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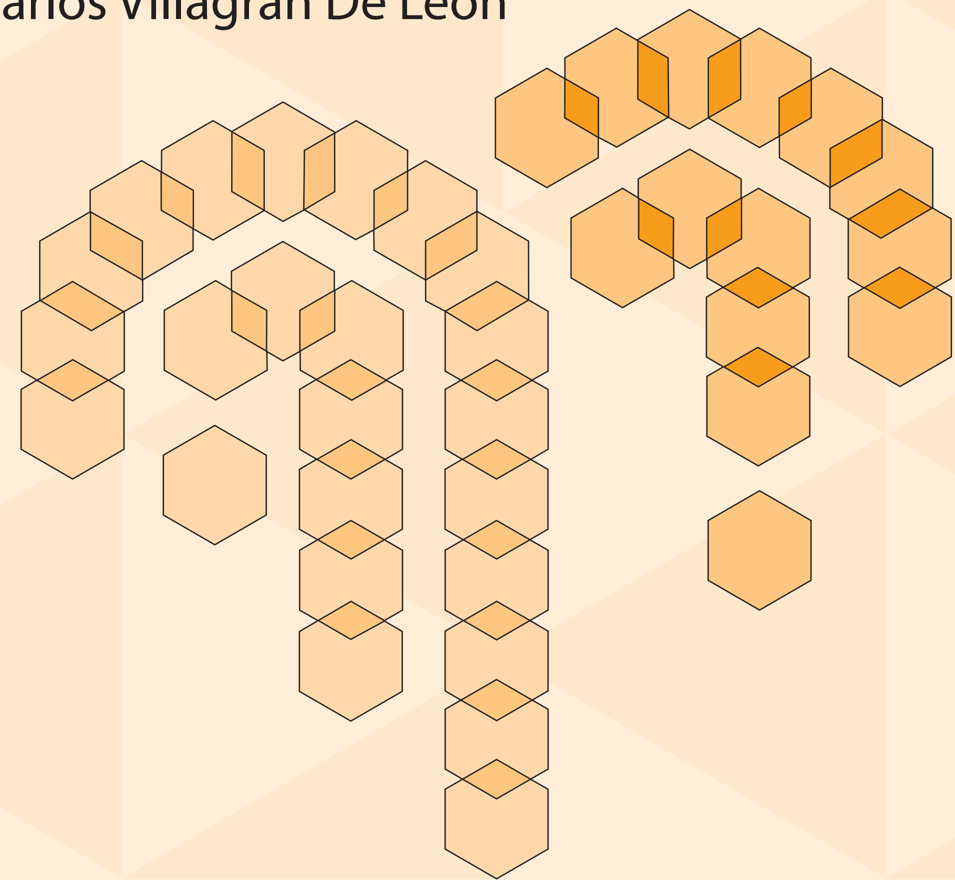
Vulnerability

A Conceptual and Methodological Review

Juan Carlos Villagrán De León



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Foreword

During the last three decades the world has faced an unprecedented increase of the frequency and magnitude of extreme environmental hazard events. The frequency of some geogene events like earthquakes and volcano emptions while random in occurrence remained fairly constant, while events related to the hydrometeorological cycle seem to increase in both frequency and magnitude. Even more troubling are the statistics regarding the associated economic losses. While the frequency seems to be between being doubled or tripled, the economic losses have undergone a six fold increase over the last 30 years.

Without even exploring other dimensions of the hazards – losses nexus it is obvious that next to the observable shift in frequency and magnitude of hazard events, something else is contributing to the over proportional growth of losses.

More wealth brought in to stand in harm's way, the exposure and vulnerability of structures, both physical and social can be the reason.

Vulnerability is however the most elusive component of the hazard-vulnerability-coping capacity-risk (losses)-recovery cycle. It needs to be defined as *"vulnerability of what", "vulnerability to what"* at *"what scale"* to mention but the most important aspects.

In order to be useful, vulnerability of a community, a building or a country should be estimated, like hazard frequencies in advance, before an extreme event strikes. "Post mortem" vulnerability assessment may be useful to find explanations why and what type of losses happened, but their use in the conception of disaster preparedness measures is limited.

We are definitely still at the beginning of what may be called *"vulnerability research".* On the theoretical level the multitude of definitions as summarized in the SOURCE No. 2 *Components of Risk,* publication of UNU-EHS clearly indicates this evolutionary stage.

However, practice could not wait till theoretical debates were settled. In the meantime assessment techniques have been developed at different scales and for different purposes. Yet there is no general consensus in definitions, terminology, not to mention policy relevant indicators and indices.

Vulnerability assessment addressing the social, economic, environmental and institutional aspects occupies the central part within the research and human capacity building scope of UNU-EHS. Review of the state-of-the-art is being published in a book entitled *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies.* UNU-EHS has established an international *Expert Working Group* (EWG) to serve as the platform of dialogue among the different schools of thought in vulnerability research. Several participants of the EWG contributed to this book.

Together with the MunichRe Foundation (MRF) UNU-EHS starts in 2006 to organize annually a summer academy on social vulnerability. Likewise annual PhD courses are held on vulnerability and risk assessment. Besides this postgraduate level, capacity building events on vulnerability assessment are an important component of continuing educational activities of the Institute.

The present issue of the SOURCE Series of UNU-EHS, *Vulnerability: A Conceptual and Methodological Review* is a concise summary of ideas, concepts and methods developed to capture vulnerability at different scales. Praxis oriented and example based, the present work of Dr. Villagrán de León provides an excellent entry into the complex problematic of vulnerability assessment for students and practitioners alike.

Janos J. Bogardi
Director UNU-EHS

About the Author

Juan Carlos Villagrán de León holds M.A. and Ph.D. degrees in experimental condensed matter physics from the University of Texas in Austin where he was a Pre- and a Post-Doctoral Fellow of the Robert A. Welch Foundation. His interest in the topic of natural disaster reduction began in 1993 supporting the *Guatemalan Disaster Management Agency* (CONRED) and the *Central American Coordination Centre for Natural Disaster Prevention* (CEPREDENAC) on issues of early warning and risk management. In recent years he has been a regional consultant in Central America for the *German Technical Cooperation Agency* (GTZ), the *United Nations Development Programme* (UNDP), US-AID; and NGOs such as Acción Contra el Hambre, Plan Internacional, and others. His activities in the field of early warning systems span the design and the implementation of such systems for different types of hazards in Central America, Mozambique, and more recently also in Sri Lanka. On risk management, he has been developing methodologies for vulnerability and risk assessment, and contributing to strengthening institutional capacities on this topic. His current research within UNU-EHS involves the identification of notions and perceptions regarding human insecurities associated with natural disasters, as well as the identification and systematisation of factors which are enhancing the generation of risks in developing countries. Juan Carlos Villagrán de León is author of several publications in Spanish and English languages on topics like risk assessment, risk management, and early warning.

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1. Introduction

Cities and societies in many regions of the world have experienced disasters throughout the centuries, provoked by natural and social events. The destruction of cities in Italy and Greece in ancient times and in Latin America during the period of the Spanish conquest due to violent volcanic eruptions and earthquakes; as well as in Asia and in the Caribbean due to typhoons and hurricanes is an example of such historic catastrophic events. While initially regarded as punishments by gods in the old ages, disasters around the world are now being understood as the manifestation of the fact that societies which are experiencing them have gone through development processes which have not taken into account hazards related to natural or social phenomena in a proper fashion. The increasing losses experienced by many developing countries in the last decades are direct evidence that such development processes are not leading to sustainability, as such losses are taking heavy tolls on limited or scarce resources which might be available for development programs. It may be concluded that some disasters are unaddressed problems within the development schemes currently in practice in such developing nations. Among the reasons for such conclusions, the following deserve mention:

- The continuation of the view that the causes of disasters are exclusively related to natural hazards which are triggering such disasters. In this sense, disasters are perceived as external or independent from the framework of development in use;
- The fact that risk and vulnerability remain invisible until a natural event manifest them, unlike poverty which is now being addressed in a more visible fashion at the local, national, and international levels; and
- A wrong belief that nature can be controlled through engineering practices and therefore disasters can be avoided.

Therefore, the main challenge within the field of disaster reduction should be to change the perception of people and make them recognize this notion of disasters as the outcome of a development process whereby societies have implicitly generated vulnerabilities and risks, which become evident during the disaster. This notion then pinpoints the disaster as a natural event which exposes vulnerabilities through losses and destruction. If developing nations exposed to natural hazards are willing to promote a more sustainable development, new policies regarding development including disaster reduction will have to be implemented, so that such societies experience fewer losses when such natural phenomena manifest themselves.

Initial efforts at systematizing poverty, development, disasters and their causes have led to a variety of concepts and frameworks. Nevertheless, the use of the same words with different meanings by research and academic communities is leading to a lack of consensus which is necessary to advance on the issue of disaster reduction. A case in point is the use of the term **vulnerability**, which can span from the notion of the predisposition of a system to be affected or damaged by an external event at a certain instant of time to the notion as a residue of potential damages which cannot be targeted through the implementation of typical measures; or as conditions of incapacity to cope with disasters once they have taken place.

In the framework proposed by the scientific community under the umbrella of the *International Strategy for Disaster Reduction* (ISDR) and its predecessor, the *International Decade for Natural Disaster Reduction* (IDNDR), the term **risk** is defined as the "probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions" (ISDR, 2004:16). Vulnerability is generally perceived as the predisposition of societies to be affected and the incapacity to cope with disasters; and **hazard**, as the probability or possibility that an external event manifests itself in a certain geographical area within a certain interval of time. Hazards can be classified as **natural** in the case of earthquakes, volcanic eruptions or hurricanes; **technological** in the case of explosions, spills, and release of toxic chemicals, and as **social** or **human-induced** in the case of civil riots, or terrorist attacks. Finally, a new emerging class of hazards, denoted as **socio-natural**, encompasses those hazards which are being created or enhanced as a result of human action: climate change as a result of agricultural fires, burns and gaseous industrial emissions; landslides due to deforestation of mountains and high-sloped hills, and salinisation as a result of poorly designed irrigation of soils are typical examples.

1.1 Risks: Paths to Disasters

In basic terms, disasters manifest pre-existing conditions within the social, economic, physical, and environmental fabrics of a society. Infrastructure, services, organisations from the simplest to the most complex kind, and diverse systems are prone to be affected by a triggering event which could be associated with a natural phenomenon such as an earthquake, a flood, a landslide; or with a technical event such as an explosion, a fire, a spill, etc. A conclusion to be derived from the previous comments is the fact that a disaster is preceded by at least two predispositions: the possibility that the triggering event takes place, usually called a hazard at this potential state; and a pre-existing vulnerability; the pre-disposition of people, processes, infrastructure, services, organisations, or systems to be affected, damaged, or destroyed by the event.

Figure 1: Risk as a dynamical process, increasing as time elapses due to various social processes

A mathematical expression for risk in terms of hazards and vulnerabilities is represented as follows:

Risk = Hazard ¤ Vulnerability [1]

where ¤ represents the function that describes the combination between the hazard and the vulnerability. An example of such a function is the simple product, as proposed by ISDR (2004):

Risk = Hazard x Vulnerability [2]

Alexander (2000: 10) defines **risk** as "the likelihood, or more formally the probability, that a particular level of loss will be sustained by a given series of elements as a result of a given level of hazard". **Total risk** would then consist of the sum of predictable casualties, damages and losses, represented via the equation:

Total Risk = (Σ elements at risk) x Hazard x Vulnerability [3]

Recent publications define risk incorporating such terms as *Coping Capacity*, *Exposure*, and *Deficiencies in Preparedness*. For example, one typical relation employed by many agencies is:

$$\text{Risk} = \frac{\text{Hazard x Vulnerability}}{\text{Coping Capacity}} \quad [4]$$

In this context, **Coping Capacities** refer to the means by which people or organisations use available resources and capacities to face adverse consequences related to a disaster. In general, such capacities involve management of resources before, during, and after the disaster.

An interesting formulation concerning vulnerability has been proposed by *Disaster Reduction Institute* (DRI) in a report to the *Department For International Development* (DFID) of England (White et al., 2005). In this formulation, vulnerability itself is seen as a combination of Exposure, Susceptibility, and Coping Capacity:

$$\text{Vulnerability} = \frac{\text{Exposure x Susceptibility}}{\text{Coping Capacity}} \quad [5]$$

In contrast to the three previous models, the author has defined the following relation for risk (Villagrán, 2001):

Risk = Hazard x Vulnerability x Deficiencies in Preparedness [6]

In this relation, **Deficiencies in Preparedness** refer to those pre-existing conditions which inhibit an institution, a community, a society, or a country to respond in an effective and opportune fashion once the event is triggering the disaster to minimize its impacts, in particular the loss of lives. Such deficiencies would include the lack of emergency committees and emergency plans, the lack of early warning systems, and related measures.

Dilley et al. (2005) as well as other authors represent risk as the combination of three components: *hazard, exposure*, and *vulnerability*. In this context vulnerability is an intrinsic characteristic of people, infrastructure, economically and environmentally important land uses while the hazard is related to magnitude, duration, location, and timing of the event. In this case, the relation between risk, hazard, vulnerability, and exposure is represented as follows:

Risk = Hazard x Exposure x Vulnerability [7]

Hahn (2003), using the terms hazard, vulnerability, exposure, and coping capacities has developed a model in which risk is represented via the formula:

Risk = Hazard + Exposure + Vulnerability - Coping Capacities [8]

Regardless of the model employed to represent risk, the end result should be the same. As expressed by ISDR.

> Risk should represent the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (ISDR, 2004:16).

Considerable research into hazards has been carried out by the natural sciences community, and vulnerability is being researched in a more holistic way by researchers worldwide. However, there is no consensus on how to measure any of the components thus far. The assessment of risk itself is rather complex, as the intrinsic components need to be assessed individually and then combined through some kind of algorithm to produce the expected outcome.

This document has been elaborated with two purposes: presenting different views on vulnerability stemming from different experts and examples of methods for vulnerability assessment that have been developed by institutions and researchers in different regions of the world. The document is intended to provide a comparative and systematic introduction to the complex notion of vulnerability, and continues with the presentation of several methods to assess vulnerability at different levels or scales, spanning from the household level to the level of countries. It concludes with a discussion on the dynamical aspects of vulnerability, and relations with other quantities such as coping capacity and resilience. As such, it is intended for graduate students and professionals from different disciplines who are entering this field of disaster-risk reduction.

2. The Many Faces of Vulnerability

As in the case of risk, vulnerability is a term used by distinct groups with different meanings. Views on vulnerability stem from research groups and professionals in:

- *Academia;*
- *Disaster management agencies;*
- *The climate change community; and*
- *Development agencies.*

The different views on vulnerability arise as a consequence of the needs confronted by each particular group to address particular issues of the potential impacts of disasters. Academia is interested in analyzing all issues pertaining to the term, from social, anthropologic, economic, environmental, to technical or engineering points of view with the purpose of characterizing it to promote awareness on the subject and to provide policy advice to governments and development agencies. In contrast, disaster reduction and development agencies, which are interested in reducing it, tend to simplify the term to practical levels which allow such agencies to assess it as an initial means to reduce it. A literature review regarding vulnerability reveals that the term has been used in many different contexts by many different authors, demonstrating the fact that the field is still "unsettled". As stated by Alwang et al. (2001) and by Brooks (2003) the literature contains many terms whose relationships can at times be unclear, and in some cases the same terms may have different meanings. In the literature one can find different notions regarding how vulnerability has been perceived:

1. *As a particular condition or state of a system before an event triggers a disaster, described in terms of criteria such as susceptibility, limitations, incapacities or deficiencies e.g. the incapacity to resist the impact of the event (resistance) and the incapacity to cope with an event (coping capacities);*
2. *As a direct consequence of the exposure to a given hazard; and*
3. *As the probability or possibility of an outcome of the system when exposed to an external event associated with a hazard, expressed in terms of potential losses such as fatalities or economic losses, or as the probability of the person or a community reaching or surpassing a certain benchmark such as the poverty gap.*

Combinations of these three notions are also found in the literature. The use of the term vulnerability in the context of natural disasters dates back to the early 70s. In 1972 the Office of Emergency Preparedness of the Executive Office of the President of the United States presented a report to the Congress of this country in which vulnerability is recognized as the predisposition of people, communities or larger jurisdictions, and of sectors such as economy, agriculture, and infrastructure to be affected by a natural disaster (OEP-EOP, 1972). While the document stresses the importance of recognizing hazards and vulnerabilities as factors leading to disasters, the document does not provide an explicit definition on vulnerability. However, the document does recognize vulnerability in relation to the different types of hazards which manifest themselves within the United States.

In 1989 R. Chambers (1989) introduced a more systematic definition for vulnerability targeting communities and their livelihoods. In his view, vulnerability is basically the "exposure to contingencies and stresses and the difficulty which some communities experience while coping with such contingencies and stresses" (Chambers, 1989: 1). Chambers then proposed external and internal sides to vulnerability:

- ***External**: related to exposure to external shocks and stresses; and*
- ***Internal**: associated with defencelessness, incapacity to cope without damaging losses.*

In this context, **shocks** are impacts related to very sudden and sometimes unpredictable events such as floods, earthquakes, fires, epidemics, etc. In contrast, **stresses** refer to pressures which are typically continuous, cumulative, and predictable, such as seasonal shortages, declining resources, etc. In addition, Chambers stressed the fact that vulnerability should not be considered as equal to poverty but related. He proposed the view of vulnerability as the inverse of security. And according to him, at the livelihood level, vulnerability can be related to assets and how people manage them. In this context, assets such as labour and human capital, while vulnerable, are the key to allowing people to cope with such shocks and stresses.

In 1993, Watts and Bohle (1993; Bohle, 2001) expanded the ideas of Chambers, still keeping the structure of external and internal sides of vulnerability. In this view, vulnerability is a multi-layered and multi-dimensional social space defined by the political, economic, and institutional capabilities of people in specific places and times.

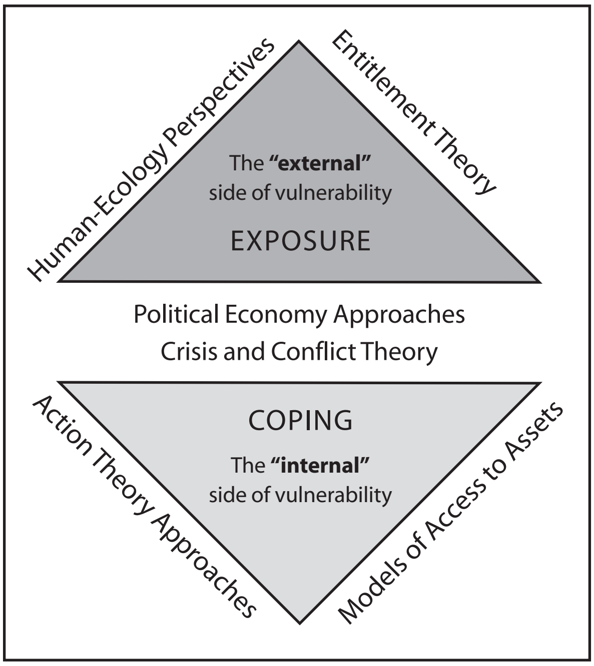

Figure 2: The two sides of vulnerability according to the Bohle model

The relation between the two sides of vulnerability in Chamber´s and Bohle´s models continues to be the same: the external side is related to exposure while the internal side is related to coping capacities (Bohle, 2004). The **exposure** side of vulnerability which is basically referring to the exposure to stresses is influenced by:

➢ *Human-Ecological Perspectives*, which target population dynamics and capacities to manage the environment;

➢ *Entitlement Theory*, which relates vulnerability to the incapacity of people to obtain or manage assets via legitimate economic means; and

➢ *Political economy approaches,* which relate vulnerability to the exposure of some groups to social inequalities and to the control of assets by some upper classes, leading to struggles, including struggles between government and some groups of people.

In contrast, the **coping** side is influenced by:

➢ *Action theory approaches,* which span the means and ways used by the people to act, either by free will or as a result of societal, governmental, or economic constraints;

➢ *Models of access to assets*, which allow people to mitigate their vulnerability via access to assets of different nature; and

➢ *Crisis and conflict theory*, which focuses on the control of resources and assets, the capacity to manage crisis situations, and the resolution of conflicts.

As in the case of the Chambers model, Bohle´s model also recognizes the relationship between vulnerability, coping capacities and assets (economic, socio - political, infrastructural, ecological, and personal). The more assets people control, the less vulnerable they are because such assets increase their capacities to cope with risks and disasters. Therefore, Bohle concludes that the most vulnerable people usually only control social assets and so the question of control over assets becomes a relevant issue especially in case of crisis and conflicts. The strength of this model relates to its capacities not only to explain vulnerability, but its causes and origins.

Alexander (2000: 12) defines vulnerability as „the potential for casualty, destruction, damage, disruption or other forms of loss with respect to a particular element". In addition, Alexander recognizes that vulnerability can be enhanced or reduced depending on the type of action taken with respect to it, and its perception is an important factor to consider. In fact, Alexander makes an explicit connection between vulnerability and the research conducted to assess it. **Deprived vulnerability** arises when research results are not disseminated nor used, while **wilful vulnerability** arises when such knowledge on vulnerability is deliberately ignored. In this respect, he comments that **pristine vulnerability** arises as a result of the lack of experience regarding hazards. These views would lead to a proposal of vulnerability reflecting the lack of use of research information. In contrast, he points out to the notion of **primary vulnerability** in relation to the high susceptibility to catastrophic damage, while **secondary vulnerability** is related to the lack of appropriate capacities and resources which can lead to a poor or deficient response in case of a disaster. In this case vulnerability relates to susceptibilities or incapacities, rather than the lack of use of knowledge.

A simple way to address vulnerability has been proposed by *the International Strategy for Disaster Reduction*. Vulnerability is defined by ISDR as „the set of conditions and processes resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to the impact of hazards" (ISDR, 2004: 16). The physical factors encompass susceptibilities of location and the built environment, and can be represented through factors such as population density, remoteness of a settlement, location, and construction materials and techniques employed to build infrastructure. The social factors are related to social issues such as levels of well-being of individuals, gender, health, literacy, education, the existence of peace and security, access to human rights, social equity, traditional values, beliefs, and organisational systems. In contrast, economic factors are related to issues of poverty and can include levels of individual, community, and national economic reserves, levels of debt, degrees of access to credits, loans, and insurance, and economic diversity. Finally, environment factors include natural resource depletion and degradation. Some of the elements that can influence environmental vulnerability are exposure to toxic and hazardous pollutants, reduced access to clean air, water, and sanitation, as well as inappropriate forms of waste management.

Pelling (2003) defines vulnerability as *the exposure to risk and an inability to avoid or absorb potential harm*. In this context, he defines **physical vulnerability** as the vulnerability of the physical environment; **social vulnerability** as experienced by people and their social, economic, and political systems; and **human vulnerability** as the combination of physical and social vulnerability.

Within the academic community devoted to research regarding natural disasters in Latin America, Cardona (2003; 2004a) and other members of LA RED[1] have proposed vulnerability as the predisposition of an element, a system, or a community to be affected or susceptible to damage. In the context of risk, vulnerability is then defined as the internal risk factor in contrast to hazard which is defined as the external risk factor. For Cardona vulnerability originates as a consequence of three factors:

- *Physical fragility or exposure*, linked to the susceptibility of human settlements to be affected by natural or social phenomena due to its location in a hazard-prone area;
- *Socio-economic fragility*, linked with the predisposition to suffer harm due to marginalization, social segregation in human settlements, and due to poverty and similar factors; and
- *Lack of resilience,* related to the limitations of access and mobilization of resources, and incapacity to respond when it comes to absorbing the impact of a disaster. It can be linked with under-development and the lack of risk-management strategies.

G. Wilches-Chaux (1993: 17) proposed the notion of vulnerability as "the incapacity of a community to absorb, via auto-adjustments, the impacts of a change in the environment". In other words, its incapacity to adapt to such a change. He proposes several types of dimensions of vulnerability: **physical, environmental, economic, social, political, technical, ideological, ecological, institutional, educational, health-related, cultural,** etc.

A. Lavell (2004) conceives the notion of two levels of risk and hence vulnerability: **exceptional vulnerability** associated with exceptional events, and **everyday vulnerability**, associated with permanent conditions of poor people (health problems, malnutrition, unemployment, income deficits, illiteracy, social and domestic violence, alcoholism, etc.) which limit their development. Such two-level vulnerability has also been proposed by Watts and Bohle (1993) in terms of a **base-level vulnerability** and a **recurrent vulnerability**.

1 LA RED: Red de Estudios Sociales en Prevención de Desastres en América Latina

A comprehensive notion of vulnerability has been proposed by Wisner (2005a: 1):

> By vulnerability we mean the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (an extreme natural event or process). It involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discrete and identifiable event (or series or ´cascade´ of such events) in nature and in society.

An important aspect to consider regarding vulnerability is the level at which it is being assessed. As Wisner points out (Wisner, 2005b), vulnerability can be conceived as a quantity having a "fractal" nature. Vulnerability in the local scale dealing with a single household is manifested in a totally different fashion then the vulnerability of a community or a county. While aggregation of individual vulnerabilities at one level is necessary to quantify vulnerability at an upper level, aggregation alone does not reflect the complete vulnerability at this upper level. Additional factors must be integrated to complete the full view of vulnerability at upper levels.

Therefore, one possible way to systematize the various notions and aspects related to vulnerability as addressed by the academic community could be carried out via the definition of dimensions of vulnerability along three basic axes:

- ***The axis of Internal and External Conditionals:*** spanning susceptibility and exposition to shocks and stresses as external conditionals and the incapacity to foresee, to resist, and to cope with the stresses and shocks as internal conditionals;
- ***The axis of General Topics:*** this dimension incorporates the view of vulnerability differentiated in terms of social, economic, physical, environmental, political, and other topics; and
- ***The axis of Geographical-Political Level:*** spanning from the human being and the single household unit to the national level including the local or community level, the municipal or district level, and the state or province level. The evaluation of vulnerability across this dimension is one more related to public policy, as political administrations in different levels are responsible for the administration of such levels.

Within the context of the small island states, vulnerability is defined as the disposition of these countries to be harmed by external economic forces or environmental hazards due to their intrinsic conditions related to small geographical size and remoteness. The *Commission for Sustainable Development of the Department of Economic and Social Affairs of the United Nations* (CSD-UN-DESA) has recognized the need to address economic, social, and environmental vulnerabilities, and has promoted the development of an index of vulnerability for these small island states (UN-DESA, 2004). Several consultants such as Professor L. Briguglio (Atkins et al., 2001; Briguglio, 2003; 2004) and M. Pelling and J. I. Uitto (2001) have embarked on the development of such indices. In this case **economic vulnerability** is linked to the following parameters:

- *Small size, which inhibits countries from taking advantage of the economics of scale;*
- *Economic openness, which means lack of control of issues managed at a global level;*
- *Export concentration narrowed to a few, selected products;*
- *Dependence on strategic imports, particularly energy and raw materials;*
- *Insularity* and *remoteness*, *leading to high transport costs; and*
- *Fragility of their ecosystems, which is exacerbated by natural phenomena.*

Vulnerability is then conceived as a particular state of the country or state at any given instant of time, characterized through particular conditions or limitations via indicators.

R. Pizarro (2001: 11) of the *Economic Committee for Latin America and Caribbean* (ECLAC) defines **social vulnerability** in terms of two components: "the insecurity and defenselessness experimented by communities, families, and individuals in their livelihoods as a consequence of the impact of a socio-economic event of traumatic character; and the second component is the management of resources and strategies which are utilized by these communities, families, and individuals to cope with the effects of this event". In addition to social vulnerability, political and institutional vulnerabilities have also been addressed by ECLAC and the Inter American Development Bank. In this context, **vulnerability** (ECLAC-IADB, 2000: 1) is defined in general terms as "the probability of a community, exposed to a natural hazard, given the degree of fragility of its elements (infrastructure, housing, productive activities, degree of organization, warning systems, political and institutional development), to suffer human and material damages". **Political vulnerability** (ECLAC-IADB, 2000: 3) is understood in terms of "the weakness of the democratic system, with its negative effects on the efficiency of public policies, the legitimacy of the government action, limited participation of citizens and the private sector in national efforts, linkage with local governments and civil organizations, the handling and management of emergencies, processing of citizen's demands and needs, and the capacity to meet them".

In contrast to this view, researchers focusing on poverty relate vulnerability to the probability of a person or a household to fall below a socially accepted norm such as the poverty line (Alwang et al., 2001). Stated in this fashion, vulnerability is referred with respect to a benchmark such as the level of poverty within a given community and is related to the exposure to external factors, which could be related to shocks and stresses as proposed by Chambers and others, or to hazards as proposed by the disaster management community. It is important to note that this definition of vulnerability is based on a benchmark: i.e. reaching a specific type of state or an outcome. In contrast to the models of Chambers and Bohle this model does not require the inclusion of coping incapacities within the notion of vulnerability.

The *World Food Programme* (WFP, 2002: 2) defines vulnerability as "the probability of an acute decline in access to food, or consumption, often in reference to some critical value that defines minimum levels of human well being". In this context, vulnerability is a result of the combination of exposure to natural hazards, economic processes such as price fluctuations; social processes such as civil unrest, and similar processes which reduce the capacity of populations to cope with such hazards. It is interesting to note that in this approach vulnerability is defined in terms of a benchmark, like in the model devoted to poverty. Nevertheless, coping incapacities are not seen as part of vulnerability, but as one of its causes.

Within the environmental community, the environment is perceived as vulnerable with respect to both extreme natural events and human action. In this context, vulnerability refers to the extent to which the environment is prone to damage or degradation. Damage can refer to loss of diversity, extent, quality, and function of ecosystems. The *International Panel on Climate Change* (IPCC) describes vulnerability as:

> The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes". Vulnerability is a function of the character, magnitude, and rate of climate variation to which the system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001: 165).

However, it is not clear what the meaning of the term "to cope with" is, as it could mean capacities to adapt before or after the presence of such climate change variability and extremes.

Within the context of climate change, Adger (1999: 252) defines **social vulnerability** as "the exposure of groups of individuals to stress as a result of the impacts of climate change and related climate extremes". Stress encompasses the disruption of livelihoods of individuals or groups and forced adaptation to the changing physical environment. Social vulnerability can then be disaggregated into **individual vulnerability** related to individuals, and **collective vulnerability** related to a nation, a region, or a community.

Furthermore, as expressed by O´Brien et al. (2004), Kelly and Adger (2000), even within the climate change community there are two contrasting interpretations concerning vulnerability. The ***end point*** interpretation which proposes vulnerability as *the residual of climate change impacts minus adaptation, that is, the remaining segments of the possible impacts of climate change that are not targeted through adaptation*. The contrasting interpretation stated as the **starting point** views vulnerability as a general characteristic of societies generated by different social and economic factors and processes. The two views incorporate impacts on adaptive capacity and their roles. In the "end point" view, adaptive capacity determines the extent of vulnerability, while in the "starting point" view, vulnerability determines the way in which adaptive capacity must be addressed. In the "end-point" interpretation, the European heat wave must be modeled as impacting the elderly who, despite whatever measures are in place at the private or public level to mitigate the heat wave, still possess some kind of vulnerability, in this case not being able to cope further with such a heat wave with the resources at their disposal. In the "starting point", elderly citizens of all types are considered as vulnerable due to aging conditions and more pre-disposition to diseases of many kinds. In contrast, young people are less vulnerable due to their healthier status in general.

Füsel et al. (2002) present a summary of the evolution of the conceptual framework regarding vulnerability from the point of view of the climate change community and recognize that the notion of risk as used by the disaster-risk community could be equivalent to the notion of vulnerability as proposed by the climate change community. As pointed out by these researchers, the disaster management community makes a separation between the internal component of risk (vulnerability) and the external component (hazard). In contrast, the definition of vulnerability within the climate change community takes into account the hazard and the exposure to it as some of its main components, and excludes the notion of external and internal factors, considering from the start that anthropogenic actions are indeed affecting the environment, and hence, some of the hazards.

Kasperson et al. (1995) defined vulnerability as a product of three dimensions: *exposure*, *resistance* (the ability to withstand impacts), and *resilience* (the ability to maintain basic infrastructures and to recover from losses). These dimensions incorporate the costs of recovery and the role of social relations and actors at various levels in determining the conditions of exposure.

In contrast, Turner and other researchers (Turner et al., 2003: 8074) have proposed the notion of vulnerability as "the degree to which a system, sub-system, or system component is likely to experience harm due to exposure to a hazard, either a perturbation, or stress/stressor". Perturbations are rapid onset events which commonly evolve outside the region or location in question. Stress is a slow but continuously increasing pressure (soil degradation, drought, etc). Stressors (the sources of stress) often reside within the system. **Risk** is defined as *the probability and magnitude of consequences after a hazard (perturbation or stress)*. The reasoning behind this modern approach, as presented by these authors is the fact that typical risk models based on hazard and vulnerability do not address:

- *The way in which the system amplifies or attenuates the impacts of the hazard;*
- *Distinctions among exposed sub-systems and components that lead to significant variations in the impacts of the hazards; and*
- *The role of political economy, especially social structures and institutions, in shaping differential exposure and impacts.*

In this particular framework the dimensions of vulnerability are: *Exposure*, *Sensitivity*, and *Adaptation / Resilience.*

The model also incorporates multiple disturbances which emanate from the human and natural environments. Stresses and perturbations are manifested via stressors. Examples of human stressors are: *macro – political economy*; *social – structural dynamics*; *globalization, etc.*

Natural stressors can be the *state of bio-sphere* or *global environmental change.*

Sensitivity is related to existing (and dynamic) conditions related to *socio – economic* and *environmental - ecological* areas.

In this model stresses and perturbations generate stressors, and can also have an impact via exposure.

In a recent publication prepared by the *Bureau of Crisis Prevention and Recovery of the United Nations Development Programme*, (UNDP-BCPR, 2004: 136), human vulnerability is defined as "a condition or process resulting from physical, social, economic, and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard". The method employed to measure human vulnerability categorizes vulnerability in terms of the outcome of recent historical disasters.

In addition, within the Hazard Management Group of the World Bank, Dilley et al. (2005: 24) use the term vulnerability to represent "the apparent weakness of the physical and social systems to particular hazards". The **physical system vulnerability** is defined in terms of fragility curves for infrastructure and quantified as a function of hazard intensity, while **social vulnerability** is mentioned as being a complex function of social, economic, political, and cultural variables. The numerical estimation of vulnerabilities is made in terms of fatalities or economic losses.

Another model regarding risks and vulnerabilities has been developed by Birkmann and Bogardi (2004) at UNU-EHS. The BBC model is based on the model of Cardona (2004b) (hence the acronym BBC) and incorporates the aspects of coping capacities and exposure originally proposed by Chambers and Bohle within vulnerability. The three types of vulnerabilities presented in the BBC model: economic, social, and environmental, are influenced by both exposure and coping capacities, as can be seen in figure 3. The primary focus

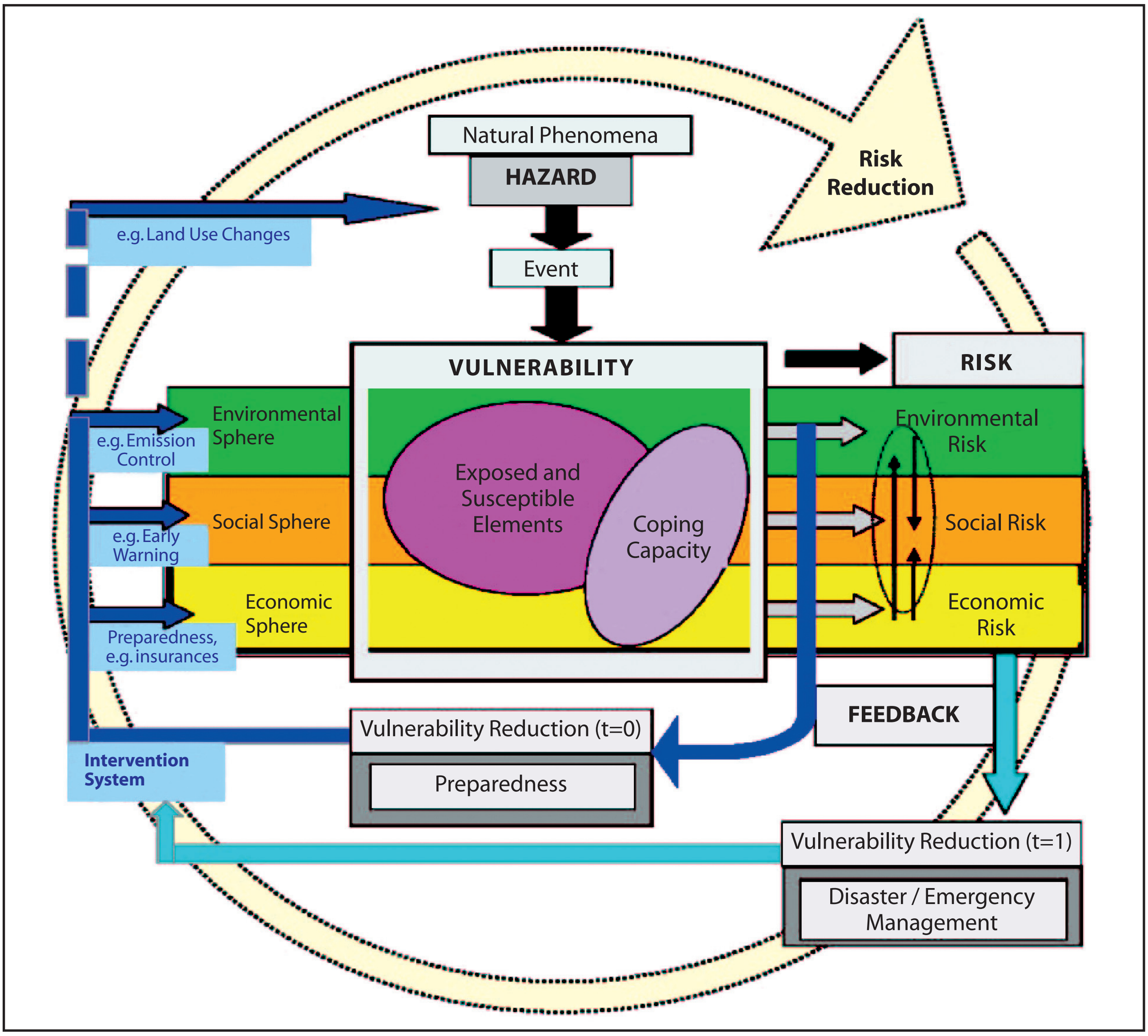

Figure 3: BBC model incorporating exposure and coping capacity in to vulnerability (Birkmann, 2005)

on social, economic and environmental issues represents the close link of the model to the debate of sustainable development.

The underlying understanding of the vulnerability of the socio-economic system (anthroposphere) on the one hand and the environmental vulnerabilities on the other hand as well as assessing them simultaneously shows a close link to the debate of vulnerability within the climate change community. In contrast to the ISDR model, this model does not incorporate explicitly physical vulnerability which leads to economic losses, and can lead to fatalities (collapse of structures).

Another approach to vulnerability has been proposed by Polsky et al. (2003: 2) who relate **global change vulnerability** with "the likelihood that a specific coupled human-environment system may experience harm from exposure to stresses associated with the alterations of societies and the biosphere, accounting for the process of adaptation". In this context, the environment and human systems are considered as a single entity which is vulnerable with respect to global climate change in terms of three characteristics: *exposure*, *sensitivity*, and *adaptive capacity*. As it can be seen, in this approach vulnerability also incorporates issues regarding adaptation.

Analyzing the literature one finds two discerning facts regarding views on vulnerabilities with respect to their dependency on the type of hazard. In one point of view, vulnerability does not depend on the type of hazard in question and can be related to issues associated with underdevelopment (poverty, power relations, access and control of assets, societal structures, insecurity, etc.), and in the contrasting point of view it does.

Models proposed by Chambers, Bohle, Briguglio, Alwang, and Pelling are examples associated with the first point of view. Models by UNDP-BCPR, World Bank, and the author are examples of the second point of view. Among the examples associated with the second view one can mention the vulnerability of infrastructure with regards to earthquakes and droughts. The impact of drought on infrastructure is negligible in comparison to that related to earthquakes. However, the impact of droughts on agriculture is vast and can be minimal in the case of earthquakes.

An additional issue regarding how vulnerability is defined is related to those factors which are included as part of it, such as coping capacity, resistance, resilience, exposition, sensitivity or susceptibility. For example, Blaikie et al. (1996) have proposed a Pressure and Release Model. The model defines vulnerability as *the characteristic of a person or group of persons in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard*. In addition, they propose the **progression of vulnerability** associated with root causes, dynamic pressures, and unsafe conditions (Blaikie, 1996; Wisner et al., 2004):

- *Root causes* are associated with economic, demographic, and political processes within a society. These reflect the exercise and distribution of power in a society*;*
- *Dynamic pressures,* which channel the root causes into particular forms of unsafe conditions, among them population growth, rapid urbanization, deforestation and decline in soil productivity, as well as the lack of training, appropriate skills, and local conditions of markets and policies;
- *Unsafe conditions,* which are manifestations of vulnerability in time and space in conjunction with the hazard in such issues as fragile local economy, lack of disaster planning and preparedness, and fragile environment.

The strength of this approach resides on its capacity not only to define vulnerability, but to explain its generation as a three step process. Figure 4 presents a diagram of this *Pressure and Release Model*.

In the *Capacity and Vulnerability Analysis* (CVA) approach (CIDA, 1996), vulnerabilities are seen as the long-term factors that affect a community's ability to respond to events or make it susceptible to disasters. The CVA approach, now employed by the Federation of the Red Cross and Red Crescent Societies, encompasses three areas: physical/material; social/organisational; and motivational/attitudinal. The framework has been adapted as a simple matrix or chart as shown in figure 5. The physical/material area includes land, climate,

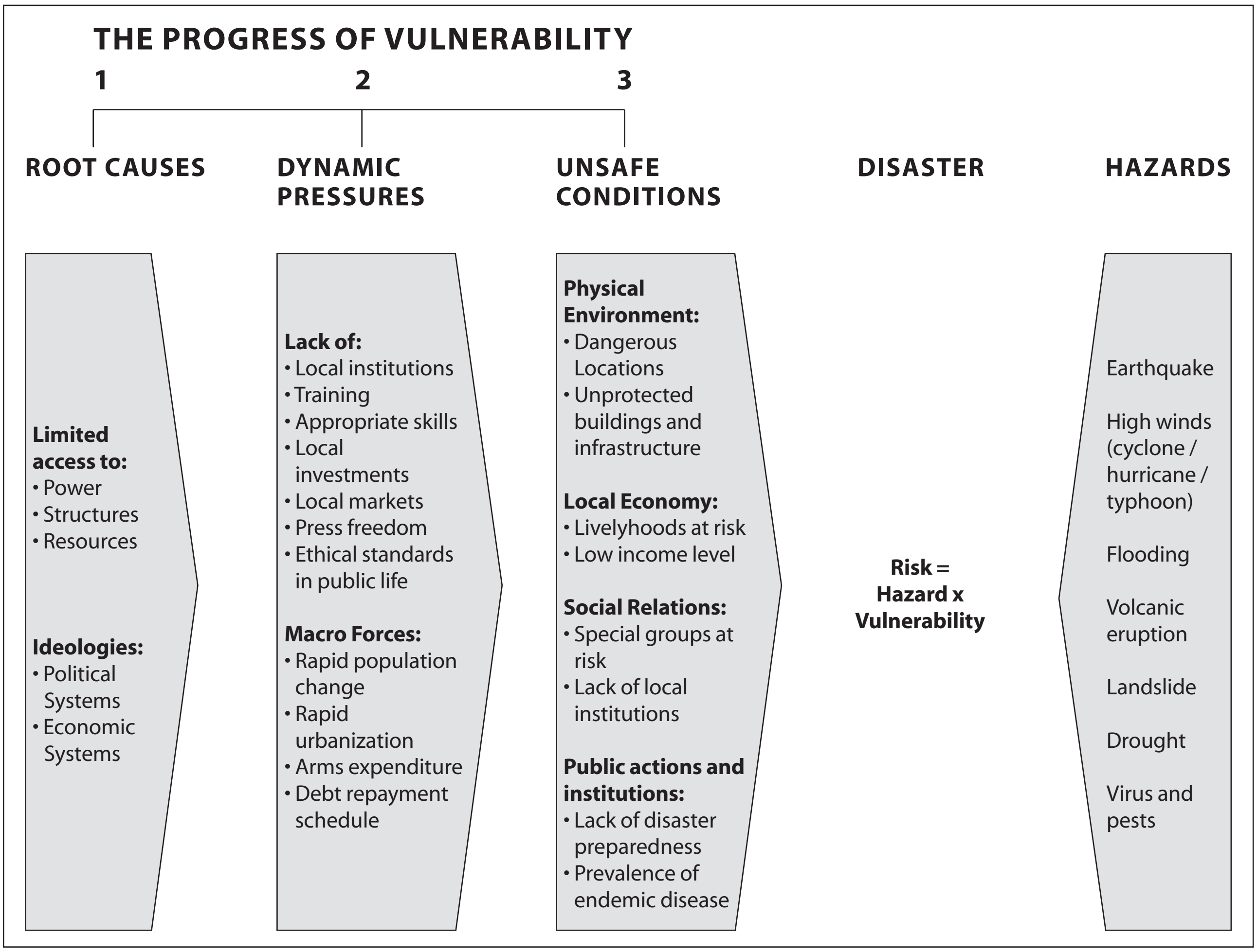

Figure 4: The Pressure and Release model proposed by Blaikie at al. (1996). Root causes lead to dynamic pressures, which lead to unsafe conditions. Risk is the combination of hazard and vulnerability (Wisner et al, 2004).

environment, health, skills, and labour, infrastructure, housing, finance and technologies and can be associated with poverty. The social/organizational area includes formal political structures and the informal community networks. It relates to how a society is organised and how it manages its internal conflicts. Finally, the motivational/attitudinal area focuses on how people view themselves and their ability to affect their environment. It is interesting to note the contrasting viewpoints on vulnerability from the poverty and *World Food Programme* and this view presented in the CVA mode. In the model of the *World Food Programme*, coping incapacities can lead to vulnerabilities. In contrast, in this CVA model, vulnerabilities are related to those factors which lead to coping incapacities.

CVA Matrix

	Vulnerabilities	Capacities
Physical / Material What productive resources, skills, and hazards exist?		
Social / Organizational What are the relations and organisations among the people?		
Motivational / Attitudinal How does the community view its ability to promote changes?		

Figure 5: The Capacity and Vulnerability Assessment Matrix

Within the *German Technical Cooperation Agency* (GTZ, 2004: 10), vulnerability denotes:

> the level of possible loss or injury or damage to humans, objects, buildings and the environment which can result from the natural hazard. Vulnerability expresses the susceptibility and predisposition to be affected or suffer injury or damage. It also captures people's inadequate options or ability to protect themselves against possible damage or recover from the consequences of natural phenomena without outside help.

Within this framework, vulnerability is a hazard dependent factor that is caused by three broad and mutually reciprocal factors:

- *Political institutional factors* associated with incommensurate legislation, such as the lack of land-use planning regulations, underdevelopment of the democratic system, lack of coordination among government institutions, corruption, and lack of instruments to spread financial risks;
- *Economic factors* such as the lack of economic resources to implement preventive measures, poverty, economic dependence on a few products and the neglect of the impact of disasters on economic activities; and
- *Socio-cultural factors* such as lack of education, religious fatalism, traditions regarding land-use and land-management, and deficiencies in social networks to negotiate competing interests in search of greater levels of general welfare.

This model by GTZ is similar to the CVA in its view of vulnerability as an incapacity to minimize the impacts of an event and to cope with it.

An emerging idea to consider regarding intrinsic properties of vulnerability is the notion that the degree of vulnerability of an infrastructure, a community, a society or a process should be related to the magnitude of the hazard in question as expressed by Cardona (2003). For example, in the case of earthquakes, most structures are not vulnerable to tremors, while, most structures are vulnerable to very large magnitude earthquakes. In this case, one could interpret this dependency of vulnerability on the magnitude of the hypothetical event.

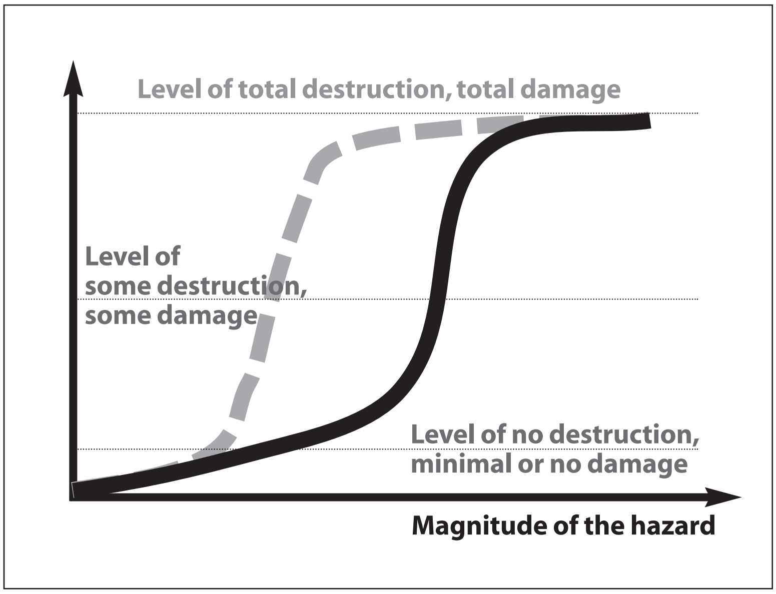

Figure 6: A representation of expected degree of damage and its variation in magnitude with respect to the magnitude of the hazard.

This idea is expressed graphically in figure 6. For very low magnitude events, the vulnerability is small, expressing the fact that probably no damages or only minor damages are to be expected should the event of this small scale occur. As the magnitude of the event increases, vulnerability also increases. For very large magnitude events, vulnerability is very high, implicating almost total destruction or damage and certainly difficulties in coping with such major damages or destruction. Figure 6 represents two possible examples, one case where considerable damages can already be expected for medium intensity events (dashed curve on the left), and the other case, where it takes a very large magnitude event to provoke damages as this represents a more resistant process or structure (solid curve on the right). The following examples will make this issue more evident.

BOX 1:

Ash deposits during volcanic eruptions and slanted roofs:

Volcanic eruptions are usually accompanied by the expulsion of ashes, which, under the influence of prevailing winds, can be deposited several kilometres away from the active cone. The structural or physical vulnerability of a house with respect to the deposition of ash on its roof is related to the inability of such a roof to support the additional load of the ash deposited, which could lead to a collapse of the roof. A house with a minimally inclined roof, for example a 5 degree slope to manage rainfall, will possess a high vulnerability, as it cannot evacuate ashes in the same way under the action of gravity. In contrast, a highly inclined roof, with a 45 degree slope can, with the aid of gravity, evacuate ashes falling on it, inhibiting the accumulation of ashes on top of it. In either case, the deposition of a layer of ash up to 1 centimetre thick will cause no damage or provoke the collapse of such roofs. However, a deposition of a layer several decimetres thick can severely damage a low-inclined roof, while the highly-inclined roof is able to impede the accumulation of such a layer.

BOX 2:

Agriculture and drought:

Maize is a traditional crop in rural areas of Latin America, dating from many centuries. However, maize can be considered as a type of crop which requires a certain amount of water for it to yield a proper crop. In contrast, sorghum, another cereal, is a plant which requires less water for such a goal. In the event of a short lasting drought, sorghum plants will be less affected than corn plants. This is to say that given a hazard of this magnitude, maize is more vulnerable than sorghum. Nevertheless, a very long-lasting drought spanning many months will inhibit the growth of either maize or sorghum. At this high level of drought, practically all seasonal agricultural crops are vulnerable. In the case of figure 6, maize would be represented by the dashed curve, while sorghum would be represented with the solid curve.

In addition to infrastructure experiencing damages as a consequence of a natural event, many social processes and activities also experience similar results, which need to be understood, so that the proper measures can be designed and implemented to make them less vulnerable.

While the models presented thus far allow for a basic understanding of vulnerability and are useful for awareness purposes, their use to assess vulnerability are limited, as such models incorporate topics too broad to be handled, in particular social and economic aspects. In many cases vulnerability is defined as a combination of various components but there are no guidelines on how to assess each component individually, nor rules on how to link such components to gather a final figure of merit regarding vulnerability. Therefore, in order to advance on issues regarding the assessment of vulnerability, it is necessary to decompose it in a different way.

Taking into consideration ideas stemming from Latin America, the author (Villagrán, 2001) has proposed a framework to decompose vulnerabilities via analyzing how disasters can impact the various sectors which compose a society; typical **sectors** being: *housing, communications, education, health, energy, industry, commerce, finance, transportation, public infrastructure, environment*, *tourism,* etc. In addition, the framework proposes the differentiation within each sector in terms of six **components**: *physical, functional, economic, human condition/gender, administrative*, and *environmental*. These components are related to what other scientists have termed "susceptibilities". A third axis or dimension would cover the **scale of consideration** spanning from the human being level to the national level.

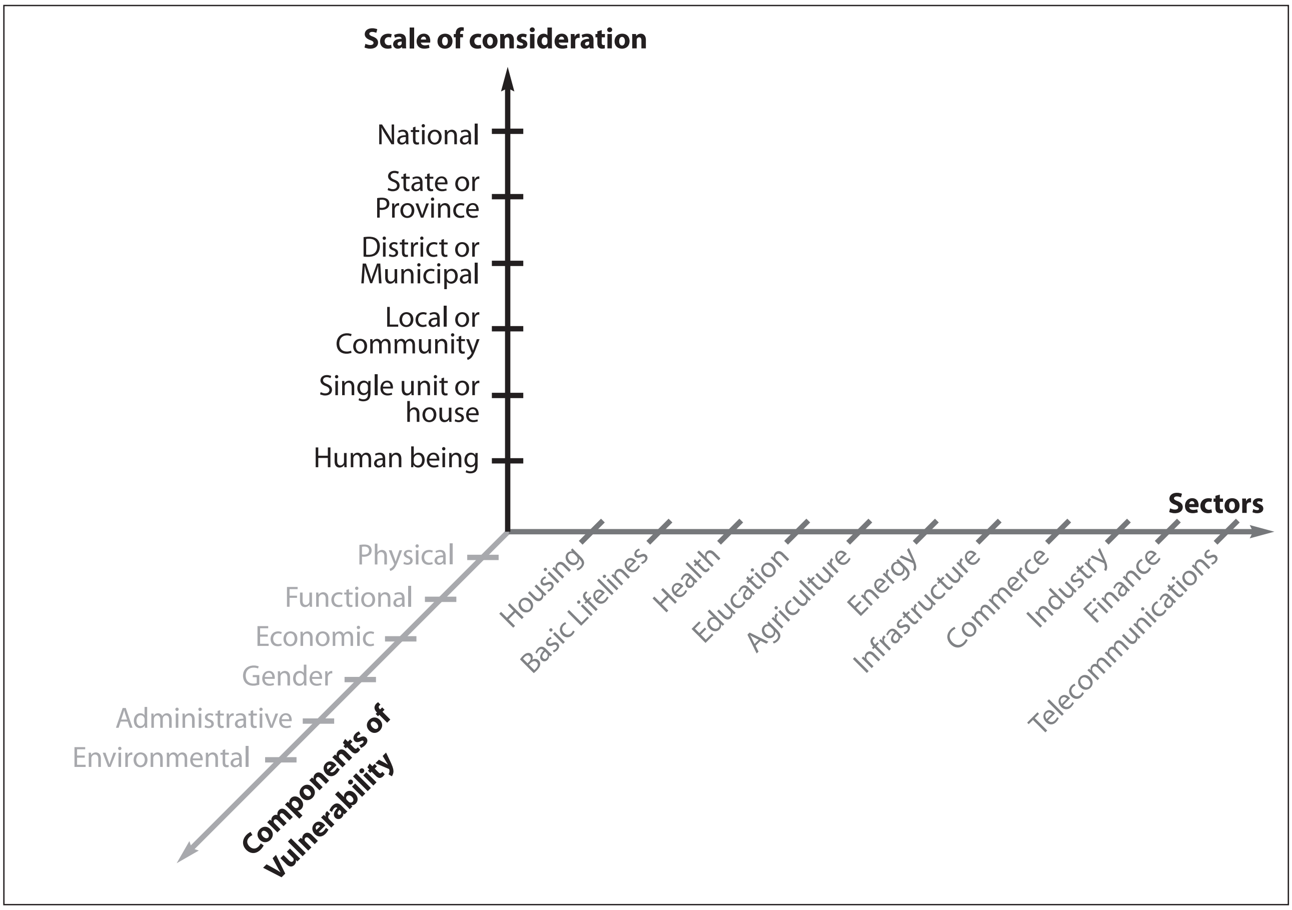

Figure 7: Framework for vulnerability introducing the notion of independent dimensions of scale of consideration, components, and sectors

The approach employing sectors has been proposed from the policy point of view because it promotes the assignation of responsibilities regarding the reduction of vulnerabilities to those private or public institutions in charge of each sector, whether these are government ministries or chambers of various kinds (chamber of commerce, industry, tourism, energy, etc.) and spans various political-administrative levels. For example, it is the responsibility of the Ministry of Education to assess and reduce the vulnerability of public education system at the national level. In contrast, it would be up to the principal of a local school in a community to manage the vulnerability of such a school, using resources at his or her disposal or requesting for this purpose whichever resources are required from the Ministry of Education. However, it is important to recognize that this model excludes coping incapacities and the incapacity to foresee vulnerabilities as part of the notion of vulnerability.

Vulnerability assessment within the context of the proposed sector-approach must start by defining which hazard is to be addressed, then the sector, subsequently the geographical level at which the assessment is being made, and finally the component of vulnerability being assessed. To assess the vulnerability one would then focus along the dimension of the following components:

- *The **physical** component relates to the predisposition of infrastructure employed by the sector to be damaged by an event associated with a specific hazard;*
- *The **functional** component relates to the predisposition of functions or services which are required for the sector to function properly, such as life-lines (energy, water, telecommunications, drainage, etc) and specific services to be damaged by an event associated with a specific hazard;*
- *The **human condition /gender** component relates to the presence of human beings and encompasses issues related to deficiencies in mobility of human beings associated with gender, age, or disabilities;*

- *The **economic components** are related to income or issues which are inherent to economics that are predisposed to be affected partially or totally;*
- *The **administrative** component relates to those issues associated with the management and execution of routine operations and how such administrative issues can be affected by an event; and*
- *The **environmental** component continues to relate to the interrelation between the sector and the environment and the vulnerability associated with this interaction.*

As stated earlier, the assessment of vulnerabilities must be carried out separately at different levels. For example, the vulnerability of a particular hospital requires the analysis of the structural components of the building; a functional vulnerability comprising elements which are essential to the functionality in relation to health functions and spans specialized medical equipment and processes such as the flow of gases, water, and electricity; as well as the storage of certain chemicals and medicines in controlled environments and the management of toxic waste for example. In the case of private health institutions, an economic vulnerability must be considered. In the case of a hospital the human condition/gender is an issue, especially due to the higher vulnerability of patients temporarily hospitalized whose mobility is restricted due to injury, treatment, or sickness; or the intrinsic vulnerability of infants and incapacitated people due to their lack of mobility while remaining in the hospital. Additional issues related to administrative /organisational processes, as well as functional relationships within different sections or departments are important to be considered (PAHO, 2000) and in extreme case issues related to environmental contamination related to the spill of particular chemicals, solid and liquid waste, particularly of the biological kind.

Within the health sector, the *Pan American Health Organization* (PAHO/WHO, 2000) classifies vulnerabilities in health facilities in three categories: **structural vulnerability,** in relation to buildings which are required for physical support; **non-structural vulnerability** comprising elements which are essential to the functionality in relation to health aspects. The third class is called **administrative /organizational vulnerability** and refers to the administrative processes, as well as functional relationships within different sections or departments.

Another modern approach regarding vulnerability is to think of a community or a society as a set of interconnecting systems. In this context, the system is composed of interacting elements where different processes are carried out using various types of resources. In this context, one must define the system through its components and interactions and determine how each element of the system, as well as the individual interactions, are vulnerable.

In conclusion, there are different ways to characterize vulnerability. However, there are standing issues which are difficult to resolve as they seem to be contradictory. Among these are:

- *The view of vulnerability as an intrinsic state of a system independent of the hazard versus the view of vulnerability depending on the type of hazard; and*
- *The view of vulnerability as an intrinsic state of the system (a single state of vulnerability due to its nature) or as a quantity that should be characterized as a function of magnitude of the hazard.*

3. Vulnerability Assessment

Vulnerability assessment constitutes its systematisation and evaluation in the contexts of a household, a livelihood, a group of people, a community, a province, a country; a sector or a system with respect to the different types of hazards. Once vulnerabilities have been systematized and evaluated; norms, regulations, and awareness programs can be designed and implemented to reduce such vulnerabilities and to minimize their future generation. A typical example along these lines is the establishment and enforcement of building codes to make infrastructure less vulnerable in many cities and countries where earthquakes are common. Building codes enforced by municipal governments have the goal of promoting a more sustainable development via minimizing the deviation of resources originally targeted for development to reconstruct infrastructure damaged in case of an earthquake. Other measures such as securing alternate, duplicate or triplicate and parallel means of carrying out a process could also be conceived to reduce existing vulnerabilities associated with systems. For example, the procurement of multiple and less vulnerable sources of income in areas prone to disasters could be a means to reduce economic vulnerabilities associated with some hazards.

As it has been stated in the previous pages, the literature is filled with notions about vulnerability emanating from different points of view and different agencies. However, the opposite is true when it comes to vulnerability assessment. In relation to the number of different definitions about vulnerability, the number of methods to assess vulnerability is very low. As a social concept, some social scientists and professionals even go as far as stating that it cannot be measured at all and that only proxies can be used to represent it. However, researchers around the world are developing and testing methods to either evaluate, or at least represent in some kind of fashion the degree of vulnerability of a system, a process, a community or an organisation. Such approaches narrow down the definition of vulnerability to a format that allows for its assessment using data available, or data that can be acquired by different means.

In the context of global change, Polsky et al. (2003) of the Belfer Center for Science and International Affairs within Harvard University have proposed an eight step method for vulnerability assessment. The eight steps are:

1. *Define the study area in tandem with stakeholders;*
2. *Become aware of the study area and its contexts;*
3. *Hypothesize who is vulnerable to what;*
4. *Develop a causal model of vulnerability;*
5. *Find indicators for the components of vulnerability;*
6. *Weight and combine the indicators;*
7. *Project future vulnerability;*
8. *Communicate vulnerability creatively.*

Vulnerability assessment has traditionally begun through the analysis of historical disasters, identifying and systematizing vulnerable conditions from damages and losses experienced by different communities. Within the realm of infrastructure, structural engineers have been engaged not only in assessing vulnerability, but identifying building materials and construction techniques to reduce them.

The most recent version of the European Macro-seismic Scale, elaborated in 1998 by Grünthal (1998) and other members of the European Commission on Seismology, depicts six **classes of vulnerability** associated with different types of constructions materials and techniques, and has gone as far a ranging the expected damage of buildings associated with each vulnerability class to earthquakes of different intensities.

For example, most adobe houses are classified under **class A** vulnerability, but some adobe houses can also be classifieds as **class B** as shown in figure 8. Such houses are expected to experience slight damage (degree equals 1) provoked by earthquakes of intensity V, substantial to heave damage for earthquakes of intensity VII; and destruction when the earthquakes reach an intensity of IX. In this scale, the hazard is associated with the intensity of the earthquake. While the scale has been developed from a systematic analysis of historical damages, it is currently being tested in those countries where data is available.

In an attempt to represent expected degrees of damages, the EMS-98 scale has been fitted with 5 degrees of damages:

1 – Negligible to slight damage;

2 – Moderate damage;

3 – Substantial to heavy damage;

4 – Very heavy damage;

5 – Destruction.

The 12 degree-scale on which the vulnerability classes are based ranges from practically not felt (intensity I) to completely devastating (intensity XII). Figure 9 illustrates how most buildings within the six different vulnerability classes experience damages according to the 5 degrees of damage proposed.

In contrast to the EMS-98 scale which focuses on the specific structural vulnerability of buildings and structures, some recent efforts on vulnerability assessment have been elaborated with the goal of comparing the degree of vulnerabilities of countries. The focus on comparison among countries has forced a prerequisite on data availability at this scale, which has led to the use of general indices such *as Gross Domestic Product* (GDP); *Human Development Index* (HDI), degrees of losses in terms of human lives and economic impacts, as well as some specific indices. The following section covers aspects related to indicators and indexing systems which are required as tools for vulnerability assessment.

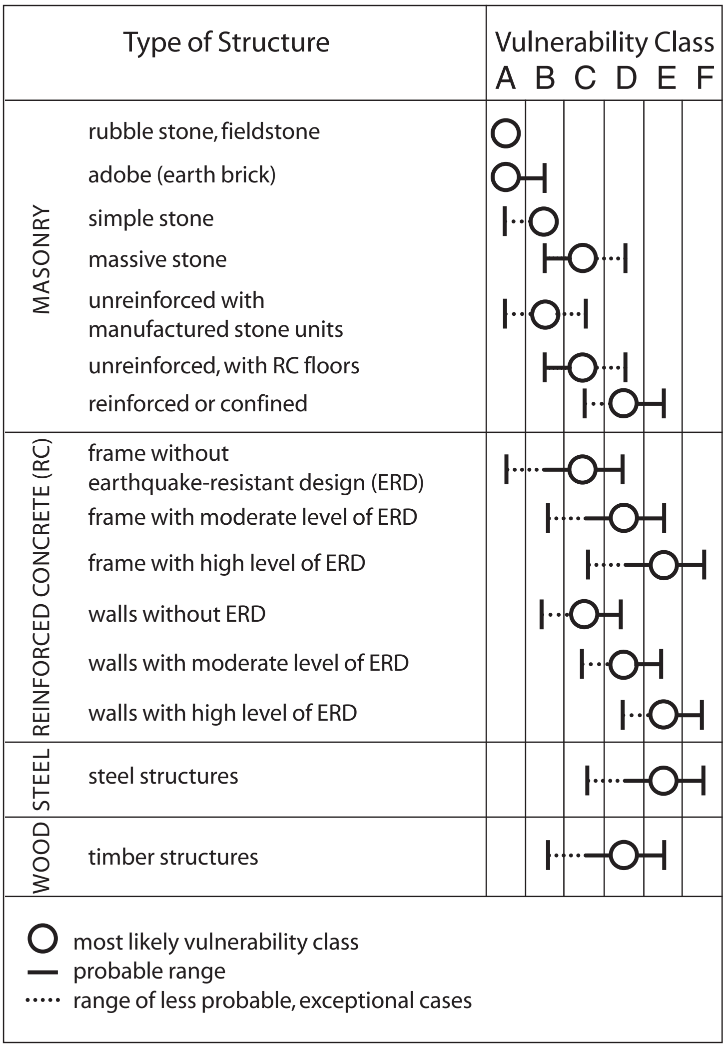

Figure 8: Vulnerability classes as proposed in the EMS-98

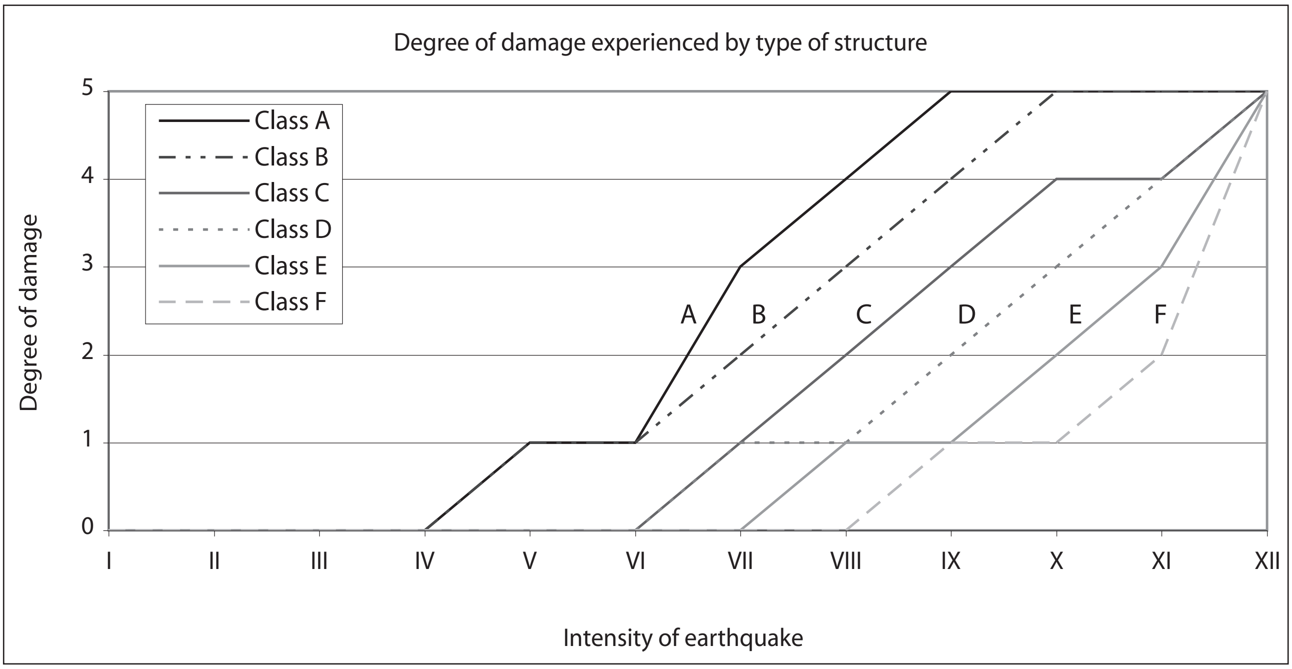

Figure 9: Degree of expected damage for the different vulnerability classes as a function of the intensity of an earthquake

3.1 Vulnerability Indexing: Characteristics

Within the realm of the planners and developers, the design and implementation of indicators and indices has allowed the measurement of the status of a community or a society, a means to compare various societies, as well as the identification of important issues which need to be addressed in order to promote the development of a given society along certain paths. For example, GDP measurements not only allow for a comparison among countries within a region, but allow for an assessment of the temporal evolution of the macro-economic situation of a country during the span of several years. In addition, specific development targets can be set by promoting policies and measures which will change the magnitude of the indicators in specific directions (increase, decrease). Typical examples of such policies are related to the imposition of limits regarding the emission of toxic gases and CO_2 concentrations in the atmosphere and related policies to reduce or control such emissions. Three aspects which are crucial in the context of indicators are the **characteristics or inherent properties** of such indicators, the **methodologies** regarding data management and processing inherent to each one, and the **availability of data** to obtain them.

The design of indicators is normally based on their expected use. For example, within the environmental sector indicators are used to monitor the state of the environment, and to monitor the success of different measures to minimize the impact of human actions on it.

The *Organization for Economic Co-operation and Development´*s (OECD) State of the Environment Group has adopted a framework comprised of a set of indicators targeting the environment and its management and sustainability. In this framework, known as the **Pressure-State-Response** model (P-S-R), the **Pressure** indicators describe those variables which directly cause environmental problems, such as toxic emissions. The **State** indicators show the current condition of the environment, such as concentration of NO_x in urban areas, current CO_2 levels, etc. The **Response** indicators demonstrate the efforts of the society to manage such issues. Examples could be the introduction of cars with catalytic converters, the use of non-leaded fuels, investments in solar energy and renewable resources, etc. While this framework implicitly addresses the vulnerability of the environment to human actions, representing the state of the environment at any given instant of time, it does not display explicitly what makes it vulnerable. What is interesting nevertheless is the fact that the framework includes response indicators which represent the actions taken to reduce the pressure related to human activities on the environment.

The adaptation of the **P-S-R** model to sectors, communities, or societies in the context of vulnerability associated with natural hazards is not straightforward, as the pressure must encompass not only those social factors such as poverty, population growth, and migration, but the intrinsic hazards, earthquakes, floods, landslides, etc.

A different approach to developing indicators has been proposed by Maclaren (1996). In this approach, indicators are developed to monitor advances made with respect to specific goals. The process begins with the **identification and definition of goals** for which the indicator is needed. In reference to vulnerability assessment, such goals might be the reduction of vulnerabilities within countries via the representation of intrinsic vulnerabilities or the representation of the status of a society with respect to specific benchmarks. The next stages in the development and of indicators are:

- ***Scoping***, which can be done through an analysis of the target audience for the indicator system, their needs, perceptions, and capacities to understand and interpret the results. As a result of the scoping process one should obtain the number of indicators that will be employed; as well as the temporal and spatial spans of the indicator system (the time frame and the geographical region where the indicators are to be measured);
- ***Selection of appropriate indicator framework***. Possible frameworks include domains (environment, economy, society); goals (basic human needs, economic prosperity, etc.); sectors (housing, health, education, etc.); issues (industrial pollution, unemployment, etc.); causal (conditions, stresses, responses), and combined frameworks;

- ➢ ***Selection criteria*** in terms of validity, reliability, easiness of calculation, accuracy, and cost effectiveness to collect and process data;
- ➢ ***Identification of potential indicators*** in terms of the framework and the selection criteria;
- ➢ ***Selection of final set of indicators*** in terms of the previous stages;
- ➢ ***Assessment of indicator performance*** in terms of the preestablished criteria.

Typical characteristics regarding indicators have been expressed by various authors. Hahn has proposed the following characteristics in relation to disaster-risk indicators (Hahn, 2003):

Validity: does the indicator measure the key element under consideration?

Sensitivity: when the outcome changes, will the indicator be sensitive to those changes?

Availability: will it be easy to measure and collect information?

Reliability: is the measurement consistent over time?

Objectivity: Can the data be reproduced under changing conditions?

Briguglio (2003) has stated as desirable the following attributes concerning indicators:

Simplicity: related to the ease of comprehension by decision makers and other users, with an intuitive meaning that captures the facets of the individual variables included in the indices.

Affordability: regarding the fact that the data from which indices are generated must be gathered at a reasonable cost of money, resources, and time.

Suitability for international and temporal comparisons

Transparency: related to the issue that the indicator should be verifiable and reproducible by persons other than the original producer. This is an essential element for validation, evaluation, and quality control. This means exposing both the data and the explanations on how the indicators are calculated in a simple manner.

In addition, within the span on the *Americas Project on Vulnerability Assessment* led by the *Inter-American Development Bank*, various researchers (Briguglio, 2003; Confort, 2003; Lavell, 2003; Munda, 2003; Suárez, 2003) point out the several potential weaknesses in relation to the development of indices as combination of indicators:

Subjective choice of variables:	related to subjectivity associated with choice of variables and computations used to calculate the index.
Measurement problems:	associated with the absence of data for certain variables, for certain countries or systems; or in relation to different methods which may be applied in various countries to compile and process data.
Averaging and weighing:	related to the combination of several indicators. The combination can be made through the use of weights, which can assign a higher, but subjective proportion of relevance to one indicator with respect to other ones.
Aggregation problems:	related to specific problems which may arise when aggregating data ad the provincial or national level from data at the local or municipal level.
Political aspects:	regarding the fact that a given indicator or index might create problems of "political" nature, or increase the level of tension among stakeholders being compared.

In the context of vulnerability associated with natural disasters, validity is a crucial characteristic, which should be verified under disaster conditions, meaning that what has been diagnosed as highly vulnerable should undergo major losses or damages once the hazard manifests itself as an event; while what has been diagnosed as low vulnerable should experience minimal losses or damages.

Within the context of sensitivity, the use of specific sets of indicators can indeed yield more precise results. However, a too sensitive approach might be too costly to execute, or be impractical due to data restrictions. Availability is an important issue related to sensitivity in the context of data. While the use of general indicators such as GDP, HDI, Population Growth and similar practically assures data availability, one runs the risk that such indicators may not be valid to reflect vulnerability directly (what is vulnerable and how), but trends related to underdevelopment. In this context it is important to recognize the trade-off and the balance between validity and availability.

While these characteristics are important in the general context of indices and indicators, specific criteria specifically related to vulnerability already mentioned in the previous sections should be incorporated, namely:

- *Validity;*
- *Sensitivity of vulnerability to the type and magnitude of the hazard;*
- *Sensitivity to social and cultural changes which may take place after an event of large proportions;*
- *Reliability.*

3.2 Vulnerability Assessment: Efforts Focusing at the National Scale

As mentioned earlier, vulnerability quantification is not a common task carried out in a consistent fashion within the context of natural disasters. While a single indicator on the vulnerability of a country, a sector, a process, or a society could be desirable to get an overview, researchers point out the relevance to monitor the different manifestations of vulnerability spanning social, economic, and physical aspects; as well as the processes or factors which are enhancing it, as well as those which can reduce it. At this time there are three issues which make it difficult to quantify vulnerability. The first issue is related to the fact that vulnerability spans all social, institutional, political, and economic contexts; sectors, systems, livelihoods, organisations, and processes; and thus there is a need to develop a framework to quantify it within these contexts. The second issue is related to the lack of consensus among different researchers and professionals regarding how to define and quantify such a term and finally there is the third issue with respect to the availability of data for this purpose. If indicators are to be developed regarding the status of vulnerability related to a particular community or a sector, such indicators could then be used to promote awareness on the subject and later to establish targets regarding its reduction.

Nevertheless, experimental or pilot efforts are being carried out at various levels from the national to the local level. Such efforts target a variety of hazards and already quantify vulnerability of countries, communities, or livelihoods with respect to specific hazards. The following sections present an overview of some of these approaches. While no comparison is attempted, efforts are made in every case to systematize some comments for all these methods with regards to their sensitivity, reliability, and applicability.

There are several approaches carried out by different groups of experts to measure vulnerabilities at the national level, each one allowing for a comparison among many or all countries of the world. Among the approaches analyzed in this document, four have emerged from the academic community (University of Colombia, Manizales Branch; University of Malta; University of Liverpool; and Columbia University in New York). Another index has been developed for the *United Nations Development Programme* under the guidance of its *Bureau of Crisis Prevention and Recovery* (BCPR-UNDP), and another one has been proposed by the *Tyndall Centre for Climate Change Research*.

3.2.1 The Disaster – Risk Index: BCPR-UNDP

UNDP-BCPR has developed a human vulnerability and risk index based on human exposure to earthquakes, tropical cyclones, droughts, and flooding. The relative human vulnerability of a country to a given hazard in this approach is calculated dividing the average number of people killed per year by the number of people exposed to such a hazard. The average is obtained from data gathered over two decades at least and is based on the OFDA-CRED EM-DAT data base. In most cases calculations are carried out with data spanning from 1980 – 2000, as this segment of the database is considered as the most reliable. The number of people exposed to a given hazard was calculated by modelling the area affected by historical events within this particular time-window. The process includes not only the affected area and the proportion of the population living within this area, but also events of different magnitude included in the database.

For example, the relative human vulnerability index associated with tropical cyclones ranges from 0.0 to 321.38 arbitrary units; from 0.0 to 491.84 arbitrary units for floods; and from 0.0 to 7652.82 arbitrary units for earthquakes. Considering the index as defined in terms of people killed in relation to people exposed, one can conclude from the results that human vulnerability to earthquakes is considerably larger than human vulnerability to floods or cyclones. It can be concluded that the collapse of infrastructure is an important factor to consider when analyzing human vulnerability to different types of hazards.

Figure 10 displays results for a sample of countries regarding tropical cyclones. The vertical scale has been expressed in a logarithmic fashion so as to view trends related to all countries in the sample.

The main conclusions from this approach can be summarized as follows:

- *The index has been calculated for 249 countries and three hazards. The selection of hazards was made according to two issues: fatalities associated with such hazards, and availability of quality data.*
- *In the case of earthquakes, Armenia, Iran, Yemen, and Turkey lead the list of highly vulnerable countries, followed by India, Italy, the Russian Federation, Algeria, and Mexico. As it to be expected, these countries have experienced recent earthquakes which have provoked disasters. Interestingly, Japan and the United States, which have experienced recent earthquakes, are displayed with very low vulnerabilities, as the ratio of*

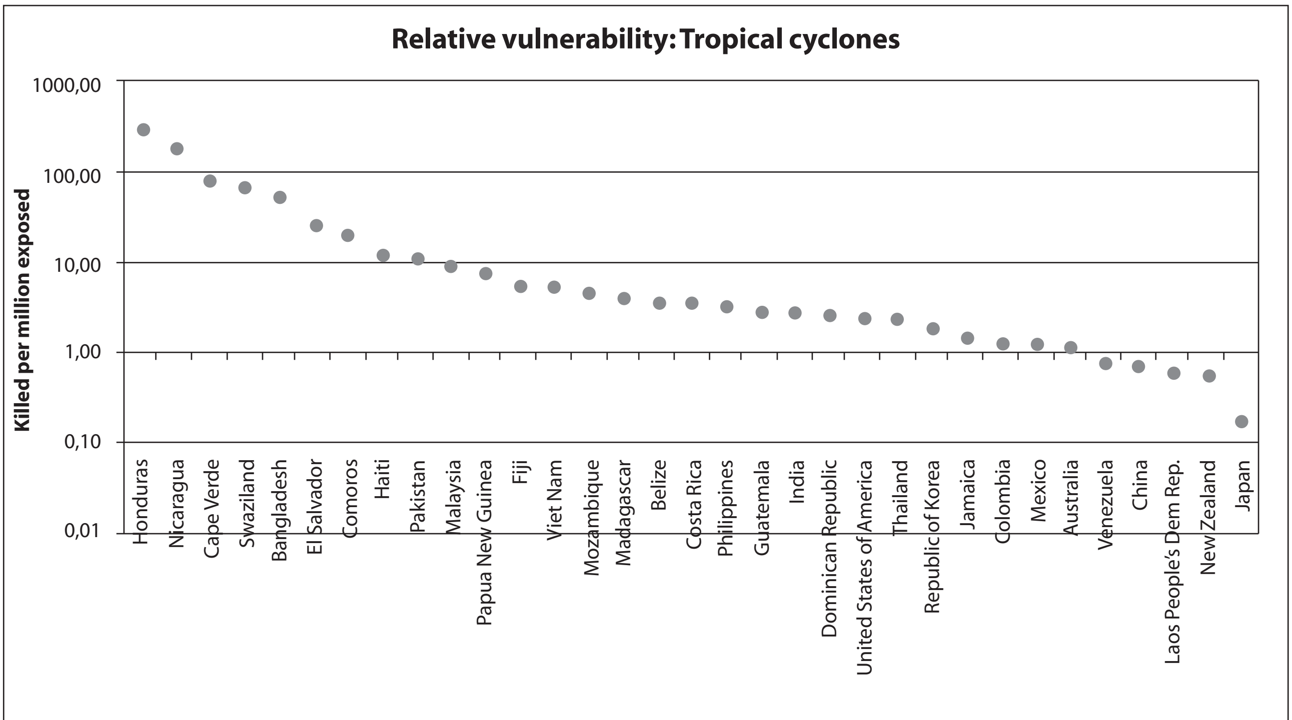

Figure 10: Relative vulnerability of countries of the world with respect to tropical cyclones as assessed by BCPR

fatalities to exposed population is very small. However, Guatemala is presented as a country with a low vulnerability despite having suffered a major earthquake in 1976, outside the time-window established for the calculation.

- *In the case of floods, Venezuela, Somalia, Djibouti and Morocco lead the list of highly vulnerable countries. Mozambique, with its great floods in the year 2000, ranks tenth in the list, Honduras ranks twenty-first despite annual floods in the northern coast and catastrophic losses during hurricane Mitch; and Haiti ranks eighty-second, despite large disasters associated with floods in the year 2004. As in the case of earthquakes in Guatemala, results in the case of floods are biased by the time-window selected for the assessment.*
- *In the case of tropical cyclones, Honduras, Nicaragua, Cape Verde and Swaziland head the list, followed by Bangladesh, El Salvador, Comoros, and Haiti.*

With respect to the method one can comment the following:

- *This is a very straightforward index in capturing the "historical" vulnerability of people with respect to various types of hazards, as it is based on mortality associated directly with each type of hazard. The calculation is simple and requires historical data on fatalities, losses, or damages for the index to be computed, which is available from various sources. The index is a mortality-calibrated index. As it has been stated by the authors, this choice was guided principally by global data availability of suitable quality.*
- *The methodology can be adapted to identify vulnerability of different social groups (children, women, elderly), as well as to different geographical levels from national to local, but data regarding mortality is not available in such categories to be able to carry out the calculation at this time for all countries.*
- *Due to the fact that the index is calculated using the OFDA- CRED EM-DAT database which is maintained on a permanent basis in conjunction with national agencies, the index can be re-evaluated on a yearly basis. This feature can be used to monitor the evolution of vulnerability and risk as a function of time in a relatively simple fashion, as data is readily available.*
- *The time-span of the calculation can be an issue to consider in the sense that the indexes are only sensible to those events present within the period used for the calculation (1980-2000). Large events taking place outside this time-window are not taken into account and such events can drastically modify the value of the indicator.*
- *The indicator is calculated independently for each type of hazard and therefore assumes that vulnerability is hazard dependant.*
- *The value which emerges from the calculation of the relative vulnerability is presented in arbitrary units, and care should be taken when comparing magnitudes of the index for various countries.*

One interesting comment regarding this method and its results is how it will be perceived, especially by those developing countries which display small values of vulnerability; as such countries may be denied any international technical or financial assistance based on their classification as low vulnerable.

3.2.2 The Hot-Spots Model: World Bank

The Hot-Spots method began to be developed in the year 2001 as an effort of the *Center for Hazards and Risk Research* at *Columbia University* in New York and other national and international institutions. The effort was carried out with the support of the Provention Consortium coordinated at that time by *the Hazard Management Unit* of the *World Bank*.

The Hot-Spots method focuses on assessing risk in relation to disaster related mortality and economic losses. In contrast to methods addressing national or sub-national scales which are adjusted to political borders, this method focuses on a grid structure spanning the whole globe. In addition, it assumes the condition of vulnerability depending on hazards.

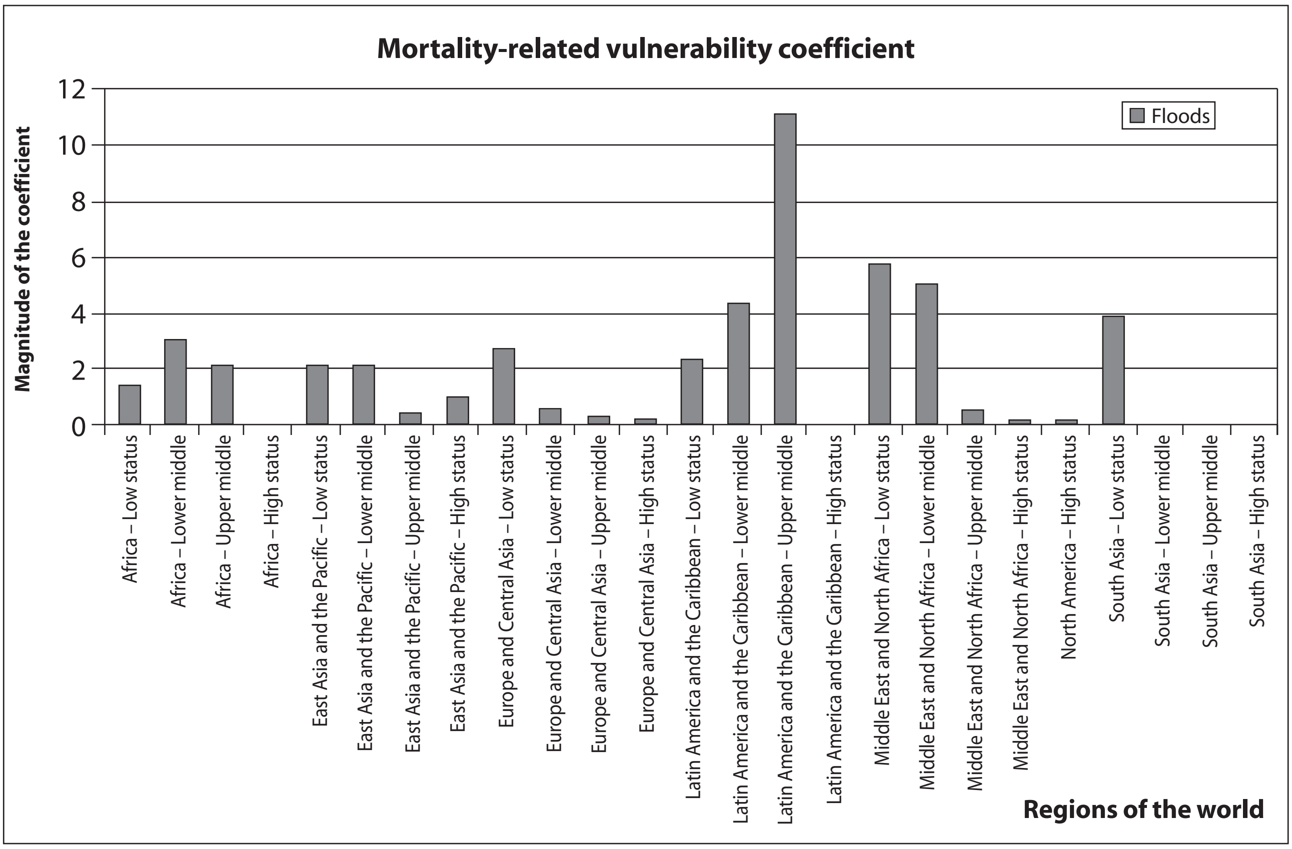

Figure 11: Mortality-related vulnerability coefficient as proposed in the Hot-Spots method developed by researchers at Columbia University for the World Bank

As in the case of the UNDP-BCPR method, the mortality-related vulnerability coefficient in relation to any hazard is calculated using the OFDA CRED-EM-DAT database and is based on hazard-specific historical mortality rates for the period 1980-2000. Vulnerability coefficients are calculated for six different hazards: cyclones, drought, earthquakes, floods, landslides, and volcanic eruptions. In addition, vulnerability coefficients for economic losses are calculated and presented for the same six hazards.

In contrast to the typical country-type methods, the Hot-Spots method presents vulnerability coefficients for seven regions of the world. In addition, each region is divided into four sub-regions, as data is assigned in relation to wealth classes and not in relation to countries or political boundaries. The main comments in relation to this method are as follows:

- ➢ *As in the UNDP-BCPR model, vulnerability indexes are based on disaster-related mortality rates and are computed independently for each hazard.*
- ➢ *In the case of earthquakes, the lower middle segment of the Middle East and North Africa and the lower middle of Europe and Central Asia display substantially higher coefficients of vulnerability related to mortality in comparison to any other region of the world. As in the case of BCPR, this result arises due to the use of the OFDA-CRED EM-DAT database spanning the period 1980-2000, which displays the most destructive earthquakes in these regions of the world for this period of time.*
- ➢ *In the case of floods, the upper middle region of Latin America and the Caribbean arise with the highest vulnerability coefficient, again due to the use of the OFDA-CRED EM-DAT database, which for this period covers the drastic Venezuelan flood, as well as hurricane Mitch in Central America.*
- ➢ *In the case of volcanic eruptions, vulnerability ranks highest again in the case of lower middle Latin America and the Caribbean, due to the eruption of volcanoes on South America (Colombia and Ecuador mostly).*

As in the previous case, it is important to recognize several aspects regarding this method:

- *The calculation requires assessing losses through the geographical pixel structure prepared specifically for the model. In this sense, the Hot-Spots method may be more difficult to implement by other agencies that the Disaster Recovery Institute (DRI) simply because of this feature of using a grid rather than national data and national boundaries.*
- *Considering the definition of vulnerability proposed in the model as the propensity to suffer damage during an event, the loss rates calculated from OFDA-CRED EM-DAT historical loss data are theoretically adequate, as they relate directly to losses which can be traced to vulnerabilities.*
- *The index is a disaster-related mortality or loss-calibrated index and is based on the OFDA-CRED EM-DAT database which is maintained on a permanent basis, therefore, the index can be re-evaluated on a yearly basis to track its temporal evolution for every region.*
- *As in the case of the BCPR model, the Hot-Spots method can easily be adapted to calculate vulnerabilities of different types and at different levels (from national to local). The limitations at this time are related to the lack of data to assess such vulnerabilities.*
- *The time-span of the calculation can be an issue in the sense that the indicators are only sensible to those events within the period used for the calculation (1980-2000). Large events taking place outside this time-window are not taken into account. However, such events can drastically modify the value of the indicator. In a similar fashion, large events inside the period can affect the magnitude of the index.*
- *The index is hazard dependant. It is calculated independently for each type of hazard.*
- *The value which emerges from the calculation of the relative vulnerability is presented in arbitrary units, and care should be taken when comparing magnitudes of the index for various countries.*

This method is very similar to the one proposed by BCPR with respect to the calculation of the vulnerability coefficients, as it is based on the same database and uses a similar procedure. However, as stated, the use of a different structure based on geographical pixels, as well as a different span of geographical areas leads to a division of the globe into 25 different areas regarding vulnerabilities.

One important element to mention which is present both in the Hot-Spots and the BCPR-UNDP methods is the fact that both models employ a simple and straightforward calculation to generate vulnerability indicators which is directly stemming from observed vulnerabilities which have become disasters (disaster related mortality and losses). The method could be understood as an extrapolation of trends in losses in countries of regions of the world and in this sense these trends can be verified against new disasters which can take place in years to come.

3.2.3 The Composite Vulnerability Index for Small Island States

In contrast to the BCPR and Hot-Spots approaches, a group headed by Dr. Briguglio (2003; 2004) has been developing a composite vulnerability index in relation to the small island developing states. The goal of the index is to point out the intrinsic vulnerability of such states in comparison to large countries which possess several advantages associated with their large scale. This index is composed of four indicators:

- *A two-level indicator which expresses whether the country is considered a small or large state, with numerical values 1 or 0 respectively;*
- *The vulnerability or susceptibility of the country in relation to natural disasters;*
- *The economic exposure of the country, which has been assessed via the export dependence, which in turn is assessed in terms of the average exports of goods and non-factor services as a percentage of the GDP; and*
- *The lack of diversification, which has been characterized in terms of the UNCTAD diversification index.*

Through the use of weighted least squares routines, the index is represented mathematically through the following equation:

$$CVI = 1.4142 + 0.0096\ Vul \times D + 0.0322\ Ex\text{-}Dep + 3.3442\ Div \quad [9]$$

In this equation:

- **Vul** represents the susceptibility of the country to natural disasters;
- **D** is a two level indicator for the respective country regarding its status as a small state;
- **Ex-Dep** represents the economic exposure of the country;
- **Div** stands for the lack of diversification in a particular country.

The selection of weights has been carried out using regression techniques and eliminating extreme values that might shift the index in undesired directions. Of the 111 countries (both small and large) over which the index has been assessed, 11 have been eliminated on this issue of extremes values. The results from this method are presented in figure 12 which displays the CVI as a function of the countries labelled on the horizontal scale. Figure 13 displays the GDP per capita for these countries in the same horizontal scale for comparison purposes. As stated by Dr. Briguglio, the use of GDP alone is not a good measure in relation to such vulnerability. Both graphs have been generated with the data provided in the article.

The results can be summarized as follows:

- ➢ *The proposed method does display that small states are in general more vulnerable than large states, but this could be a direct outcome of the proposed method.*
- ➢ *The degree of vulnerability is independent of the GDP per capita. Many countries with high GDP per capita are indexed with a higher vulnerability than countries with a low GDP per capita. For example, Bahamas and Singapore which have large GDP per capita are at the top of the list of vulnerable countries.*
- ➢ *Vanuatu, Antigua & Barbuda, Tonga, and the Bahamas lead the index as the most vulnerable small states. In contrast, Haiti, the Dominican Republic, and Cape Verde are at the bottom of the list.*

As in the case of the BCPR-UNDP index, output values are expressed in arbitrary units ranging from 1.4142 to 13.295, the highest value corresponding to the country Vanuatu. In this case, it is important to recognize several aspects:

- ➢ *The time-span of the calculation of the vulnerability to natural disasters can again be an issue in the sense that the indicator is only sensible to those events within the period used for the calculation. Large events taking place outside this time-window are not taken into account. However, such a factor can have a lesser effect on the index, as this parameter is only one of four on which the index is based and the respective weight is rather small in comparison to the other weights;*
- ➢ *The way in which indicators are deduced precludes the capacity of the model to discern among natural hazards. The model assumes equal outcomes regardless of the type of hazard in question;*
- ➢ *As in the previous case, the value which emerges from the calculation of the vulnerability is presented in arbitrary units, and thus care should be taken when comparing numerical indexes of various countries;*
- ➢ *Considering the definition of vulnerability proposed in the model as the propensity to suffer damage during an event, the loss rates calculated from OFDA-CRED EM-DAT historical loss data are theoretically adequate, as they relate directly to losses which can be traces to vulnerabilities;*
- ➢ *The index can be updated regularly, but it is expected that only two indicators will change with time: the susceptibility to natural disasters and the lack of diversification;*
- ➢ *Given the structure of the index, it is only employed at the national level. It cannot be adapted to lower levels such as municipal or local levels.*

While the DRI procedure tried to focus on calculating vulnerabilities as a function of hazards, the CVI index has been developed specifically in mind to enhance the perspective of vulnerabilities of small states.

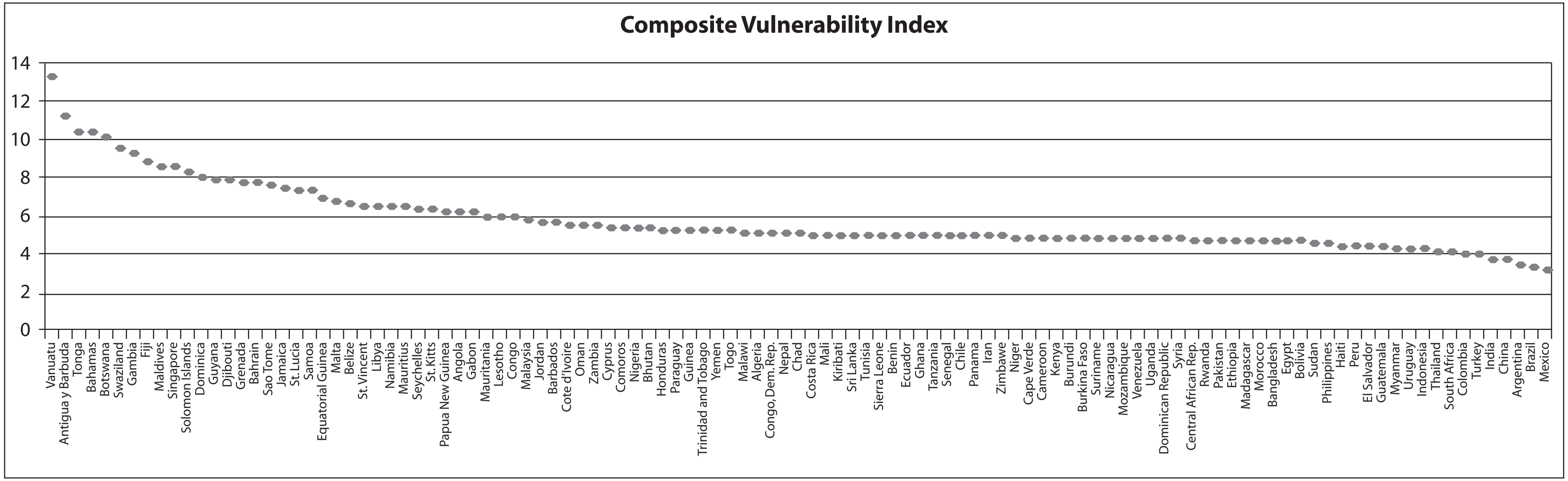

Figure 12: Composite vulnerability index for countries of the world according to the model developed for small island developing states

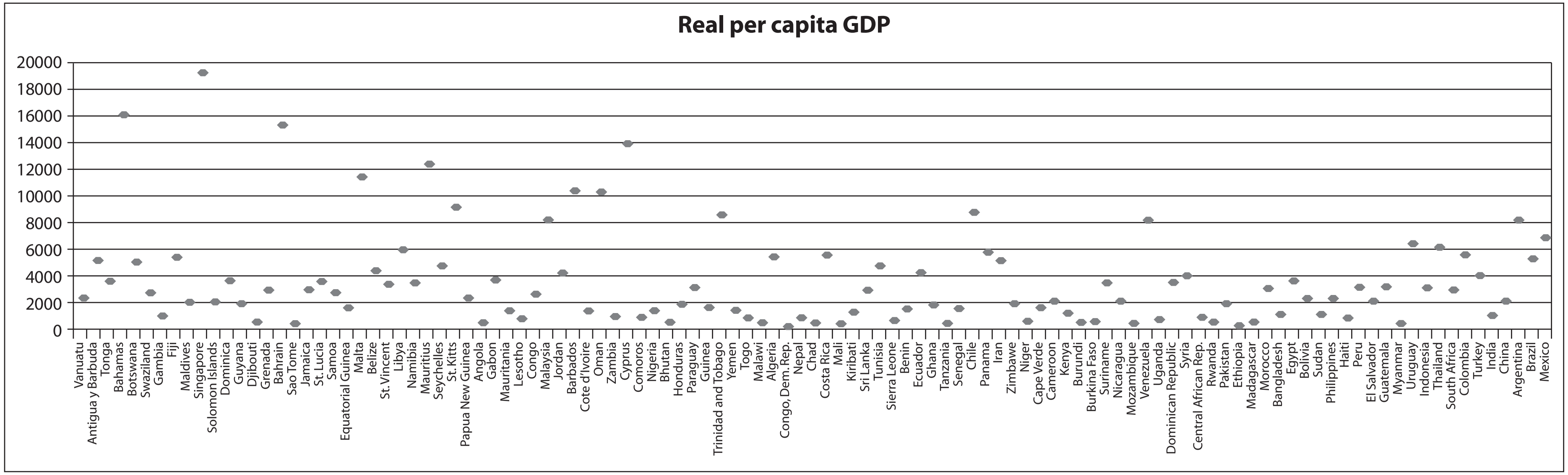

Figure 13: Real per capita GDP index for countries of the world

3.2.4 Small Island Developing States: Natural Disaster Vulnerability Indicators

Pelling and Uitto (2001) elaborated a method to assess the vulnerability of small island states which is similar to the previous one, but using five different indicators to create this index. The indicators used are:

- ***Human Development Index***;
- ***Debt Service Ratio;***
- ***Public Expenditure on Health***;
- ***Adult Literacy***; and
- ***GDP per capita***.

The method combines the five indicators using equal weights for each one and represents vulnerability in a scale from 1 to 4, 1 being most vulnerable and 4 being least vulnerable. The process starts with scaling each parameter to develop an indicator for all countries in units from 1 to 4, and then combining the five indicators in this narrow scale for a given country via a simple average.

In terms of the vulnerability, the main outcomes from this model are:

- *Haiti, Comoros, Jamaica, and Papua-New Guinea are pinpointed as the most vulnerable countries; while Singapore, Cuba, and Barbados are the least vulnerable in the list of 24 countries considered.*
- *As indicated by the authors, the validity of the model has been proven in recent years considering the disasters experienced by Haiti in 2004 and 2005 during the hurricane season in contrast to Cuba, where there were no fatalities during the same season.*

As in the previous case, it is important to recognize several aspects regarding the method:

- *The index is the same for any type of natural hazard. It is in this sense hazard-independent.*
- *The model is simple to use, and could be extrapolated to sub-national levels if data is available. In addition, the selected indicators are such that the model could be applied to all countries of the world and not just to the small island states.*

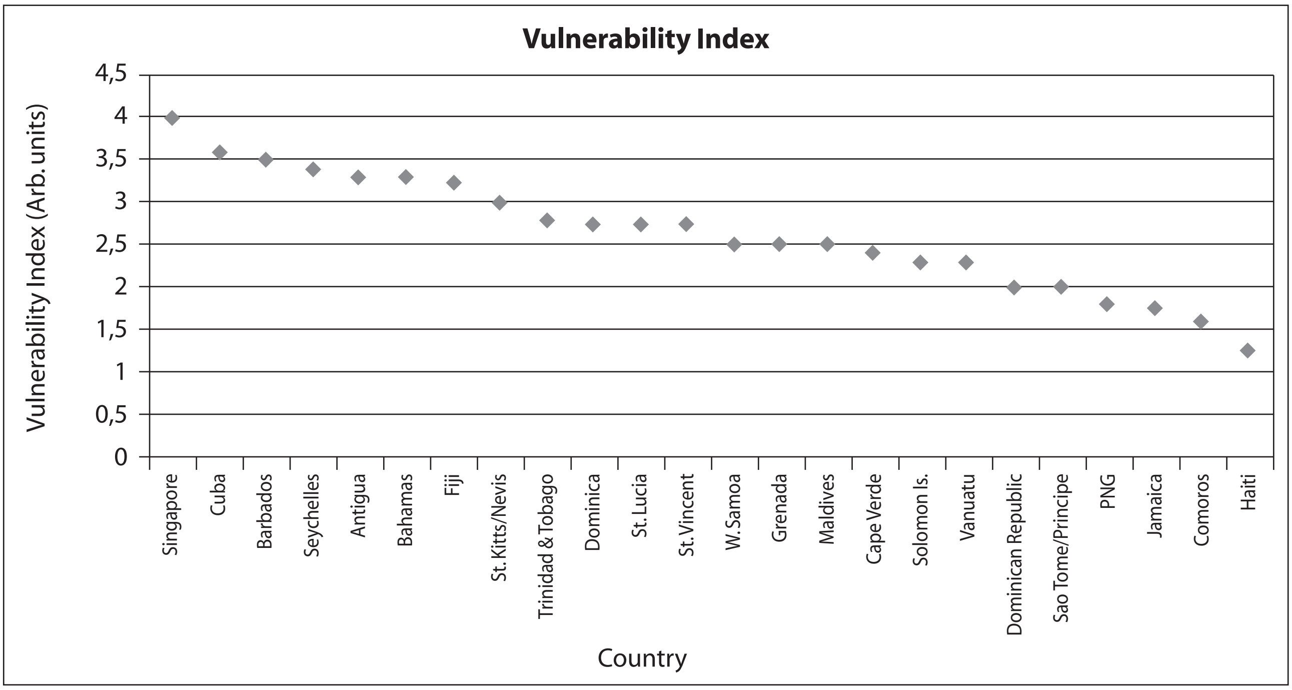

Figure 14: Vulnerability index for small island states as proposed by Pelling and Uitto (2001)

- *The index can be updated on a yearly basis to track changes in vulnerability within each country as all indicators are accessible for such a calculation.*
- *Because the index is not calculated using historical losses or fatalities, this method does not suffer from the limitations that the BCPR-UNDP and the Hot-Spots methods in this respect.*
- *The value which emerges from the calculation of the relative vulnerability is presented in arbitrary units, and care should be taken when comparing magnitudes of the index for various countries.*

3.2.5 The Social Vulnerability Index for Africa

Vincent (2004) has defined a *Social Vulnerability Index* (SVI) for African nations with respect to the hazard defined as the changing of water availability. In this context, vulnerability encompasses the ability of a country to anticipate, resist, cope, and respond to this hazard. The SVI is constructed in terms of five indicators:

- ***Economic well being and stability,*** which is represented in terms of standard of living/poverty and change in urban population;
- ***Demographic structure***, which is assessed in terms of dependant population and the proportion of working population with HIV/AIDS;
- ***Institutional stability and strength of public infrastructure***, measured in terms of health expenditure as a proportion of GDP; number of telephones per thousand inhabitants; and a corruption index (only available for some countries);
- ***Global interconnectivity,*** which is represented in terms of the trade balance of the country; and
- ***Natural resource dependence***, assessed through the percentage of rural population within the country.

The SVI is calculated through a simple equation:

$$\mathbf{SVI = 0.2\, I_{ewb} + 0.2\, I_{ds} + 0.4\, I_{is} + 0.1\, I_{gi} + 0.1\, I_{nrd}} \qquad [10]$$

In this equation:

I_{ewb} is the indicator associated to economic well being;

I_{ds} is the indicator related to demographic structure;

I_{is} is the indicator associated to institutional stability;

I_{gi} is the indicator related to global interconnectivity;

I_{nrd} is the indicator associated to natural resource dependence.

The weights have been assigned to each indicator via suggestions emanating from an expert group. Most of the data has been acquired from international sources such as the World Bank, UN agencies, ITU, and Transparency International. Results for 50 countries are presented in figure 15. The results can be summarized as follows:

- *Niger, Sierra Leone, Burundi, and Madagascar head the list, while Djibouti, Mauritius, Algeria, Tunisia, and South Africa are the countries displaying the least social vulnerability.*
- *There is no geographical trend regarding the vulnerability of the African countries. Least vulnerable countries lie at the south and north of the continent.*

In relation to the model itself, the following comments can be made:

- *The calculation of the index is straightforward. It is also based on a small number of indicators, using a simple formula.*
- *The index does not display the vulnerability of country in an explicit or direct fashion. In this sense, it does not display directly how the parameters are vulnerable directly to water availability.*

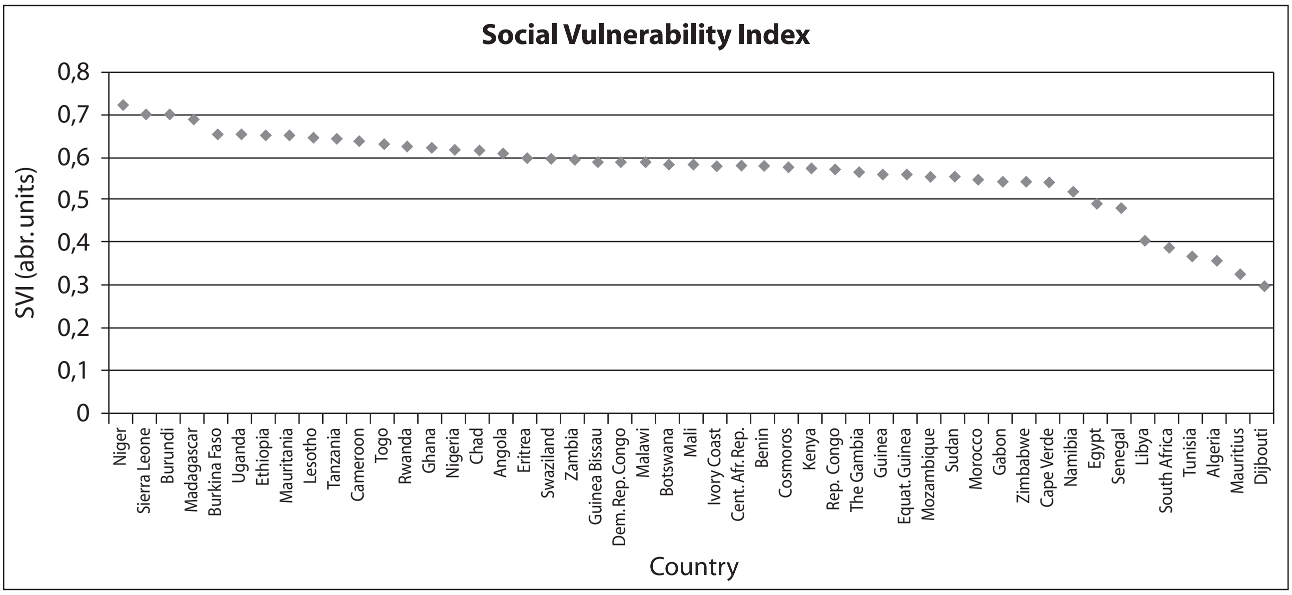

Figure 15: Social vulnerability index for African countries as proposed by Vincent (2004)

- *The way in which indicators are deduced precludes the capacity of the model to discern between natural and social hazards. The model is based on indicators which are not directly related to the particular hazard proposed: water availability.*
- *The magnitude of the vulnerability of a country is independent of the magnitude of the hazard in question.*
- *As in the previous cases, the value which emerges from the calculation of the vulnerability is presented in arbitrary units, and should not be employed in a linear fashion.*

3.2.6 Disaster-Risk Indices: IADB-ECLAC-IES

In the American hemisphere, the *Institute of Environmental Studies* of the *University of Colombia* in Manizales, the *Economic Committee for Latin America and the Caribbean*, and the *Inter-American Development Bank* are carrying out an assessment of risks as part of the Program on Information and Indicators on Risk Management. The ongoing effort focuses on establishing a set of indicators which can be used to represent risks and risk management at the national scale, so that decision makers in specific countries can identify and recognize existing risks, the possibilities regarding the generation of new risks from the perspective of natural disasters, and the evaluation of measures implemented to reduce them. The model proposes four indices:

- *The Disaster Deficit Index* (DDI) which targets possible economic losses which a country may face as a consequence of a natural disaster and the implications regarding resources required to cope with such a situation. It does so from the macroeconomic and financial perspective;
- *The Local Disaster Index (*LDI) which should represent the predisposition of a country to suffer the impact of small but frequent events and the type of impacts that can be expected at the local level. It identifies social and environmental risks that derive from these frequent small disasters;
- *The Prevalent Vulnerability Index* (PVI) which is designed to capture the inherent conditions between risk and development in terms of exposure and susceptibility in prone areas, as well as socio-economic fragility and lack of resilience regarding possible events;
- *The Risk Management Index* (RMI) which focuses on the measurement of performance regarding risk management practices within a country and targets issues such as risk identification and risk-reduction measures, disaster management measures (response and recovery); governance and financial protection or risk-transfer schemes.

The initial testing phase included twelve countries from the American Hemisphere[2]. While one index is labelled explicitly in relation to vulnerability, two others can be related to vulnerability within the contexts described previously, and the fourth one refers more to the measures which are being taken to minimize risks, including vulnerabilities. This set of indices is not as concise as the DRI or the CVI, as it has been tailor-made to capture several aspects related to risks, vulnerability, and risk management. In addition, care has been taken to account for such aspects as local effects, lack of resilience, fragility, and measures to cope with the existing situation. In addition, each of the indices has been conformed to several indicators, making use of several different databases such as DESINVENTAR, specific country surveys, as well as aggregations based on expert opinion. As Cardona points out (Cardona, 2004a), the approach is rather holistic; flexible; easy to use; and to update periodically, and easily understood by decision makers.

The *Disaster Deficit Index* is measured in terms of the ratio between the loss associated with the maximum considered event and the economic resilience related to the possible funds available to cope with such an event. The evaluation has been done for potential events with three distinct return periods: 50 years, 100 years, and 500 years. Figure 16 displays the results for the DDI for these three distinct return periods. The graph has been elaborated trying to arrange countries by region. At the left the Caribbean countries, next the Central American countries, followed by Mexico, and then the South American countries. From this graph one could conclude that in general there is no geographical trend regarding the DDI, nor is there a trend related to the size of the country.

The *Local Disaster Index* has been assessed through the use of the DESINVETAR database, which was developed by LA RED, and is maintained within every country included in the survey on a permanent basis. The index is based on three indicators calculated for five year periods: loss of life, affected persons, and economic losses. Such parameters were represented via the losses from destroyed houses and crops associated with natural events of different nature (landslides and debris flows; seismo-tectonic events, floods and storms, and other types of events). Figure 17 displays results for the period 1996-2000.

The Local Disaster Index is then calculated via the sum of three components:

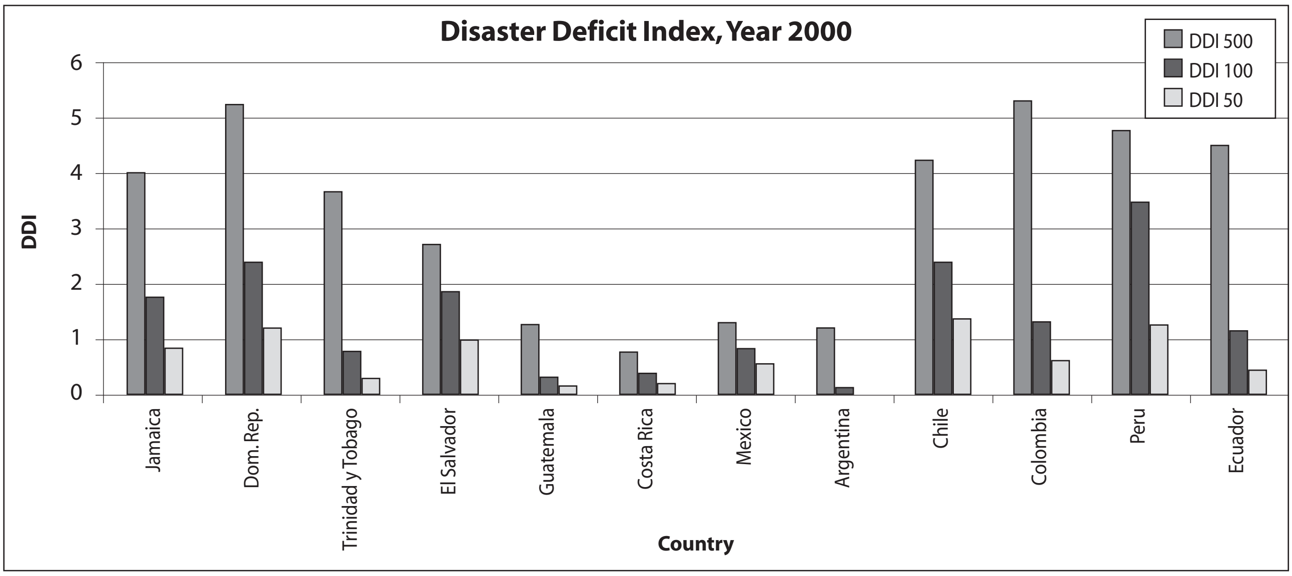

Figure 16: Disaster Deficit Index for several Latin American countries as assessed via the model developed for the Inter-Amercan Development Bank

2 The countries are: Argentina, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Peru, Trinidad & Tobago, and El Salvador.

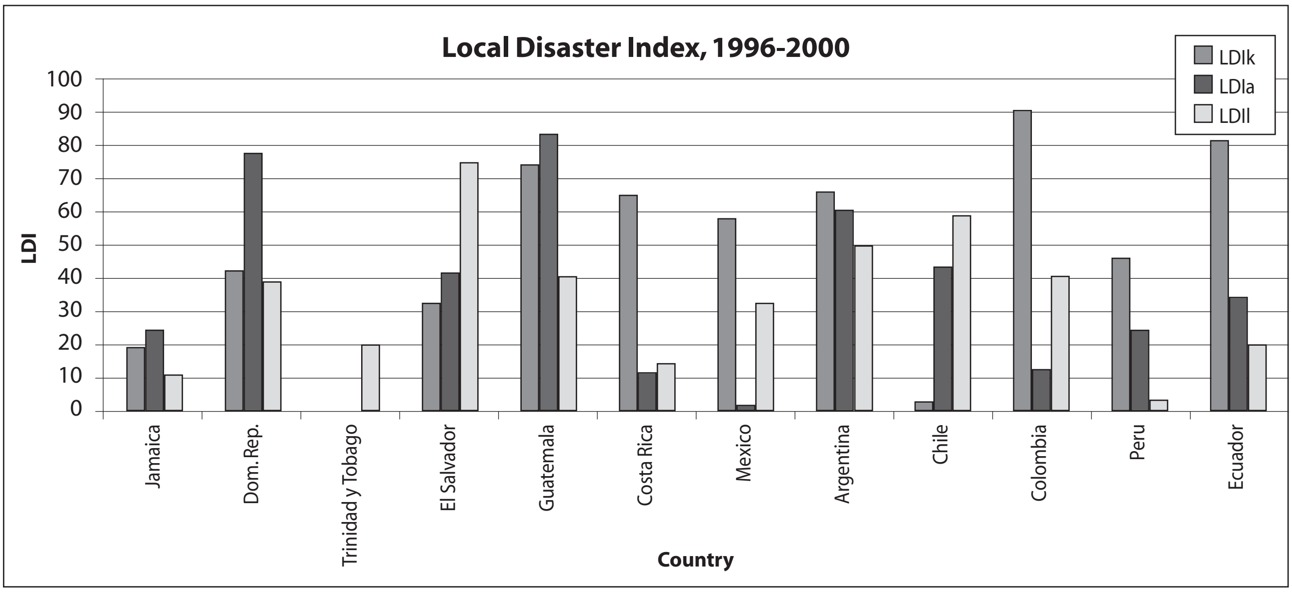

Figure 17: Local Disaster Index for several Latin American countries as assessed via the model developed for the Inter-American Development Bank

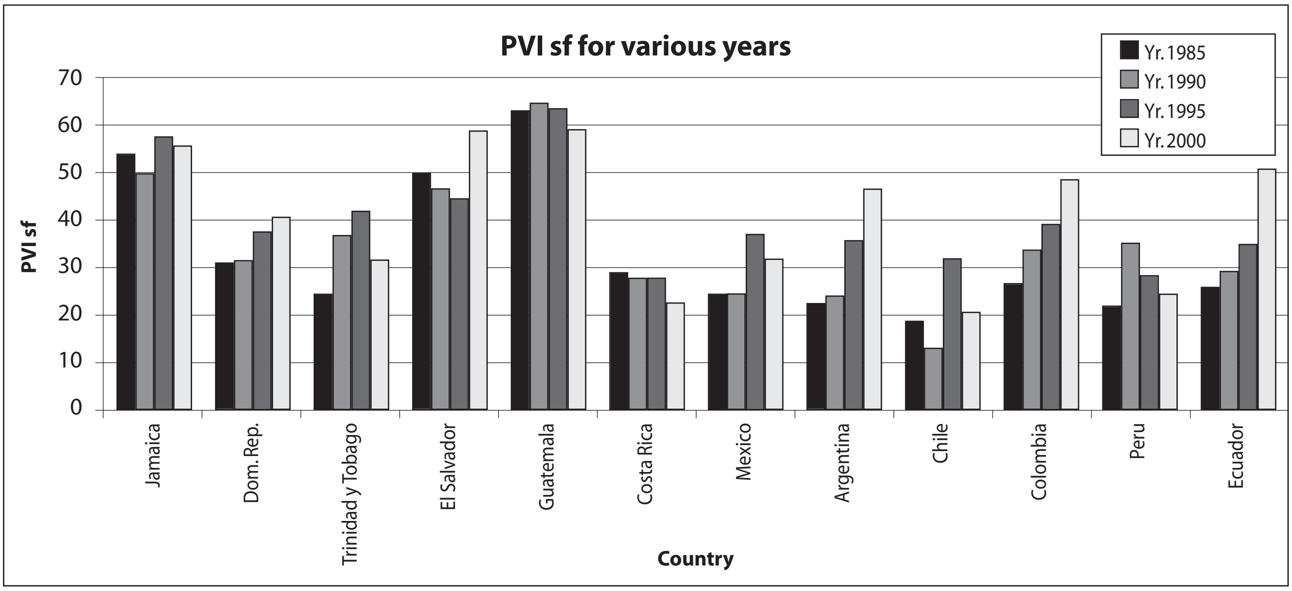

Figure 18: The Prevalent Vulnerability Index for several Latin American countries as assessed via the model developed for the Inter-American Development Bank

LDI_k refers to the subindicator associated with number of people killed;

LDI_a refers to the subindicator related to number of people affected; and

LDI_i is the subindicator related to economic losses.

As is to be expected, this index should be representative of disasters and their impacts within this period of time. Guatemala and El Salvador are assigned high values due to damages and losses associated with hurricane Mitch. In addition, the analysis covers various time periods: 1982-85, 1986-90, 1991-95, and 1996-2000. As Cardona states in the report, analysis of such data suggests that Guatemala, Argentina, Dominican Republic, Colombia, and El Salvador are showing a historical tendency to increase the magnitude of this index over the years, which could be associated with the processes of environmental degradation.

The *Prevalent Vulnerability Index* is composed of three sub-indices: exposure and susceptibility; fragility; and lack of resilience. Each sub-index has been calculated through a set of indicators. For example, in the case of socio-economic fragility, the following indicators are employed: human poverty index, dependents as a proportion of working age population, social disparity (Gini index), unemployment, inflation regarding food prices, dependency of GDP growth on agriculture, debt servicing, and human-induced soil degradation. Results indicate that Guatemala has been consistently heading in this index, followed somewhat by Jamaica. In contrast, Chile, Costa Rica, and Peru are at the bottom of the list. Another important aspect to note is associated with changes over time. Argentina, Colombia, Ecuador, and the Dominican Republic have indices which have grown consistently in the twenty year span, while Costa Rica has been able to decrease it within the same period.

Concerning the *Risk Management Index*, it is composed of four sub-indices which have been calculated using different sets of indicators. As in the case of the PVI, it has been analyzed and presented in terms of time-periods spanning five years each, beginning in 1985. In addition, data is provided on the indivual sub-indices, as well as on the general index overall. Data has been accessed through the use of a specific survey using a multiple choice format spanning 5 categories for each indicator.

In comparison with the three previous techniques to assess vulnerability (BCPR, Hot-Spots, and SIDS), this index is quite complex, and requires the use of data from such databases as DESINVENTAR, as well as specific surveys which need to be answered by several agencies. Nevertheless, as expected, it is more precise in describing the various issues related to vulnerabilities using not only economic terms (DDI), but other factors as well. In this case, it is important to recognize several aspects:

- *While there is a specific indicator related to vulnerability (PVI), the LDI and the DDI can also be representative of existing vulnerabilities, especially when comparing this method with the other methods presented previously. In addition, the expected losses are in a way representative of the predisposition of countries and local regions to be affected, hence vulnerable.*
- *Considering the way in which the model is presented, the dependency of vulnerability of different types of hazard is included via the assessment in an implicit fashion.*
- *The magnitude of some indices is directly related to the magnitude of the event (DDI). However, this is not really the case for the other indices.*

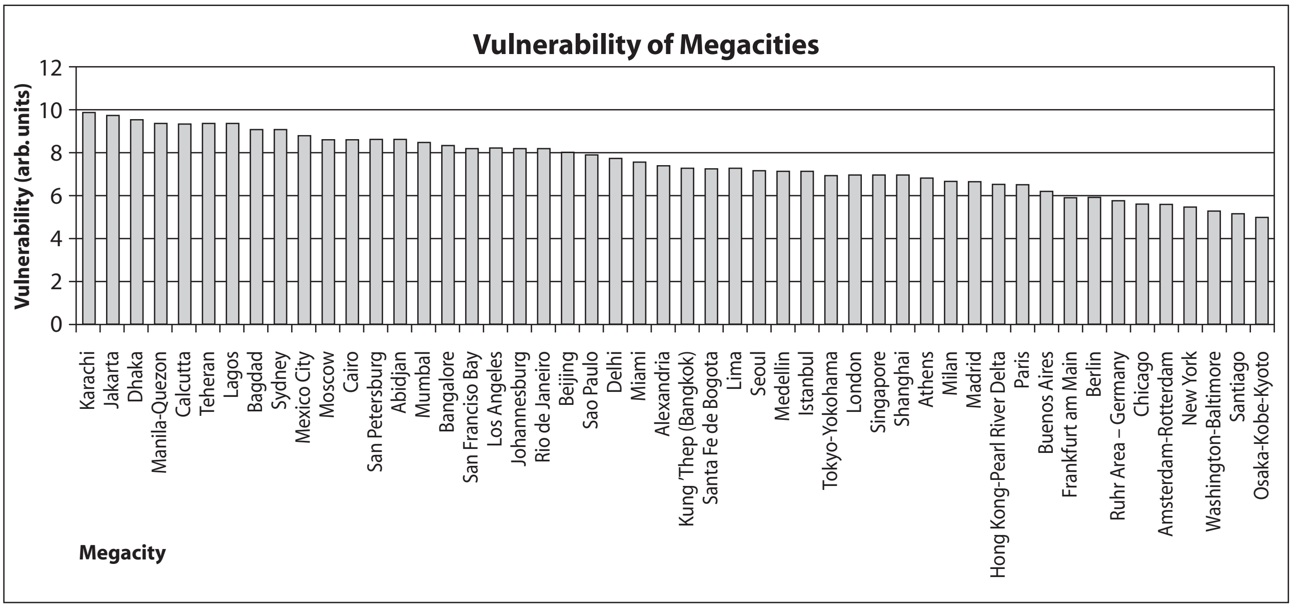

Figure 19: Vulnerability of megacities as estimated by Munich Re

3.3 Vulnerability Assessment: Megacity Scale

Munich Re (2003) has developed a method to calculate risks associated with various hazards for megacities around the world. The calculation of vulnerability involves the combination of three parameters, one which is hazard-dependent while the other two are hazard-independent. The parameters are:

- *Structural vulnerability: related to the building classes most predominant in the city;*
- *Standard of preparedness / safeguards: associated with the existence of building regulations, town and country planning with respect to hazards; and*
- *General quality of construction and building density.*

Structural vulnerability, preparedness, and quality of construction were assessed using a four degree scale (very good, good, average, and below average). Building density was represented through population density and was normalized in a range from 0 to 4 units. The three components were assigned equal weights and combined to generate a single indicator for each city. Figure 19 displays the results for the megacities considered in the assessment carried out by Munich Re.

Figure 20 displays data provided by Munich Re for the vulnerability of each megacity. The list is headed by Karachi, Jakarta, Dhaka, Manila and Calcutta. These cities have vulnerability indicators above nine arbitrary units (out of 10 possible units). The cities with the lowest vulnerabilities are Washington-Baltimore, Santiago and Osaka-Kobe-Kyoto. One interesting aspect to note is the fact that there is no correlation between the vulnerability of the city and its population, as displayed in figure 20. Very large cities such as Mexico and Tokyo present values which are not in the high or the low regimes and other cities span the entire scale.

The following comments can be made in regards to this approach:

- *The index makes use of information on the current status of the city in terms of infrastructure and population, and is not based on historical outcomes of previous disasters.*
- *While the index has been developed taking into account several hazards, the vulnerability indicator is expressed as a single one encompassing all hazards.*
- *The index has been designed to try to capture in an explicit or direct fashion the physical vulnerability of city.*

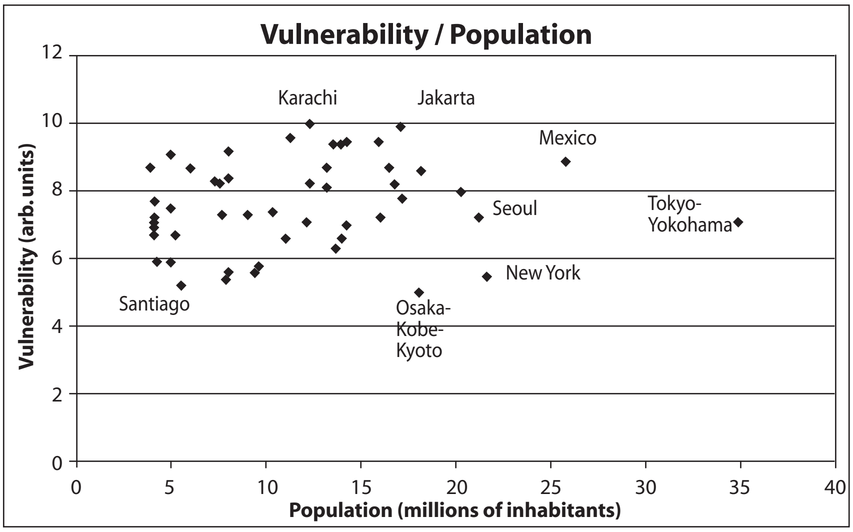

Figure 20: Vulnerability and population of megacities showing the lack of a correlation among these two parameters according to the Munich Re model

- *The index does not capture how vulnerability depends on the magnitude of the hazard. It assigns one single value of vulnerability for each city regardless of hazard or its magnitude.*
- *The value which emerges from the calculation of the indices should not be employed in a linear fashion when comparing cities.*

One feature which is missing in both the national level as well as the megacity level approaches is the linking of the magnitude of the vulnerability with some basic parameter or benchmark, a means to identify whether the vulnerability magnitude of a country is leading towards a disaster or just to an emergency. For example, the *Prevalent Vulnerability Index* of Guatemala situated in the order of sixty arbitrary units, is twice as large as that of Costa Rica, which lies between twenty five and thirty units. Yet, it is not clear whether any of these countries are really in a situation which should merit critical attention of the world, or whether both countries have vulnerabilities which need no attention from the international community.

In a similar fashion, Haiti and Pakistan share similar values of relative vulnerabilities in relation to tropical cyclones. However, is there anything in the value that could have predicted the major disasters which Haiti faced during 2004? Can it be concluded that any country which is assigned a magnitude above 10 arbitrary units is highly vulnerable?

3.4 Vulnerability Assessment: Local Scale

Some authors have focused on vulnerability assessments at the local scale through the use of specific surveys, creating indices and indicators based on different factors. While the combination of factors may have a drawback regarding the use of arbitrary weighing factors, such approaches can focus on the identification of specific elements which are vulnerable, thus yielding direct information on the state of vulnerability of a process, a system, or a sector. The following sections present efforts regarding vulnerability assessment at the community scale.

3.4.1 Vulnerability and Risk at Local Level: GTZ 2002

Hahn (2003) proposed the use of several indicators to assess the four types of vulnerability factors proposed by ISDR at the municipal level. Table 1 displays the variables used to assess each type of vulnerability:

Table 1: Indicators proposed by H. Hahn to assess vulnerabilities

Physical/demographic	Social	Economic	Environment
➢ Population density ➢ Demographic pressure ➢ Insecure settlements ➢ Access to basic services	➢ Level of poverty ➢ Degree of illiteracy ➢ Attitude ➢ Decentralization ➢ Community participation	➢ Local resource base ➢ Diversification ➢ Small enterprises ➢ Accessibility	➢ Forest area ➢ Degraded area ➢ Over-used area

The method includes the use of data currently available from municipal and national sources, as well as a questionnaire to acquire the remaining data. In addition, the model assigns 3 possible ranges to the data related to each of the indicators, and uses weights for the vulnerability index when calculating it for each type of hazard. The procedure is elaborated in such a way that the index can range from 0 to 100 units, and is representative of the entire community. The following example for the municipality of Villa Canales in Guatemala presents how the index is calculated numerically in the case of earthquakes.

Table 2: Indicators for the city of Villa Canales in Guatemala

Indicator	Weight	Value	Product
V1 - Density	3	1	3
V2 – Demographic pressure	3	3	9
V3 – Insecure settlements	1	1	1
V4 – Access to basic services	1	2	2
V5 – Poverty level	2	2	4
V6 – Illiteracy rate	2	2	4
V7 - Attitude	3	2	6
V8 - Decentralization	1	2	2
V9 – Community participation	2	2	4
V10 – Local resource base	3	3	9
V11 - Diversification	2	3	6
V12 – Small enterprises	2	2	4
V13 - Accessibility	2	2	4
V14 – Forested area	2	2	4
Total value of index	33		

The vulnerability index is calculated through the combination of the 14 indicators with their respective weights, which range from 1 to 3 arbitrary units. The overall sum of weights is 33. This is because the methodology has been created with the idea of conveying a measure regarding risk, where vulnerability of one of the three components (in this model Risk = Hazard + Exposure + Vulnerability) – Coping Capacities.

3.4.2 Household Sector Approach: CIMDEN 2001

In a different approach, the author has developed a procedure to assess four different types of vulnerabilities associated with the housing sector at the local level: physical or structural, functional, social, and economic income. In this method, each type of vulnerability is measured through parameters which are directly related to the type of vulnerability in question, classifying the different types of options commonly available in communities for these variables in three ranges: low, medium, and high. For example, in the case of volcanic eruptions, the structural vulnerability of a house is analyzed through five parameters: walls, roof materials, roof inclination, roof support material, doors, and windows. The classification in terms of low, medium, and high classes is introduced in terms of the construction material employed, recognizing that some are more vulnerable than others. The classification of materials into the three categories has been based on an analysis of historical impacts of eruptions in houses throughout Central America. The parameters are assigned weights, and are then combined in a linear fashion. The overall vulnerability is presented in terms of arbitrary units and classified in three ranges according to a pre-defined table.

In this case, it is important to recognize several aspects:

➢ *In this model, physical or structural vulnerability is expressed according the present condition of the house and addresses those elements which can lead to damages or destruction in case of an event.*

		LOW	MEDIUM	HIGH
	WEIGHT	1	3	5
Walls	15	block, brick metallic structure	adobe	cardboard, light wood, plastic, bamboo
Roof, materials	10	concrete slab	galvanized sheeting, cement tiles	straw, plastic brick tiles
Roof, inclination	5	very inclined	modetately inclined	low inclination
Roof, support material	5	steel structure new, treated wood	old, non-treated wood	weights, stones
Doors	1	metal, wood	small windows	large windows
Windows	1	metal, wood	small glass	large glass

$$V_{estruct} = 15 \times 5 + 10 \times 5 + 5 \times 5 + 5 \times 3 + 1 \times 1 + 1 \times 1$$
$$= 167$$

Degree of structural vulnerability	Numerical range
Low	37–80 points
Medium	81–130 points
High	131–185 points

Figure 21: Matrix to assess structural vulnerability of a house in case of volcanic eruptions. Vulnerability is assessed via indicators based on construction materials for different structural elements of a house.

- ➢ *The method has been adapted to handle different hazards. Adaptation to different hazards is made recognizing the impact of the hazard on the various components of the house.*
- ➢ *The indicators display in an explicit or direct fashion the vulnerability of the household through the four types of vulnerabilities. It assumes that different options can be classified with higher or lower degrees of vulnerabilities, and computes a value according to the assigned weights to each parameter considered.*
- ➢ *The indicators do not show how vulnerability depends on the magnitude of the hazard. The method is based on the consideration of a very high magnitude event, but cannot cope with small-magnitude events.*
- ➢ *The vulnerability assessment can be employed to assess the vulnerability of a single house, but can be aggregated at the community, municipal, province, and national level. Figure 22 displays the assessment of vulnerability in houses located in the urban settlement Las Torres in Guatemala city. Lots have been classified and identified as low vulnerable (green), medium vulnerable (yellow) and highly vulnerable (red). Grey polygons represent cases where no data was available.*
- ➢ *The method identifies options to reduce the degree of vulnerabilities explicitly, but has been constructed for specific regions of the world (construction materials and construction techniques present in one region of the world for example). Its extrapolation to other regions of the world will need adaptation.*
- ➢ *The method requires a specific survey at the household level to gather information on the four types of vulnerabilities within the housing sector for each house.*

Thus far, the method has been applied in rural communities of Guatemala spanning earthquakes, landslides, and volcanic eruptions (Villagrán, 2004; 2005).

3.4.3 Vulnerability at the Community Level Using Census Data: Guatemala

A similar approach has been developed by the author in an effort to characterize structural and social vulnerabilities using census data provided by the National Statistic Institute of Guatemala (Villagrán, 2002).

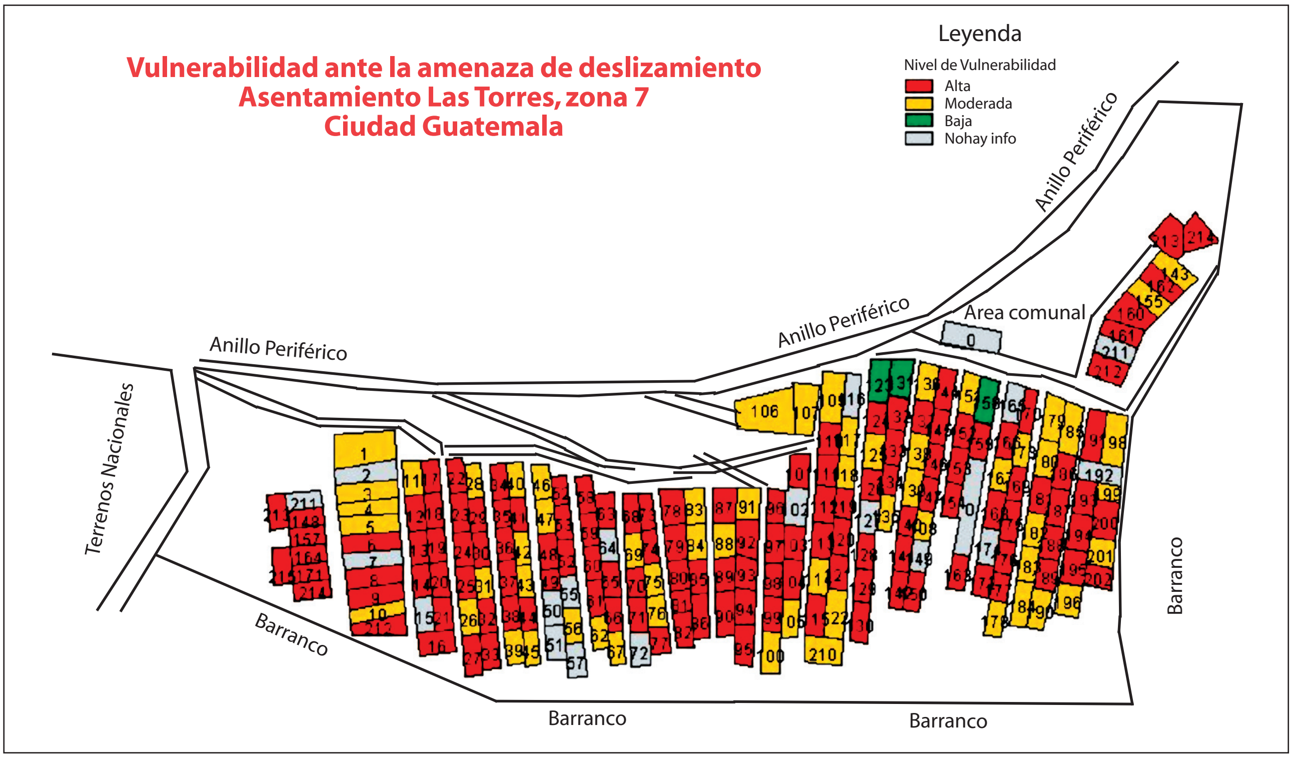

Figure 22: Vulnerability of houses in the Las Torres urban settlement in Guatemala city
Source: Perez, 2001

Pilot efforts conducted in Guatemala for various types of hazards allow for the comparison of vulnerabilities among different communities. As in the previous case, indicators for structural vulnerability are constructed on the basis of construction materials for walls, floors, and roofs, considering their susceptibility to failure, thus provoking damages to the infrastructure. The visualizations using GIS techniques (such as ARC-VIEW mapping features) then becomes in itself a powerful tool to detect regions where several communities display high or low vulnerabilities, as well as comparisons among communities located within the same geographical region.

If hazard maps are available in a digital format, vulnerabilities and hazards can then be linked using GIS software to produce risk maps. Figure 23 illustrates communities at risk in relation to floods for the Escuintla department (province) in Guatemala. Using the auto-scaling features of ARC-VIEW, colors are assigned to communities according to their level of risk. In this case red signifies high risk, whereas light blue signifies low risk and grey signifies no risk at all (outside the hazard area).

3.4.4 Normalizing Vulnerability and Risk to Compare Communities

When generating vulnerability and risk information regarding the housing sector for communities of different sizes in a geographical region such as a province, an emerging issue is the fact that larger communities can display large numerical vulnerabilities just on account of a greater number of houses. In an effort to compare small and large communities, the author has defined the concept of **normalized risk** (Villagrán, 2002; 2004) which is obtained dividing the total risk for the community by the number of houses.

This normalization process then yields new data on communities that allows for more coherent comparisons. The use of normalized risks allows for the identification of geographical zones where either emergencies or disasters can be expected, on account that a community with a large normalized risk will lead to a disaster, whereas a community with a low normalized risk will lead to an emergency which can be handled without the need of external resources and assistance. Figure 24 displays normalized risks the same case of the Escuintla department in Guatemala. Comparing figures 23 and 24, it can be seen that some of the communities have been assigned different colors when this distinction is applied.

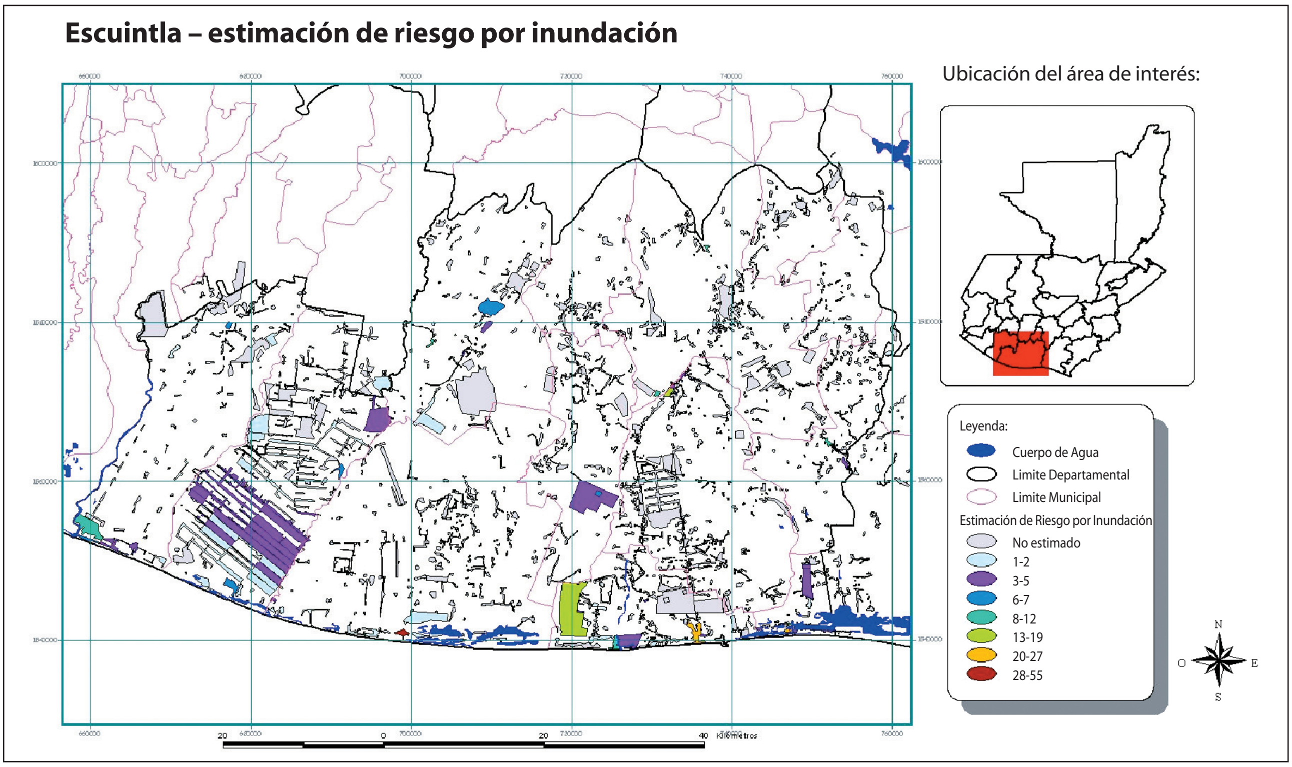

Figure 23: Risk of communities within the Escuintla department with respect to floods

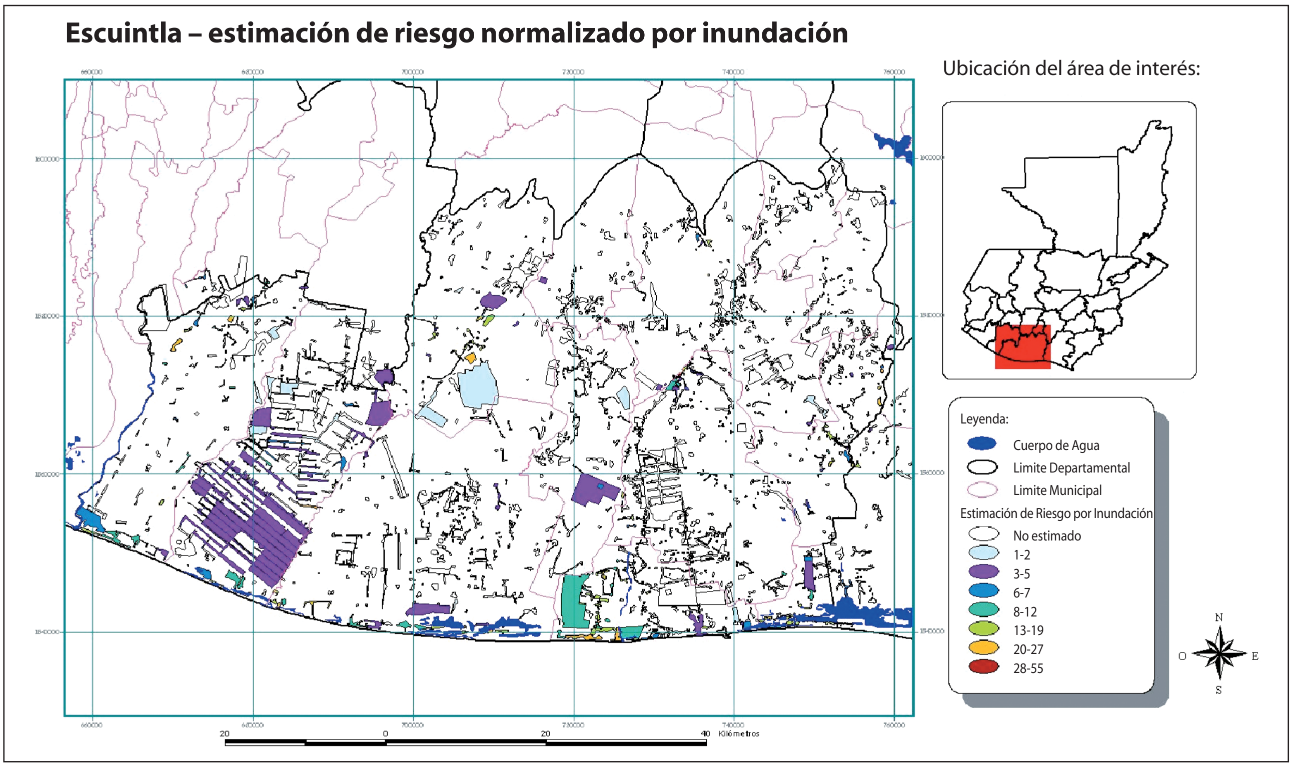

Figure 24: Normalized risk of communities within the Escuintla department with respect to floods

In general terms, the following comments can be made regarding this approach:

- *Vulnerability is assessed at the level of towns and cities using data representing aggregation of parameters at this level.*
- *The indicators are developed specifically for each type of hazard, adapting the method in terms of structural components of the houses. However, its validity may be limited due to the fact that census data contain only limited information regarding elements required to complete the vulnerability assessment; and thus, relevant factors may be left out of the calculation. For example, in the case of floods the height of the floor of the house or structure with respect to the ground is a very important parameter, but it is not included in the census data.*
- *The indicators do not show explicitly how vulnerability depends on the magnitude of the hazard.*
- *The method allows for the aggregation to higher levels (municipal districts, provinces, and up to the national level).*

3.4.5 A Holistic Approach for Seismic Risk in Cities: Bogota, Colombia

Recently, Barbat (2003) presented a method to evaluate seismic risk in a holistic way. Vulnerability is represented within the method as a combination of demographic, economic and strategic exposure, absence of economic and social development, deficiencies in absorbing the impact, deficiencies in institutional management procedures and lack of capacity to respond in case of emergency. To represent vulnerability, three factors are proposed:

- ***Exposure***, which refers in general to the volume and concentration of elements in a given area, and is calculated combining population exposure, density of population, built area, industrial area, and Government and institutional area;
- ***Social fragility***, characterized in terms of existing conditions of poverty and marginality, low health levels, delinquency and basic unsatisfied needs of the population. This sub-index is calculated in terms of extension of slum neighbourhoods, mortality, delinquency and social disparity; and

- ***Lack of resilience***, which represents the weaknesses of the city to absorb the impact of a crisis, the lack of capacity to respond in case of emergency and deficiencies in institutional management within the urban area. This sub-index is calculated using parameters such as the density of hospital beds, human health resources, public space and shelter facilities, rescue and fire-fighting manpower, development level, and preparedness emergency planning.

Care is taken to scale the indicators before combining them using weights. The assessment has been carried out for Bogotá city via an assessment of the 19 administrative districts which compose this city. Estimation of the weights has been performed using the Analytical Hierarchy Process (Cardona 2003). Vulnerability ranges from 2.5 to 6.8 units for the 19 districts and risks range from 2.3 to 7.6 units for these districts. Results have been displayed in maps using GIS tools. General comments of this methodology are:

- *The indicators are constructed on proxies which are related to vulnerability. However, coping capacities could be deduced from the third sub-index.*
- *The indicators do not show explicitly how vulnerability depends on the magnitude of the hazard.*
- *The method requires a specific survey to gather information on three sub-indices, but can be applied rather easily in any city.*

Table 3 presents the weights assigned to the various indicators of the three sub-indices.

Table 3: Weights assigned to the different indicators to quantify risks

Sub Index	Weight	Indicator	Weight
Exposure	**0.25**	Population	0.25
		Density of population	0.20
		Built area	0.25
		Industrial area	0.15
		Government institutional area	0.15
Social fragility	**0.40**	Slum neighbourhoods	0.40
		Mortality rate	0.10
		Delinquency rate	0.10
		Social disparity index	0.40
Lack of resilience	**0.35**	Hospital beds	0.15
		Health human resources	0.15
		Public space and shelter facilities	0.15
		Rescue and firemen manpower	0.15
		Development level	0.20
		Preparedness emergency planning	0.20

4. Discussion

The need to develop indicators to evaluate vulnerabilities and risks is a must for developing countries, which need a strategy to invest scarce funds to maximize the results related to risk reduction. This paper has presented a review of the conceptual models proposed to define, characterize and evaluate vulnerability at different scales, from the local to the national levels. One main result from this summary is the fact that vulnerability needs to be understood in a wide context which spans many sectors, components, and levels.

From a dynamic point of view, vulnerability changes continually with time. Changes are related to those factors which can augment it, reduce it, or maintain it in that state. Bankoff, Frerks, and Hilhorst (2004) and several other authors state that vulnerability is generated through social processes. Issues such as class, gender, ethnicity, poverty, and power relations, among others, lead to unequal exposure to risk.

An interesting discussion on issues related to policies and the role of government agencies as generators of vulnerabilities is presented by Heijmans (2004). This author argues the case of **development aggression** as a cause for vulnerability generation related to national level projects such as the construction of dams for hydro-electric power. In such cases, people living in rural areas are displaced and relocated in different geographical regions without the necessary resources to reconstruct livelihoods and social networks required to cope with new risks. In addition, she points out to the expansion of cities and private interests from real state developers as another cause for the generation of vulnerabilities.

In contrast to this issue of development aggression, Delica-Wilson and Willison (2004) point out the issue of "stress" as a factor which can affect capacities of people and communities to cope with risks. Stresses, as they argue, impact social networks, livelihoods, and human security and is generated through social and political unrest for example.

Factors which may allow vulnerability to be reduced encompass improved coping capacities, such as enhanced accesses to resources, alternate but more productive ways of live, measures which reduce the level of poverty, institutional and political changes such as decentralization, improvements in livelihoods, etc.

Factors which maintain vulnerability can be associated with the inertia of the political, financial and social systems. Institutional inertia, an active strategy for maintaining control and the status quo, is one such example (Heijmans, Delica-Wilson, Cardona, Bankoff, 2004). In a similar fashion, a static state of poverty may force a household or a community to stay within the same status, inhibiting possible changes to reduce vulnerabilities. Another factor which can be mentioned is the constant inequitable distribution of productive resources.

Factors which augment vulnerability can be internal or external. Adverse situations, the result of civil or political unrest, can augment the state of vulnerability through the removal of resources normally available; political malpractices which may shy away potential resources. In the case of external factors, one can consider natural disasters as such, some negative aspects associated with globalization and the international markets. Table 4 presents some of the many factors which have been cited in the literature.

Table 4: Factors which generate or reduce vulnerabilities

Factors which can lead to the generation of vulnerability	Factors which can enhance vulnerability	Factors which can reduce vulnerabilities
• Inequality due to prevailing political, social and economic models • Demographic differences • Unequal terms of international trade • Marginality, poverty and level of development • Lack of access to credit, mobilization of resources • Trends in land occupancy • Habits and traditions • Inadequate organization systems • Lack of responsibility regarding the generation of vulnerabilities • Unemployment, income deficits, illiteracy • City expansion, uncontrolled, unplanned growth due to migration to urban areas • Development aggression • Use of inappropriate technology • Lack of building codes or their enforcement	• Increasing population • Densification of vulnerable areas in particular geographic regions • Marginality, poverty and level of development • Lack of access to credit, mobilization of resources • Trends in land occupancy • Habits and traditions • Unemployment, income deficits, illiteracy • Social and domestic violence • City expansion, uncontrolled, unplanned growth • Development aggression • Use of inappropriate technology • Lack of building codes or their enforcement • Previous disasters • Gender • Disintegration of social patterns and livelihoods	• Improvements in social networks and livelihoods • More equal distribution of political and economic resources • Training and education • Urban planning • Implementation, enforcement of building codes • Diversification, duplication of resources • Provide more opportunities, resources, and power to women • Target marginal, informal, and micro-economic sectors during reconstruction phases after disasters

4.1 Vulnerability and Coping Capacities

While most authors agree on defining vulnerability as the predisposition of something to be affected, some authors have also included such factors as lack of resilience and coping capacities into the definition, as well as the leading causes regarding vulnerability. An analysis of the segment "predisposition of something to be affected" normally would leave out the coping capacities if one considers coping capacities just to include aspects related to the response, once the event has taken place and people need to respond. In this sense, coping capacities would encompass those measures that allow people to respond after the event, but not before. However, a more expanded point of view considers coping capacities to include measures which are taken prior to the event, which can reduce the vulnerability, as well as measures which can be implemented to try to contain the event once it has manifested itself within a specific geographical area in addition to measures to respond.

In the diagram presented in figure 25 coping capacities have been embedded within the ellipse at the top of the figure. Examples of containment measures in the case of floods could span the containment of a damaged levee which has been bridged using people to repair the levee in a temporary fashion, using sacks of sand in an effort to impede the flood from reaching a city or a population. As an additional example one can mention the case of forest fire-fighting activities undertaken by fire-fighters to combat and to contain a forest fire, so that it does not reach a community. However, it must be realized that such containment measures are not available in the case of some hazards such as earthquakes and tsunamis.

Allowing coping capacities to include both pre- and post-disaster measures, one must still separate them, as indicated in the diagram, as measures to reduce vulnerability will be different to those related to how to cope with the losses, once they have been materialized. Measures associated with the response phase can only take place once the event that triggers the disaster has manifested itself. The diagram also includes in the right side two distinct outcomes related to the degree of damage: emergency and disaster. Within the

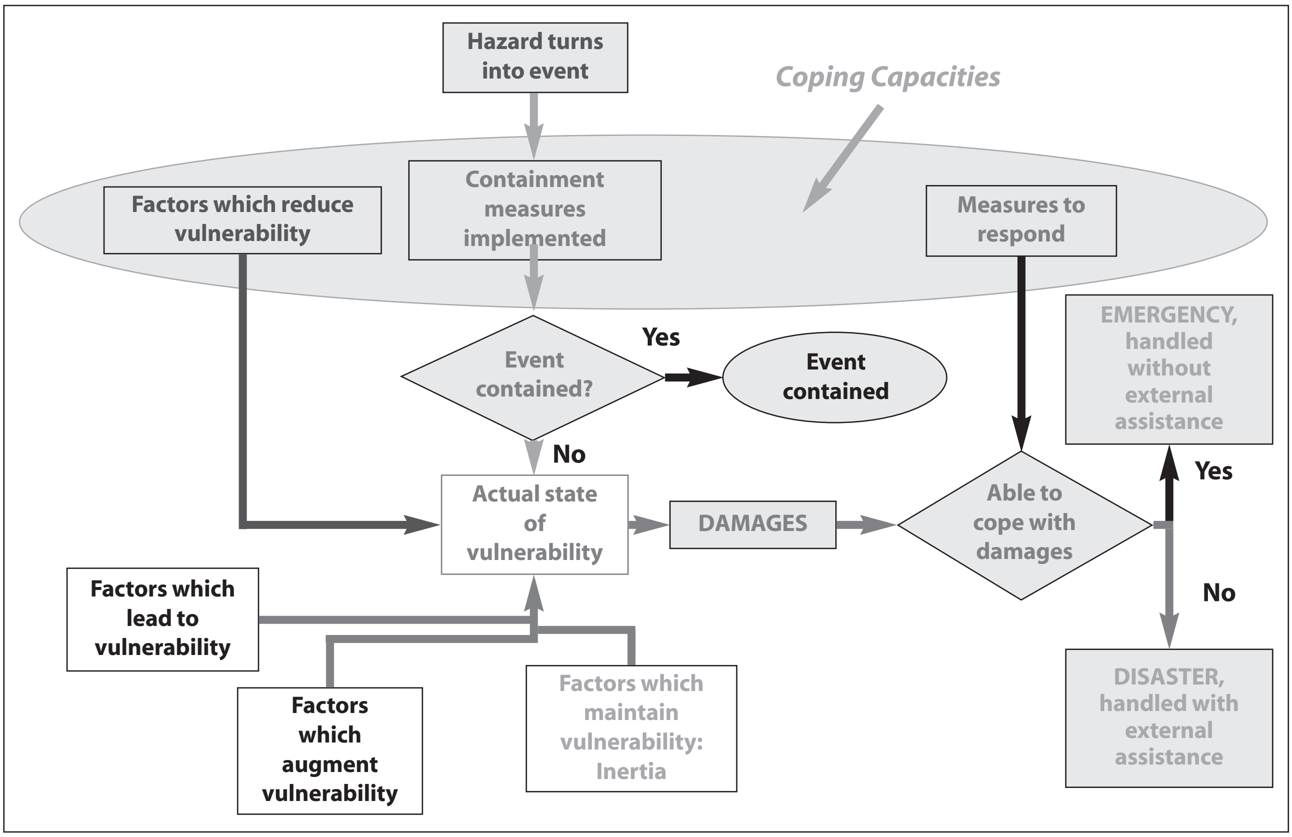

Figure 25: Elements of risk: hazard, vulnerability, and coping capacity in the context of disasters

disaster management community, emergencies are defined as those events which can be handled without any external assistance; while disasters require external assistance, as damages have surpassed coping capacities.

4.2 Vulnerability and Resilience

Several authors consider resilience as an intrinsic ability of a system, an element, or a community to resist the impact of a natural or a social event. That is, the ability of the system not to be affected by the event in the first place. If resilience is to be considered in this way, then vulnerability and resilience are reciprocal terms. A more vulnerable system should be less resilient, and a system is less vulnerable if it is more resilient.

However, other authors consider resilience as the ability of the system or element to absorb the impact, and cope with it successfully. Again, depending on the notion of vulnerability, both terms could be reciprocal. For example, rural people in Africa build houses out of mud and straw, two elements commonly found near rivers. Houses of this kind are easily destroyed in the case of floods, but since the construction elements are easily available, then one could say that such communities are resilient, as their houses can be easily destroyed, but easily reconstructed. The contrasting view would pinpoint houses as very vulnerable to floods, but assigning the community the coping capacities to reconstruct them after they have been damaged or destroyed.

An interesting framework for vulnerability has been proposed by M. Pelling (2003) which encompasses vulnerability in terms of exposure, resistance, and resilience. In this model, **exposure** is related to the location of the system or element with respect to the hazard and the environmental surroundings; **resistance** is related to the economical, psychological, and physical health of systems of maintenance, as well as the capacity of individuals or communities to withstand the impact of the event and is related with livelihoods; while **resilience** is defined as the ability to cope with or adapt to the hazard stress through preparedness and spontaneous adaptations once the event has manifested itself.

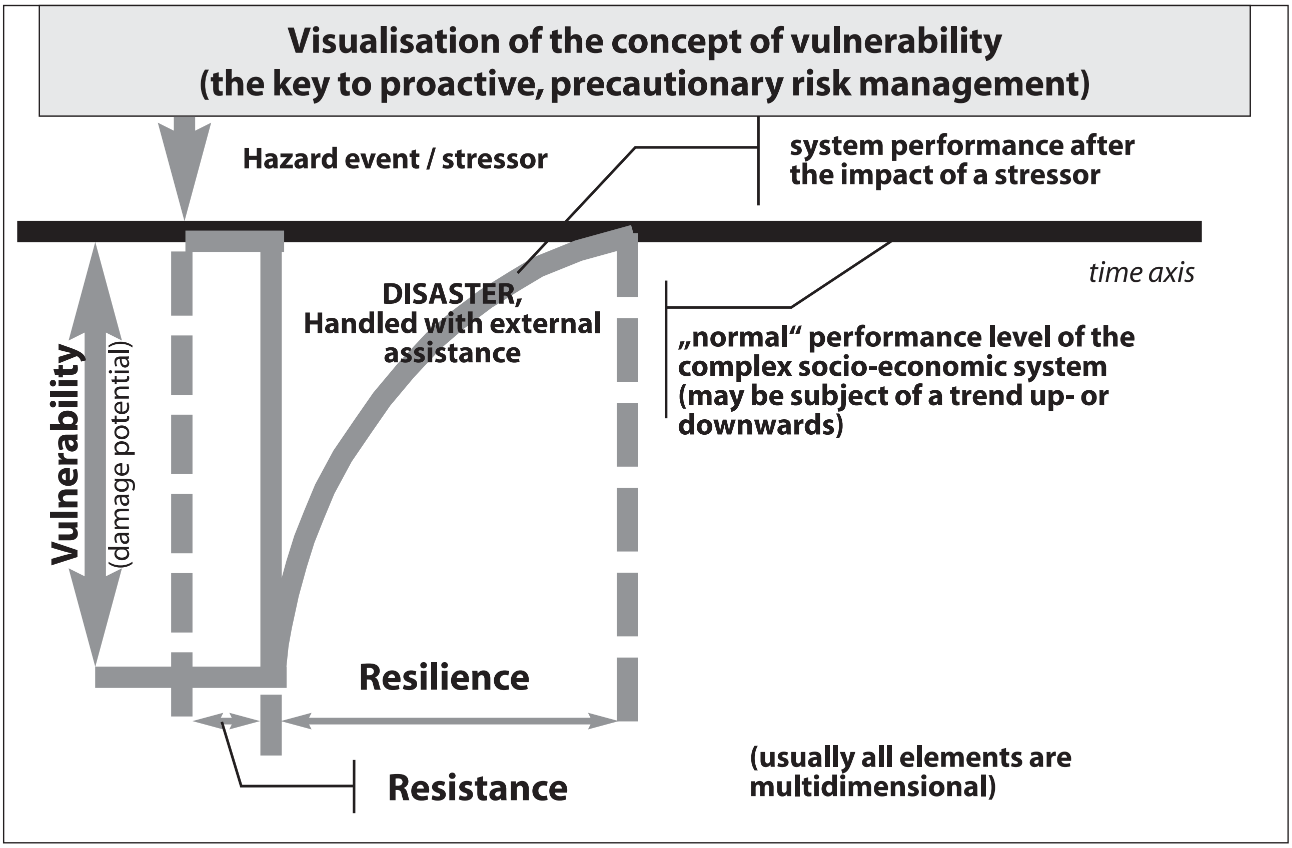

Figure 26: Bogardi´s notion of vulnerability spanning damage potential, resistance, and resilience
Source: Bogardi, 2006

A similar approach has been introduced by J. Bogardi (2006) linking vulnerability to resistance and resilience. In this approach, **resistance** is related to the capacity of the system to remain unchanged for an interval of time after the event manifested itself. After that interval of time, the system undergoes changes as the event takes its toll. **Resilience**, in contrast to resistance, is then related to the capacity of the system to recover to its state prior to the disaster.

As Bogardi points out, the intervals of time associated with resistance and resilience could be used initially as surrogate indices. In this approach coping capacity could be defined as the combination of resistance and resilience. Vulnerability would continue to be defined as a combination of the damage potential, resilience, and resistance.

4.3 Vulnerability Perception

A final aspect to consider regarding vulnerability is related to how it is perceived by those affected by it, and by those who have to do something about it. For example, Fordham (2004) describes very precisely how men are blind to particular vulnerabilities of women and children. Surveys conducted in several parts of the world reflect the fact that women and men have different views on the vulnerabilities of their families.

While addressing the different perceptions is an important issue, a crucial issue is related to whether people are even aware of some of their vulnerabilities. For very rare events such as large earthquakes and tsunamis, there is usually no historical or social memory, and so, the younger generations which never went through such events might reconstruct vulnerabilities from one historical event to the next. In a different context, the importation of building techniques from foreign nations might lead to vulnerabilities which people are not aware of, simply because some hazards do not manifest themselves in all parts of the world on a frequent basis.

Another important aspect outlined by Heijmans (2004) is related to the fact that different perceptions of vulnerabilities lead to different approaches on how to handle them. This can be particularly illustrated when national level agencies try to solve particular problems in rural areas, without being aware of the vulnerability of their proposed solutions. For example, in the northern coast of Honduras, the ministry of public works constructed levees along the shores of several rivers, only to be destroyed a year later by new floods. While local people were already aware of the failures of previous attempts, government agencies never consulted those people and kept rebuilding vulnerable levees.

In a similar context, several researchers point out to the deficits which several NGOs manifest when trying to assess vulnerabilities using indirect approaches. Such assessment may not take into account social issues such as livelihoods, social networks, and other social phenomena; only restricting themselves to issues regarding the physical vulnerability of structures, or some methods developed in some regions of the world which do not necessarily apply in other communities, and/or other countries. Thus, they are not capturing vulnerabilities as perceived by members of such communities.

4.4 Coping with Many Faces of Vulnerability

Vulnerability assessment focuses on understanding the intrinsic predisposition of people, systems or communities to be affected, and can include the assessment of the factors which lead to, augment, reduce, or maintain such vulnerabilities. However, the many different ways in which scientists and researchers are using the term, and the fact that vulnerability spans many sectors, levels, and intricate particularities of societies, makes it difficult to come up with a single means to assess it.

As a resort to cope with this situation, a generally accepted framework needs to be developed and put into practice, which allows researchers to link concepts with specific words. Such a framework needs to encompass issues regarding the various contexts, levels, and sectors which are currently being addressed all over the world. This might mean having to define specific means to every particular word used, and avoid using the same word to express different ideas or contexts; in other words, a common language for everybody to use, rich enough in terms to satisfy everybody, but precise enough so that each term encompasses one single, specific idea.

5. Concluding Remarks

There are many different views on vulnerability stemming from different research groups around the globe, which is indicative of the fact that this field remains "unsettled" yet. While initially there was a goal of describing vulnerability in terms of basic elements, two trends are emerging in the last decade:

- *The development of models which explain vulnerability and its dynamics in terms of root causes which are leading to it.*
- *The development of indicators or indexes which may allow for vulnerability to be traced throughout the years or to compare countries, cities, or societies in this respect.*

Being a very context-rich term, vulnerability assessment should be decomposed to incorporate dimensions or topics and levels; and methods developed to assess the degree of vulnerability in each dimension and level using the appropriate units. As stated before, the goal with vulnerability assessment should be to quantify it so that subsequent evaluations can be carried out to determine if it is being reduced or not. As it is to be expected, the precision of the models can vary depending on data availability, as well as on the parameters or proxies employed to assess it. The identification of benchmarks via such methodologies is of the essence to set targets towards its control.

In contrast to the assessment of vulnerability per se, the identification and characterization of these factors contributing to the generation or enhancement of vulnerability are also of utmost importance, as only by targeting such root causes or factors a society can control such a process of vulnerability generation.

Considering the advances made in recent years, two challenges lie ahead:

- The development of theories that can indeed explain vulnerability and its root causes, which also incorporate models that can predict outcomes. Those outcomes could be verified after the manifestation of an event that triggers disasters exposing such vulnerabilities.
- Reaching a consensus on one particular model or theory, so that it can then be applied systematically throughout the world, or at least throughout developing nations which continually face disasters. The climate change community has advanced considerably in this sense via simple indicators that have been agreed upon in international conferences. And benchmarks are now being established in many countries. While the engineering community has advanced in the design of indicators and building codes to inhibit the generation of physical vulnerabilities in infrastructure, the real question is whether the social scientists are ready to reach such a consensus.

The *World Conference on Disaster Reduction* held in Kobe in January 2005 was one of those international conferences gathering representatives and practitioners from countries around the world. While NGOs were calling for the establishment of benchmarks and targets, this conference only replicated an outcome which was already a decade old: *the reduction of vulnerabilities in all countries and at all levels*. Being a complex subject, vulnerability will require additional efforts in terms of research and testing of models before a consensus is reached. This is therefore the challenge for the next decade.

Abbreviations

BBC	Birkmann-Bogardi-Cardona model on vulnerability, UNU-EHS
CIDA	Canadian International Development Agency
CRED	Centre for Research on the Epidemiology of Disasters
CSD-UN-DESA	Commission for Sustainable Development, Department of Economic and Social Affairs, UN
CVA	Capacity and Vulnerability Analysis
CVI	Composite Vulnerability Index
DDI	Disaster Deficit Index
DFID	Department for International Development, England
DRI	Disaster Recovery Institute
ECLAC	Economic Committee for Latin America and the Caribbean, UN
GDP	Gross Domestic Product
GTZ	German Technical Cooperation Agency
HDI	Human Development Index, UNDP
IADB	Inter-American Development Bank
IDNDR	International Decade for Natural Disaster Reduction, UN
IES	Institute of Environmental Studies, University of Colombia, Manizales
IPCC	International Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
ITU	International Telecommunication Union
LDI	Local Disaster Index
OECD	Organization for Economic Co-operation and Development
OFDA	Office of Foreign Disaster Aid, United Stated
PAHO	Pan American Health Organization
PVI	Prevalent Vulnerability Index
RMI	Risk Management Index
SIDS	Small Island Developing States
SVI	Social Vulnerability Index
UBNI	Unsatisfied Basic Needs Index
UN	United Nations
UN DESA	Department of Economic and Social Affairs, UN
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNDP-BCPR	Bureau of Crisis Prevention and Recovery, UNDP
UNU	United Nations University
UNU-EHS	Institute for Environment and Human Security, UNU
WFP	World Food Programme, UN

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