the dynamic nature of vulnerability without becoming mere rhetorical indicators.

Different prevailing approaches have been developed for the analysis of vulnerability. Birkmann (2006) mentions several conceptual frameworks of vulnerability developed within the social sciences, such as the double structure of vulnerability (Bohle, 2001) that explains the importance of coping and response capacity as the internal side of vulnerability and exposure as the external side, or the sustainable livelihood framework (Chambers and Conway, 1992) where the key elements are the livelihood assets or capitals (human, natural, financial, social and physical), and the vulnerability context is understood as shocks, trends and seasonality, and the influence of transforming structures. Other research groups have different frameworks for vulnerability. The school of climate change developed the Risk-Hazard (RH) model (Turner et al., 2003) that explains the impact of a hazard as a function of exposure of a system to the hazard and the response of the system as shown in Figure 2.1, where the concept of vulnerability is commonly implicit.

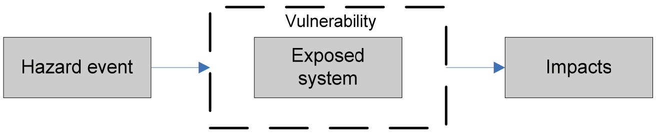

Figure 2.1. RH model (Turner et al., 2003)

This model includes a detailed description of the factors that compose vulnerability (see Figure 2.2). The first factor or *exposure* deals with the physical components of the system and the characteristics of the hazard. The second factor or *sensitivity* deals with the human components (social, economical, political, institutional and cultural). The third factor or *resilience* deals with the response of the system, therefore entrails aspects of institutional, political, and economical origin. Resilience has been defined as the adaptive capacity or the ability of the system to respond, cope, and recover (Stephen and Downing, 2001; Turner et al., 2003). Some other models (Cardona, 2001a; Cutter et al., 2000; Davidson, 1997), based on the RH model, consider vulnerability as a linear function of several factors, as explained in section 2.5.2.

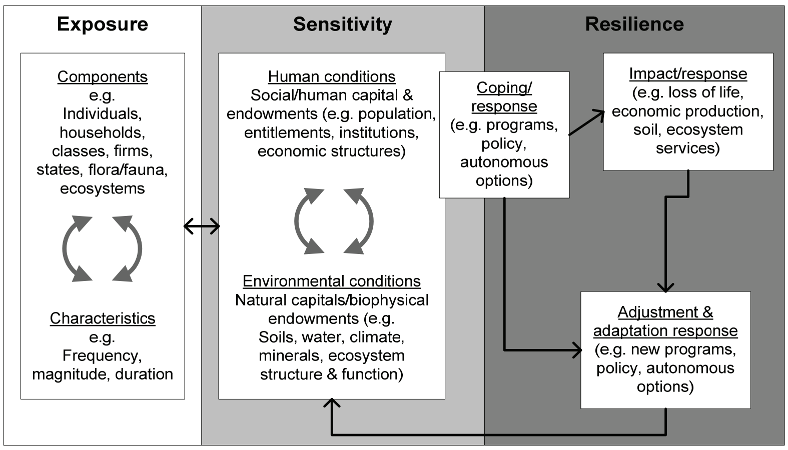

Figure 2.2. Vulnerability Components (Turner et al., 2003)

Mark Pelling (2003) presents a slightly different model defining *human vulnerability* as the result of Exposure, Resistance, and Resilience, based on the work of Castree and Braun (2001). His model is presented in Figure 2.3. In this model, the concept of Resistance can be regarded as the concept of Sensitivity in the RH model.

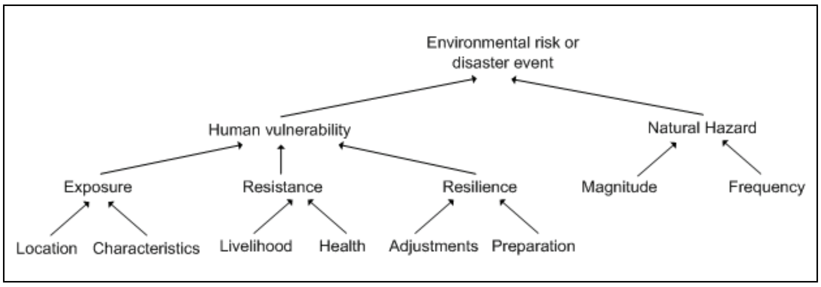

Figure 2.3. Components of Risk (Pelling, 2003)

The PAR model shown in Figure 2.4 depicts vulnerability as a series of levels of social factors called root causes and dynamic pressures, with the social, cultural, and political processes that together make the unsafe conditions (Wisner et al., 2004). The authors of the model describe it as “progression of vulnerability” or “chain of causation”.

Root causes are the interrelated set of widespread and general processes within a society and a world economy (Wisner et al., 2004). They are generally economic, demographic, and political processes. Dynamic pressures are processes and activities that ‘translate’ the effects of root causes into unsafe conditions. They are normally conjunctural manifestations of underlying economic, social, and political patterns. Unsafe conditions are the specific forms in which the vulnerability of a population is expressed in time and space in conjunction with a hazard.

In the PAR model, the concepts of resistance/sensitivity and resilience are not explicit, but nevertheless hidden capacities can be unveiled by understanding the underlying dynamic pressures and root causes. As the authors say, this model represents a progression of vulnerability and at the same time it represents the levels of study of vulnerability. Root causes are indistinctively tied to national and international actions and inequalities, especially in the economic arena, representing the exercise and distribution of power in society. Dynamic pressures have a more evident relation with national and regional policies that translate the Root Causes into Unsafe Conditions.

The United Nations University through its Institute for Environment and Human Security (UNU-EHS) developed two frameworks for vulnerability. The onion framework (Bogardi and Birkmann, 2004), where two axes are defined: the reality axis and the opportunity axis. The reality axis shows how an event can cause damage affecting the economic sphere and only when the impact of the event disrupts the social sphere a disaster occurs. The opportunity axis on the other hand compares the event to the hazard, the damage to the risk and the disaster to the vulnerability, understood as the capacities existing in the social sphere. This model is illustrated in Figure 2.5.

The second framework is the BBC. This framework is a combination of existing models, and is mainly based on the conceptual work of Bogardi and Birkmann (2004) and Cardona (1999 and 2001). This framework, presented in Figure 2.6, stresses the fact that vulnerability analysis goes beyond the estimation of deficiencies and assessment of disaster impacts in the past. It underlines the need to view vulnerability as dynamic, focusing on vulnerabilities, coping capacities and potential intervention tools to reduce it (feedback-loop system) (Birkmann, 2006).

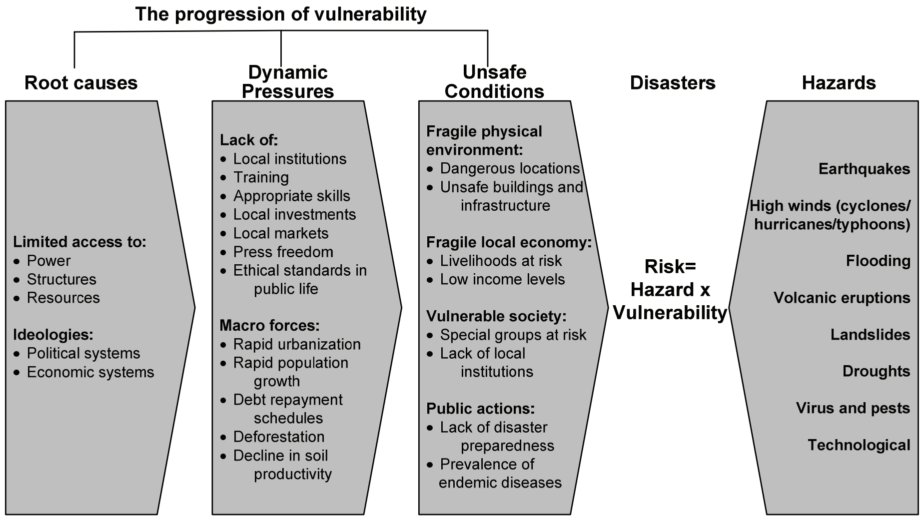

Figure 2.4. PAR model (Turner et al., 2003; Wisner et al., 2004)

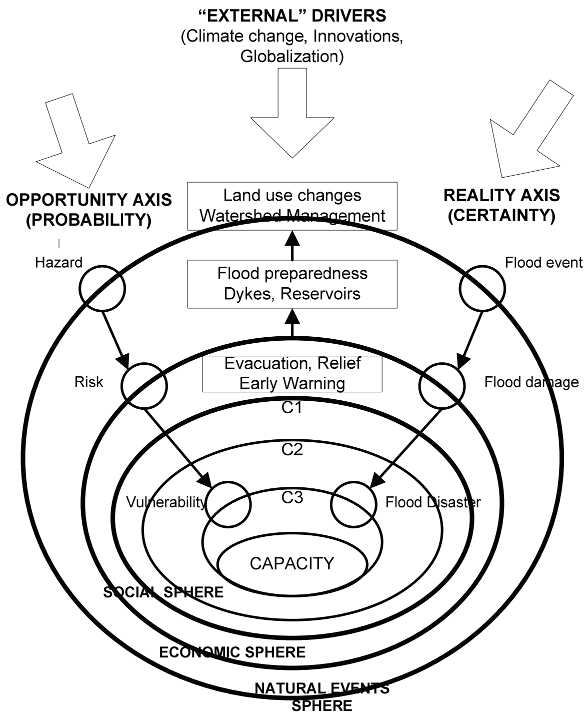

Figure 2.5. Onion Framework (Bogardi and Birkmann, 2004)

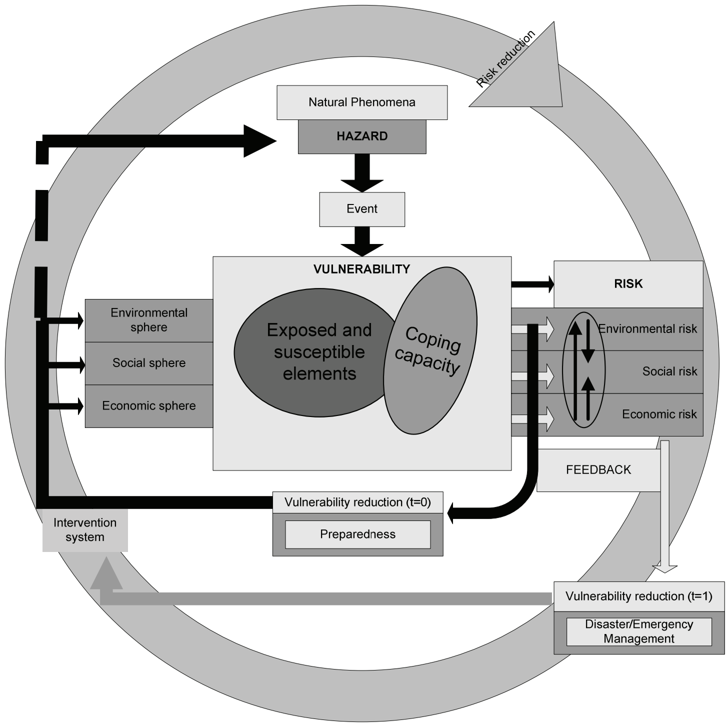

Figure 2.6. BBC Conceptual Framework (Birkmann, 2006)

Other authors (Adger, 2000; Adger and Kelly, 1999; Briguglio, 1995; Gommes et al., 1998; Smit and Pilifosova, 2002; Warrick et al., 1996) argue that vulnerability has to be seen as a function of exposure and adaptive capacity.

Vulnerability is complex, dynamic, compounding, and cumulative (Anderson, 1995) and whatever function is selected to describe it should include these characteristics. The models described previously are primarily tools for explaining vulnerability, not for measuring it. They cannot be applied directly without a great deal of understanding of the underlying political and economical processes and a detailed data collection and analysis. Although they do not measure vulnerability directly, they allow researchers to develop new means of measuring the different parameters that are needed to understand vulnerability.

Several aspects are common to most frameworks. What is commonly called “Elements at risk” is redefined in most models as exposure, whereas the “Capacities and inherent conditions” of a society are defined as sensitivity, resistance, or resilience.

The factors used to measure both exposure and capacity, have different use in the disaster management chain (Figure 2.7). In the pre-disaster phases, the knowledge about the sensitivity is fundamental for the mitigation and preparedness activities in terms of identifying target groups (public awareness activities and emergency response planning and training activities). The exposure information is important for building code implementation and the strengthening or retrofitting of existing structures.

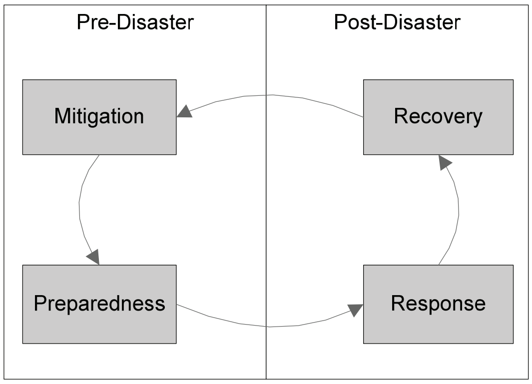

Figure 2.7. Disaster management chain

Defining exposure is a mere exercise, no matter how hard the information collection can be, of listing elements at risk or, in common terms, the existing physical elements in a city, such as: building stock, transportation networks, communication networks, water supply systems, sewage systems, utilities, etc. and the population subjected to a probable hazard (day and night time distribution). However, different types of vulnerability can be defined according to the subject of interest. All of them appear as key elements at different stages of the disaster management chain and at the same time they are used to identify exposure and capacities. These vulnerability types will be discussed in the next section.

2.4 Vulnerability types

Vulnerability deals with tangible and intangible assets; from the purely physical and social factors (infrastructure, population, etc.) to more subtle factors like cultural assets and ethnic or gender issues that are more complicated to represent spatially. Anderson and Woodrow (1989) developed a *Capacities and Vulnerabilities Analysis Matrix* that shows this clear division between Physical/Material, Social/Organizational, and Motivational/Attitudinal. From this initial proposal, the perception of capacities and the actual measurable capacities have also increased (Davis, 2003). Vulnerability has been split up into types for the sake of simplicity and order. Several authors (Anderson and Woodrow, 1989; Blaikie et al., 1996; Cardona, 2001a; ICRC, 1996; Lavell, 1993; Wilches Chaux, 1993), have proposed various subdivisions using similar terms, whereas some of them have also included political and institutional vulnerability. However, this classification can complicate the information collection processes because some types are so intertwined that setting up a clear division is almost impossible. For the sake of simplicity, only four types will be considered.

2.4.1 Physical Vulnerability

It is restricted to tangible elements, basically buildings and infrastructure, their location and characteristics. This type of vulnerability is related to the *Exposure* component of the RH model and to the *Unsafe Conditions* in the PAR model. The inventory of tangible elements defined as physical vulnerability can give a snapshot of the physical conditions of a city. All the physical cultural assets are included in this category (temples, churches, monuments, etc.).

2.4.2 Social-Cultural Vulnerability

This type of vulnerability includes tangible and intangible elements, and refers to people, households, and the community. The social-cultural vulnerability is partially related to the *Exposure* component of the RH model, because people have a location (dwelling, commuting, working) and to the *Unsafe Conditions* in the PAR model, as age distribution, dependency ratio, literacy, etc., that shape the state or the conditions in which they can face a hazard. All the aspects related to ethnic or religion issues and gender are included in this category.

2.4.3 Economic Vulnerability

Although it has typically included intangible elements and dealt with economic dependence at different levels (national, regional, local, individual), this type of vulnerability should include livelihoods and all types of production and income assets.

When related to exposure, it measures the cost of infrastructure replacement and rebuilding, as well as the cost of human lives and after-event costs (demolishing, rubbish disposal, burials). In terms of resistance or sensitivity, it measures the social cost in terms of unemployment (due to the sudden stop of industries and commerce) and the costs of stopped economic activities (industrial and commercial income). In brief, it accounts for the cost of exposed elements (physical infrastructure and lives) if lost, recovery costs, and the derived costs of the suspension of activities of the various economic sectors.

At the household level it measures the capacities that a family or a household head has to rebuild and survive after an event strikes (insurance, financial means, savings, etc.). At the enterprise level it measures the capacity of a firm to restart activities or to keep producing independently of the conditions of their own infrastructure (for example damage or collapse of physical infrastructure like buildings or machinery) or of the local infrastructure (for example utilities networks or roads).

2.4.4 Political-Institutional Vulnerability

This type of vulnerability, accounts for intangible elements such as government structure and decision making, political participation, disaster/risk related organizations, including response capacity of relief organizations and health-care services.

2.5 Measuring Vulnerability

As mentioned in the previous section, some models have attempted to "measure" vulnerability, generally by a linear weighted sum of indicators as proposed by Cardona (Cardona, 2001a) and Davidson (1997). Other authors have improved the vulnerability evaluation by including more complex techniques such as fuzzy logic (García and Hurtado, 2003); Bertin matrices, principal component analysis (PCA) and weighted map overlay (Chardon, 1999); and decision matrices or decision trees that account for uncertainty in the data and scale problems (Dwyer et al., 2004; Smith et al., 2005).

Up to now we can say that vulnerability has to be measured both for tangible and intangible elements. Those elements give information about the actual state of the physical elements as well as the people, therefore establishing the Unsafe Conditions in the PAR model, or the so called Exposure in the RH model and in Pelling's model.

Any attempt to understand vulnerability and the factors that control it should clearly separate exposed "elements" (physical inventories) from the characteristics that make those "elements" (infrastructure, population, economical assets, etc.) vulnerable. It should also include some type of measurement of the capacities within a given community to withstand a hazard and recover from it.

The elements that define vulnerability can be subdivided in terms of the aspect that they represent; that is, exposure, resistance or resilience.

- Exposure is directly related to the location of the element; therefore, for all the elements, knowledge about their geographic location in terms of the hazard is fundamental, as well as a comprehensive knowledge about the characteristics of the hazard.
- Resistance/Sensitivity deals with those aspects or attributes of the element that define its ability to cope with the hazard, for example the building characteristics in terms of physical vulnerability, or the mobility of a human in terms of social vulnerability.
- Resilience deals with those aspects or attributes of the element that define their recovery capacity after a hazard strikes, for example insurance to pay for the rebuilding of collapsed structures or the availability of provisional shelter offered by social facilities (schools, religious facilities, etc.).

At the same time, each of these elements has a set of attributes that explain whether they convey information about unsafe conditions, dynamic pressures, or root causes.

To measure the Dynamic Pressures and Root Causes, as explained in the PAR model, a comprehensive analysis of factors such as ethnicity, gender, social networks, economic factors, and political aspects have to be considered. The same applies to measuring Sensitivity/Resistance and Resilience. A recollection or inventory of these issues may not directly serve to measure vulnerability, considering that they are not permanent properties, but change with respect to a particular hazard (e.g. homeless people are more vulnerable to floods than to earthquakes). Therefore, accounting for the data can allow a comprehensive assessment of vulnerability to different hazards.

As Ben Wisner (2004) wisely argues, inventories and checklists can be very useful; however, these checklists don't clarify why and how the different elements are associated with a higher probability of injury, loss of life, or general economic disruption.

Important aspects of vulnerability have been defined in the previous sections, such as types and models. Although vulnerability is a topic on which scientists have devoted a considerable amount of research in the past years, there is no specific method based on the existing theoretical models to measure it *per se*. Vulnerability has been assessed basically in three ways: on the basis of some form of historical record of impacts, indirectly within a risk index, or as an estimated loss due to a specific hazard. In the following section these ways of assessing vulnerability are reviewed.

2.5.1 Historical record of impacts

Some examples of vulnerability assessed on the basis of some form of historical record of impacts are:

- Total damage from significant disaster events, defined as events causing damage that exceeds 1 percent of gross national product (GNP) over the period 1970–89 (Briguglio, 1995);

- Percentage of the population affected by natural disasters over the period 1970–96 (Atkins et al., 2000);
- Total number of natural disasters over the period 1970–96, expressed in relation to total land area (Atkins et al., 2000).

2.5.2 Indices and indicators

As stated before, vulnerability has also been assessed indirectly using risk indices. Several risk assessments methods assess it qualitatively or indirectly, with an overall risk index. Risk assessments made by international agencies and organizations are generally built upon indices that allow them to perform a certain risk ranking between cities or countries. However, any ranking is sensitive to both the period of analysis and the type of hazard faced by a particular geographic region. A country might have a high score because of a single extreme event with very low probability of recurrence, or a very low score because it has not experienced such an event (Benson, 2003). The methods to calculate the indices or indicators vary from socially oriented (Dwyer et al., 2004) to holistically oriented (IADB and Universidad Nacional de Colombia - Sede Manizales. Instituto de Estudios Ambientales, 2005). The following indices and indicators are examples of these ranking attempts, and are presented from country to city level.

Disaster Risk Index (DRI): measures the physical exposure and relative vulnerability of a country. The DRI enables the calculation of the average risk of death per country in large- and medium-scale disasters associated with earthquakes, tropical cyclones, and floods based on data from 1980 to 2000. It also enables the identification of a number of socio-economic and environmental variables that are correlated with risk of death and which may point to causal processes of disaster risk. In the DRI, countries are indexed for each hazard type according to their degree of physical exposure, their degree of relative vulnerability, and their degree of risk (UNDP, 2004a; UNDP, 2004b).

IDB Indicator System: It is a selection of indicators used for benchmarking countries in different periods, from 1980 to 2000, and cross-national comparisons in a systematic and quantitative fashion. Each index has a number of variables that are associated with it and empirically measured. The choice of variables was driven by a consideration of a number of factors including: country coverage, the soundness of the data, direct relevance to the phenomenon that the indicators are intended to measure, and quality. Four components or composite indicators reflect the principal elements that represent vulnerability and show the advances of different countries in risk management: (IADB and Universidad Nacional de Colombia - Sede Manizales. Instituto de Estudios Ambientales, 2005).

Disaster Deficit Index, DDI, measures country risk from a macro-economic and financial perspective when faced with possible catastrophic events;

Local Disaster Index, LDI, identify the social and environmental risk that derives from more recurrent lower level events which are often chronic at the local and sub national levels;

Prevalent Vulnerability Index, PVI, is made up of a series of indicators that characterize prevailing vulnerability conditions reflected in exposure in prone areas, socioeconomic fragility, and lack of social resilience in general;

Risk Management Index, RMI, brings together a group of indicators related to the risk management performance of the country, reflecting the organizational, development, capacity, and institutional action taken to reduce vulnerability and losses, to prepare for crisis, and efficiently recover

The IDB indicator system was designed to measure indicators at national level using existing information from existing national and international databases. Although it can be used at local level, it was primarily designed for national and sub-national comparisons. It gives a complete idea of how vulnerable a country is, according to the hazards that affect it.

Urban Earthquake Disaster Risk Index (EDRI): Is a composite index that allows direct comparison of the relative overall earthquake disaster risk of cities worldwide. It describes the relative contributions of various factors to that overall risk (Davidson, 1997).

Seismic Risk Index (SRI): Is a composite index that measures risk to earthquakes within cities. First, the model defines the physical seismic risk index (also called hard) based on descriptors obtained from estimating potential urban losses due to future earthquakes. Second, it defines the context seismic risk index (also called soft) obtained as the scaled product of the seismic hazard and context vulnerability descriptors. Both the physical seismic risk index and the context seismic risk index are combined using weights (Cardona, 2001a).

The DRI measures risks for country indexation purposes; therefore, it uses national indicators such as GDP (Gross Domestic Product) or HDI (Human Development Index). On the other hand, the EDRI measures risk at city level, but as a general index for comparison with other cities worldwide. None of the results of these indices can be used at the local level for risk reduction practices. In the case of the SRI, the measurement of risk can be performed within cities, allowing for comparison at different aggregation levels. No matter how the different authors group the vulnerability factors in all three indices, the information used for the assessment is basically the same, except when the SRI is used to assess risk within a city, where more detailed information is needed.

Social Vulnerability Indicators: Set of indicators used to measure the vulnerability of an individual within a household, involving a quantifiable indicator selection, a risk perception questionnaire, a decision tree analysis, and a synthetic estimation. The method is based on 13 social indicators (age, gender, income, employment, etc.) and 2 hazard indicators (residence damage and injuries). The risk perception questionnaire collected data on perceived vulnerability instead of the availability of actual vulnerability data. The questionnaire respondents were asked to rank the ability of hypothetical individuals to recover from a natural hazard impact based on their own perceptions of the situation. The hypothetical individuals were developed using the 15 indicators. With these results, a decision tree analysis was applied to the questionnaire data in order to sort and classify it, and to find relationships between the indicator attributes. The decision tree analysis found 11 decision rules that determine high vulnerability to natural hazards. Each rule demonstrates that a combination of two or more indicator attributes are required in order to predict the vulnerability of a person within a household, challenging the notion that one personal attribute can determine vulnerability. The attributes (referred to as vulnerability indicators) of most importance relate to various levels of injury sustained, residence damage, house insurance, income, and type of house ownership. The findings suggest that individual and household finances, combined with other specific indicators, play a significant role in determining an individual's vulnerability to a natural hazard impact (Dwyer et al., 2004). The Social vulnerability indicators of Dwyer et al (2004) depend heavily on the local circumstances and responses of the risk perception questionnaire. A risk perception questionnaire must be developed for every case study to account for local differences; however, it relates to the specific perception of risk of individual households instead of general rankings of indicators defined by "experts". Acknowledging people's perception is a step forward in understanding risk. Another important contribution is that of challenging individual attributes as determinant of vulnerability, but rather a combination of several attributes or factors as "responsible" of the overall vulnerability.

These indices or indicators represent values that can only be used for comparison purposes between countries, cities, or areas within a city. They don't quantify the vulnerability as such and tangentially touch relevant aspects of capacity that play an immense role in the relief and recovery. Indices are useful for ranking purpose in order to define intervention policies, but lack the detail to specifically tackle the vulnerability aspects that are directly related to risk reduction. In Annex I a complete comparison of indicators for different risk indices is presented.

2.5.3 Loss estimation methods

The third way of assessing vulnerability of an urban system is to perform loss estimations for a specific hazard or a combination of hazards. Computer applications have been developed by different companies and institutions to perform loss estimations for different natural hazards. Some of the freely available applications are RADIUS (GeoHazardsInternational, 1999) and HAZUS-MH (FEMA, 2003). The RADIUS model only analyzes earthquake hazard, while HAZUS-MH analyzes earthquake, flood, and hurricane hazard.

There are other commercial or non-free applications, such as NHEMATIS (Nobility-Environmental-Software-Systems-Inc., 1999), MRQuake, MRStorm and MRFlood (MunichRe, 2000), RiskLink-ALM, RiskLink-DLM, RiskBrowser and RMS-DataWizard (RMS, 2004), and CLASIC/2, CATRADER, CATMAP/2, AIRProfiler, ALERT (AIR, 2004). These will not be considered in the analysis due to their commercial nature, and that they are basically aimed at supporting insurance company's analyses.

RADIUS (Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters): The amount of information needed by RADIUS enables users to perform an aggregated loss estimation using a gridded mesh, that, depending on the information available, weights each mesh unit assigning it a degree of loss in terms of number of buildings damaged, length of lifelines damaged, and as a number of casualties and injured people. The accuracy of the estimation depends on the detail of the information provided; nevertheless, the algorithms are based on broad assumptions, for instance, soil characteristics and fragility curves (developed for settings different from the one where the methodology is applied). Radius provides a rapid assessment of possible damages according to the detail of the information provided. Although all the categories and weights can be changed, Radius only gives a rough estimate of damage due to the few categories considered and the "raster-like" unit distribution that doesn't account for the typical political administrative boundaries used for decision making and policies.

Hazus-MH: Allows a very detailed analysis of losses based on an enormous amount of information. The information collection can be especially difficult in developing countries due to the poor or inexistent databases and the costs and time needed to update the information necessary for this method. However, after a thorough campaign of information acquisition and preparation, information must be adapted to the requirements of Hazus-MH. Special attention should be drawn on the issue of the classifications used by Hazus; since they were designed for the United States of America, other classifications have to be adapted, introducing other sources of error and uncertainty in the loss estimation.

Although these loss estimation methods can give local authorities a loss scenario for a specific hazard, they provide limited insight on how to use that information for the relief and recovery process. They also lack information about the capacities of the community to withstand, cope, and recover from a disaster. Loss estimations can only be considered part of a vulnerability analysis when used as complete inventories of exposed infrastructure and population. In Annex II a summary of the factors considered to perform the loss estimation for the RADIUS and HAZUS initiatives are presented.

2.6 Vulnerability elements: inventories or indicators?

The information needs to perform a vulnerability assessment can be explained from two different points of view. The first one, theoretical vulnerability models that basically define vulnerability in terms of Exposure, Resistance/Sensitivity and Resilience; and the second one, from what is called in this research the Disaster Phases: Impact, Relief, and Recovery. An extended explanation of these 2 points of view for defining the vulnerability elements is presented in the following paragraphs.

Bridging the gap between information needs for vulnerability assessment and the actual use of that information by municipal authorities is one of the main purposes of this research. Municipalities collect data for multiple purposes. In many cases that data corresponds to the data needed to produce vulnerability information. In some other cases, the data has to be collected for the sole purpose of assessing an aspect of vulnerability. However, for the already available and new data collected, there is a need to transform it into information, and that information into actions.

Once the data needs have been assessed, a set of tools has to be defined to produce appropriate information at different scales and levels of decision-making. From this point on, other issues arise in terms of whom to deliver the information to improve decision making, or whom to make responsible for the systematic collection and administration of the information. Information responsibility is directly linked to the capacities of the municipal institutions that ultimately lead us to information management issues and existing tools and solutions to adequately handle the latter.

As mentioned above, the first issue to solve is the data and information needs. A comprehensive list of elements with their attributes is the first step in a vulnerability assessment. The elements relate to each other, enhancing dangerous or unsafe conditions, or boosting adaptive capacities and resilience of the communities subjected to one or several hazards. A specific attribute, such as age, can be a disadvantage in terms of mobility (increased exposure), but an advantage in terms of experience and knowledge (coping capacity and resistance). These relationships can be expressed as vulnerability chains. Most models can be redefined in terms of information needs.

In The PAR model, for example, the information needs are illustrated in Figure 2.8.

An initial approach to define the elements that shape vulnerability is presented in Annex III based on the work of (Buckle et al., 2001; Cannon et al., 2003; Chang and Falit-Baiamonte, 2002; Moser, 1998; Pelling, 2003; Sanderson, 2000; Smith et al., 2005; Wisner et al., 2004) and grouped by the aspect of vulnerability that it is most related to, following the existing vulnerability models.

Although most theoretical vulnerability models talk about exposure, the concept is more developed in Pelling's work (2003) and backs up the Disaster Phase approach. Pelling defines two types of impact as the possible consequences of a hazard. First, Direct Impacts, that is Physical Damage (housing, infrastructure) and Loss of lives or injuries, and second, the Systemic Loss, that has its root cause in the direct impacts.

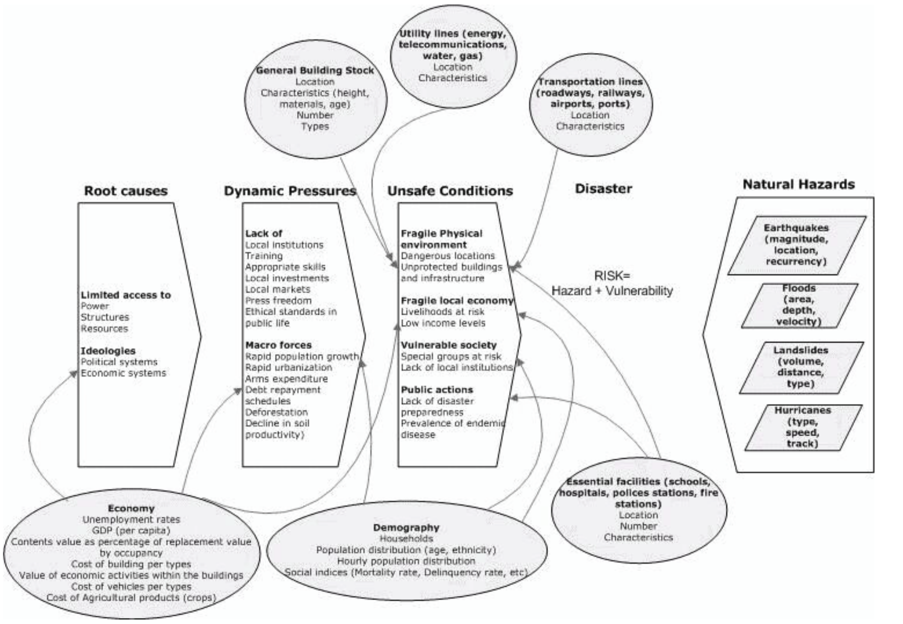

Figure 2.8. Information Needs for PAR Model

This chain of impacts leads us to separate vulnerability assessment in two main classes:

- Physical Exposure: Widely discussed in the literature, it can be defined as the elements at risk, or the inventory of those people or artifacts that are exposed to a hazard (UNDP, 2004a).
- Attenuating or Enhancing Factors: refer to the pre-existing conditions of those elements at risk, not only in physical or material terms, but also in social and psychological terms.

In the case of earthquake, the population is not directly exposed to the hazard, as it happens with a flood or a tropical storm. A person can perfectly withstand the ground movement induced by the earthquake without injuries. In the case of urban settings, the effects of the earthquake on the infrastructure create collapsing structures and dangerous debris that ultimately kill people. At this point, one may ask if the exposure of the people is not directly related then to the probability of being located in a building that is susceptible of collapsing or getting damaged by a certain magnitude earthquake. Following this premise, the damage to existing infrastructure depends on the infrastructure characteristics, such as structural type and materials, just to mention a couple, and at the same time define people's physical exposure. Only after the hazardous event has ceased, what has been defined as Social Vulnerability/Capacity is considered, determining the response of the community after the earthquake, defining how they cope and recover with the consequences of the event. The direct impacts on the population depend directly on the physical vulnerability of the infrastructure.

A disaster event can be analyzed in a phase-like manner in order to understand the different events and the information needed to mitigate, prevent, attend, and recover. Figure 2.9 illustrates the disaster event with each of the phases and the information needs in Figure 2.10. Three phases can be defined:

t_0 Impact Phase: the moment when the disaster strikes

t_1 Relief Phase: refers to the first days after the impact of the disaster when the community and the local aid agencies start the damage assessment and engage in the rescue and relief operations

t_2 Recovery Phase: refers to the months and even years following the disaster when national and international agencies, with the help of the community, rebuild their infrastructure, economy, and their livelihoods.

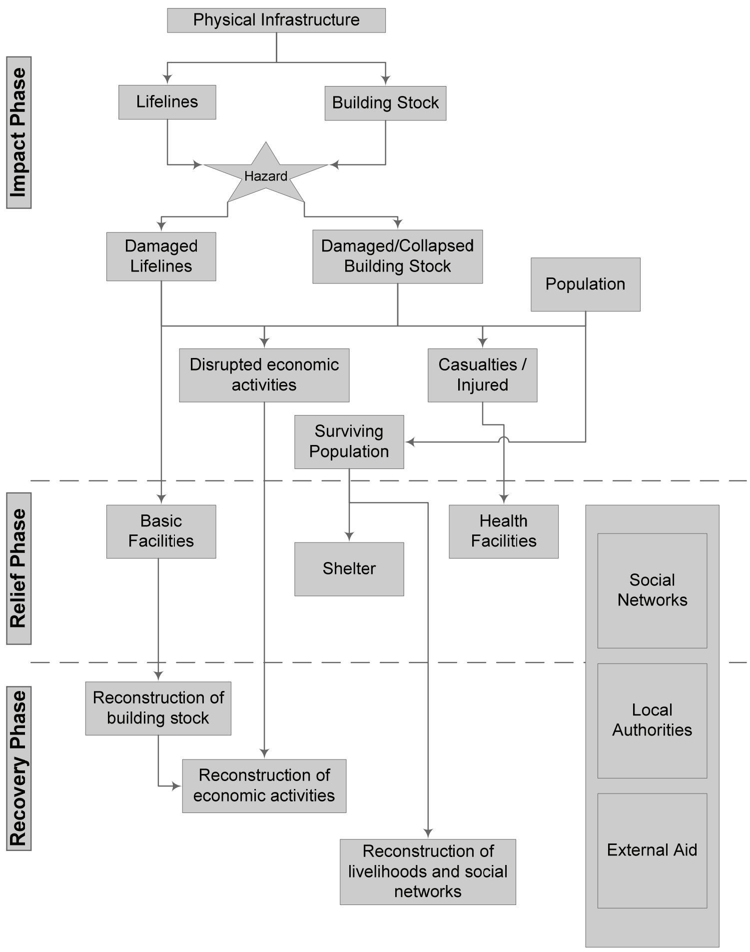

Figure 2.9. Phases of a disaster event (source: this research)

Each phase has a different duration and has different information requirements, in order to tackle specific problems adequately.

For municipal authorities, the second approach (phase-like analysis) will render a more realistic overview of the information needs, whereas the first approach (theoretical vulnerability models) gives them a set of elements where the linkage is not so evident. Nevertheless, both approaches can be used simultaneously to understand more clearly the interrelations and importance of each element.

Some of the elements listed can be collected directly as physical inventories, others can be collected as indicators, but the information collection and processing depends entirely on the scale of the information.

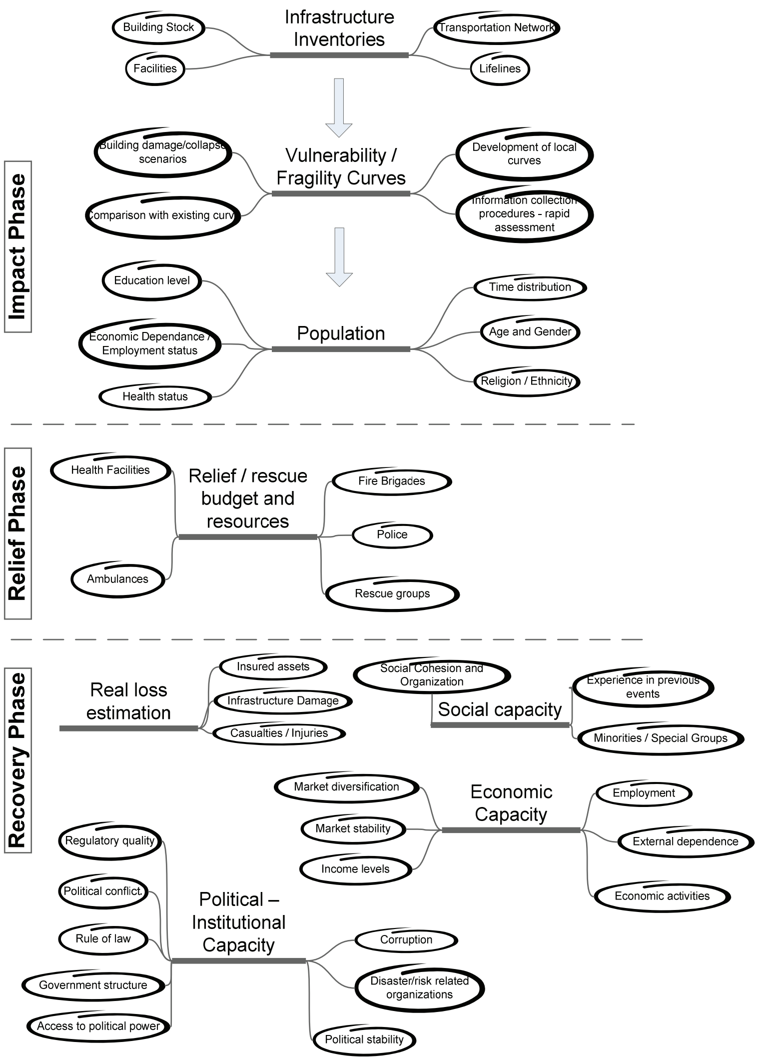

Figure 2.10. Disaster Management Information Needs (source: this research)

Figure 2.10 shows the main aspects that have to be considered in the information collection process. To adequately estimate losses for the impact phase it is important to highlight the relevance of acquiring consistent information to generate local vulnerability curves, since all the possible disaster scenarios depend upon this information. The more accurate the vulnerability curves, the more realistic the scenario, and therefore the authorities have a better idea of the possible consequences of a hazard. In this regard, very few risk indices use directly vulnerability curves, and only loss estimation methods consider their use, but normally adapt curves from very different settings that have no relation with the local conditions.

Vulnerability elements can be measured at different scales, ranging from national, regional to local. Establishing the adequate scale for the measurement of each vulnerability element is of extreme importance in order to avoid cross-level fallacies that can lead to inappropriate interpretations of phenomena. The vulnerability elements that need to be measured are complex, non-linear, and discontinuous, especially those that are intangible, complicating even more the selection of a scale. Scale plays a major role in the ranking problem stated before, as it defines costs and coverage of the data to be collected. Within this research, a relative scale with three levels has been defined. Macro level: deals with vulnerability elements that can be generalized at the municipal level. Meso level: deals with semi-detailed information generalized at ward, commune, neighborhood, or even homogeneous unit level. Information is generally represented by indicators. Micro level: deals with detailed information collected at the household level or element by element (e.g. building stock).

Some vulnerability elements cross all three levels, as they deal with non-scale issues (for example governance), or they can simply not be regarded as scalable. In the same way, other elements surpass this scale and belong to national and regional levels. In Figure 2.11 a general scheme of how the vulnerability can be measured at different scales is presented and the different details that can be expected.

Macro level	**Physical vulnerability** • General building stock: aggregated values of built-up areas and types Transportation network: length of road network, major infrastructure elements • Utilities infrastructure: length of networks, coverage, major infrastructure elements • Social Facilities: number of facilities per type • Historical and cultural assets: total number • Environmental Assets: area occupied, importance	**Socio-cultural vulnerability** • Population: general demographic profiles • Educational coverage	**Economic vulnerability** • GDP • Debt levels • Aggregated statistics by economic sector • Land Use distribution in % (commercial, residential, industrial, etc.)	**Political-Institutional vulnerability** • Political conflict • Policies and laws (building codes) • Political structures • Good governance • Established networks regionally/ nationally • Linkages with other regional/ national bodies
Meso level	**Physical vulnerability** • General building stock: aggregated values of built-up areas and types (commercial, residential, industrial, etc.) by administrative unit • Utilities infrastructure: length of networks, coverage, major infrastructure elements • Social Facilities: number of facilities per type and administrative unit • Historical and cultural assets: total number • Environmental Assets: area occupied, importance	**Socio-cultural vulnerability** • Population: demographic profiles per administrative unit • Minorities / Special groups: information on group distribution • Criminal statistics • Income levels/Stratification • Educational coverage/ absenteeism	**Economic vulnerability** • Household income levels by administrative unit • Land Use information (%) • Land Tenure information (%)	• Land-use planning • Access/Distribution of information and traditional knowledge • Organizations and management capacity
Micro level	**Physical vulnerability** • General building stock: detailed information on building characteristics • Transportation network: detailed info on road network and major infrastructure elements • Utilities infrastructure: detailed info on networks and major infrastructure elements • Social Facilities: detailed info on each facility • Historical and cultural assets: detailed characteristics • Environmental Assets: detailed info on each asset	**Socio-cultural vulnerability** • Population: detailed info per household (age, gender, religion, caste, literacy levels, immigration status, overcrowding, dependence ratio, nutritional status, health care access) • Minorities / Special groups: information on group distribution and characteristics • Income levels/Stratification	**Economic vulnerability** • Household income levels • Agribusiness and mining (primary sector): detailed info (employees, production, etc.) • Industrial activities • (secondary sector): detailed info (employees, production, etc.) • Service sector: detailed info (employees, production, etc.) • Land Tenure / Land Use	• Participatory community structures and management • Preparedness activities • Warning systems

Figure 2.11. Data collection levels

A set of elements or indicators has to be defined for each level. In the case indicators are selected to represent a vulnerability element, these must comply with the following criteria (Dwyer et al., 2004):

- Validity: Indicators need to accurately represent concepts expressed in the model or be acknowledged as valid substitutes for these concepts. The indicators must use credible data and be verifiable to ensure validity.
- Data Availability and Quality: Most criteria lists specify that data must be available for each indicator and from a reliable source. The data must be credible and reproducible to ensure quality.
- Sensitivity: Indicators assume a temporal aspect, as they are designed to measure change in a system or process. Indicators must be aligned with the time-scale on which they capture change, whether days, months, or years. This will ensure that the indicators are sensitive to change over time and therefore provide greater insight into the details of the factor being measured.
- Understandability: Indicators are used to represent concepts to a variety of people and therefore should be easily understood, while also reflecting the complexity of the concept represented; therefore, it is ideal that indicators are unambiguous and accessible.
- Quantitativeness: Indicators must be measurable via a readily understood method. Clear methods of measurement will encourage wider indicator acceptance and limit the bias or subjectivity of the data collector. A well explained method of quantitative measurement will provide clarity and can be comprehended by decision makers. Nevertheless qualitative information such as good governance can also be essential.
- Objectivity: Indicators must have classifications that can be explored further by other methods, such as surveys, statistics, and data analysis, and by other researchers; therefore, the indicator should remain the same over time. However, the data for the classifications will change to reflect trends.

2.7 Conclusions

A thorough review has been presented of existing methods to assess vulnerability. These methods have been developed from disciplines as diverse as the global environmental change community, social geographers, hazard and risk researchers and political economists. All of them have elements in common, such as defining vulnerability in terms of the conditions that make a community vulnerable to a hazard.

For this specific research, and based on the work of multiple authors cited previously, vulnerability is decomposed in two major components: physical exposure and attenuating or enhancing factors. However, these major components have been divided up in a phase-like manner, to account for the complexities and differences that arise within a municipality when dealing with hazards like earthquakes and their impacts. A municipality can have different levels of vulnerability and capacities according to the phase assessed.

Figure 2.9 to Figure 2.11 form the conceptual model of vulnerability information used in this research. Although a general list of elements can be presented as the one in Annex III, the final selection of the elements/indicators needed to assess vulnerability depends on the local circumstances. The vulnerability elements can be represented by one or several geographic features. A set of attributes is defined for each of them; however, the attributes may vary according to the selected scale for information collection. Attribute domains can also be defined to meet specific site conditions in order to speed up the data collection processes and not have to rely on experts. These domains may vary from site to site and should be adapted according to local conditions.

The elements listed in Annex III can be ranked according to the importance of the information for vulnerability assessments, collection, and maintenance costs, and conditioning factors such as political situation, or information sharing policies that can delay or even prevent collection. Not only should the information collection cost be considered but also the cost of rebuilding or replacing tangible and intangible assets. The question that has to be considered is: What is the municipality willing to risk?

Ranking the vulnerability elements according to their importance has to do with the social, economic, and physical implications of that information; that is, it is not the same thing to collect information on the building stock and its characteristics than to collect information on an ethnic minority. The building stock information is fundamental for the assessment of possible casualties in case of collapse, while the second is just one of the indicators of social cohesion or resilience of special groups. Nevertheless, knowing what hazard, how often, what elements can be affected, and their characteristics doesn't mean that the cost of rebuilding or replacing them can be used directly in the ranking. Evaluation criteria are different at each locality and should be defined accordingly; however, all the vulnerability types should be represented in an equitable way.

The main ranking criterion is the importance of each element within each type. Defining importance is a difficult task. One way of "measuring" importance is to try to evaluate the contribution of each element to its vulnerability. Let's say in physical vulnerability the element building stock represents 40%, utilities infrastructure represents 25% and facilities represents 20%. This means that these 3 elements represent 85% of the total physical vulnerability and the rest only 15%. Defining these percentages can somehow be a subjective exercise, resulting from interviewing experts or simply defined by a decision maker.

Although information collection costs are an item that requires consideration, if the main aim is to measure vulnerability, the only ranking criteria should be importance. If the elements are set to compete with each other, in the end less important elements will be selected if a simple multi criteria evaluation method is used. The method could select an element only because it is cheap to collect, but non-important.

Other important considerations in the element ranking would be the already available information that municipalities handle and the understandability of these information for decision makers and local authorities. Information is not useful if it doesn't transmit the correct messages to those reading it.

Multi criteria evaluation could be a useful tool for defining the importance of each element, based on what they represent in terms of exposure, resistance, and resilience and for each of the disaster phases. Some methods that can be applied are those of multi-attribute utility functions (utility function aggregation) or simpler methods such as weighted average values. The method of compromise programming can be used in the same way.

The use of several methods is desirable to check for uncertainty and inconsistency on the valuation of preferences by the experts or decision makers. The method used is described in detail in Chapter 4.

Chapter 3
Information Provision at Municipal Level

"A rock pile ceases to be a rock pile the moment a single man contemplates it, bearing within him the image of a cathedral."
Antoine de Saint-Exupery (1900-1944)

Probably the opening quote of this chapter doesn't seem at first related to the title, but if we look at municipal resources as the rock pile, one can envision the possibilities of using them in the construction of the "municipal cathedral". To build up the "municipal cathedral" is to set up an organization that can deliver products or services to customers through the management of its resources and under policy guidelines (Huxhold, 1991).

Municipal governments worldwide perform operations such as road construction and maintenance, distribute drinking water, collect sewage, provide energy and gas, collect solid waste, manage public schools and libraries, build and manage other public facilities, and collect taxes and revenues, amongst many others. In the provision of all these services and products, the municipality has to collect, manage, analyze, and store data from multiple sources (primary and secondary).

In this chapter, an overview of urban management theories and the information pyramid within municipalities is presented. The main functions of municipal administrations, their data sources, and the information processes within municipalities are also addressed. Finally, the link between vulnerability variables and municipal information sets up the context for the introduction of the case studies in the following chapters.

3.1 Urban management: from supply-driven to comprehensive institutional development

Almost all towns and cities have a representative or quasi-representative system of local government. One of the earliest forms of local self-government institutions are municipalities. Traditionally, municipal organizations have been structured along hierarchical lines, where a chief administrative officer (generally the mayor) is in charge of a series of institutional sub-systems in charge of the municipal functions (police, fire, public works, finance, city planning, waste disposal, street lighting, health and sanitation, etc.). This pattern served local governments well in the past; but with increasing complexities of urban life and demands for more democratic, representative and therefore participatory forms of local governments, newer models of municipal management grew in Europe, the Americas and the Asia-Pacific regions (Samad, 1994).

In the 1970's the lowest level of government was known as "local government". Generally, "local governments" (at least in urban areas) collected taxes and provided a limited range of services for their citizens. What had been called "urban administration" in the 1960s and 1970's, partly due to the influence of business approaches to public administration, began to be called "urban management" in the 1980´s. Urban administration implies registration and control, whereas urban management implies efficiency and enablement (Stren, 1993). Although the concept of urban management remains somewhat ambiguous and elusive, leading to multiple interpretations and approaches, Van Dijk (2006b) defines urban management as the effort to coordinate and integrate public as well as private actions to tackle the major problems the inhabitants of cities are facing and to make a more competitive, equitable, and sustainable city. Davey presents a more concise definition where it states that urban management is concerned with the plans, programs, and practices that seek to ensure that population growth is matched by access to basic infrastructure, shelter, and employment.

The main themes on which urban management focuses can be thus summarized (Mattingly, 1995; McCarney et al., 1995; Stren, 1993):

- Reform of public administration: inclusion of private sector actors and a process of capacity building within the administration.
- Infrastructure management and service delivery: inclusion of public sector actors in the management of urban utilities through partnerships and subcontracting.
- Improved management of land to generate revenues through tax collection.

No matter which definition is used, cities in developed and developing countries have defined their specific management model to provide the citizens with services that ensure development. These models vary widely from one country to the other, and are directly related to the degree of decentralized authority that the municipalities have.

3.2 Urban Management Models

One can find many differences between the urban management models, especially related first to the relationship of municipal boundaries to urban settlements, and second to the extent of municipal functions (UNCHS, 1991).

In the first case, the relationship of municipal boundaries to urban settlements in cities such as Bombay, Lusaka and Nairobi, a single local authority has been responsible for the core city and virtually all suburban development. Cairo, Calcutta and Manila, by contrast, represent cities fragmented into a number of municipal jurisdictions. The degree of fragmentation may have effects on the way the different municipal tasks are performed, and especially important are the data needed to perform these tasks, the collection procedures and the data management (Davey, 1989).

In the second case, the extent of municipal functions, refuse collection, market administration, local road maintenance, cleansing, drainage, lighting, parks and recreation are virtually always municipal responsibilities. What varies widely is municipal involvement in public utilities (water and sewerage are provided sometimes by a national corporation, or typically by a metropolitan corporation or a municipally controlled enterprise, and electricity, usually a national utility responsibility, but sometimes a function of local government, and even private companies); social services; public protection (police force is normally out of the municipal jurisdiction); trunk roads (which can be a national, provincial, or local responsibility); provision of rental or purchase housing or serviced sites (sometimes a municipal activity, sometimes that of a special purpose authority); and regulation of land use and development (usually a municipal task, but on occasion, provincial or metropolitan authority function). In the same way, the degree of integration between responsible offices varies in a vertical chain of administration. American, British and to some extent Spanish traditions treat municipalities as separate political, legal, and administrative entities, albeit subject to varying degrees of external supervision. French and Ottoman traditions place local government within a vertical hierarchy of governmental institutions; locally elected assemblies have legislative powers, but executive responsibility is often exercised by administrators (governors, prefects, etc.) with a dual responsibility to central and local government (Davey, 1989).

Another aspect that differs between urban management models is the existence of an elected leader, governor or mayor, or an administrator appointed by central or local government. Some urban models require central or provincial government approval of budgets, revenue tariffs, staff appointments, contracts, and development plans. Finally, the nature and buoyancy of revenue sources is variable within urban management models (UNCHS, 1991).

Various models of urban management tend to be found in different development regions. In Latin America, the ECLAC (Economic Commission for Latin America and the Caribbean) has sponsored several research projects on the subject of urban management. Jordan and Simioni (1998), define urban management (*gestión local*) as the modified roles and attributions of local authorities that give them more autonomy, financing independence, and discretion in decision making, thus assuming a dynamic role as generator and promoter of local development. This is different from that of previous administration concepts based only in the control of land use, land occupation, and public space transformation, and the provision of basic services and facilities. The efforts of urban management are directed towards the generation of an administrative process that adapts to the characteristics and development needs of the locality. The municipality as a provider of services and responsible for building new infrastructure also becomes responsible for the administration and operation of these products and services, opening spaces for community participation in decision making. The municipality takes on a new role of facilitator of processes, and is therefore responsible for the management of information needed to take decisions. In general terms, urban management is not the sole domain of public authorities. It recognizes multi-actor engagement, in establishing and implementing a coordinated development program, where financial resources are invested trying to achieve sustainable development.

In Asia, according to Sproats (2004), most countries have long indigenous histories of local governance, although not necessarily institutional forms of local government. Occupation by colonial powers in Asia left legacies of centralized administrative rule more suited to command, maintenance of law and order, and revenue extraction rather than governance and participation at the local level. Inherently, colonial models of administration were imposed on local communities mostly with disregard for their historical systems of governance and even in those not colonized present local systems have been either influenced by the colonial powers in the region. One of the characteristics of local government this century has been the renationalizing of local government following independence. Local government has been reshaped by the respective national identities. Although there are several differences between countries in this region, one can find basically three common aspects in local government: sharing of administrative responsibility, separation of powers, and integration of civil services. However, central governments are not evidencing widespread commitment to reform if it moves beyond administrative improvement. A key manifestation of this lack of commitment to reform local government is the plethora of organizations and agencies, either central or sub-national, often with overlapping or conflicting mandates. In general terms, local governments consisting either of municipal councils or municipal corporations headed by a regularly elected mayor, are supposed to be formed as democratic institutions based on the principle of self-government and to represent the people's desires and strengths.

In Africa, urban management refers to the political and administrative structures of cities and the major challenges that they face to provide both social and physical infrastructure services. These include managing urban economic resources, particularly land and the assets of the built environment, creating employment, and attracting investment in order to improve the quality and quantity of goods and services available (Clarke, 1991).

McGill (1994; 1995) suggests that urban management in developing countries should seek to achieve the simple but fundamental twin objective of:

- planning for, providing, and maintaining a city's infrastructure and services, and
- making sure that the city's local government is in a fit state, organizationally and financially, to ensure that provision and maintenance.

3.3 Urban Management Structure

In most developing countries, the basic general structure of municipalities is that of a controlling body (Municipal Council) and an executive body (the Major). The main general areas of urban management are defined within these 2 bodies (Arriagada, 2002) and are illustrated in Figure 3.1:

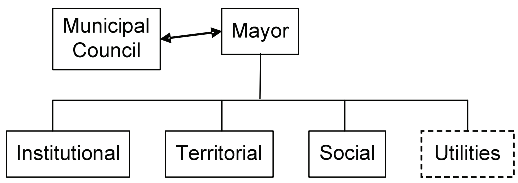

Figure 3.1 General Municipal Structure for developing countries

- **Institutional:** is the basic organization of the municipal institution that supports the provision of services.
- **Territorial:** deals with the physical environment and the infrastructure.
- **Social:** focuses on achieving socio-economic development to promote upgrading and reducing inequalities.
- Utilities: this area is not present in some cases, as is the case when external agencies are in charge of them.

The services of a municipality are those of providing social welfare, regulating land use, and supporting development, growth, and redistribution. To provide these services, the municipalities have to deal with the following sectors (Leman, 1994):

- **Land management:** the municipality is responsible for accurate and timely mapping, gathering, and maintenance of land-related data in order to know what they have and where; land registration procedures to facilitate effective administration of property rights; clear and fair mechanisms for assembly, transfer, and disposal of land including accurate market valuation mechanisms; comprehensive and participatory planning of land uses in order to ensure orderly urban development; and efficient and effective procedures and systems for generating revenue from land through taxation, user fees, and public value capture mechanisms.

- **Natural environment management:** although several levels of government overlap on this issue, municipalities are responsible for the proper management of water resources, air quality, and land resources to ensure economic and social development, avoiding serious environmental damage or depletion of resources.
- **Infrastructure:** the municipality is responsible for the planning, construction, operation, and maintenance of urban infrastructure. That includes some or all of the following systems -water supply and treatment, sanitation and solid waste management, energy generation and distribution, transportation, and communication ranging from telephone services to telecommunications. In some cases one or more of these systems are the responsibility of an external agency.
- **Housing and community facilities:** municipalities are responsible for making public land available for public low-cost housing construction; providing basic infrastructure, organizing and assisting communities in availing of housing finance, and rationalizing building and planning regulations in order to decrease capital construction costs and encourage wider private sector participation in housing construction. It is a responsibility of the municipality to ensure that new buildings are built according to existing regulations.
- **Social services** (including poverty alleviation): In general, municipalities are responsible for the management of a diverse range of social services, including: healthcare, education (at least at the primary level), security from crime, public safety from fire and natural disasters and during emergencies, welfare programs for the aged and the handicapped, the alleviation of poverty, and recreation (open spaces, parks, sports and cultural facilities, etc.).
- **Economic development:** municipalities have a direct effect on economic development through policies and programs influencing, among other things, investment, climate, distribution of goods and services, and the cost of doing business through taxation and other mechanisms. These affect all economic sectors: primary economic activities dealing with resource extraction and food production (e.g. agriculture in the periphery of urban areas); secondary activities of manufacturing and construction, tertiary activities related to physical distribution of goods and resources, and quaternary functions comprising support services such as banking and insurance.

In Table 3.1, a summarized list of common tasks in municipal administrations is presented. Although most of the sectors described are represented, the extent to which they are really accomplished is difficult to establish, since every municipality is a special case. Some of the sectors are under-represented. Such is the case of the economic development sector, where there is no direct task related. In large cities it can be of the local government domain considering that they have a more autonomous government given their tax revenues, but for smaller cities it is commonly of state domain rather than of local government. The same happens in the case of land management, where the only related task could be planning and engineering services or housing. It is difficult to establish in a list of summarized tasks per continent, what exactly comprises each of them and how related they are to each of the sectors that the urban managers have to deal with. In the following section a detailed look on information will clarify the relationships between municipal tasks and sectors.

One thing that most municipalities in the developing world have in common is that there is no task that specifically addresses risk management. Although it can be considered a sub-task in Planning, it is never stated clearly. The result is ambiguity and poor accountability for performance in the event of a disaster.

Table 3.1 General tasks of municipal administrations in Latin America and South Asia

Sector	Tasks	South Asia	Latin America
Public utilities	Water supply	**X**	**X**
	Sewerage and drainage	**X**	**X**
	Electricity	**X**	**X**
	Telephone		**X**
Social services	Primary education		**X**
	Health	x	**X**
	Social welfare		**X**
	Housing		**X**
	Registration of births, marriages and deaths	**X**	
Transportation	Highways and roads	**X**	**X**
	Street lighting	**X**	**X**
	Mass transportation		**X**
	Traffic control.	**X**	
General urban services	Refuse collection (Waste disposal)	**X**	**X**
	Parks and recreation		**X**
	Markets and abattoirs		
	Cemeteries		
	Fire protection		
	Law enforcement		
	Slaughterhouses	**X**	
	Street cleansing		**X**
	Arboriculture	**X**	
Planning	Planning and engineering services	x	**X**

X (in bold): major task; x: minor task (Information sources for Asia: (Samad, 1994) and (van Dijk, 2006a); for Latin America (Jordan and Simioni, 1998)).

In all cases, urban management is a process that needs four basic resources to work: people, information, financial resources, and policies. People: represented by all the individuals within the municipality, external organizations, and the community. Financial resources: represented in money, materials, facilities, etc. Policies: represented by laws and enactments that allow the municipality to influence and control actions. Information: the main study subject in this research is represented by the data generated internally and externally, and utilized for municipal policy making, plan development and implementation. Information is a key determinant of local government performance.

3.4 Urban Information Pyramid

Already in the late 1950s, planners started to develop and use computerized models, planning information systems, and decision-support systems to improve performance (Nedovic-Budic, 2000). Currently, developed countries apply geo-information technology in many aspects of the planning process, including data collection, storage, data analysis and presentation, planning and policy making, communication with the public, policy implementation and administration. This geo-information technology (GIT) trend has also spread to developing countries and today it is difficult to envision a municipality that does not use or is not considering the use of geo-information technology to enhance urban management. The awareness that 80% of all the information used by local governments today is geographical (Masser and Ottens, 1999) contributes to the diffusion and adoption of GIT by local governments around the world.

The term "urban information pyramid" was introduced by Huxhold (1991), to represent the information flows and how the different levels of the organization use information (see Figure 3.2). He defines 3 levels of decision making in public organizations as:

- Operations: related to the production or delivery of the product or service. It is at this level where government policies and management expertise produce actions that affect the public, and where more people intervene and much data is collected, largely through routine administrative procedures such as development control.
- Management: controls the organization's resources needed to run its operations. At this level policies are formulated into plans and resources are managed to ensure that the operations level works toward plan implementation. In terms of information needs, generally the primary data collected at operational level is summarized at this level.
- Policy: establishes the long term, overall direction of the organization. At this level policies are established, fewer people are involved, and the information is even more highly summarized.

New trends of public administration suggest that community involvement has increased for decision making at the policy level. At the management level, there has been a clear trend towards the adoption of IT for administrative purposes. At the operations level, two sub-levels can be devised: technical, where sub-contracting practices are common, including private companies; and the socio-economic unit, where the participatory based approach is used and includes communities, companies, and associations.

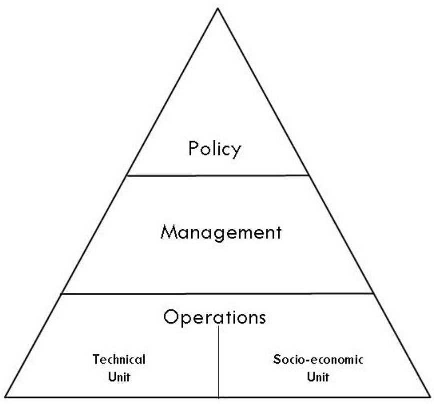

Figure 3.2 The urban information pyramid (Huxhold, 1991)

Data used at the operations level is combined with other available data through horizontal data integration and is also summarized for use at higher levels (vertical integration). Huxhold (1991) cleverly describes the information flows within the organization, stating that the information gathered at the lowest level is used by managers to deploy resources, by policy makers to initiate plans and programs that, in turn, are sent down to the managers where they are formulated into actions for the operations level to implement.

The data needed by municipal administrations is non-geographical as well as geographical. Information systems to handle non geographic data have been in place for several decades, but only until the 1990's municipalities started handling geographical information within geographic information systems (GIS).

Urban planners are often considered to have been leaders in the use of geo-information technology. Several researchers in urban planning have identified the types of knowledge required in the planning process, the temporal and the subject domains that this information must have (Batty, 1993; Eweg, 1994; Masser and Ottens, 1999; Webster, 1993). These domains and types of knowledge are:

The knowledge needed for the planning process is basically the object, the normative, the process, and the method. The object refers to defining clearly the nature and location of the planning; the normative refers to the laws, policies, norms and standards that support decisions; the process refers to the logistics of planning; and the method to define how to achieve what has been planned, including methods for data capture, processing, public participation, etc.

The temporal domain required during the planning process consists of: retrospective, current, and prospective. Retrospective refers to the relevant developments that already exist, and includes the object, normative process and methods used to achieve those developments; current refers to the current issues and problems; and prospective refers to possible future developments.

The subject domain needed during the planning process consists of information on four main subjects: population (households, cultural assets, income, welfare); economic activity (production, distribution, labor market); physical environment (land use, building stock, infrastructure, environmental assets); and public finances (tax base, investments, service provision, welfare payments). There is a clear relationship or overlap between the sectors that provide services within a municipality and the subject domain, as seen in Table 3.2.

All this information and data gathered by municipal administrations for different subject domains, at different points in time, in different formats both analog and digital, and as simple as a JPG image or a GIS layer, can be put together for multiple purposes and uses if adequately incorporated in an Urban Information System. In the following section, the term Urban Information System is defined and some applications within the context of urban management are presented.

Table 3.2 Comparison between Municipal Sectors and the Subject Domain

Sector	Subject Domain
Land management	Public finances (tax base, investments, service provision, welfare payments).
Infrastructure	Physical environment (land use, building stock, infrastructure, environmental assets)
Social services	Population (households, cultural assets, income, welfare)
Natural environment management	Physical environment (land use, building stock, infrastructure, environmental assets)
Housing and community facilities	Population (households, cultural assets, income, welfare) Physical environment (land use, building stock, infrastructure, environmental assets)
Economic development	Economic activity (production, distribution, labor market) Public finances (tax base, investments, service provision, welfare payments).

3.5 Urban Information Systems (UIS)

Van Dijk (2006a) defines an UIS as an ensemble of discrete sets of data concerning all relevant aspects of a city, accessible to computer processing and analysis. The last part of the definition is perhaps the most complex, considering that many municipalities in developing countries have digital datasets, but fail in making them accessible to computer processing and analysis by others, even to other municipal officers.

Several problems arise when talking about UIS's. The fact that a municipality possesses digital data sets does not imply that they count with an UIS. Clear policies about what data and information are important to be collected, the collection frequency (updating), the scale, the processing, dissemination, and the probable users must be well defined in order to avoid high costs in data collection. Not only policies on data collection have to be established, but also standards for data collection, manipulation, and sharing.

In section 3.3 the sectors that are needed to provide urban services were described. Most of them apply geo-information technology (IT) to perform their tasks and ultimately provide services. Land management handles an accurate register of existing parcels, land ownership, and changes. Urban planning uses timely and accurate information, allowing urban planners to integrate demographic, social, physical, and economical data through GIS. Social welfare programs use social, economic, and demographic information, to design and implement social development plans, also allowing forms of participatory GIS (PGIS). Other applications of GIT are used for e-government, where the people can interact with the municipal administration by visualizing information, downloading or filling out forms, querying existing information, and even provide feedback and valuable household information (e.g. surveys). In the same way, other sectors include monitoring aspects that range from environmental problems to poverty. And finally risk management where natural hazard can be assessed as well as conditions, vulnerability, and capacity in order to perform multi-temporal analysis that can guide the urban managers in whether their policies for risk reduction are working.

UIS developed for cities in developed countries are not directly transferable to cities in developing countries. Cities in developing countries present specific characteristics that make them different from cities in developed countries, especially in their ability to adopt geo-information technology (Bishop et al., 2000; Williamson, 1991). Some of the differences they observe are a rapid population growth that is not matched by growth in the delivery of services, utilities, and infrastructure; the growth of the cities is dictated by market forces rather than strategic planning; laws and guidelines for land registration and management are diverse and often uncoordinated; real tenure and ownership is often obscured and unregulated; unplanned developments make it difficult to provide utilities; inexistence or poor land information systems impede maintenance of services and infrastructure and the planning exercise; and there is little spatial information, if no information at all, (particularly large scale base maps), lack of skilled personnel to handle the spatial information, and lack of funding or political will to support the UIS.

A first approach to setting up an UIS in any municipality will be to build it following Huxhold's information pyramid. If the information needs are clear at the management level, the technical level should be able to provide it and the policy level will then have reliable data to take informed decisions. However, the information needs do not always dictate the data needs. Each office within the administration of the municipality has specific needs in terms of data to fulfill, and in that sense those needs are the ones which dictate the immediate data needs. Identifying the processes inside a municipality will clarify the information needed, and hence the data that should be collected and processed. Therefore, a clear definition of functions and duties will eventually lead to the definition of data needs and in a more developed stage, the possibility of using that same data in multiple tasks.

The implementation of an UIS in a municipality is directly related to the availability and quality of the geo-information in that specific municipality. If there is no geo-information, a first step before collecting it is to define the quality standards that the data should have in order to produce reliable information. If there is some data, the quality aspect should be thoroughly documented to avoid problems in the future. The next section examines this issue in detail.

3.6 Quality of Geographic Information

The issue of geo-information quality has been addressed by several researchers in the past decades, but researchers have hardly paid attention to the practical use of quality information (de Bruin et al., 2001; Goovaerts, 1999). Data and geo-information production has increased largely in the past decades, but only in this century has it become mandatory to conform to accuracy standards (defined by each country) not only for national mapping agencies, but also for the private sector. Since geo-information is becoming more widely used for decision support, using low-quality data is becoming more widespread and the chance of taking wrong decisions based on inaccurate data is higher. In the same way, due to the growth of the internet, accessing secondary data sources is easier, but in the same way, poor quality data is easier to get (OMB, 2001). Government agencies are also starting to focus on the usability of spatial data because decisions taken using this data should be legally defensible. Despite the advances in understanding components of data quality (Chrisman, 1982; Chrisman, 1984; Chrisman, 1995; Guptill and Morrison, 1995), almost no progress has been made in the development of methods to assess fitness for use (Veregin, 1999).

Quality can be defined as fitness for use, including both quality of design, conformance to the design (production oriented quality), customer satisfaction, and the fulfillment of the needs of a society or the environment (Jakobsson and Tsoulos, 2007). Most of the quality descriptions of spatial data have been developed to serve the production-oriented approach. ISO 19113 and ISO 19114 standards follow this approach based on the data quality concepts developed already in the 1980's (see for exampleChrisman, 1982; Goodchild and Gopal, 1989; Goodchild and Jeansoulin, 1998; Guptill and Morrison, 1995). This approach to geo-information quality is more data centered (ISO 19113), and considers that geo-information quality is defined by space, time, and theme (where, when, what), just as geo-information itself. In this sense, what was used to assess quality was accuracy (spatial, temporal, and thematic), resolution (spatial, temporal and thematic), consistency, and completeness (NCGIA, 1995).

The concepts of error propagation in data analysis and the concept of uncertainty in geographic information have also undergone extensive research. Usability is another viewpoint, which has its roots in engineering, especially in software development. Nielsen (1993), Hunter et al (2003), and Wachowicz (2003) have discussed the possible elements for data usability. Data usability is an important aspect in application and user interface development. Rönnbäck (2004) has described a questionnaire-based method useful in data quality assessment related to spatial analysis and especially the evaluation of data usability in the decision-taking phase.

Hunter, Wachowicz, and Bregt (2003) address the issue of spatial data usability and describe at least 40 elements of usability that relate to spatial information. The main elements that determine usability depend on the type of application for which the data are used. In the case of this research, the most relevant elements are: adding of value through data integration; speed of access; cost; integrity; presentation; data producer's reputation – standards; type of decision; validity and reliability (trust, e.g. census data); data quality as accuracy/freedom from error – positional and attribute accuracy; logical consistency; completeness; and temporal accuracy or shelf-life.

Lillrank (1998) defines four viewpoints to analyze geographic quality concepts (Figure 3.3):

- A production-centered perspective focusing on variations in the production process where the most common measure is the number of defective or non-conforming products.
- A planning-centered perspective focusing on the characteristics of products.
- A customer-centered perspective focusing on the value of products and services to the customer.
- A system-centered perspective taking into account all stakeholders influenced by the organization or its products oriented quality.

From the urban information pyramid point of view, the policy level is in charge of the application development. The guidelines for geo-information management are given at this level. The management level is in charge of supervising aspects such as SDI development, harmonization and interoperability, and data quality specifications. The operations level is in charge of producing information useful for the different customers and giving quality metadata, so the information can be assessed not only by its intrinsic value, but also by its quality. This level is also responsible for service delivery to external customers, and therefore has two masters – their chiefs and their clients.

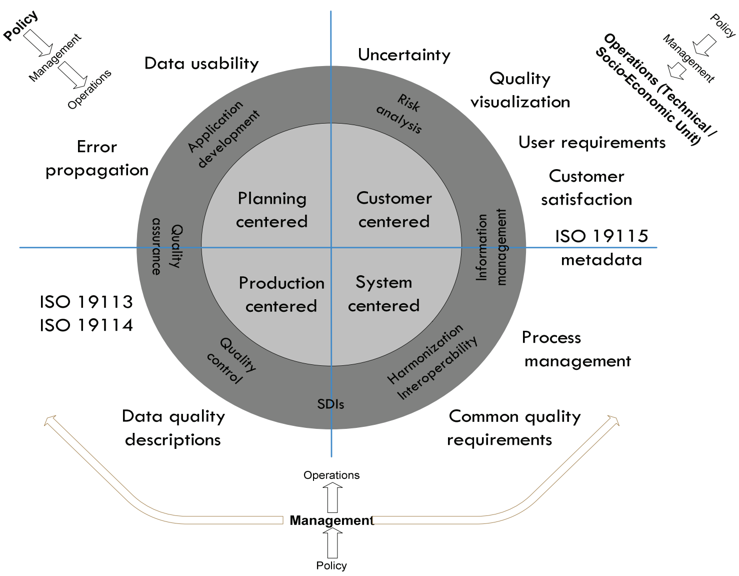

Figure 3.3. Quality management viewpoints (adapted from Jakobsson and Tsoulos (2007))

Information management is essential in the system-centered view. Common quality requirements are needed for harmonizing reference datasets. Customer satisfaction surveys are used for evaluating finished applications. Quality function deployment, which is a common tool in quality management, might be utilized in transforming the users' quality requirements to specifications (Jahn and Frank, 2004).

Geo-information quality has been addressed from the data- or method-centered point of view, from the user or goal-centered perspective, and finally a more holistic approach has considered geo-information quality as made up of components. This latter approach has been called system-oriented (Josselin, 2003). A modified version of Josselin's system-oriented framework is presented in Figure 3.4. In this framework, the three components of the system: data, users, and methods with their characteristics define the concept of geo-information quality or fitness for use. It is important to highlight that the components are equally important, but in this research we will focus on the data component from a user perspective. In other words, data will not be solely evaluated using concepts such as accuracy, but more in terms of completeness, reliability, integrity, and shelf-life, defined specifically following the user's objectives (vulnerability assessment).

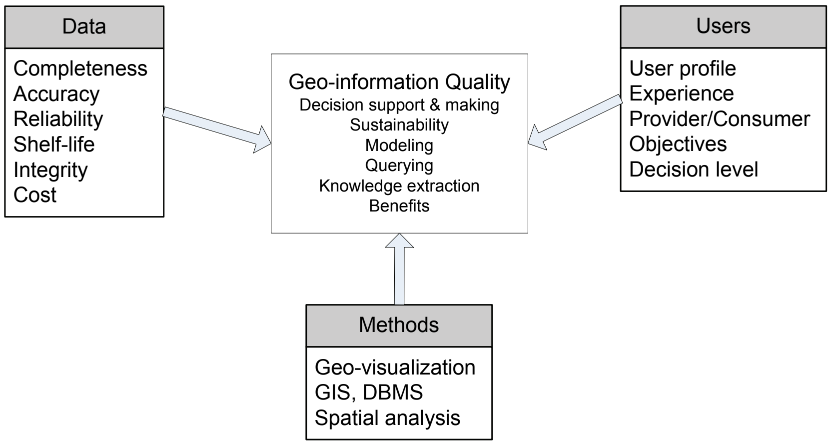

Figure 3.4. Geo-information quality framework

It is also important to consider the user acceptance of the geo-information and the geo-information system. The Technology Acceptance Model (TAM) is an information system (IS) model developed to predict the adoption and use of an IS (McCoy et al., 2007). Although the TAM models how users come to accept and use a technology, it can be applied to "measure" how users will accept the use of geo-information, considering a set of factors that include (Davis, 1989):

- Perceived usefulness (PU) - the degree to which a person believes that using a particular system would enhance his or her job performance.
- Perceived ease-of-use (PEOU) - the degree to which a person believes that using a particular system would be free from effort.

In the next chapter, the methods used to assess fitness for use of geo-information for urban vulnerability assessment will be presented.

3.7 Vulnerability variables in the context of an UIS

We have previously seen that a typical UIS contains a number of data sets that could be useful for vulnerability assessment. Each urban management sector is responsible for the collection/generation, maintenance and updating of specific information. This information can be easily linked to the information needs presented in Chapter 2, as illustrated in Figure 3.5.

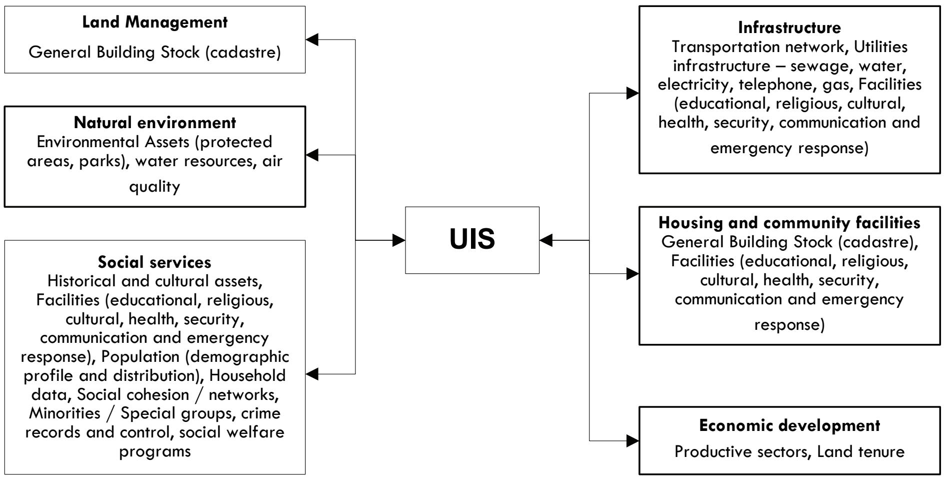

Figure 3.5 Information responsibilities per sector

The general areas that a municipality has to define in terms of information provision related to vulnerability are:

- Physical or Built Environment: includes infrastructure (utilities), building stock, transportation network, public space.
- Social: Household information (demographic data), Special groups, Social networks, Education, health and recreation facilities (although these can be included as infrastructure or building stock).
- Economical: General information on productive sectors, Land tenure
- Natural environment: information on environmental assets.

3.8 Conclusions

Pelling (2006) wisely summarizes the problem by stating that urban risk has for too long been a marginal policy concern. Rapid urbanization makes this position untenable. More and more of humanity, and the majority of the physical assets that drive development, are located in cities at risk.

A clear understanding of the concept of urban management, the different models, and the urban management structure aids in the definition of the relation between information collected for municipal purposes and information needed to perform a vulnerability assessment. If urban management effectively addresses the 6 sectors identified by Leman, in terms of information, many of the vulnerability variables will potentially be already available in the UIS.

Organizing municipal geo-information within an UIS raises the challenge of data integration, thus increasing its usability. Once the information is organized and used within an UIS, the issue of geo-information quality and fitness for use arise. In order to assess fitness for use of geo-information for urban vulnerability assessments, this research will focus on the data component from a user perspective in terms of completeness, reliability, integrity, and shelf-life, defined specifically following the user's objectives.

The question of assessing vulnerability using already available information at municipalities in the developing world is addressed in the chapter 5, where 2 case studies of municipalities in completely different contexts are presented.

Chapter 4
Methods

"If a man will begin with certainties, he will end in doubts; but if he will be content to begin with doubts, he will end in certainties."
Sir Francis Bacon (1561-1626)

In the previous chapters the theoretical overview of vulnerability and information provision at municipal level was given. This chapter provides an overview of the methods used to reach the research objectives. A description of the conceptual research model is outlined. Subsequent to the research model, the methodological design is discussed, including the design of surveys, expert workshops, and the processing of information through spatial data quality and fitness for use evaluators.

4.1 Conceptual Research Model

The main problem in analyzing the vulnerability of populations and urban centers to natural hazards is the information necessary as a tool to prevent, provide relief, and recover from a disaster situation. In this context it is essential to know the availability, quality, and quantity of data, as well as the possibilities to analyze and continuously and timely process this data.

The research follows the conceptual model presented in Figure 4.1 to achieve the stated objectives. Basically, a two way approach that combines a series of theoretical steps to vulnerability assessment and a practical, data driven approach to the problem of using available municipal information for vulnerability assessments and its fitness for use is adopted.

In the theoretical approach, the normal sequence of stages in vulnerability assessments is: needs, information, and data. Needs are the vulnerability models according to existing literature on risk management, from different perspectives and vulnerability types for earthquake hazard. Information is the definition of vulnerability factors/variables needed to assess the models and types. Finally, data is the exploration of available information in the case study cities and the evaluation of selected indicators.

A practical approach is also undertaken using the case studies as basis, which essentially follows the opposite path. This data-driven path starts from the available municipal data and the data processing to obtain relevant information for the assessment of specific indicators.

Vulnerability assessments using existing municipal information require an a priori definition of what the information needs are in terms of data collection and information generation. In this sense, a 2 way approach was implemented. First, a theoretical approach that gives us insight on what the information needs are based on existing vulnerability models, then what information is needed (indicators), and finally which data is needed to assess those indicators. Second, a practical approach that deals with the problem in a reverse manner. That means that each municipality starts with certain data that has already been collected for various purposes. That data is then turned into new forms of information by multiple processes, and finally that information must be presented to the municipality in order to be used as a decision element when vulnerability reduction and building capacity measures are defined.

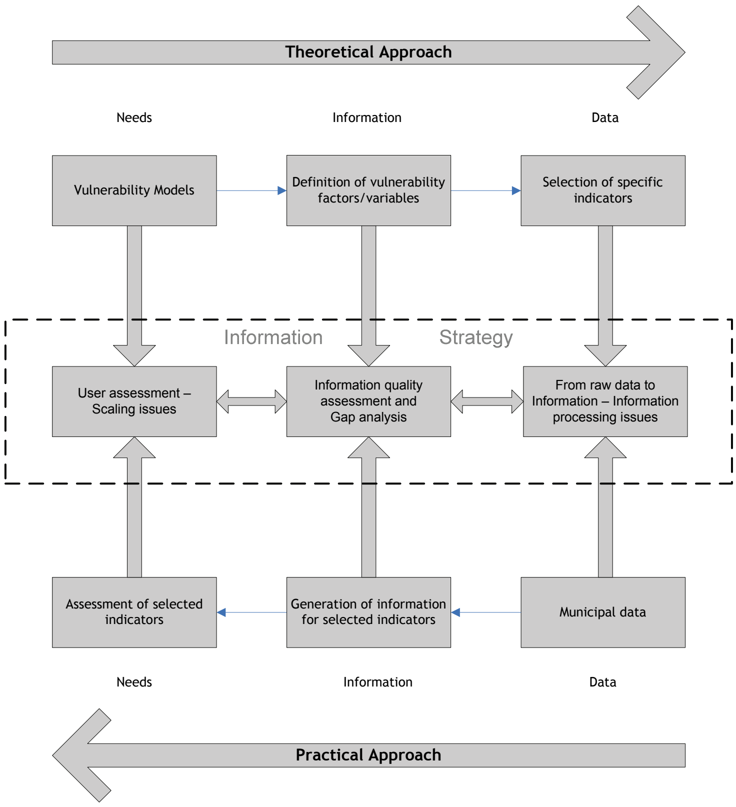

Figure 4.1 Conceptual Research Model

Each indicator presents a different challenge. In some cases, the raw data is already the indicator, but in many other cases, for example the Building Stock Fragility indicator, thorough processing is required in order to present the final indicators. Several issues arise in the process of producing the indicator. Cadastral data is not collected with the purpose of assessing building vulnerability, but instead is collected basically for taxation purposes. Nevertheless, some of the data collected is useful for assessing vulnerability. If consistent standards for data collection are developed, the same information could be used for both purposes.

In terms of information generation, the models used to generate the indicators should be agreed upon. Analytical hierarchical processes (AHP), Decision trees, Fuzzy Logic, or other methods of combining spatial data sets should be documented so that each new assessment is done in a manner which will allow multi-temporal analysis. Another factor that needs consideration is the aggregation level at which each indicator is presented, since the aggregation level allows different intervention programs and plans.

There are gaps between the theoretical needs of information and data and the real data available. They need to comprehend the flaws, gaps, and usefulness of the data that they have already collected. Unveiling these aspects will allow the municipality to define an information strategy to improve data collection and information generation processes.

A general model for the analysis of the information was created. It encompasses the required information for each of the 3 phases of the occurrence and response to the disaster. It allows us to measure the vulnerability of a city and the possibility to plan and manage in order to reduce or increase the knowledge about this vulnerability in a region through information.

The gathering of this data poses important challenges at the planning level, since it implies that the data is available and organized in a systematic manner. In its raw form, the information has different nature, different domains and different collection and analysis dynamics (probability, aggregated projections, cartographic information, information with geographic representation, general political information, etc.), which complicates the exercise of analyzing its quantity and quality.

The analytical exercise requires three elements:

- Interdisciplinary participation of experts
- Rating of the information through homogeneous indicators (given the different natures of the information)
- Design of evaluators or indicators of value of the homogeneous elements.

A methodological design is done with these considerations, starting from the design of surveys, expert workshops, and the processing of information through spatial data quality and fitness for use evaluators.

The main proposal of the general analysis model is the analysis of vulnerability of a region for the 3 stages of a disaster (1- Impact, 2- Relief, and 3- Recovery), that follow each other in time and require different municipal strategies to cope with them. Considering this, the availability of data for the analysis of vulnerability in each phase starts with the identification of the required information -indicators- and their specific attributes. A list of indicators exists for each phase (required information) that in turn will be rated in importance according to different attributes. Some indicators are common to different evaluation phases, but their application to the analysis and/or solution proposals or plans is different.

It is important to note that the attributes are fundamental in the pre-design of evaluators of the data collected in the survey, since they determine the scales and the possibilities for rating and comparison. The attributes included in the survey are the following:

- Availability: if the data exists and other municipal offices are able to obtain and use it.
- Completeness: measurable omission of the objects described in the specification.
- Integrity and Reliability: a measure of the internal validity of the data. If the data can support decisions and is useful in the way required
- Scale: refers to the appropriate amount of detail in the data.
- Shelf-life: how long can the information be considered up-to-date, or the frequency with which it should be collected.

The rating of the importance of the different elements as they relate to the phase of analysis is required. This information can be obtained through the expert workshops. For each attribute a set of possible answers is determined:

- Availability: Yes or No
- Integrity/Reliability: Good (3), Regular (2) or Bad (1)
- Completeness: Quantitatively measured as a percentage.
- Scale: Municipal (single data value represents the whole municipality), Commune (data value represents the whole commune), Neighborhood (single data value represents the whole neighborhood), Element/Household (each value represents a specific element, e.g. road, building, parcel, household, etc.)
- Shelf-life: Difference between data age and shelf life.

Two other attributes should be defined before hand for each indicator:

- Minimum acceptable scale: the minimum scale at which the information is usable for the purpose of evaluating the indicator (Municipality, Commune, Neighborhood, or Element).
- Minimum preferred scale: the ideal scale at which the information should be to ensure the rigorous evaluation of the indicator (Municipality, Commune, Neighborhood, or Element).

4.2 Surveys

The ideal case is that the municipality has all the information needed for the vulnerability assessment, but it is also clear that not all the information requirements are equally important when facing a data poor/limited resource situation. Faced with this situation, analysts can nevertheless perform acceptable assessments with some of the information, optimizing resources and working progressively on vulnerability assessments and mostly on strategies to improve the information incrementally over time. In this case, a measurement of the vulnerability assessment results with limited or poor information is very important, hence the use of the evaluators of the data available.

Multi-criteria evaluation (MCE) was used in this research due to the diversity of backgrounds of the risk experts and the amount of indicators per phase that had to be considered. MCE is a method for ranking management alternatives based on evaluation criteria, weighted by the user, and provides a rational basis for decision making in the face of uncertainty. It enables the decision maker to choose among alternatives. Unfortunately, choosing among Multi-Criteria Evaluation methods to rank multiple attribute alternatives is critical, not only because each method produces different rankings (Tecle, 1992), but also because choosing a method is in itself subjective and based upon the predisposition of the decision maker (Hobbs, 1986). Therefore, the method should be as simple and transparent as possible.

Three surveys were designed to determine the importance of the indicators for the municipalities to define the data requirements and the data characteristics. Each survey is explained in detail in the next sections.

4.2.1 Fitness for Use Surveys

A selection of respondents within the municipality should be made before engaging in the surveys. Only risk experts should be involved in the filling of Surveys 1 and 2. Survey

3 should be filled out by the geo-information experts of each office within the municipality.

Since there can be contradictory information within the surveys and lack of consistency, each of them has a "test" that determines whether the information filled in by the expert is suitable for use or not. Although a consistency check can be applied to one of the surveys filled by the experts, in some cases the results can be adapted to comply with the test when necessary, using prior information and knowledge about information and risk management inherent in the diverse background and knowledge of the municipal risk experts.

4.2.2 Survey 1: Indicator Comparison Matrix

The first survey is a comparison matrix where experts are requested to use comparison values to rate the relative importance of the indicators within each of the phases for each vulnerability type (see Table 4.1). The Pairwise Comparison Method (PCM) of the Analytical Hierarchical Process (AHP) was selected for this purpose considering that it is easier for the respondents to compare on a one by one basis, multiple indictors of diverse nature. The main aim of the PCM is to make a ranking of *n* given factors or alternatives. To compare the factors often a scale [1/9,1/8,…,1/2,1,2,…,8,9] introduced by Saaty (1980) is used. A scale of only three values was selected in this research to avoid inconsistency by the risk experts when filling the matrix.

Table 4.1 Survey 1: Indicator Comparison Matrix

Phase X		Indicator j				ΣSI_i	Weight
		Ind. 1	Ind. 2	…	Ind. n		
Indicator i	Ind. 1	1				SI_1	$SI_1/\Sigma SI_i$
	Ind. 2		1			SI_2	$SI_2/\Sigma SI_i$
	⋮			1		⋮	
	Ind. n				1	SI_n	$SI_n/\Sigma SI_i$
						ΣSI_i	

In this case, a scale of [1/3, 1, 3] is used to simplify the comparison values, where:

1/3 i is less important than j

1 i = j

3 i is more important than j

The weights or importance of each indicator within the phase are determined with this matrix. The resultant matrix should be consistent and reciprocal. There are some reasons for inconsistent data, namely the mistakes of a person providing his or her opinions or using 9-point semantic scale. The quantity of numbers appearing in the scale depend on the complexity of the problem (Kwiesielewicz and van Uden, 2004). Several authors have discussed the problems of scale (Finan and Hurley, 1999; Triantaphyllou, 2000; Triantaphyllou and Mann, 1995). A reasonable requirement is to make inconsistencies as few as possible. The most common approach is to calculate a consistency index according to the formula:

$$CI=(\lambda_{max}-n)/(n-1)$$

Where λ_{max} denotes the maximal eigen value of the pairwise comparison matrix. When the matrix is consistent then $\lambda_{max}=n$ and $CI=0$ (Saaty, 1980).

The *CI* should be as close as possible to zero, but until now the literature does not tell precisely what values are permissible. The standard procedure is to accept the set of values, when *CI* is not bigger than 1/10 of the mean consistency index of randomly generated matrices. To calculate the level of inconsistency, Saaty (1980) defined the Consistency Ratio (CR) as:

$$CR=CI/RI$$

Where *RI* is the average value of CI for random matrices using the Saaty scale obtained by Forman (1990) and Saaty (1980) only accepts a matrix as a consistent one if CR < 0.1.

A historical study of several RIs used and a way of estimating this index can be seen in Alonso and Lamata (2004). The main idea is that the CR is a normalized value, since it is divided by an arithmetic mean of random matrix consistency indexes (RI). Various authors (Lane and Verdini, 1989); Golden and Wang, 1990; Noble, 1990; Forman, 1990; Tumala and Wan 1994; and Saaty 1994 cited in Alonso and Lamata (2006)) have computed and obtained different RIs depending on the simulation method and the number of generated matrices involved in the process. Alonso and Lamata (2006) argue that in different situations the decision maker might need different levels of consistency and he/she can represent these levels using percentages. One specific matrix is therefore either consistent or not (i.e. either accepted or not as a consistent matrix) depending on two different factors (Alonso and Lamata, 2006):

a) A consistency index (λ_{max})

b) The level of consistency needed (α), $0 < \alpha \leq 1$. α is a number that relates the value of the error (consistency error) which is calculated for the matrix against the "average error" of the matrices with the same dimension as the matrix.

Average error is the difference between the mean of λmax and the "perfect" one of the matrices of a specific dimension n as:

$$Avg\,Err(n) \equiv \bar{\lambda}_{max}(n) - n$$

and the error of a specific matrix (mat) of dimension n can be defined as:

$$Err\ (mat) = \lambda_{max}\ (mat) - n$$

The matrix is consistent if and only if:

$$\frac{Err(mat)}{AvgErr(mat)} \leq \alpha$$

Therefore, a matrix will be sufficiently consistent if and only if:

$$\lambda_{max} - n \leq \alpha(\bar{\lambda}_{max}(n) - n)$$

and using the adjustment line proposed by the mentioned authors:

$$\lambda_{max} \leq n + \alpha(1.7699n - 4.3513)$$

If a matrix of a specific dimension n, and with a certain level of consistency needed α if and only if the above equation is satisfied.

For each matrix the consistency index (λ_{max}) should be calculated before averaging the scores obtained from all the surveys. Considering the variety of respondents of the surveys the consistency level (α) that will be used to define if the matrices are consistent is 0.5. This value can be modified by the person processing the surveys adapting the value of α to the specific requirements of consistency. Only the matrices that comply with the consistency index will be considered in the score averaging.

4.2.3 Survey 2: Data requirements and Attribute Importance

The second survey is designed to rate the relative importance of each attribute for each indicator, and define the shelf-life, minimum acceptable scale, and minimum preferred scale (see Table 4.2).

Table 4.2 Survey 2: Data Requirements

PHASE X	Indicator	Attributes	Importance	Minimum Acceptable Scale (MAS)	Minimum Preferred Scale (MPS)	Shelf-Life
	Ind. 1	Attribute 1				
		Attribute 2				
		…				
		Attribute n				
	Ind. 2	Attribute 1				
	…	…				
	Ind. n					

There is no consistency index for this survey, but decisions can be taken when contradictory answers are obtained from the respondents, using the most common or average answer of the other respondents.

The attribute importance within the indicator is a value between 0 and 1, that added up for each indicator will sum 1. Experts should define the importance of each attribute in the overall assessment of the indicator. The average values of importance will be calculated from the multiple respondents and will be used as the final importance value.

In the case of minimum acceptable scale, the mode is used as criteria for selecting the final value. In case there is more than one mode (in the case of even number of surveys applied), the lowest value (highest resolution) will be selected, considering that a considerable number of the respondents coincide with that specific scale as necessary for a thorough assessment. The same procedure is applied in the case of minimum preferred scale. In the case of shelf-life, since there can be many possible answers the average value is used as final criteria to select the shelf-life of the specific indicator/attribute.

4.2.4 Survey 3: Data Characteristics

The third survey is designed to obtain answers about the state of the data needed to measure each of the attributes. In this survey, the questions about availability, reliability, completeness, integrity, and age are asked (see Table 4.3).

Table 4.3 Survey 3: Data Characteristics

Indicator	Attributes	Availability	Completeness	Integrity/ Reliability	Scale	Date
Indicator 1	Attribute 1					
	Attribute 2					
	…					
	Attribute n					
Indicator 2	Attribute 1					
…	…					
Indicator n						

Once the surveys are filled in by at least 3 experts, to account for different perceptions, the following criteria will be applied to define the value to use in case of differences or contradictions in the surveys:

- Availability: if at least one respondent answers “yes”, it will be assumed that the information is available.
- Completeness: the average percentage value will be used.
- Integrity: an average score will be calculated and approximated to the nearest entire value (1, 2, or 3).
- Scale: the lowest value (highest resolution) will be selected.
- Reliability: the mode will be used, but in case there is a tie, the information will be considered reliable (yes).
- Information date: the newest value will be used.

4.3 Fitness for Use Evaluators

The concepts of spatial data usability fitness for use are very recent. There are barely any methods to assess them. Only a few methods can be actually found in the literature (Bruin et al., 2001; Devillers et al., 2005; Hunter et al., 2003; Josselin, 2003; Worboys, 1998), but none of them has a comprehensive method for evaluating fitness for use considering the variables defined previously. In view of this, two evaluators of the fitness for use or usability of the information were designed. Establishing information updating and collection priorities can be achieved by using the results obtained by these evaluators.

4.3.1 Evaluator 1 – Current data state

This evaluator determines the condition of the data to calculate each attribute and indicator. This evaluator gives the decision makers information on how good the data is, how good is the assessment of each indicator, and how good is the overall vulnerability assessment for each phase in terms of available information. The results yield values between 0 (worst) and 5 (best), according to pre-defined decision rules (Figure 4.2)

A threshold value for completeness of 30% is defined as representative of existing information. Values under 30% are considered as insufficient information for calculating an indicator.

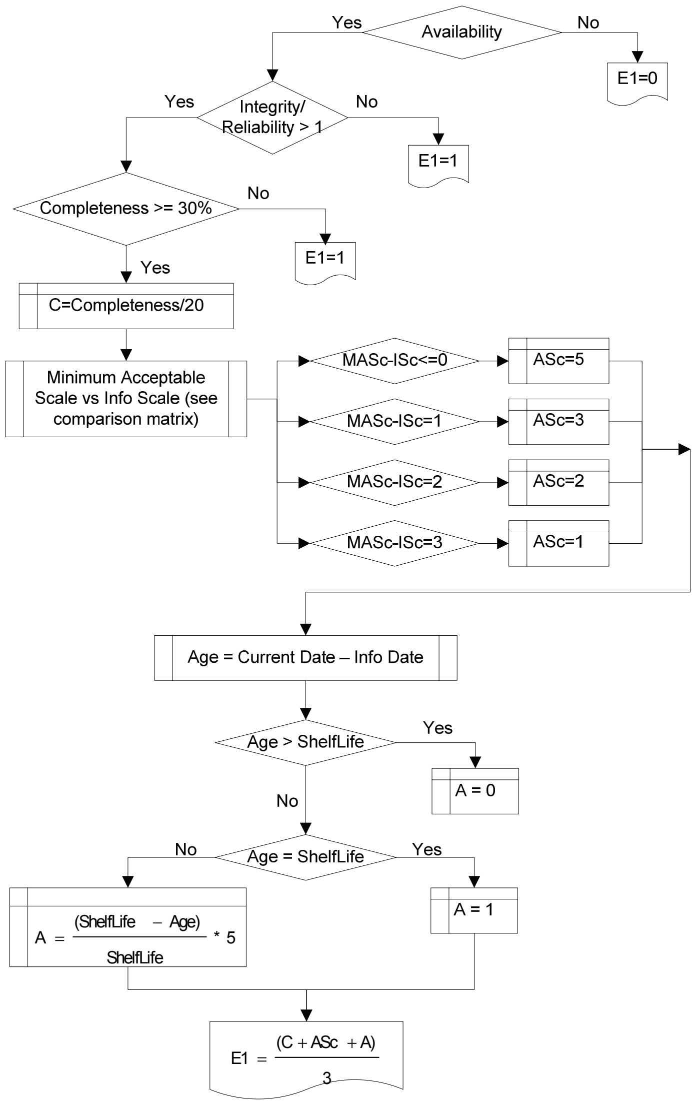

Figure 4.2 Fitness for Use Evaluator 1 - Data current state

The results obtained for each attribute are multiplied by its importance score of the attribute (obtained in survey No. 2) and then summed to obtain a value for each indicator. This value is then multiplied by the indicator importance score obtained in survey No. 1, as illustrated in the following equation.

$$S2i = \left(\sum_{i=1}^{n} S2Ai * IAi \right) * IIi$$

Where S2Ai is the score obtained for each attribute i; IAi is the importance score of each attribute i; and IIi is the indicator importance score.

The resulting score values are interpreted as follows:

- <2: The use of the information is not recommended for decision making. It is suggested to evaluate each of the attributes and indicators to undertake improvement actions.
- 2 to 3.9: the information can be used in general decision making processes, strategic projects, or general guidelines.
- 4 to 5: the resulting information is appropriate for decision making processes, direct intervention, and project definition.

4.3.2 Evaluator 2 – Data distance to desired condition

This evaluator refers to how far away the data under consideration is from the desired conditions for these data. The farther away it is, the larger the amount of work in terms of collecting or updating data will be. The knowledge that this evaluator gives to the decision makers will help set a strategy for information collection, giving priority to the most important indicators with the poorest results. The evaluator is calculated as can be seen in Figure 4.3.

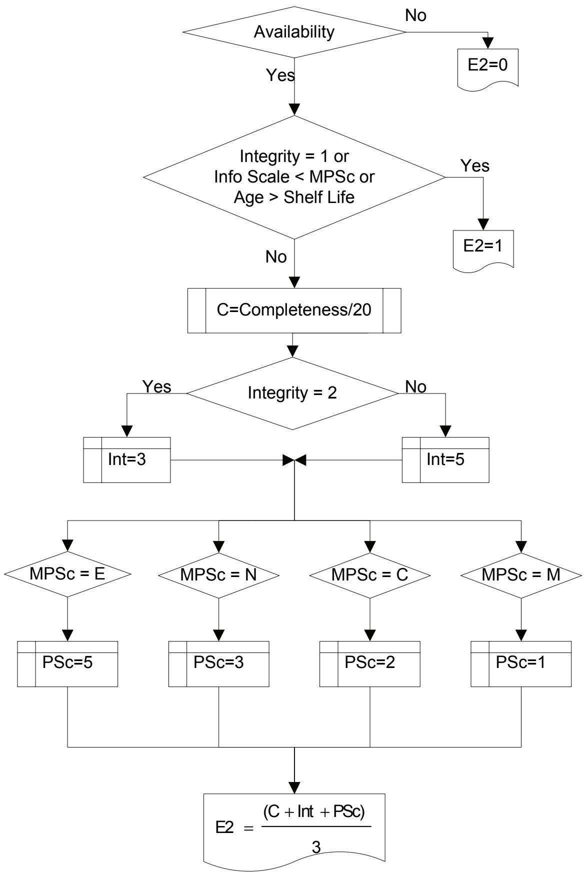

Figure 4.3 Fitness for Use Evaluator 2 – Data distance to required condition

Just as evaluator 1, the results obtained for each attribute are multiplied by its importance score (obtained in survey No. 2) and then summed to obtain a value for each indicator. This value is then multiplied by the indicator importance score obtained in survey No. 1.

The resulting score values are interpreted as follows:

- < 2: the results are deficient. Improvement actions such as collection and updating of data should be undertaken.
- 2 to 3.9: the results that can be obtained with this data can be improved. Improvement actions such as collection and updating of data should be undertaken. Special attention should be given to those indicators and attributes that have the lowest results.
- 4 to 5: the quality of the information is adequate, however it is recommended to undertake regular updating and data maintenance processes.

4.4 Conclusions

In this chapter a general overview of the methods used to achieve the research goals have been presented. The survey design is explained and the two evaluators of fitness for use are defined. In the following chapters, the data is analyzed and discussed in order to provide answers to the research questions and ultimately to evaluate the feasibility of implementing the methodology for urban vulnerability assessments using municipal data.

Chapter 5
Case studies

"I do not believe in a fate that falls on men however they act; but I do believe in a fate that falls on them unless they act."
Gilbert Chesterton (1874-1936)

In this chapter a description of the case studies is presented. First, the criteria and conditions to select the case studies are outlined. Second, the general characteristics of the case study cities are described, their urban management styles, and finally the existing laws and by-laws in terms of risk management that each city and country has.

5.1 Case Study Selection

Choosing a real-life context helps bring down to earth such a complex phenomenon as urban vulnerability. A multiple-case design was chosen to allow cross-case analysis and comparison and the possibility of evaluating vulnerability and information availability in diverse settings. The case studies are used to develop concepts, prove the methodology designed to assess the indicators and the fitness for use of the data used, and draw specific implications. In this research, two case studies were selected to portray different urban management conditions in terms of available information and capacity. These cities were selected to provide a framework for discussion for future application of the methodology in other urban settings in the developing world. A list of conditions had to be met first in order to select the case study cities:

- To be located in an earthquake hazard prone area
- One case study should present poor, scattered, disorganized or non-existent digital data (for vulnerability assessments) and low capacity; that means a Data Poor- Capacity Deficient municipality.
- The other case study should present more data, some how organized and have moderate capacity, that is a Data Rich - Capacity Moderate municipality.
- The case study cities should be involved or willing to get involved in the SLARIM project to facilitate the fieldwork activities and also provide some previous knowledge on the existing information and capacities of the municipalities.
- That only the municipality is in charge of urban management of the city.
- The local authority should be interested in the project and willing to collaborate.

5.2 Data Rich – Capacity Moderate Case Study: Medellín, Colombia

Medellín, the second largest city in Colombia, and capital of Antioquia is situated in the Aburrá Valley, surrounded by high mountains. It is located at 06°17'29" N and 75°32'10" W; 1475 meters above sea level and 569 km away from Bogotá, the country's capital (Figure 5.1).

Figure 5.1 Location of Medellín, Colombia (Google Maps)

The city extends from south to north with the Medellín River as its main axis, occupying 382 km^2. Medellín is part of the Metropolitan Area of the Aburrá Valley, formed by nine more municipalities that make up an urban unit of more than 3.5 million inhabitants (Figure 5.2). The urban area of Medellín occupies 105 km2 and has an estimated population of 2,261,045 inhabitants (DANE, 2005).

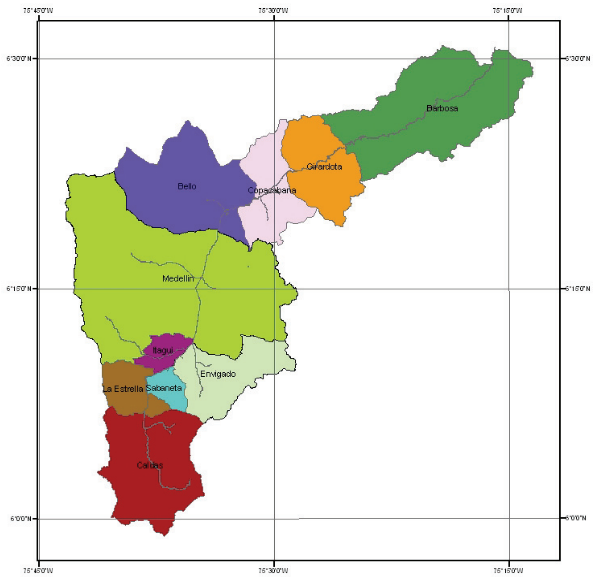

Figure 5.2 Metropolitan Area of the Aburrá Valley

The municipality of Medellín, located in the Aburrá Valley, is limited by two branches of the Central Cordillera separated by the watershed of the Medellín River. It presents mainly a mountainous relief, where the hills of El Volador, El Picacho, Pan de Azúcar and Nutibara are the most impressive. Towards the Cordillera that surrounds the valley, heights up to 3000 m. can be found. The only river that crosses the valley is the Medellín River, which receives the waters of more than 100 smaller streams that run down the slopes of the Cordillera (e.g. Santa Elena stream).

The most important economic activities are related to manufacturing, especially textiles for export, food and beverages, tobacco, clothing, agricultural machinery, chemical products, rubber, and furniture. In the rural areas there are also important economic activities such as agriculture, with coffee and other minor crops. The city is an important commercial center where several of the most important economic firms in the country have their main offices. It is also a major regional center with various large service industries (education, health, etc.). The city connects by fairly good roads with all the main cities in the country; it has two airports (José María Córdoba and Olaya Herrera), as well as the first mass transportation system in the country. Medellín has 35 hospitals, one clinic, 40 health centers, 469 preschools, 389 primary schools, 216 high schools, and 30 universities and professional training centers. The city is divided into 16 communes and 5 rural districts (Figure 5.3). The communes are subdivided into 249 neighborhoods. Population distribution by commune is presented in Table 5.1.

Table 5.1 Population distribution by commune

Commune No.	Name	Males	Females	Total
01	Popular	59983	71334	131317
02	Santa Cruz	45857	54562	100419
03	Manrique	79460	96414	175874
04	Aranjuez	77717	90764	168481
05	Castilla	69981	85727	155708
06	Doce de Octu-	94450	110075	204525
07	Robledo	85368	98861	184229
08	Villa Hermosa	58502	66093	124595
09	Buenos Aires	69188	83350	152538
10	La Candelaria	42485	49956	92441
11	Laureles-	57292	73684	130976
12	La América	48602	60042	108644
13	San Javier	61872	72844	134716
14	El Poblado	46865	62048	108913
15	Guayabal	40259	50270	90529
16	Belén	86633	110507	197140
			Total	2261045

Source: Encuesta de Calidad de Vida – Municipio de Medellín, 2005

The Central Cordillera, where the city of Medellín lies, forms a part of the Andean block located between the Nazca plate to the west, with an eastward subduction movement of about 6-8 cm/year, the South American plate to the east, moving west-southwest at a velocity of 1-3 cm/year, and the Caribbean Plate to the north. The limits of the Caribbean plate have not been appropriately defined. The Caribbean plate has a displacement relatively smaller in a general west-east direction within the interest zone. These relative displacements imply compression, traction, and shearing stresses in the region. As a consequence of this stress field, some flexure folding and shearing are present in the plates, showing up along some known geologic faults (Sarria, 1999). The topographic, geologic, and tectonic conditions of the country have been responsible for many disasters, especially in the northwestern part, where the triple junction of plates occurs.

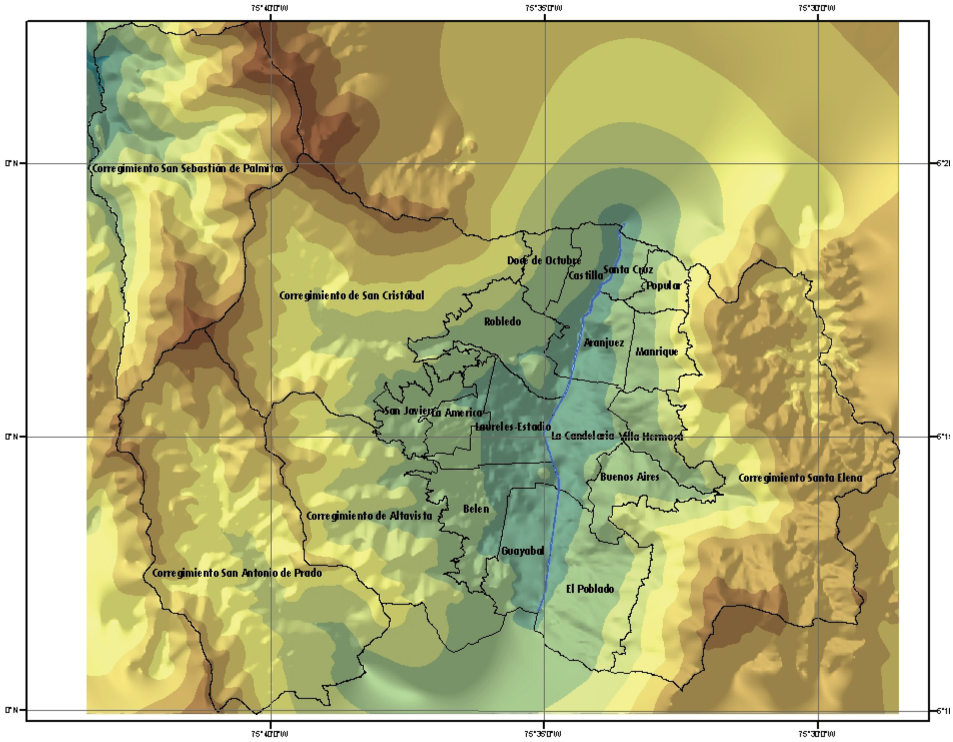

Figure 5.3. Communes and Rural Districts of Medellín

According to the National Building Code (NSR-98), Medellín lies in an intermediate earthquake hazard zone (ACIS, 1998) (see Figure 5.4C). Therefore, the city is prone to earthquakes resulting from the complex seismic setting of the country. It is also prone to landslides, debris flows, and flash floods due to the steep slopes that surround it and the geological and hydrological conditions of the area.

Until the 1980's, disasters in Medellín were considered as random phenomena and the city was planned using only geological maps scale 1:50000 published in 1963. There was no official policy for identifying and managing areas threatened by hazards. Several disasters have been registered in Medellín:

- Earthquakes: 1938, 1961, 1962, 1973 and 1979.
- Geological and geotechnical problems due to natural and human factors: Media Luna (1954) and Santo Domingo Savio (1974).
- Landslides: 343 events registered between 1977 and 1988, the one in Villa Tina was the most important due to its impact and high number of casualties.
- Flash floods and debris flows in the following streams: Santa Elena, La Iguaná, La Loca, and La Mina, with 599 reported events.

In 1999, the Medellín Seismological Group published a report about the seismic hazards in Medellín, summarizing studies done since 1995 and obtaining, among others, the re-evaluation of the seismic risk for the municipality, the analysis of the seismic hazard, geotechnical characterization of the city, and definition of the 14 different homogeneous zones that make up Medellín (Figure 5.5). The Seismic microzoning of the Metropolitan Area was done in 2001 and it constitutes a complement to this study for the city of Medellín.

The Seismic Zoning of Medellín presents peak ground accelerations (PGA) for each Homogeneous Zone, therefore surpassing the National Building Code in terms of detail. Instead of using one PGA for the whole city, engineers design and build their buildings according to the zone where they are located, applying the specific spectrum for the design earthquake as presented in Figure 5.6 and using the spectral coefficients in Table 5.2.

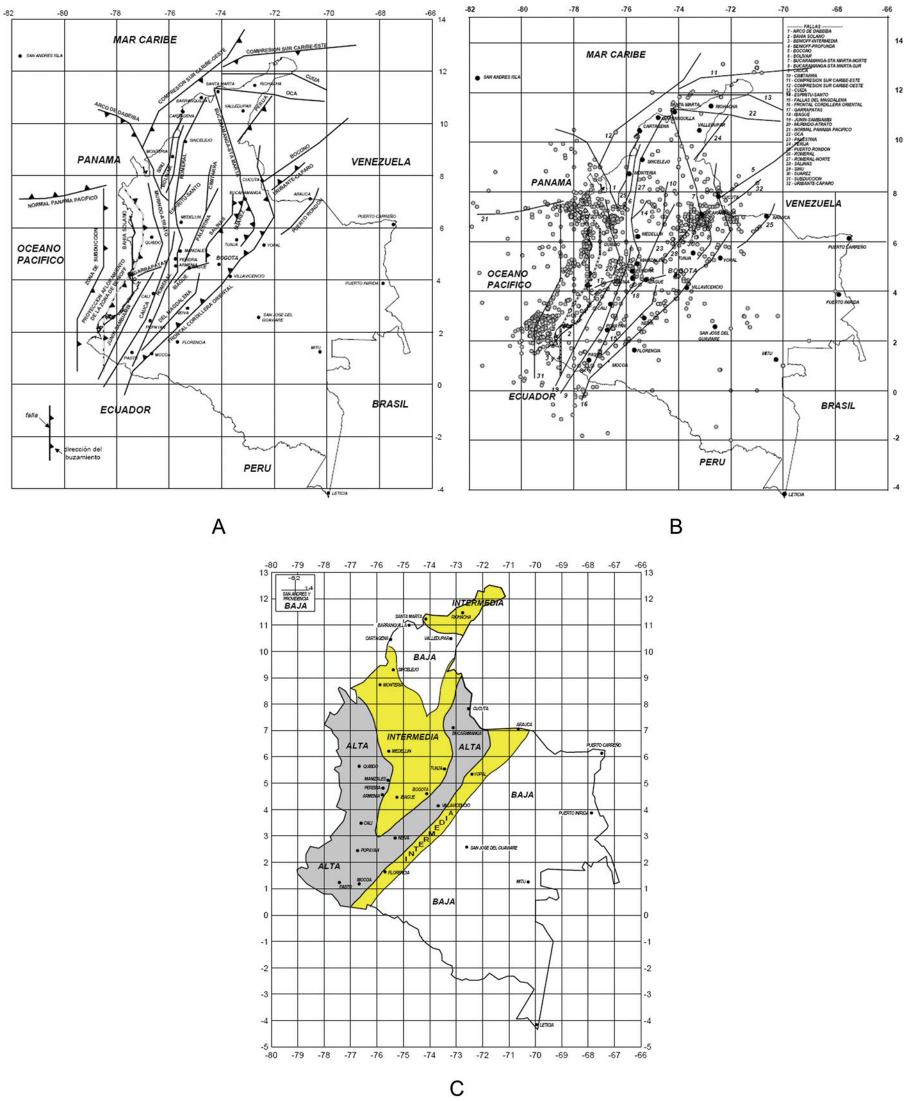

Figure 5.4 Earthquake Hazard in Colombia (ACIS, 1998) A- Main Fault Systems; B - Epicenters of earthquakes with Ms >= 4 (1556 – 1995); and C – National Seismic Zoning Map

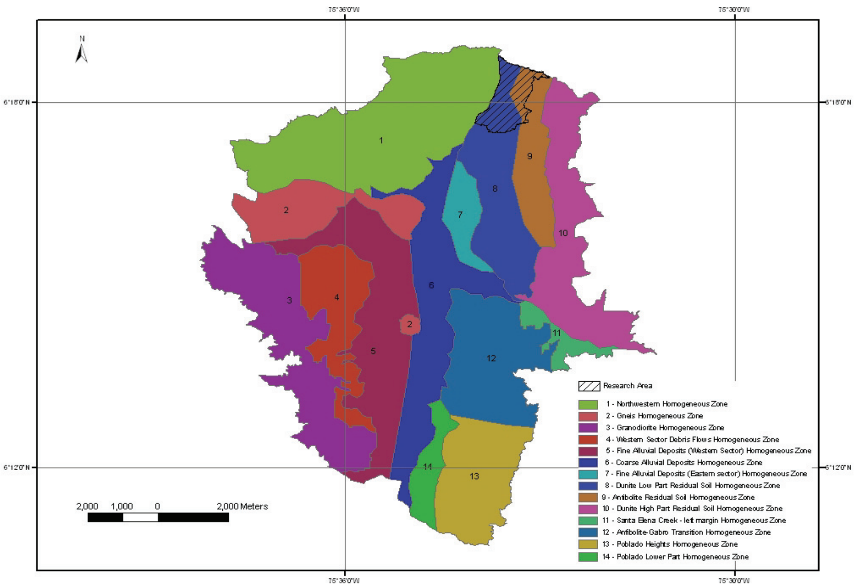

Figure 5.5 Seismic Zoning - Homogeneous Zones

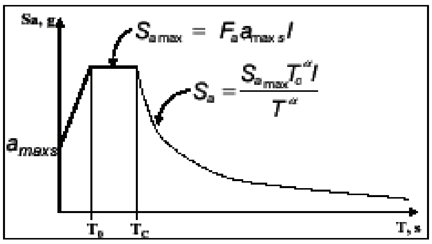

Figure 5.6 Generalized Spectrum

Table 5.2 Spectral Coefficients for Design Earthquake

Homogeneous Zones	a_{maxs}	F_a	S_{amax}/I	T_0	T_C	α
1	0.27	2.60	0.70	0.10	0.60	1.34
2	0.34	2.35	0.80	0.10	0.40	1.17
3	0.30	2.66	0.80	0.20	0.70	1.52
4	0.23	2.17	0.50	0.10	0.65	1.22
5	0.18	3.33	0.60	0.10	0.60	1.26
6	0.18	2.77	0.50	0.10	0.50	1.07
7	0.18	3.33	0.60	0.10	0.60	1.26
8	0.23	2.40	0.55	0.10	0.75	1.37
9	0.26	2.70	0.70	0.10	0.55	1.28
10	0.38	2.10	0.80	0.10	0.50	1.29
11	0.26	2.88	0.75	0.10	0.65	1.43
12	0.26	3.07	0.80	0.15	0.70	1.52
13	0.26	3.07	0.80	0.10	0.50	1.29
14	0.20	3.00	0.60	0.10	0.55	1.21

5.2.1 Colombian Risk Management Legal Framework

The Colombian government, in its obligation to bring security to its inhabitants, created a system of national aid (headed by the Colombian Red Cross) as a means of help in case of a public calamity. It was established by Law 49 of November 22, 1948. The National Emergency Committee (CNE) was established by Law 9 of January 24, 1979. The first laws about disaster management appear here. Three consecutive disasters of great magnitude -the tsunami of Tumaco in 1979, the Popayán earthquake in 1983, and the Armero avalanche in 1985- and the manner in which they were addressed, lead to the guidelines for the creation of a National System for Disaster Prevention and Aid (SNPAD) that would serve as a basis to regulate decision-making and the way of facing these problems. The concept of emergency was replaced by disaster, new extraordinary powers were added, and the National Fund for Calamities (FNC) was revived.

In 1989, with the Decree-Law 919 of May 1, the new law 46/88 was put in place and the National Office for Disaster Prevention and Aid (ONPAD) was created as an answer to the urgent need of the national government to meet through an adequate organization the innumerable social and economical problems generated by the public calamity and the disasters of natural and man-made origin that society and the country in general had suffered in the last decades of the twentieth century. During the nineties, the ONPAD was moved from one ministry to the other and changed names several times, until December 1999, when its name was modified to General Directorate for Disaster Prevention and Aid (DGPAD), the name which it currently holds. In January 13, 1998, through the Decree 093, the National Plan for Disaster Prevention and Aid (PNPAD) was adopted, including the objectives, principles, strategies, programs, and sub-programs that should guide the activities of the System. In Annex 4 a brief description of the laws and decrees that have led to the DGPAD are presented.

As can be seen, the general policy of the state since 1986 has been one of consolidating the incorporation of risk mitigation and disaster prevention in the process of social and economical development of the country, with the aim of eliminating or reducing loss of life and material and environmental assets. This is achieved through the strengthening of the institutional competencies, the organization and participation of the inhabitants, and the application of measures for the change of the factors that generate risks, such as the potential hazards and risks of natural or man-made origin and the vulnerability of the social context and material of human settlements and fragile exposed ecosystems.

The objectives of the DGPAD are: to prevent disasters and mitigate risks; to incorporate risk management variables into development planning; to promote public, private, and community involvement in risk management; to bring effective response in case of disaster; to give priority aid to specially vulnerable areas; to consolidate the National System for Disaster Prevention and Aid (SNPAD); and to strengthen international cooperation in the areas of prevention, mitigation, aid, rehabilitation, and reconstruction (MinJusticia, 2008a).

The strategies defined to achieve the objectives are: to gain knowledge about natural and man-made risks; to incorporate risk prevention and reduction into planning; to strengthen the institutional development of the system for disaster prevention and aid; and to socialize risk prevention and mitigation.

5.2.1.1 National System for Disaster Prevention and Aid (SNPAD)

This system is composed of public and private entities that make plans, programs, projects, and actions to reach the following objectives (MinJusticia, 2008b):

- Define the responsibilities and functions of all the public and community organisms and entities in the phases of management, rehabilitation, reconstruction, and development that arise due to disaster situations.
- Integrate the public and private efforts for the aid and prevention of disaster situations.
- Guarantee the opportune and efficient management of all the human, technical, administrative, and economical resources that are necessary for disaster prevention and aid.

The structure of the SNPAD is formed by three general committees: National, Departmental, and Local (Annex V) that operate according to the magnitude of the disaster and their ability to provide aid.

The National Committee designs the guidelines and policies that allow the development of different action plans. At the technical level, it is made up of civil employees and academics belonging to private or public entities related to the disciplines of risk management. In its operational level, it is made up of organisms that intervene in disaster situations, such as the Civil Defense, Red Cross, and Armed Forces, among others.

At the department level, it is represented by the regional committees headed by the governors and advised by the technical bodies of the zone.

The local committees make up the nucleus of the system, since they are the ones that face the risk directly. They are headed by the municipal mayor and are advised by the local, departmental, or national organizations according to the type of need or the degree of the disaster. The participation of the citizens is relevant in this context, particularly those affected by the disaster.

The departmental and local governments allocate government money to economically support their risk management and disaster aid plans. In case of a disaster of national impact and of great magnitude (for example, the earthquake in Armenia in 1999), the national government can generate exceptional tax resources destined to the emergency aid and relief and recovery planning through emergency declarations.

5.2.2 Disaster related Legal Framework for the Medellín Municipality

The Medellín Municipality is ruled by the same norms stipulated by the National Government. The following are some decrees of interest that were issued by the Municipal Administration:

- *Decree 377 of 1986*, which creates the Metropolitan Emergency Operative Committee (COME). Its functions are centered on the definition of mitigation policies and disaster aid and rescue in the municipal area.
- *Agreement 14 of 1994*, which establishes the Municipal System for Disaster Prevention and Aid (SIMPAD), which is a part of the National System of Disaster Prevention and is within the DAPARD (Administrative Department of Disaster Prevention and Aid). Through this agreement, the SIMPAD assumes the competencies of an emergency committee within this area of the national emergency system and is established as a municipal entity for risk management for its population.

- *Agreement 62 of 1998*, which adopts the territorial ordinance plan (POT), according to what was stipulated in Law 388 of 1997. The POT has a duration of nine years, understood as tree mayoral terms. Its intention is to establish the directives for the spatial layout of the municipality. The POT represents, according to the visions of different social groups, a conceptual vision for a competitive city, environmentally sustainable, socially balanced, comfortable, and spatially and functionally integrated, starting from structural elements and a system of centralities previously identified.

5.2.2.1 SIMPAD (Municipal System for Disaster Prevention and Aid of the Medellín Municipality)

Initially, disaster aid in the Medellín Municipality was directed at massive aid to the injured by the emergency services. It was headed by the health sector and showed high efficiency in its interventions. The COME (created in 1986) was conceived as the municipal entity for emergency aid, incorporating, in addition to the health sector, different local organizations with executive responsibilities in the management of risk in their respective jurisdictions.

The COME had to be restructured considering the urban development dynamics existing in Medellín, the increase in disaster events, the terrorist wave at the end of the eighties and beginning of the nineties, and the phenomena of El Niño and La Niña in the nineties, the development of the guidelines proposed by the General Directorate for Disaster Prevention and Aid (DGPAD), and the directives and support given by the United Nations in the International Decade for Disaster Aid and Reduction. The new COME was to redefined as an organization that would research the reality of the municipality and would follow the legislation currently in effect.

The formation of the SIMPAD (Municipal System for Disaster Prevention and Aid) in 1994 was guided by the organizational, operative, and financial restructuring of the COME. It was shaped into a planning and coordinating system that consolidated the institution and the cooperating entities dealing with the complete handling of the management of risks existing in the city. The main function of the SIMPAD can be summarized in three large strategies: "Emergency prevention, integral emergency aid, and recovery". Prevention activities are directed especially towards the identification of the risks to which the city is subject. The city has advanced in what pertains to seismic microzonation and it has the second largest accelerographic network of Latin America after Mexico City. It also has instruments at the main streams in the city to detect peak points of flood hazard. One could say that prevention work is focused on research and training, and is all related to the process of formation of social networks through neighborhood emergency committees. The second strategy, emergency aid, seeks to have not only an immediate response after a potentially catastrophic event happens, but also to have the city stocked with the supply centers and chains that allow an effective response at the moment that a first, second, or third level emergency arises. A third part, maybe the weakest in the system, is recovery. This is mostly due to the nature of the events that happen in the city, which are so varied in kind that they require special planning. Permanent mitigation work is done in order to minimize the risks that come from natural events, as well as man-made events or a combination of phenomena.

The Victim Aid Network of the SIMPAD has three commissions to take care of these three larger strategies. The SIMPAD today counts on its director, operations coordinators, and workers it employs. Ten commissions are coordinated through this office, in which all the Medellín municipal secretariats participate.

These commissions are, among others:

- Technical Commission that coordinates the Public Works Secretariat.
- Education Commission of the Education Secretariat.
- Rescue and Recovery Commission, made up by the various volunteer groups of the city.
- Supply Commission, coordinated by the Administrative Service Secretariat.

The SIMPAD's 10 commissions integrate the whole Municipality.

5.2.2.2 Seismic Prevention Program for the city of Medellín

The municipal administration, knowing the need for better understanding the behavior of the seismic phenomena for the city of Medellín, established the bases of the "Program for Seismic Prevention" through the project of Cooperation for Disaster Prevention. This started at the beginning of the nineties with the synthesis and evaluation of the available historical information and included as well the study of risk, zoning, instrumentation, analysis, and studies of physical vulnerability of the city. This study was conducted in 1998 by several institutions of the city, such as Ingeominas, Eafit University, the Faculty of Mines of the National University, and the engineering firm Integral.

The intention of this program was to translate the technical data and historical references into guidelines for the design and application of policies and elements that allow the evaluation (to an extent) of the hazard to which the city is exposed. To date, several important results worth mentioning have been achieved within this program:

Historical-Seismic Catalogue for the city of Medellín: It is a collection of historical information reported by diverse document sources. It includes information since the earthquake of 1730 until the last events reported in 1979. It is the intention that this catalogue becomes an input for the identification of seismic hazards and a guide for the management and application and that it is applied in works that involve the development of new methodologies to correctly guide the development of the city.

Methodology for the determination of seismic risk in Medellín: Around 1994 and with the help of the United Nations, the municipal administration established the study "Program for Seismic Prevention for Medellín", through an agreement with EAFIT University.

Formation of the Medellín Seismological Group: Made up by the SIMPAD, Ingeominas, the Faculty of Mines of the National University, Eafit University, and the engineering firm Integral as main and collaborating entities in the development of research on this subject.

Elaboration of the instrumentation and seismic micro-zoning of the Medellín urban area: This work summarizes the efforts conducted since 1996 by the SIMPAD as head of the Medellín Seismological Group. It implements the accelerographic network of Medellín (RAM), and allows the monitoring and constant control of potentially hazardous phenomena. A study of the seismic hazard in Medellín, published in 1999, summarizes studies done since 1997 and obtains, among others, the reevaluation of the seismic risk for the municipality, the analysis of the seismic hazard, geotechnical characterization of the city, and definition of the 14 different homogeneous zones that make up Medellín. The seismic microzonation of the metropolitan area was done in 2001 and it constitutes a complement to this study for the city of Medellín.

5.2.2.3 Emergency plan for a seismic event in the city of Medellín.

The creation of the municipal plan for disaster prevention and aid was prepared by the municipality according to the guidelines of the National Plan for Disaster Prevention and Aid (Ministry of the Interior and Justice, Law 46 of November 1988, Decree 919 of 1989). The formulation of the Strategic Plan for Emergency Prevention and Aid for Medellín is based on the development of actions and coordination, organization, and integration of the institutional and inter-sectoral information. This allowed the development and diagnostic of the administrative, technical, operational, and logistical aspects for emergency prevention in the city.

5.3 Data Poor – Capacity Deficient Case Study: Lalitpur, Nepal

Lalitpur sub-metropolitan city –LSMC-, popularly known as Patan, is currently one of the most vibrant cities of the Kingdom of Nepal, located about 5 kilometers south-east of Kathmandu, the capital. With its urban history dating back to as far as 2300 years, LSMC is one of the three major cities located inside the Kathmandu valley, at the central hilly part of the country (see Figure 5.7). Since ancient times, Lalitpur has been preserving its unique place and role in the geo-political and economic arena of the country. Lalitpur is extremely rich in its arts and architecture and boasts a large community of artisans, especially metal and wood workers. In fact, the literal translation of Lalitpur is city of fine arts. It nurtures a large number of sacred buildings, temples, pagodas, stupas and shikharas, monasteries, and chaityas. UNESCO has listed the conglomerate of the buildings in Patan Durbar Square as a World Heritage Site (one of the seven Heritage sites in the Kathmandu valley).

The sub-metropolitan city area is divided into 22 administrative units called wards, as presented in Figure 5.7. In Nepal, a ward is the lowest formal administrative unit. Usually the boundary of the ward is defined using natural boundaries like rivers, roads, or foot trails. The ward is chaired by a ward president elected by local people with other members representing their respective area.

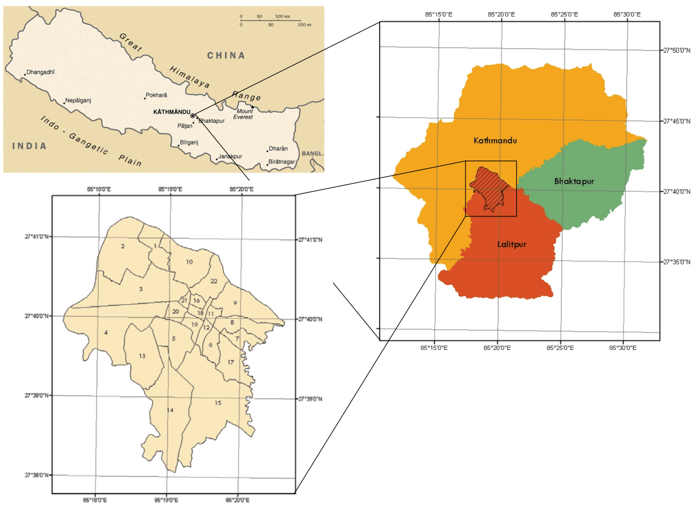

Figure 5.7 Location of Nepal, the Kathmandu Valley and Lalitpur urban area (wards)

According to the Central Bureau of Statistics (CBS), in its 2001 census, the total population of the city is 162,997 inhabitants, 84,208 males and 78, 789 females. The total number of households is 35,000, with an average household size of 4.66 persons. The total area of the city is 15.15 km^2 (which doesn't include the district area) and the population density is 10,758 persons per km^2. Relatively, the main urban area of the municipality is on flat terrain with an elevation of about 1280 m to 1330m. The population distribution by wards is presented in Table 5.3.

Table 5.3 Population distribution by wards in Lalitpur (source CBS 2001 (unpublished data))

Ward	Area (Ha)	Households	Population	Males	Females
1	41.12	1691	7,096	3,993	3,103
2	129.75	2284	10,459	5,491	4,968
3	148.02	2365	10,637	5,473	5,164
4	180.69	2523	10,971	5,511	5,460
5	70.54	1397	6,573	3,243	3,330
6	25.46	1311	6,352	3,322	3,030
7	23.84	1299	6,408	3,304	3,104
8	44.36	1407	7,355	3,798	3,557
9	77.22	1706	8,135	4,447	3,688
10	81.10	1222	5,430	2,974	2,456
11	12.52	780	4,238	2,153	2,085
12	13.19	1129	5,677	2,136	3,541
13	95.26	1400	6,553	3,524	3,029
14	184.63	2498	11,530	5,745	5,785
15	243.31	2694	11,352	6,042	5,310
16	9.80	989	5,294	2,630	2,664
17	56.68	1509	6,693	3,576	3,117
18	12.82	1287	6,915	3,503	3,412
19	17.53	1266	6,048	3,138	2,910
20	19.84	1447	6,519	3,383	3,136
21	9.38	906	4,249	2,156	2,093
22	46.10	1890	8,513	4,666	3,847
Total	1515.43	35000	162,997	84,208	78,789

Nepal is among the countries with the highest seismicity in the world, which is related to the presence of active faults between tectonic plates along the Himalayas, mainly in the Main Boundary Fault (MBF) and Main Central Thrust (MCT). As described in chapter 4, NSET and JICA defined an earthquake scenario for the Kathmandu Valley illustrated in Figure 5.8 and Figure 5.9.

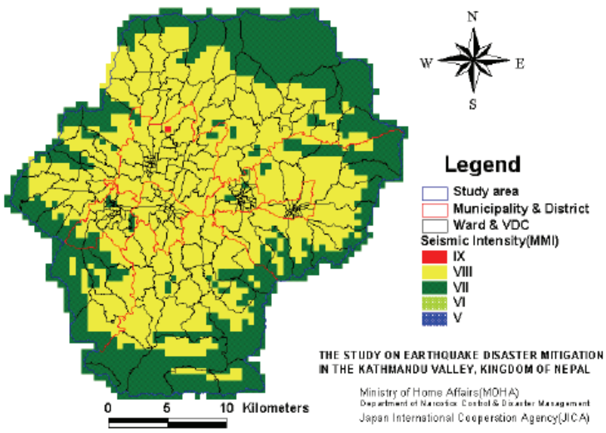

Figure 5.8. Seismic intensity map - mid-Nepal earthquake (source: JICA)

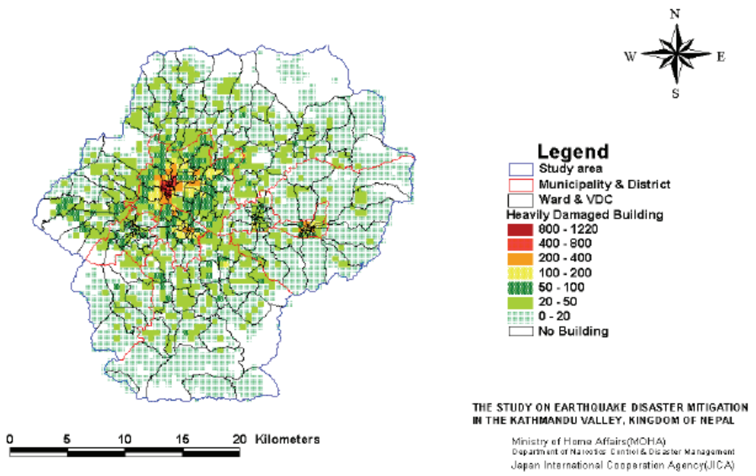

Figure 5.9. Heavily damaged buildings - mid-Nepal earthquake (source: JICA)

5.3.1 Nepali Risk Management Legal Framework

Nepal has a legal framework for the roles and responsibilities of the government as it pertains to disaster management. This legal framework is provided in the Local Administration Act (1971); the Natural Disaster Relief Act (1982); the Constitution of the Kingdom of Nepal (1990); the HMG (Allocation of Functions) (Second Amendment) Rules (1996); the Local Self-Governance Act (1999); the Buildings Act (1998); and the Kathmandu Valley Town Development Act (2000).

There was no structured disaster policy before the advent of the Natural Disaster Relief Act (NDRA) in 1982. Prior to 1982, relief and rescue work was carried out either on the basis of the capacity of the organizations or as social work. Thus, realizing the need, the Natural Disaster relief Act, 1982 was formulated and amended twice in 1989 and 1992. The act is a milestone in disaster management in Nepal.

The National Disaster Relief Regulations (NDRR) could not be formulated; therefore the Act is not fully effective. Duties and responsibilities of several other disaster management agencies have to be reflected in the regulations as each of them is not stipulated in the Act. The NDRA does not describe the duties and responsibilities of all disaster management related agencies other than the Ministry of Home Affairs. There is not only a lack of disaster management regulations, but also a lack of job descriptions, lack of coordination and cooperation, and a lack of responsibilities.

The provisions for the Relief and Treatment Sub-Committee, Supply, Shelter and Rehabilitation Sub-Committee; Regional Natural Disaster Relief Committee, District Natural Disaster Relief Committee, and Local Natural Disaster Relief Committees have been made in the NDRA, but the committees only exist on paper.

The NDRA does not describe the functions and duties of the district and local management related agencies. Thus, disaster victims do not get immediate, efficient, and effective rescue and relief services. Sometimes duplication of relief works has also been experienced, mainly due to the absence of dialogue and mutual understanding among disaster management related agencies. District management related agencies try to avoid their responsibilities, since there is no clear description of their functions in the Act (MOHA, 2005).

5.3.1.1 Natural Disaster Relief Act, 1982

This act provides guidelines for the relief work that should follow a natural calamity. It was supposed to come into force immediately, but has only been implemented partially. Most of the sections are focused on the relief and recovery activities, but none in prevention. There is only one slight mention in the functions of the Central Committee in terms of defining policies for "control" and prevention of natural calamities. The NDRA defines a working structure in case of a disaster. The general structure of the committees is presented in Figure 5.10, and the functions and duties of each committee are presented in Table 5.4.

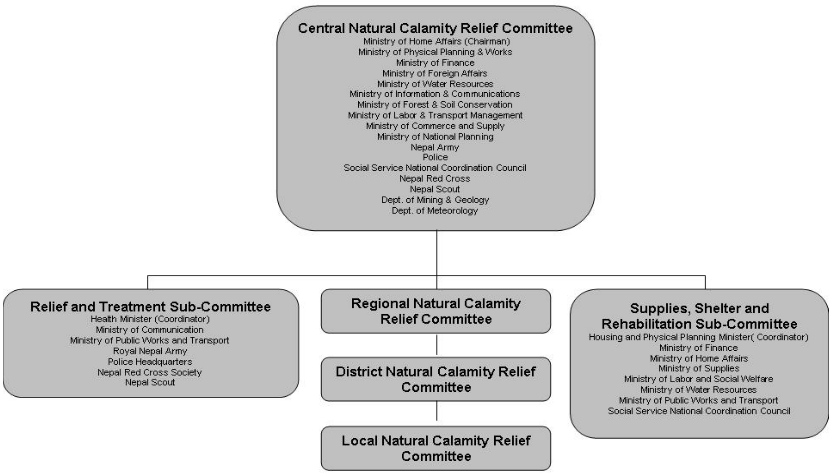

Figure 5.10 Nepal Disaster Management Organization

According to the NRA, all the governmental, nongovernmental offices, organizations, and individuals of the concerned area and in the vicinity should help the central, regional, district, and local committees by providing assistance in the relief work.

Table 5.4 Functions and duties of the NDRA committees

Central Committee	To make recommendations to the national government (NG) to declare the areas affected by a natural calamity as disaster areas. To formulate the national policies regarding relief work, including the rehabilitation of the victims and the reconstruction of the areas affected by it. At the same time, those policies should include the control and prevention of natural calamity and advance preparations. The committee should also prepare programs according to the policies and submit them to the NG. To implement the policy and program formulated after it has been approved by the NG. To keep the money, food stuff, clothes, medicines, construction material, and other goods received within Nepal and from outside as aid or donation under the Central Natural Calamity Aid To send such goods as required for relief work in disaster areas. To network the social organizations and to coordinate the activities of those organizations. To form groups and send them to the disaster area to assist in the natural calamity relief work, To direct the District Committee and Local Committee on matters relating to relief work, To perform the works specified by the NG for the execution of natural calamity relief work, To report on work progress to the NG from time to time.
Regional Committee	To give necessary suggestions to the Central Committee regarding the formulation of policy at regional level on the Natural calamity relief work and preparation of the progress hereunder. To coordinate or cause the coordination between District Committees regarding natural calamity relief work. To provide information to the Central Committee about natural calamity work from time to time.

District Committee	To coordinate or cause the coordination between local committees regarding calamity relief work. To formulate district level plans on natural calamity relief work and submit such plans to the Regional Committee. To monitor the natural calamity relief work being conducted by the local committees and to support the ongoing work. To provide information to the Regional Committee about natural calamity relief work from time to time. To work in accordance with the directives of the Central and Regional Committees.
Local Committee	To prepare detailed descriptions of the losses caused by natural calamity and to submit to the District Committee an estimate of the means and resources required for the relief and rehabilitation of the victims of natural calamity. To organize volunteer teams according to need and conduct or order the relief work. To make necessary arrangements to take the injured in the natural calamity to the nearest hospitals and health posts as soon as possible. To make arrangements for the evacuation of the victims of natural calamity to a safe place. To systematically distribute the cash and kind received in assistance from the District Committees and local resources to the families of the victims of natural calamity. To conduct an awareness program as a precaution for the prevention and control of the possible events of a natural calamity. To hand over the goods and cash balance and the accounts thereof to the District Committee upon completion of natural calamity relief work.

5.3.1.2 Disaster Management Planning

The Ninth Plan (1998 to 2002) underlines the need to strengthen the disaster management capabilities of the Kingdom of Nepal. The plan envisages that an attempt should be made for prevention, mitigation, and reduction of natural disasters through more advanced geological, hydrological, and meteorological research. Hazard mapping, vulnerability assessments, risk analysis, and an early warning system have to be developed; trained and efficient manpower should be made available to run them. The 9th plan also stresses the need to strengthen the capability of the fire brigades. The plan suggests that the policies and regulations concerning disaster management should be amended according to need. The plan emphasizes the importance and the need for national and/or international assistance.

Responding to the call of the United Nations, Nepal constituted a high level National Committee for the International Decade for Natural Disaster Reduction (IDNDR) which is chaired by the Minister of Home Affairs and represented by other high level dignitaries from Governmental and Non-Governmental agencies. This committee formulates policies for natural disaster reduction. The National Action Plan (NAP) of HMG has been prepared under the direction of the IDNDR National Committee. The NAP includes disaster reduction activities, timelines, and courses of action for disaster actors, and specifies that available resources should be mobilized in the given period.

The disaster preparedness plan includes the following activities:

- Measures related to national policy and planning for making institutional organization, providing legal framework, and adopting a national policy and plan on disaster management.
- Measures related to geological, hydrological, and meteorological hazard assessment and environmental engineering studies.
- Infrastructure specific and hazard specific preparedness measures.
- Measures related to strengthening firefighting capabilities in fire prone areas.
- Measures related to raising awareness, training, rehearsal, and simulation activities.
- Measures related to the establishment of a disaster management information system and stock piling of emergency supply materials.
- Risk assessment for development planning.

- Policies on the role of NGOs, local community, the private sector, and also people's participation, especially women and socially disadvantaged groups.
- Incorporation of environmental impact assessment for disaster reduction development planning.
- Promotion of regional and sub-regional cooperation between countries expecting the same types of hazards.
- Establishment of a documentation centre on disaster activities.

Of the above activities, the one about establishing a disaster management information system (DMIS) is the most relevant in terms of this research. There is no information about the nature of this DMIS, but it would be of most importance to define its aim.

In addition to the above, Nepal has prepared a National Comprehensive Plan on Disaster Management in cooperation with UNDP/UNDRO/UNDTCD. This plan emphasizes the improvement of national capacity for disaster management and institutional structures. This plan also focuses on hazard mapping, risk assessment, vulnerability analysis, and other issues. As the objectives of this plan are very wide and, keeping in view the resource constraints, it will take a long time to attain all the objectives. The UNDP and concerned government agencies have already prepared the food, health, and logistic sectors.

The involvement of public media is contributing to raise public awareness in cooperation with various governmental, non-governmental, and social organizations. Each year, various public awareness raising programs are being launched in radio and television. In addition, posters, pamphlets, and notification in the media are being given to significantly raise public awareness. Different governmental and non-governmental organizations like JICA, DPTC, UNDP, USAID, ADPC, NASC, NSET, and various other agencies are being involved in conducting various types of workshops, seminars, and training programs on disaster management. Such activities have been contributing significantly to raise public awareness and to manpower development.

According to the Ministry of Home Affairs (1999; 2005), the Department of Mines and Geology (DOMG) is preparing a landslide inventory. The Water Induced Disaster Prevention Technical Centre (DPTC) is carrying out thematic studies on landslides and monitoring several landslides. The Department of Soil Conservation (DOSC) is doing some protection work in different districts. The Department of Roads (DOR) is carrying out some bio-engineering works in cooperation with Tribhuvan University (TU), in order to stabilize slopes and road cut sides. The Department of Hydrology and Meteorology and the International Centre for Integrated Mountain Development (ICIMOD) are preparing the map of flood prone areas. ICIMOD conducts research and training activities on natural hazards as well. The Department of Hydrology and Meteorology (DOHM) is involved in generating data on earthquakes and weather forecasts in the country. Tribhuvan University has established a Mountain Risk Engineering Unit for training purposes.

External organizations such as the Japan International Cooperation Agency (JICA), the National Society for Earthquake Technology (NSET), Geohazards International (GHI), and ITC have developed research projects to calculate seismic risk and assess infrastructure and population vulnerability. NSET, and GHI with the help of USAID undertook the “Kathmandu Valley Earthquake Risk Management Project - KVERMP” in 1997. The project lasted three years, and produced a simplified earthquake scenario for Kathmandu valley (NSET, 1999). In 2001, NSET with the collaboration of JICA enhanced the previous study and included a detailed survey of 1183 buildings in the whole valley. With this data, and the intensity data of the 1988 earthquake, they calculated the probable building damage and casualties that they would expect if an earthquake of IX MMI (Mercalli Modified Intensity) occurred. They estimated that 60% of the building stock in Lalitpur will be damaged beyond repair. On 2003 the same NGO's assessed the earthquake risk of Kathmandu valley using RADIUS. In 2004, MSc students from ITC under the SLARIM project assessed building damage using "homogeneous units", a more detailed approach than that of the KVERMP project (500 mesh), but without detailed data of individual buildings. Fifty percent building damage was estimated for Lalitpur (Guragain, 2004). On 2006 two other MSc students of ITC collected detailed data on individual buildings in two wards, and estimated the probability of collapse and the probable casualties (Jimee, 2006). These research projects showed how detailed data can be collected with minimum effort to provide a solid basis to assess seismic vulnerability and risk.

5.3.2 Disaster related framework for the municipality of Lalitpur

According to the NDRA (MOHA, 1982), various ministries and their regional or district offices are responsible for disaster mitigation activities within their jurisdiction. Nevertheless, none of them has a disaster management unit within their organization and hence no fund is allocated for prevention, mitigation, preparedness, relief, and recovery. Only the Special Disaster Unit (SDU) within the Ministry of Home Affairs can form the Central Disaster Relief Committee (CDRC) and District Disaster Relief Committee (DDRC) allocate the funds to carry out rescue and relief works and provide financial assistance to disaster victims. The local governments get funds in case of natural calamities either from the District Disaster Relief Committee or from the District Development Committee (Shrestha, 2002). Not only do local authorities lack a disaster management policy, they also hardly have any information on disaster management available or have sharing agreements with other agencies that might have it.

Both cities, Kathmandu and Lalitpur, are ineffective in regulating urban housing through issuing building permits and controlling construction work under the revised bylaws, maybe due to legal constraints or duplicate responsibility among government agencies and negligence of the public. Nevertheless, Lalitpur has set up a Building Permit System in 2002, and in 2003 made it mandatory to comply with the earthquake safety code of the Nepal National Building Code (December 1995). Although not fully functional, it is a step in the right direction in terms of regulating building construction, and it may also offer scope for future vulnerability assessment efforts.

In terms of emergency facilities, the city preparedness level is far less than satisfactory. There are only five firefighting units (3 in Kathmandu, 1 in Lalitpur, and 1 in Bhaktapur) providing services for abut 200 fire cases in the valley per year. On top of the limited number of units, the congested narrow road network, the absence of fire hydrants, and a general shortage of water, added to untrained and understaffed fire statiions with poor budget, makes the work of the fire brigades a nightmare. Similarly, no independent ambulance services are available except those administered and funded by organizations such as the Nepal Red Cross, Nepal Paropakar Sansthan, Nepal Police, and major government and semi-government hospitals, including some social organizations providing limited service in urban areas (Shrestha, 2002). In the same report, Shrestha (2002) states that the health services and facilities do not have an emergency response plan nor can they provide any effective services during a natural calamity.

5.4 Conclusions

The municipality of Medellín, especially its government officers, have been aware of the importance of understanding the territory's dynamic. This awareness can be seen in the amount of technical information available. All the projects that the city has conducted have focused on seismic hazards, emergency plans, and risk management, and reflect the existence of a vast scientific and technical community and a local management team interested in considering risk management one of the pillars of urban planning. The extensive legal framework gives the local administration tools to effectively undertake the tasks of risk management. Nevertheless, the application of all the laws and decrees has been partial or nonexistent, allowing the vulnerability to escalate and therefore increase the risk.

A special remark must be made in terms of the information available. Although, as expressed previously, an enormous effort in information collection has been made in various projects, this does not translate into the easy access to this information There is a clear structure in terms of "what to do" and "who is responsible for what" in case of emergencies, but there are no specific rules for information collection and management responsibility of the secretariats, without mentioning the difficulties to share and access this information.

In the case of Lalitpur, the Local Self-Governance Act of 1999 has empowered municipalities to prepare, implement, and monitor their own development plans. However, Shrestha (2002) reports that low priority on disaster mitigation in the Municipality Act 2048 and District Development Act 2048 (1991-92), technical and financial constrains, coupled with confrontation between the District Development Committee (DDC) and a municipality controlled by two different political parties, has rendered the local government unable to take responsibilities.

As seen, both case studies present complete risk management frameworks, but when it comes to implementation a severe gap is identified. The efforts to implement the risk management frameworks are different because each city is in a different development stage in terms of political and technical maturity. While Medellín has been a decentralized municipality for more than a century, Lalitpur has only been for little more than a decade, since the Municipal Act (1992) and the Local Self Government Act (1999) were enacted. Not only because Lalitpur is a very young municipality, the political turmoil in Nepal and the difficulty to have democratic elections, has left the city without a proper major for several years.

The municipality of Medellín has used geo-information technologies (GIT) in its everyday activities for as long as a decade. Although this process has not been as straight-forward as one would like, a lot has been learned and it has become an important element of urban planning and the design of development plans. In Lalitpur, on the contrary, the use of geo-information for municipal processes is not a priority. Only the motivation of a couple of officers has made the compilation of the city atlas possible. However, this atlas is used only for descriptive purposes and is not really used for urban planning.

Chapter 6
Fitness for Use of
Municipal Geo-information for
Vulnerability Assessments

Cities happen to be problems in organized complexity, like the life sciences. They present situations in which half a dozen or several dozen quantities are varying simultaneously and in subtly interconnected ways…The variables are many but they are not helter skelter; they are "interrelated into an organic whole".
Jane Jacobs, 1961

In the previous chapter, an introduction to the general situation of the cities of Medellín and Lalitpur was given. This chapter gives an in depth analysis of the municipal setting and the geo-information specifics of each city in order to perform the fitness for use evaluation. A detailed explanation of the municipal setting and the available information is undertaken, performing a critical analysis of quality issues. The fitness for use is assessed, with a comprehensive analysis of the current geo-information available for vulnerability assessments. This analysis includes how far off is the ideal situation in each municipality in terms of geo-information availability, accessibility, and quality. More attention is given to Medellín considering that it is a data-rich case that can serve as a model to envision a development path for Lalitpur and transfer some useful lessons.

6.1 Data Rich – Capacity Moderate Case Study

6.1.1 Municipal administration

Medellín municipality has an administrative structure for public management. Each department has its own functions and responsibilities, which are executed according to a macro-process operating model defined in the Decree 151 of 2002, and the modifying Decree 2851 of 2005 (see Table 6.1). The macro-process operating model is made up of processes within the administrative cycle of Planning-Doing-Verifying-Acting. This model has its basis in the constitutional and legislative norms that rule the municipalities, maintaining a permanent relationship between the processes, the mission and nature, and the vision of the municipality. In this model, two macro-processes deal directly with information management and disaster prevention and aid, but in general, all the processes imply information collection and management. Some of the information gathered for those processes is useful for assessing vulnerability.

The municipal structure presented in Figure 6.1 shows several offices in charge of information collection shaded in gray. The municipality is currently engaged in setting up a centralized information system called SITE (Sistema de Información Territorial) basically focused on the monitoring of land use and the real estate market (Metroinformación, 2006).

Table 6.1 Administrative Macro-Processes

	Macro-processes	Processes
Planning	Strategic	Social and Economical Planning, Territory Planning, Financial Planning, Organizational Planning
Doing	Management	Management of Assets and Services, Human Resource Management, Legal Function, Organizational Development, Citizen Service
	Public Treasury	Income, Budget, Treasury, Public Accounts
	Public Communication	Organizational Communication, Informative Communication
	Information	Information Technology Management, Information Administration
	Basic services	Health, Education, Social Aid
	Social and Economic	Citizen Participation, Social Development, Housing, Development and Competitiveness
	Culture	Cultural Development, Civility Strengthening
	Coexistence and citizen safety	Civil Order, Mobility Management, Disaster Prevention and Aid
	Territorial Development and Sustainability	Environmental Sustainability, Land Management, Public Works
Verifying	Control	Evaluation of Management and Results, Evaluation of the Internal Control System
Acting	Continuous Improvement	Improvement of the Internal Control System, Improvement of the Management and Results

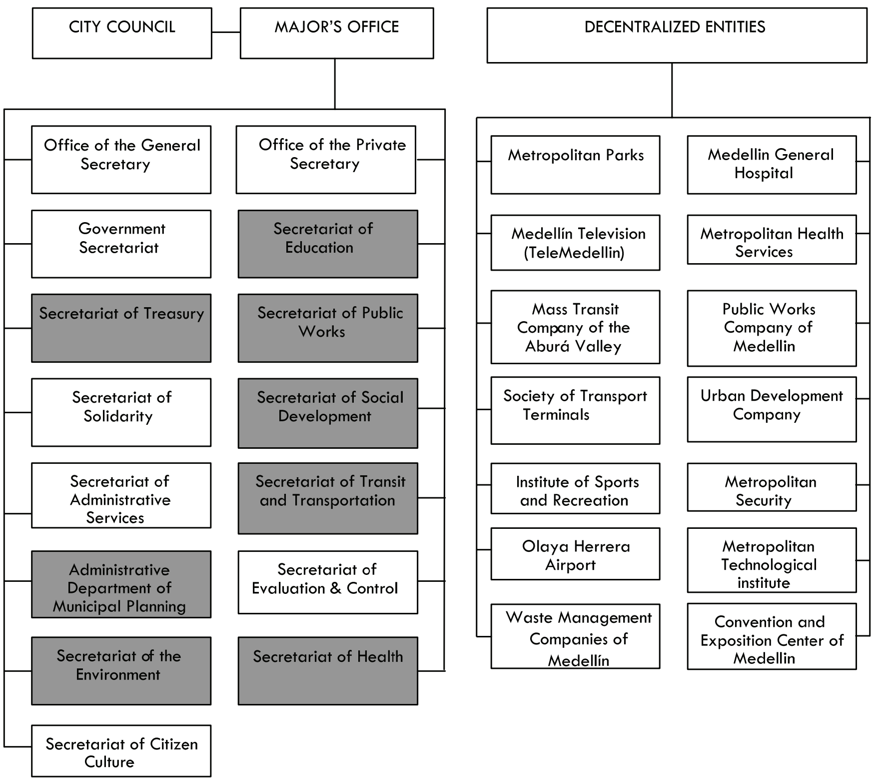

Figure 6.1. Municipal Structure of Medellín

SITE is a corporate project that serves as the access mechanism for geographic and territorial information developed by the Medellín Municipality. The Administrative Department of Municipal Planning (ADMP) and the Secretariats of Treasury, Environment, and Public Works have contributed their specialized knowledge to enable the planning process of the Municipality through the compilation, adjustment, and completion of attribute and spatial data, providing a better picture of the territory and an adequate environment for the analysis of social, economic, environmental, and urban data as a tool for decision making based on policies and rules for data management.

6.1.2 Spatial and Non-spatial datasets for Medellín and Santa Cruz Commune (No. 2)

For this research, Santa Cruz commune (No. 2) was selected to illustrate the municipal information available and how the indicators can be computed. This commune presents different occupation types, ranging from formal to informal settlements, and offers an interesting study area due to its social heterogeneity. The municipality of Medellín has a considerable amount of digital information, in scales that range from 1:2000 to 1:25000, but most of them are under 1:10000. In Annex VI a list of datasets is given.

Commune No. 2, also known as Santa Cruz, is divided into 11 neighborhoods: La Isla, El Playón de Los Comuneros, Pablo VI, La Frontera, La Francia, Andalucía, Villa del Socorro, Villa Niza, Moscú N° 1, Santa Cruz, and La Rosa (see Figure 6.2). It has a total population of 131317 inhabitants forming 24228 households in an area of 2.2 km^2.

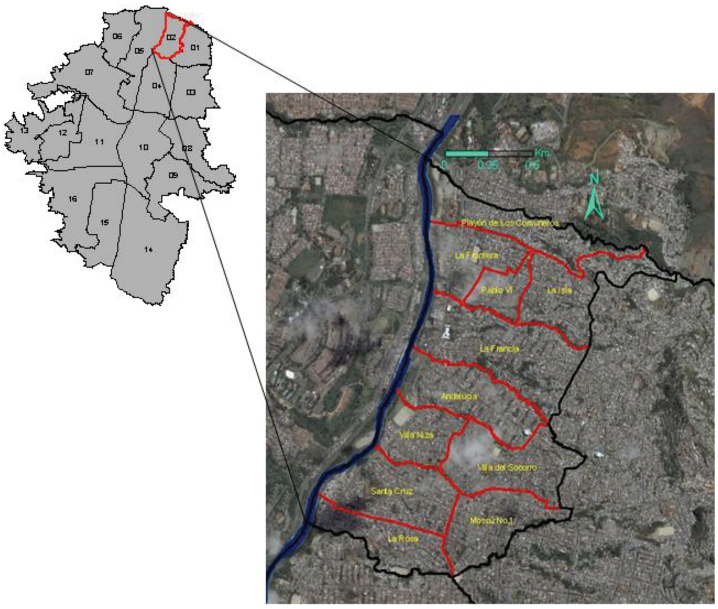

Figure 6.2 Overview of Santa Cruz Commune (No. 2)

A detailed census used for social security purposes, called **SISBEN**, is held every 2 or 3 years, to collect information on the home characteristics, the household members, and their economic characteristics. The social security coverage is defined with these surveys. Only homes in economic strata 1, 2 or 3 (the lowest strata) are entitled to access the free social security system. These surveys are very complete and give detailed information for socio-economic assessments, and may have potential for assessing certain aspects of population vulnerability. A very similar survey called Survey on Quality of Life (SQL) has been organized every year since 2002, where very similar questions to SISBEN are asked. The difference between these 2 surveys is that SISBEN is made on a household basis, and in communes where the predominant socio-economic strata is less than 3, while five percent of the households in each commune is sampled for the SQL, thus presenting information for the whole city. Also available is the Household census in high risk "non-recoverable" areas: detailed information about 22 thousand households distributed all around the city. In Santa Cruz commune, 445 homes are considered to be located in high risk, non-recoverable areas.

To assess building (physical) vulnerability, one can rely upon cadastre information and the SISBEN survey, which includes information similar to the survey on quality of life. In Annex VII a comparison between building characteristics in cadastral information and the SISBEN surveys is presented.

With respect to the population distribution very little information is available. From the SISBEN survey, population data can be extracted, but without details about hourly distribution. To cope with this lack of temporal information, general population distribution models can be used. Nevertheless, the metropolitan area has a mobility database, with information collected through surveys during 2005. With this information an hourly estimation can be calculated. Census information on a house basis is impossible to get from the National Statistics Department (DANE).

Information for the assessment of political-institutional and economical vulnerability is scarcer; however, some indicators can be calculated from information derived from other sources, such as the reports of the Emergency Preparedness Plan for Medellín, the Risk Management Plan, and other general information about governance.

6.1.3 Vulnerability Indicators and Information Sources for Medellín

Once the information sources within the municipality were identified, a list of meaningful and suitable indicators, attributes and sources was compiled for the case study. In Table 6.2, the number of indicators that should be assessed and their attributes per phase and vulnerability type is presented. The detailed list of indicators and attributes is given in Annex IX.

Table 6.2 Indicators by phase and vulnerability type

Vulnerability Type		Impact	Relief	Recovery	Total
Physical	Indicators	7	4	8	19
	Attributes	12	7	15	34
Socio-cultural	Indicators	4	2	3	7
	Attributes	6	4	6	16
Economic	Indicators	1	1	2	4
	Attributes	1	2	7	10
Political-Institutional	Indicators	1	4	2	7
	Attributes	1	7	4	12
Total	Indicators	13	11	15	39
	Attributes	20	20	32	72

6.1.4 Fitness for use assessment of Geo-information for Medellín

Fourteen municipal officers belonging to SIMPAD, the municipal planning department and Metropolitan Area of the Aburrá Valley (AMVA) filled out the three surveys designed to capture the information on relative importance of the attributes, data available and current state. The surveys were processed according to the methods explained in chapter 4. The final survey results are presented.

In chapter 2, four types of vulnerability were analyzed for three different disaster phases (Impact, Relief, and Recovery). For each one, a set of indicators was defined after a comprehensive review of existing methodologies and literature on methods and indicators for measuring vulnerability. The indicators that are relevant to the city of Medellín were determined in the first survey. In this survey, the comparison of the relative importance of these indicators is done by phase. In Table 6.3 the weights obtained for each indicator per phase are presented. These weights are important to determine the relevance of the information for each phase.

Table 6.3 Survey 1: Indicator weights by phase for Medellín

Phase	Indicators	Weight
Impact	Building Stock Fragility	0.14
	Emergency Services Capacity	0.10
	Environmental Assets Fragility	0.03
	Law and Policy Enforcement	0.10
	Minorities/Special Groups	0.03
	Population distribution	0.14
	Population Capacity	0.09
	Population Fragility	0.05
	Transportation Infrastructure Fragility	0.07
	Cultural and Historical Assets Fragility	0.03
	Utilities Infrastructure Fragility	0.08
	Local Economic Fragility	0.06
	Emergency communications Fragility	0.08
Relief	Environmental Assets Fragility	0.03
	Governance	0.09
	Health Facilities Capacity	0.13
	Household Economic Fragility	0.06
	Minorities/Special Groups	0.03
	Municipal Preparedness	0.11
	Organizations and Administrative Capacity	0.09
	Participatory Structures	0.06
	Shelter Facilities	0.11
	Social cohesion and Organization	0.07
	Emergency communications Capacity	0.10
	Household Economic Capacity	0.15
Recovery	Environmental Assets Recovery capacity	0.03
	Facilities recovery capacity	0.07
	Governance	0.05
	Household Economic Capacity	0.08
	Building Stock Recovery Capacity	0.11
	Participatory Structures	0.04
	Population Capacity	0.06
	Population Fragility	0.07
	Shelter Facilities	0.07
	Social cohesion and Organization	0.06
	Transportation Infrastructure Recovery capacity	0.10
	Utilities Infrastructure Recovery Capacity	0.10
	Cultural and Historical Assets Recovery Capacity	0.07
	Local Economic capacity	0.12
	Emergency communications Recovery Capacity	0.05

For each of the matrices, a consistency index was calculated, and the consistency level of the final matrix was checked using the method of Alonso and Lamata (2006). All of the matrices are consistent according to the method described in Chapter 4 (see Table 6.4).

Table 6.4 Consistency check for comparison matrices in Medellín

	Impact	Relief	Recovery
n	13	12	15
Lambda max	14.80	12.94	17.38
Consistency Index CI ((lambda max-n)/(n-1))	0.15	0.09	0.17
Consistency Ratio CR	0.06	0.04	0.05
Alpha	0.20	0.20	0.20
Complies with consistency level	yes	yes	yes

The results for the second survey on data requirements can be found in Annex XI, but to illustrate how the table is filled the information for the Impact Phase is presented in Table 6.5.

Table 6.5 Survey 2: Data Requirements for Impact Phase

Indicator	Attributes	Importance	Minimum Acceptable Scale (MAS)	Minimum preferred Scale (MPS)	Shelf-Life (years)
Building Stock Fragility	Age	0.25	2	4	10
	Conservation State	0.15	2	4	10
	Number of floors	0.25	2	4	10
	Structural Type	0.35	2	4	10
Cultural and Historical Assets Fragility	Importance	1	2	4	10
Emergency communications Fragility	Ability to coordinate the emergency services	1	1	1	1
Emergency Services Capacity	Number of emergency services and distribution	1	2	4	1
Environmental Assets Fragility	Biodiversity index	0.3	4	4	5
	Endemic species	0.4	4	4	5
	Type of environmentall asset	0.3	4	4	5
Law and Policy Enforcement	Application of construction code and soil use norms	1	2	4	3
Local Economic Fragility	Economical activities by type	1	2	4	3
Minorities/Special Groups	Location & Characteristics	1	2	4	2
Population Capacity	Educational level of the population	0.6	3	4	2
	Previous Hazard/Risk knowledge	0.4	3	4	2
Population distribution	Time distribution of the population	1	3	4	10
Population Fragility	Population Age/Gender	0.5	3	4	2
	Population Religion/Ethnicity	0.5	3	4	10
Transportation Infrastructure Fragility	Types and characteristics (road network, ports, railways, airports, terminals, stations, bridges)	1	2	4	10
Utilities Infrastructure Fragility	Facilities coverage (water, sewage, electricity, telephone, gas)	1	2	4	10

For MAS and MPS: 1=Municipality; 2= Commune; 3=Neighborhood; and 4= Element

In Annex XII the results for survey No. 3 are presented. To illustrate the data requirements the table corresponding to the Relief Phase is included in this section (Table 6.6). Once the three surveys are processed, the evaluators can be assessed.

Table 6.6 Survey 3: Data Characteristics for the Relief Phase

Indicator	Attributes	Available (y/n)	Complete (0 to 1)	Quality/ Usability	Scale (Municipality=1, Commune=2, Neighborhood=3, Element=4)	Data Date
Emergency communications capacity	Existing communications facilities (radio, tv)	Y	1	3	1	2007
	Previous educational campaigns on risk management	Y	0.9	3	3	2007
Environmental assets fragility	Biodiversity index	Y	0	2	1	2005
	Endemic species	N	0			
	Type of environmental asset	Y	1	2	4	2005
Governance	Government dependence	Y	1	3	1	2006
	Government Structure	Y	1	3	1	2007
	Rule of law (criminality)	Y	1	2	3	2006
Health facilities capacity	Type of health facilities	Y	0.9	2	4	2005
Household economic fragility	Financial Status (debt, savings)	N	0			
	Subsidies	N	0			
Minorities/Special groups	Location & Characteristics	Y	0	2	3	2005
Municipal preparedness	Emergency groups	Y	1	3	2	2007
	SISBEN coverage	Y	1	3	4	2005
Organizations and Administrative Capacity	Emergency preparation	Y	1	3	3	2007
Participatory structures	Committees and organizations per administrative unit	N	0			
Shelter facilities	Facilities type (education, cultural, religious, etc.)	Y	1	2	4	2005
Social cohesion and organization	Experience in previous events	N				
	Participation in Groups	Y	1	3	4	2006
	Time in the neighborhood	Y	1	3	2	2005

6.1.5 How adequate is the information for the vulnerability assessment?

In Table 6.7 the evaluation results for the indicators (all phases), to assess their current state, are shown. As explained in chapter 4, indicators whose final result is less than 2, meaning that the use of this information is not recommended for decision making; improvement actions have to be undertaken. If the result is between 2 and 3, the information can be used in general decision making processes, strategic projects or general guidelines; and if the result is between 4 and 5, the resulting information is appropriate for decision making processes, direct intervention and project definition. To present these results in an understandable way, a grey scheme is used: dark grey for low scores; light grey for medium scores, and white for high scores.

Table 6.7 Indicator scores for Evaluator 1 - current data state

Phase	Indicator	Weight	Evaluator 1
Impact	Building Stock Fragility	0.14	4.50
	Cultural and Historical Assets Fragility	0.03	4.67
	Emergency communications Fragility	0.08	3.50
	Emergency Services Capacity	0.10	2.83
	Environmental Assets Fragility	0.03	1.30
	Law and Policy Enforcement	0.10	0.00
	Local Economic Fragility	0.06	3.17
	Minorities/Special Groups	0.03	2.83
	Population Capacity	0.09	2.20
	Population distribution	0.14	4.67
	Population Fragility	0.05	2.93
	Transportation Infrastructure Fragility	0.07	3.67
	Utilities Infrastructure Fragility	0.08	3.83
		Weighted score	2.90
Relief	Emergency communications Capacity	0.10	4.92
	Environmental Assets Fragility	0.03	1.30
	Governance	0.09	4.62
	Health Facilities Capacity	0.13	3.72
	Household Economic Fragility	0.06	0.00
	Minorities/Special Groups	0.03	2.83
	Municipal Preparedness	0.11	4.00
	Organizations and Administrative Capacity	0.09	5.00
	Participatory Structures	0.06	0.00
	Shelter Facilities	0.11	3.67
	Social cohesion and Organization	0.07	2.40
		Weighted score	2.90
Recovery	Building Stock Recovery Capacity	0.11	0.00
	Cultural and Historical Assets Recovery Capacity	0.07	0.00
	Emergency communications Recovery Capacity	0.05	0.00
	Environmental Assets Recovery capacity	0.03	0.00
	Facilities recovery capacity	0.07	0.00
	Governance	0.05	4.17
	Household Economic Capacity	0.08	2.93
	Local Economic capacity	0.12	0.00
	Participatory Structures	0.04	5.00
	Population Capacity	0.06	0.73
	Population Fragility	0.07	3.67
	Shelter Facilities	0.07	3.89
	Social cohesion and Organization	0.06	0.87
	Transportation Infrastructure Recovery capacity	0.10	0.00
	Utilities Infrastructure Recovery Capacity	0.10	0.00
		Weighted score	1.37

The impact phase has an average score of 2.90, the relief phase of 2.90, and the recovery phase of 1.37, which means that a considerable number of attributes have information deficiencies. The scores for the impact and relief phase are not perfect, but they can be used in general decision making processes, and an intervention in terms of information collection can achieve better results. However, the weighted score for the recovery phase is very poor. No decisions can be taken based on the results, since there is hardly any information available. If the municipality wants to assess the recovery phase vulnerability, a thorough data collection campaign has to be undertaken.

To understand why some indicators appear dark grey (scores < 2), one can take a look at the scores obtained by the attributes that correspond to that indicator, before multiplying them by their respective importance.

In Table 6.8, the attribute scores for the impact phase are presented. It is easy to identify which specific attributes have information problems. To see the whole attribute score table see Annex XIII

Table 6.8 Impact Phase Attribute scores for Evaluator1 – Current data state

Indicator	Attributes	Importance of Attribute within the indicator	Evaluator 1
Building Stock Fragility	Age	0.25	4.50
	Conservation State	0.15	4.50
	Number of floors	0.25	4.50
	Structural Type	0.35	4.50
Cultural and Historical Assets Fragility	Importance	1	4.67
Emergency communications Fragility	Ability to coordinate the emergency services	1	3.50
Emergency Services Capacity	Number of emergency services and distribution	1	2.83
Environmental Assets Fragility	Biodiversity index	0.3	0.00
	Endemic species	0.4	0.00
	Type of environmental asset	0.3	4.33
Law and Policy Enforcement	Application of construction code and soil use norms	1	0.00
Local Economic Fragility	Economical activities by type	1	3.17
Minorities/Special Groups	Location & Characteristics	1	2.83
Population Capacity	Educational level of the population	0.6	3.67
	Previous Hazard/Risk knowledge	0.4	0.00
Population distribution	Time distribution of the population	1	4.67
Population Fragility	Population Age/Gender	0.8	3.67
	Population Religion/Ethnicity	0.2	0.00
Transportation Infrastructure Fragility	Types and characteristics	1	3.67
Utilities Infrastructure Fragility	Facilities coverage	1	3.83
	Insurance	0.7	0.00

Consider for example the Environmental asset fragility indicator. The overall score for this indicator is 1.3, and the attributes considered in the calculation of this indicator are Biodiversity index, Endemic species, and Type of environmental asset. Data is only available for the type of environmental asset, while the other 2 attributes have no data available. In general terms, the information about the type of asset has a score of 4.33, which is high, meaning that the information is adequate and meets the requirements needed to assess thoroughly the attribute, whereas the other 2 attributes have a score of zero (0).

Municipal officers will immediately understand that there is a problem of non-existent data and not a quality issue. Just as this indicator was analyzed, each low score can also be analyzed as illustrated in Table 6.9. This way of presenting the data problems allows decision makers and the officers responsible for information collection and updating to tackle specific data problems.

Table 6.9 Data problems per phase – Evaluator 1

	Impact	Relief	Recovery
Availability	Environmental Assets Fragility (Endemic species) Population Capacity (Previous Hazard/Risk knowledge) Population Fragility (Population Religion/Ethnicity)	Environmental Assets Fragility (Endemic species) Household Economic Fragility (Financial Status (debt savings)) Household Economic Fragility (Subsidies) Social cohesion and Organization (Experience in previous events) Participatory Structures (Committees and organizations per administrative unit)	Building Stock Recovery Capacity (Allocated recovery budget and Insurance) Cultural and Historical Assets Recovery Capacity (Allocated recovery budget and Insurance) Emergency communications Recovery Capacity (Allocated recovery budget and Insurance) Environmental Assets Recovery capacity (Allocated recovery budget and Insurance) Facilities recovery capacity (Allocated recovery budget and Insurance) Household Economic Capacity (Insurance) Local Economic capacity (Financial Status (debt savings) and Insurance) Social cohesion and Organization (Experience in previous events) Social cohesion and Organization (Participation in Groups) Social cohesion and Organization (Political participation) Transportation Infrastructure Recovery capacity (Allocated recovery budget and Insurance) Utilities Infrastructure Recovery Capacity (Allocated recovery budget and Insurance)
Old and out of date information	Emergency communications Fragility Emergency Services Capacity Law and Policy Enforcement Local Economic Fragility Minorities/Special Groups Population Capacity Population Fragility Transportation Infrastructure Fragility	Governance (Rule of law –criminality-) Minorities/Special Groups (Location & Characteristics) Municipal Preparedness (SISBEN coverage) Shelter Facilities (Facilities type (education cultural religious etc.))	Household Economic Capacity (Economic dependence (% of dependents)) Household Economic Capacity (Employment) Household Economic Capacity (Income level) Household Economic Capacity (Tenure) Population Capacity (Health Insurance)
Coarser scales than minimum acceptable scale	Environmental Assets Fragility (Biodiversity index)	Environmental Assets Fragility (Biodiversity index)	None

6.1.6 How far off is the actual information compared to the ideal information for the vulnerability assessment?

In Table 6.10 the evaluation results for the indicators (all phases) of the assessment of how far off they are from an ideal are shown. As explained in chapter 4, indicators whose final result is less than 2 mean that the results are deficient and improvement actions such as collection and updating of data should be undertaken in order to provide information for decision making. If the result is between 2 and 3.9, the results that can be obtained with this data can be improved substantially. In the same way as results less than 2, improvement actions such as collection and updating of data should be undertaken. Special attention should be given to those indicators and attributes that have the lowest results. If the results are between 4 and 5, the quality of the information is adequate and only updating and data maintenance processes are recommended. In the same way as the results for evaluator 1 a grey scheme is used.

Table 6.10 Indicator scores for Evaluator 2 - Distance to required data condition

Phase	Indicator	Weight	Evaluator 2
Impact	Building Stock Fragility	0.14	4.35
	Cultural and Historical Assets Fragility	0.03	4.33
	Emergency communications Fragility	0.08	4.17
	Emergency Services Capacity	0.10	1.00
	Environmental Assets Fragility	0.03	1.60
	Law and Policy Enforcement	0.10	2.67
	Local Economic Fragility	0.06	1.00
	Minorities/Special Groups	0.03	3.50
	Population Capacity	0.09	3.00
	Population distribution	0.14	5.00
	Population Fragility	0.05	4.00
	Transportation Infrastructure Fragility	0.07	4.33
	Utilities Infrastructure Fragility	0.08	4.17
		Weighted score	3.21
Relief	Emergency communications Capacity	0.10	3.92
	Environmental Assets Fragility	0.03	1.60
	Governance	0.09	3.67
	Health Facilities Capacity	0.13	4.17
	Household Economic Fragility	0.06	0.00
	Minorities/Special Groups	0.03	1.00
	Municipal Preparedness	0.11	3.00
	Organizations and Administrative Capacity	0.09	4.33
	Participatory Structures	0.06	0.00
	Shelter Facilities	0.11	4.33
	Social cohesion and Organization	0.07	2.20
		Weighted score	2.62
Recovery	Building Stock Recovery Capacity	0.11	0.00
	Cultural and Historical Assets Recovery Capacity	0.07	0.00
	Emergency communications Recovery Capacity	0.05	0.00
	Environmental Assets Recovery capacity	0.03	0.00
	Facilities recovery capacity	0.07	0.00
	Governance	0.05	3.67
	Household Economic Capacity	0.08	4.00
	Local Economic capacity	0.12	0.00
	Participatory Structures	0.04	4.33
	Population Capacity	0.06	5.00
	Population Fragility	0.07	5.00
	Shelter Facilities	0.07	4.33
	Social cohesion and Organization	0.06	0.20
	Transportation Infrastructure Recovery capacity	0.10	0.00
	Utilities Infrastructure Recovery Capacity	0.10	0.00
		Weighted score	**1.55**

The Impact phase has an average score of 3.21, the relief phase of 2.62 and the recovery phase of 1.55, which means that some attributes have severe information deficiencies. The scores for the impact and relief phase are not in the highest rank, but the information collection or updating effort probably does not need to be very extensive. Only those indicators attributes with very low scores should be checked to define what aspects have to be improved. On the other hand, the weighted score for the recovery phase is very poor, and a thorough data collection campaign has to be done.

A careful look at the scores obtained by the attributes can shed light on the specific problems an indicator can have. Once the attributes with low scores are identified, a detailed analysis of each of the aspects evaluated and the original values can determine what problem to tackle. In Annex XIV, the scores obtained for the attributes in all phases are shown.

Low scores of indicators are due to the fact that their underlying data is out of date or at a less detailed scale than needed. For example, the indicator for Local Economic Fragility of the impact phase has a final score of 1. In order to define where the problem lies for this indicator, one has to go back to Survey 3 (Annex XIII), and review the characteristics to see which one does not match the required values. This indicator, economic activities by type as the only attribute, has the following values:

- Available (y/n): yes
- Completeness (0 a 1): 0.9 (90%)
- Integrity/Validity (Good=3, Regular=2, Bad=1): 3
- Scale (Municipality=1, Commune=2, neighborhood=3, Element=4): 4
- Information Date: 2001
- Minimum Acceptable Scale (MRS): 2
- Minimum Preferred Scale (MDS): 4
- Shelf life (years): 3

The problem with this indicator is that the information is out of date. In the same way as evaluator 1, the low values can all be analyzed as shown in Table 6.11.

Table 6.11 Data problems per phase – Evaluator 2

Problem	Impact	Relief	Recovery
Availability	Environmental Assets Fragility (Endemic species) Population Capacity (Previous Hazard/Risk knowledge) Population Fragility (Population Religion/Ethnicity)	Environmental Assets Fragility (Endemic species) Household Economic Fragility (Financial Status (debt, savings)) Household Economic Fragility (Subsidies) Social cohesion and Organization (Experience in previous events) Participatory Structures (Committees and organizations per administrative unit)	Building Stock Recovery Capacity (Allocated recovery budget and Insurance) Cultural and Historical Assets Recovery Capacity (Allocated recovery budget and Insurance) Emergency communications Recovery Capacity (Allocated recovery budget and Insurance) Environmental Assets Recovery capacity (Allocated recovery budget and Insurance) Facilities recovery capacity (Allocated recovery budget and Insurance) Household Economic Capacity (Insurance) Local Economic capacity (Financial Status (debt, savings) and Insurance) Social cohesion and Organization (Experience in previous events) Social cohesion and Organization (Participation in Groups) Social cohesion and Organization (Political participation) Transportation Infrastructure Recovery capacity (Allocated recovery budget and Insurance) Utilities Infrastructure Recovery Capacity (Allocated recovery budget and Insurance)
Completeness (less than 10%)	Law and Policy Enforcement (Application of construction code and soil use norms) Environmental Assets Fragility (Biodiversity index)	Environmental Assets Fragility (Biodiversity index)	None

Problem	Impact	Relief	Recovery
Coarser scales than minimum preferred scale	Environmental Assets Fragility (Biodiversity index) Emergency Services Capacity (Number of emergency services and distribution)	Environmental Assets Fragility (Biodiversity index) Governance (Government dependence) Emergency communications Capacity (Existing communications facilities (radio, tv)) Governance (Government Structure)	Governance (Government dependence) Governance (Government Structure)

6.1.7 Gap Analysis and Development Path

The city of Medellín has a considerable amount of data and a group of geo-information technicians. This data is collected and used by different municipal offices. The fitness for use evaluation shows that this data has medium low scores for the state of the information (evaluator 1) and medium scores for the gap between current data and ideal data for the vulnerability assessment.

Specific information problems were unveiled with both evaluators. With this knowledge, municipal authorities in charge of risk management can define which secretariats are responsible for collecting new data or updating existing one, using the quality criteria defined for the ideal information sets.

The city already has a centralized information repository (SITE), which allows all secretariats to retrieve and visualize data sets. One of the disadvantages of this system is that it does not allow the individual secretariats to upload new or updated data or to modify the data dictionary corresponding to those data sets whenever the scale or the attributes and even the domains change. To do so, they have to ask the Metroinformación Office of the Administrative Department of Planning to perform the tasks needed, therefore increasing bureaucracy and slowing up information flows, but maintaining perhaps a higher quality standard as a result.

Current trends in information management indicate that setting up enormous information repositories is not the correct path (Morales, 2006). Maintenance and updating of the former is an epic task. Instead, the development of geo-information services is revealing a more straightforward manner of sharing and using data. Managing data as closely to the source where it is produced as possible, gives more responsibility to the people in charge of data collection and management, without disregarding that there should be guidelines and control mechanisms with respect to standards and quality.

The city of Medellín must realize that the next step in the development path is to set up a Spatial Data Infrastructure (SDI) that not only serves as a data catalogue and retrieval facility, but is also a service-oriented infrastructure. Morales (2006) clearly states that “today’s geo-information business should not only focus on acquiring, storing, and publishing data but also give attention to adding value and integrating spatial data to enable the development of information services that can lead to improved spatial data use and better decisions”. Morales also argues, that it is important to acknowledge the use of information, since it has been widely neglected over the communication aspect of the geo-information value chain (generation, communication, and use).

For example, the Open Geospatial Consortium (OGC) has led to the specification of a Web Feature Service (WFS) standard giving rise to a capability of viewing other organization’s data. In this sense, the city of Medellín and the Metropolitan Area of the

Aburrá Valley, should start thinking of an integrated geo-information service infrastructure (GSI) using the OGC standards and defining a set of specific data standards for information exchange and use. The city has to recognize the reusability of the acquired data to make decisions in other areas different from the one that the data was originally meant for. The basics steps of setting up an SDI should be followed to end up with a GSI were in-place mechanisms will manage independent collections of core services, supporting their combination or assembly, and improve reusability and flexibility. This path is illustrated in Figure 6.3.

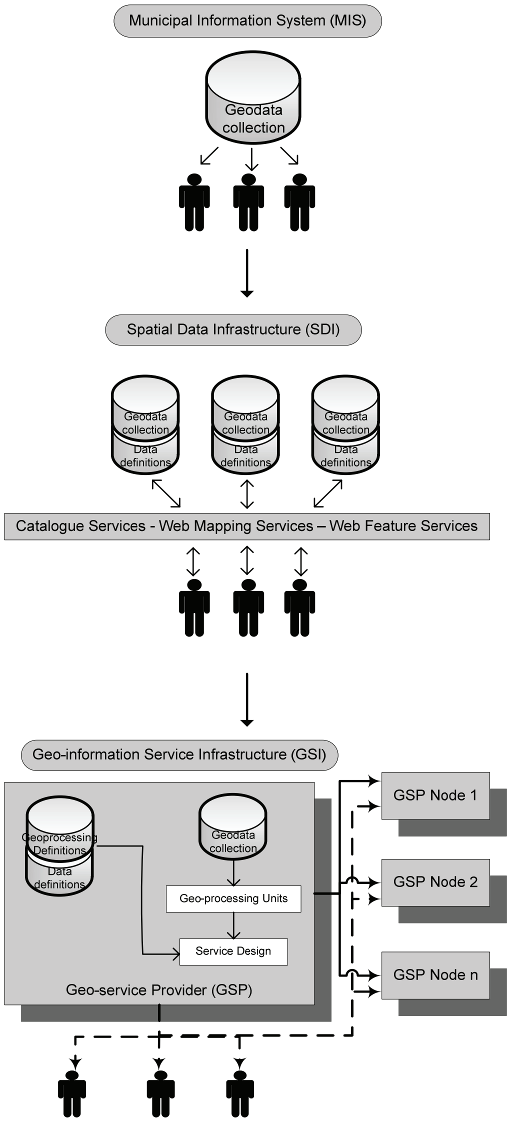

Figure 6.3. Information Management Development Path

6.2 Data Poor – Capacity Deficient Case Study

6.2.1 Municipal Setting

Administratively Nepal is divided into 14 zones and 75 districts. To spread balanced development throughout, the country is divided into five development regions. Each development region has two to three zones and each zone has four to eight districts. Districts are further divided into smaller units, called Village Development Committees (VDC) and municipalities. There are altogether 3914 VDCs and 58 municipalities. Each VDC is composed of 9 wards; municipality wards range from 9 to 35. The 1992 Municipality Act divided municipalities into three categories, based on population size and income:

- Metropolis (Mahanagarpalika): municipality with more than 300,000 inhabitants, minimum annual revenue of Rs. 70 million and relevant infrastructure facilities.
- Sub-metropolis (Upa-mahanagarpalika): also called Sub-metropolitan areas, are defined as municipalities with annual revenue of at least Rs 20 million, a population of 100,000 or more, and other urban facilities.
- Municipality (Nagarpalika): area with a population of 20,000 or more and revenue of at least Rs 10 million, with basic urban amenities.

The capital city of Kathmandu is the only Metropolis in the country. There are 4 sub-metropolitan cities (Lalitpur, Biratnagar, Birgunj and Pokhara) and the remaining 53 urban areas are municipalities. In Nepal, the functions, powers, and responsibilities of municipalities are defined in the Local Self Governance Act (LSGA). The Municipal functions are divided into two categories: mandatory and optional.

The mandatory functions are:

Relating to planning, administration, and finance, the municipality formulates periodical and annual plans; maintains coordination with governmental, non-governmental, and donor agencies while formulating plans and service programs; imposes taxes, and punishes those who do not pay taxes, fees, charges etc.

Relating to development, the municipality is in charge of physical development; water resources, environment and sanitation; education sports and culture; works and transport; health services; social welfare; and industry and tourism.

Other functions are the plantation on either side of the roads and other necessary places; management of places for keeping pinfolds and animal slaughter houses; management of crematoriums; birth, death, and other personal events registration; approve the opening of cinema halls; block numbers of the houses updating; roads and alleys lighting; arrangements for markets, fairs and exhibitions.

In addition to the mandatory function mentioned above, the optional functions of the municipality are to control unplanned settlements within the municipal area; arrange for the aged rest houses and orphanages; arrange for the supply of electricity and communication facilities; arrange for recreational parks, playing grounds, museums, zoos, etc.; collect data of unemployed persons and launch employment-generating programs; launch programs to control river pollution; carry out preventive and relief works to lessen the loss of life and property; arrange for dead body carriers.

A general municipal structure is defined as presented in Figure 6.4.

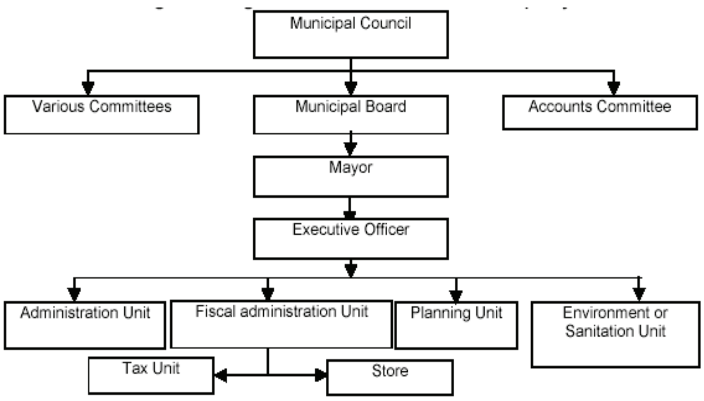

Figure 6.4. General Municipal Structure

6.2.2 Municipal Functions in Lalitpur

Although there is a general municipal structure for Nepal's municipalities, Lalitpur has its own structure, as shown in Figure 6.5. The main differences with the general municipality structure is that Lalitpur has defined a couple of new sections such as the Community Development Section and the Public Health Section and it also has formed a GIS & E-governance unit, that even if not fully operative, is starting to promote some processes of information management and web-based services within the municipality. There is no Functions Manual, but in general terms the functions of the most important sections or units, in terms of municipal administration, are:

Administration Division, made up of 3 sections, taxation, tourism, and administration.

Taxation Section: responsible for collecting revenues (properties, building permits, local development fees), commercial activities tax, land tax (to buy, to sell or to get a loan), and house tax (depends on the quality of the construction, area and location). The land tax is only paid by the citizens if they need to buy, sell, or ask for a loan; there is no culture of tax paying. The house tax is almost impossible to collect since there is no database of existing constructions, probably due to the fact that there is no addressing system and although there is a national cadastre with parcel records, it is outdated.
Tourism Section: responsible for generating revenues from tourism (tourism fee). This section is also responsible of attracting tourism, keeping the tourist statistics, and publishing tourist maps and brochures. The money collected by this section is spent in tourism promotion.
The administration section, Account Section, Internal Audit Section, Market management and implementation section, Mahendra Youth Hostel and Reserve Pool deal only with the internal management of the municipality, like personnel and financial issues.

Community Development Section: Responsible for developing training programs focused on women and children, such as neonatal care, health, savings, etc.

Public Health Section: Responsible for the statistics of morbidity and mortality rates, health camps, health training programs, and vaccination programs.

Sanitation and Environment Improvement Section: Responsible for trash collection and disposal and cleaning of the sewerage systems.

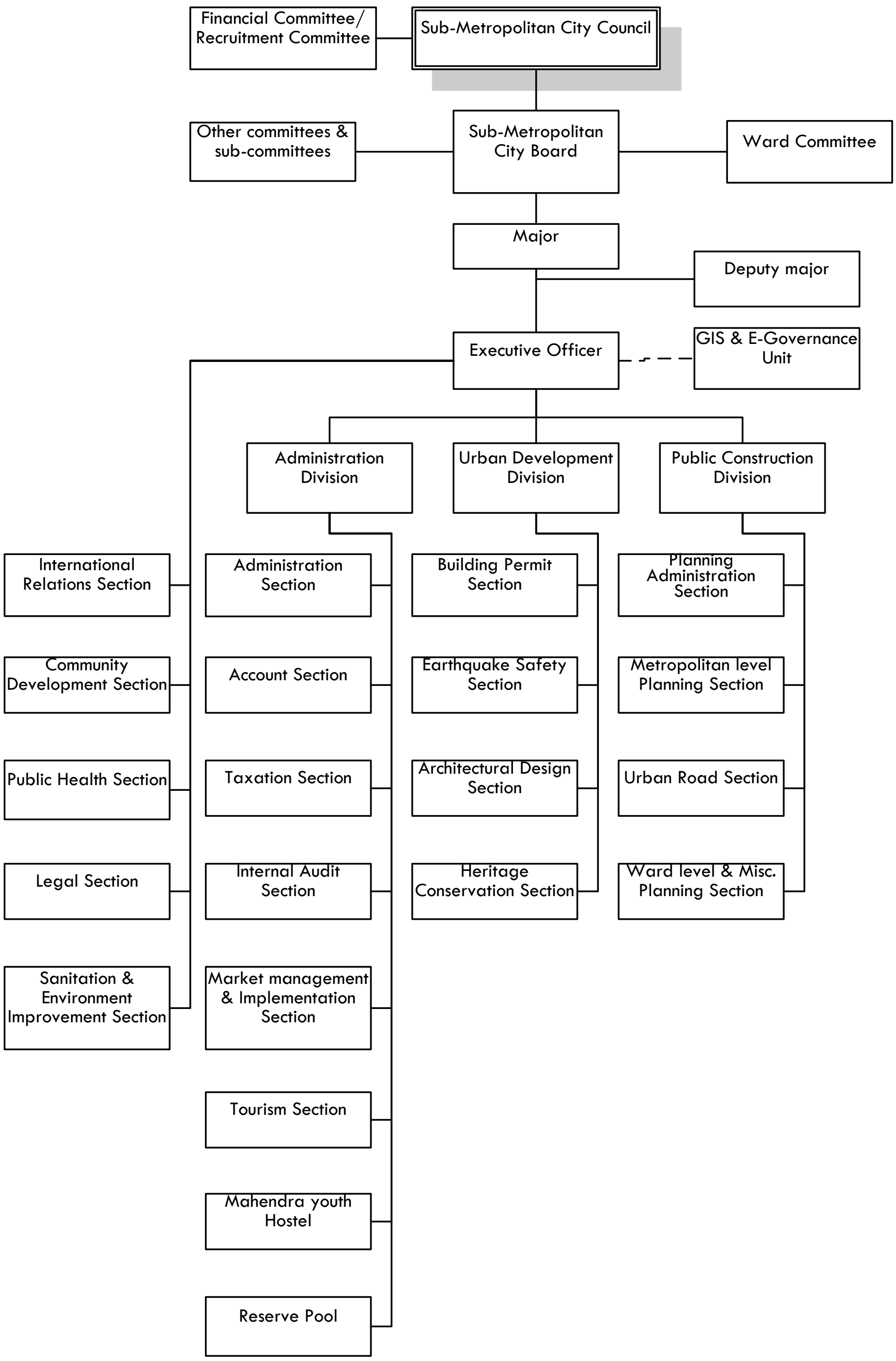

Figure 6.5. Organization Structure of Lalitpur

Urban Development Division: Responsible for the long term strategic planning. This section is subdivided in:

- Building Permit Section: acts according to the development plan in terms of issuing building permits.
- Earthquake Safety Section: reviews that the permits issued are submitted according to the National Building Code (NBC) in terms of earthquake safety.
- Architectural Design Section: Responsible for architectural drawings of municipal buildings.
- Heritage Conservation Section: responsible for checking building permits in the core area and the restoration of temples and monuments. The subsection Culture and Archeology Unit is responsible for archeological research in historical sites and the inventories of tangible and intangible cultural assets.

Public Construction Division: Responsible for all "line" agencies (energy, water and sewerage). This office is in charge of joint infrastructure projects with the community (65% the municipality, 35% the community) and is subdivided in:

- Planning Administration Section: responsible for joint projects with the community.
- Metropolitan Level Planning Section: responsible for deciding the project priority (community projects or internal projects).
- Urban Road Section: responsible for maintenance of minor roads within the municipality and the construction of new roads.
- Ward Level & Miscellaneous Planning Section: There is no information available about this section. Several municipal officers were asked, but none knew the functions.

GIS and E-governance Unit: Responsible for the collection, updating and management of spatial information of the municipality (maps and databases). This section is also in charge of the city profile atlas and the municipality's website, where some information services are provided.

6.2.3 Assessment of municipal conditions for a MIS

6.2.3.1 Data collection procedures, information processing, storage and outputs

In contrast to Medellín, Lalitpur municipality acts more as a data user than a producer of the data they actually need. Very little data is produced by the municipality, although many processes generate data, none is stored in digital format, nor is it properly linked to spatial data. Storage procedures are very primitive (e.g. the Building Permit System – BPS-, which only keeps paper records). The GIS and E-governance unit uses a couple of computers, but there is no organization wide network, no storage unit nor backing up practices to ensure that the information collected in different projects (especially NGO-sponsored conservation projects) is available at any time for consultation.

6.2.3.2 Human resources and available infrastructure, within the municipality structure or outside

The municipality does not have sufficient GIS trained personnel as such. All the head engineers from the major offices attended a GIS training course (3 weeks) in ArcGIS at ICIMOD (International Centre for Integrated Mountain Development). All of them recognize the importance of GIS as a tool for management and planning, but none of the offices is really committed nor has the capacity to devote an employee to GIS data input, processing and analysis. To overcome this resource problem, the GIS and e-governance unit was set up, but still the personnel in charge does not have the adequate technical profile to manage GIS information needed for different offices. With external aid (ITC), they have set up a GIS lab where several projects have been developed: a pilot project GIS application for urban heritage management and the conversion of vector maps in CAD format (Kathmandu Urban Development Project –KUDP- maps) to thematic maps to be included in the city profile. There is however no evident interaction between existing information systems. LSMC acts only as an information user at this early stage of development.

6.2.4 Spatial and non-spatial datasets for Lalitpur

The municipality of Lalitpur has a city profile atlas, based on maps updated in 1998 by the Kathmandu Urban Development Program (KUDP) and some other maps made by ITC MSc students in previous years (Guragain, 2004; Islam, 2004; Jimee, 2006; Khanal, 2005; Piya, 2004; Tung, 2004). Other datasets available are presented in Annex XVI. The GIS information that LSMCO manages, does not have a standardized cartographic projection. The Survey Department stated that the Modified "Universal Transverse Mercator - UTM" projection with the Nepal datum was selected as the geo-reference. Topographic maps are made with that georeference. However, for data exchange the projection is dropped in favor of Latitude-Longitude (degrees.decimals), with the Nepal datum. Chhatkuli et al (2003) defined the projection parameters to be used in Nepal.

The geographic information in the city profile is supposed to use the cartographic projection defined by Chhatkuli et al (2003)according to the KUDP maps (1998). However, some discrepancies and errors have been found with a georeferenced IKONOS image of 2001. Further research on the issue of the coordinate systems used is suggested.

Wards 9 and 20 (see Figure 6.6) were selected for information collection purposes. They present different occupation types. On one hand, Ward No. 20 is located in the core area of Lalitpur where traditional style architecture is found and more commercial uses are common. On the other hand, Ward No. 9 is located in the fringe area, thus the buildings present modern architecture and building techniques and the use is more residential.

Figure 6.6. Location of Wards No. 9 and 20

6.2.4.1 Data acquisition

Joint efforts were undertaken with MSc students to set up the information needed for the 2 wards to assess the feasibility of replicating the data collection process within already existing data collection processes. Two MSc. students, Ganesh Jimee and Ramesh Thapaliya, both from Nepal participated in the data collection process for wards No. 9 and No. 20. Ward No. 20 has 988 buildings and ward No. 9 has 1690 buildings. In both wards a thorough building survey was performed. The information collected in the survey is the one presented in Annex XVII. In this survey, the building height, materials, structural type, qualitative (relative) age, condition, form, adjacency and space use were recorded. The information was processed in an Access database where entry forms were designed to facilitate the data input process. The outputs resulting from this data collection can be checked in a series of MSc theses (Jimee, 2006; Thapaliya, 2006), as well as the MSc work under the SLARIM project in Lalitpur of Piya (2004), Destegul (2004), Islam (2004), Guragain (2004), Khanal (2005), and Tung (2004).

Another important aspect of the assessment of social vulnerability is population distribution. The census information provided by the Central Bureau of Statistics (CBS) is aggregated at ward level, making it difficult to redistribute the population on a building basis. Not only is the information, given by CBS to the municipality, aggregated, but it only considers and counts population which owns the house, thus tenants are not counted in the municipality, but in their home village or town where the parents or other family members own their residence. Therefore, to obtain more reliable information that could be extrapolated for different space uses, in ward No. 20 a household survey was made. It is a 10% sample of the buildings previously surveyed.

Two different surveys were designed, one for residential space use where questions about origin, ethnicity, language, education, religions, and other topics were asked and another for evaluating community awareness and population distribution patterns during daytime and night time. The questions asked in both surveys are presented in Annex XVII. For both surveys, it was important to establish the space uses that would be considered.

The data collection procedure tested in the 2 wards proved to be relatively easy to follow by the municipal officers and could be readily extended to the rest of the wards. The municipality can always rely on the relationship with Kathmandu University – Faculty of Architecture to hire students to perform the surveys and process the information. The effort should not be very complicated or prolonged and in a few weeks the municipality could obtain valuable information about existing buildings that could be used not only for vulnerability assessments, but also for taxation purposes.

In the same way, a more “real” approach to the number of inhabitants and their distribution could be obtained, since the census data only counts people in their towns of origin, not accounting for all the persons that have migrated to the Kathmandu Metropolitan area. This population distribution information has multiple uses other than vulnerability assessments, such as planning, service provision, utilities distribution, etc.

6.2.5 Vulnerability Indicators and Information Sources

In the case of Lalitpur, although there is some information available, the scale and date of this data does not serve the purpose of performing a vulnerability assessment. In the fitness for use assessment, a complete overview of the information problems present in Lalitpur will be given.

6.2.6 Fitness for use assessment of Geo-information for Lalitpur

Within the municipality there is no section devoted to risk management and there are no experts in the matter. Nevertheless, there are several NGO's working actively on the subject of risk management, such as the National Society for Earthquake Technology (NSET) and the Japanese International Cooperation Agency (JICA). These two organizations have worked jointly on projects such as the Kathmandu Valley Earthquake Risk Management Project (KVERMP) and the National Building Code of Nepal. Several MSc students from ITC worked for their thesis projects under the SLARIM (Strengthening Local Authorities in Risk Management) project. Two of these students (Ganesh Jimee and Suman Shrestha) were contacted to fill out the surveys for this research project, since one of them works at NSET and the other one at the municipality. Dr Cees van Westen was surveyed, considering that he has a wide experience in Lalitpur after supervising several MSc theses related to risk management. A fourth survey was filled by the author. The surveys were processed according to the methods explained in chapter 4, and the final survey results are presented in Annex XIX and Annex XX.

The indicators that are relevant to the city of Lalitpur are determined in the first survey. In this survey, the comparison of the relative importance of these indicators is done by phase. In Table 6.12 the weights obtained for each indicator per phase are presented. These weights are important to determine the relevance of the information for each phase. Once the three surveys are processed (Annex XIX, Annex XX, and Annex XXI), the evaluators are assessed.

Table 6.12 Survey 1: Indicator weights by phase for Lalitpur

Phase	Indicators	Weight
Impact	Building Stock Fragility	0.136
	Emergency Services Capacity	0.093
	Environmental Assets Fragility	0.021
	Law and Policy Enforcement	0.073
	Minorities/Special Groups	0.023
	Population distribution	0.123
	Population Capacity	0.100
	Population Fragility	0.074
	Transportation Infrastructure Fragility	0.052
	Cultural and Historical Assets Fragility	0.091
	Utilities Infrastructure Fragility	0.069
	Local Economic Fragility	0.078
	Emergency communications Fragility	0.065
Relief	Environmental Assets Fragility	0.024
	Governance	0.104
	Health Facilities Capacity	0.133
	Household Economic Fragility	0.074
	Minorities/Special Groups	0.030
	Municipal Preparedness	0.099
	Organizations and Administrative Capacity	0.093
	Participatory Structures	0.053
	Shelter Facilities	0.134
	Social cohesion and Organization	0.058
	Emergency communications Capacity	0.080
	Household Economic Capacity	0.117

Phase	Indicators	Weight
Recovery	Environmental Assets Recovery capacity	0.019
	Facilities recovery capacity	0.055
	Governance	0.071
	Household Economic Capacity	0.090
	Building Stock Recovery Capacity	0.090
	Participatory Structures	0.034
	Population Capacity	0.097
	Population Fragility	0.082
	Shelter Facilities	0.067
	Social cohesion and Organization	0.050
	Transportation Infrastructure Recovery capacity	0.069
	Utilities Infrastructure Recovery Capacity	0.078
	Cultural and Historical Assets Recovery Capacity	0.069
	Local Economic capacity	0.106
	Emergency communications Recovery Capacity	0.022

Just as the matrices for Medellín, for each of the matrices for Lalitpur, a consistency index was calculated, and the consistency level of the final matrix was checked using the Alonso and Lamata method (Alonso and Lamata, 2006) (see Table 6.13). Once the three surveys are processed (Annex XIX, Annex XX and Annex XXI), Annex XX, and Annex XXI), the evaluators are assessed.

Table 6.13 Consistency check for comparison matrices in Lalitpur

	Impact	Relief	Recovery
n	13	12	15
Lambda max	14.72	13.95	17.36
Consistency Index CI ((lambda max-n)/(n-1))	0.14	0.18	0.17
Consistency Ratio CR	0.06	0.09	0.05
Alpha	0.20	0.20	0.20
Complies with consistency level	yes	yes	yes

6.2.7 How adequate is the information for the assessment?

To assess the current state of the indicators in all phases, the evaluation results are shown in Table 6.14. As explained in chapter 4, indicators whose final result is less than 2, mean that the use of this information is not recommendable for decision making; improvement actions have to be undertaken. If the result is between 2 and 3, the information can be used in general decision making processes, strategic projects or general guidelines; and if the result is between 4 and 5, the resulting information is apt for decision making processes, direct intervention and project definition. To present these results in an understandable way, a three color scheme is used: dark grey for low scores; light grey for medium scores, and white for high scores.

The Impact phase has an average score of 0.97, the relief phase of 1.18 and the recovery phase of 0.27, which means that most attributes have information deficiencies. The weighted scores for all phases are very poor. No decisions can be taken based on the results, since there is basically no data available. If the municipality wants to assess vulnerability, a thorough data collection campaign has to be done. It is easy to identify which specific attributes have information problems (see Annex XXII).

Municipal officers will immediately understand that the main problem is non-existent data. In Table 6.15, a summary of problems is presented. In this way, decision makers and the officers responsible for information collection and updating can tackle directly the data problems.

Table 6.14 Indicator scores for Evaluator 1 - current data state

Phase	Indicator	Weight	Evaluator 1
Impact	Building Stock Fragility	0.136	0.00
	Cultural and Historical Assets Fragility	0.093	4.50
	Emergency communications Fragility	0.021	0.00
	Emergency Services Capacity	0.073	0.00
	Environmental Assets Fragility	0.023	0.00
	Law and Policy Enforcement	0.123	1.83
	Local Economic Fragility	0.100	0.00
	Minorities/Special Groups	0.074	0.00
	Population Capacity	0.052	0.00
	Population distribution	0.091	0.00
	Population Fragility	0.069	2.94
	Transportation Infrastructure Fragility	0.078	3.83
	Utilities Infrastructure Fragility	0.065	0.00
		Weighted score	0.97
Relief	Emergency communications Capacity	0.080	0.00
	Environmental Assets Fragility	0.024	0.00
	Governance	0.104	0.90
	Health Facilities Capacity	0.133	2.17
	Household Economic Fragility	0.074	0.00
	Minorities/Special Groups	0.030	1.50
	Municipal Preparedness	0.099	3.33
	Organizations and Administrative Capacity	0.093	0.00
	Participatory Structures	0.053	0.00
	Shelter Facilities	0.134	3.17
	Social cohesion and Organization	0.058	0.00
		Weighted score	1.18
Recovery	Building Stock Recovery Capacity	0.090	0.00
	Cultural and Historical Assets Recovery Capacity	0.069	0.00
	Emergency communications Recovery Capacity	0.022	0.00
	Environmental Assets Recovery capacity	0.019	0.00
	Facilities recovery capacity	0.055	0.00
	Governance	0.071	1.06
	Household Economic Capacity	0.090	2.22
	Local Economic capacity	0.106	0.00
	Participatory Structures	0.034	0.00
	Population Capacity	0.097	0.00
	Population Fragility	0.082	0.00
	Shelter Facilities	0.067	0.00
	Social cohesion and Organization	0.050	0.00
	Transportation Infrastructure Recovery capacity	0.069	0.00
	Utilities Infrastructure Recovery Capacity	0.078	0.00
		Weighted score	0.27

Table 6.15 Data problems per phase for Evaluator 1

Problem	Impact	Relief	Recovery
Old and out of date information	Law and Policy Enforcement (Application of construction code and soil use norms); Local Economic Fragility (Economical activities by type); Population Capacity (Educational level of the population); Population Fragility (Population Age/Gender)	Health Facilities Capacity (Type of health facilities); Minorities/Special Groups (Location & Characteristics)	Household Economic Capacity (Economic dependence (% of dependents), Employment, Income level, and Tenure)

Problem	Impact	Relief	Recovery
Availability	Building Stock Fragility (Conservation State); Emergency communications Fragility (Ability to coordinate the emergency services); Emergency Services Capacity (Number of emergency services and distribution); Environmental Assets Fragility (Biodiversity index, Endemic species, and Type of environmental asset); Minorities/Special Groups (Location & Characteristics)	Emergency communications Capacity (Existing communications facilities (radio, tv), and Previous educational campaigns on risk management); Environmental Assets Fragility (Biodiversity index, Endemic species, and Type of environmental asset); Governance (Government dependence, and Rule of law (criminality)); Household Economic Fragility (Subsidies); Organizations and Administrative Capacity (Emergency preparation; Participatory Structures (Committees and organizations per administrative unit; Social cohesion and Organization (Participation in Groups, and Time in the neighborhood)	Building Stock Recovery Capacity (Allocated recovery budget, and Insurance); Cultural and Historical Assets Recovery Capacity (Insurance); Emergency communications Recovery Capacity (Allocated recovery budget, and Insurance); Environmental Assets Recovery capacity (Allocated recovery budget, and Insurance); Facilities recovery capacity (Insurance); Governance (Government dependence, Rule of law (criminality)); Household Economic Capacity (Insurance); Local Economic capacity (Financial Status (debt, savings), and Insurance)); Participatory Structures (Committees and organizations per administrative unit); Population Capacity (Health Insurance); Population Fragility (Household Masculinity Index); Shelter Facilities (Facilities type (education, cultural, religious, etc.)); Social cohesion and Organization (Experience in previous events, Participation in Groups, Political participation, and Time in the neighborhood); Transportation Infrastructure Recovery capacity (Allocated recovery budget, and Insurance); Utilities Infrastructure Recovery Capacity (Allocated recovery budget, and Insurance)
Coarser scales than Minimum acceptable scale	Law and Policy Enforcement (Application of construction code and soil use norms); Local Economic Fragility (Economical activities by type); Population Capacity (Educational level of the population, and Previous Hazard/Risk knowledge); Population distribution (Time distribution of the population); Population Fragility (Population Age/Gender, and Population Religion/Ethnicity); Transportation Infrastructure Fragility (Types and characteristics); Utilities Infrastructure Fragility (Facilities coverage)	Household Economic Fragility (Financial Status (debt, savings)); Minorities/Special Groups (Location & Characteristics)	Household Economic Capacity (Economic dependence (% of dependents), Employment, Income level, and Tenure)
Completeness (less than 30%):	Building Stock Fragility (Age, Number of floors, and Structural Type); Local Economic Fragility (Economical activities by type); Population Capacity (Educational level of the population and Previous Hazard/Risk knowledge); Population distribution (Time distribution of the population); Utilities Infrastructure Fragility (Facilities coverage)	Social cohesion and Organization (Experience in previous events); Household Economic Fragility (Financial Status (debt, savings))	None

6.2.8 How far off is the current information compared to the ideal information for the assessment?

In Table 6.16 the evaluation results for the indicators to assess how far off they are from an ideal are shown. As explained in chapter 4, indicators whose final result is less than 2 mean that the results are deficient, and improvement actions such as collection and updating of data should be undertaken in order to provide information for decision making. If the result is between 2 and 3.9, the results that can be obtained with this data can be improved substantially. The same holds for results less than 2, improvement actions such as collection and updating of data should be undertaken.

Table 6.16 Indicator scores for Evaluator 2

Phase	Indicator	Weight	Evaluator 2
Impact	Building Stock Fragility	0.136	2.43
	Cultural and Historical Assets Fragility	0.093	4.83
	Emergency communications Fragility	0.021	0.00
	Emergency Services Capacity	0.073	0.00
	Environmental Assets Fragility	0.023	0.00
	Law and Policy Enforcement	0.123	1.00
	Local Economic Fragility	0.100	1.00
	Minorities/Special Groups	0.074	0.00
	Population Capacity	0.052	1.00
	Population distribution	0.091	1.00
	Population Fragility	0.069	1.00
	Transportation Infrastructure Fragility	0.078	1.00
	Utilities Infrastructure Fragility	0.065	1.00
		Weighted score	1.34
Relief	Emergency communications Capacity	0.080	0.00
	Environmental Assets Fragility	0.024	0.00
	Governance	0.104	0.67
	Health Facilities Capacity	0.133	1.00
	Household Economic Fragility	0.074	0.73
	Minorities/Special Groups	0.030	1.00
	Municipal Preparedness	0.099	1.00
	Organizations and Administrative Capacity	0.093	0.00
	Participatory Structures	0.053	0.00
	Shelter Facilities	0.134	1.00
	Social cohesion and Organization	0.058	0.33
		Weighted score	0.54
Recovery	Building Stock Recovery Capacity	0.090	0.00
	Cultural and Historical Assets Recovery Capac-	0.069	0.00
	Emergency communications Recovery Capacity	0.022	0.00
	Environmental Assets Recovery capacity	0.019	0.00
	Facilities recovery capacity	0.055	0.53
	Governance	0.071	1.06
	Household Economic Capacity	0.090	0.83
	Local Economic capacity	0.106	0.00
	Participatory Structures	0.034	0.00
	Population Capacity	0.097	0.00
	Population Fragility	0.082	0.00
	Shelter Facilities	0.067	0.00
	Social cohesion and Organization	0.050	0.00
	Transportation Infrastructure Recovery capacity	0.069	0.00
	Utilities Infrastructure Recovery Capacity	0.078	0.00
	Weighted score		0.18

Special attention should be given to those indicators and attributes that have the lowest results. If the results are between 4 and 5, the quality of the information is adequate and only updating and data maintenance processes are recommended.

In the same way as the results for evaluator 1, a grey scheme is used. The Impact phase has an average score of 1.34, the relief phase of 0.54 and the recovery phase of 0.18, which means that most attributes have severe information deficiencies. The scores for all phases are in the lowest rank. The indicators attributes with very low scores should be checked to define what aspects have to be improved, and a thorough data collection campaign has to be organized. Most low scores for indicators are due to the fact that they information is non-existent, out of date or at a less detailed scale than needed.

6.2.9 Gap Analysis and Development Path

The city of Lalitpur has scarce data and the data that does exist has severe quality deficiencies. Establishing a development path for Lalitpur in terms of geo-information management immediately remits us to the subject of political will. In Lalitpur, there is a lack of governability, considering that the municipality has been without a formally elected mayor for more than 3 years, and had to work with appointed majors that do not have the favor of the municipal officers, the city council, and the people. Since the appointment is temporary, most mayors haven't made long term interventions. In order to develop an information management policy, there has to be a drastic change in the way governance is organized and working in the municipality. Real political will is needed to organize the functions and processes that, although clear on paper, are not implemented in reality. It is also necessary to start generating income locally to become economically independent from the Ministry of Home Affairs (MOHA). There are major income sources for Lalitpur that can be exploited, by the taxation section, such as the property tax, that is now only paid by the citizens when they need an official clearance to buy or sell a property. The lack of updated cadastre maps depicting the parcels and the corresponding attribute data (owner, area, etc.), doesn't help in the process.

Hypothetically, if there is political will to make those changes in Lalitpur, the first step will be to devise a development plan for the city and acquire the necessary datasets to support the planning process. The city has several officers with MSc degrees in urban planning that can work on this development plan and define the datasets needed.

A simplified municipal structure organization can be similar to the general municipal structure for Nepal (Figure 6.4), where there is an Administration Unit, a Fiscal Administration Unit in charge of taxes, a Planning Unit, and several other units such as the Environment and Sanitation Unit or the Education Unit, Social Welfare Unit, Health Unit, etc. Each of these units has specific tasks defined by the municipality and an annual budget. The sections present in the current organization structure can be re-structured to fit in the simplified structure eliminating a lot of single-person sub-sections and units.

The existing GIS Unit was set up due to the cooperation effort done by ITC, by providing software and hardware to boost the use of GIS within the municipality. Nevertheless, to date this effort has not led to the acquisition of new and better datasets nor does it support the use of existing datasets in the planning process.

Today, the city of Lalitpur is faced with the challenge of improving the way they intervene the territory they inhabit. One way of improving is using spatial technologies to increase the geographic knowledge of their physical assets, and their population with their social and cultural characteristics.

The results obtained with the fitness for use evaluators show how seriously deficient their datasets are. This can be seen as an opportunity to set up a geo-database especially designed to satisfy the municipal needs, instead of the common practice of using whatever datasets are generated in multiple projects that do not take into account all the data needs of the different units and end up in redundant data collection efforts. The path to travel is long, but it only takes a few enthusiastic municipal officers, supported by the administration, that can give dynamism to the process. The municipality can always use the academic support of Tribhuvan University (Faculty of Architecture) and the financial and technical support of NGO's and institutions such as ITC, ICIMOD, etc. As explained earlier in this chapter, minor efforts, such as collecting general information using the work force of university students can reveal enormous amounts of data and information relevant for the municipality.

The path is relatively straight forward but fraught with difficulties, to set up an MIS thinking of an SDI, and to put in place metadata and data standards. Once geo-information becomes a daily need for most municipal offices, and they have the capacity to deal with their own geo-information, the municipality can think of setting up geo-services linked to the Nepali Geo-information Infrastructure Project (NGIIP).

6.3 General Comparison between case studies

In the following figures, the values for the evaluators in each phase are plotted in a xy scatter graph. The results for both case studies are plotted to appreciate the differences between the current information state and the development path.

In Figure 6.7 the indicators that correspond to Medellín for the impact phase are mostly located in the upper right quadrant of the graph, meaning that the current state of the data is good and that the path to achieve the desired data condition is not long. Only 2 indicators have values lower than 2 for Evaluator 2. Three indicators have values lower than 2 for Evaluator 1, which means, that their current state is not adequate. On the other hand, the indicators for Lalitpur are far from desired. Most values are located in the lower quadrants of the graph, which means that they are below 2, except the indicator corresponding to the cultural and historical assets fragility, since they have plenty of data on that subject, and the indicator for building stock fragility, that although not very high above 2, indicates that there is some data about the building stock.

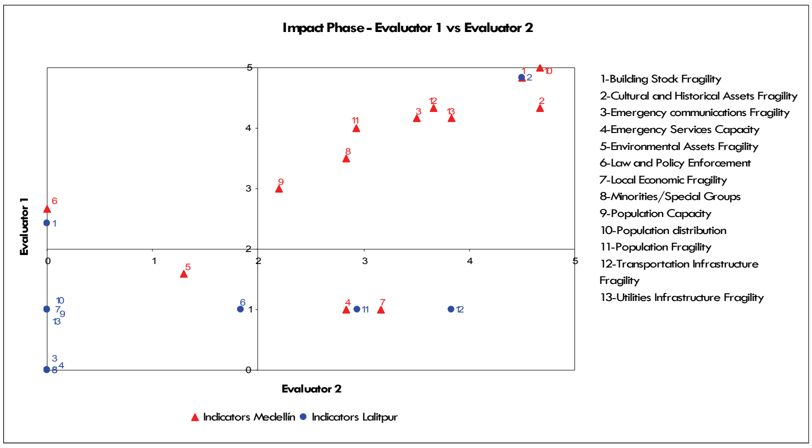

Figure 6.7. Comparison between indicators for Impact phase E1 vs E2

For the relief phase (see Figure 6.8), things are not much different. Medellín has only three indicators with values under 2 for Evaluator 2, and only 2 indicators under 2 for Evaluator 1. Lalitpur on the other hand, has no values in the upper quadrants and only 3 values over 2 for Evaluator 2.

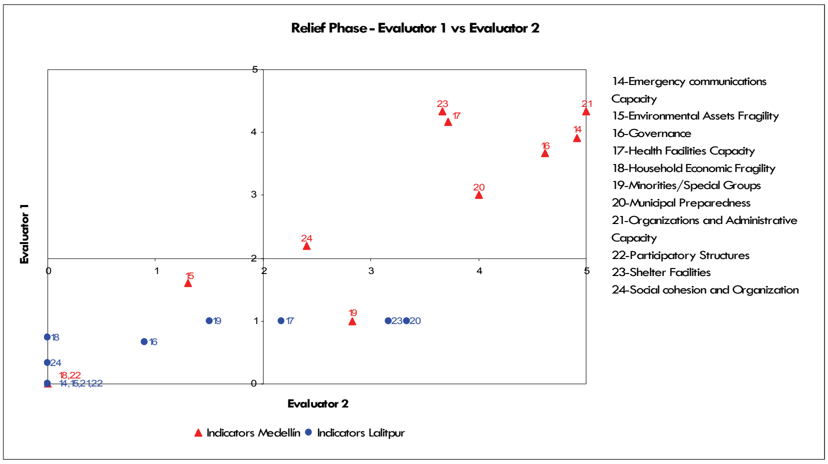

Figure 6.8. Comparison between indicators for Relief phase E1 vs E2

For the recovery phase (Figure 6.9) the situation is much worse for Lalitpur, since all values except 1 are located in the lower left quadrant of the graph, meaning that their current state is deplorable and that there is a long way to get the data necessary for an adequate vulnerability assessment. Medellín, presents an interesting extreme distribution of the values. Almost half of them are located in the upper right quadrant and the other half is located in the lower left quadrant for Evaluators 1 and 2, meaning that there are some data issues for several indicators, while the other half is currently adequate or almost adequate and needs little effort to achieve the desired data condition.

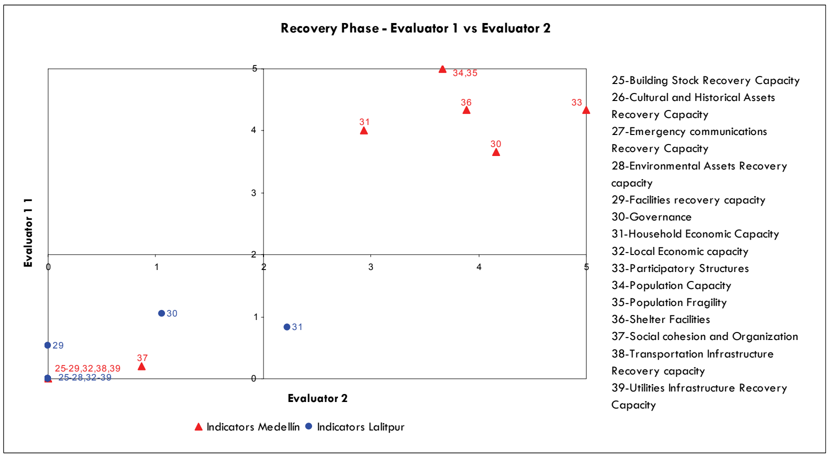

Figure 6.9. Comparison between indicators for Recovery phase E1 vs E2

Chapter 7
Vulnerability Indicator assessment for Medellín, Colombia

"Fairy tales do not tell children the dragons exist. Children already know that dragons exist. Fairy tales tell children the dragons can be killed."
Gilbert Chesterton (1874-1936)

In the previous chapters, a general overview and introduction to the city of Medellín was presented, as well as the fitness for use of the municipal geo-information. In this chapter, the data available at the municipality are used to calculate the vulnerability indicators by phase for Santa Cruz Commune (No. 2) of the city of Medellín. The methods used to compute these indicators are explained and illustrated with maps. This indicator-by-indicator assessment was done to illustrate the use of the data and the possible results that can be achieved with it. The equations and methods used to calculate each indicator are explained so they can be reproduced and extended to other communes. However, they are not the only existent methods to calculate each of them, and therefore different methods that adapt better to the type of data available can be used. These equations and methods were selected from the literature review, and in some cases defined by the author with the help of experts in each field. Finally some conclusions and recommendations are given.

7.1 Physical Vulnerability Indicators

The indicators needed to measure physical vulnerability are basically inventories of elements. In Table 7.1, the indicators and attributes that were used to measure physical vulnerability are presented, as well as the municipal sources. Several sources may mean that there is duplication and sometimes even conflict of information or that several scales are available. Each indicator was calculated using a different method. However, the best available data was used to compute the indicators. For each indicator, the applied method is described. Even though the case study was limited to one commune, the idea of the general methodology is that it could be applied in the whole city, so policy makers can compare areas and perform gap analysis to define the appropriate data collection strategies and the interventions to reduce vulnerability.

To calculate a vulnerability index for each phase and vulnerability type, each indicator/attribute was standardized using the max-min (interval) standardization method (Janssen et al., 2000) to ensure that the measurement units are the same. With this standardization method, the values were normalized with a linear function between the absolute lowest score and the highest score.

Table 7.1 Physical Vulnerability Indicators, and Information sources

Phase	Indicator	Sources
Impact	Building Stock Fragility	Cadastre – Sec. of Treasure
	Cultural and Historical Assets Fragility	Metro-information - ADMP
	Emergency communications Fragility	SIMPAD – Sec. of Environment
	Emergency Services Capacity	SIMPAD – Sec. of Environment
	Environmental Assets Fragility	No information available
	Transportation Infrastructure Fragility	Metro-information – ADMP
	Utilities Infrastructure Fragility	Metro-information – ADMP
Relief	Emergency communications Capacity	Metro-information – ADMP & SIMPAD – Sec.
	Environmental Assets Fragility	No information available
	Health Facilities Capacity	Metro-information – ADMP
	Shelter Facilities	Metro-information – ADMP
Recovery	Building Stock Recovery Capacity	No information available
	Cultural and Historical Assets Recovery	No information available
	Emergency communications Recovery	No information available
	Environmental Assets Recovery capacity	No information available
	Facilities recovery capacity	No information available
	Shelter Facilities	Metro-information - ADMP
	Transportation Infrastructure Recovery	No information available
	Utilities Infrastructure Recovery Capac-	No information available

If the indicator/attribute represents a capacity or has a benefit effect, a higher value means a better condition (e.g. emergency services capacity), the formula used is:

$$\frac{(Value - lowestvalue)}{(Highestvalue - lowestvalue)}$$

and the absolute highest score is indicated with a 1, and the absolute lowest with a 0.

For fragility indicators/attributes the formula used is:

$$\frac{(Value - lowestvalue)}{(Highestvalue - lowestvalue)} + 1$$

And the absolute highest score is indicated with a 0, and the absolute lowest with a 1.

7.1.1 Building Stock Fragility

The Building Stock Fragility indicator reflects the complex interaction between structural type (materials, state, and height), location within the block, and facilities. To assess building stock fragility, 4 attributes have to be known (age, conservation state, number of floors, and structural type). The basic data source is the Cadastre Office.

The Cadastre Office supplied 2 databases: Database number 1 (DB1) has data on Buildings and Parcels with spatial representation (geodatabase); and Database number 2 (DB2) has data on parcels but without spatial representation. The parcel coding does not coincide for both databases, so a process of generating id codes for each parcel of DB2 using existing fields in order to match with DB1 parcel's codes has to be done before any further spatial analysis. Once the coding problem was solved, a second problem was faced. There are multiple parcels in DB2 for each parcel in DB1, since in an individual parcel of DB1 there can be a multi-storey building with multiple owners. Since there are four attributes needed to assess building stock fragility, values for each parcel must be generated. To assign the age variable to each parcel in DB1, the maximum value of the parcel data from DB2 was selected. To assign the conservation state, the worse (minimum) value was used, in order to represent the worse scenario for each building. To assign the number of floors, the maximum value was chosen, therefore ensuring that the total number of floors of each building was correct. To assign the structural type, a similar procedure to conservation state was performed, selecting the worse case scenario, which means the most fragile structural types. In Figure 7.1, the four attributes are presented, with the most favorable conditions in green and the least favorable conditions in red.

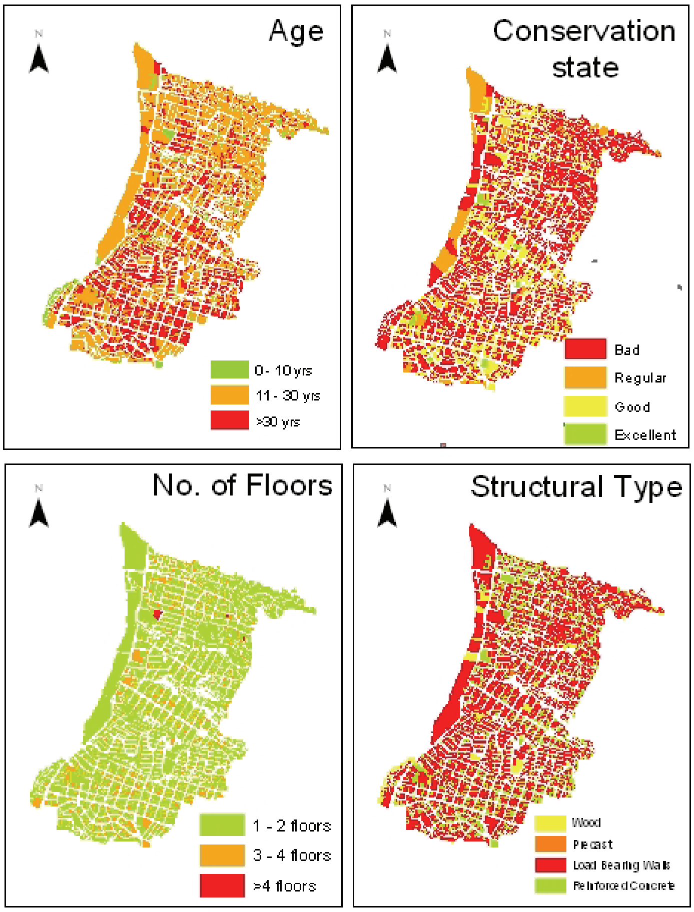

Figure 7.1. Building Stock Fragility Attributes

Once the attributes were processed, the indicator was calculated. In the case of Building Stock Fragility several decision trees were defined using the information provided by experts (see Figure 7.2).

With these decision trees, each variable was given a score and all the possible combinations were given a final value that indicates how fragile each building is. The final values are presented for 2 aggregation levels: building by building and aggregated on a block basis (see Figure 7.3). The values range from 1 to 5, being 1 the least fragile and 5 the most fragile.

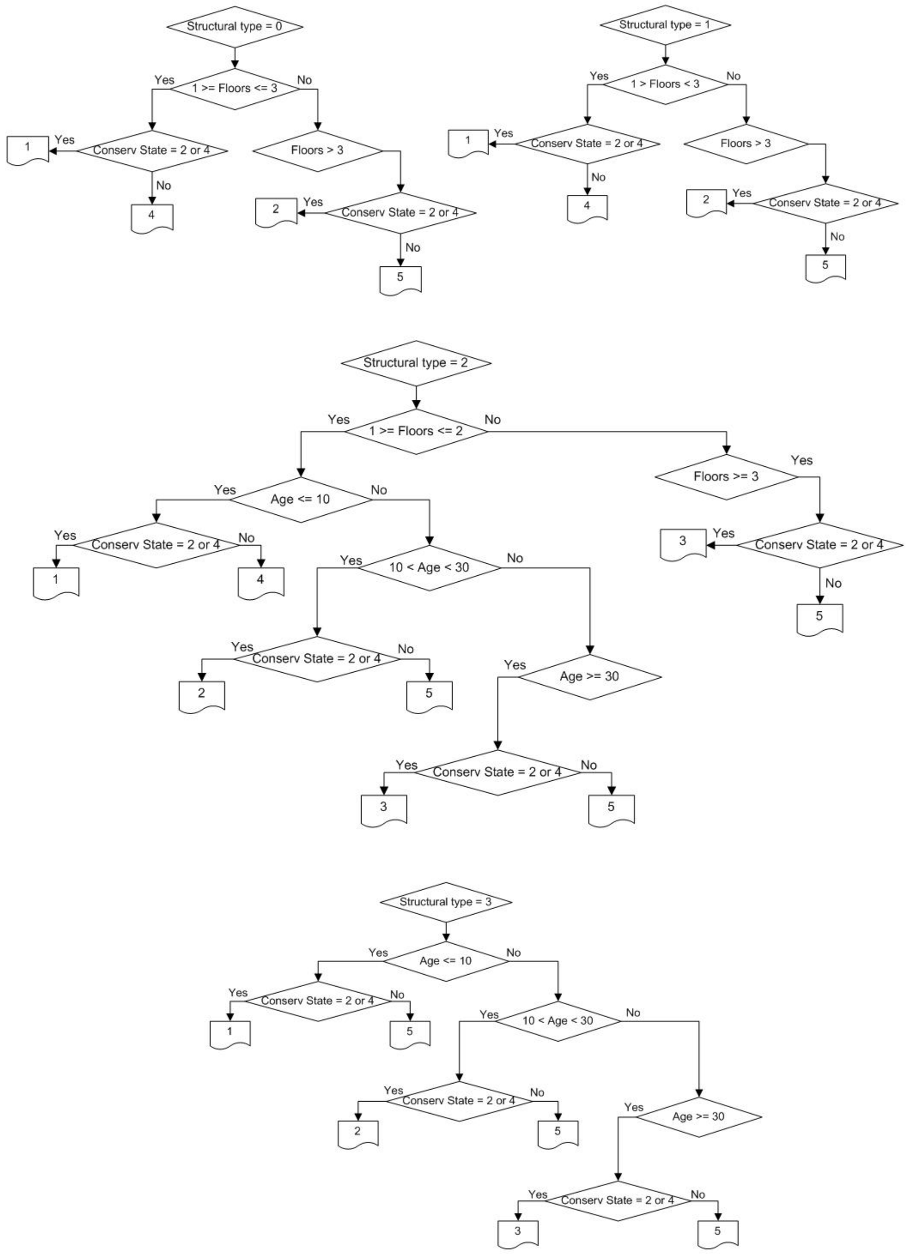

Figure 7.2. Building Stock Fragility Decision Trees

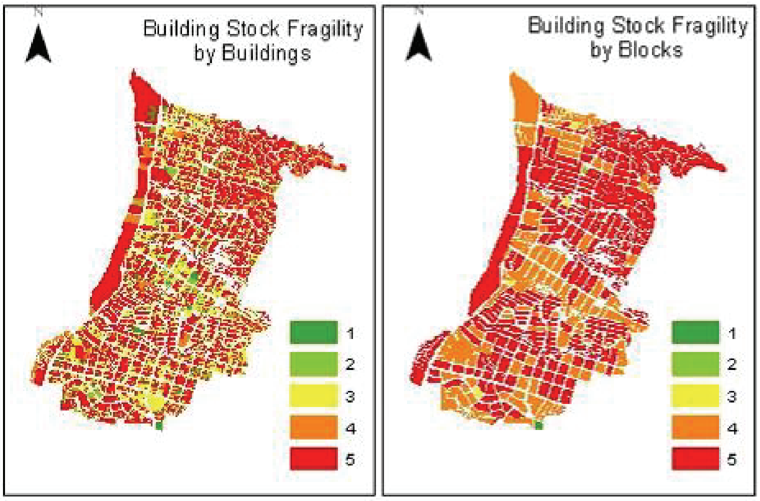

Figure 7.3. Building Stock Fragility Indicators

7.1.2 Cultural and Historical Assets

The Cultural and Historical Assets Indicator was calculated using the information provided by Metroinformación. All the architectonically important buildings are included, including some religious facilities, such as temples, convents, and cemeteries, and even in some cases, whole neighborhoods defined by the Administrative Department of Municipal Planning. These buildings are given a score of relative importance according to their age and characteristics. There are no Cultural or Historical Assets in Commune 2.

7.1.3 Transportation Infrastructure Fragility

The Transportation Infrastructure Fragility Indicator was calculated with two separate indicators. The first one uses data on road width and length collected for the Mobility Plan (Figure 7.4). The second one uses information on Transportation Facilities (Table 7.2). Road width and length data was used to calculate total road area per neighborhood and total road length per neighborhood, as follows:

$$TI_a = \frac{\sum_{i=1}^{n} RA_i}{AC_i} \quad \text{or} \quad TI_l = \frac{\sum_{i=1}^{n} RL_i}{AC_i}$$

Where:

RA*i*: Road area of each road segment *i* in m^2 (length * width)

RL*i*: Road length of each road segment *i* in m

AC*i*: Area of Commune *i* in m^2.

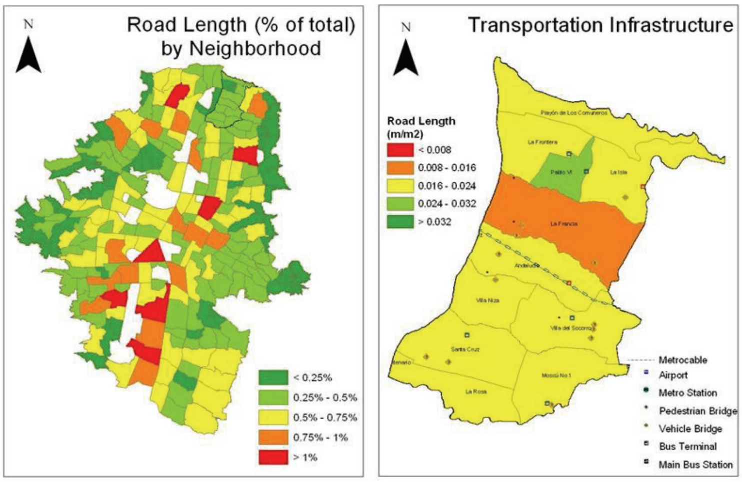

Figure 7.4. Transportation Infrastructure Fragility Indicators

Table 7.2 Transportation Infrastructure in Commune 2

Neighborhood	Pedestrian Bridge	Vehicle Bridge	Formal bus terminal	Informal bus terminal	Total Facilities	Road length (m)
La Isla	0	1	0	1	2	4485
La Francia	2	1	1	0	4	5150
Andalucía	1	0	0	1	2	3900
Villa del Socorro	3	0	1	0	4	5040
Villa Niza	0	1	1	0	2	3395
Moscú No. 1	1	0	2	0	3	4100
Santa Cruz	2	0	1	0	3	4615
La Rosa	0	0	0	0	0	3430
Pablo VI	0	0	0	0	0	2250
La Frontera	0	0	0	0	0	3020
Playón de los Comuneros	0	0	0	0	0	4175

The transportation facilities (airports, metro stations, bus stations, main bus stations, pedestrian bridges, and vehicle bridges) were simply added up by type and presented by neighborhood in order to assess the amount of resources needed to replace them.

7.1.4 Utilities Infrastructure Fragility

The information for utilities was delivered by the utilities company (Empresas Públicas de Medellín –EPM-) as point data indicating the type of energy connection (Industrial, Commercial, or Residential) or as polygon data indicating sewage and water coverage by zones. The point data for energy coverage was aggregated by block and by neighborhood. The polygon data for water and sewage coverage was not used because it lacks information on number of users per polygon.

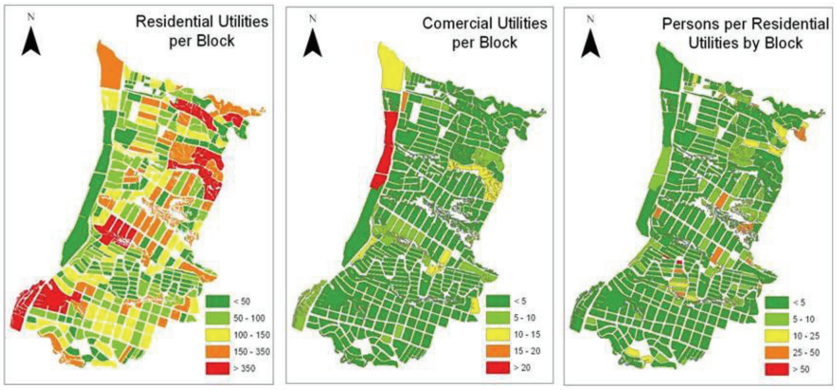

Figure 7.5. Residential, Commercial and Industrial Utilities

7.1.5 Emergency communications fragility and capacity, and Emergency Services Capacity

The municipality has an Emergency Plan (SIMPAD, 2005), where a review of all the agencies in charge of emergency response, their capacities and personnel is presented. From this Plan, a series of indicators were analyzed.

Emergency communications capacity (ECC): the city has a communications protocol in place in case of emergency. There is an integrated emergency line (123), where calls are received and resources are allocated, that is a fundamental part of the Integral Security System. This emergency line connects the Metropolitan Police, the Army, CTI (Technical Investigative Corps), DAS (Administrative Security Department), Secretariat of Transit and Transportation, Secretariat of Government, Police Inspections, Fire Brigade, SIMPAD, Red Cross, Civil defense, Secretariat of Health, Metrosalud, and the Colombian Air Force, facilitating coordinate work between them, procuring a maximum level of operative efficiency. In Medellín, the Emergency Communications Capacity has proven to be effective in several emergencies where the communication protocol has been applied. However, the protocol has never been tried in an emergency that involves the whole city, only in local emergencies with few injured or killed. The communications protocol also relies on a series of instruments such as the Citizen Support Network (RAPCI), a Video Security System (distributed throughout the city), community alarms, and a communications system with three transmitting stations that cover the city. In terms of previous educational campaigns on risk management, SIMPAD has a permanent social commission in charge of participating in scenarios where the environmental education topic is debated. It also helps all the education institutions to establish work mechanisms in terms of prevention, attention, and emergency recovery, through the School Committees for Prevention and Attention of Disasters (CEPAD). A unique value cannot be assigned to each individual commune, but a score for the whole city, in a 1 to 5 scale (being 1 poor and 5 good) can be given to the communications system in terms of capacity, using the following equation:

ECC = 0.5 * (Emergency communications system) + 0.5 * (Previous educational campaigns on risk management)

A score was given to both attributes by the sub-director of SIMPAD. For Medellín, ECC = 0.5*(4) + 0.5*(2) = 3, according to the knowledge he has about the system.

Emergency Communications Fragility: Assessing the fragility of the system is a hard task, since it relies on a fixed telephone line that can be interrupted with a seismic event. However, all the organizations that are connected through this emergency line have other communication networks in place via shortwave radio. In terms of fragility in case of an earthquake, the score will be 2 (using the previous range). This system has also never been tried in a major emergency.

Emergency Services Capacity: This indicator assesses the number of ambulances, other emergency vehicles, per 25,000 inhabitants, and firefighters available in the city in case of emergency. The city of Medellín has 29 public and 64 private ambulances; 172 fire-fighters, and 500 volunteers, therefore the indicators for the city will be:

ESC1 = (25000 * (29+64)) / 2,261,045 = 1.02 ambulances per 25,000 inhabitants.

ESC2= 2,261,045 / 672 = 3365 inhabitants/firefighter, or 0.3 firefighters for 1000 inhabitants.

There is no international standard value to determine if these figures are low or not. Nevertheless they indicate the amount of people that each unit has to cover.

7.1.6 Environmental Assets Fragility

The Environmental Assets Fragility Indicator is calculated both for the Impact Phase and the Relief Phase. In Medellín the Secretariat of Environment has an inventory of environmentally important areas, divided in strategic ecosystems, structuring hills, and other areas. Each area can be classified according to its Biodiversity Index, the existence of endemic species, and the type of environmental asset. For each polygon, an Environmental Asset fragility Indicator should be calculated as follows:

Biodiversity Index = number of species in the area / the total number of individuals in the area

Endemic species = 1 (yes), or 0 (no)

Type of environmental assets: Natural (rivers, seas, lakes, forests), and artificial (parks, sewer systems, waste treatment facilities, environmental research facilities). Each of them can have a score between 0 and 1, being 0 non important and 1 very important.

EAF = Biodiversity index* 0.4 + Endemic Species * 0.3 + Type of Env. Asset * 0.3

There are no environmental assets in Commune 2.

7.1.7 Health Facilities

To calculate the health facility indicator, it is necessary to know the number of nearby health facilities (considering accessibility issues) and the number of people that live in the area in order to establish the number of health facilities by type and the number and the number of persons they can attend. This indicator can be calculated as the area of influence of a health facility and the people it can serve, or it can be calculated as the minimum distance from each household (parcel) to the nearest health facility that can attend an injured patient during the relief phase. As a combined indicator capacity-distance, it can show which facilities have higher demand and the distance that a member of a household has to travel.

Considering the level of the health facilities, the facilities corresponding to health post, health center, and intermediate health unit were selected to represent the facilities that are likely to be closest to the injured persons during the impact phase, and for which an area of influence of 1000m was used. Within that area of influence, the total number of persons was calculated as the sum of the proportion of inhabitants of the neighborhood, according to the overlap of the area of influence and the neighborhood (see equation below). Facilities such as hospitals and clinics that are of regional, metropolitan, and municipal hierarchy are not considered in terms of number of people they serve within an area of influence, since all the population of the city will fall within that area of influence.

$$Is_i = \left(\frac{Ao_{ij}}{An_i} \right) * Popn_i$$

Where:

Is_i: Inhabitants served by facility i

Ao_{ij}: Overlap Area between Area of Influence i and Neighborhood j

An_i: Area of Neighborhood Polygon i

Pop_n: Total number of inhabitants in the neighborhood i

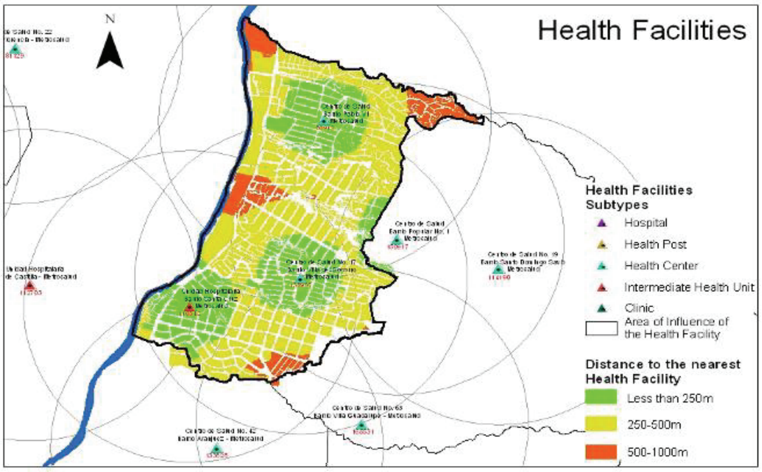

Figure 7.6. Health Facilities

The Health Facilities information is provided by the Secretariat of Health (Metrosalud). There is an inventory of health facilities ranked according to their capacity in 5 hierarchies (Metropolitan, City, Zone, Neighborhood and block level), and subtypes (Health Center, Health Post, Intermediate Health Unit, Clinic, Hospital). Although the specific capacity of each institution is not available yet, the hierarchy and subtype indicate the relative importance. In Figure 7.6 the health facilities in Commune 2 and neighboring communes are presented.

In Medellín, the river represents an obstacle in east-west communication corridors, therefore, the inhabitants of Commune 2, can access in an easier way the Health Facilities located in the east side of the river than those on the west side.

7.1.8 Shelter Facilities

The indicator for shelter facilities is calculated using information of other existing facilities, such as religious, sport, educational, and social assistance facilities (see Figure 7.7). Ideally, and according to the municipal data model, they should have information on their capacity to give shelter to people, but they do not have this attribute yet.

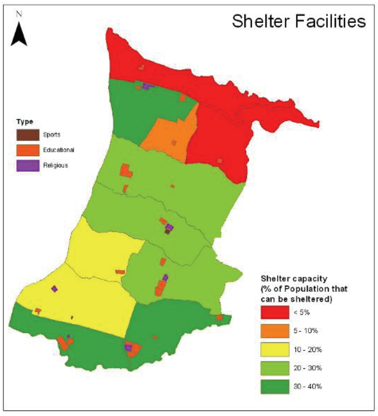

Figure 7.7. Shelter Facilities

Considering that the average person needs at least 2 m^2 as shelter area (only temporary allocation, not long term), one can deduce that if the total shelter area available in each neighborhood is divided by the total population, the percentage of population that can be sheltered can be calculated, as presented in the following equation. The resulting values are presented in Table 7.3.

$$Sh_i = \frac{\sum_{i=1}^{n} A_{iSh i}}{Pop_{i i}}$$

Where:

Sh_i: Shelter facilities indicator for neighborhood i

A_{Shi}: Shelter area available for every neighborhood i

Pop_i: Population of the neighborhood i

Table 7.3 Shelter Facilities Capacities and Areas by Neighborhood

Neighborhood	Number of shelters	Capacity (persons)	Area (m2)
La Isla	1	344	687
Playón de Los Comuneros	1	332	664
Pablo VI	1	359	717
La Frontera	3	2193	4386
La Francia	3	3414	6830
Andalucía	3	2021	4042
Villa del Socorro	4	3934	7869
Villa Niza	1	739	1477
Moscú No.1	6	4838	9677
Santa Cruz	3	1068	2135
La Rosa	3	2880	5760

There is no information to calculate the recovery capacity of the following indicators: building stock, cultural and historical Assets, emergency communications, environmental assets, facilities, transportation infrastructure, and utilities infrastructure. They should basically be tables by commune or neighborhood, indicating the available money or percentage of municipal budget allocated for recovery.

7.1.9 Aggregated Physical Vulnerability Indexes

Following the scores given by the experts to each indicator (see Chapter 6), and after standardizing the resulting values for each one, an aggregated physical vulnerability index for each phase can be calculated, as follows:

$PVII = BSF*W_{BSF} + CHA*W_{CHA} + ECF*W_{ECF} + ESC*W_{ESC} + EAF*WF_{EAF} + TIF*W_{TIF} + UIF*W_{UIF}$

Where:

PVII: Physical Vulnerability Index for the Impact Phase

BSF: Building Stock Fragility

CHA: Cultural and Historical Assets

ECF: Emergency Communications Fragility

ESC: Emergency Services Capacity

EAF: Environmental Asset Fragility

TIF: Transportation Infrastructure Fragility

UIF: Utilities Infrastructure Fragility

W_x: the corresponding weights or importance scores, according to the surveys.

The scores given to each indicator that has relevance for the city of Medellín can be seen in the matrices in the Annexes, and in Chapter 6.

7.2 Socio-Cultural and Economic Vulnerability Indicators

The indicators needed to measure socio-cultural and economic vulnerability, are a bit more difficult to calculate than those used to measure physical vulnerability. In Table 7.4 the indicators, attributes, and sources that are used to measure socio-cultural vulnerability are presented.

The socio-cultural and economic vulnerability indicators are calculated mostly using information provided in the SISBEN surveys, under the responsibility of the Secretariat of Health. The SISBEN surveys provide access to up-to-date reliable social and economic information about specific groups in the districts and municipalities of the country. They are a basic tool that enables precise social and economical diagnosis of specific groups within the population which can be applied to individual homes. It is very useful in the creation of development plans for the municipalities through the technical, objective, uniform, and equitable selection of benefits for social programs according to their specific social and economical condition, represented by the SISBEN index, which is a quality of life summary indicator. The focusing process requires the periodic update of the database and its use by all the entities that run the social programs at the department, district, and municipal level, which will allow the harmonization of criteria and beneficiary selection (DNP, 2006).

Table 7.4 Socio-Cultural Vulnerability Indicators, Attributes and Information sources

	Indicator	Attributes	Sources
Impact	Minorities/Special Groups	Location & Characteristics	SISBEN – Sec of Health and Census data from the National Administrative Dept Statistics (DANE)
	Population distribution	Time distribution of the population	SISBEN – Sec of Health and Mobility Plan surveys
	Population Capacity	Educational level of the population	SISBEN – Sec of Health
		Previous Hazard/Risk knowledge	SIMPAD (Neighborhood Emergency Committees)
	Population Fragility	Vulnerable Population (Age groups)	SISBEN – Sec of Health and DANE
Relief	Minorities/Special Groups	Location & Characteristics	SISBEN – Sec of Health
	Social cohesion and Organization	Experience in previous events	No information available
		Religion/Ethnicity	No information available
		Participation in Groups	SIMPAD – Sec. of Environment
		Time in the neighborhood	Sec of Social Development Education Dept.
		Political participation	No information available
Recovery	Population Capacity	Health Insurance	SISBEN - Education Dept.
	Population Fragility	Household Masculinity Index	SISBEN – Sec of Health and DANE
	Social cohesion and Organization	Experience in previous events	SISBEN – Sec of Health
		Religion/Ethnicity	No information available
		Participation in Groups	SISBEN – Sec of Health
		Political participation	SISBEN – Sec of Health
		Time in the neighborhood	SIMPAD
	Minorities/Special Groups	Location & Characteristics	SISBEN – Sec of Health

Although the SISBEN data is thoroughly collected, the following situations are frequently present and make the data processing difficult:

- Several references to the same household (possibly due to errors in address geo-coding). Address geo-coding is relatively poor (around 25% error) in Medellín, due to errors in the addresses and errors in the street names, but mainly due to shortcomings of the geo-coding software used. The particular address system in Medellín required a geo-coding software especially designed to suit the city's needs, but it is still under development. In many cases, the software cannot locate the exact address, and therefore, locates addresses to the point at the intersection. Due to this, one can find multiple points, located at an intersection, that correspond to different addresses.
- Buildings with several households (very common in apartment buildings with many different owners/tenants).
- Several households living in each building storey.

To organize the SISBEN data for spatial use, the following pre-processing was done:

- Separation of SISBEN data in two tables: one with household data and another with household member's information. A household id is assigned as a posted key field in the latter.
- Revision and correction of all SISBEN point data that fall outside of a parcel polygon, due to geo-coding errors. This was done by using distance functions

(nearest parcel) that assign a unique parcel code to each SISBEN point (spatial join).

Since the points corresponding to the survey can not be visualized due to the possible overlaps (see Figure 7.8), it is better to display the results aggregated by parcel.

To display data by parcel, the following procedure was followed:

- A parcel_id is assigned to each SISBEN point using a spatial join with the parcel map, where each point is given the parcel_id of the polygon in which it falls in (see figure). The new point map is called SISBEN_Parcel.
- The SISBEN_Parcel table will now have a Household_id and a Parcel_id.
- In ACCESS, a new table is generated, using the SISBEN survey data, that calculates the attribute of interest (e.g. income, total persons by activity type, etc.). This table is added to the SISBEN_Parcel table using the common field Household_id.
- A new table is generated by grouping the SISBEN_Parcel table by Parcel_id, since many households can fall within a parcel. The new table is imported to the geo-database and joined to the Parcel map in order to display the data.

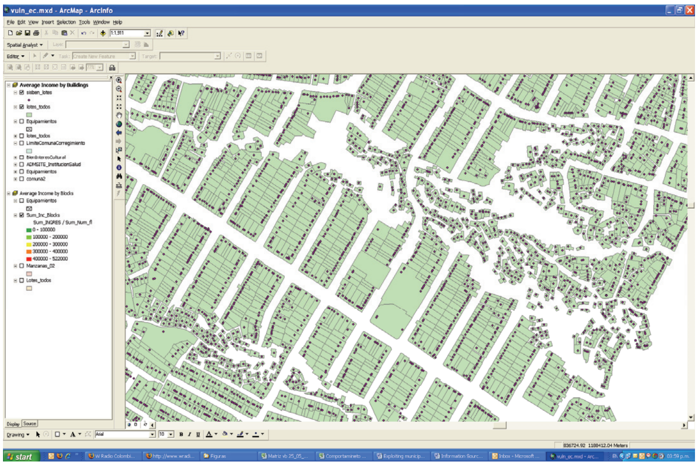

Figure 7.8. SISBEN point data

Once, the SISBEN data is ready for display by parcel. The Socio-cultural indicators are calculated as follows.

The indicator for Minorities/Special Groups is calculated using SISBEN data. There is no available information on the distribution of ethnic groups (displaced population, Afro-Colombians, or indigenous groups), only about disabled population. This information is aggregated on a block and neighborhood basis. There is no information on the characteristics of the disabilities. The Census data (DANE, 2005), indicates the distribution and characteristics of disabled people at commune level.

One of the most important socio-cultural vulnerability indicators is the time-distribution of the population. The Population distribution indicator was calculated using the surveys done for the Metropolitan Area Mobility Plan. These surveys contain information about household composition and mobility patterns of each household member (number of members, relationship, age, gender, mobility habits, etc.). The surveys were processed in Excel, separated in three (3) worksheets:

- Household data: contains general information about the household (address, neighborhood, commune, socio-economic stratum, number of members, number of vehicles, etc.)
- Household Members: contains data about the household members (age, gender, occupation, etc.)
- Member's trips: contains data about the trips made the day before the survey by each household member, transportation means, origin, destination, starting time, finishing time, and duration).

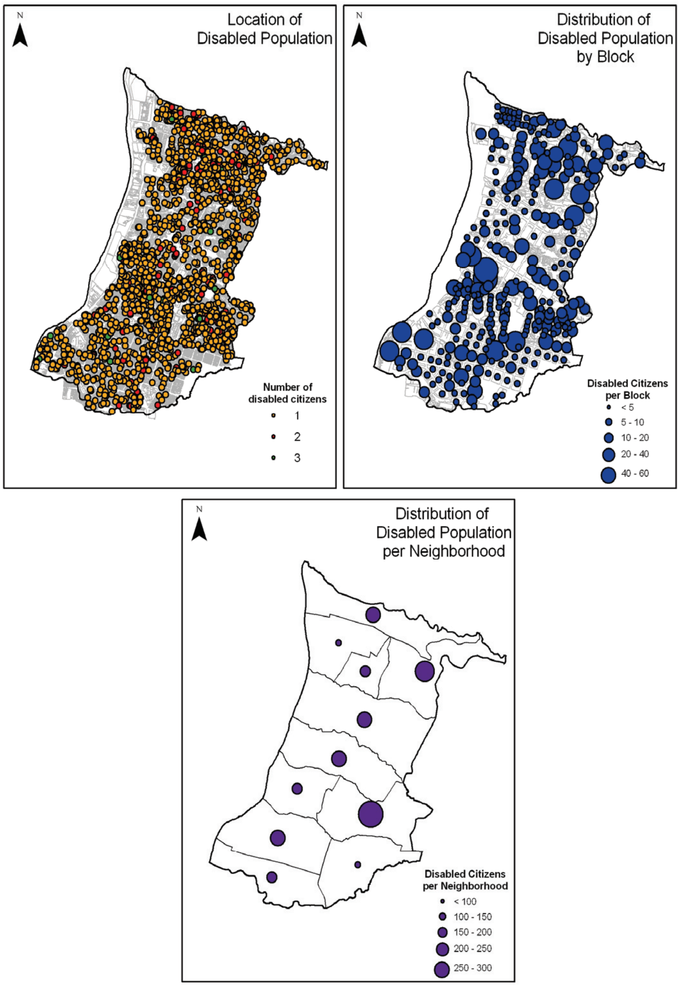

Figure 7.9. Minorities/Special Groups: Disabled Population

The hourly population fluctuation (in-out patterns) for all communes of Medellín, and for the neighborhoods of Commune 2 can be observed in Figure 7.10 and Figure 7.11 respectively.

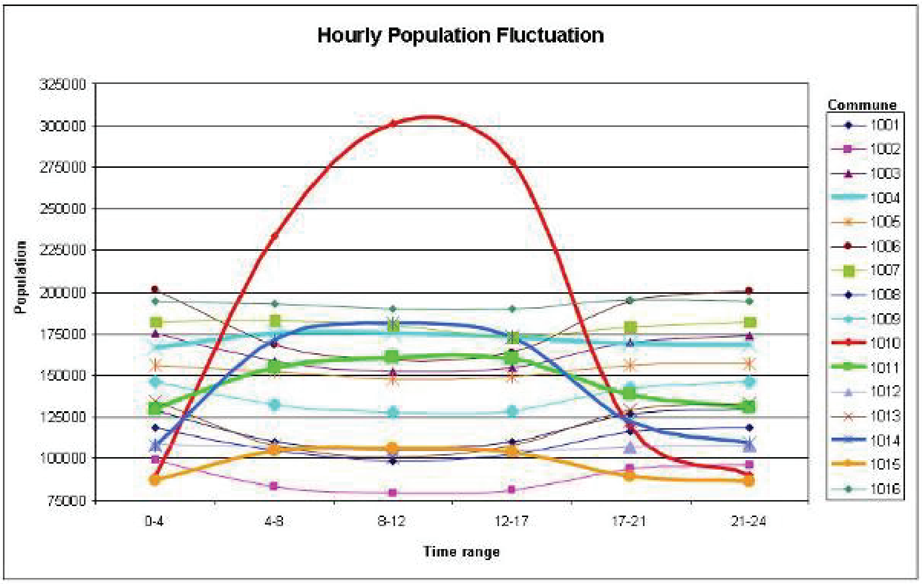

Figure 7.10. Hourly Population Fluctuation by Communes

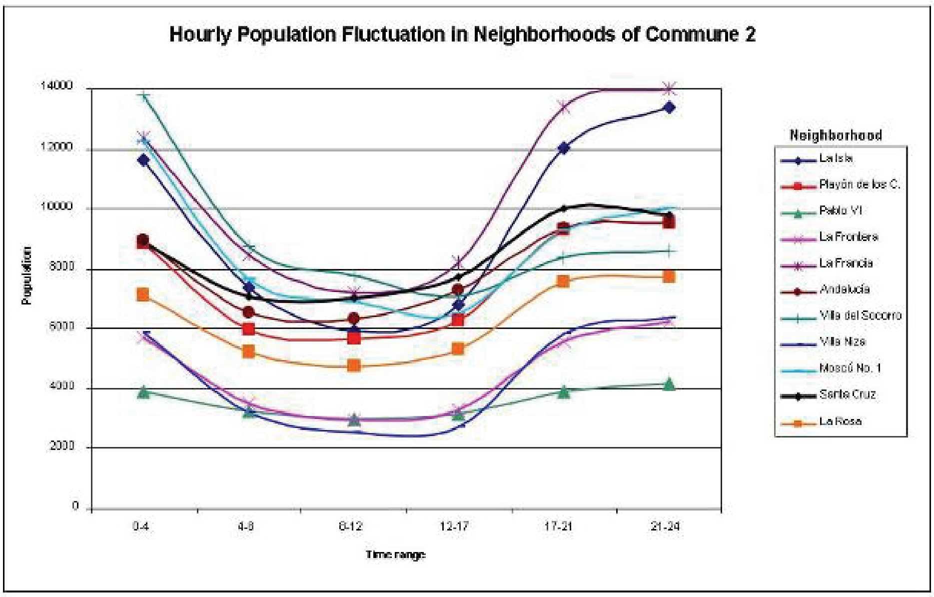

Figure 7.11. Hourly Population Fluctuation within Commune 2

The data contained in the database was used to define mobility profiles by occupation and socioeconomic stratum, that is, to calculate who is in or out of the commune at any given time. In Figure 7.12 these profiles are presented for the city of Medellín.

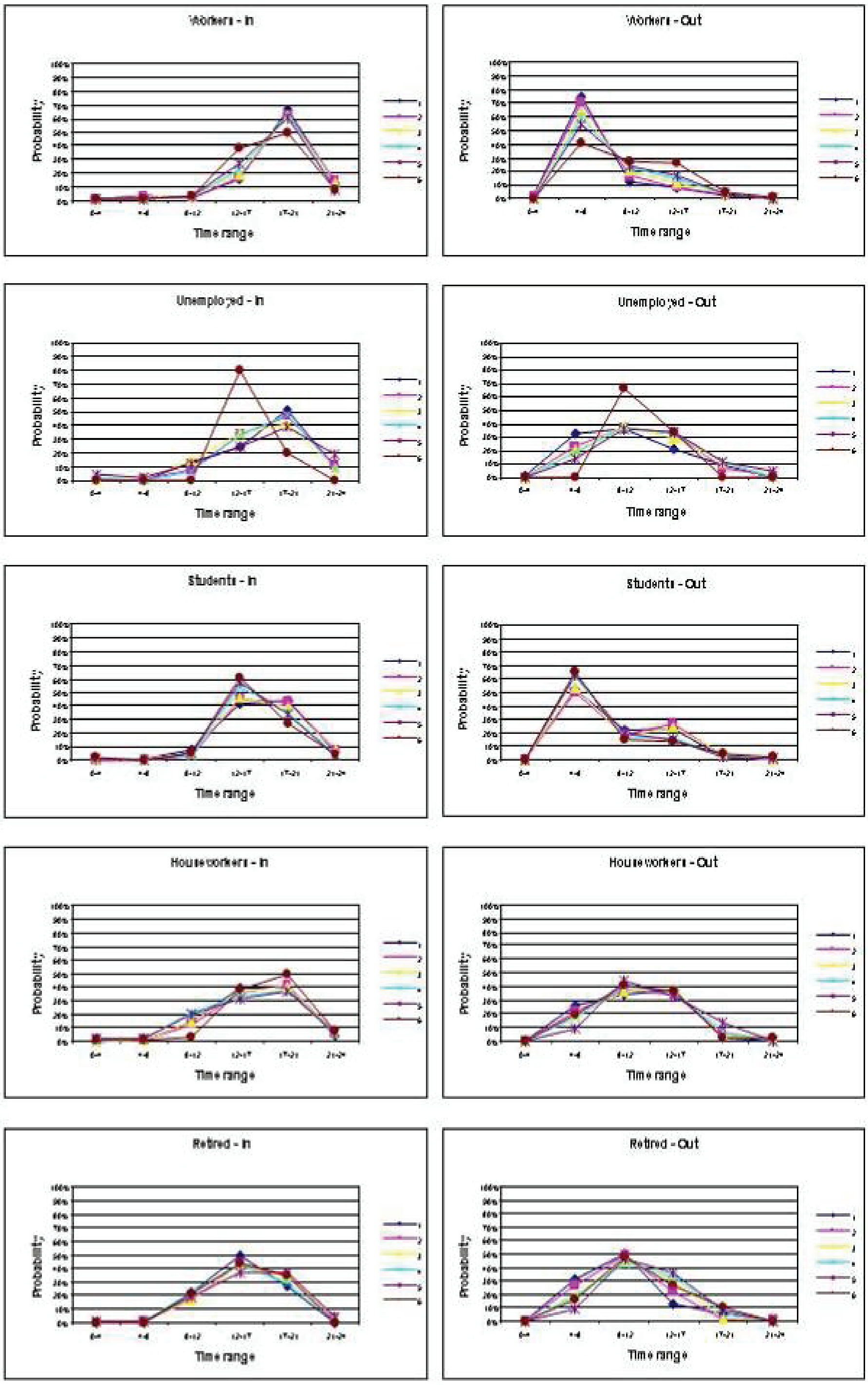

Figure 7.12. Mobility Patterns by Occupation and Socioeconomic stratum

Once the patterns and hourly fluctuations were established, the population remaining in the commune was calculated by multiplying the members of each household, according to their socio-economic stratum and occupation, by the probability of being in (100 – probability of being out), and then adding the population that enters the commune at any given time (see Figure 7.13).

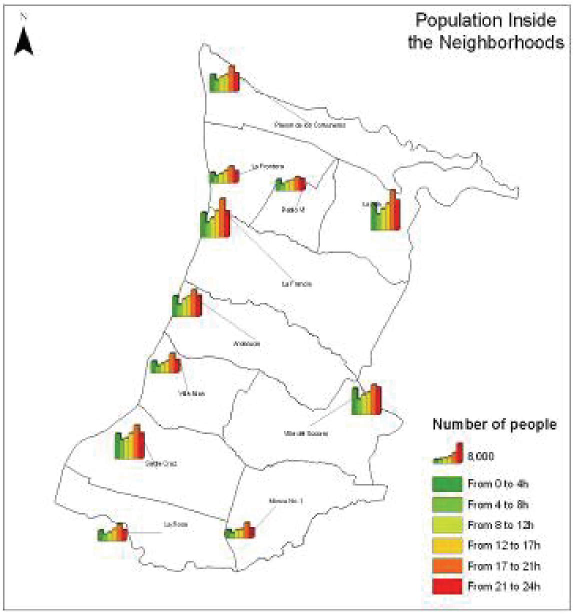

Figure 7.13. Population Inside each neighborhood

To represent the population by blocks, the population that enters each neighborhood is divided by the number of blocks and distributed accordingly (see Figure 7.14).

For the calculation of the Population Preparedness, two attributes have to be processed first; educational level, and previous hazard/risk knowledge.

The educational level of the population is an attribute derived from SISBEN data. For each household, SISBEN data has information on the educational level of each member. A rank sum method is used to calculate the educational level attribute. Since there are 6 possible educational levels the weights (Table 7.5) are assigned using the following equation (Janssen and Van Herwijnen, 1994):

$$w_j = \frac{n - r_j + 1}{\sum_{i=1}^{n} (n - r_i + 1)}$$

Where:

w_j: weight for factor j

n: number of factors

r_j: ranking position of factor j

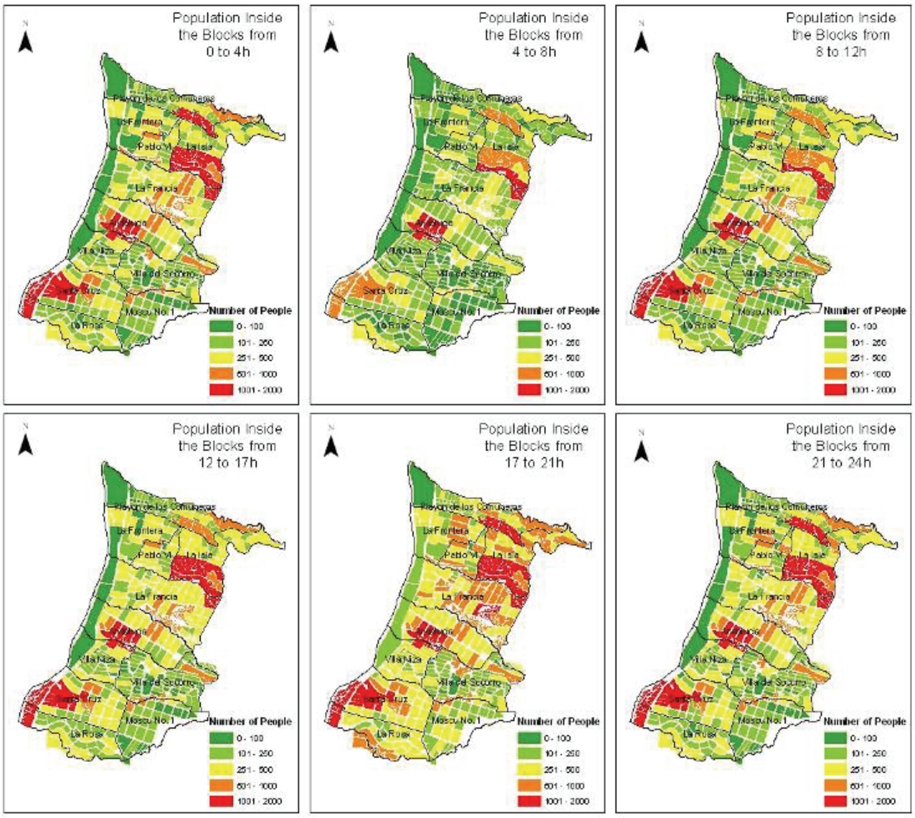

Figure 7.14. Population Inside each block during different time ranges

Once the weights are obtained, the educational level attribute is calculated as:

$$EL_i = \frac{(\sum_{i=1}^{n}(\sum m_j) * w_j)}{n_m}$$

Where:

EL_i: Educational level for household i

m_j: number of members of household i with educational level j

w_j: weight for educational level j

n_m: total number of household members

The values obtained range from 0.05 to 0.29. These values are reclassified in a 1 to 5 scale as shown in Table 7.5 (columns 3 and 4).

Although the household educational levels are calculated individually, they are presented as average values per parcel, and then aggregated at block and neighborhood level. When aggregated, the average educational level at block level and neighborhood level is somewhere between 1 and 2 (according to Table 7.5), with values ranging from 0.09 to 0.12 and 0.10 to 0.11, respectively.

Table 7.5 Weights and Scores for Educational Level

Educational Level	Weight	Average Educational Level	Score
Postgraduate	0.29	>0.24 and <=0.29	5
University	0.24	>0.19 and <=0.24	4
Technical	0.19	>0.15 and <=0.19	3
Secondary	0.14	>0.1 and <= 0.15	2
Elementary	0.10	>0.05 and <=0.1	1
None	0.05		

For the Previous Hazard Knowledge, a simple rule is established. If at least one household member has knowledge (from school, from educational campaigns, or from a past experience), the household is given a score of 5, otherwise it is given a score of 0.

The population preparedness indicator is calculated as the average value between educational level score and previous hazard knowledge score.

In Medellín, there is only information available for the educational level, therefore, the attribute Previous Hazard Knowledge will be considered as equal to 0. However, it is important to note, that the city has some data about previous hazard knowledge collected in the census of the households located in "high risk non-recoverable areas", and that the municipality has considered the inclusion of this question in the SISBEN survey or in the Survey on Quality of Life. The Population preparedness indicator for Commune 2 is presented in Figure 7.15.

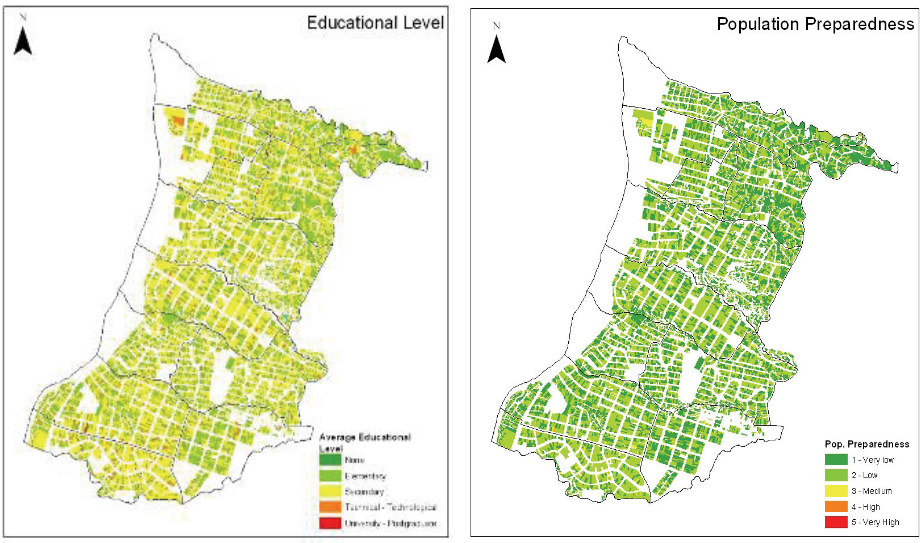

Figure 7.15. Educational Level and Population Preparedness

The population fragility indicator for the relief phase is calculated using the age/gender distribution information provided by the SISBEN and the DANE (Departamento Administrativo Nacional de Estadística) census data. A vulnerable population ratio is calculated using the following equation:

$$Vp_i = \frac{\sum_{j=1}^{n} (M_{0-9} + M_{65} + F_{0-9} + F_{65})}{\sum_{j=1}^{n} Tpop_j}$$

Where:

Vp_i: Vulnerable Population of parcel i

$M_{0\text{-}9}$: Number of males between 0 and 9 years in each household

M_{65}: Number of males 65 or older in each household

$F_{0\text{-}9}$: Number of females between 0 and 9 years in each household

F_{65}: Number of females 65 or older in each household

$Tpop_j$: Total persons living in household j

Since the population age is not available from the SISBEN data, census data from DANE was used to define the percentage of females/males per age group. Although DANE census data is collected on a household level, for dissemination purposes it is aggregated to commune level and upwards and made available at: the institution's website (www.dane.gov.co/censo). The data for Commune 2 is presented in Table 7.6.

Table 7.6 Population Distribution by Age Groups

Age Group	Males	Females	Total	% Males	% Females
0 to 9	9740	9173	18913	21%	17%
10 to 14	5148	4814	9962	11%	9%
15 to 64	28207	34212	65135	62%	66%
>=65	2764	3646	6410	6%	7%
Total	45859	51845	100420	100	100

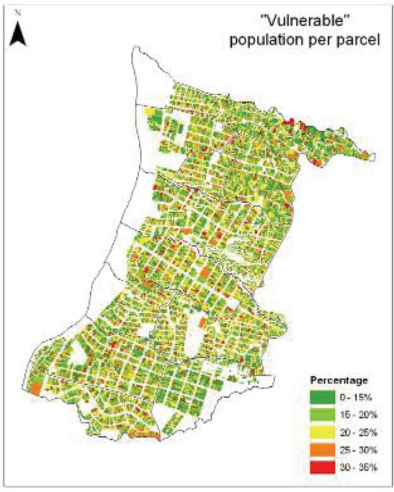

Figure 7.16. "Vulnerable" population per parcel

The total population of males and the total population of females per parcel were multiplied by these percentages, to calculate the number of people per age group per parcel. Subsequently, the people between 0 and 9 and people over 65 were summed as vulnerable population. This value was then normalized by the total population of the parcel. The values were also calculated for blocks and neighborhoods. When aggregated by blocks and neighborhoods, the average value is 25.9% for both levels, which means that there is 1 person out of every 4 that can be considered as vulnerable.

The population fragility indicator for the recovery phase is determined using the Household Masculinity Index, that is, the ratio between female household heads and total households. For every parcel the ratio was calculated and then aggregated at block and neighborhood level (see Figure 7.17).

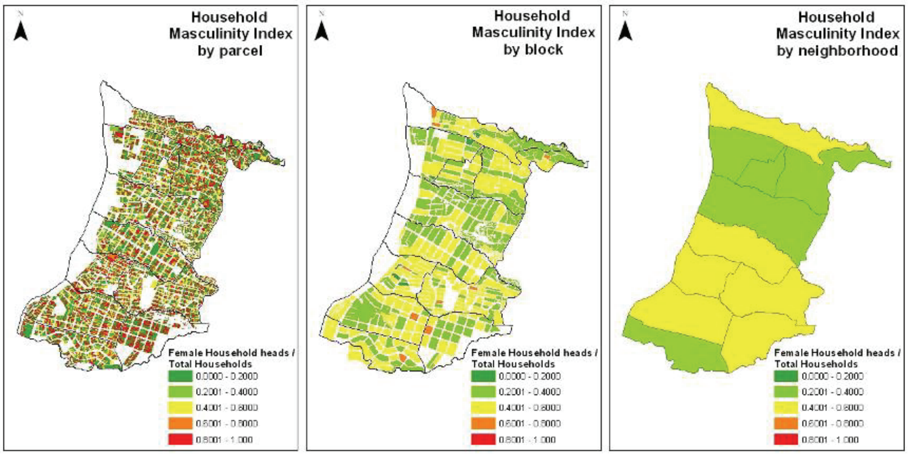

Figure 7.17. Household Masculinity Index

The social cohesion and organization indicator is derived from 4 attributes: experience in previous events, religion/ethnicity, political participation, participation in groups, and time in the neighborhood. To define the value for this indicator, for each household, the procedure presented in Figure 7.18 was followed.

Experience in previous events is of course common in areas where recurrent and frequent disasters occur, such as annual floods. In the case of earthquakes, this information is scarcer and is only collected in specific surveys. Nevertheless in some municipalities this information is collected and updated in different surveys and censuses performed by NGO's or government offices. Other assumptions can be made based on the population's age and years lived in the area. For example, in cities that have been affected by an earthquake in recent years, one can assume that the population that has been living in it, before the event happened, has some kind of experience.

The experience in previous events can have two possible values: 5- existent or 0 – non existent, for each household member. Determining if a household belongs to a religious or ethnic group, helps in the assessment of social cohesion, since people who belong to the same group normally tend to help each other in case of need, thus contributing to the overall cohesion and organization. Belonging to a group is therefore assigned a value of 5, and not belonging a value of 0. Participation in groups is also derived from data collected in specific surveys or censuses, but it can also be calculated using secondary information, such as existing groups, and their area/population reach. Time in the neighborhood is normally collected in the national census, and can be used directly if the information is aggregated at the appropriate level.

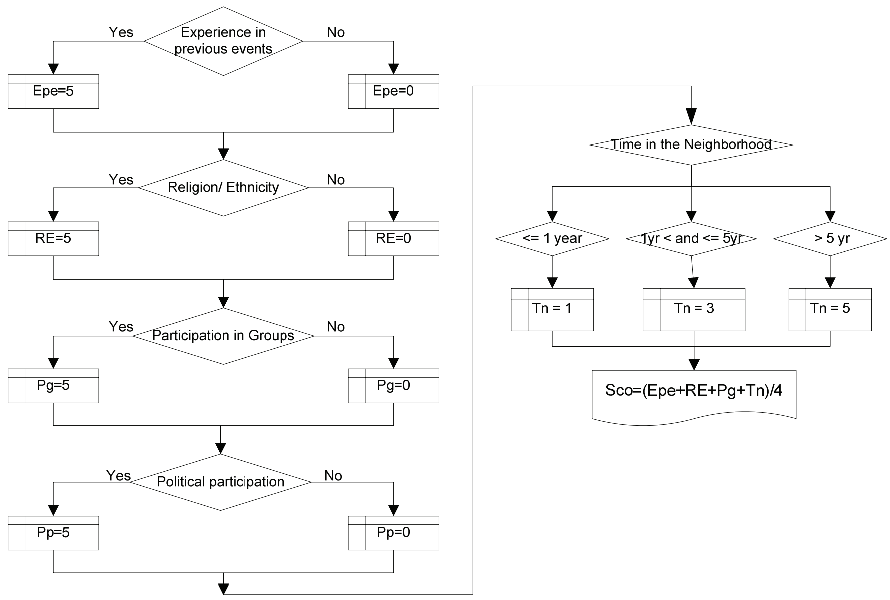

Figure 7.18. Procedure to calculate Social cohesion and Organization

The population capacity can be assessed using the health insured population as an indicator of how many people can count on health services during the recovery phase. Nevertheless, health insurance depends on whether the persons are employed or not. If there is an extended disruption of economic activities as a result of a major earthquake, there will most probably be a cease of health insurance.

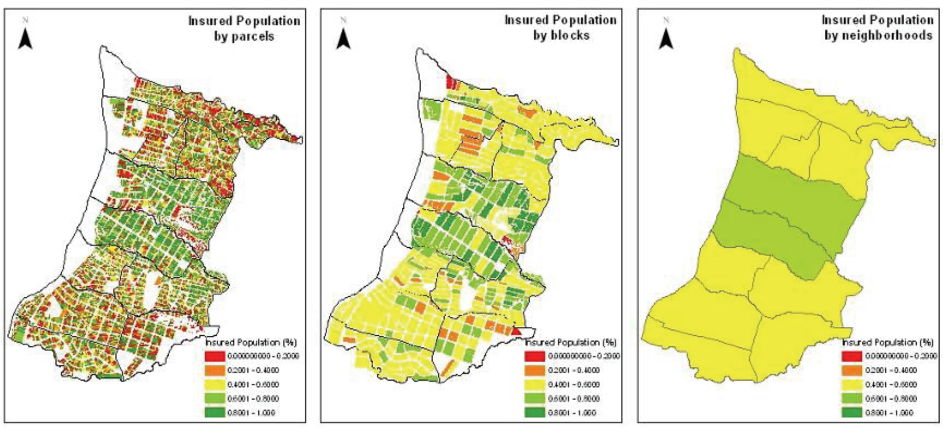

Figure 7.19. Health Insured Population

As indicated previously, in Table 7.7 the list of economic indicators, attributes and sources is presented.

Table 7.7 Economic Vulnerability Indicators, Attributes and Information sources

Phase	Indicator	Attributes	Sources
Impact	Economic Fragility	Economical activities by type	Census of economic activities - Metro-information - ADMP
Relief	Household Economic Fragility	Financial Status (debt, savings)	SISBEN – Sec of Health
		Subsidies	No information available
Recovery	Economic activities capacity	Financial Status (debt, savings)	No information available
		Insurance	No information available
	Household Economic Capacity	Economic dependence (% of dependents)	No information available
		Employment	SISBEN – Sec of Health
		Income level	SISBEN – Sec of Health
		Insurance	No information available
		Tenure	SISBEN – Sec of Health

To assess the Economic Fragility, basic information on economic activities by type is needed. Ideally it should include information on employed people, but just knowing how many businesses are located in a specific area can help determine how fragile the economy can be in case a hazard, such as if an earthquake strikes. The chamber of commerce of most cities has a detailed census of economic activities. In most cases it in not geo-referenced, but it can always be aggregated at different levels, and with the addresses of the companies it can be easily geo-coded using the municipality's geo-coding software. In the case of Medellín, there is a census of economic activities by block for three sectors: commerce, industry and services. To represent this information, it was aggregated at three levels as seen in Figure 7.20.

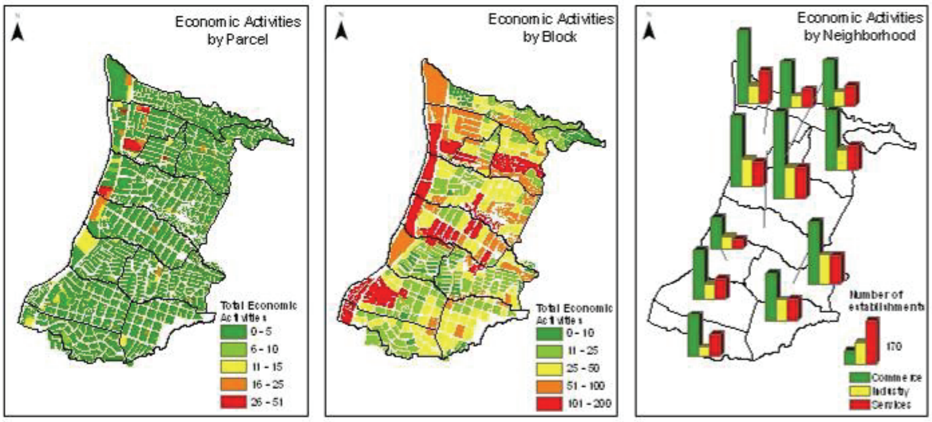

Figure 7.20. Economic activities

For Household Economic Fragility (debt, savings, subsidies) and Economic activities capacity (debt, savings + insurance), there is no information for the city of Medellín. These values can be displayed if available using the same spatial units (parcel, block, neighborhood, and commune)

To calculate Household Economic Capacity, four attributes are considered: economic dependence, employment, income level, insurance, and tenure.

Normally a household's economic dependence is calculated as the ratio between vulnerable members of the household (younger than 14 and older than 64), divided by the members with ages between 15 and 64. However, it can also be calculated as the ratio between members without income divided by members with income. Economic dependence was assessed using both methods to illustrate the different possibilities (see Figure 7.21 and Figure 7.22).

Average Income by household was calculated using the SISBEN data and the cadastre parcels to visualize the results. The average income data can be visualized by parcel or by block, as shown in Figure 7.23.

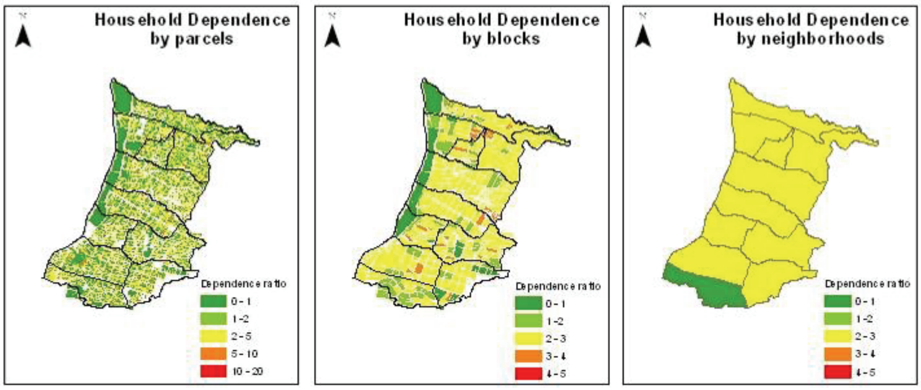

Figure 7.21. Household Economic Dependence (ratio between members with income and members without income)

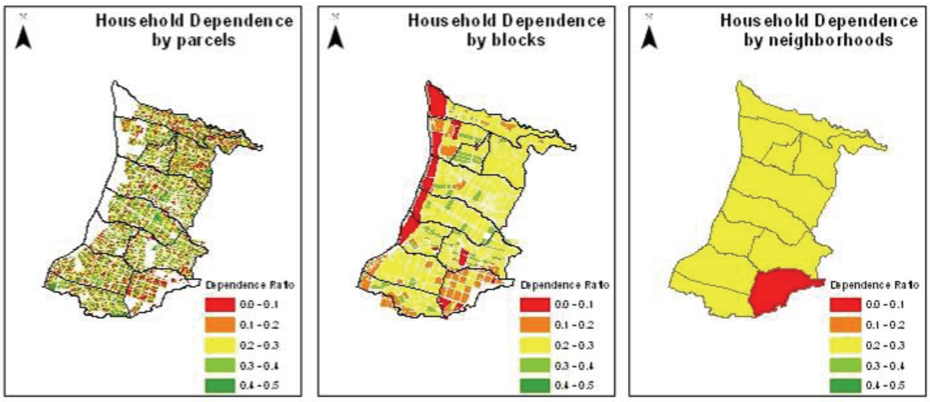

Figure 7.22. Household Economic Dependence (ratio between members younger than 14 and older than 64 and members between 15 and 64)

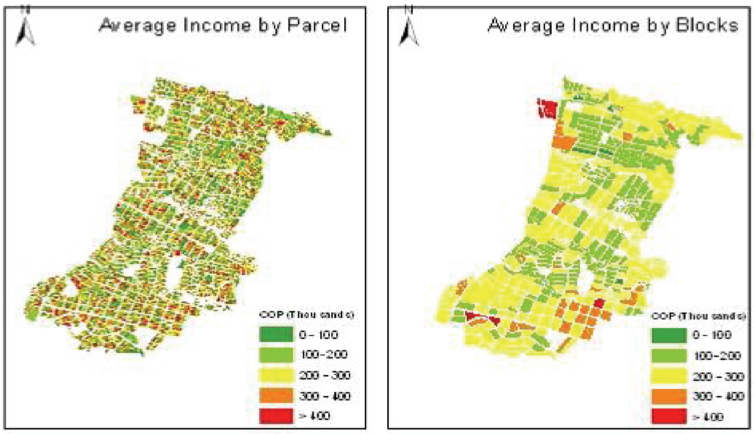

Figure 7.23. Average Household Income

7.3 Political-Institutional Vulnerability Indicators

The indicators needed to measure Political-Institutional Vulnerability are definitely more difficult to calculate than those used to measure the other three types of vulnerability. In Table 7.8, the indicators, attributes, and sources that are used to measure political-institutional vulnerability are presented.

Table 7.8 Political-Institutional Vulnerability Indicators, Attributes and Information sources

Table 7.8 Political-Institutional Vulnerability Indicators, Attributes and Information sources

Phase	Indicator	Attributes	Sources
Impact	Law and Policy Enforcement	Application of construction code and soil use norms	Metro-information - ADMP
Relief	Governance	Government dependence	Municipal Administration and DGPAD
		Government Structure	Municipal Administration and DGPAD
		Rule of law (criminality)	Metro Seguridad
	Municipal Preparedness	Emergency groups	SIMPAD
	Organizations and Administrative Capacity	Emergency preparation	Metro-information - ADMP
	Participatory Structures	Committees and organizations per administrative unit	SIMPAD
Recovery	Governance	Government dependence	Municipal Administration and DGPAD
		Government Structure	Municipal Administration and DGPAD
		Rule of law (criminality)	Metro Seguridad
	Participatory Structures	Committees and organizations per administrative unit	SIMPAD

To calculate the indicator for Law and Policy Enforcement, data about buildings that do not comply with the building code, provided by the planning office of the municipality and buildings that do not comply with soil use norms, as reported by the planning office, can be used to derive percentage of no-compliant buildings per block, neighborhood, and commune. The municipality of Medellín did not provide the information although they do have the reports of non-compliant buildings. Therefore, this indicator was not calculated for commune 2.

The indicator for Governance is calculated using information on the three aspects defined by Transparency International, which are: visibility, institutionality, and citizen participation. This indicator measures the existence of objective institutional conditions in each municipality that favor transparency and control the risk of corruption. It is a unique value for the whole municipality. The value for Medellín is 4,53 on a 1 to 5 scale (Transparencia por Colombia, 2006).

The municipality of Medellín has a couple of reports on Emergency preparedness. These reports are: the Integral Plan for Risk Management in the High Risk Non-Recoverable Areas of Medellín (Plan Integral para la gestión del riesgo en las zonas de alto riesgo no recuperables de la ciudad de Medellín (CES and CEMPAS, 2005; EAFIT, 2005)), and the Emergency Plan for Medellín (Plan de Emergencias de Medellín (CES and CEMPAS 2005)). In these reports, the Municipal Preparedness is delineated. Although the city has an office dedicated to handle emergencies, SIMPAD, a thorough evaluation of its preparedness in case of earthquake has never been made. In terms of Municipal Preparedness, Medellín can be rated with a 3 in a scale of 1 to 5 (where 1 is poor and 5 is excellent) for earthquake preparedness. This score was given by the director of SIMPAD after a brief discussion on emergency preparedness of the city.

To define an indicator for Organizations and Administrative Capacity, a review of the emergency preparedness of the different offices within the administration should be assessed. A simple score between 1 to 5 (where 1 is poor and 5 is excellent) can be used, and can be easily given by the mayor or the head of the planning department, since they are aware of the number of offices that have designed or adopted an emergency preparedness plan according to the guidelines given by SIMPAD. The score for Medellín will be 2, since the only office aware of risks is SIMPAD. The rest of the municipality has never devised a drill or procedure in case of earthquake, other than evacuating their respective offices.

The indicator for Participatory Structures assesses the number of committees and organizations per administrative unit. In Medellín there are 77 in total. For Commune No. 2 there are 6 neighborhood emergency committees, which is a considerable amount for the commune.

7.4 Information Aggregation

The assessment of a global vulnerability per phase has no sense if the issue of scales and units is not considered. The data and the information produced have been collected in multiple scales that range from element to municipal scale. Each indicator should be analyzed individually to define what type of intervention is needed in order to reduce that specific vulnerability.

At the same time, it can be important to aggregate the results at different scales (block, neighborhood and commune), to allow decision makers to define the levels of intervention. A simple example of this exercise can be done using the location and distribution of disabled population. In Figure 7.24, the three levels of aggregation are presented. Municipal authorities in charge of the disabled population should define if they need to know the exact location of this population or instead a general distribution by neighborhood or commune will suit them better, considering that the only intervention will be to enhance the preparedness of these persons in case of emergency.

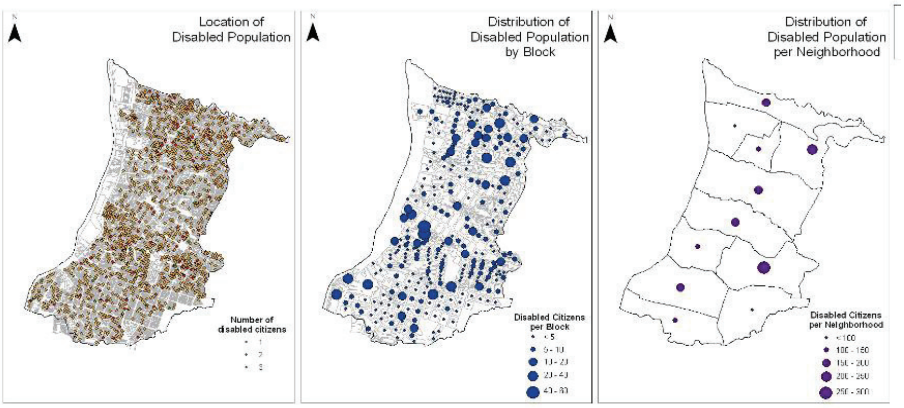

Figure 7.24. Information aggregation levels

7.5 Conclusions

The document entitled "Methodological Guide for the Formulation of Regional Urban Plans; Applicable to Cities" issued by the Colombian government is a clear example of how urban planning is carried out in many countries. The guidelines are very thorough in describing the procedure for deriving hazard maps for earthquakes, floods, and land-slides. They are also very thorough in showing how to map population densities, land-uses, infrastructural services (both social and physical), the socio-economic status of the population, and environmental issues such as ecological conservation, mining effects and pollution. However, a major flaw can be observed in these guidelines since they do not mention of "what to do next". The following is the only description given: "The hazard information is useful when contrasted with maps on population density, infrastructure location, and socio- economic profile of the population" (IGAC, 1996).

In this chapter an overview of how municipal information can be used to assess multiple indicators for different vulnerability phases was presented. As seen, multiple formats, sources and lack of standards in the data collection and processing, complicate the task of processing raw data in order to assess the indicators.

Each city must define how to assess these indicators. The ones presented in this chapter serve the purpose of demonstrating how the indicators can be constructed and applied using the data available, the units in which it comes, and the scale.

Chapter 8 Conclusions and further research

"It is good to have an end to journey towards; but it is the journey that matters in the end."
Ursula K. Le Guin

Throughout the thesis, in each chapter, specific conclusions have been drawn. However, some general conclusions can be discussed. The aim of this chapter is to discuss the main results of this research in relation to the research objectives and questions, considering theoretical, methodological and practical issues. Recommendations for further research are also given.

The main objective of this research was to develop a methodology to assess the fitness for use of municipal geo-data for earthquake vulnerability assessment. It establishes whether and to what extent the vulnerability indicators calculated, using this geo-data, are suitable for decision making. Other objectives included the definition of the indicators and information needs for the three disaster phases in terms of the main vulnerability types, the understanding of municipal processes and the geo-data used within these processes, and the application and assessment of the proposed methodology in two concrete contexts with different characteristics: Medellín and Lalitpur.

The following subsections discuss the answers to the research questions posed in Chapter 1.

8.1 Reflections on vulnerability and vulnerability indicators

Multiple schools of thought have worked on the problem of vulnerability. How to define it, measure it and ultimately tackle it. Vulnerability/Capacity has to be studied using a set of subcomponents or types to define it as a whole. Basically, vulnerability was divided in two major components: physical exposure and attenuating or enhancing factors, and studied in phases.

Three phases of a disaster were defined: impact, relief, and recovery. The impact phase is defined as the moment when the disaster strikes. The Relief phase refers to the first days (2 to 5) after the impact of the disaster when the community and the local aid agencies start the damage assessment and engage in the rescue and relief operations. The recovery phase refers to the months and even years following the disaster, when national and international agencies, with the help of the community rebuild their infrastructure, their economy, and their livelihoods.

The physical exposure is mostly calculated in the impact phase, whereas social, cultural, economic, and political-institutional indicators are mainly calculated for the relief and recovery phase, and account for attenuating or enhancing factors.

With this phase approach in mind, different vulnerability indicators and their attributes were selected to represent the elements that enhance dangerous conditions or boost adaptive capacities and resilience during each phase. Although the list of elements is very similar for each city, the final selection of the elements needed to assess vulnerability depends on the local circumstances.

A chain of events was identified, unveiling processes and events that take place during disaster attention. Those processes and events require specific geo-data sets that have to be acquired to assess the municipal vulnerability.

This phase approach renders municipal authorities information for different moments of the disaster that have a different duration and demand different resources and solutions. Traditional vulnerability models provide a set of elements that are not linked and do not help the municipal authorities to identify clearly if it is prepared to respond adequately during each phase.

In the same way, with the phase approach they can prioritize the issues that have to be addressed in order to reduce the municipal vulnerability. Seeing each indicator separately, and not a linear or weighted combination of elements, allows them to define and monitor specific actions to improve the capacities and reduce the fragility, or at least allocate the budget resources that will be needed to attend an emergency..

Vulnerability is a spatial problem and it needs geo-data to measure it, but is all geo-data suitable for assessing the problem? Assessments can always be performed no matter what data is available. If the data does not exist, researchers can use supposed starting parameters; however, evaluating the state of the data and how far-off it is from the preferred state can help envision the magnitude of the collection task ahead.

8.2 Municipal management models and their commitment to geo-data collection and management

The problem of producing adequate geo-information necessarily has to be understood from the perspective of the geo-data collectors and managers. Municipalities are the main geo-data handlers within cities; therefore, geo-information is a strategic asset for them, since they need it for development planning and day-to-day activities. In Latin America and Asia, different urban management models are used, leading to different ways of handling geo-data. The level of maturity of a municipality determines whether they consider geo-information as an asset or not, and treat it as an important component of municipal processes.

Two different urban management styles are seen in the case study cities. Medellín is a consolidated municipality with a long tradition of governance. The major is elected every three years, backed up by a solid democracy, even with a severe armed conflict going on in many areas of the country. The complicated political situation of the country has not affected the work of the municipality. In the last two administrations, an admirable effort has been done to make the work of the municipality as transparent to the public as possible. The idea of investing the municipal budget according to inequalities identified within the city has been the driving force of plans and programs. The revision of the ordinance plan (done every 3 years) and the commitment to repair the previous unequal allocation of the municipal budget represented a unique opportunity to study vulnerability, not only from the physical point of view, but from the social, cultural, economic, political, and institutional point of view. Geo-data sets have been compiled and new data needs have been unveiled, as well as the will to use them properly and make them as accessible to the public (researchers, NGO's, students, etc.) as possible. Development is guided by a complete set of norms defined in the ordinance plan; however, informal settlements and developments occur on a daily basis that the municipality can hardly control. The consolidation of vast and poorly urbanized areas with an evident infrastructure deficit requires a major shift in planning and control mechanisms.

On the other hand, Lalitpur has suffered directly the consequences of the political unrest that shook Nepal in the past decade. Although the king has been overthrown, and the monarchy has been abolished, the country is still subject to unstable political conditions. Municipalities as such have only existed in Nepal in the last decade (since 1999), explaining the state of immaturity of the administration. Lalitpur has not elected a major in more than five years. The majors are appointed and changed continuously by the central government, thus the commitment to engage in long term plans is not a concern for them. Although the municipal structure of Lalitpur shows a planning division, no real long term planning is done. Development plans are national and municipalities only limit their tasks to basic functions (birth and death registration, tax collection, and other immediate problems). New developments are mainly defined by informal developers in the fringe areas, and are not supervised by the building permit section, which only has capacity to review the building plans of formal developments.

Both municipalities present different urban management styles, but similar problems at different scales. Municipal authorities in Medellín are definitely committed to solve those problems, whereas authorities in Lalitpur are hardly aware of the magnitude and characteristics of them.

Political will is the decisive factor in changing the way things are, but until there is will, the management and operations level of the municipality have to devise a path to obtain the necessary geo-data that will be used to design and implement a development plan, that includes risk reduction.

Typical geo-data sets were revealed, such as cadastre data, social welfare data, demographic data, and infrastructure data. These data sets are used for specific municipal tasks at each division or secretariat. Many of the factors and processes associated with vulnerability can be measured using data already within the municipality. This data may be located in a structured Municipal Information System, or distributed in different offices with different formats and quality. In both cases a set of tools is needed to produce appropriate information at different scales and levels of decision-making.

In most urban management models, risk is not a concern. However, the current urban growth and the increased knowledge of the hazards that pose a threat to cities force municipal administrations to pay attention to risk management issues.

Municipal information systems allow data integration, thus increasing its usability.

8.3 Implications and use of the concept of geo-information quality

Decision makers rely on technical staff that provides them with information on multiple variables, but they hardly ever doubt the quality or reliability of that information unless it is evidently outdated or wrong. Since geo-information is becoming more widely used for decision support, using low-quality data is becoming more widespread and the chance of taking wrong decisions based on inaccurate data is higher. More and more municipalities are relying on secondary data considering that it is cheaper to acquire than collecting new and updated data. Although the issue of geo-information quality has been discussed by researchers in the past decades, few methods have been described to assess fitness for use of geo-data.

Most of the quality descriptions of spatial data have been developed to serve the production-oriented approach, where geo-information quality is defined by space, time, and theme (where, when, what), just as geo-information itself, using accuracy (spatial, temporal, and thematic), resolution (spatial, temporal and thematic), consistency, and completeness.

Spatial data usability is another way of addressing the issue of geo-data quality. The most relevant elements of data usability for this research were: adding of value through data integration; integrity; data validity and reliability (trust); data quality as accuracy/freedom from error – positional and attribute accuracy; logical consistency; completeness; temporal accuracy or shelf-life.

Geo-information quality has been addressed from the data- or method-centered point of view, from the user or goal-centered perspective, and finally a more holistic approach has considered geo-information quality as made up of components, or system-oriented. In this system, data, users and methods define the fitness for use. For this research data was not be evaluated using concepts such as accuracy, but in terms of completeness, reliability, integrity, and shelf-life, defined specifically for vulnerability assessments.

8.4 Fitness for use surveys: shortcomings and advantages

Three elements were decisive in the analytical exercise of assessing fitness for use: interdisciplinary participation of experts, rating of the information through homogeneous indicators (given the different natures of the information), and the evaluators of value of the homogeneous indicators.

Assessing fitness for use of municipal geo-information is not a trivial task. It involves a careful review of existing geo-data, with its attributes and characteristics, from a vulnerability perspective. This means looking at the data's current state and imagining an ideal or preferred state to compute sound vulnerability indicators.

Vulnerability assessments can always be performed no matter what data is available. If the data doesn't exist, researchers can use supposed starting parameters. However, evaluating the state of the data and how far-off it is from the preferred state can help envision the magnitude of the collection task ahead.

A set of indicators was defined for each phase. Each of them is rated according to different quality attributes. Some indicators are common to different evaluation phases and were rated accordingly. The quality attributes defined to assess fitness for use were: availability, completeness, integrity and reliability, scale, and shelf-life. Each attribute is described in detail in Chapter 4. For each indicator the minimum acceptable scale and the minimum preferred scale were also defined. In order to rate the indicators according to the quality attributes, three surveys were performed for each municipality. These surveys supply information about the importance of the indicators for that specific municipality, the data requirements, and the data characteristics.

The selection of the survey respondents is very important to guarantee the coherency of the answers and to effectively incorporate all the vulnerability elements that are relevant for that specific city. If there are no risk experts within the municipality, external persons such as academics can be surveyed if they are well aware of the vulnerability elements of their city and have some knowledge on available data sets and their characteristics. A comprehensive list of vulnerability elements that is useful for any city, especially in developing countries, is the basis for the rating of the importance, and therefore most of the cases will be covered not allowing for important elements to disappear just because the respondents did not consider them. Only differences in some elements will arise from one city to the other. For example in the case studies considered in this research the elements and weights are very similar, as can be seen in Table 8.1, being 0.061 the greatest difference in the cultural and historical asset indicator.

Table 8.1 Absolute difference between weights for vulnerability indicators in case studies

Phase	Indicators	Weights for Medellín	Weights for Lalitpur	Difference between weights
Impact	Building Stock Fragility	0.14	0.136	0.004
	Emergency Services Capacity	0.10	0.093	0.007
	Environmental Assets Fragility	0.03	0.021	0.009
	Law and Policy Enforcement	0.10	0.073	0.027
	Minorities/Special Groups	0.03	0.023	0.007
	Population distribution	0.14	0.123	0.017
	Population Capacity	0.09	0.100	0.01
	Population Fragility	0.05	0.074	0.024
	Transportation Infrastructure Fragility	0.07	0.052	0.018
	Cultural and Historical Assets Fragility	0.03	0.091	0.061
	Utilities Infrastructure Fragility	0.08	0.069	0.011
	Local Economic Fragility	0.06	0.078	0.018
	Emergency communications Fragility	0.08	0.065	0.015
Relief	Environmental Assets Fragility	0.03	0.024	0.006
	Governance	0.09	0.104	0.014
	Health Facilities Capacity	0.13	0.133	0.003
	Household Economic Fragility	0.06	0.074	0.014
	Minorities/Special Groups	0.03	0.030	0
	Municipal Preparedness	0.11	0.099	0.011
	Organizations and Administrative Ca-	0.09	0.093	0.003
	Participatory Structures	0.06	0.053	0.007
	Shelter Facilities	0.11	0.134	0.024
	Social cohesion and Organization	0.07	0.058	0.012
	Emergency communications Capacity	0.10	0.080	0.02
	Household Economic Capacity	0.15	0.117	0.033
Recovery	Environmental Assets Recovery capacity	0.03	0.019	0.011
	Facilities recovery capacity	0.07	0.055	0.015
	Governance	0.05	0.071	0.021
	Household Economic Capacity	0.08	0.090	0.01
	Building Stock Recovery Capacity	0.11	0.090	0.02
	Participatory Structures	0.04	0.034	0.006
	Population Capacity	0.06	0.097	0.037
	Population Fragility	0.07	0.082	0.012
	Shelter Facilities	0.07	0.067	0.003
	Social cohesion and Organization	0.06	0.050	0.01
	Transportation Infrastructure Recovery	0.10	0.069	0.031
	Utilities Infrastructure Recovery Capac-	0.10	0.078	0.022
	Cultural and Historical Assets Recovery	0.07	0.069	0.001
	Local Economic capacity	0.12	0.106	0.014
	Emergency communications Recovery	0.05	0.022	0.028

In Medellín, 14 respondents were selected from SIMPAD, and the metropolitan area to fill in surveys 1 and 2. Most of them have actively worked in emergency planning and response for at least two years. Survey 3 was answered by officers of Metro-información that are in charge of collecting, handling, and delivering municipal geo-data. They have an updated inventory of existing data sets with complete metadata. In Lalitpur, the selection of respondents was more complicated, since there are no risk experts within the municipality. The respondents selected were Ganesh Jimee, a former Nepalese MSc student of ITC that currently works at NSET, Suman Shrestha, also a former Nepalese MSc student of ITC that currently works at the municipality in the GIS section, Dr Cees van Westen since he has a wide experience in Lalitpur after supervising several MSc thesis related to risk management, and the author. However, consistency indexes were calculated for all matrices corresponding to survey 1 to ensure the consistency level of the final matrix. In Medellín, two surveys had to be discarded because they were not completely filled and presented consistency indexes less than the threshold value (see section 4.2.2). In Lalitpur, all the surveys complied with the consistency index.

It can always be argued that the method is subjective because it depends on the answers given by the respondents. Nevertheless, selecting respondents with prior knowledge of risk reduction and vulnerability assessments, plus the consistency index, plus the use of at all three surveys, ensures that there is little space to consider that weights will be unevenly distributed.

The intention of using risk experts from all disciplines, and not only engineers or earth scientists, allows a more comprehensive analysis of the vulnerability, and helps unveil the subtleties that will eventually define the relief and recovery process.

Decision makers should be informed not only about vulnerability aspects, but also about the quality of the information in which the former analysis is based. Understanding that some indicators can not be used because the data used for the calculations was insufficient, outdated, unavailable, incomplete, or unreliable, points out the direction in which the data collection efforts should be undertaken. Other indicators may have an intermediate value indicating that they can only be used in general decision making processes or general guidelines. These indicators have to be improved, but only after defining if there are other indicators that are more important (according to the ranking) that have worse evaluation results. For example, in Medellín, data on law and policy enforcement is urgently needed, as well as data on emergency services capacity. A simple way to set up a data collection priority list is to average the results of both evaluators and order the results in terms of indicator importance (descending) and average evaluator scores (ascending), resulting in the data priorities arising clearly, as illustrated in Table 8.2.

Many decision makers will like to see an overall vulnerability index associated to a fitness for use index, but this overall value will never give the detailed results that are needed to define a data collection campaign tackling the specific issues that each vulnerability indicator might present.

Table 8.2 Data collection and updating priorities for Medellín

Phase	Indicator	Weight	Average ((E1+E2)/2)	Evaluator 1	Evaluator 2
Impact	Building Stock Fragility	0.14	4.425	4.5	4.35
	Population distribution	0.14	4.835	4.67	5
	Law and Policy Enforcement	0.1	1.335	0	2.67
	Emergency Services Capacity	0.1	1.915	2.83	1
	Population Capacity	0.09	2.6	2.2	3
	Emergency communications Fragility	0.08	3.835	3.5	4.17
	Utilities Infrastructure Fragility	0.08	4	3.83	4.17
	Transportation Infrastructure Fragility	0.07	4	3.67	4.33
	Local Economic Fragility	0.06	2.085	3.17	1

Phase	Indicator	Weight	Average ((E1+E2)/2)	Evaluator 1	Evaluator 2
	Population Fragility	0.05	3.465	2.93	4
	Environmental Assets Fragility	0.03	1.45	1.3	1.6
	Minorities/Special Groups	0.03	3.165	2.83	3.5
	Cultural and Historical Assets Fragility	0.03	4.5	4.67	4.33
Relief	Health Facilities Capacity	0.13	3.945	3.72	4.17
	Municipal Preparedness	0.11	3.5	4	3
	Shelter Facilities	0.11	4	3.67	4.33
	Emergency communications Capacity	0.1	4.42	4.92	3.92
	Governance	0.09	4.145	4.62	3.67
	Organizations and Administrative Capacity	0.09	4.665	5	4.33
	Social cohesion and Organization	0.07	2.3	2.4	2.2
	Household Economic Fragility	0.06	0	0	0
	Participatory Structures	0.06	0	0	0
	Environmental Assets Fragility	0.03	1.45	1.3	1.6
	Minorities/Special Groups	0.03	1.915	2.83	1
Recovery	Local Economic capacity	0.12	0	0	0
	Building Stock Recovery Capacity	0.11	0	0	0
	Transportation Infrastructure Recovery capacity	0.1	0	0	0
	Utilities Infrastructure Recovery Capacity	0.1	0	0	0
	Household Economic Capacity	0.08	3.465	2.93	4
	Cultural and Historical Assets Recovery Capacity	0.07	0	0	0
	Facilities recovery capacity	0.07	0	0	0
	Shelter Facilities	0.07	4.11	3.89	4.33
	Population Fragility	0.07	4.335	3.67	5
	Social cohesion and Organization	0.06	0.535	0.87	0.2
	Population Capacity	0.06	2.865	0.73	5
	Emergency communications Recovery Capacity	0.05	0	0	0
	Governance	0.05	3.92	4.17	3.67
	Participatory Structures	0.04	4.665	5	4.33
	Environmental Assets Recovery capacity	0.03	0	0	0

8.5 Municipal data sets for vulnerability assessments

As explained in Chapter 6, both municipalities have digital data sets that can be used for vulnerability assessments. Lalitpur has more deficient data sets than Medellín, and the analysis performed with this data will only give decision makers a general idea of what is going on in terms of vulnerability, but without the required detail and outdated.

In Medellín, minimum changes are required to produce inconsistency-free databases, such as a set of domains for each field and a set of rules that highlight data problems when being input.

Gaps in the data collection are found for each indicator, especially in terms of what is really needed (theoretical approach) and what is actually collected (attribute detail); however, this problem can be solved by redefining the way in which the indicator is calculated.

Lalitpur is faced with the challenge of using spatial technologies to increase the geographic knowledge of their territory. The results obtained with the fitness for use evaluators show how seriously deficient their datasets are. If municipal authorities seize the immense challenge ahead, and see it as an opportunity to set up a municipal geo-database, instead of using datasets generated by external organizations with different needs in mind, they can define their data needs and embark in non-redundant collection efforts. The municipality has to start by setting up a municipal information system that accounts for the data used in its processes, with defined standards and formats, looking forward to more complex geo-spatial tasks and eventually implementing an SDI that can support geo-services.

In Medellín, the challenges are different. It already has a considerable amount of data and a group of well trained geo-information technicians. Most of the data is already organized in the centralized information repository (SITE), which allows data retrieval and visualization of multiple data sets using the intranet. The city has to perform a critical analysis on the existent data sets and elaborate a collection and updating strategy. More geo-information services will have to be designed to satisfy the growing needs of the secretariats and the general public. In the same way, the municipality has to delineate a geo-information development path that will ensure that the data sets needed for planning and daily tasks are available and accessible.

8.6 Further research

Although there is still a lack of consensus within the scientific community on what vulnerability encompasses, new vulnerability models keep appearing. Each of them gives a little bit more insight on the processes and interactions between components and vulnerability types. Severe discrepancies arise between researchers when studying risk. One school thinks that risk should be limited to evaluating the hazard, defining elements at risk and quantifying losses for different scenarios, whereas the other school acknowledges that risk studies should consist of the evaluation of hazards and the complete understanding of vulnerability and capacity. The second school quantifies and measures elements at risk, and also tries to discover the subtle and complex dynamics of social and cultural vulnerability. The problem of vulnerability invites researchers to keep on proposing new methods of quantifying these intangible elements that in the long run determine how a society withstands and recovers forma a disaster.

Information is not useful if it does not transmit the correct messages to those reading it. Creative ways of visualizing vulnerability have to be developed to adequately communicate to decision makers and the general public where the problems are.

Further exploration on the aggregation and disaggregation levels of the vulnerability indicators has to be done. Is there only aggregation level for all indicators or does each indicator has its own aggregation level, indicating municipal authorities where the problem can be? Workshops with experts should be set up to explore which aggregation levels show them the detail needed to understand what is going on and what can be done.

More complex methods of constructing indicators should be explored, especially for the social vulnerability indicators. This indicators should try to expose as much as possible, the root causes of vulnerability.

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Annexes

Annex I. Comparison of Indicators for different Risk Indices

Risk or Vulnerability Indices		EDRI-Davidson	SRI-Cardona	Social Vulnerability Indicators Dwyer et al	Cities Project-Granger
Hazard conditions	Knowledge on prev-ious events	-	Destroyed area; Deaths; Injured; Number of water pipe failures; Number of gas pipe failures; Longitude of fallen electricity networks; Number of telephone centrals affected; Number of electrical substations affected		
	Hazards	Ground Shaking; Percent of urban-ized area with soft soil; Percent of urbanized area with high liquefaction susceptibility; Percent of wooden buildings (fire potential after earthquake); Tsunami potential indicator	Spectral acceleration in short periods; Soft soils area; Liquefaction potential areas; Landslide susceptibility		
Exposure	Physical Infrastructure Exposure	Population; Per capita GDP; Number of housing units; Urbanized land area	Population; Population density; Built up area; Industrial area; Institutional area		Houses; Average house occupancy; Flats; Average flat occupancy; Logistic Facilities; Water supply facilities; Telecommunications; Lifeline length
	Population Exposure	Population			Terminal facilities; Population density; Gender
	Economic Exposure	Per capita GDP			Public safety; Business premises; Relative socioeconomic disadvantage index (SEIFA/ABS); Economic Resources
Social Vulnerability	Population Vulnerability/Social Fragility	Percent of population younger than 4 or older than 65	Marginal areas; Mortality rate; Delinquency rate; Social disparity index	Population growth; Urban growth; Population density; Age dependency ratio	Community facilities; Large families; Single parent families; Visitors
Physical Vulnerability	Physical Vulnerability	Seismic code indicator; City wealth indicator; City age indicator; Population density; City development speed indicator			Houses; Average house occupancy; Flats; Average flat occupancy; Logistic Facilities; Water supply facilities; Telecommunications; Lifeline length
Economic Vulnerability	Economic Vulnerability			Gross Domestic Product per inhabitant at purchasing power parity; Total debt service (% of the exports of goods and services); Inflation, food prices (annual %); Unemployment, total (% of total labor force)	

Risk or Vulnerability Indices		EDRI-Davidson	SRI-Cardona	Social Vulnerability Indicators Dwyer et al	Cities Project-Granger
External Context	Economic External Context	Economic context indicator			
Dependency and quality of the environment	-			Forests and woodland (in % of land area); Human-Induced Soil Degradation (GLASOD)	
Emergency Response and Recovery capacity / Resilience	Planning indicator	Planning Indicator	Development level; Emergency operatives	% of people with access to improved water supply; Number of physicians (per 1,000 inhabitants); Number of hospital beds; Life expectancy at birth for both sexes; Illiteracy rate; Number of radios (per 1,000 inhabitants)	
	Resources	Per capita GDP; Ten year average of annual real growth in per capita GDP; Housing vacancy rate; Number of hospitals per 100,000 people; Number of physicians per 100,000 people	Hospital beds; Number of doctors; Rescue personnel;		
	Mobility and access	Extreme weather indicator; Population density; City layout indicator	Public space;		

Annex II. Minimum inventory for Loss Estimation in the RADIUS model and HAZUS-MH Model

RADIUS		HAZUS-MH	
Required Input	**Desired Output**	**Required Input**	**Desired Output**
Earthquake Hazard		Potential earth science hazards (PESH)	
Definition of scenario earthquake and attenuation functions, soil map	Seismic intensity, such as PGA and MMI Intensity	Definition of scenario earthquake and attenuation functions, soil map	Intensities of ground shaking for scenario earthquake
Collateral hazard potential		Liquefaction and landslide susceptibility maps	Permanent ground displacements
Landslide potential; liquefaction potential; tsunami potential	Collateral damage		
Building inventory		General building stock	
Location; Building types (percentage per mesh area); Height	Building damage	Total square footage of each occupancy by census tract, occupancy to building type relationships	Damage to general building stock by occupancy or building type
Lifeline information (water, electricity, sewage, roadway and telecommunication systems; dams, bridges and tunnels)		Transportation lifelines / Utility lifelines	
Location; Classes of components	Lifeline damage	Locations and classes of components; Estimates of repair times for each level of damage	Damage; Restoration times
Population inventory		Direct social losses	
Total population (distribution per mesh area)	Casualties, such as number of deaths and injuries	Number of households per census tract; Population including ethnicity, age, income; Population distribution at three times of day	Number of displaced households; Number of people requiring temporary shelter; Casualties in four categories of severity based on event at three different times of day
Critical facilities		High potential loss facilities	
Location; Classes of components (characteristics)	Critical facilities damage	Location and building type of each facility; Number of beds at each facility; Locations and types of facilities; Location, building type, and value of military installations	Damage and functionality of essential facilities; Loss of beds and estimated recovery time for hospitals; Map of high potential loss facilities; Damage and loss for military installations
		Induced physical damage	
		General building stock inventory, average speed of fire engines, and speed and direction of wind; Inventory of facilities containing hazardous materials; General building stock inventory and estimates of type and unit weight of debris	Number of ignitions and percentage of burned area by census tract; Map of facilities containing hazardous materials; Type and weight of debris
		Economic losses	
		Cost per square foot to repair damage by structural type and occupancy for each level of damage; Contents value as percentage of replacement value by occupancy; Annual gross sales in $ per square foot; Rental costs per month per square foot by occupancy; Income in $ per square foot per month by occupancy; Loss Wages in $ per square foot per month by occupancy; Rental costs per month per square foot by occupancy; Costs of repair/replacement of components; Costs of repair/replacement of components; Cost of vehicles; Agricultural products	Structural and nonstructural cost of repair or re-placement; Loss of contents; Business inventory damage or loss; Relocation costs; Business income loss; Employee wage; Loss of rental income; Cost of damage to transportation components; Cost of damage to utility components; Cost of damaged vehicles; Loss of crops
		Indirect economic losses	
		Unemployment rates, input/output model parameters	Long-term economic effects on the region

Annex III. Vulnerability Elements: exposure, resistance, resilience

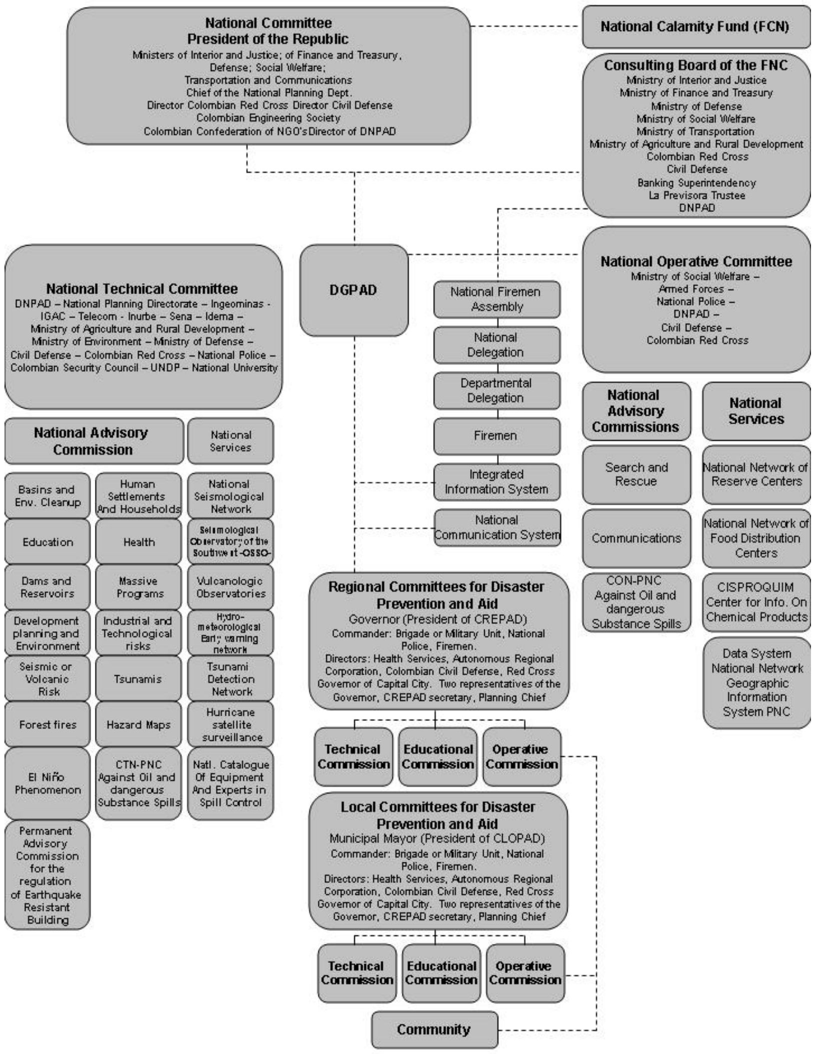
	Element	Exposure	Resistance/Sensitivity	Resilience
Physical Vulnerability	General Building Stock	Location; Hazard characteristics at the site	Characteristics (age, height, materials, current state, structural type, maintenance, etc.)	Insurance; Recovery budget
	Transportation network	Location; Hazard characteristics at the site	Type of transportation element and its particular characteristics (roads, railways, canals, ports, airports, terminals, stations, bridges, etc.)	Insurance; Recovery budget; Basic assets needed to ensure reconstruction efforts (first to be rebuilt)
	Utilities infrastructure – sewage, water, electricity, telephone, gas	Location; Hazard characteristics at the site	Type of facilities and its particular characteristics (pipe, station, cables, etc.)	Insurance; Recovery budget; Basic assets needed to ensure reconstruction efforts (first to be rebuilt)
	Facilities (educational, religious, cultural, health, security, communication and emergency response)	Location; Hazard characteristics at the site	Type of facilities and its characteristics in terms of space available as shelter and sanitary conditions	Insurance; Recovery budget; Provisional shelter
	Facilities (communication and emergency response)	Location; Hazard characteristics at the site	Communication facilities in terms of coverage; Emergency response in terms of available units and response capacity	Insurance; Recovery budget; Information dissemination; First aid and victim search; Aid distribution and organization
	Historical and cultural assets	Location; Hazard characteristics at the site	Types and characteristics (In cities with areas declared as World Heritage, this issue has a high importance)	Insurance; Recovery budget
	Environmental Assets (protected areas, parks)	Location; Hazard characteristics at the site	Endemic species; Biodiversity	Insurance; Recovery budget
Social-Cultural Vulnerability	Population (demographic profile)	Location (day/night); Characteristics of the building or area where the population is located in terms of the hazard; Hazard characteristics	Age; Educational level (literacy); Hazard – Risk - Disaster prevention knowledge; Caste / Religion; Ethnicity; Gender	Insurance; Age; Educational level (literacy); Hazard – Risk - Disaster prevention knowledge; Group memberships; Electoral activity (political involvement)
	Household head	Location of occupation site; Characteristics of the building or area where the Household head work is done in terms of the hazard; Hazard characteristics	Occupation	Occupation; Income level; Capacity to work
	Household	Location; Characteristics of the building; Hazard characteristics	Dependence ratio; Overcrowding; Disability and health status (including mental health); Scholastic absenteeism; Nutritional status; Security and stress level; House Ownership	Health insurance; Extended family structure; Informal social support - social networks;
	Social cohesion		Income distribution; Crime; Political affiliation; Stratification	Leadership (formal and informal); Ethnic belonging; Solidarity (family, clan, tribe)
	Minorities / Special groups	Location; Characteristics of the building or living area; Hazard characteristics	Characteristics (e.g. immigration status, language proficiency if spoken language is different from official, etc.)	Specific capacities according to the minority (variable, has to be defined according to the groups)

	Element	Exposure	Resistance/Sensitivity	Resilience
Economic Vulnerability	Household		Income level	Financial condition (debt, mortgage, loans); Reserve financial and material resources; Ownership of assets (capitals)
	Agribusiness and mining (primary sector)	Location; Characteristics of the agribusiness or mine (animal stock, cultivated area, type of products); Hazard characteristics	Stored products; Animal stock; Cultivated products; Market conditions; Number of employees; Dependence on other industries; Type of competition (existence of monopolies)	Location of customers; Insurance; Debt / loans;
	Industrial activities (secondary sector)	Location; Characteristics of the industry (type); Number of employees; Hazard characteristics	Product stock; Number of employees; Dependence on other industries; Type of competition (existence of monopolies)	Location of customers; Insurance; Debt / loans;
	Service sector	Location; Characteristics of the agribusiness (animal stock, cultivated area, type of products); Hazard characteristics	Number of employees; Dependence on other industries or services; Type of competition (existence of monopolies)	Location of customers; Insurance; Debt / loans
	Land Tenure			
Political –Institutional Vulnerability	Political conflict	Location		
	Policies and laws (building codes)		Enforcement	
	Land-use planning	Location; Hazard characteristics	Regulations; Enforcement	
	Political structures		Government dependence; Budget allocation	Recovery budget
	Access/Distribution of information and traditional knowledge	Location of facilities;	Types; Media; Coverage	Types; Media; Coverage
	Organizations and management capacity	Location	Types; Coverage; Preparedness; Budget	Types; Coverage; Preparedness; Budget
	Linkages with other regional/national bodies		Characteristics; Structure	Characteristics; Structure
	Good governance			
	Established networks regionally/nationally		Characteristics; Structure	Characteristics; Structure
	Participatory community structures and management		Characteristics; Structure	Characteristics; Structure
	Preparedness activities		Stakeholders involved; Hazards and magnitude considered	
	Warning systems	Location	Coverage	

Annex IV . Legal antecedents of the DGPAD

Decree 1547 of 1984	Created the National Calamity Fund, intended as a financial tool for Prevention, Aid and Rehabilitation of emergencies and disasters countrywide.
Law 46 of November 1988	In which the National System for Prevention and Disaster Aid (SNPAD) is created.
Decree 919 of 1989	In which the National System for the Prevention and Disaster Aid and other applications are dictated. This law establishes the coordination that must exist at different levels between state organisms, without modifying their individual autonomy and competences.
Law of Urban Reform. Decree 004 of 1993 partially regulating the 3rd law of 1991	The situations of disaster or public calamity in urban zones are established in this decree. In chapter 2, article 4 of this law, the National Institute of Housing of Social Interest and Urban Reform (INURBE) is declared competent to qualify, adjudicate, and distribute the family housing subsidy to homes located in risk zones, this according to studies directly verified or corroborated by the DNPAD (National Directorate for Prevention and Disaster Aid), the INGEOMINAS or the IDEAM, whichever it corresponds to.
Law 99 of 1993	The Ministry of the Environment is created with this law, reorganizing the public sector in charge of the management and conservation of the environment, organizing the National System of the Environment (SINA), and dictating the policies of disaster prevention as a matter of collective interest, determining as mandatory the adherence to measures to avoid or mitigate the effects of a potential disaster. This law creates and transforms the regional corporations and defines them as corporate entities of public character. It integrates entities that, by their characteristics, constitute a geographical-political unit in charge of managing the environment and its resources inside its area of jurisdiction, as well as to encourage its sustainable development.
Reform 338 of 1997, Decree 919, by which the 9th law of 1989 and the 3rd law of 1991 are modified and other dispositions on the territorial organization are dictated	This law encompasses risk studies (including seismic risk) in the rural and urban areas. Its purpose is to establish disaster prevention measures, relocating households, restricting areas, and formulating risk mitigating measures.
Law 400 of 1997, Decree 33 of 1998 regulating the norms of earthquake resistant design and construction	This law declares the collective norms of earthquake resistant design and construction NSR-98, which update and replace the old design norms approved in 1984. This law signals the duty of the state to defend the life and honor of the inhabitants of the state. It guarantees by its enforcement the adequate development of building practices, taking into account the technical criteria that safeguard the wellbeing of its inhabitants and the development of the country.
Decree 93 of 1998	Adopts the National Plan for Prevention and Disaster Aid, whose objectives are risk reduction and disaster prevention, effective response in case of disaster and rapid recuperation of affected areas. It also established the following strategies: knowledge of natural and man-made hazards, inclusion of prevention and reduction of risks in planning, institutional strengthening, and socialization of disaster prevention and mitigation.

Annex V. Structure of DGPAD



Annex VI. General datasets for the city of Medellín

Map	Description	Type	Extent
Antennas	Telecommunication antennas	P	C
Suitable Use	Suitable land use	A	C
Basic Loading Areas	Basic Loading Areas (zones defined by the facilities company -EPM-)	A	C
Neighborhoods	Neighborhoods	A	M
Soil Classification	Land use classification areas	A	M
Double Drainage	Medellín River	A	C
Simple Drainage	Brooks	L	C
Axes	Incomplete Road Axes	L	C
Facilities	Facilities (sports, health, religious, security,	A	C
Structuring Public Space	Public Space	A	M
Urban Equilibrium Generators	Zones defined as generating urban equilib-	A	C
Industrial and Commercial Energy Installations	Industrial and Commercial Energy Installations	A	C
Residential Energy Installations	Residential Installations	A	C
Boundary of the Metropolitan Area	Boundary of the Metropolitan Area	A	MA
Boundary of Communes and Districts	Boundary of Communes and Districts	A	M
Municipal Boundary	Municipal Boundary	A	M
City Blocks	City Blocks according to the DANE divisions	P	C
Seismic Microzonation	Homogenous Microzonation Zones	A	U
Squares	Public squares	A	U
Posts	Electrical posts	P	C
High Voltage Network	High Voltage Lines	L	C
DANE Sector	DANE census zones	A	C
Soil Protection	Includes protection areas along streams	A	C
Water Tanks	Public facilities company Water Tanks	P	C
Towers	High Voltage Network Towers	P	C
Treatment or Intervention	Zones of treatment or urban intervention	A	C
Geological Units	Geological and lithological units	A	C
Soil Use	Soil use	A	C
Zones	Zonas de division político administrativa	A	U
Green zones	Green zones	A	U
Sisben (Commune 2)	SISBEN Welfare system surveys	P	C
Quality of Life Surveys	Quality of Life Surveys	P	C
Buildings	Buildings	P	C
Lots	Lots	A	C
City Blocks	City Blocks	A	C

Type: A: Area or Polygon; L: Line; P: Point

Extent: C: Commune No. 2; M: Municipality; U: Urban area of the municipality and MA: Metropolitan Area.

Annex VII. Detailed aspects of Surveys on Quality of Life

- Wall materials
- Floor materials
- Drinking water access
- Trash collection and disposition
- Sanitary facilities
- Total number of electrical appliances per household
- Number of private vehicles
- Social security coverage
- Household head's educational level (literacy)
- Household head partner's educational level (literacy)
- Overcrowding ratio
- Proportion of persons younger than 6
- Dependence ratio
- Social security coverage ratio (other household members)
- Proportion of illiterate household members
- Proportion of minors, between 6 and 12, not assisting to school
- Proportion of minors, between 13 and 18, not assisting to school

Annex VIII. Comparison between building characteristics in Cadastre Data and SISBEN surveys

Cadastre Information	SISBEN
Structure type	Type of building
Total number of floors	
Number of rooms	Number of rooms
Number of bathrooms (toilets)	Number of bathrooms (toilets)
Number of commercial areas	
Wall materials	Wall materials
Roof materials	Floor materials
Structural elements conservation state	
Façade materials type	
Façade materials	
Floor materials	
Non structural elements conservation state	
Bathroom size	
Bathroom wall materials	
Bathroom furnishing	Type of toilet
	Location of toilet
	Own or shared toilet
	Number of showers/tubs
Bathroom conservation state	
Kitchen size	
Kitchen wall materials	
Kitchen furnishing	
Kitchen conservation state	
Water facilities	Water facilities
Sewage facilities	Sewage facilities
Energy facilities	Energy facilities
Telephone facilities	Telephone facilities
	Gas
	Trash collection
Height	
Age	
Economic stratum	Economic stratum
	Hazards

Annex IX. List of Indicators and attributes needed for vulnerability assessments

	Vulnerability	Indicator	Attributes
Impact	Economic	Local Economic Fragility	Economical activities by type
	Physical	Building Stock Fragility	Age
			Conservation State
			Number of floors
			Structural Type
		Cultural and Historical Assets Fragility	Importance
		Emergency communications Fragility	Ability to coordinate the emergency services
		Emergency Services Capacity	Number of emergency services and distribution
		Environmental Assets Fragility	Biodiversity index
			Type of environmental asset
			Endemic species
		Transportation Infrastructure Fragility	Types and characteristics
		Utilities Infrastructure Fragility	Facilities coverage
	Political-Institutional	Law and Policy Enforcement	Application of construction code and soil use norms
	Social	Minorities/Special Groups	Location & Characteristics
		Population Capacity	Educational level of the population
			Previous Hazard/Risk knowledge
		Population distribution	Time distribution of the population
		Population Fragility	Population Age/Gender
			Population Religion/Ethnicity
Relief	Economic	Household Economic Fragility	Financial Status (debt, savings)
			Subsidies
	Physical	Emergency communications Capacity	Existing communications facilities (radio, tv)
			Previous educational campaigns on risk management
		Environmental Assets Fragility	Biodiversity index
			Type of environmental asset
			Endemic species
		Health Facilities Capacity	Type of health facilities
		Shelter Facilities	Facilities type (education, cultural, religious, etc.)
	Political-Institutional	Governance	Government dependence
			Government Structure
			Rule of law (criminality)
		Municipal Preparedness	Emergency groups
			SISBEN coverage
		Organizations and Administrative Capacity	Emergency preparation
		Participatory Structures	Committees and organizations per administrative unit
	Social	Minorities/Special Groups	Location & Characteristics
		Social cohesion and Organization	Participation in Groups
			Time in the neighborhood
			Experience in previous events
Recovery	Economic	Household Economic Capacity	Economic dependence (% of dependents)
			Employment
			Income level
			Tenure
			Insurance
		Local Economic capacity	Financial Status (debt, savings)
			Insurance
	Physical	Building Stock Recovery Capacity	Allocated recovery budget
			Insurance
		Cultural and Historical Assets Recovery Capacity	Allocated recovery budget
			Insurance
		Emergency communications Recovery Capacity	Allocated recovery budget
			Insurance
		Environmental Assets Recovery capacity	Allocated recovery budget
			Insurance
		Facilities recovery capacity	Allocated recovery budget
			Insurance

	Vulnerability	Indicator	Attributes
		Shelter Facilities	Facilities type (education, cultural, religious, etc.)
		Transportation Infrastructure Recovery capacity	Allocated recovery budget
			Insurance
		Utilities Infrastructure Recovery Capacity	Allocated recovery budget
			Insurance
	Political-Institutional	Governance	Government dependence
			Government Structure
			Rule of law (criminality)
		Participatory Structures	Committees and organizations per administrative unit
	Social	Population Capacity	Health Insurance
		Social cohesion and Organization	Time in the neighborhood
			Experience in previous events
			Participation in Groups
			Political participation

Annex X. Survey 1: Indicator Comparison matrices for each vulnerability phase for Medellín

Impact Phase	1	2	3	4	5	6	7	8	9	10	11	12	13
1-Building Stock Fragility	1	3	3	3	3	1	3	3	3	3	3	3	3
2-Emergency Services Capacity	1/3	1	3	1	3	1/3	1/3	1/3	3	3	3	3	3
3-Environmental Assets Fragility	1/3	1/3	1	1/3	1	1/3	1/3	1	1/3	1	1/3	1/3	1/3
4-Law and Policy Enforcement	1/3	1	3	1	3	1/3	1	3	3	3	3	3	1
5-Minorities/Special Groups	1/3	1/3	1	1/3	1	1/3	1/3	1	1/3	1/3	1/3	1/3	1/3
6-Population distribution	1	3	3	3	3	1	3	3	3	3	3	3	3
7-Population Capacity	1/3	3	3	1	3	1/3	1	3	1	3	1	3	1
8-Population Fragility	1/3	3	1	1/3	1	1/3	1/3	1	1/3	3	1/3	1	1/3
9-Transportation Infrastructure Fragility	1/3	1/3	3	1/3	3	1/3	1	3	1	3	1	1	1
10-Cultural and Historical Assets Fragility	1/3	1/3	1	1/3	3	1/3	1/3	1/3	1/3	1	1/3	1/3	1/3
11-Utilities Infrastructure Fragility	1/3	1/3	3	1/3	3	1/3	1	3	1	3	1	3	1
12-Local Economic Fragility	1/3	1/3	3	1/3	3	1/3	1/3	1	1	3	1/3	1	1/3
13-Emergency communications Fragility	1/3	1/3	3	1	3	1/3	1	3	1	3	1	3	1

Relief Phase	1	2	3	4	5	6	7	8	9	10	11	12
1-Environmental Assets Fragility	1	1/3	1/3	1/3	1	1/3	1/3	1/3	1/3	1/3	1/3	1/3
2-Governance	3	1	1/3	1	3	1	1	3	1	3	1	1/3
3-Health Facilities Capacity	3	3	1	3	3	1	3	3	1	3	1	1/3
4-Household Economic Fragility	3	1	1/3	1	3	1/3	1/3	1	1/3	1	1/3	1/3
5-Minorities/Special Groups	1	1/3	1/3	1/3	1	1/3	1/3	1/3	1/3	1/3	1/3	1/3
6-Municipal Preparedness	3	1	1	3	3	1	3	3	1	1	1	1/3
7-Organizations and Administrative Capacity	3	1	1/3	3	3	1/3	1	3	1	1	1	1/3
8-Participatory Structures	3	1/3	1/3	1	3	1/3	1/3	1	1/3	1	1/3	1/3
9-Shelter Facilities	3	1	1	3	3	1	1	3	1	3	1	1
10-Social cohesion and Organization	3	1/3	1/3	1	3	1	1	1	1/3	1	1	1
11-Emergency communications Capacity	3	1	1	3	3	1	1	3	1	1	1	1/3
12-Household Economic Capacity	3	3	3	3	3	3	3	3	1	1	3	1

Recovery Phase	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1-Environmental Assets Recovery capacity	1	1/3	1/3	1	1/3	1/3	1	1/3	1/3	1	1	1	1/3	1/3
2-Facilities recovery capacity	3	1	3	1	1	1	1/3	3	1	1/3	1/3	1	1/3	1
3-Governance	3	1/3	1	1/3	1/3	3	1	1	1	1/3	1/3	1/3	1/3	1/3
4-Household Economic Capacity	1	1	3	1	1	3	1	1	1	1	1	1	1	3
5-Building Stock Recovery Capacity	3	1	3	1	1	3	1	3	3	1	1	3	1	3
6-Participatory Structures	3	1	1/3	1/3	1/3	1	1	1/3	1	1/3	1/3	1/3	1/3	1
7-Population Capacity	1	3	1	1	1	1	1	1	1	1/3	1/3	1	1/3	3
8-Shelter Facilities	3	1/3	1	1	1/3	3	1	1	1	1	1	1	1/3	3
9-Social cohesion and Organization	3	1	1	1	1/3	1	1	1	1	1/3	1/3	1/3	1/3	3
10-Transportation Infrastructure Recovery capacity	1	3	3	1	1	3	3	1	3	1	1	1	1	3
11-Utilities Infrastructure Recovery Capacity	1	3	3	1	1	3	3	1	3	1	1	1	1	3
12-Cultural and Historical Assets Recovery Capacity	1	1	3	1	1/3	3	1	1	3	1	1	1	1/3	1
13-Local Economic capacity	3	3	3	1	1	3	3	3	3	1	1	3	1	3
14-Emergency communications Recovery Capacity	3	1	3	1/3	1/3	1	1/3	1/3	1/3	1/3	1/3	1	1/3	1

Annex XI. Survey 2: Data Requirements for Medellín

	Indicator	Attributes	Weight	Minimum Acceptable Scale (MAS)	Minimum Preferred Scale (MPS)	Shelf-Life (years)
Impact	Building Stock Fragility	Age	0.25	2	4	10
		Conservation State	0.05	2	4	10
		Number of floors	0.25	2	4	10
		Structural Type	0.35	2	4	10
	Cultural and Historical Assets Fragility	Importance	1	2	4	10
	Emergency communications Fragility	Ability to coordinate the emergency services	1	1	1	1
	Emergency Services Capacity	Number of emergency services and distribution	1	2	4	1
	Environmental Assets Fragility	Biodiversity index	0.3	4	4	5
		Endemic species	0.4	4	4	5
		Type of environmental asset	0.3	4	4	5
	Law and Policy Enforcement	Application of construction code and soil use norms	1	2	4	3
	Local Economic Fragility	Economical activities by type	1	2	4	3
	Minorities/Special Groups	Location & Characteristics	1	2	4	2
	Population Capacity	Educational level of the population	0.6	3	4	2
		Previous Hazard/Risk knowledge	0.4	3	4	2
	Population distribution	Time distribution of the population	1	3	4	10
	Population Fragility	Population Age/Gender	0.5	3	4	2
		Population Religion/Ethnicity	0.5	3	4	10
	Transportation Infrastructure Fragility	Types and characteristics (road network, ports, railways, airports, terminals, stations, bridges)	1	2	4	10
	Utilities Infrastructure Fragility	Facilities coverage (water, sewage, electricity, telephone, gas)	1	2	4	10
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv)	0.5	1	1	1
		Previous educational campaigns on risk management	0.5	1	3	2
	Environmental Assets Fragility	Biodiversity index	0.3	4	4	5
		Endemic species	0.4	4	4	5
		Type of environmental asset	0.3	4	4	5
	Governance	Government dependence	0.6	1	1	4
		Government Structure	0.3	1	1	3
		Rule of law (criminality)	0.1	1	1	1
	Health Facilities Capacity	Type of health facilities	1	2	4	3
	Household Economic Fragility	Financial Status (debt, savings)	0.5	3	4	2
		Subsidies	0.5	3	4	2
	Minorities/Special Groups	Location & Characteristics	1	3	4	2
	Municipal Preparedness	Emergency groups	0.5	3	4	1
		SISBEN coverage	0.5	3	4	2
	Organizations and Administrative Capacity	Emergency preparation	1	1	3	1
	Participatory Structures	Committees and organizations per administrative unit	1	2	3	1
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1	2	4	2
	Social cohesion and Organization	Experience in previous events	0.4	3	4	5
		Participation in Groups	0.4	3	4	2
		Time in the neighborhood	0.2	3	4	5

	Indicator	Attributes	Weight	Minimum Acceptable Scale (MAS)	Minimum Preferred Scale (MPS)	Shelf-Life (years)
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	0.3	1	4	10
		Insurance	0.7	1	4	10
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	0.3	1	4	3
		Insurance	0.7	1	4	3
	Emergency communications Recovery Capacity	Allocated recovery budget	0.3	1	1	3
		Insurance	0.7	1	1	3
	Environmental Assets Recovery capacity	Allocated recovery budget	0.3	1	4	3
		Insurance	0.7	1	4	3
	Facilities recovery capacity	Allocated recovery budget	0.3	1	4	3
		Insurance	0.7	1	4	3
	Governance	Government dependence	0.4	1	1	2
		Government Structure	0.4	1	1	2
		Rule of law (criminality)	0.2	1	1	2
	Household Economic Capacity	Economic dependence (% of dependents)	0.1	2	4	2
		Employment	0.3	2	4	2
		Income level	0.3	2	4	2
		Insurance	0.2	2	4	2
		Tenure	0.1	2	4	2
	Local Economic capacity	Financial Status (debt, savings)	0.3	1	4	5
		Insurance	0.7	1	4	5
	Participatory Structures	Committees and organizations per administrative unit	1	2	3	1
	Population Capacities	Health Insurance	0.2	2	4	2
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1	2	4	3
	Social cohesion and Organization	Experience in previous events	0.2	2	3	5
		Participation in Groups	0.4	2	3	2
		Political participation	0.2	2	3	3
		Time in the neighborhood	0.2	2	3	5
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	0.3	1	1	3
		Insurance	0.7	1	1	3
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	0.3	1	1	3
		Insurance	0.7	1	1	3

Annex XII. Survey 3: Data Characteristics for Medellín

	Indicator	Attributes	Available (y/n)	Completeness (0 a 1)	Quality / Usability (G 3,R 2,B 1)	Scale (Municipality=1, Commune=2, neighborhood=3, Element=4)	Data Date
Impact	Building Stock Fragility	Age	Y	0.9	3	4	2005
		Conservation State	Y	0.9	3	4	2005
		Number of floors	Y	0.9	3	4	2005
		Structural Type	Y	0.9	3	4	2005
	Cultural and Historical Assets Fragility	Importance	Y	1	2	4	2005
	Emergency communications Fragility	Ability to coordinate the emergency services	Y	0.9	3	3	2006
	Emergency Services Capacity	Number of emergency services and distribution	Y	0.9	3	1	2006
	Environmental Assets Fragility	Biodiversity index	Y	0.1	2	1	2005
		Endemic species	N	0			
		Type of environmental asset	Y	1	2	4	2005
	Law and Policy Enforcement	Application of construction code and soil use norms	Y	0	2	4	2005
	Local Economic Fragility	Economical activities by type	Y	0.9	3	4	2001
	Minorities/Special Groups	Location & Characteristics	Y	0	2	4	2005
	Population Capacity	Educational level of the population	Y	1	3	4	2005
		Previous Hazard/Risk knowledge	N	0			
	Population distribution	Time distribution of the population	Y	1	3	4	2005
	Population Fragility	Population Age/Gender	Y	1	3	4	2005
		Population Religion/Ethnicity	N	0			
	Transportation Infrastructure Fragility	Types and characteristics (road network, ports, railways, airports, terminals, stations, bridges)	Y	1	2	4	1997
	Utilities Infrastructure Fragility	Facilities coverage (water, sewage, electricity, telephone, gas)	Y	0.5	3	4	2005
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv)	Y	1	3	1	2007
		Previous educational campaigns on risk management	Y	0.9	3	3	2007
	Environmental Assets Fragility	Biodiversity index	Y	0.1	2	1	2005
		Endemic species	N	0			
		Type of environmental asset	Y	1	2	4	2005
	Governance	Government dependence	Y	1	3	1	2006
		Government Structure	Y	1	3	1	2007
		Rule of law (criminality)	Y	1	2	3	2006
	Health Facilities Capacity	Type of health facilities	Y	0.9	2	4	2005
	Household Economic Fragility	Financial Status (debt, savings)	N	0			
		Subsidies	N	0			
	Minorities/Special Groups	Location & Characteristics	Y	0	2	3	2005
	Municipal Preparedness	Emergency groups	Y	1	3	2	2007
		SISBEN coverage	Y	1	3	4	2005

	Indicator	Attributes	Available (y/n)	Completeness (0 a 1)	Quality / Usability (G 3,R 2,B 1)	Scale (Municipality=1, Commune=2, neighborhood=3, Element=4)	Data Date
	Organizations and Administrative Capacity	Emergency preparation	Y	1	3	3	2007
	Participatory Structures	Committees and organizations per administrative unit	N	0			
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	Y	1	2	4	2005
	Social cohesion and Organization	Experience in previous events	N				
		Participation in Groups	Y	1	3	4	2006
		Time in the neighborhood	Y	1	3	2	2005
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	N	0			
		Insurance	N	0			
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	N	0			
		Insurance	N	0			
	Emergency communications Recovery Capacity	Allocated recovery budget	N	0			
		Insurance	N	0			
	Environmental Assets Recovery capacity	Allocated recovery budget	N	0			
		Insurance	N	0			
	Facilities recovery capacity	Allocated recovery budget	N	0			
		Insurance	N	0			
	Governance	Government dependence	Y	1	3	1	2006
		Government Structure	Y	1	3	1	2006
		Rule of law (criminality)	Y	1	2	3	2006
	Household Economic Capacity	Economic dependence (% of dependents)	Y	1	3	4	2005
		Employment	Y	1	3	4	2005
		Income level	Y	1	3	4	2005
		Insurance	N	0			
		Tenure	Y	1	3	4	2005
	Local Economic capacity	Financial Status (debt, savings)	N	0			
		Insurance	N	0			
	Participatory Structures	Committees and organizations per administrative unit	Y	1	3	3	2007
	Population Capacities	Health Insurance	Y	1	3	4	2005
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	Y	1	2	4	2005
	Social cohesion and Organization	Experience in previous events	N	0			
		Participation in Groups	N	0			
		Political participation	N	0			
		Time in the neighborhood	Y	1	3	2	2005
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	N	0			
		Insurance	N	0			
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	N	0			
		Insurance	N	0			

Annex XIII. Attribute scores for Evaluator1 – current data state

	Indicator	Attributes	Attribute Importance	Evaluator 1
Impact	Building Stock Fragility	Age	0.25	4.50
		Conservation State	0.15	4.50
		Number of floors	0.25	4.50
		Structural Type	0.35	4.50
	Cultural and Historical Assets Fragility	Importance	1	4.67
	Emergency communications Fragility	Ability to coordinate the emergency services	1	3.50
	Emergency Services Capacity	Number of emergency services and distribution	1	2.83
	Environmental Assets Fragility	Biodiversity index	0.3	0.00
		Endemic species	0.4	0.00
		Type of environmental asset	0.3	4.33
	Law and Policy Enforcement	Application of construction code and soil use norms	1	0.00
	Local Economic Fragility	Economical activities by type	1	3.17
	Minorities/Special Groups	Location & Characteristics	1	2.83
	Population Capacity	Educational level of the population	0.6	3.67
		Previous Hazard/Risk knowledge	0.4	0.00
	Population distribution	Time distribution of the population	1	4.67
	Population Fragility	Population Age/Gender	0.8	3.67
		Population Religion/Ethnicity	0.2	0.00
	Transportation Infrastructure Fragility	Types and characteristics	1	3.67
	Utilities Infrastructure Fragility	Facilities coverage	1	3.83
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv, etc.)	0.5	5.00
		Previous educational campaigns on risk management	0.5	4.83
	Environmental Assets Fragility	Biodiversity index	0.3	0.00
		Endemic species	0.4	0.00
		Type of environmental asset	0.3	4.33
	Governance	Government dependence	0.6	4.58
		Government Structure	0.3	5.00
		Rule of law (criminality)	0.1	3.67
	Health Facilities Capacity	Type of health facilities	1	3.72
	Household Economic Fragility	Financial Status (debt, savings)	0.5	0.00
		Subsidies	0.5	0.00
	Minorities/Special Groups	Location & Characteristics	1	2.83
	Municipal Preparedness	Emergency groups	0.5	4.33
		SISBEN coverage	0.5	3.67
	Organizations and Administrative Capacity	Emergency preparation	1	5.00
	Participatory Structures	Committees and organizations per administrative unit	1	0.00
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1	3.67
	Social cohesion and Organization	Experience in previous events	0.4	0.00
		Participation in Groups	0.4	4.17
		Time in the neighborhood	0.2	3.67
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Emergency communications Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Environmental Assets Recovery capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Facilities recovery capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00

	Indicator	Attributes	Attribute Importance	Evaluator 1
	Governance	Government dependence	0.4	4.17
		Government Structure	0.4	4.17
		Rule of law (criminality)	0.2	4.17
	Household Economic Capacity	Economic dependence (% of dependents)	0.1	3.33
		Employment	0.3	3.33
		Income level	0.3	3.33
		Insurance	0.2	0.00
		Tenure	0.1	3.33
	Local Economic capacity	Financial Status (debt, savings)	0.3	0.00
		Insurance	0.7	0.00
	Participatory Structures	Committees and organizations per administrative unit	1	5.00
	Population Capacity	Health Insurance	1	3.33
	Population Fragility	Household Masculinity Index	1	3.67
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1	3.89
	Social cohesion and Organization	Experience in previous events	0.2	0.00
		Participation in Groups	0.4	0.00
		Political participation	0.2	0.00
		Time in the neighborhood	0.2	4.33
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00

Annex XIV. Attribute scores for Evaluator 2 – Data distance to required condition

	Indicator	Attributes	Attribute Importance	Evaluator 2
Impact	Building Stock Fragility	Age	0.25	4.83
		Conservation State	0.15	4.83
		Number of floors	0.25	4.83
		Structural Type	0.35	4.83
	Cultural and Historical Assets Fragility	Importance	1	4.33
	Emergency communications Fragility	Ability to coordinate the emergency services	1	4.17
	Emergency Services Capacity	Number of emergency services and distribution	1	1.00
	Environmental Assets Fragility	Biodiversity index	0.3	1.00
		Endemic species	0.4	0.00
		Type of environmental asset	0.3	4.33
	Law and Policy Enforcement	Application of construction code and soil use norms	1	2.67
	Local Economic Fragility	Economical activities by type	1	1.00
	Minorities/Special Groups	Location & Characteristics	1	3.50
	Population Capacity	Educational level of the population	0.6	5.00
		Previous Hazard/Risk knowledge	0.4	0.00
	Population distribution	Time distribution of the population	1	5.00
	Population Fragility	Population Age/Gender	0.8	5.00
		Population Religion/Ethnicity	0.2	0.00
	Transportation Infrastructure Fragility	Types and characteristics	1	4.33
	Utilities Infrastructure Fragility	Facilities coverage	1	4.17
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv, etc.)	0.5	3.67
		Previous educational campaigns on risk management	0.5	4.17
	Environmental Assets Fragility	Biodiversity index	0.3	1.00
		Endemic species	0.4	0.00
		Type of environmental asset	0.3	4.33
	Governance	Government dependence	0.6	3.67
		Government Structure	0.3	3.67
		Rule of law (criminality)	0.1	3.67
	Health Facilities Capacity	Type of health facilities	1	4.17
	Household Economic Fragility	Financial Status (debt, savings)	0.5	0.00
		Subsidies	0.5	0.00
	Minorities/Special Groups	Location & Characteristics	1	1.00
	Municipal Preparedness	Emergency groups	0.5	1.00
		SISBEN coverage	0.5	5.00
	Organizations and Administrative Capacity	Emergency preparation	1	4.33
	Participatory Structures	Committees and organizations per administrative unit	1	0.00
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1	4.33
	Social cohesion and Organization	Experience in previous events	0.4	0.00
		Participation in Groups	0.4	5.00
		Time in the neighborhood	0.2	1.00
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Emergency communications Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Environmental Assets Recovery capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Facilities recovery capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00

	Indicator	Attributes	Attribute Importance	Evaluator 2
	Governance	Government dependence	0.4	3.67
		Government Structure	0.4	3.67
		Rule of law (criminality)	0.2	3.67
	Household Economic Capacity	Economic dependence (% of dependents)	0.1	5.00
		Employment	0.3	5.00
		Income level	0.3	5.00
		Insurance	0.2	0.00
		Tenure	0.1	5.00
	Local Economic capacity	Financial Status (debt, savings)	0.3	0.00
		Insurance	0.7	0.00
	Participatory Structures	Committees and organizations per administrative unit	1	4.33
	Population Capacity	Health Insurance	1	5.00
	Population Fragility	Household Masculinity Index	1	5.00
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1	4.33
	Social cohesion and Organization	Experience in previous events	0.2	0.00
		Participation in Groups	0.4	0.00
		Political participation	0.2	0.00
		Time in the neighborhood	0.2	1.00
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	0.3	0.00
		Insurance	0.7	0.00

Annex XV. Digital Maps City Profile Lalitpur

Map	Type	Source
Bahils, Bahals & Hitis	Point	KUDP
Building Footprint	Polygon	KUDP-ITC
District Boundary	Line	KUDP
Drainage & Sewerage Network	Line	KUDP
Electrical Network - Feeders	Line	KUDP
Electrical Network – High Tension lines	Line	KUDP
Electrical Network – Substations, Branch fuses, Sectionlizers,	Line	KUDP
Electrical Network – Transformers	Point	KUDP
Kathmandu Valley districts *	Polygon	KUDP
Kingdom of Nepal *	Polygon	ESRI
Lalitpur municipality boundary *	Polygon	KUDP
Municipal boundary	Polygon	KUDP
Open spaces	Polygon	KUDP
Road network	Line	KUDP
Stone and tiered temples	Point	KUDP
Ward boundaries	Polygon	KUDP-LSMC
Telecommunication cabinets	Point	KUDP-Telecom
Telecommunication lines	Line	KUDP-Telecom
Solid waste collection route	Line	LSMC
Solid_waste_containers	Point	LSMC
Educational Facilities	Point	KUDP
Governmental Facilities	Point	KUDP
Health Facilities	Point	KUDP
Commercial Facilities (Banks, Hotels and Petrol Pumps)	Point	KUDP
NGO's and INGO's	Point	KUDP
Embassies	Point	KUDP
Security Facilities	Point	KUDP
Social Facilities	Point	KUDP

* Only for location purposes because if overlaid with the municipal maps, the coordinate systems don't coincide.

Annex XVI. Other Spatial Datasets available for Lalitpur (thematic and framework datasets)

	KUDP CAD maps	Household Survey Monument Zone	Cadastre Maps	Topographic map	Architectural Survey in other heritage sites
Scale	1:2000	1:2000	1:5000	1:25000	1:2000
Date	1998	2004	1960's	1996	2002-2003
Data Quality	Inconsistencies in coordinates. Projection parameters have errors. Deficient Positional accuracy compared with IKONOS image.	Heritage conservation project. Detailed building characteristics of old structures.	The maps are not updated, therefore they can't be used as a parcel base for taxation purposes, nor do they have an addressing system.	-	Representation problems (the elements are represented as cells, not as polygons (buildings) or points.
Spatial Referencing	Modified UTM Nepal – Ellipsoid 1830	Modified UTM Nepal – Ellipsoid 1830	?	Modified UTM Nepal – Ellipsoid 1830	Modified UTM Nepal – Ellipsoid 1830
Availability (access policies)	Public availability (fixed price)	Public availability (free distribution in LSMCO)	Public availability (fixed price)	Public availability (fixed price)	Public availability (free distribution in LSMCO)
Geographic Coverage	Kathmandu Valley	Core Area LSMC	LSMC	Kathmandu Valley	LSMC
Attribute information	None	Building characteristics / Socio-economic data	Parcel id	None	None (the database is not linked to the spatial information)
Format	CAD (dwg)	GIS (ArcView)	Paper	Paper	Access / Autocad (dwg)
Metadata	Only projection Info and Source	None	None	Projection and source info	None
Standards	Only layer standards but with lots of inconsistencies between sheets	None	None	-	None
Provider	Dept. of Urban Development and Building Construction	LSMC	Dept of Survey	Dept of Survey	LSMC

Aerial Photographs and Satellite Images:				
Information	**Source**	**Format**	**Scale**	**Date**
Aerial Photographs	Dept. of Survey	Paper (scanned)	1:15000	1998
Aerial Photographs from helicopter	-	Digital	Various	2003
IKONOS image	ICIMOD	Digital (geotiff)	1 m resolution	Sep 30, 2001

Observations: The KUDP CAD maps that Lalitpur municipality has been using as base maps, made by a consulting company called AutoCarto. The KUDP maps were made using cartographic information from previous mapping projects:

- Topographic map (contours) from a Water supply and sewage mapping project performed by an Italian (Aermap)-English (Binnie & Partners) company in 1975. Scale 1:2000 with strange coordinate values (e.g. 1109800, 2277000), probably using a projection with false origin in India. No data about projection parameters is given in the original paper maps.

- Other features, such as building footprint, roads, etc were derived from a Telecommunications mapping project, done by a Danish mapping company (Kampsax Geoplan) in 1992, using UTM Zone 45 and WGS 84. They used GPS to perform all the survey.

AutoCarto simply projected the Danish project information from UTM45-WGS84 to UTM45-Everest ellipsoid, and fitted the contour lines by matching. Nevertheless, the CAD maps have 2 coordinate systems in the corners of each sheet and the values of the coordinates can not be matched from one projection to the other according to the parameters they have written in the maps.

If the Autocad maps are overlaid with the Ikonos image, they fairly coincide, since they are both projected in the same system (UTM 45 – WGS 84), but in some parts the differences (error) are as high as 30m. A rough guess can be that the differences are due to the GPS error they had back in 1992.

The CAD maps have a lot of error, especially in the fringe areas, making it almost impossible to use the IKONOS image to update the “new” buildings (up to 2001). ITC MSc students “updated” the building footprint, but the “digitized” buildings don’t coincide with the IKONOS image. The projection used for the IKONOS image, and the Danish project are not the official projections in Nepal, therefore they should both be projected either to latitude-longitude or to the official Nepalese projection parameters. The autocad map should be georeferenced using the image as the true location source.

For now, the municipality will keep on working with the Autocad maps, that have been converted to GIS by Urban Planning MSc students from Tribhuvan University, sponsored by the municipality, following the data dictionary designed for such purpose.

Annex XVII. Physical Characteristics Survey Forms

PHYSICAL, SOCIO-CULTURAL AND ECONOMIC CHARACTERISTICS SURVEY FORM

Ward No.		Date:		Surveyor:	
Block No.		Building No.		Supervisor:	

I. Physical characteristics of the building

	No. of floors		Space Use	Structural Type	Age
8					
7					
6					
5					
4					
3					
2					
1					

Predominant floor material:			
Mud		Wood	
Cement		Stone	
Predominant roof material:			
Tiles		Tin roof	
RCC Flat Roof		Plastic/Cloth	
G.I./Fiber glass Sheets		Hay	
Predominant wall material:			
Industrial mud bricks (local)		Industrial mud bricks (chinese)	
Sun dried Mud bricks		Hollow concrete blocks	
Non dried mud bricks		Other	

Mortar type		Lime surkhi	
Mud		Cement Sand	

Geometric form of the building:		Building structurally bound		
		Plinth bands	Yes	No
Regular (L:W <= 1:3)		Lintel bands	Yes	No
Regular (L:W > 1:3)		Roof band	Yes	No
Irregular		Gable band	Yes	No

Wall cracks	Yes	No
Floor cracks or settlements	Yes	No
Wall or floor dampness	Yes	No

How is the building in relation to adjacent buildings?	Right		Left	
Attached	Yes	No	Yes	No
Separated (<1m)	Yes	No	Yes	No
Separated (>1m)	Yes	No	Yes	No

Floor heights coincide between adjacent buildings?		
Left	Yes	No
Right	Yes	No

Annex XVIII. Socio-Cultural and Economic Characteristics Survey Forms - Household Characteristics and Community Awareness and Preparedness

SOCIO-CULTURAL AND ECONOMIC CHARACTERISTICS SURVEY FORM - Household Characteristics

Ward No.		Block No.		Surveyor:	
Building No:		Survey No.		Date	
Household Head Age:		Household Head Sex:	M F		Total No. persons in househo

Caste/Ethnic Group				**Why are you living here:**		**Where do you originally come from:**	
Newar		Madeshi		Family ties			
Brahman		Rai/Limbu		Work motives		Another ward	
Gurung/Magar		Sherpa		Displacement (armed conflict)		Another municipality	
Chhetri		Other				Another VDC	
Religion		Muslim		Economic displacement		Another region	
Hinduism		Christianity		Other		Another country	
Buddhism		Other		**Type of Ownership:**			
Language	Newari	Englis		Own		Loan	
Nepali	Hindi	Other		Rent		Invasion	

		M 0-5	M 6-13	M 14-1	M 19-5	M > 60	F 0-5	F 6-13	F 14-1	F 19-5	F > 60	Total
Activities	Working											
	Studying											
	Not studying											
	Household activities											
	Handicaped											
	Retired											
	Unemployed											
Education	Nursery											
	Preschool (KG1-											
	Elementary (1st-3rd)											
	Secondary (4th-10th)											
	Higher sec. (11th-											
	Higher education											
	Technical/Vocationa											
Type of job	Fixed income job											
	Variable income job											
	Daily wage basis											
Occupation	Public Sector / Govt.											
	Manufacturer/Indust											
	Services											
	Trade											
	Agri. / Forestry											
	Construction											
	Others											
Work/Study Place	Same ward											
	Another ward											
	Another municipality											
	Another VDC											
	Another Region											
	Another Country											
Relationship to Household head	Spouse											
	Son/Daughter											
	Parent											
	Grandparent/Grandc											
	Brother/Sister											
	Aunt/Uncle											
	Cousin											
	Inlaw											
	Other											

Facilities		**Main source of Drinking Water**		**Main type of Cooking/Lighting**		**Average Monthly Expenditure by Item**		**Monthly expenditur**	
Water									
Sewage		Water main		Electricity		Food		< 3	
Electricity		Dug Well		Gas		Clothes		3 - 5	
Telephone		Boring well		Kerosene		House Rent		5 - 7	
Television		Sunken water		Wood		Education		7-10	
Radio		Spring		Other		Electricity		10-13	
Insuranc		**How many have health coverage?**				Telephone		13-16	
House		**In the last year how many people have**				Water		16-	
House assets		Respiratory diseases				Gas		20-	
Life		Diseases related to water quality				Recreation		25-	
Health		Skin diseases				Medicine		> 30	

SOCIO-CULTURAL AND ECONOMIC CHARACTERISTICS SURVEY FORM

Ward No.		Block No.		Surveyor:	
Building No:		Survey No.		Date (dd/mm/yy):	

Population Distribution

In average how many persons work/stay here during:

Morning (6am-9am):		Day (9am- 5pm):		Evening (5pm-9pm):		Night (9pm-6am):	

Community awareness and Preparedness

How many persons of this household belong to:

Social groups		Disaster Prevention groups	
Ecological groups		Women groups	
Health groups		Political groups	
Emergency and Rescue groups		Other	

Knowledge and Awareness

Have you participated any earthquake awareness raising programs?	
Have you listened/watched the earthquake awareness programs on Radio/TV?	
Do you know any organization that can aid you in reducing earthquake vulnerability?	
Do you know about the earthquake safety day (ESD) in Nepal?	
Do you think the Municipality is prepared for a disaster?	
Do you think old buildings could be made earthquake safe (retrofitting)?	
Do you know about the building code implementation in LSMC?	
Do you know about aftershocks?	
Do you know about early warning systems?	
Do you think you live in risk?	

Do you know the location of the nearest of the following places?

Hospital		Shelter house	
Open space		Police station	

Preparedness

Have you used any earthquake safety measures in your building?	
Have you discussed with your family reducing earthquake vulnerability?	
Have you identified a safe place inside your house if there is an earthquake?	
Have you fixed properly the TV, cupboard, computer, frame etc.?	
Have you prepared an emergency kit (first-aid, dry food, identity documents, water)?	
In case of a disaster, do you have temporal lodging?	

How many persons of this household have received training in:

Disaster Prevention		Evacuations	
Emergency preparedness		Rescue	
First Aid		Other	

Response during an earthquake

How do you react if you are on the upper floor of a tall building?

Use the elevator		Use stairs	
Jump through window		Look for a safe place	

If it is dark what do you use to make light?

Kerosene lamp		Electricity	
Gas lighter		Torchlight (flash light)	

Outdoors, which is the safest place?

Open space		By an electricity pole	
Under a tree		Near a tall building	
Under a bridge		Other	

Would you pick up or touch fallen power lines?	
Would you drink tap water?	
Would you help other victims and organize rescue teams?	

Who do you blame for the losses (lives and property) due to an earthquake?

God		Mason	
Government		Engineer	
Municipality		Nobody	
Myself			

Respondent/Observations:

Annex XIX. Survey 1: Indicator Comparison matrices for each vulnerability phase for Lalitpur

Impact Phase	1	2	3	4	5	6	7	8	9	10	11	12	13
1-Building Stock Fragility	1	3	3	3	3	1	3	3	3	1	3	3	3
2-Emergency Services Capacity	1/3	1	3	1	3	1/3	1	1	1	3	3	3	1
3-Environmental Assets Fragility	1/3	1/3	1	1/3	1	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
4-Law and Policy Enforcement	1/3	1	3	1	3	1/3	1	3	1	3	3	3	1
5-Minorities/Special Groups	1/3	1/3	1	1/3	1	1/3	1/3	1	1/3	1/3	1/3	1/3	1/3
6-Population distribution	1	3	3	3	3	1	3	3	3	1	3	3	3
7-Population Capacity	1/3	1	3	1	3	1/3	1	3	1	1	1	3	3
8-Population Fragility	1/3	1	3	1/3	1	1/3	1/3	1	1/3	1/3	1/3	1/3	1/3
9-Transportation Infrastructure Fragility	1/3	1	3	1	3	1/3	1	3	1	1/3	1	1/3	1
10-Cultural and Historical Assets Fragility	1/3	1/3	3	1/3	3	1	1	3	3	1	1	1	3
11-Utilities Infrastructure Fragility	1/3	1/3	3	1/3	3	1/3	1	3	1	1	1	1/3	1/3
12-Local Economic Fragility	1/3	1/3	3	1/3	3	1/3	1/3	3	3	1	3	1	3
13-Emergency communications Fragility	1/3	1	3	1	3	1/3	1/3	3	1	1/3	3	1/3	1

Relief Phase	1	2	3	4	5	6	7	8	9	10	11	12
Environmental Assets Fragility	1	1/3	1/3	1/3	1	1/3	1/3	1	1/3	1/3	1/3	1/3
Governance	3	1	1	1	3	3	3	3	1	1	1	1/3
Health Facilities Capacity	3	1	1	1	3	3	3	3	1	3	3	1/3
Household Economic Fragility	3	1	1	1	3	1/3	1/3	1/3	1/3	1	1/3	1/3
Minorities/Special Groups	1	1/3	1/3	1/3	1	1/3	1/3	1/3	1/3	1	1/3	1/3
Municipal Preparedness	3	1/3	1/3	3	3	1	3	1	1/3	1	3	1/3
Organizations and Administrative Capacity	3	1/3	1/3	3	3	1/3	1	3	1/3	1	1	1/3
Participatory Structures	1	1/3	1/3	3	3	1	1/3	1	1/3	1	1	1/3
Shelter Facilities	3	1	1	3	3	3	3	3	1	3	3	1
Social cohesion and Organization	3	1	1/3	1	1	1	1	1	1/3	1	3	1
Emergency communications Capacity	3	1	1/3	3	3	1/3	1	1	1/3	3	1	1/3
Household Economic Capacity	3	3	3	3	3	3	3	3	1	1	3	1

Relief Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Environmental Assets Recovery capacity	1	1	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1
Facilities recovery capacity	1	1	1	1/3	1/3	1	1	1	1	1/3	1/3	1/3	1/3	1/3	1
Governance	3	1	1	1	1	3	3	3	3	1	1	1	1	1	3
Household Economic Capacity	3	3	1	1	3	3	1	1	3	1	1	1	3	1	3
Building Stock Recovery Capacity	3	3	1	1/3	1	3	3	3	3	1	1	1	3	1	3
Participatory Structures	3	1	1/3	1/3	1/3	1	1/3	1	1/3	1	1/3	1/3	3	1/3	1
Population Capacity	3	1	1/3	1	1/3	3	1	3	1	1	3	3	3	1	3
Population Fragility	3	1	1/3	1	1/3	1	1/3	1	3	1/3	1	1	1	1	3
Shelter Facilities	3	1	1/3	1/3	1/3	3	1	1/3	1	1/3	1	1/3	1/3	1	3
Social cohesion and Organization	3	3	1	1	1	1	1	3	3	1	1/3	1/3	1	1/3	1
Transportation Infrastructure Recovery capacity	3	3	1	1	1	3	1/3	1	1	3	1	1	1/3	1/3	3
Utilities Infrastructure Recovery Capacity	3	3	1	1	1	3	1/3	1	3	3	1	1	1/3	1/3	3
Cultural and Historical Assets Recovery Capacity	3	3	1	1/3	1/3	1/3	1/3	1	3	1	3	3	1	1	3
Local Economic capacity	3	3	1	1	1	3	1	1	1	3	3	3	1	1	3
Emergency communications Recovery Capacity	1	1	1/3	1/3	1/3	1	1/3	1/3	1/3	1	1/3	1/3	1/3	1/3	1

Annex XX. Survey 2: Data Requirements for Lalitpur

	Indicator	Attributes	Attribute Importance	Minimum Acceptable Scale (MAS)	Minimum Preferred Scale (MPS)	Shelf-Life (years)
Impact	Building Stock Fragility	Age	0.12	2	4	10
		Conservation State	0.15	2	4	10
		Number of floors	0.28	2	4	10
		Structural Type	0.45	2	4	10
	Cultural and Historical Assets Fragility	Importance	1.00	2	4	10
	Emergency communications Fragility	Ability to coordinate the emergency services	1.00	1	1	1
	Emergency Services Capacity	Number of emergency services and distribution	1.00	2	4	1
	Environmental Assets Fragility	Biodiversity index	0.32	4	4	5
		Endemic species	0.43	4	4	5
		Type of environmental asset	0.25	4	4	5
	Law and Policy Enforcement	Application of construction code and soil use norms	1.00	2	4	3
	Local Economic Fragility	Economical activities by type	1.00	2	4	3
	Minorities/Special Groups	Location & Characteristics	1.00	2	4	2
	Population Capacity	Educational level of the population	0.63	3	4	2
		Previous Hazard/Risk knowledge	0.37	3	4	2
	Population distribution	Time distribution of the population	1.00	3	4	10
	Population Fragility	Population Age/Gender	0.63	3	4	2
		Population Religion/Ethnicity	0.37	3	4	10
	Transportation Infrastructure Fragility	Types and characteristics (road network, ports, railways, airports, terminals, stations, bridges)	1.00	2	4	10
	Utilities Infrastructure Fragility	Facilities coverage (water, sewage, electricity, telephone, gas)	1.00	2	4	10
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv)	0.67	1	1	1
		Previous educational campaigns on risk management	0.33	1	3	2
	Environmental Assets Fragility	Biodiversity index	0.32	4	4	5
		Endemic species	0.43	4	4	5

	Indicator	Attributes	Attribute Importance	Minimum Acceptable Scale (MAS)	Minimum Preferred Scale (MPS)	Shelf-Life (years)
		Type of environmental asset	0.25	4	4	5
	Governance	Government dependence	0.40	1	1	4
		Government Structure	0.27	1	1	3
		Rule of law (criminality)	0.33	1	1	1
	Health Facilities Capacity	Type of health facilities	1.00	2	4	3
	Household Economic Fragility	Financial Status (debt, savings)	0.73	3	4	2
		Subsidies	0.27	3	4	2
	Minorities/Special Groups	Location & Characteristics	1.00	3	4	2
	Municipal Preparedness	Emergency groups	1.00	3	4	1
		SISBEN coverage	1.00	3	4	2
	Organizations and Administrative Capacity	Emergency preparation	1.00	1	3	1
	Participatory Structures	Committees and organizations per administrative unit	1.00	2	3	1
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	0.33	2	4	2
	Social cohesion and Organization	Experience in previous events	0.37	3	4	5
		Participation in Groups	0.30	3	4	2
		Time in the neighborhood	0.50	3	4	5
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	0.50	1	4	10
		Insurance	0.56	1	4	10
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	0.44	1	4	3
		Insurance	0.50	1	4	3
	Emergency communications Recovery Capacity	Allocated recovery budget	0.50	1	1	3
		Insurance	0.63	1	1	3
	Environmental Assets Recovery capacity	Allocated recovery budget	0.37	1	4	3
		Insurance	0.53	1	4	3
	Facilities recovery capacity	Allocated recovery budget	0.47	1	4	3
		Insurance	0.37	1	4	3
	Governance	Government dependence	0.33	1	1	2
		Government Structure	0.30	1	1	2
		Rule of law (criminality)	0.15	1	1	2
	Household Economic Capacity	Economic dependence (% of dependents)	0.25	2	4	2
		Employment	0.30	2	4	2
		Income level	0.17	2	4	2
		Insurance	0.13	2	4	2
		Tenure	0.50	2	4	2
	Local Economic	Financial Status	0.50	1	4	5

	Indicator	Attributes	Attribute Importance	Minimum Acceptable Scale (MAS)	Minimum Preferred Scale (MPS)	Shelf-Life (years)
	capacity	(debt, savings)				
		Insurance	1.00	1	4	5
	Participatory Structures	Committees and organizations per administrative unit	1.00	2	3	1
	Population Capacities	Health Insurance	1.00	2	4	2
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1.00	2	4	3
	Social cohesion and Organization	Experience in previous events	0.33	2	3	5
		Participation in Groups	0.23	2	3	2
		Political participation	0.27	2	3	3
		Time in the neighborhood	0.17	2	3	5
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	0.56	1	1	3
		Insurance	0.44	1	1	3
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	0.56	1	1	3
		Insurance	0.44	1	1	3

Annex XXI. Survey 3: Data Characteristics for Lalitpur

Phase	Indicator	Attributes	Available (y/n)	Completeness (0 a 1)	Quality/Usability (G 3,R 2,B 1)	Scale (Municipality=1, Commune=2, neighborhood=3, Element=4)	Data Date
Impact	Building Stock Fragility	Age	y	0.2	2	1	2005
		Conservation State	n	0			
		Number of floors	y	0.1	2	1	2005
		Structural Type	y	0.1	2	1	2005
	Cultural and Historical Assets Fragility	Importance	y	0.9	3	4	2005
	Emergency communications Fragility	Ability to co-ordinate the emergency services	n	0			
	Emergency Services Capacity	Number of emergency services and distribution	n	0			
	Environmental Assets Fragility	Biodiversity index	n	0			
		Endemic species	n	0			
		Type of environmental asset	n	0			
	Law and Policy Enforcement	Application of construction code and soil use norms	y	0.5	3	1	1994
	Local Economic Fragility	Economical activities by type	y	0.1	2	1	2001
	Minorities/Special Groups	Location & Characteristics	n	0			
	Population Capacity	Educational level of the population	y	0.1	2	1	2001
		Previous Hazard/Risk knowledge	y	0.2	2	2	2005
	Population distribution	Time distribution of the population	y	0.1	2	1	2005
	Population Fragility	Population Age/Gender	y	1	2	1	2001
		Population Religion/Ethnicity	y	1	2	1	2001
	Transportation Infrastructure Fragility	Types and characteristics (road network, ports, railways, airports, terminals, stations, bridges)	y	0.9	2	1	2005
	Utilities Infrastructure Fragility	Facilities coverage (water, sewage, electricity, telephone, gas)	y	0.3	2	1	2005

Phase	Indicator	Attributes	Available (y/n)	Completeness (0 a 1)	Quality/Usability (G 3,R 2,B 1)	Scale (Municipality=1, Commune=2, neighborhood=3, Element=4)	Data Date
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv)	n				
		Previous educational campaigns on risk management	n				
	Environmental Assets Fragility	Biodiversity index	n				
		Endemic species	n				
		Type of environmental asset	n				
	Governance	Government dependence	n				
		Government Structure	y	0.7	2	1	2005
		Rule of law (criminality)	n				
	Health Facilities Capacity	Type of health facilities	y	0.7	2	1	2003
	Household Economic Fragility	Financial Status (debt, savings)	y	0.3	2	1	2001
		Subsidies	n				
	Minorities/Special Groups	Location & Characteristics	y	0.5	2	1	2001
	Municipal Preparedness	Emergency groups	y	0.4	3	2	2007
		SISBEN coverage	n				
	Organizations and Administrative Capacity	Emergency preparation	n				
	Participatory Structures	Committees and organizations per administrative unit	y	0.7	2	2	2005
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	y	0.1	2	1	
	Social cohesion and Organization	Experience in previous events	n				
		Participation in Groups	n				
		Time in the neighborhood	n				
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	n				
		Insurance	n				
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	y				
		Insurance	n				
	Emergency communications Recovery Capacity	Allocated recovery budget	n				
		Insurance	n				
	Environmental Assets Recovery capacity	Allocated recovery budget	n				

Phase	Indicator	Attributes	Available (y/n)	Completeness (0 a 1)	Quality/Usability (G 3,R 2,B 1)	Scale (Municipality=1, Commune=2, neighborhood=3, Element=4)	Data Date
		Insurance	n				
	Facilities recovery capacity	Allocated recovery budget					
		Insurance	n				
	Governance	Government dependence	n				
		Government Structure	y	0.7	3	1	2005
		Rule of law (criminality)	n				
	Household Economic Capacity	Economic dependence (% of dependents)	y	1	2	1	2001
		Employment	y	1	2	1	2001
		Income level	y	1	2	1	2001
		Insurance	n				
		Tenure	y	1	2	1	2001
	Local Economic capacity	Financial Status (debt, savings)	n				
		Insurance	n				
	Participatory Structures	Committees and organizations per administrative unit	n				
	Population Capacities	Health Insurance	n				
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	n				
	Social cohesion and Organization	Experience in previous events	n				
		Participation in Groups	n				
		Political participation	n				
		Time in the neighborhood	n				
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	n				
		Insurance	n				
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	n				
		Insurance	n				

Annex XXII. Attribute scores for Evaluator1 in Lalitpur

	Indicator	Attributes	Attribute importance	Evaluator 1
Impact	Building Stock Fragility	Age	0.117	0.00
		Conservation State	0.150	0.00
		Number of floors	0.283	0.00
		Structural Type	0.450	0.00
	Cultural and Historical Assets Fragility	Importance	1.000	4.50
	Emergency communications Fragility	Ability to coordinate the emergency services	1.000	0.00
	Emergency Services Capacity	Number of emergency services and distribution	1.000	0.00
	Environmental Assets Fragility	Biodiversity index	0.317	0.00
		Endemic species	0.433	0.00
		Type of environmental asset	0.250	0.00
	Law and Policy Enforcement	Application of construction code and soil use norms	1.000	1.83
	Local Economic Fragility	Economical activities by type	1.000	0.00
	Minorities/Special Groups	Location & Characteristics	1.000	0.00
	Population Capacity	Educational level of the population	0.633	0.00
		Previous Hazard/Risk knowledge	0.367	0.00
	Population distribution	Time distribution of the population	1.000	0.00
	Population Fragility	Population Age/Gender	0.633	2.33
		Population Religion/Ethnicity	0.367	4.00
	Transportation Infrastructure Fragility	Types and characteristics	1.000	3.83
	Utilities Infrastructure Fragility	Facilities coverage	1.000	0.00
Relief	Emergency communications Capacity	Existing communications facilities (radio, tv, etc.)	0.667	0.00
		Previous educational campaigns on risk management	0.333	0.00
	Environmental Assets Fragility	Biodiversity index	0.317	0.00
		Endemic species	0.433	0.00
		Type of environmental asset	0.250	0.00
	Governance	Government dependence	0.400	0.00
		Government Structure	0.267	3.39
		Rule of law (criminality)	0.333	0.00
	Health Facilities Capacity	Type of health facilities	1.000	2.17
	Household Economic Fragility	Financial Status (debt, savings)	0.733	0.00
		Subsidies	0.267	0.00
	Minorities/Special Groups	Location & Characteristics	1.000	1.50
	Municipal Preparedness	Emergency groups	1.000	3.33
		SISBEN coverage	1.000	0.00
	Organizations and Administrative Capacity	Emergency preparation	1.000	0.00
	Participatory Structures	Committees and organizations per administrative unit	1.000	3.17
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	0.333	0.00
	Social cohesion and Organization	Experience in previous events	0.367	0.00
		Participation in Groups	0.300	0.00
		Time in the neighborhood	0.667	0.00
Recovery	Building Stock Recovery Capacity	Allocated recovery budget	0.497	0.00
		Insurance	0.503	0.00
	Cultural and Historical Assets Recovery Capacity	Allocated recovery budget	0.563	0.00
		Insurance	0.437	0.00
	Emergency communications Recovery Capacity	Allocated recovery budget	0.497	0.00
		Insurance	0.503	0.00
	Environmental Assets Recovery capacity	Allocated recovery budget	0.630	0.00
		Insurance	0.370	0.00
	Facilities recovery capacity	Allocated recovery budget	0.530	0.00
		Insurance	0.470	0.00

	Indicator	Attributes	Attribute importance	Evaluator 1
	Governance	Government dependence	0.367	0.00
		Government Structure	0.333	3.17
		Rule of law (criminality)	0.300	0.00
	Household Economic Capacity	Economic dependence (% of dependents)	0.150	2.67
		Employment	0.250	2.67
		Income level	0.300	2.67
		Insurance	0.167	0.00
		Tenure	0.133	2.67
	Local Economic capacity	Financial Status (debt, savings)	0.497	0.00
		Insurance	0.503	0.00
	Participatory Structures	Committees and organizations per administrative unit	1.000	0.00
	Population Capacity	Health Insurance	1.000	0.00
	Population Fragility	Household Masculinity Index	1.000	0.00
	Shelter Facilities	Facilities type (education, cultural, religious, etc.)	1.000	0.00
	Social cohesion and Organization	Experience in previous events	0.333	0.00
		Participation in Groups	0.233	0.00
		Political participation	0.267	0.00
		Time in the neighborhood	0.167	0.00
	Transportation Infrastructure Recovery capacity	Allocated recovery budget	0.563	0.00
		Insurance	0.437	0.00
	Utilities Infrastructure Recovery Capacity	Allocated recovery budget	0.563	0.00
		Insurance	0.437	0.00

Summary

Even though natural hazard threats are present in most parts of the world, according to the data collected in the International Disaster Database, most of them occur in developing countries, and remain a major obstacle to sustainable development and the achievement of the Millennium Development Goals. The trend during the last decades shows an increase in the number of natural hazard events and their consequences. Natural hazards cannot be avoided, but understanding and measuring the factors that make up vulnerability, the main variable in the risk equation that can be managed, is an important research task. In this endeavor, information is a key element in vulnerability reduction. Most planning authorities rely on hazard maps to define risk management plans and projects, but these maps only depict the threat and not the whole picture of how, who, and what and can be affected by these hazards. Information, or rather the availability of useful information, is a critical element for effectively tackling vulnerability. Defining the fitness for use of municipal geo-information for earthquake vulnerability assessment is the main topic of this research. A methodology was developed to establish whether and to what extent the vulnerability indicators calculated using this municipal geo-information are suitable for decision making. This is done by understanding the different types of vulnerability, and re-defining it in terms of the three disaster stages: impact, relief and recovery. The main proposal of the general analysis model is the analysis of vulnerability of a region for the 3 stages of a disaster, which follow each other in time and require different municipal strategies to cope with them. Considering this, the availability of data for the analysis of vulnerability in each phase starts with the identification of the required information -indicators- and their specific attributes. A list of indicators is defined for each phase (required information) that in turn will be rated in importance according to different attributes. Some indicators are common to different evaluation phases, but their application to the analysis and/or solution proposals or plans is different. The indicators are assessed in terms of five attributes: availability, completeness, integrity and reliability, scale, and shelf-life. Two case studies were selected to portray different urban management conditions in terms of available information and capacity. The first case study selected was Medellín, Colombia, a data rich - capacity moderate municipality, and the second case study selected was Lalitpur, Nepal a data poor- capacity deficient municipality. The methodology was tested in both cities. The scores obtained by the attributes for each city shed light on the specific problems that an indicator has. Once the attributes with low scores are identified, a detailed analysis of each of the aspects evaluated and the original values can determine what problem to tackle. To illustrate the use of municipal data available vulnerability indicators by phase were calculated for Medellín.

Samenvatting

Natuurrampen doen zich overal in de wereld voor. Volgens de gegevens uit de 'International Disaster Database' komen ze het meest voor in de ontwikkelingslanden. Daar vormen ze nog steeds een belangrijke hindernis voor het bereiken van de Millennium ontwikkelingsdoelstellingen. De afgelopen decennia is ser prake van een toename van het aantal rampen en de consequenties ervan. Omdat natuurrampen niet voorkomen kunnen worden dient onderzoek gedaan te worden naar het begrijpen en meten van de factoren die de kwetsbaarheid voor die rampen bepalen. Zij vormen immers de belangrijkste variabelen in de risicovergelijking die door de mens te beïnvloeden zijn. Het beschikbaar zijn van de noodzakelijke informatie is daarbij essentieel om de kwetsbaarheid terug te kunnen dringen. Veel ruimtelijke planners baseren zich op kaarten die kansen op rampen aangeven om plannen en projecten voor risicobeheer op te stellen. Maar dit type kaarten toont alleen de bedreigingen en niet het hele beeld van hoe, wie, wat en waar kan worden geraakt door een ramp. Meer specifieke informatie moet beschikbaar zijn om kwetsbaarheid doeltreffend te kunnen aanpakken. Het belangrijkste onderwerp van dit onderzoek is het bepalen van de bruikbaarheid van reguliere gemeentelijke geo-informatie is voor het beoordelen van de kwetsbaarheid voor aardbevingen. Er is een methodologie ontwikkeld om vast te stellen of en in welke mate kwetsbaarheidsindicatoren, die gebaseerd zijn op gemeentelijke gegevens, geschikt zijn om de besluitvorming te ondersteunen. Dit is gedaan door de verschillende typen kwetsbaarheid nader te ontleden en te herdefiniëren voor de drie rampfasen: inslag, hulp en herstel. In het algemene analysemodel is de kwetsbaarheid voor elk van de drie rampfasen, die elkaar in de tijd opvolgen, geanalyseerd. Dit omdat elke fase een eigen strategie vereist in het omgaan met kwetsbaarheid. Daarom worden voor elke fase eerst de vereiste indicatoren en hun specifieke kenmerken geïdentificeerd. Voor de drie fasen is een lijst met indicatoren opgesteld met een score voor het belang van elk kenmerk. Sommige indicatoren zijn bruikbaar voor verschillende fasen, maar hun toepassing voor de analyse en/of voor het opstellen van plannen verschilt. De indicatoren zijn beoordeeld op basis van vijf kenmerken: aanwezigheid, compleetheid, integriteit en betrouwbaarheid, schaal en actualiteit. De methodologie is getoetst in twee gevalstudies met duidelijke verschillen ten aanzien van bestuurskracht en beschikbaarheid van informatie en capaciteit. De eerste studie betreft Medellin in Colombia, waar sprake is van een ruime beschikbaarheid van gegevens en een redelijke bestuurlijke capaciteit. De tweede studie is uitgevoerd in Lalitpur in Nepal waar weinig informatie beschikbaar is en bovendien het bestuur zwak is. De berekende scores voor de kenmerken van de indicatoren laten zien welke informatieproblemen aanwezig zijn. Vervolgens kan uit een nadere analyse van elk van de probleempunten afgeleid worden hoe deze kunnen worden opgelost. Om het gebruik van gemeentelijke gegevens voor het samenstellen van kwetsbaarheidsindicatoren te illustreren zijn deze voor Medellin berekend.

Resumen

A pesar de que las amenazas naturales están presentes en la mayor parte del mundo de acuerdo con los datos recolectados por la base de datos internacional de desastres, la mayoría de ellos ocurre en países en desarrollo y representan un obstáculo para el desarrollo y el logro de las metas de desarrollo del milenio. La tendencia en las últimas décadas muestra un incremento en el número de eventos de amenazas de origen natural y en sus consecuencias. Las amenazas naturales no pueden evitarse, pero entender y medir los factores que componen la vulnerabilidad, la variable principal que puede manipularse en la ecuación del riesgo, es una tarea de investigación importante. En esta tarea, la información es un elemento clave en la reducción de la vulnerabilidad. La mayoría de autoridades de planificación se basan en mapas de amenaza para definir los planes y proyectos de administración de riesgos, pero estos mapas sólo muestran la amenaza y no el cuadro completo de cómo, qué y quien puede ser afectado por estas amenazas. La información, o más bien la disponibilidad de información útil, es un elemento crítico en la reducción efectiva de la vulnerabilidad. Definir la aptitud de uso de la geo-información municipal para evaluación de la vulnerabilidad urbana ante sismos es el tema principal de esta investigación. Se desarrolló una metodología para establecer si los indicadores de vulnerabilidad calculados usando esta geo-información municipal son aptos para tomar decisiones. Esto se llevó a cabo entendiendo los distintos tipos de vulnerabilidad y redefiniéndolos en términos de las tres etapas de un desastre: impacto, ayuda y recuperación. El propósito general del modelo de análisis es el análisis de la vulnerabilidad de una región en las tres fases del desastre que se suceden en el tiempo y que requieren diferentes estrategias municipales para atenderlas. Teniendo esto en cuenta, la disponibilidad de datos para el análisis de la vulnerabilidad en cada fase empieza con la identificación de la información requerida --indicadores- y sus atributos específicos. Se define entonces una lista de indicadores para cada fase que a su vez serán calificados en términos de importancia de acuerdo con los diferentes atributos. Algunos indicadores aparecen en diferentes fases de evaluación, pero su aplicación en el análisis y en las propuestas de reducción o en los planes es diferente. Los indicadores se evalúan en términos de cinco atributos: disponibilidad, completitud, integridad y confiabilidad, escala y vida-útil. Dos casos de estudio se seleccionaron para representar dos estados o condiciones de administración urbana en términos de información disponible y capacidad. El primer caso de estudio fue Medellín, Colombia, municipio rico en datos y de capacidad moderada y Lalitpur, Nepal, municipio de pocos datos y capacidad deficiente. La metodología se probó en ambas ciudades. Las calificaciones obtenidas para cada ciudad muestran los problemas de información específicos que un indicador puede tener. Una vez que los atributos con calificaciones bajas se han identificado, un análisis detallado de cada uno de los aspectos evaluados y de los valores originales permite determinar cuales problemas enfrentar y cómo. Para ilustrar el uso de geo-información municipal disponible, se calcularon indicadores de vulnerabilidad por fase para Medellín.

Curriculum Vitae

Verónica Botero Fernández was born on the 9th of February, 1970 in Medellín, Colombia. In 1994 she obtained her bachelor's degree in Civil Engineering from EAFIT University in Medellín, Colombia. In 1997 she obtained her M.Sc. degree in Geological Survey from the International Institute for Geo-information Science and Earth Observation, in Enschede, the Netherlands. From 1994 to 1995 she worked as a geotechnical engineer for Integral S.A., a major engineering consulting company in Colombia. In 1997, after obtaining her M.Sc. she returned to Colombia to work at the same engineering company, but as a geo-information analyst, and participated in national and international projects in Colombia, Venezuela and Mexico. She has been part-time lecturer in several universities in Colombia, and in 2001 she became a full-time lecturer at the Faculty of Mines of the National University of Colombia (Universidad Nacional de Colombia), in the areas of geo-information science and digital image processing. She has participated in several research projects that have involved the use of geo-information for urban and rural planning, and disaster management. Currently her research interests are geo-information for urban modeling and planning, spatial data infrastructures, geo-services, and geo-information for disaster management.