INDICATORS OF DISASTER RISK AND RISK MANAGEMENT

Main Technical Report

National University of Colombia – Manizales
Institute of Environmental Studies
Inter-American Development Bank

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SYSTEM OF INDICATORS FOR DISASTER RISK MANAGEMENT

PROGRAM FOR LATIN AMERICA AND THE CARIBBEAN

MAIN TECHNICAL REPORT

Study coordinated by

Instituto de Estudios Ambientales

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ACRONYMS

AHP	Analytical Hierarchy Procedure
CAPRADE	Comité Andino de Prevención y Atención de Desastres (Andean Committee for Disaster Prevention and Attention)
CDERA	Caribbean Disaster Emergency Response Agency
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres Naturales en América Central (Center of Coordination for Natural Disasters in Central America).
CEDERI	Centro de Estudios sobre Desastres y Riesgos (Center of Studies on Risks and Disasters of University of Los Andes, Colombia).
CID	Centro de Investigaciones para el Desarrollo (Center of Researches for Development of the National University of Colombia)
DDI	Disaster Deficit Index
ECLAC	Economic Commission for Latin America and the Caribbean
EERI	Earthquake Engineering Research Institute
EMI	Earthquakes and Megacities Initiative
HABITAT	United Nation Human Settlements Program
IDB	Inter-American Development Bank
IDEA	Instituto de Estudios Ambientales (Institute of Environmental Studies of the National University of Colombia)
ISDR	International Strategy for Disaster Reduction
LA RED	Red de Estudios Sociales en Prevención de Desastres de América Latina (Latin American Network of Social Studies on Disaster Prevention)
LDI	Local Disaster Index
MCE	Maximum Considered Event
NGO	Non Governmental Organization
OAS	Organization of American States
PAHO	Pan-American Health Organization
PVI	Prevalent Vulnerability Index
PML	Probable Maximum Loss
RMI	Risk Management Index
UNAM	Universidad Nacional Autónoma de México (Nacional University Autonomous of Mexico)
UNC	Universidad Nacional de Colombia (National University of Colombia)
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization

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4. Application Results

5. Comments, criticisms and suggestions for future developments

INTRODUCTION

Disaster risk is not only associated with the occurrence of intense physical phenomena, but also with the vulnerability conditions that favor or facilitate disasters when these phenomena occur. Vulnerability is intimately related to social processes in disaster prone areas and is also usually related to the fragility, susceptibility or lack of resilience of the population when faced with various hazards. In other words, disasters are socio-environmental by nature and their occurrence is the result of socially created risk. This means that in order to reduce disaster risk, society must embark in a decision-making processes. This process is not only required during the reconstruction phase immediately following a disaster, but should also be a part of overall national public policy formulation and development planning. This, in turn, requires institutional strengthening and investments in reducing vulnerability.

All types of risk management capabilities need to be strengthened in order to reduce vulnerability. In addition, existing risks and likely future risks must also be identified. This cannot be accomplished without an adequate measure of risk and monitoring to determine the effectiveness and efficiency of corrective or prospective intervention measures to mitigate or prevent disasters. The evaluation and follow-up of risk is needed to make sure that all those who might be affected by it, as well as those responsible for risk management are made aware of it and can identify its causes. To this end, evaluation and follow up must be undertaken using methods that facilitate an understanding of the problem and that can help guide the decision-making process. The system of indicators proposed in this report measures risk and vulnerability using relative indices at the national level. The aim is to provide national decisionmakers with access to the information that they need to identify risk and propose adequate disaster risk management policies and actions. The proposed system of indicators allows for the identification of economic and social factors that affect risk and risk management, as well as the international comparison of these factors.

To make sure that this methodology is easy to use, it must include a limited number of aggregate indicators that will be of use to policymakers. While this methodology is national in nature, the research also evaluated subnational and urban data using a similar conceptual and methodological approach in order to illustrate the application of this model at the regional and local levels. The goal of this research program was to adjust the methodology and apply it to a wide range of countries in order to identify analytical factors (economic, social, resilience, etc.) to carry out an analysis of the risk and risk management conditions in those countries. The integrated system detailed in this report allows a holistic, relative and comparative analysis of risk and risk management. In accordance with program requirements, this methodology is expected to have three major impacts at the national level.

First, it should lead to an improvement in the use and presentation of information on risk. This will assist policymakers in identifying investment priorities to reduce risk (such as prevention and mitigation measures), and direct the post disaster recovery process.

Second, the methodology provides a way to measure key elements of vulnerability for countries facing natural phenomena. It also provides a way to identify national risk management capacities, as well as comparative data for evaluating the effects of policies and investments on risk management.

Third, application of this methodology should promote the exchange of technical information for public policy formulation and risk management programs throughout the region.

This system of indicators, as outcome of the IDB-IDEA program, provides a holistic approach to evaluation (Cardona 2001; 2004) that is also flexible and compatible with other evaluation methods. As a result, it is likely to be increasingly used to measure risk and risk management conditions. The systems main advantage lies in its ability to disaggregate results and identify factors that should take priority in risk management actions, while measuring the effectiveness of those actions. The main objective is to facilitate the decision-making process. In other words, the concept underlying this methodology is one of controlling risk rather than obtaining a precise evaluation of it (physical truth).

In addition, the research program is expected to help fill an important information gap for national decisionmakers in the financial, economic, environmental, public health, territorial organization, and housing and infrastructure sectors. The methodology provides a tool for monitoring and promoting the development of risk management capacities. Because the data is comparable across countries, it will make it possible for policymakers to gauge their country's relative position and compare their evolution over time. Finally, the results of the Disaster Risk Indicators Program yield a tool that the IDB can use to guide its policy dialogue and assistance to member countries. It also contributes to the Bank's Action Plan proposed for 2000 and, in particular, to promoting the "evaluation of methods available for estimating risk, establishing indicators of vulnerability and vulnerability reduction and stimulating the production and diffusion of wide-ranging information on risks." It is also related to an IDB strategic area; namely, it provides information on risks in order to facilitate decision-making (Clarke and Keipi, 2000). Also it is part of the new IDB Action Plan 2005-2008 to improve the disaster risk management in Latin America and the Caribbean.

1. GENERAL DESCRIPTION

Disaster risk management requires risk "dimensioning", and risk measuring signifies to take into account not only the expected physical damage, victims and economic equivalent loss, but also social, organizational and institutional factors. The difficulty in achieving effective disaster risk management has been, in part, the result of the lack of a comprehensive conceptual framework of disaster risk to facilitate a multidisciplinary evaluation and intervention. Most existing indices and evaluation techniques do not adequately express risk and are not based on a holistic approach that invites intervention.

It is necessary to make risk "manifest" in different ways. The various planning agencies dealing with the economy, the environment, housing, infrastructure, agriculture, or health, to mention but a few relevant areas, must be made aware of the risks that each sector faces. In addition, the concerns of different levels of government should be addressed in a meaningful way. For example, risk is very different at the local level (a community or small town) than it is at the national level. If risk is not presented and explained in a way that attracts stakeholders' attention, it will not be possible to make progress in reducing the impact of disasters.

Disaster risk is most detailed at a micro-social or territorial scale. As we aggregate and work at more macro scales, details are lost. However, decision-making and information needs at each level are quite different, as are the social actors and stakeholders. This means that appropriate evaluation tools are necessary to make it easy to understand the problem and guide the decision-making process. It is fundamentally important to understand how vulnerability is generated, how it increases and how it builds up. Performance benchmarks are also needed to facilitate decision-makers' access to relevant information as well as the identification and proposal of effective policies and actions.

Creating a measurement system based on composite indicators is a major conceptual and technical challenge, which is made even more so when the aim is to produce indicators that are transparent, robust, representative, replicable, comparable, and easy to understand. All methodologies have their limitations that reflect the complexity of what is to be measured and what can be achieved. As a result, for example, the lack of data may make it necessary to accept approaches and criteria that are less exact or comprehensive than what would have been desired. These trade-offs are unavoidable when dealing with risk and may even be considered desirable. Based on the conceptual framework developed for this program (Cardona *et al.* 2003a), a system of risk indicators is proposed that represents the current vulnerability and risk management situation in each country. The indicators proposed are transparent, relatively easy to update periodically, and easily understood by public policymakers.

The Disaster Risk Management Indicators Program in Americas meets this need. The system of indicators proposed by IDEA permits a systematic and quantitative benchmarking of each country during different periods between 1980 and 2000, as well as comparisons across countries. It also provides a more analytically rigorous and data driven approach to risk management decision-making. This system of indicators enables the depiction of disaster risk at the national level,[1] al-

[1] To illustrate the concept, this report also details the use of the methodology at the subnational and urban level.

lowing the identification of key issues by economic and social category. It also makes possible the creation of national risk management performance benchmarks in order to establish performance targets for improving management effectiveness.

The system describes a series of risk factors that should be reduced through public policies and actions to reduce vulnerability and maximize the resilience and coping capacity of the population. The risk factors are generally represented by indicators available in international databases. Lack of data in some cases makes it necessary to also propose more subjective qualitative indicators. In the case of risk management indicators, some indices are weighted using national experts to provide opinions and information. Each index was derived on the basis of current theory and statistical techniques, and has a number of empirical variables associated with it. The choice of variables was driven by a number of factors, including: country coverage, the soundness of the data, direct relevance to the phenomenon that the indicators are intended to measure, and quality. Direct measures were used wherever possible, although proxies had to be used in some cases. In general, the variables used are those that have extensive country coverage; however, in some cases more narrow variables are used if they measure critical aspects of risk that would otherwise be overlooked.

Four components or composite indicators have been designed to represent the main elements of vulnerability and show each country's progress in managing risk. The four indicators are the Disaster Deficit Index (*DDI*), the Local Disaster Index (*LDI*), the Prevalent Vulnerability Index (*PVI*), and the Risk Management Index (*RMI*).

The *Disaster Deficit Index* measures country risk from a macroeconomic and financial perspective according to possible catastrophic events. It requires the estimation of critical impacts during a given period of exposure, as well as the country's financial ability to cope with the situation.

The *Local Disaster Index* identifies the social and environmental risks resulting from more recurrent lower level events (which are often chronic at the local and subnational levels). These events have a disproportionate impact on more socially and economically vulnerable populations, and have highly damaging impacts on national development.

The *Prevalent Vulnerability Index* is made up of a series of indicators that characterize prevalent vulnerability conditions reflected in exposure in prone areas, socioeconomic weaknesses and lack of social resilience in general.

The *Risk Management Index* brings together a group of indicators that measure a country's risk management performance. These indicators reflect the organizational, development, capacity and institutional actions taken to reduce vulnerability and losses, to prepare for crisis and to recover efficiently from disasters.

The system of indicators covers different areas of the risk problem, taking into account issues such as: potential damages and losses resulting from extreme events; recurrent disasters or losses; social and environmental conditions that make particular countries or regions more disaster prone; the capacity of the economy to recover; the operation of key services; institutional capacity and the effectiveness of basic risk management instruments (such as risk identification, prevention and mitigation measures, financial mechanisms and risk transfer); emergency response levels; and preparedness and recovery capacity.

The Disaster Deficit Index relates assumed (deductive) indicators and depends on the simple modeling of physical risk as a function of the occurrence of a potentially extreme hazard (scientific prediction). The Local Disaster Index relies on indicators of past events with different impact levels (history). The Prevalent Vulnerability and the Risk Management indices are composites derived by aggregating quantitative and qualitative indicators. The indices were constructed using a multi-attribute technique and the indicators were carefully related and weighted. Each abovementioned index has a short description as follows.

1.1 The Disaster Deficit Index (DDI)

This index measures the economic loss that a particular country could suffer when a catastrophic event takes place, and the implications in terms of resources needed to address the situation. Construction of the *DDI* requires undertaking a forecast based on historical and scientific evidence, as well as measuring the value of infrastructure and other goods and services that are likely to be affected. In order to do this, we must define an arbitrary reference point in terms of the severity or periodicity of dangerous phenomena. Objective modeling must take into account existing information and knowledge gaps and restrictions. The *DDI* captures the relationship between the demand for contingent resources to cover the losses caused by the Maximum Considered Event (*MCE*),[2] and the public sector's economic resilience (that is, the availability of internal and external funds for restoring affected inventories).

$$DDI = \frac{MCE\ loss}{Economic\, Resilience} \tag{1.1}$$

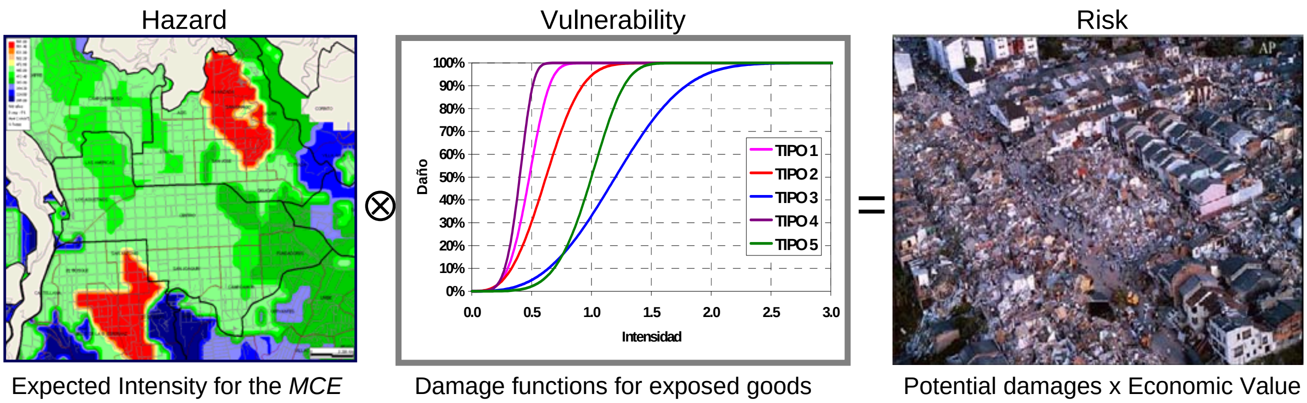
Potential losses (index numerator) are calculated using a model that takes into account different hazards (which are calculated in probabilistic form according to historical data on the intensity of past phenomena) and the actual physical vulnerability of the elements exposed to such phenomena. Figure 1.1 shows a diagram illustrating the way to obtain the *DDI.*

Economic resilience (the denominator of the index), on the other hand, represents the possible internal and external funds available to government, in its role as a promoter of recovery and as owner of affected goods, at the moment of the evaluation. Access to such funds has restrictions and associated costs and these must be estimated as feasible values according to the macroeconomic and financial conditions of the country. In this evaluation the following aspects have been into account: the *insurance and reassurance payments* that the country would approximately receive for goods and infrastructure insured by government; the *reserve funds for disasters* that the country has available during the evaluation year; the funds that may be received as *aid and donations*, public or private, national or international; the possible value of *new taxes* that the country could collect in case of disasters; the *margin for budgetary reallocations* of the country, which usually corresponds to the margin of discretional expenses available to government; the feasible

[2] This model follows the insurance industry in establishing a reference point (the Probable Maximum Loss, PML) for calculating potential losses (ASTM, 1999; Ordaz, 2002).

value of *external credit* that the country could obtain from multilateral organisms and in the external capital market; and the *internal credit* the country may obtain from commercial and, at times, the Central Bank, when this is legal, signifying immediate liquidity.

Figure 1.1 Diagram for DDI calculation



$$DDI = \frac{MCE\ loss}{Economic\ Resilience}$$

Description	Indicators
Insurance and reassurance payments	F_1^P
Reserve funds for disasters	F_2^P
Aid and donations	F_3^P
New taxes	F_4^P
Budgetary reallocations	F_5^P
External credit	F_6^P
Internal credit	F_7^P

A *DDI* greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the *DDI*, the greater the gap between losses and the country's ability to face them. If constrictions for additional debt exist, this situation implies the impossibility to recover.

To help place the Disaster Deficit Index in context, we've developed a complementary indicator, ***DDI'***, to illustrate the portion of a country's annual Capital Expenditure (CE) that corresponds to the expected annual loss or the pure risk premium. That is, ***DDI'*** shows the percentage of the annual investment budget that would be needed to pay for future disasters.

$$DDI' = \frac{Expected\ annual\ loss}{Capital\ expenditures} \tag{1.2}$$

The pure premium value is equivalent to the annual average investment or saving that a country would have to make in order to approximately cover losses associated with major future disasters.

These indicators provide a simple way of measuring a country's fiscal exposure and potential deficit (or contingency liabilities) in case of an extreme disaster. They allow national decisionmakers to measure the budgetary implications of such an event and highlight the importance of including this type of information in financial and budgetary processes (Freeman *et al.*, 2002a). These results substantiate the need to identify and propose effective policies and actions such as, for example, using insurance and reinsurance (transfer mechanisms) to protect government resources or establishing reserves based on adequate loss estimation criteria. Other such actions include contracting contingency credits and, in particular, the need to invest in structural (retrofitting) and nonstructural prevention and mitigation to reduce potential damage and losses as well as the potential economic impact of disasters.

1.2 The Local Disaster Index (LDI)

The *LDI* identifies the social and environmental risks resulting from more recurrent lower level events (which are often chronic at the local and subnational levels). These events have a disproportionate impact on more socially and economically vulnerable populations, and have highly damaging impacts on national development. This index represents the propensity of a country to experience small-scale disasters and their cumulative impact on local development. The index attempts to represent the spatial variability and dispersion of risk in a country resulting from small and recurrent events. This approach is concerned with the national significance of recurrent small scale events that rarely enter international, or even national, disaster databases, but which pose a serious and cumulative development problem for local areas and, more than likely, also for the country as a whole. These events may be the result of socio-natural processes associated with environmental deterioration (Lavell 2003a/b) and are persistent or chronic in nature. They include landslides, avalanches, flooding, forest fires, and droughts as well as small earthquakes, hurricanes and volcanic eruptions.

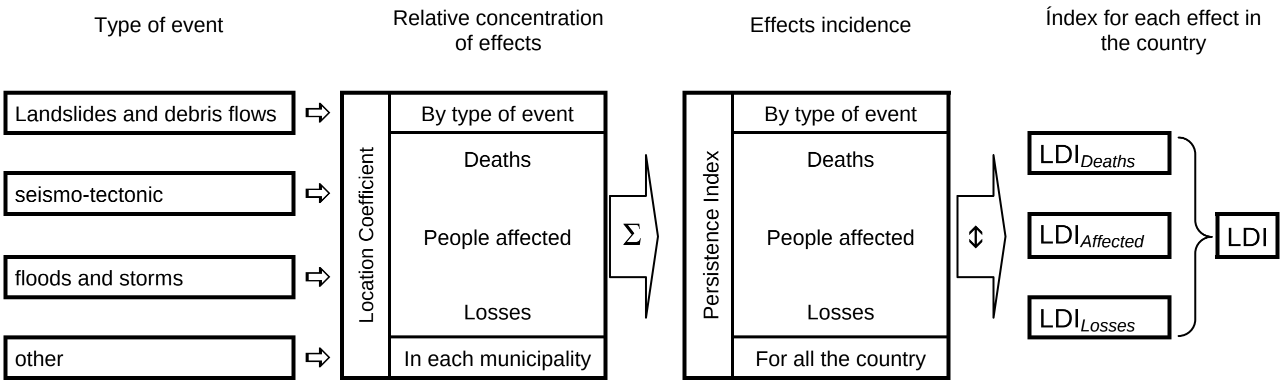
The *LDI* is equal to the sum of three local disaster subindicators that are calculated based on data from the DesInventar database[3] for number of deaths, number of people affected and losses in each municipality.

$$LDI = LDI_{Deaths} + LDI_{Affected} + LDI_{Losses} \qquad (1.3)$$

The LDI captures simultaneously the incidence and uniformity of the distribution of local effects. That is, it accounts for the relative weight and persistence of the effects attributable to phenomena that give rise to municipal scale disasters. The higher the relative value of the index, the more uniform the magnitude and distribution of the effects of various hazards among municipalities. A low LDI value means low spatial distribution of the effects among the municipalities where events have occurred. Figure 1.2 illustrates schematically how *LDI* is obtained for a country based on the information of events in each municipality.

[3] Data base implemented by La Red de Estudios Sociales en Prevención de Desastres de América Latina (LA RED).

Figure 1.2 LDI Estimation



Similarly, we calculated a *LDI'* that takes into account the concentration of losses (direct physical damage) at the municipal level and is aggregated for all events in all countries. This indicator shows the disparity of risk within a single country. A *LDI'* value close to 1.0 means that few municipalities concentrate the most of the losses for the country.

The usefulness of these indices for economic analysts and sector officials in charge of establishing rural and urban policies lies in the fact that they allow them to measure the persistence and cumulative impact of local disasters. As such, they can prompt the consideration of risk in territorial planning at the local level, as well as the protection of hydrographic basins. They can also be used to justify resource transfers to the local level that are earmarked for risk management and the creation of social safety nets.

1.3 The Prevalent Vulnerability Index (PVI)

The *PVI* depicts predominant vulnerability conditions by measuring exposure in prone areas, socioeconomic fragility and lack of social resilience. These items provide a measure of direct as well as indirect and intangible impacts of hazard events. The index is a composite indicator that provides a comparative measure of a country's pattern or situation. Inherent[4] vulnerability conditions underscore the relationship between risk and development (UNDP 2004). Vulnerability, and therefore risk, are the result of inadequate economic growth, on the one hand, and deficiencies that may be corrected by means of adequate development processes. Although the indicators proposed are recognized as useful for measuring development (Holzmann and Jorgensen 2000; Holzmann 2001) their use here is intended to capture favorable conditions for direct physical impacts (exposure and susceptibility), as well as indirect and, at times, intangible impacts (socioeconomic fragility and lack of resilience) of potential physical events (Masure 2003; Davis, 2003). The PVI is an average of these three types of composite indicators:

$$PVI = (PVI_{Exposure} + PVI_{Fragility} + PVI_{Lack\ of\ Resilience})/3 \qquad (1.4)$$

[4] That is to say, the predominant socioeconomic conditions that favor or facilitate negative effects as a result of adverse physical phenomena (Briguglio 2003b).

The indicators used for describing exposure, prevalent socioeconomic conditions and lack of resilience have been estimated in a consistent fashion (directly or in inverse fashion, accordingly), recognizing that their influence explains why adverse economic, social and environmental impacts take place following a dangerous event (Cardona and Barbat 2000; Cardona 2004). Each one is made up of a set of indicators that express situations, causes, susceptibilities, weaknesses or relative absences affecting the country, region or locality under study, and which would benefit from risk reduction actions. The indicators were identified based on figures, indices, existing rates or proportions derived from reliable databases available worldwide or in each country.

The best indicators of exposure and/or physical susceptibility (PVI_{ES}) are the susceptible population, assets, investment, production, livelihoods, historic monuments, and human activities (Masure 2003; Lavell 2003b). Other indicators include population growth and density rates, as well as agricultural and urban growth rates. Figure 1.3 shows the PVI_{ES} composition.

Figure 1.3 PVI_{ES} Estimation

Description	Indicator	Weight	
Population growth, average annual rate (%)	**ES1**	w1	PVI_{ES}
Urban growth, avg. annual rate (%)	**ES2**	w2	
Population density, people/5 Km^2	**ES3**	w3	
Poverty-population below US$ 1 per day PPP	**ES4**	w4	
Capital stock, million US$ dollar/1000 km^2	**ES5**	w5	
Imports and exports of goods and services, % GDP	**ES6**	w6	
Gross domestic fixed investment, % of GDP	**ES7**	w7	
Arable land and permanent crops, % land area	**ES8**	w8	

These variables reflect the nation’s susceptibility to dangerous events, whatever their nature or severity. Exposure and susceptibility are necessary conditions for the existence of risk. Although, in any strict sense it would be necessary to establish if exposure is relevant for each potential type of event, we may nevertheless assert that certain variables reflect comparatively adverse situations where natural hazards can be deemed to be permanent external factors without needing to establish their exact nature.

Figure 1.4 PVI_{SF} Estimation

Description	Indicator	Weight	
Human Poverty Index, HPI-1	**SF1**	w1	PVI_{SF}
Dependents as proportion of working age population	**SF2**	w2	
Social disparity, concentration of income measured using Gini index	**SF3**	w3	
Unemployment, as % of total labor force	**SF4**	w4	
Inflation, food prices, annual %	**SF5**	w5	
Dependency of GDP growth of agriculture, annual %	**SF6**	w6	
Debt servicing, % of GDP	**SF7**	w7	
Human-induced Soil Degradation (GLASOD)	**SF8**	w8	

Socioeconomic fragility (PVI_{SF}), may be represented by indicators such as poverty, lack of personal safety, dependency, illiteracy, income inequality, unemployment, inflation, debt and environmental deterioration. These indicators reflect relative weaknesses that increase the direct effects of dangerous phenomena (Cannon 2003; Davis 2003; Wisner 2003). Even though these effects are not necessarily cumulative (and in some cases may be superfluous or correlated), their influence is especially important at the social and economic levels (Benson 2003b). Figure 1.4 shows the PVI_{SF} composition.

These indicators show that there exists an intrinsic predisposition for adverse social impacts in the face of dangerous phenomena regardless of their nature or intensity (Lavell 2003b; Wisner 2003). The propensity to suffer negative impacts establishes a vulnerability condition of the population, although it would be necessary to establish the relevance of this propensity in the face of all types of hazard. Nevertheless, as with exposure, it is possible to suggest that certain values of specific variables reflect a relatively unfavorable situation in the eventuality of natural hazard, regardless of the exact characteristics of those hazards.

Lack of resilience (PVI_{LR}), seen as a vulnerability factor, may be represented by means of the complementary or inverse[5] relationship of a number of variables that measure human development, human capital, economic redistribution, governance, financial protection, community awareness, the degree of preparedness to face crisis situations, and environmental protection. These indicators are useful to identify and guide actions to improve personal safety (Cannon 2003; Davis 2003; Lavell 2003a/b; Wisner 2003). Figure 1.5 shows the PVI_{LR} composition.

Figure 1.5 $\mathbf{PVI_{LR}}$ Estimation

Description	Indicator	Weight
Human Development Index, HDI [Inv]	**LR1**	w1
Gender-related Development Index, GDI [Inv]	**LR2**	w2
Social expenditure; on pensions, health, and education, % of GDP [Inv]	**LR3**	w3
Governance Index (Kaufmann) [Inv]	**LR4**	w4
Insurance of infrastructure and housing, % of GD [Inv]	**LR5**	w5
Television sets per 1000 people [Inv]	**LR6**	w6
Hospital beds per 1000 people [Inv]	**LR7**	w7
Environmental Sustainability Index, ESI [Inv]	**LR8**	w8

→ PVI_{LR}

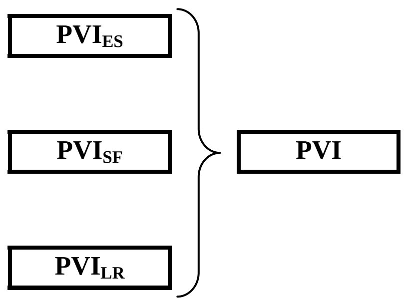
These indicators capture the capacity to recover from or absorb the impact of dangerous phenomena, whatever their nature and severity (Briguglio 2003b). Not being able to adequately face disasters is a vulnerability condition, although in a strict sense it is necessary to establish this with reference to all potential types of hazard. Nevertheless, as with exposure and socioeconomic fragility, we can posit that some economic and social variables (Benson 2003b) reflect a comparatively unfavorable position if natural hazards exist. The factors of lack of resilience are not very dependant or conditioned by the action of the event.

In general, *PVI* reflects susceptibility due to the degree of physical exposure of goods and people PVI_{ES}, that favor the direct impact in case of hazard events. In the same way, it reflects conditions

[5] The symbol [Inv] is used here to indicate an inverse variable ($\neg R$ = 1- R).

of socioeconomic fragility that favor the indirect and intangible impact, $PVI_{SF.}$ Also, it reflects lack of capacity to absorb consequences, for efficient response and recovering, PVI_{LR}. Reduction of these kinds of factors, as the purpose of the human sustainable development process and explicit policies for risk reduction, is one of the aspects that should be emphasized. Figure 1.6 shows how *PVI* is obtained.

Figure 1.6 PVI Evaluation



The *PVI* should form part of a system of indicators that allows the implementation of effective prevention, mitigation, preparedness and risk transfer measures to reduce risk. The information provided by an index such as the *PVI* should prove useful to ministries of housing and urban development, environment, agriculture, health and social welfare, economy and planning. Although the relationship between risk and development should be emphasized, it must be noted that activities to promote development do not, in and of themselves, automatically reduce vulnerability.

1.4 The Risk Management Index (RMI)

The *RMI* brings together a group of indicators that measure a country's risk management performance. These indicators reflect the organizational, development, capacity and institutional actions taken to reduce vulnerability and losses, to prepare for crisis and to recover efficiently from disasters. This index was designed to assess risk management *performance.* It provides a qualitative measure of management based on predefined *targets* or *benchmarks* that risk management efforts should aim to achieve. The design of the *RMI* involved establishing a scale of achievement levels (Davis 2003; Masure 2003) or determining the "distance" between current conditions and an objective threshold or conditions in a reference country (Munda 2003).

The *RMI* was constructed by quantifying four public policies, each of which has six indicators. The policies include the identification of risk, risk reduction, disaster management, and governance and financial protection. Risk identification (RI) is a measure of individual perceptions, how those perceptions are understood by society as a whole, and the objective assessment of risk. Risk reduction (RR) involves prevention and mitigation measures. Disaster management (DM) involves measures of response and recovery. And, finally, governance and financial protection (FP) measures the degree of institutionalization and risk transfer. The *RMI* is defined as the average of the four composite indicators:

$$RMI = (RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP})/4 \tag{1.5}$$

Each indicator was estimated based on five performance levels (*low, incipient, significant, outstanding*, and *optimal*) that correspond to a range from 1 (low) to 5 (optimal).[6] This methodological approach permits the use of each reference level simultaneously as a "performance target" and allows for comparison and identification of results or achievements. Government efforts at formulating, implementing, and evaluating policies should bear these performance targets in mind (Carreño *et al.* 2004)

It is important to recognize and understand the collective risk to design prevention and mitigation measures. It depends on the individual and social risk awareness and the methodological approaches to assess it. It then becomes necessary to measure risk and portray it by means of models, maps, and indices capable of providing accurate information for society as a whole and, in particular, for decisionmakers. Methodologically, RMI_{RI} includes the evaluation of hazards, the characteristics of vulnerability in the face of these hazards, and estimates of the potential impacts during a particular period of exposure. The measurement of risk seen as a basis for intervention is relevant when the population recognizes and understands that risk. Figure 1.7 shows the RMI_{RI} composition.

Figure 1.7 $\mathbf{RMI_{RI}}$ Estimation

Description	Indicator	Weight	
Systematic disaster and loss inventory	**RI1**	w1	RMI_{RI}
Hazard monitoring and forecasting	**RI2**	w4	
Hazard evaluation and mapping	**RI3**	w5	
Vulnerability and risk assessment	**RI4**	w6	
Public information and community participation	**RI5**	w7	
Training and education on risk management	**RI6**	w8	

The major aim of risk management is to reduce risk (RMI_{RR}). Reducing risk generally requires the implementation of structural and nonstructural prevention and mitigation measures. It implies a process of anticipating potential sources of risk, putting into practice procedures and other measures to either avoid hazard, when it is possible, or reduce the economic, social and environmental impacts through corrective and prospective interventions of existing and future vulnerability conditions. Figure 1.8 shows the RMI_{RR} composition.

Figure 1.8 $\mathbf{RMI_{RR}}$ Estimation

Description	Indicator	Weight	
Risk consideration in land use and urban planning	**RR1**	w1	RMI_{RR}
Hydrographic basin intervention and environmental protection	**RR2**	w4	
Implementation of hazard-event control and protection techniques	**RR3**	w5	
Housing improvement and human settlement relocation from prone areas	**RR4**	w6	
Updating and enforcement of safety standards and construction codes	**RR5**	w7	
Reinforcement and retrofitting of public and private assets	**RR6**	w8	

[6] It is also possible to estimate the *RMI* by means of weighted sums of fixed values (such as 1 through 5, for example), instead of using fuzzy sets and linguistic descriptions. However, that simplification eliminates the nonlinearity of risk management and yields less accurate results.

The goal of disaster management (RMI_{DM}) is to provide appropriate response and recovery efforts following a disaster. It is a function of the degree of preparation of the responsible institutions as well as the community as a whole. The goal is to respond efficiently and appropriately when risk has become disaster. Effectiveness implies that the institutions (and other actors) involved have adequate organizational abilities, as well as the capacity and plans in place to address the consequences of disasters. Figure 1.9 shows the RMI_{DM} composition.

Figure 1.9 $\mathbf{RMI_{DM}}$ Estimation

Description	Indicator	Weight
Organization and coordination of emergency operations	**DM1**	w1
Emergency response planning and implementation of warning systems	**DM2**	w4
Endowment of equipments, tools and infrastructure	**DM3**	w5
Simulation, updating and test of inter institutional response	**DM4**	w6
Community preparedness and training	**DM5**	w7
Rehabilitation and reconstruction planning	**DM6**	w8

RMI_{DM}

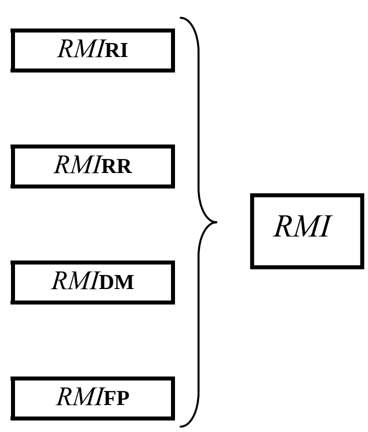
Adequate governance and financial protection (RMI_{FP}) are fundamental for sustainability, economic growth and development. They are also basic to risk management, which requires coordination among social actors as well as effective institutional actions and social participation. Governance also depends on an adequate allocation and use of financial resources to manage and implement appropriate retention and transfer strategies for dealing with disaster losses. Figure 1.10 shows the RMI_{FP} composition. Lastly, figure 1.11 shows how to obtain *RMI*.

Figure 1.10 $\mathbf{RMI_{FP}}$ Estimation

Description	Indicator	Weight
Interinstitutional, multisectoral and decentralizing organization	**FP1**	w1
Reserve funds for institutional strengthening	**FP2**	w4
Budget allocation and mobilization	**FP3**	w5
Implementation of social safety nets and funds response	**FP4**	w6
Insurance coverage and loss transfer strategies of public assets	**FP5**	w7
Housing and private sector insurance and reinsurance coverage	**FP6**	w8

RMI_{FP}

Figure 1.12 RMI Evaluation



1.5 Indicators at Subnational and Urban Level

Depending on the country, subnational divisions (department, states or provinces) have different degrees of political, financial and administrative autonomy. Nevertheless, the system of indicators that was developed allows for the individual or collective evaluation of subnational areas and was developed using the same concepts and approaches outlined for the nation as a whole. All results for the indicators and for different periods are included in the reports of Barbat and Carreño (2004a/b). Risk analysis can further be disaggregated to metropolitan areas, which are usually made up of administrative units such as districts, municipalities, communes or localities which will have different risk levels.

Dropping down the spatial and administrative scale the need for evaluations within urban-metropolitan areas and large cities is also desirable. Taking into account the spatial scale at which urban risk analysis is undertaken, it is necessary to estimate or to have the scenarios of damage and loss that could exist for the different exposed elements that characterize the city (i.e., buildings, public works, roads, etc.). The estimation of a *MCE* for the city would allow us to evaluate in greater detail the potential direct damage and impacts to prioritize interventions and actions required to reduce risk in each area of the city.

Figure 1.12 Indicators of Physical Risk, Social Fragility and Lack of Resilience and Their Weights

Ind	Description	w
F_{RF1}	Damaged area	w1
F_{RF2}	Number of deceased	w2
F_{RF3}	Number of injured	w3
F_{RF4}	Ruptures in water mains	w4
F_{RF5}	Rupture in gas network	w5
F_{RF6}	Fallen lengths on HT power lines	w6
F_{RF7}	Telephone exchanges affected	w7
F_{RF8}	Electricity substations affected	w8

R_P **Physical Risk**

Ind	Description	w
F_{FS1}	Slums-squatter neighborhoods	w1
F_{FS2}	Mortality rate	w2
F_{FS3}	Delinquency rate	w3
F_{FS4}	Social disparity index	w4
F_{FS5}	Population density	w5
F_{FR1}	Hospital beds	w6
F_{FR2}	Health human resources	w7
F_{FR3}	Public space/shelter facilities	w8
F_{FR4}	Rescue and firemen manpower	w9
F_{FR5}	Development level	w10
F_{FR6}	Preparedness/emergency planning	w11

F **Impact Factor**

$$R_T = R_P\left(1 + F\right)$$

The urban risk indicators are similar to those used at other levels but with the addition of two new indicators: the Index of Physical Risk, R_P, and the Impact Factor, F. The former is based on hard data, while the latter is based on soft variables that depict social fragility and lack of resilience. In turn, these two indicators allow us to create a Total Risk Index, R_T, for each unit of analysis. These indicators require greater detail than that used at the national or regional level and they focus on urban variables (Cardona and Barbat 2000; Barbat 2003a/b; Barbat and Carreño 2004a/b). In other words, we have developed a methodology that combines the Disaster Deficit and the Prevalent Vulnerability indices used for the national and subnational analyses. Figure 1.12 shows how to obtain total risk indices for each analysis unit at urban level.

1.6 Additional Information

The indicators and the variables used in the system of indicators construction were chosen through an extensive review of the risk management literature, assessment of available data, and broad-based consultation and analysis. Section 2 of this report shows the technical aspects for each index. Additionally, the following reports of this program present the details on the conceptual framework, the methodological support, data treatment and the statistical techniques used in the modeling (Cardona *et al.* 2003a/b; 2004a/b; 2005).[7]

a) "Results of Application of the System of Indicators on Twelve Countries of the Americas" Report of the program of indicators on disaster risk management in the Americas IDB-IDEA.
b) "Disaster Risk and Risk Management Benchmarking: A Methodology Based on Indicators at National Level". Report of the program of indicators on disaster risk management in the Americas IDB-IDEA;
c) "Indicators for Risk Measurement: Methodological fundamentals". Report of the program of indicators on disaster risk management in the Americas IDB-IDEA;
d) "The Notion of Disaster Risk: Conceptual framework for integrated management". Report of the program of indicators on disaster risk management in the Americas IDB-IDEA.

An executive summary titled "Indicators of Disaster Risk and Risk Management: Program for Latin American and the Caribbean" (Cardona 2005) has been published by IDB as a special report of the Sustainable Development Department. The cited report was presented in the World Conference on Disaster Reduction held in Kobe/Hyogo Japan, on January 2005. These reports are also available on the web page before mentioned.

[7] See also http://idea.unalmzl.edu.co

2. TECHNICAL FUNDAMENTALS

2.1 The Disaster Deficit Index (DDI)

The first component of the indicator system measures country risk from an economic and financial perspective when facing possible catastrophic events. This requires an estimation of critical impacts during a given exposure time and capacity of the country to face up this situation financially. This requires the definition of some arbitrary reference points in terms of the severity or period of return of dangerous phenomenon. This risk factor must be modeled in the most objective fashion taking into account existing restrictions as regards information and knowledge.

This analytical and prospective model does not use the registry of losses (killed and affected) in historical disasters but rather the intensity of the phenomena. From an actuarial perspective we must avoid making risk estimations in inductive form, based on previous damage statistics over short time periods. Modeling must be deductive in both evaluating the occurrence of high consequence and low probability events and evaluating the levels of vulnerability of the exposed elements. We attempted the same procedure as is used by the insurance industry where a reference point is established for calculating feasible losses, known as the Probable Maximum Loss, PML (ASTM 1999, Ordaz 2002) and whose period of return is fixed arbitrarily. In this case a Maximum Considered Event, *MCE*, has been defined for which it is relevant to plan corrective or prospective actions that allow a reduction of the possible negative consequences for each country or sub-national unit under analysis. The economic loss or demand for contingent funds (the numerator of the index) is obtained from the modeling of the potential impact of the *MCE* for three return periods: 50, 100 and 500[8] years, equivalent to 18, 10 and 2 percent of probability of exceedance in a period of 10 years of exposure.

One may conclude that even where different hazards exist with potentially different impacts on the country, their impact during similar time periods will not be the same. An indicator could be constructed that represents the maximum probable demand in socio economic terms associated with the most critical loss scenario taking into account the *MCE* for the unit under analysis. This situation would generally be associated with a major or extreme catastrophic event such as a very severe earthquake, hurricane, tsunami, volcanic eruption or flood. Such a selection does not necessarily require detailed analysis of all possible dangerous phenomenon only for one or two types of event given that the type of event that is likely to be associated with the *MCE* may be easily identifiable.

The approach proposed here is fundamentally a probabilistic risk model similar to those used for loss transfer and retention aims. Due to this, it is substantially different to that used by UNDP (2004), to estimate the Disaster Risk Index, DRI, or at *Hot Spots* project of World Bank (2004), and to those applied in the majority of the models proposed for estimating the impact of disasters on economic growth. The present approach was chosen given that serious theoretical controversies still exist in terms of whether disasters cause a significant impact on economic development.

[8] The majority of existing construction codes takes as a basis the maximum possible intensity of events in approximately a 500 year time period. Especially important civil constructions are designed for maximum intensity events of several thousand years. However, the majority of buildings and public works constructed in the twentieth century have not been designed to these security levels.

According to the results obtained by Albala-Bertrand (1993/2002) disasters usually affect the less productive capital and unskilled labor. Therefore, while leading to profound social consequences, they have little effect on the macro economy of a country. Similar models have been formulated by IIASA and Freeman *et al.* (2002a/b). Benson *et al.* (2003a) and ECLAC (2003) amongst others, argue that in the long run such impacts may be important for certain economies. Due to this and in order to contribute to economic growth approaches, an analytical approximation to the topic is presented in Appendix 2.1-1.

The *DDI,* which is calculated using equation 2.1, captures the relationship between the demand for contingent economic funds and the economic losses that the public sector must assume, $L_R{}^P$, and the economic resilience present in this sector, $R_E{}^P$, which corresponds to the availability of internal and external funds for restituting affected inventories[9] (Cardona *et al.* 2004),

$$IDD = \frac{L_R{}^P}{R_E{}^P}, \qquad (2.1)$$

where:

$$L_R{}^P = \varphi\, L_R \qquad (2.2)$$

$L_R{}^P$ represents the maximum direct economic impact in probabilistic terms on public and private stocks that are governments' responsibility.[10] This value is a fraction φ of the direct total impact, L_R, which is associated with an *MCE* of intensity I_R, and whose annual exceedance rate (or return period, R) will be defined in the same way for all countries such as to allow comparison. The value of public sector capital inventory losses is a fraction φ of the loss of all affected goods.

The impact of the *MCE* is calculated using a risk model described later in this text, and determines the physical losses and value suffered by the physical and human stock in the region. Such a negative impact may be divided in terms of public and private capital stock (Cardona *et al.* 2004a). The net losses related to the *MCE* may be distributed according to the division between public and private sectors in the aggregate capital stock of the economy. See Appendix 2.1-2.

We will start by assuming that all goods exposed to disaster are concentrated in a geographical region of limited size (say, a city) which allows the assumption that everything in this area is concentrated in a point in space and that everything is affected simultaneously with the same intensity. This loss can be estimated as follows:

$$L_R = E\, V(I_R F_S)\, K \qquad (2.3)$$

[9] A similar approach has been proposed by Freeman *et al.* (2002a). In this report they say that being able to quickly access sufficient funds for reconstruction after a disaster is critical to a countries´ ability to recover with minimal long-term consequences.
[10] In the case of a major event it is possible that the government would have to offer subventions and soft loans to support the poorer population that have lost their housing and means of sustenance and in order to compensate lost employment due to the paralysis of different economic sectors.

where:

- E is the economic value of all the property exposed;
- $V(\,)$ is the *vulnerability function*, which relates the intensity of the event with the fraction of the value that is lost if an event of such intensity takes place;
- I_R is the intensity of the event associated to the selected return period;
- F_S is a factor that corrects intensities to account for local site effects;
- K is a factor that corrects for uncertainty in the vulnerability function.

As can be noted, this loss estimator includes all the classic components of risk analysis: the hazard – implied in I_R–, the vulnerability –given by function $V(\,)$– and the value of the exposed property, E. Then, L_R, as defined in equation 2.3, is the exact value of the loss associated with a given return period, R, if the appropriate value of K is used. Factor E in equation 2.3 refers to the monetary value of all the property exposed to damage in the geographical area under analysis. This includes, for instance, buildings, crops, industry and infrastructure. Ideally, one should include in this number all the property exposed in the area under analysis. However, this would be impossible (and maybe unnecessary) given the scope of this research. For this reason, and as suggested by Lavell (2003b), we believe that only the most important portions of exposed property need to be taken into account.[11]

The government, apart from being an owner, also has responsibilities for economic reactivation, protection of the poorest socioeconomic sectors, and persons that lose their employment. Depending on the type of *MCE*, (a hurricane, an earthquake, a volcanic eruption or an extreme flood) such impacts would be defined taking as a reference point only the case of the maximum aggregated loss for the country where this loss is greater than any value loss caused by other lower intensity events (lower than the *MCE*).[12]

Economic resilience, R_E^P, is defined in equation 2.4:

$$R_E{}^P = \sum_{i=1}^{n} F_i{}^P \qquad (2.4)$$

where F_i^P represents the possible internal and external funds available to government (in its role as a promoter of recovery and as owner of affected goods), at the moment of the evaluation. Access to such funds has restrictions and associated costs and these must be estimated as feasible values according to the macroeconomic and financial conditions of the country. For each case it is necessary to estimate the following values:

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[11] In the case of the public sector, roads, bridges, energy plants, hospitals, schools, airports, ports, offices etc may be important. Even in the case of concessions (operations of public sector goods by private sector) where the property is still controlled by government or sub national government infrastructure, recovery, despite decentralization processes, may depend on the national government.

[12] It may be for example that an earthquake, considered as the *MCE*, could have minimum effects on crops. Other important event, as a severe flood, may have a great impact on crops but is not considered to be the *MCE*.

- F_1^P, corresponds to the *insurance and reassurance payments* that the country would approximately receive for goods and infrastructure insured by government. Insurance is a very incipient business in the developing countries and an insurance culture does not exist. The vast majority of insurance payments made after large scale events have been to the private sector, in particular to large industries. In various countries it is obligatory to insure public goods, but this legal requirement is not complied with thoroughly, particularly when dealing with decentralized territorial entities and local governments. A simple manner of estimating the value of insured physical wealth could be by calculating the expenses on insurance as a proportion of GDP. For example, if this is equivalent to 2% of GDP this means that 2% of losses will be covered by insurance companies.

- F_2^P, corresponds to the *reserve funds for disasters* that the country has available during the evaluation year. In various countries formally established calamity or disaster funds exist that have an annual budget and at times accumulated reserves from previous years. In various countries principal and sectoral funds may be found in different institutions and ministries, such as public works and infrastructure, health, civil defense, and others. Or, decentralized funds exist at the territorial levels. This sum must be estimated as the total of the reserves available to the nation for the affected zones.

- F_3^P, represents the funds that may be received as *aids and donations*, public or private, national or international. Usually external aid is given for emergency response and few resources are available for rehabilitation and reconstruction. After a major event, help is generally received in the form of food, clothing, tents, and equipment, but little is received in cash. Although detailed information is not often available as to aid received from governments, NGOs and humanitarian aid agencies, in order to estimate this, an approximate and realistic analysis of such aid seen as a percentage of losses during previous events must be undertaken.

- F_4^P, corresponds to the possible value of *new taxes* that countries could collect in case of disasters. Experiences exist that indicate that taxes have been imposed ranging between 2 and 3 per thousand and applied to financial and banking operations. But this type of tax may lead to contention and transfer of savings abroad. In general, severe doubts exist as regards the feasibility of imposing such taxes due to their unpopularity. This value should be calculated taking into account political feasibility. In Appendix 2.1-3 a simple method is presented for estimating taxes on financial transactions.[13]

- F_5^P, estimates the *margin for budgetary reallocations* in each country. In countries where limitations and constitutional controls on budget exist this value usually corresponds to the margin of discretional expenses available to government. In some countries this depends on the political decision of competent existing authorities. However, restrictions exist that impede larger reallocations due to the inevitable obligations of public spending on such things as salaries, transferences, social expenses, and debt servicing. Equally, there may be accumulated obligations related to previous budgets, as is explained in Appendix 2.1-4. Reallocation of non executed loans from multilateral organizations may be considered here. If it is impossible to obtain a pre-

[13] In some cases it may be feasible to introduce a transitory tax as was done in Colombia to finance reconstruction after the earthquake in the coffee axis in 1999.

cise estimate of the margin for budgetary reallocation this may be very approximately calculated as a 60% of the investment in capital goods as a percentage of GDP.

- F_6^P, corresponds to the feasible value of *external credit* that the country could obtain from multilateral organisms and in the external capital market. Generally, loan conditions with multilateral organisms are more favorable but are restricted with regard to the level of sustainability of external debt and the relationship between debt servicing and exports. Interest rates in general depend on income per capita. Access to credits on the international capital market depends on internal and external financial risk calculations. This will determine the risk premiums and the commercial rates for debt titles. No matter what, access to credit signifies an increase in debt service obligations and the reduction of the countries capacity to absorb new debt. Therefore, the maximum value of external credit should be estimated through an analysis of the obligations and limitations for government. Appendix 2.1-5 presents a method for calculating the external financial situation of a country.

- F_7^P, represents the *internal credit* a country may obtain from commercial and, at times, the Central Bank, when this is legal, signifying immediate liquidity. Also, it is at times possible to obtain resources from international reserves when a major disaster occurs, although this type of operation is generally complicated and may signify a risk for the balance of payments. Credit with commercial banks also has limitations and costs and depends on the workings of local credit markets. In general these will be scarce. In weak markets a large credit may affect internal consumption, local investment and interest rates. The additional available credit should be estimated taking into account the capacity to pay the loan and the capacity of national capital markets. Appendix 2.1-6 illustrates how access to internal credit may be approximately calculated.

It is important to indicate that this estimation is proposed considering restrictions or feasible values and without considering possible associated costs of access to some of these funds and opportunity costs which could be important.

In complimentary fashion and in order to help put the *DDI* in context an additional collateral indicator, *DDI'*, has been proposed. This shows the proportion of the countries capital expenditures, E_C^P, corresponding to the expected annual loss, L_y^P, or the pure risk premium. That is to say, what proportion of investment would comprise the annual payment for future disasters as obtained from equation 2.5.

$$IDD' = \frac{L_y^{\ P}}{E_C^{\ P}} \qquad (2.5)$$

The expected annual loss L_y^P, as explained in Appendix 2.1-8, is defined as the expected loss value in any one year. This value is equivalent to the annual average investment or saving that a country would have to make in order to approximately cover losses associated with major future events.

The DDI' was also estimated with respect to the amount of sustainable resources due to inter-temporal surplus, F_8^P.That is to say, the percentage the technical premium of potential savings at present values represents and as expressed in equation 2.6.

$$IDD^{'} = \frac{L_y^{\ P}}{F_8^{\ P}} \tag{2.6}$$

The sustainable amount of resources due to inter-temporal surplus, F_S^P, is the saving which the government can employ, calculated over a ten year period, in order to best attend the impacts of disasters. What we need to know is if the government, from an orthodox perspective, complies with its inter-temporal budgetary restriction. That is to say, if the flows of expenditures and incomes guarantee –in present value terms– that current and future primary surpluses allow a canceling of the present stock of debt. In other words, financial discipline requires that government action be limited and that the financial capacity to deal with disasters must comply with the inter-temporal restriction of public finances. In order to estimate this annual amount of sustainable resources a method is proposed in Appendix 2.1-7.

In the case that annual losses exceed the amount of resources available in the surplus it is predicted that over time there will be a debt due to disasters that inevitably increase the overall debt levels. That is to say, the country does not have sufficient resources to attend future disasters. In the case that restrictions to additional indebtedness should exist, this situation would signify that recovery is impossible. In general, if inter-temporal surplus is negative, premium payment would increase the existent deficit.

In the following paragraphs we will analyze the theoretical framework of risk and the variables involved in equation 2.3 from a specific hazard and vulnerability perspective.

2.1.1 Physical Risk Estimation

The computation of losses during future natural hazard events is always a very complex problem. Due to the uncertainties of this process, losses must be regarded as random variables, which can only be known in a probabilistic sense, i.e. through their probability distributions. Consequently, this approach has been adopted in this model (Ordaz and Santa-Cruz 2003).

Given existing knowledge, it is clearly theoretically impossible to predict the times of occurrence and magnitudes of all future natural hazard events. In view of the uncertain nature of the processes involved, our second best choice is to estimate the probability distribution of the times of occurrence and impacts of all future disasters. In general, however, this estimation is also a titanic task.

A convenient way of describing the required probability distributions (those of the occurrence times and the sizes of the physical impact) is the use of the exceedance rate curve of the physical losses. This curve relates the value of the loss with the annual frequency with which this loss value is exceeded; the inverse of the exceedance rate is the return period. Appendix 2.1-9 presents an imaginary example of a curve of exceedance rates and some words about the return periods. Appendix 2.1-10 gives mathematical relations between the exceedance rates and other interesting and useful measures of risk.

2.1.1.1 Hazard

In this context, *intensity* is defined as a local measure of the disturbance produced by a natural event in those physical characteristics of the environment relevant to the phenomenon under study. For all type of hazards, it is almost impossible to describe the intensity with a single parameter. For instance, when dealing with earthquake hazards, the peak ground acceleration gives some general information about the magnitude of the ground motion, but does not give indications about its frequency content. This is crucial for an accurate estimation of structural response. Also, in the case of floods, water height is not a complete description of the intensity of the flood, because damage might also depend on the speed of flow.

In view of this, it is understood that a single-parameter description of intensity will always be incomplete. However, a multi-variable description of intensity is far too complex for our goals (actually, very few, if any risk studies undertaken in the past have considered multi-variable descriptions of intensity). We propose to use a single measure of intensity for each type of hazard that correlates well with damage and for which hazard measures, which will be described later, are relatively easy to obtain. Table 2.1.1 presents our suggested intensity measures for the various types of hazards more relevant for Latin America and the Caribbean.

It should be noted that since we are mainly interested in disasters that have an economic impact at the national level, we have restricted ourselves to those hazards that produce large, immediate economic losses. Other hazards, like landslides, are extremely important to local level, and historically have produced many victims. However, their economic impact has been very limited. Slow on-set disasters, like deforestation and drought, are also very important, but their economic impacts are deferred over time. As these do not have immediate effects, they are beyond the scope of the proposed estimation model.

Table 2.1.1 Suggested Intensity Measures for Different Types of Hazards

Type of Hazard	Local Intensity Measure
Flood	Average water height
Earthquake	Peak ground acceleration
High winds	Wind speed
Volcanic eruption	Volcanic Explosive Index (VEI)[14]
Volcanic ash fall	Depth of ash fall

[14] In rigor, VEI is not a measure of local intensity. However, no such measure has been developed for volcanic eruptions. On the other hand, the direct impact of volcanic eruptions is generally restricted to a few tens of kilometers around the volcano. In view of this, and considerations that will be dealt with later, we believe that VEI is suitable for our purposes.

In many cases, hazard estimations are obtained from regional studies, or by assuming average environmental conditions. For example, seismic hazard maps are usually produced assuming average firm soil conditions, i.e. assuming that there are no significant amplifications of seismic intensity due to bland soils. Also, wind velocity maps are generally produced assuming average exposure conditions, that is to say, velocities are not obtained for sites on hills, but for reference sites. However, for each type of hazard, particular environmental characteristics may exist in the cities under study that cause intensities to be larger or smaller than the intensities in the neighborhood. In other words, environmental characteristics may exist that differ from those corresponding to the standard characteristics used in hazard evaluation. These characteristics are known as *local site conditions*, and they give rise to *local site effects*.

In the framework of the present project, the local site effects in all cities and for all types of hazards are impossible to take into account in any accurate manner. Our first rough approach would be to simply ignore the site effects. This amounts to taking F_S=1 in equation 2.3. However, there are cases in which the local site effects cannot be disregarded. Since by definition these site effects are local, it would be impossible for us to give general rules as to the adequate values of F_S for all cities and types of hazard. In our view, appropriate values would have to be assigned by the local experts who participate in the loss estimations for different countries.

Once an appropriate intensity is chosen for each type of phenomenon, a probabilistic hazard description must be given. Usually, the hazard is expressed in terms of the exceedance rates of intensity values. This concept is very similar to the one described in Appendix 2.1-9, in the sense that it defines how often a given value of intensity is exceeded. It must be noted that, for our purposes, we require *local* indications of hazard, that is, exceedance rates of intensity at the points or cities of interest (remember that one of our assumptions is that all property in a city is concentrated in a point or in a geographical area of limited size).

Figure 2.1.1 Example of Intensity Exceedance Rate for Floods.
The measure of intensity is the average water height in a city due to flooding

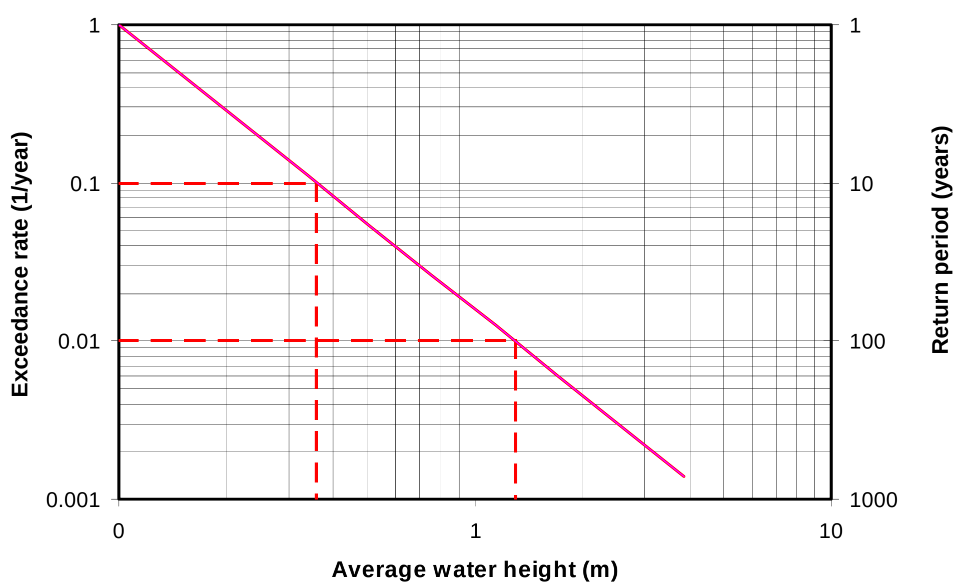


Figure 2.1.1 shows a hypothetical exceedance rate curve for the intensity associated with flooding; the intensity measure is the average water height in a city. Figure 2.1.1 shows, for example, that a water height of 0.36 m will be exceeded, on average, once every 10 years (exceedance rate of 0.1/year) or that a 1.2-meter (or more) flood will take place with a return period of 100 years, that is to say, with an exceedance rate of 0.01/year. In principle, a hazard curve must be constructed for every type of hazard and every city under study. However, recalling equation 2.3, it is needed just a few points of this curve, namely those intensities associated to the selected return periods.

In the following table we summarize the information needs of our method in order to appropriately describe the hazards. For each city assuming return periods of 50, 100 and 500 years, equivalent to 18%, 10% and 2% probability of exceedance in a period of 10 years of exposure:

Table 2.1.2 Required Values to Describe Hazard

Type of Hazard	Required Values
Flood	Average water height that is exceeded, on average, every 50, 100 and 500 years
Earthquake	Peak ground acceleration that is exceeded, on average, every 50, 100 and 500 years
High winds	Wind speed that is exceeded, on average, every 50, 100 and 500 years
Volcanic eruption	Volcanic Explosive Index (VEI) that is exceeded, on average, every 50, 100 and 500 years[15]
Volcanic ash fall	Depth of ash fall that is exceeded, on average, every 50, 100 and 500 years

2.1.1.2 Vulnerability

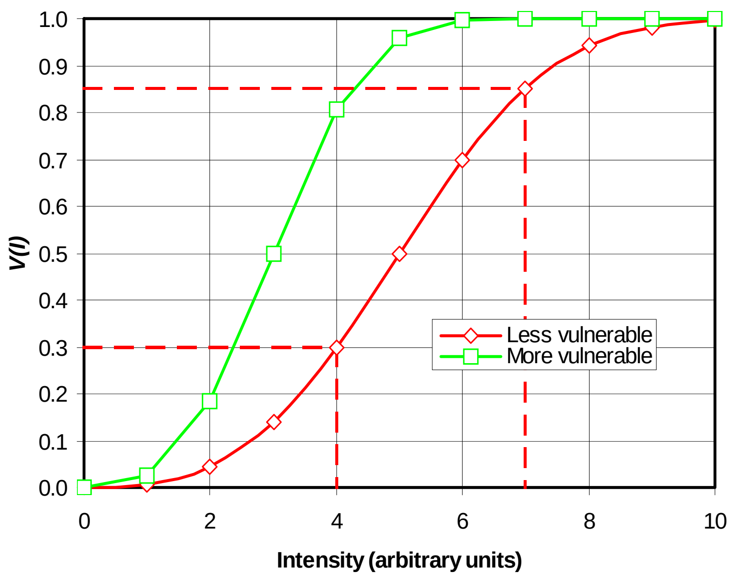
As indicated in equation 2.3, *V (I)* is the vulnerability function, which relates the intensity of the event, *I*, with the expected fraction of the value that is lost if an event of such intensity takes place. Vulnerability functions usually have shapes like that shown in figure 2.1.2. This figure reveals that for a certain hazard in the city for which the vulnerability function was derived, if an event with intensity I=4 occurs, the expected damage to buildings tagged as "less vulnerable", will amount to about 13% of the values exposed while if the intensity is 7, then the expected damages for the same type of buildings will be close to 0.85 times the values exposed.

A building is said to be *more vulnerable* than another if greater damage is expected in the former than in the latter given similar hazard intensities (see figure 2.1.2).[16] Vulnerability functions are highly hazard-specific. In other words, in the same city, buildings and infrastructure might be very vulnerable to a certain hazard and much less vulnerable to another.

[15] This applies to cities within an 80 km radius of an active volcano. If the city is outside this radius, this hazard will be disregarded.

[16] In figure 2.1.2 we have plotted a very simple case: one building is less vulnerable than the other for all the intensity range. However, it is conceivable that a building is more vulnerable than the other, say, for the low intensity levels, while the situation is reversed for the high intensity levels.

Figure 2.1.2 Schematic Representation of Vulnerability Functions of Two Buildings in the Same City, for the Same Type of Hazard



As defined, vulnerability functions might change depending on technological, educational, cultural and social factors. For instance, for the same seismic intensity, buildings in a city might be more vulnerable than buildings in another city due to higher dissemination of construction technology or application of seismic-resistant design in the latter. Thus, in rigor, vulnerability functions should be expressed in the following way:

$$V(I) = V(I;\phi) \qquad (2.7)$$

where ϕ is a set of parameters that will be denoted as vulnerability factors. In fact, it is through these factors that the effects of prevention can be appreciated, and their economic impact can be assessed.

Consider, for instance, that the vulnerability curves correspond to earthquake hazard. Here it is conceivable that the application of seismic-resistant design in a city (a change in one of the vulnerability factors) could move the vulnerability function from the "more vulnerable" to the "less vulnerable" case of figure 2.1.2. Then, when subjected to the same level of intensity (say, I=2), the application of seismic regulations would mean losses of 5% of the exposed value as opposed to a 20% loss without seismic regulations. Usually, the costs of development, implementation and enforcement of seismic regulations would be much less than the amount saved by reducing the vulnerability, so improving the design practices would be a sound decision even from the economic point of view.

As may be noted in the preceding paragraphs, we always refer to $V(I;\phi)$ as being related to the *expected* damage, that is, to the expected value (in the probabilistic sense) of the damage. Due to the uncertainties involved, it is impossible to deterministically predict the damage resulting from an event with a given intensity. Thus, we try to predict its expected damage with $V(I;\phi)$, keeping in mind that there are uncertainties that cannot be neglected. There are, of course, rigorous probabilistic ways to account for this uncertainty (see Appendix 2.1-10). One way of solving this problem is to find a factor, that we call *K* (see equation 2.3), which relates the loss estimator that would be obtained accounting for the uncertainty with the loss estimators obtained disregarding this uncertainty. Factor *K* depends on several things: the uncertainty in the vulnerability relation, the shape of the intensity exceedance rate curve, and the return period. We have found that, under reasonable hypotheses, a factor of K=1.2~1.3 is reasonable for our goals.[17] However, Appendix 2.1-10 gives several options of computing factor *K*, with various degrees of precision and computational effort.

So far, our analysis has been restricted to estimate losses in cities or regions of limited geographical size. The key to the definition of "limited geographical size" is our hypothesis that everything within the city is affected simultaneously by the event under study. In reality, damage during disasters varies, sometimes widely, even within a city, so our hypothesis hardly, if ever, holds. But, this assumption has to be made for the sake of simplicity. However, for extensive regions, comprising several cities, perhaps hundreds of kilometers apart, it would be extremely risky to assume that everything is affected simultaneously. In view of this, we have to derive ways to combine the computed loss estimators for each city in order to obtain a reasonable combined estimator for the whole country. We shall call these rules the *aggregation rules* (See Appendix 2.1-11).

Appendix 2.1-1 Analytical Approach about Growth and Disasters

One central aspect in the analysis of the incidence of natural phenomena on the economic system is the determination of their effects on the dynamic of capital accumulation- how, for example does an earthquake, flood or hurricane affect the level and growth of GNP? The reply must be elaborated from both a theoretical and empirical angle. Unfortunately, it is only recently that researchers have directed their efforts to examining the relations between geography and economic performance. A first systematic international effort in this direction was made by Gallup, Sachs and Mellinger (1999). The IDB Latin American project directed by Gallup, Gaviria and Lora (2003) takes up on a similar line of thought. The present appendix summarizes some models of economic growth where natural disasters are seen as determinants of capital accumulation.

The neoclassical model of standard growth is inevitably the starting point for analysis. The essential characteristic of this model is that the long term rate of economic growth is determined by exogenous variables. When the economy reaches a stable equilibrium (that is to say, when capital accumulation ceases and all variables remain constant in per capita terms), the rate of growth of GDP will be determined by population growth and technological change. The first factor is determined by demographic variables whilst the second is seen as an "invisible hand" or as a measure of ignorance.

[17] Note that if a constant factor K=1.2 is used for all countries, cities and types of hazard then it becomes irrelevant for comparison purposes. However, we prefer to deal with *K* explicitly for two reasons. The first is of symbolic nature: it helps to keep in mind that our estimation process is uncertain and that we must account for uncertainty in a formal way. The second reason is that, as defined, our loss estimators have a clear meaning: they are economic losses, measured in monetary units. Thus, their scale is relevant.

To the extent that the supply factors are the nucleus for the structuring of the model it is not surprising that demand side variables play no role in long term dynamics. In the same way, it may be asserted that exogenous impacts such as those associated with disasters do not affect the growth of GDP in the static state. However, during the long term transition process they may impact in the level and rate of growth of income, but once the "stable state" is reached the determinants of growth in GNP are technical change and population growth.

In the neoclassical growth model one assumes the existence of an aggregate production function, with constant scale gains in the factors of production. For simplicities sake it is assumed that only two inputs exist: capital and labor, measured in efficiency units. The population grows at a constant rate n and technological change grows at rate x. Capital depreciates at a rate of δ. The basic growth equation may be expressed in per capita terms in the following way:

$$\dot{k} = s(k,\mu) f(k) - (n + \delta + \mathrm{x})\mathrm{k} \qquad (2.1\text{-}1.1)$$

Where k is the capital-labor relationship measured in efficiency units; $s(k,\mu)$ is the savings rate, which depends on the capital stock (k) and on μ, which is the rate of loss of income per disaster; $f(k)$ is the intensive production function (expressed in per capita terms) and $\dot{k}$ is the rate of change of the capital-labor relationship.

If the production function behaves normally (obeys the Inada conditions) a unique, stable stationary equilibrium state for the system can be found (when $\dot{k}$=0). In say state, the rate of growth for all variables is the same. In fact the rate growth of GDP is equal to the population growth rate plus the rate of technical change. Following on from this it is clear that exogenous negative impacts associated with things such as an earthquake or large floods do not affect the long term growth of the economy (Albala Bertrand 1993/2002). However, they may reduce the savings level in society and thus the amount of capital and product per person in the stationary state.

Let us suppose that a natural phenomenon has a negative impact on the savings rate. This displaces the curve $sf(k)$, downwards which in turn reduces the capital per capita level of the stationary state (and, of course, income per capita). If the economy has as yet not reached its inert state, the event may reduce the GNP growth rate per person during the transition period. The impact in the sustained growth trajectory may be obtained from the derivation of the function $\dot{k}$=0 with respect to μ, as is expressed in equation 2.1-1.2.

$$(s(k,\mu)\frac{df(k)}{dk} + \frac{ds(k,\mu)}{dk} f(k) - (n + x + \delta))\frac{\mathrm{dk}}{\mathrm{d}\mu} = -\frac{ds(k,\mu)}{d\mu} f(k) \qquad (2.1\text{-}1.2)$$

The term that accompanies dk/dμ inevitably has a negative sign where it is guaranteed that the equilibrium growth trajectory is locally stable. If this is the case, the capital-labor relation (or per capita income) decreases if the derivative of the savings rate with respect to the disaster impact is negative (Atkinson and Stiglitz 1980; Ministerio de Economia y Finanzas 1988). Under these conditions, the neoclassical growth model predicts an inverse relationship between disaster losses and per capita income. However, no relationship is established between such events and the long term growth rate of the economy. Only recently with new models of economic growth has some type of relationship been achieved between disasters and the rate of per capita income growth. This new generation of models commenced with the pioneer work of Romer (1986) and Lucas (1988) who managed to make the rate of growth endogenous to technical change (Aghion and Howitt 1999).

The model maintains the supposition of decreasing returns and introduces a new factor of production in the production function that generates growing externalities and gains in the aggregate. The new input was baptized "human capital" by its creators, in the widest possible sense (education, health and knowledge). The central ideas of this new growth theory may be derived from a very simple growth model. A production function with constant scale gains is taken as a starting point, although it is also assumed that the capital accumulation process does not affect the investment earnings rate. That is to say, the mean and marginal product of capital remains constant in the long run. The production function is expressed as follows:

$$Y = AK \qquad (2.1\text{-}1.3)$$

where Y is the product, K is the capital stock. The function may be expressed in per capita terms, normalizing all the variables for population L, which grows at a rate of n. Thus:

$$y = Ak \qquad (2.1\text{-}1.4)$$

where, $y=Y/L$, is the per capita GDP, and $k=K/L$ is the capital-labor relation. Assuming the saving rate is s and that it is considered constant, using the accumulation equation, the GDP per capita growth rate may be expressed as:

$$\gamma = sA - n - \delta \qquad (2.1\text{-}1.5)$$

where A is the scale and technology indicator, s is the saving rate, n is the population growth rate and δ is the rate of depreciation. Therefore, the level of income per capita at moment t may be expressed in exponential terms as:

$$y_t = y_0 e^{(sA-n-\delta)t} \qquad (2.1\text{-}1.6)$$

in logarithmic terms we arrive at:

$$\ln y_t = \ln y_0 + (sA - n - \delta)t \qquad (2.1\text{-}1.7)$$

As may be deduced from the previous expressions, any event that affects the rate of savings and depreciation may increase or reduce either the level or rate of growth of income per capita. Following Ermoliev *et al.* (2000), it is assumed that disasters occur randomly at moments T_1, T_2, etc. and defining L_1, L_2, etc. as the net loss in insurances and other compensations the GDP per capita is then expressed as:

$$\ln y_t = \ln y_0 + (sA - n - \delta)t - L_1 - L_2 - .... - L_{N(t)} \qquad (2.1\text{-}1.8)$$

Assuming that disasters do not depend on the state of the economy, that their magnitude is random, identically distributed with a mathematical expectation μ and that the temporality of the events has a stationary distribution with a mathematical expectation of λ, then the GDP per capita trajectory is:

$$E \ln y_t = \ln y_0 + (sA - n - \delta - \lambda\mu)t \qquad (2.1\text{-}1.9)$$

This expression clearly illustrates that recurrent and random disasters affect per capita income and growth rates in the long term. In this model, this is brought about by a greater rhythm of depreciation of capital stock (destruction of bridges, hydroelectric plants, roads, buildings and equipment) As Ermoliev *et al.* (2000) sustain: "…a very complex situation arises when the [impacts] are endogenously determined by the dynamics and spatial pattern of growth. In the general case, the shocks $L_1, L_2, \ldots$ and other parameters are affected by the growth of $y(t)$. The savings rate can depend on income levels and distribution in the economy. Obviously, the lower the rate of income the lower the rate of savings. In this case the [impacts] may reduce these even to negative levels, that is to say, indebtedness. The growth trajectory shows poverty thresholds and traps in such cases".

Although it is possible from a theoretical viewpoint to rigorously model essential aspects of the disaster- economic growth dynamic-development relation, empirical studies are still scarce. Gallup, Gaviria, and Lora (2003) find that disasters can have a negative impact on GDP growth rates in Latin America, after controlling for variables such as initial per capita GDP, educational levels, life expectancy, the levels of free trade, quality of institutions, physical infrastructure and physical and human geography indicators. However, the indicator they use, deaths, does not necessarily rigorously measure the macro-economic effects of natural disasters. A more systematic and rigorous treatment of the topic has been undertaken by Charlotte Benson (2003a). In her research, evidence is also found to suggest that disasters reduce national growth rates given that they may affect long term investment returns and capital accumulation.

Recently, the ECLAC (2003) updated its manual for the evaluation of he socio-economic and environmental impact of disasters. In particular, methodologies are presented to examine the short and medium term macroeconomic effects. Variables include GDP, growth rates, investment, balance of payments, inflation and public finances. Finally, in the work of Freeman *et al.* (2002a) an interesting exercise is attempted using a Monte Carlo simulation model for El Salvador, where they purport to illustrate how a countries growth rate is greater if insurance is taken against disaster as compared to other alternatives, including taking no preventive measures.

Appendix 2.1-2 Estimation of Public and Private Participation in the Aggregated Capital Stock of the Economy

The negative impact associated with the *MCE* during time period *t* in zone *j* may be defined as L_t^j. Such loss may be divided into public and private capital stock, as is expressed in equation 2.1-2.1

$$L_t^j = L_t^{jg} + L_t^{jp} \qquad (2.1\text{-}2.1)$$

where, g refers to public stock and p to private capital stock. Depending on the availability of data on public and private investment, greater levels of disaggregation could be obtained. Here it is clear that the loss of public and private stock in region j is random. To the extent that the *MCE* is a low frequency unique event it is practically impossible to reconstruct the loss distribution functions amongst wealth. One arbitrary criterion for distributing the net losses due to the *MCE* is according to public and private participation in capital stock.

Efforts have been made in Latin America to measure aggregated capital stock. Hofman (2000) obtains disaggregated figures for various countries. Although property rights are not identified in this work it is feasible to obtain a capital series if public and private investment is available. The proposed method departs of the equation of accumulation 2.1-2.2:

$$K_t = (1-\delta)K_{t-1} + I_t \qquad (2.1\text{-}2.2)$$

where K is the capital stock, I is investment and δ is the rate of depreciation. The initial capital stock to which the former expression is applied may be estimated once the capital-product (*K/Y)* relation is known for the baseline year (for example, 1950). This is determined according to the average of the relationship between investment and GDP *(I/Y)* for the study period (for example, 1950-2000, divided by the average growth rate of real GDP and the rate of depreciation. After obtaining the series of public and private capitals the participation per year may be obtained. These coefficients are then applied in order to obtain public and private loss. Thus, if we define β_t^j as the participation of public capital in the total for year t in region j we get the expression shown in 2.1-2.3 for capital stock

$$K_t^{jg} = \beta_t^j K_t^j \quad \text{and} \quad K_t^{jp} = (1-\beta_t^j)K_t^j \qquad (2.1\text{-}2.3)$$

where, K_t^j is the capital stock for region j at time period t.

In order to determine the value of losses of public capital (K_t^{jg}) and private capital (K_t^{jp}), one applies the loss factor that is obtained from the proposed risk model.

Losses due to unemployment

Natural disasters imply costs that go beyond the stock of physical wealth of the society. An earthquake, flood or hurricane, also generate costs in terms of flows. The event may signify an important increase in the unemployment rate and a large scale reduction in the incomes of survivors. Thus, losses could also include an estimate of such factors, when we are dealing with deterministic evaluations of potential impacts, or the case of a specific event for which data may be obtained on the decisions adopted by government or as to well defined suppositions.

A simple way is to estimate increases in the unemployment rate related to a deviation of GDP away from its potential level after a disaster. This may be obtained via Okun´s law. The following relationship can be estimated using simple econometric methods:

$$u_t = TND - \theta_1 G + \theta_2 Dummy + e_t \qquad (2.1\text{-}2.4)$$

where u_t is the rate of unemployment observed at time *t*; *TND* is the natural unemployment rate, *G* is the percentage deviation observed with respect to potential GDP and *Dummy* is a variable that is able to capture the long term effect on unemployment. This assumes a value of 1 in the disaster period and 0 otherwise.

The coefficient θ_1 is the regression parameter that allows us to determine the marginal effect of a reduction of GDP from its potential level; θ_2 is the coefficient that measures the increase in the natural unemployment rate as a consequence of disaster; e_t is an error with a mean zero and constant variance. So, the resources required to attend the population that losses their income can be determined as:

$$\theta_1 * \Delta G * EAP * Sub * n \qquad (2.1\text{-}2.5)$$

where the *EAP* is the economically active population in region *j*, *Sub* is the amount of subsidy (unemployment insurance), and *n* is the number of periods in which help is granted.

Appendix 2.1-3 Estimation of Tax Revenue due to Financial Movements

The resources derived form a tax of *x* per thousand on financial movements may be estimated using the Fisher quantitative equation.

$$MV = PT \qquad (2.1\text{-}3.1)$$

where *M* is the quantity of money; *V* is the speed of money; *PT* is the value of transactions. It is assumed that the taxable base of the tax for the productive sector *i* is a constant proportion of *PTi*, that is to say:

$$BGi = \sigma(PTi) \qquad (2.1\text{-}3.2)$$

therefore, the fiscal income deriving from sector *i* transactions are

$$Ti = t(BGi) = t(\sigma(PTi)) \qquad (2.1\text{-}3.3)$$

where *BGi* is the taxable base, *Ti* is the fiscal income, *t* is the rate of *x* per thousand (2 per thousand, for example) and σ is a parameter that may be determined arbitrarily.

The calculation could even be further simplified if we assume that the income of sector *i* is:

$$Yi = \xi(PTi) \qquad (2.1\text{-}3.4)$$

that is to say, a proportion of total transactions. Thus, the income of *x* per thousand for the sector *i* are:

$$Ti = t(Yi(\sigma/\xi)) \qquad (2.1\text{-}3.5)$$

assuming that σ=1, the income per sector may be calculated by means of an input-output matrix as proposed by Rodríguez (2003).

Appendix 2.1-4 Accumulation of Obligations of Former Periods

Fixing the amount of resources that may be obtained through budgetary reallocations implies detailed knowledge of the budgetary process in each country. That is to say, knowledge of the norms and institutions that define the allocation of national and sub-national government resources must be available. It must be realized that any yearly budget al.so has allocations that for diverse motives correspond to previous years. This must be taken into account, if possible, in order to determine the discretional expense (investment) that can be reallocated at any particular time. In general, the process may be divided into the following stages:

1. Appropriations: that may be modified, increased, reduced or transferred between ends during the fiscal year.
2. Commitments: when subscribing formal contracts.
3. Obligations: when work has been finished and goods and services are handed over and the respective bills are submitted.
4. Payments: when the treasury emits checks.
5. Cash: when the checks are changed.

When a fiscal year is finalized not all jobs have been finished. Commitments have been acquired but not obligations. These expense categories are known in some countries as “appropriation reserves” and are active through the coming period. In other cases, when work is finished and the products handed over, but checks have not been emitted, “payable accounts” accumulate that are liable during the following fiscal year. This is known as floating debt. The inter-temporal accumulation of these obligations restricts government freedom. Finally, we have what are sometime known as “future obligations” which consist in authorized commitments to projects that last more than a fiscal period. So, in order to determine the amount of discretional expenditure the following budgetary items must be subtracted:

Total Expense - Operating Costs – Payments - Private debt interest (national and external) - Floating Debt = Capital Expenditures + External debt interest with multilateral agencies + Future obligations.

Thus, it is proposed that reallocations of expenses contemplate Capital Expenditures, possible suspension of debt interest payments with multilateral organizations and future obligations. The percentage corresponding to these expenses could be determined in proportion to their opportunity cost.

Appendix 2.1-5 External Financial Management Analysis of the Country

In relation to external credit if it is indeed true that a certain level of insecurity exists, it is possible to estimate the amounts that could be obtained undertaking an analysis of the external financial situation of the country. Conventional vulnerability indicators are:

- Reserves / payments for current and following years.
- Reserves / service of total external debt.
- Reserves / (payments+ deficit on current account)

International markets observe country characteristics and indicators. If these report values much below 1, this could indicate serious liquidity and even solvency problems. This would close off the capital market as a source of resources for the country. The multilateral organizations are another source of external resources and in general maintain their credit lines open. Nevertheless, feasible amounts also depend on the internal and financial conditions of the country.

One means of estimating the amount of external debt that could be obtained is by calculating the level of indebtedness in foreign currency that complies with the condition of external sustainability. The basis for this is the fundamental basic identity of flows and stock for an open and relatively small economy:

$$e_{t+1}F_{t+1} = (1+r^*)e_tF_t - BC_t \qquad (2.1\text{-}5.1)$$

where, *et* is the inverse of the real average rate of change, *r** is the international interest rate, *Ft* is the level of external debt, *BCt* is the trade balance measured in national monetary units. Resolving this equation recursively one arrives at the expression 2.1-5.2:

$$F_t = \sum_{j=0}^{\infty}\left[\prod_{k=0}^{j}(1+r_{t+k}^*)\right]^{-1} BC_{t+j} + \lim_{T\to\infty}\left[\prod_{k=0}^{j}(1+r_{t+k}^*)\right]^{-1} e_{t+T}F_{t+T+1} \qquad (2.1\text{-}5.2)$$

As no country can play a Ponzi type game, that is to say, cancel its debt with new foreign debt for ever (given that foreign investors place a limit on the roll over of the debt), the country will have to pay all its obligations at some time. This means that the present value of the national external debt must in the end be zero. In equation 6.2 this means that the second term from the left hand side of the equation is equal to zero. Thus, the condition for external sustainability is reduced to:

$$F_t = \sum_{j=0}^{\infty}\left[\prod_{k=0}^{j}(1+r_{t+k}^*)\right]^{-1} BC_{t+j} \qquad (2.1\text{-}5.3)$$

Equation 2.1-5.3 expresses that the external obligations of a country are sustainable when the commercial surplus, at current values, are equal to actual foreign passives. The econometric test of external sustainability implies that the current account must be a stationary variable. Nevertheless, the value of the sustainable external debt can be arrived at. The indicator is constructed normalizing all expressions for GDP. Such a level may be defined as in equation 2.1-5.4

$$\bar{f} = \frac{bt_t}{r_t^* - q_t - \theta} \qquad (2.1\text{-}5.4)$$

where q_t is the real appreciation of domestic currency, *bt* is the trade balance as a percentage of GDP, $\bar{f}$ is the sustainable external debt as a percentage of GDP, *r** is the international interest rate and θ the product growth rate. If at the moment a disaster occurs that $\bar{f} - f > 0$, (where *f* is the size of the external debt as a percentage of effective GDP), the country could indebt itself by that amount.

The sustainability boundary: an alternative indicator

One of the most serious problems that can prevent the use of the sustainable external indebtedness indicator is its great sensibility to erratic changes of real change rate and real interest rate. In fact during 1980's decade, Latin American countries suffered big exogenous shocks that generated a great macroeconomic instability. Additionally, external debt crisis and hyperinflations were presented. In this context, real interest rates were negative and types of changes underwent the great volatility. As indicators are valid approaches when these variables present "normal" variations, in some cases results could be little reliable.

By the same way, internal monetary credit indicator could not be used in the period abovementioned because institutional changes were implemented that invalidate any reasonable assumption on the access of internal indebtedness resources. Particularly, it is important to mention the independence of Central Banks that prevent the access of government to direct monetary credit. For these reasons, a valid alternative is to use or to verify with another indicator that is known as sustainability boundary.

Considering, at first, the following definition of sustainability: the balance of public debt is sustainable when the next condition is satisfied:

$$\left(\frac{D}{Y}\right)_t \leq \left(\frac{D}{Y}\right)_0 \qquad (2.1\text{-}5.5)$$

where:
$D > 0$; is the public debt at the end of the year
Y, is GDP between 0 and t

This condition indicates that public debt is defined as sustainable when fraction D/Y decreases or is constant. Deriving respecting time, previous condition is equivalent to:

$$\frac{\theta}{g}\frac{D}{Y} \leq \frac{D}{Y} \quad \text{con } \theta < g \qquad (2.1\text{-}5.6)$$

where θ is the nominal rate of growth of public debt and g is the rate of growth of GDP. Additionally, the fiscal deficit conventional definitions are used (S) and of primary deficit (Sp), formally:

$$S = -\Delta D = T - G - iD \qquad (2.1\text{-}5.7)$$
$$Sp = T - G = S + iD = -\Delta D + iD \qquad (2.1\text{-}5.8)$$

Where *ΔD* is the absolute variation of public debt, *T* are the total incomes, *G* are the total expenditures (nets of interest), *I* is interest rate and *D* is public debt. Expressing previous identities in terms of GDP (*Y*), we have:

$$\frac{S}{Y} = -\frac{\Delta D}{D}\frac{D}{Y} = -\theta\frac{D}{Y},$$
$$\frac{Sp}{Y} = \frac{S}{Y} + i\frac{D}{Y} = (i-\theta)\frac{D}{Y} \qquad (2.1\text{-}5.9)$$

In order to obtain sustainability boundary, conditions (2.1-5.6) and (2.1-5.9) are compared and following condition that relates primary deficit (net of interest) and the ratio of debt to GDP is obtained:

$$\frac{Sp}{Y} \geq (i-g)\frac{D}{Y} \qquad (2.1\text{-}5.10)$$

where
Sp is the primary surplus
i is the interest rate
g is the rate of growth of GDP

This algebraic expression can be represented in a simple diagram of two dimensions that clarify the meaning of sustainability boundary conditions (Pasinetti, 1998). For exercise it was preferred to work with an interest rate of 10% and with a real growth rate average. The reason is that during several periods, interest rates were negatives and the nominal GDP growth rates presented great fluctuations. There were used averages of five years forward for primary deficit and growth rates. Whith this it is tried to make a contrafactual calculation that consists in the assumption that if a catastrophic event occurs in the period t_0, the country could have access to additional credit depending on the condition that establishes the sustainability boundary.

Thus, if the country is within the boundary, then, given the average parameters of five years forward, begins to increase amount of feasible debt until the point in which country get out of boundary. In this limit, it stops and is assumed that amount of feasible debt is the one that could be obtained if conditions were stayed during the five years. Therefore, the new debt is total amount divided by five. In order to decide composition between internal and external indebtedness it is assumed that government determines 50% for each one. In this way, new external and internal feasible indebtedness value is obtained if a catastrophe takes place in the year t_0. However, if country is outside of sustainability boundary, a value of new credit equal to zero is assigned.

Appendix 2.1-6 Approach for Internal Credit Access Assessment

One approach to determining government access to internal credit is by restricting analysis to the banking sector (this supposes that no other agents are able to offer resources to government). The idea is to determine the amount of banking sector credit in the private sector prior to a disaster and then introduce a new investment option using public debt bonds in order to attend the disaster calculated as a percentage of the total amount of banking sector deposits. Commencing with the Systems Financial Balance the following identity can be established

$$D+A = F_p+R \qquad (2.1\text{-}6.1)$$

where D corresponds to deposits of all types (savings, current account, CD), A are rediscounts from the Central Bank, R are reserves in the Central Bank and F_p private sector credit. Making some adjustments and redefining terms, the credit for the private sector may be expressed as in equation 2.1-6.2:

$$\hat{F}_p = \frac{(1-r)}{(1-d)(e+r)} B \qquad (2.1\text{-}6.2)$$

where $r=R/D$, is the ratio of reserves R to deposits D; $d=A/Fp$, the ratio of rediscounts A to credit to the private sector Fp; $e=E/D$, the ratio of cash E to deposits D; and B is the monetary base. The coefficients may be estimated by means of averages for a determined period, thus allowing the value of credit available to the private sector prior to impact to be obtained. Once the disaster occurs the government could look to the banking sector to obtain liquid resources. It is assumed that the amount e is expressed as a percentage of system deposits, $b=B/D$. Thus, the equation 2.1-6.2 is converted into the following:

$$\hat{F}_p = \frac{(1-r-b)}{(1-d)(e+r)} B \qquad (2.1\text{-}6.3)$$

From this expression we may determine b as a proportion of deposits, given the Fp for the equation prior to the disaster.

Appendix 2.1-7 Estimation of Sustainable Inter-temporal Expenditure for Disasters

Fiscal policy is a sequence of (g, h, d, t) and an initial value of the debt b_0, where g is the operating and investment expenses as a percentage of GDP, h are the transferences from government as a percentage of GDP, d is the cost of attending disasters as a percentage of GDP and t is government income as a percentage of GDP. Fiscal policy is said to be sustainable if the debt does not grow more rapidly than the interest rate or, in a similar fashion, if the ratio of debt to GDP grows no faster than the difference between the real interest rate and GDP. That is to say, r-θ, where r is the interest rate and θ the rate of growth of GDP. The condition of sustainability is formally expressed as:

$$-b_0 = \int_0^{\infty} (g+h+d-t)e^{-(r-\theta)s} ds \qquad (2.1\text{-}7.1)$$

This expression simply states that fiscal policy is sustainable if the present value of the primary surplus -(*g*+*h*+*d*-*t)* discounted at a rate *r*-*θ* is exactly equal to the value of the initial debt. Therefore, the interesting thing to know is if at any given moment a drastic change is required in the fiscal variables and if this is so, what is their magnitude? Considering this idea, we may pose the following question: What is the constant expense rate to attend disasters (*d**) that assures the sustainability condition? In order to reply, we must assume certain trajectories for *g, h* and *t,* and then use the sustainability condition in order to determine the sustainable level of *d**. The sustainability condition may be written in the following manner:

$$-b_0 = \int_0^{\infty} (g+h-t)e^{-(r-\theta)s}ds + \int_0^{\infty} d^* e^{-(r-\theta)s}ds \qquad (2.1\text{-}7.2)$$

reordering terms and integrating we arrive at the following expression

$$-b_0 - \int_0^{\infty} (g+h-t)e^{-(r-\theta)s}ds = \frac{d^*}{r-\theta} \qquad (2.1\text{-}7.3)$$

finding and ordering signs we arrive at the following reply to the question

$$d^* = \left[\int_0^{\infty} (t-g-h)e^{-(r-\theta)s}ds - b_0\right](r-\theta) \qquad (2.1\text{-}7.4)$$

thus, we may define the indicator *d*-d*, where *d** is the expenditure on disasters which complies with the sustainability condition and *d* is the current expenditure in order to face up to a major disaster. If *d*-d* < 0, one may conclude that the government could not face all the costs unless it is willing to reallocate expenses, increase taxes or increase internal and external debt such as to disobey the sustainability condition. As is clear from the equation, in order to determine *d** we require information for infinite horizons as regards the real interest and growth rate as well as regards the flows of fiscal variables. This information demand obliges us to design indicators for finite time periods. Supposing that we wish to determine the level of constant expenditure for disaster *d** sustainable for *n* years. The idea is that for the flows of *t, g, h* the level of *d** guarantees that the rate of debt of GDP after *n* years could be equal to the balance of the initial debt, that is to say, b_0. Using the same accounting scheme it is possible to obtain the following expression:

$$d_n^* = \left[\left(1-e^{-(r-\theta)n}\right)^{-1}\int_0^{n} (t-g-h)e^{-(r-\theta)s}ds - b_0\right](r-\theta) \qquad (2.1\text{-}7.5)$$

If *n*, *r* and *θ* are small, d_n^* is approximately equal to the average value of the primary surplus during the *n* periods less the balance of the debt as a percentage of GDP multiplied by the real net interest rate of the GDP growth rate, as it is expressed by the equation once the solution of the integral is obtained, as follows:

$$d_n^* = (t-g-h) - b_0(r-\theta) \qquad (2.1\text{-}7.6$$

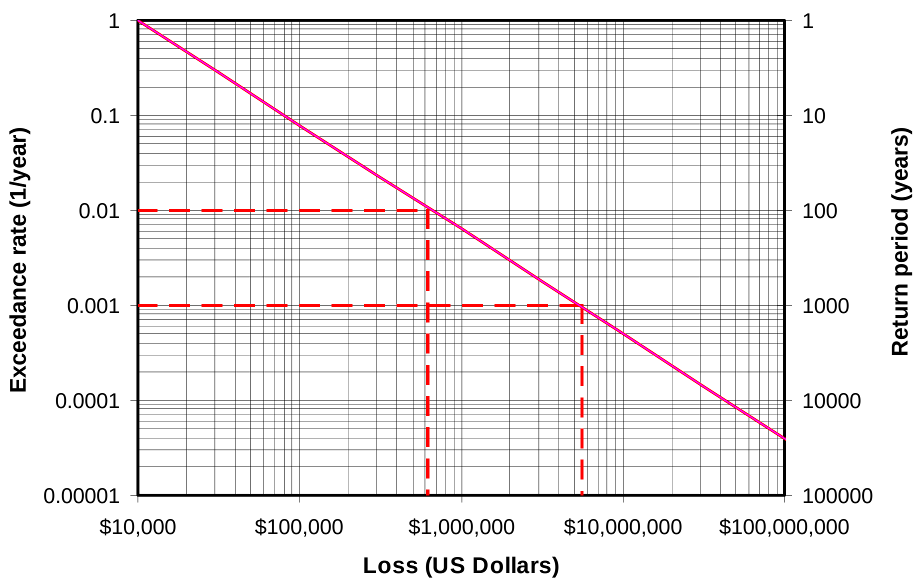
Appendix 2.1-8 A Few Words on the Exceedance Rate Curves and Return Periods

Figure 2.1-8.1 depicts an example of an imaginary exceedance rate curve. It indicates, for instance, that a loss equal or larger than around 600,000 USD will take place 0.01 times per year or, alternatively, once every 100 years –its return period. Also, it shows that a loss of around 5,600,000 USD has an exceedance rate of 0.001/year, or a return period of 1000 years.

As shown in Appendix 2.1-9, under reasonable hypotheses, a curve like the one presented in figure 2.1-8.1 contains all the information required to assess, in the probabilistic sense, the economic impact of the associated disaster. Determination of this curve requires a full-fledged probabilistic analysis, whose description is beyond the scope of this paper.

However, we postulate that it is feasible to approximately estimate a few points of the exceedance rate curve of the economic losses, with which good indicators of the economic impact can be computed. In other words, we postulate that the losses associated to selected return periods are good measures of the expected losses, and that they can be computed with approximate methods.

Figure 2.1-8.1 Curve of Exceedance Rates and Return Periods of Economical Losses in an Imaginary Example



The concept of return period has proven to be a tricky one. The return period of a disaster with a loss *L* is the average time between events that produce losses equal or higher than *L*. For example, if we say that the return period of a disaster producing losses of 1,000,000 USD is 100 years, we mean that, on average, we should expect one disaster with losses equal or higher than 1,000,000 every 100 years. Note that we imply nothing about how much time we would have to wait to see the next disaster of this kind (the kind of disasters that produce losses above 1,000,000 USD); we are only specifying the average waiting time.

However, perhaps due to psychological factors related with risk perception, people seem to believe that if a given disaster is associated with return period T_R, it is almost impossible to have a disaster of this kind the next year, or within two years, or, in general, relatively near in the future. The concept of return period seems to imply the notion of periodicity, so people act as if they believed that the probability of having a disaster of the kind examined grows as the waiting time approaches the return period. Although models of some waiting processes have this peculiarity, empirical evidence shows that, for most cases, a Poisson model is a better representation of the process of occurrence of disasters in time.

As shown in Appendix 2.1-9, if the time occurrences are Poissonian, then the times between events are independent and exponentially with parameter λ; this quantity is exactly the exceedance rate of the disaster or, in other words, the inverse of its return period. Hence, the probability, P_F, of having at least one disaster of the kind analyzed in the next T_E years (often called the *exposure time*) can be computed with the following expression (see Appendix 2.1-9):

$$P_F = 1 - e^{-\frac{T_E}{T_R}} \qquad (2.1\text{-}8.1)$$

Results are somehow surprising. Figure 2.1-8.2 shows P_F as a function of return period and exposure time.

For instance, even when talking about a relatively infrequent disaster –the one with a return period of 100 years- the probability of having at least one of these events the next year is about 1% (it is, obviously, not impossible), and the probability of having this disaster within the next 10 years is close to 10%. For a more frequent disaster (T_R=20 years), the probability of experiencing one of its kind (or larger) the next year is 5%, while, with a 40% chance, we will suffer it within 10 years. For reference, we have included some of these values in Table 2.1-8.1.

Figure 2.1-8.2 Probability of Having at Least one Disaster of Different Return Periods in the Next T_E Years

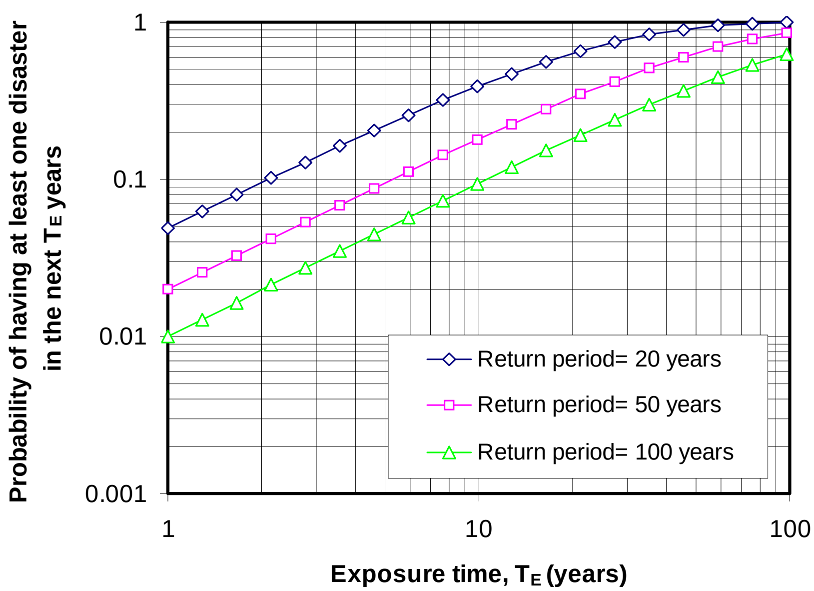


Table 2.1-8.1 Probability of Having at Least one Disaster of Return Period T_R in the Next T_E years

Exposure Time, TE (the next N years)	Return Period of the Event, TR (years)		
	20	50	100
1	5%	2%	1%
5	22%	10%	5%
10	39%	18%	10%
20	**63%**	33%	18%
50	92%	**63%**	39%
100	99%	86%	**63%**
200	100%	98%	86%

In our experience, risk is better perceived when expressed in terms of probabilities of exceedance in given time spans (the "probability of ruin" of classic probabilistic analysis) than when specified in terms of the return period of the "ruin".

Appendix 2.1-9 Mathematical Relations Between the Exceedance Rates and Other Interesting and Useful Measures of Risk

Let $\lambda(I)$ be the intensity exceedance rate, defined as the mean number of events per unit time whose intensity is greater than the value I. Let al.so $\nu(y)$ be the exceedance rate of the losses, that is, the mean number of events per unit time that produce a loss greater than the value y. In general, $\nu(y)$ is computed as follows:

$$\nu(y) = \int_0^\infty -\frac{d\lambda(I)}{dI} \Pr(Y > y \mid I) dI \qquad (2.1\text{-}9.1)$$

where $\Pr(Y>y|I)$ is the probability that the losses are greater than y given that an event with intensity I took place. Computation of these probabilities involves the use of a vulnerability function that relates losses and intensity in the probabilistic sense.

The return period of loss y, $T_r(y)$ is defined as the mean time between events that produce losses equal or greater than y. The return period of this loss is the inverse of its exceedance rate:

$$T_r(y) = \frac{1}{\nu(y)} \qquad (2.1\text{-}9.2)$$

The probability distribution of the loss during the next event, $P(y)$, is the probability that the loss is less than y in the next event. This distribution is given by:

$$P(y) = \Pr(Y < y) = 1 - \frac{\nu(y)}{\nu(0)} \tag{2.1-9.3}$$

where $\nu(0)$ is the mean number of events per unit time. By definition, $\nu(\infty)=0$. The probability density function of the loss during the next event can be obtained by derivation of equation 2.1-9.3:

$$p(y) = -\frac{1}{\nu(0)} \frac{d\nu(y)}{dy} \tag{2.1-9.4}$$

If the occurrence process of the events is of Poisson type, then the probability that the largest loss in a year is greater than a given value, *z*, is the following:

$$\Pr(y_{\max} > z) = 1 - e^{-\nu(z)} \tag{2.1-9.5}$$

Also under the assumption of a Poissonian process, the probability of having at least one event producing losses equal or greater than *y* in the next T_E years, P_0, is given by:

$$P_0 = 1 - e^{-\nu(y)T_E} \tag{2.1-9.6}$$

From the Poisson assumption, it also follows that the probability density function of the times between events that produce losses equal or greater than *y* is exponential with parameter $\nu(y)$, that is:

$$p_t(t) = \nu(y)e^{-\nu(y)t} \tag{2.1-9.7}$$

The expected annual loss is defined as the mean value of the sum of losses in one year. It can be computed as follows:

$$\bar{y} = \nu(0)\int_0^\infty yp(y)dy \tag{2.1-9.8}$$

where $p(y)$ is given in equation 2.1-9.4. Replacing 2.1-9.4 in 2.1-9.8 yields:

$$\bar{y} = -\int_0^\infty y\frac{d\nu(y)}{dy}dy = -\int_0^\infty yd\nu(y) \tag{2.1-9.9}$$

Equation 2.1-9.9 shows that the expected annual loss can be computed by integration of the loss exceedance rate curve.

The annual expected loss in the insurance industry is known as the pure or technical rate. This is the expected value of losses that would occur in any one year supposing that the process by which events occur is stationary and that the resistance of damaged structures is restored immediately after the event (Esteva, 1970).

Appendix 2.1-10 How to Account for Uncertainties in the Vulnerability Functions

As stated in Appendix 2.1-9, the exceedance rate of the losses can be computed with the following expression:

$$\nu(y) = \int_0^\infty -\frac{d\lambda(I)}{dI} \Pr(Y > y \mid I)\, dI \qquad (2.1\text{-}10.1)$$

where $\lambda(I)$ is the intensity exceedance rate and $\Pr(Y>y|I)$ is the probability that the losses are greater than y given that an event with intensity I took place. Figure 2.1-10.1 depicts an example of $\lambda(I)$, which refers to earthquake hazard; in this case, I denotes peak ground acceleration.

Let $V(I)$ be the vulnerability function, that is, the expected value of the loss given that an event with intensity I took place. If the vulnerability function were deterministic then, given an event with intensity I, the loss would be exactly equal to its expected value, $V(I)$, without uncertainty. Figure 2.1-10.2 gives an example of an earthquake vulnerability function.

Figure 2.1-10.1 Example of Intensity Exceedance Rate, λ(I)

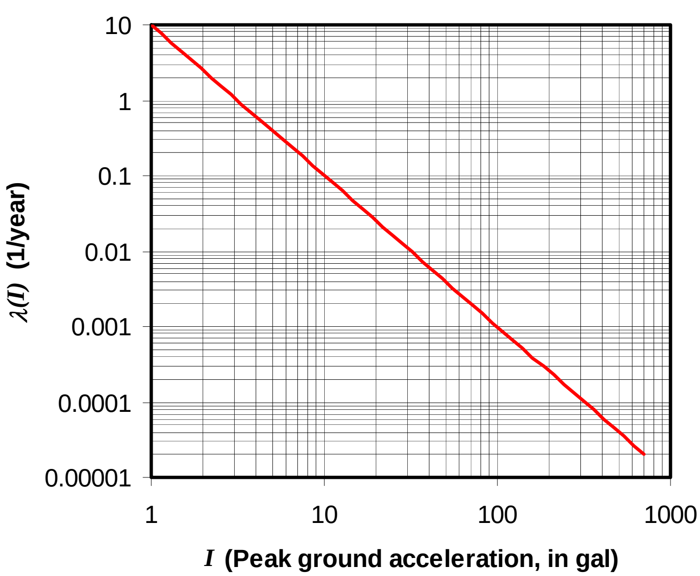
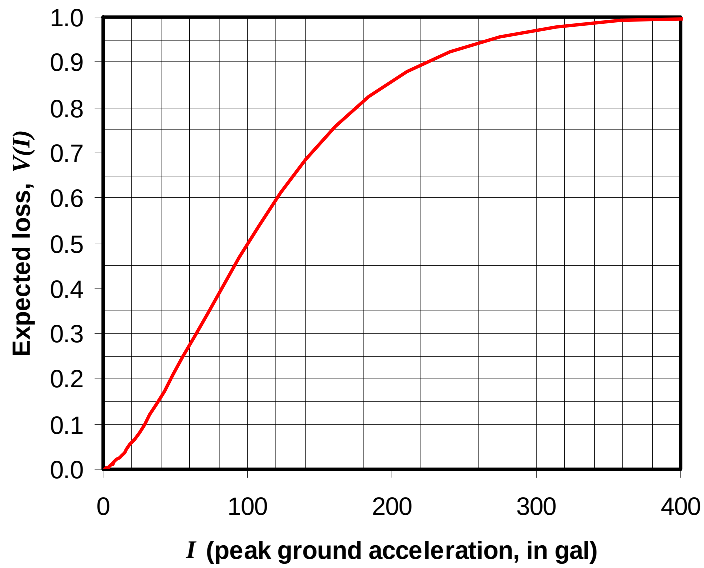


Figure 2.1-10.2 Example of an Earthquake Vulnerability Function



In the case of a deterministic vulnerability function,

$$\Pr(Y > y \mid I) = \begin{cases} 0 & if\ I < Ic(y) \\ 1 & if\ I \geq Ic(y) \end{cases} \qquad (2.1\text{-}10.2)$$

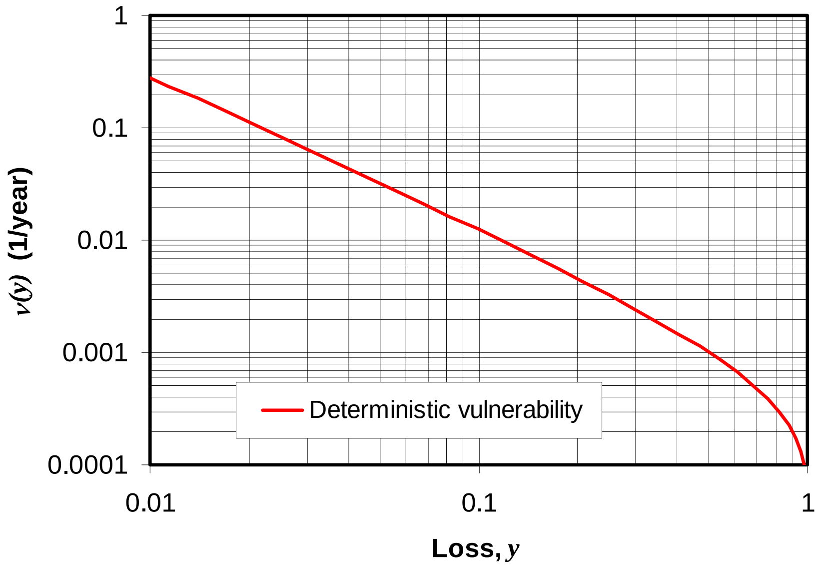
where $Ic(y)=V^{-1}(y)$ is the intensity that (deterministically) produces a loss equal to y. Replacing 2.1-10.1 in 2.1-10.2, one obtains:

$$\nu(y) = -\int_{Ic(y)}^{\infty} d\lambda(I) = -[\lambda(\infty) - \lambda(Ic(y))] = \lambda[Ic(y)] \qquad (2.1\text{-}10.3)$$

In other words, the exceedance rate of loss y is equal to the exceedance rate of the intensity that, deterministically, produces a loss equal to y. Figure 2.1-10.3 presents an example of the exceedance rate of loss y, computed using the intensity exceedance rate and vulnerability curves form figures 2.1-10.1 and 2.1-10.2, respectively.

However, vulnerability functions are not deterministic, and the underlying uncertainty must be accounted for. This could be done by formally computing the integral given in equation 2.1-10.1, which would need a detailed knowledge of the probability distributions of the damage states, or “fragility”, of the structure. To continue with the example, we will assume that the structural fragility is known, and given in the following terms. The expected value of the losses for a given intensity will again be the vulnerability function of Figure 2.1-10.2.

Figure 2.1-10.3 Exceedance Rate of Loss y, Computed with the Intensity Exceedance Rate and Vulnerability Curves Form, Figures 2.1-10.1 and 2.1-10.2, Respectively. Vulnerability has been Assumed Deterministic

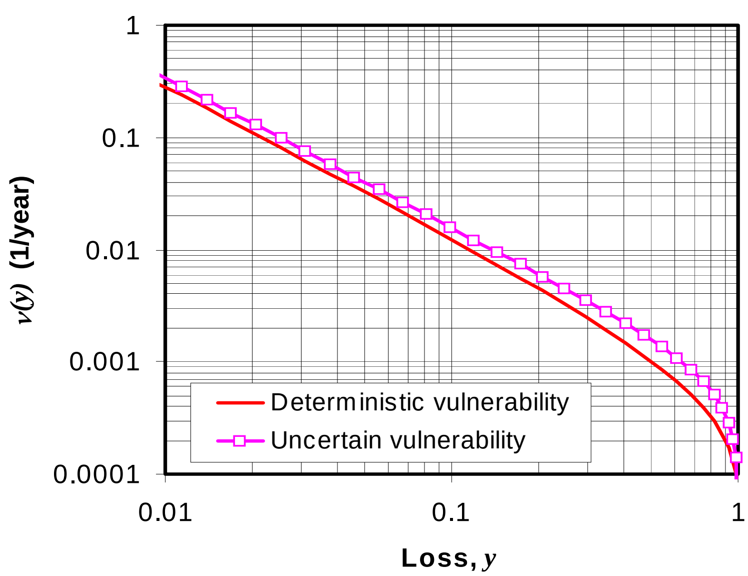


The standard deviation of the losses given an intensity will be described by:

$$\sigma(I) = V(I)[1 - V(I)] \qquad (2.1\text{-}10.4)$$

Furthermore, we will assume that, given an intensity, losses have a Beta distribution with the expected value and variance already defined.

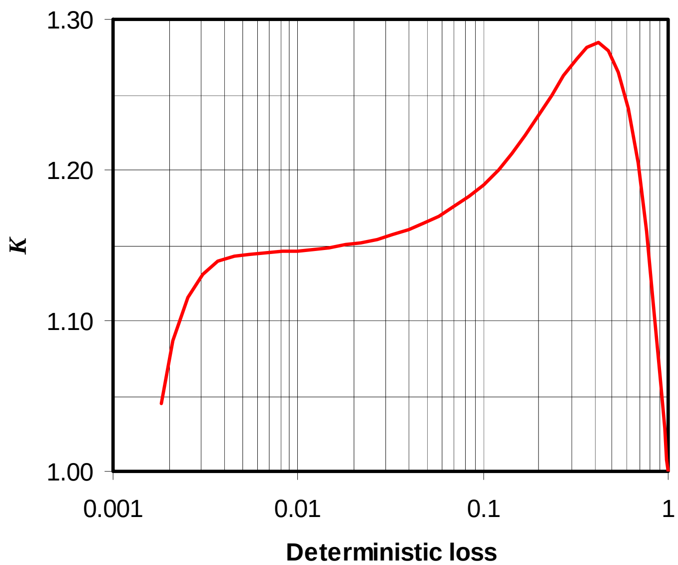
Figure 2.1-10.4 Exceedance Rate of Loss y, Computed with the Intensity Exceedance Rate and Vulnerability Curves Form, Figures 2.1-10.1 and 2.1-10.2, Respectively. Two cases are presented: deterministic and uncertain vulnerabilities



Under these assumptions, and accounting for uncertainties in the vulnerability relations, we obtain the loss exceedance rate curve of figure 2.1-10.4, where we compare this curve with the one obtained without account for the uncertainty in the vulnerability relation.

Note in figure 2.1-10.4 that, for a given exceedance rate or return period, the associated loss for uncertain vulnerability is larger than the associated loss in the deterministic case, which is the usual effect of uncertainty in vulnerability functions. Then, it is clear that to account for uncertainty, the losses computed ignoring it must be multiplied by a factor larger than 1. In the main text this factor has been called *K,* defined as the ratio between losses associated to a return period considering uncertain vulnerability and the losses associated to the same return period but computed ignoring the uncertainty in the vulnerability relation. Figure 2.1-10.5 shows factor *K* as a function of deterministic losses for the example developed in this appendix.

Figure 2.1-10.5 Factor K is Depicted as a Function of the Deterministic Losses.



As it can be appreciated, exact computation of factor *K* is cumbersome and requires detailed information about the fragility of the structure. Within the scope of this project, this information is unlikely to be available. To partially solve this problem, we propose the first order approximation that will be described in the following paragraphs.

We will assume that, given an event with intensity *I*, the losses have Rosenblueth's distribution (1981), that is, a probability density function consisting of two probability masses of values P_1 and P_2 at y_1 and y_2, respectively. Formally,

$$p(y \mid I) = P_1\delta(y_1) + P_2\delta(y_2) \qquad (2.1\text{-}10.5)$$

where $P_1+P_2=1$ and δ is Dirac's Delta function. Under these assumptions,

$$\Pr(Y > y \mid I) = \begin{cases} 0 & if \quad y < y_1 \\ P_1 & if \quad y_1 \le y < y_2 \\ 1 & if \quad y \ge y_2 \end{cases} \qquad (2.1\text{-}10.6)$$

from where it follows that

$$\nu(y) = -\int_0^{I_1} \frac{d\lambda(I)}{dI} 0 dI - P_1 \int_{I_1}^{I_2} \frac{d\lambda(I)}{dI} dI - \int_{I_2}^{\infty} \frac{d\lambda(I)}{dI} dI \qquad (2.1\text{-}10.7)$$

where $I_1=V^{-1}(y1)$ and $I_2=V^{-1}(y2)$. From equation 2.1-10.7, and recalling that $\lambda(\infty)=0$, the following expression can be obtained:

$$\nu(y) \approx P_1\lambda(I_1) + P_2\lambda(I_2) \qquad (2.1\text{-}10.8)$$

Equation 2.1-10.8 is an approximation to the exact value of $\nu(y)$. However, it can be appreciated that this approximation is much easier to compute than the exact value. If, as it is common, the loss given an intensity is assumed to have a Beta distribution, then P_1, P_2, y_1 and y_2 can be computed with the following expressions:

$$y_1 = \frac{a^2 + a(b+2) + b + 1 - \sqrt{(a+1)(b+1)(a+b+1)}}{(a+b+2)(a+b+1)} \qquad (2.1\text{-}10.9)$$

$$P_1 = \frac{1}{2}\frac{ab(a+b+2)^2}{((a^2 - b - b^2 + a)u + (a+b)^2 + ab^2 + a^2b + a + b)(a+b)} \qquad (2.1\text{-}10.10)$$

$$u = \sqrt{\frac{(a+1)(b+1)}{a+b+1}} \qquad (2.1\text{-}10.11)$$

$$P_2 = 1 - P_1 \qquad (2.1\text{-}10.12)$$

$$y_2 = \frac{1}{P_2}\left(\frac{a}{a+b} - P_1 y_1\right) \qquad (2.1\text{-}10.13)$$

where a and b are the parameters of the Beta distribution related to the expected value of the loss and its variance in the following way:

$$a = \frac{1 - V(I) - V(I)\, C^2(I)}{C^2(I)} \qquad (2.1\text{-}10.14)$$

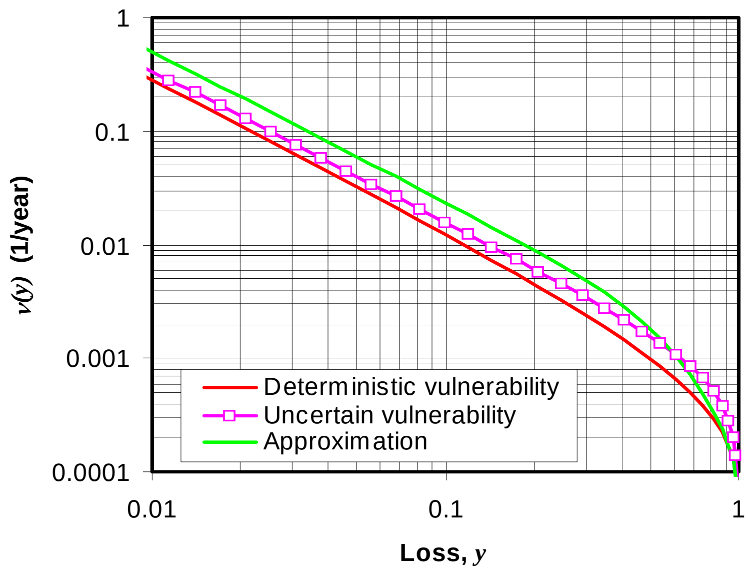
$$b = a\left[\frac{1 - V(I)}{V(I)}\right] \qquad (2.1\text{-}10.15)$$

where

$$C(I) = \frac{\sigma(I)}{V(I)} \tag{2.1-10.16}$$

In figure 2.1-10.6 we show an example of the loss exceedance rates computed with the approximation described.

Figure 2.1-10.6 Approximation to the Loss Exceedance Rate Computed using Rosenblueth's Distribution. It is compared with the exact value ("Uncertain vulnerability") and the case of deterministic vulnerability.



Appendix 2.1-11 Derivation on the Loss-Aggregation Rules Proposed

We want to obtain the total economic loss in a country with a return period T_r due to natural disasters. The exceedance rate of the loss for the *i*-th city can be modeled as:

$$\nu_i(y_i) = K_i (y_i)^{\rho_i} \qquad \rho_I<0 \tag{2.1-11.1}$$

where y_i is the value of the loss in the city, K_i and ρ_i are parameters of the function of loss exceedance rate. The value of ρ_i is the slope of the curve ν_i *versus* y_i in logarithmic scale. Suppose we know the losses for the main cities in the country for the return period $T_r=1/\nu_0$. The value K_i can be computed from 2.1-11.1:

$$K_i = \frac{\nu_0}{(p_i)^{\rho_1}} \tag{2.1-11.2}$$

where p_i is the loss at the i-th city with return period T_r. Consider that there are two cities in the country and they are far enough apart such that their losses are independent of each other. In this case, the exceedance rate of the total loss is the sum of the exceedance rates of the individual losses:

$$\nu(y) = \nu_1(y) + \nu_2(y) \qquad (2.1\text{-}11.3)$$

We are looking for the value of y such that $\nu(y)=\nu_0$. Replacing 2.1-11.1 and 2.1-11.2 in equation 2.1-11.3,

$$\nu_o = \frac{\nu_o}{(p_1)^{\rho_1}} y^{\rho_1} + \frac{\nu_o}{(p_2)^{\rho_2}} y^{\rho_2} \qquad (2.1\text{-}11.4)$$

$$1 = \frac{1}{(p_1)^{\rho_1}} y^{\rho_1} + \frac{1}{(p_2)^{\rho_2}} y^{\rho_2} \qquad (2.1\text{-}11.5)$$

For simplicity, we will assume that $\rho_1=\rho_2=\rho$. In view of this, equation 2.1-11.5 can then be re-written as:

$$y^{\rho} = p_1{}^{\rho} + p_2{}^{\rho} \qquad (2.1\text{-}11.6)$$

Equation 2.1-11.6 is then the combination rule for the case of independent losses.

We propose to estimate coefficient ρ with the loss exceedance rate curve of the city that has the greater loss for the selected return period, computed using a deterministic vulnerability function; this loss will be called y_m.

For example, consider the following intensity exceedance rate, typical of earthquake hazard:

$$\lambda(I) = \left(\frac{I_0}{I}\right)^r \qquad (2.1\text{-}11.7)$$

where I stands for intensity and I_0 and r are parameters. Consider also the following vulnerability function, also taken from earthquake hazard:

$$V(I) = 1 - \exp\left\{\ln 0.5\left(\frac{I}{\gamma}\right)^{\alpha}\right\} \qquad (2.1\text{-}11.8)$$

where α and γ are parameters. If the vulnerability function is deterministic, then the exceedance rate of loss y is equal to the exceedance rate of the intensity that produces this loss:

$$\nu(y) = \lambda[I(y)] \qquad (2.1\text{-}11.9)$$

I(y) can be obtained by inverting equation 2.1-11.8:

$$I(y) = \gamma \ln(2)^{-1/\alpha} \left[-\ln(1-y) \right]^{1/\alpha} \tag{2.1-11.10}$$

and, from equation 11.9 we have that

$$\nu(y) = \left[\frac{I_0 \ln(2)}{-\ln(1-y)} \right]^{r/\alpha} \gamma^{-r} \tag{2.1-11.11}$$

Recalling that ρ can be regarded as the slope of the total loss exceedance rate curve, $\nu(y)$, in log-log scale, it follows that

$$\rho = \frac{d \ln \nu(y)}{d \ln y} = y \frac{d \ln \nu(y)}{dy} \tag{2.1-11.12}$$

valued at $y=y_m$. In view of this, ρ can be computed from equations 2.1-11.11 and 2.1-11.12, yielding:

$$\rho = \frac{r y_m}{\alpha (1 - y_m) \ln(1 - y_m)} \tag{2.1-11.13}$$

which is the value that should be used in the combination rule given by equation 2.1-11.6.

2.2 The Local Disaster Index (LDI)

The indicators for this index may be computed using the information available in the DesInventar data base established by LA RED for many Latin American and Caribbean countries. Information is registered at the local or municipal level and distinguishes between types of event (phenomenon) and their impacts. Calculations may be made as regards temporal and spatial accumulation of events (La RED 2002). This data base has over 80,000 registers for 16 countries with near to 70% of these corresponding to the period 1970 to the present date. In general, this data base registers effects for most of events, result of the climatic variability and environmental global change.

In that many different types of event are registered in the DesInventar data base, these are classified in six different categories: geodynamic internal and external phenomena, hydrological, atmospheric, technological, and biological, as it is indicated in Appendix 2.2-1. However, in order to simplify with regard to the external geodynamic phenomena these are referred to colloquially as a) *landslides and debris flows* and internal phenomena are referred to as b) *seismo-tectonic*. Hydrological and atmospheric phenomena are grouped and referred to colloquially as c) *floods and storms*. In the same way, technological and biological phenomena are known as d) *other* events.

The DesInventar data base includes diverse and differing information. On scrutiny, we consider the information presented on deaths, housing destroyed, and number of affected the most reliable (LA RED 2002). Relatively complete information also exists on injured, homeless, and affected housing and crops. The remaining information, covering impacts in other sectors such as infrastructure, industry and services, is not considered sufficiently complete and reliable.

According to the abovementioned, the data base should be standardized in order to take into account three variables: i) deaths, ii) number of affected and iii) direct losses –represented as the economic value in housing and crops– for the four types of event. It is convenient to sum the number of people affected with the homeless, when they are different figures in the database, given that in some countries one or the other denomination is used to depict the same thing. We also sum destroyed and affected housing, where an affected house is taken to be equivalent to 0.25 destroyed houses.[18]

The reposition value of any destroyed house is assumed as the average cost of a social housing unit according to the existing standards in each country (number of square meters) during the period of analysis. And, that the value per square meter of social housing is equivalent to one legally established minimum salary during the same time period. On the other hand, we propose that the value of one hectare of crops is calculated on the basis of the weighted average price of usually affected crop areas, taking into account expert opinion in the country at the time of analysis.

Given that information available in DesInventar allows estimations for all municipalities and localities in a country, each value should be normalized taking the area (in square km) of munici-

[18] In general, when damage to constructions exceeds 50% one considers it irreparable. So, for this type of calculations we consider it justified to assume that an "affected dwelling" will have on average 25% damage.

palities as a base. Normalized values allow us to obtain a notion of local levels of concentration and are the values that should be used for constructing national aggregated indicators.

Given the former considerations, the *LDI*, obtained from equation 2.2.1, corresponds to the addition of three local disaster sub-indices, taking into account deaths K, affected A, and losses L:

$$LDI = LDI_K + LDI_A + LDI_L \tag{2.2.1}$$

The local disaster sub-indices for each type of variable (K,A,L) are obtained from equation 2.2.2.

$$LDI_{(K,A,L)} = \left(1 - \sum_{e=1}^{E}\left(\frac{PI_e}{PI}\right)^2\right)\lambda\,\Big|_{(K,A,L)} \quad \text{where} \quad PI_{(K,A,L)} = \sum_{e=1}^{E} PI_{e\,(K,A,L)} \tag{2.2.2}$$

λ is a scaling coefficient and PI_e, as expressed in equation 2.2.3, corresponds to the Persistence Index of effects (K,A,L) caused by each type of event e ; which in this case are four: i) landslides and debris flows, ii) seismo-tectonic, iii) floods and storms and iv) others,

$$PI_{e(K,A,L)} = 100 \sum_{m=1}^{M} LC_{em(K,A,L)} \tag{2.2.3}$$

LC_{em} corresponds to a Location Coefficient of effects x (K,A,L) caused by each type of event e in each municipality m, as is established in equation 2.2.4

$$LC_{em(K,A,L)} = \frac{x_{em}\, x_{eC}}{x_m\, x_C}\,\eta\,\Big|_{(K,A,L)} \tag{2.2.4}$$

where the values of variable x corresponding to K, A or L, are:

x_{em} the value x caused by event e in municipality m;
x_m sum totals for x caused by all types of event considered in municipality m;
x_{eC} the value of x for event e throughout the country;
x_C the total sum of x throughout the country, and
η is the relation between all types of events E and the number of municipalities in country M, where some effects have been registered.

These coefficients account for the relative weight of the effects caused by different types of event in the municipalities with respect to the country as a whole. Therefore, the Persistence Indices capture simultaneously for a given period (year, five years etc.) the incidence –or relative concentration– and the homogeneity of local level effects for each type of event with respect to other municipalities and types of event in the country.

It is important to point out that the indices and coefficients are not sensitive to the fact that one country has a larger number of disasters, municipalities, types of event, or greater size than another. This allows for comparisons to be independent of these characteristics. On the other hand, each sub index may be of internal interest to a country given that it reflects the persistence of effects according to type of event and location in each municipality. Other expressions that may be used to measure other similar persistence characteristics of data are described in Appendix 2.2-2.

The value of these local disaster sub-indices, *LDI* *(K, A, L)* increases if a uniform distribution of the variable (effects) exists amongst municipalities and the different types of event. Thus the lowest values signify a high level of disparity and that the variable is concentrated. In case λ is equal to (400/3) the maximum value of the sub-index will be 100. This means that the variable is similar for all types of event and that there is a similar distribution between municipalities.

The final *LDI* value takes into account total deaths, affected and losses. Even though, it is important to indicate *LDI* is a persistence and uniform dispersion measure for those values.

The *LDI'* is proposed as a collateral indicator which puts the *LDI* in context. This indicator is expressed through equation 2.2.5 and measures the concentration of aggregate losses at the municipal level for all events in the country.[19]

$$LDI' = \frac{\sum_{i=1}^{M-1} q_i}{2\sum_{i=1}^{M-1} p_i} \tag{2.2.5}$$

where

$$q_i = \frac{Z_i}{Z_M} \tag{2.2.6}$$

whose values are obtained from equation 2.2.7

$$Z_i = \sum_{j=1}^{i} x_{mL\,j}\, m_j \quad \text{y} \quad Z_M = \sum_{j=1}^{M} x_{mL\,j}\, m_j \tag{2.2.7}$$

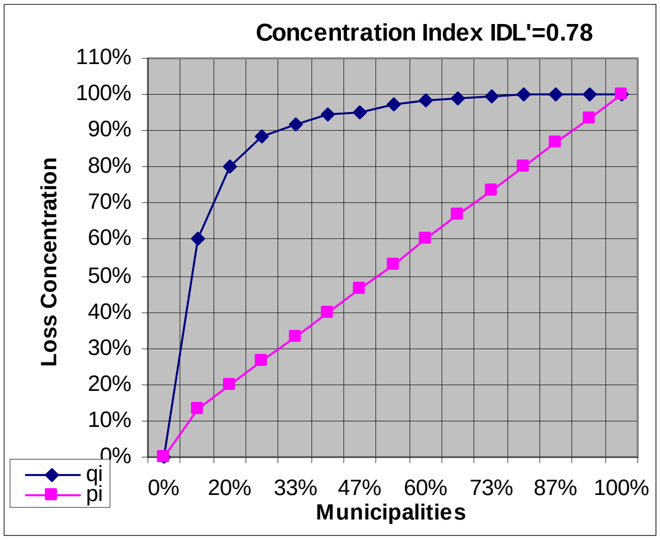
previous ordering of the values of x_{mL} in descending form, maintaining the correspondence with the respective municipality *m*, and

$$p_i = \frac{N_i}{N_M} \tag{2.2.8}$$

is the relationship resulting from the position of the municipality with respect to all municipalities in the country. Figure 2.2.1 presents a hypothetical case of the forementioned relationships. In this case a 0.78 concentration means, for example, 20% of the analyzed country municipalities concentrates 70% of the total losses.

[19] The value of this index varies between 0.5, uniform distribution, and 1.0 which signifies high concentration.

Figure 2.2.1 Shows a High Concentration of Losses in a Few Municipalities After Ordering the Loss Aggregation from Greater to Lower



A similar index to that proposed can be found with the Gini index based on the Lorenz Curve and described in Appendix 2.2-2.

The formulation of this index is particularly important given that it allows the adequate comparison of large and small countries.

Appendix 2.2-1 Categories for Grouping of the DesInventar Events

The DesInventar data base provides a wide range of denominations for events that have led to local disasters in the different countries. Some are synonyms or names specifically used in each country to refer to a particular type of phenomenon but which may in general be classified in a well defined category. Although many phenomena are the result of a combination of situations of diverse origin, in order to simplify things here we will use the following categories:

a) Geodynamic phenomena: Endogenous or exogenous phenomena depending on whether they are generated by internal or external earth geodynamics. This includes phenomena of tectonic origin such as earthquakes, volcanic eruptions, tsunami, and large scale deformations of the earth caused by liquefaction or the movement of geological faults. Other phenomena include those caused by mass earth movements including rock falls, landslides, low flows, debris and mud flows, avalanches and subsidence. This category can be divided in geodynamic external o internal phenomena.

b) Hydrological Phenomena: Events related to water dynamics above and below the earths surface. This includes flat land, slow floods and rapid onset, steep slope flooding; river and lake overflows and the flooding of low lands due to unusual increases in water levels and flows; soil and coast erosion, sedimentation, salinization, water table depletion, desertification and drought.

c) Atmospheric Phenomena: This includes meteorological phenomena such as tornados and whirlwinds; torrential rains and storms; climatic phenomena such as freezing, hail storms, abrupt temperature changes, forest fires; and, events generated at the ocean-atmosphere interface such as hurricanes (typhoons and cyclones) and El Niño. The latter in turn generate other extreme hydrological and geodynamic events, exacerbated due to the intensity of their effects and by global climatic changes.

d) Technological events: System failures due to carelessness, lack of maintenance, operational errors, material fatigue, or mechanical mal-function. Some examples include: air and sea accidents, railroad crashes, bursting of dams, over-pressure in pipelines, explosions, fires etc. We may also include those related with biotical toxic and dangerous agents such as chemical material escapes, oil spills, radioactive material escapes etc.

e) Biological Phenomena: Basically referring to epidemics and plagues that may affect humans, animals and crops. Epidemics may include viral diseases such as cholera, small pox, flu, AIDS. Plagues contemplate such things as locust swarms, African bee swarms, and mice and rats.

Some of these phenomena, which are usually referenced at the DesInventar data base, for different countries, are included in table 2.2-1.1.

Table 2.2-1.1 Classification Event Used

Colloquially Denomination	Phenomena
Landslides and debris flows	**External geodynamic phenomena**
	Landslides, rock falls, debris flows, avalanche, mass removal, subsidence, land sinks (and other terms used in some countries in Spanish, such as aluvión, deslave, huaico, etc.)
Seismo-tectonic	**Internal geodynamic phenomena**
	Earthquake, volcanic eruption, tsunami, fault, liquefaction
Floods and storms	**Hydrological Phenomena**
	Flood, river bore, sedimentation, erosion, flood tide, overflow, water table depletion, drought.
	Atmospheric phenomena
	Storms (electric and tropical), tempests, whirlwinds, hurricanes, rain, fog, hail, snow-storm, frost and freezing spells, heat wave, forest fire.
Other	**Technological phenomena**
	Fires, accidents, explosion, escapes, pollution, collapse, structures
	Biological phenomena
	Epidemics, biological, plague.

Appendix 2.2-2 Other possible indicators on persistence of effects

Other possibilities exist for measuring the uniformity, diversification, disparity and concentration of a variable between municipalities and types of events considered in disaster data bases.

An alternative location coefficient is expressed in equation 2.2-2.1

$$LC_{em} = \frac{x_{em}\, x_C}{x_m\, x_{eC}} \qquad (2.2\text{-}2.1)$$

where the values of variable x are:

x_{em} the value x caused by event e in municipality m;
x_m sum totals for x caused by all types of event considered in municipality m;
x_{eC} the value of x for event e throughout the country;
x_C the total sum of x throughout the country.

Other expressions of persistence indices may be proposed that differentially account for uniformity and concentration of effects both as regards type of events and at the municipal level, according to our particular interests. These expressions are shown in the equations 2.2-2.2 and 2.2-2.3:

$$PI_e{}' = \frac{1}{\rho}\sum_{m=1}^{M}\left|\left(\frac{x_{em}}{x_m}\right)^2 - \left(\frac{x_{eC}}{x_C}\right)^2\right| \quad \text{and} \quad PI_m{}' = \frac{1}{\rho}\sum_{e=1}^{E}\left|\left(\frac{x_{em}}{x_m}\right)^2 - \left(\frac{x_{eC}}{x_C}\right)^2\right| \qquad (2.2\text{-}2.2)$$

$$PI_e{}'' = \frac{1}{\rho}\sum_{m=1}^{M}\left|\left(\frac{x_{em}}{x_{eC}}\right) - \left(\frac{x_m}{x_C}\right)\right| \quad \text{and} \quad PI_m{}'' = \frac{1}{\rho}\sum_{e=1}^{E}\left|\left(\frac{x_{em}}{x_{eC}}\right) - \left(\frac{x_m}{x_C}\right)\right| \qquad (2.2\text{-}2.3)$$

where ρ is a constant that allows us to scale the value of the index and which if used alternatively should have a value of 0.1

These expressions capture the composition of the variables at the municipal level or with regard to type of event, as compared to the country as a whole. They give a greater weight to the relative concentration of the variable that is measured and adopt null values when the participation, of the type of event or the municipality, according to the case, coincides with its participation at national level.

In addition, there are other expressions as presented in equation 2.2-2.4 which account for the uniformity in the distribution of the values of the variables.

$$CD_e = 1 - \frac{\left(\sum_{e=1}^{E} x_{em}\right)^2}{E\sum_{e=1}^{E}\left(x_{em}\right)^2} \quad \text{or} \quad I_m^2 = 1 - \sum_{m=1}^{M}\left(\frac{x_{em}}{x_m}\right)^2 \qquad (2.2\text{-}2.4)$$

These expressions are usually known as coefficients of diversification. In the first case, the value is null when the distribution of the variable is uniform and maximum in the opposite case. In the second case, known as the quadratic index, the value is null to the extent there is disparity and concentration, and maximum when there is a uniform distribution of the variable. These two measures are interpreted similarly but their results are opposed.

The Gini or Lorenz Index

This index is used to measure the distribution of a variable. Using the same nomenclature as *LDI***'**. This may be expressed using equation 2.2-2.5

$$LI = \frac{\sum_{i=1}^{M-1}\left(p_i - q_i\right)}{\sum_{i=1}^{M-1} p_i} \qquad (2.2\text{-}2.5)$$

Where the value of q_i is obtained by the ascending ordering of the considered variable (also known as the Lorenz Curve)

This index has null value when a perfectly uniform distribution exists and its value is close to 1.0 when there is high disparity. The relation between the concentration index proposed for *LDI***'** and the Gini/Lorenz index is established in equation 2.2-2.6,

$$LDI' = \frac{LI + 1}{2} \qquad (2.2\text{-}2.6)$$

2.3 The Prevalent Vulnerability Index (PVI)

The idea of estimating prevalent vulnerability as a reflex or *proxy* of risk means to recognize that what we hope to depict comparatively is a situation or pattern in a country. This is substantiated by the fact that what distinguishes vulnerability from risk is that risk is a situation that demands a dimensioning of vulnerability over time. That is to say, the pattern is time referenced and this determines whether risk is higher or lower. In other words, given the importance of the concept of vulnerability, it has been proposed for this comparative evaluation, a reading of hazard (the factor that establishes the time dimension) as a tacit situation.

Vulnerability is a key issue in understanding disaster risk. This must be adequately dimensioned in any indicator model and taking into account the spatial or social scale considered. In this project we have attempted to identify certain needs and options as regards this dimension. From the outset we must recognize that a clear specification needs to be made prior to analysis as regards the particular social structures or contexts to which we are referring with the application of vulnerability analysis. This must take into account the insecurity, fragility, resilience, etc. of the different components that come into play: poor population, critical infrastructure, subsistence economies, and modern agricultural sectors, at the national, sub national or local levels. Here, we offer an analysis based on the identification of three categories or components of vulnerability -exposure and physical susceptibility, socio-economic fragility, and lack of resilience (see Cardona *et al.* 2003a). This is one alternative amongst many.[20]

Using composite indicators to estimate or measure vulnerability and risk permits the combination of quantitative and qualitative evaluation techniques. Indicators permit the identification of features that are not possible to estimate or turn out to be imprecise using mathematical models or algorithms. However, any indicator model must be consistent in the way it relates the selected variables. This implies, for example, that with proposed estimations we must define if the relations are accumulative or multiplicative. We must also be able to discern if variables are to be given different weights that allow us to judge their contribution to what we wish to measure or represent, or if their contribution is merely indicative and for comparative purposes. See Appendix 2.3-1 (JRC-EC 2002).

It is generally recommendable to utilize a maximum of ten indicators such that the concerted allocation of weighting factors may be achieved. In this case, for each sub-index, eight indicators are used. Tables 2.3.1 and 2.3.3 show the variables groups, which have been identified as indicators for *PVI* estimation.

[20] Wisner *et al.* (2003) in their book *At Risk* identify five vulnerability factors or components (presented in this project by Terry Cannon and Ian Davis, co-authors of the mentioned study) that help explain the vulnerability of people and their livelihoods —initial well being, resilience of livelihoods, mechanisms for self protection, mechanisms of social protection, and aspects related to the structure of government, civil society, participation, development of social capital etc.

Table 2.2-1.2 Indicators of Exposure and Susceptibility

Indicator	Relevance	Source
ES1. Population growth, avg. annual rate (%)	Population growth, in general, signifies a larger number of persons exposed to hazards or that persons may come to occupy areas prone to adverse effects associated with dangerous phenomena.	UNDESA WB WB
ES2. Urban growth, avg. annual rate (%).	Rapid urbanization due to rural-urban migration or migration of displaced persons due to conflict signifies urban environmental problems, difficulties in providing services and secure housing and occupation of unsafe areas.	UNDESA WB GEO HABITAT
ES3. Population density, people/5 Km^2	The concentration of population spatially favors negative effects for human settlements especially in marginal areas that usually coincide with those at greatest risk of flooding and landslides.	UNEP/GRID GEO
ES4. Poverty-population below US$ 1 per day PPP disposable income.[21]	Lower income families are normally those most affected when risk materializes in loss. In urban areas safe sites can not be acquired and in rural areas means of sustenance are constantly lost.	WB UNICEF
ES5. Capital stock, million US$ dollar/1000 km^2	Public and private sector stocks and capital constitute exposed physical elements infrastructure, buildings, inventories, and investments that may suffer the direct impact of dangerous physical phenomena.	WB Ministries of Finance and Planning
ES6. Imports and exports of goods and services, % of GDP	The economic transactions that account for the volume of commercial, agricultural, industrial and service sector flows and that represent economic relations and flows that may be affected by a disaster.	WB
ES7. Gross domestic fixed investment, % of GDP.	Capital expenses made by governments represent investments that increase the stock of capital and therefore the volume and value of exposed elements.	WB
ES8. Arable land and permanent crops, % land area.	Permanent crops and usable soil are sensitive to the action of certain phenomena such as floods, landslides and volcanic eruptions, or are sustenance means for vulnerable populations	FAO GEO

UNDESA: United Nations Department of Economical and Social Affairs; WB: World Bank; GEO: Group on Earth Observations; HABITAT: United Nations Human Settlements Program; UNEP/GRID: United Nations Environment Program / Global Resource Information Database; UNICEF: United Nations Children's Fund; FAO: Food and Agriculture Organization of the United Nations.

[21] Purchasing power parity: conversion to international dollars that have the same purchasing power that a dollar has in the USA (UNDP 2001).

Table 2.2-1.3 Indicators of Socio-economic Fragility

Indicator	Relevance	Source
SF1. Human Poverty Index, HPI-1.	Conditions of human insecurity and the lack of access to basic services reflect greater lack of protection when faced with any hazard type. People living under conditions of extreme poverty are normally more seriously affected by disaster.	UNDP
SF2. Dependents as proportion of working age population (15-64)	The proportion of elderly persons and children with respect to the population in capacity to work represents a segment of the population that is disadvantaged in general when faced with disaster crisis conditions.	WB
SF3. Social disparity, concentration of income measured using Gini index.	Income concentration favoring a low percentage of the population represents a condition of reduced "well-being" and quality of life for the majority, even if economic growth occurs.[22] The absence of social welfare and human development signifies an absence of security when faced with hazards	WB
SF4. Unemployment, as % of total labor force.	To be unemployed is an additional economic disadvantage to the population given that the lack of income signifies a reduced capacity to gain access to resources and means of protection.	ILO WB
SF5. Inflation, food prices, annual %	The loss of purchasing power is an economic disadvantage which signifies an additional reduction in the capacity of the population to accede to resources and reflects economic problems that impact in a macro manner on the response of the population.	UNICEF WB
SF6. Dependency of GDP growth of agriculture, annual %	Dependency on the agricultural sector has an impact on society in general due to the recurrent effects on production of events associated with climate variability and global environmental change.	WB
SF7. Debt servicing, % of GDP.	High levels of indebtedness mean a low margin of resources and the need to increase debt levels to cover recovery after disasters. Where restrictions exist to assuming new obligations, debt could become unsustainable and the possibility of non-recovery exists.	WB
SF8. Human-induced Soil Degradation (GLASOD).	The degradation of the soil due to anthropogenic intervention is a reflection of environmental deterioration and inadequate use of natural resources. This degradation increases the generation of socio natural hazards and a reduction in the cushioning of extreme phenomena.	FAO/UNEP GEO

UNDP: United Nations Development Program; WB: World Bank; ILO: International Labour Organization; UNICEF: United Nations Children's Fund; FAO: Food and Agriculture Organization of the United Nations; UNEP: United Nations Environment Program; GEO: Group on Earth Observations. GLASOD: Global Assessment of Soil Degradation.

[22] Growth is insufficient to guarantee social well-being and redistribution policies must exist (CID 2003; Barreto 2003).

Table 2.2-1.4 Resilience Indicators (Lack of Resilience)

Indicator	Relevance	Source
LR1. Human Development Index, HDI [Inv]	Represents the development level of a population taking into account average longevity, literacy levels, educational levels, and income according to purchasing power per capita. The greater the development level the greater the capacity to reduce risk and face disasters.	UNDP
LR2. Gender-related Development Index, GDI [Inv]	This allows us to adjust the development level to reflect inequalities between men and women using the same HDI dimensions. It represents the capacity of women as human capital. Greater participation and equality signify that the population has greater capacity to face adversity.	UNDP
LR3. Social expenditure; on pensions, health, and education, % of GDP [Inv]	This signifies resources dedicated to the improvement of the security levels of the poorer and more vulnerable population. An adequate and ample coverage by social investment programs reduces the fragility of people most affected by disasters.	WB
LR4. Governance Index[23] [Inv]	This represents public sector efficiency, legitimacy, transparency, and democracy. Greater social governance means better institutionalization, legisla-tion, equity, and integration of risk management in development planning.	WBI
LR5. Insurance of infrastructure and housing, % of GDP [Inv]	An adequate coverage of potential losses in housing and public and private goods by the insurance industry signifies greater financial protection for the population when faced with feasible hazards.	Ministries of Finance and Planning
LR6. Television sets per 1000 people [Inv]	Information reception using audiovisual technology facilitates the efficient, opportune and continuous diffusion of knowledge. An adequate diffusion and coverage improves understanding of risk and disaster and positively influences perceptions and consciousness amongst the population.	WB
LR7. Hospital beds per 1000 people [Inv]	From the disaster response perspective having adequate health infrastructure and capacity provides greater capacity to attend the population when disasters and emergencies occur.	WB
LR8. Environmental Sustainability Index,[24] ESI [Inv]	Environmental sustainability means efforts in obtaining better future environmental conditions. Environmental management has a great influence in the reduction of vulnerability and the prevention of disasters.	WEF

UNPD: United Nations Development Program; WB: World Bank; WBI: World Bank Institute; TI: Transparency International; WEF: World Environment Foundation.

[23]Scaling of six indicators proposed by Daniel Kaufmann et al. that consider some dimensions of governance: The Voice and Accountability; Political Stability; Absence of Violence; Government Effectiveness; Regulatory Quality; Rule of Law; and Control of Corruption (Kaufmann et al. 2003).

[24] Some indices or indicators have not been estimated for all periods that may be evaluated with comparative ends. We will opt to maintain constant values that do not affect the aggregation when estimating the respective sub indices of prevalent vulnerability.

Composite indicators have received a substantial amount of attention in recent years and various methodologies have been adopted to handle the issue. There are several methods, which are applied for developing composite indicators, depending on the knowledge of the developers, or the complexity of the data. Participatory methods, in the form of expert opinion or public opinion polls, are often preferred for the evaluation of the importance of the indicators in respect to purely statistical methods, so that the composite indicator will be accepted by the public and the policy-makers.

The *PVI* indicators have been chosen such that they best represent the situation under analysis using reliable and quality data (Comfort 2003). The use of variables that represent similar aspects, or the repeated use of the same indicator, means that they are being assigned a greater weight as regards other variables used in the indicator system or model (Davidson 1997; Cardona 2001; Briguglio, 2003a). For that reason, once the country subindicators values are available, it is necessary to develop a set of statistical procedures to refine their use. Correlations, dependencies and redundancy may be detected amongst indicators. In Appendixes 2.3-1 and 2.3-2, this procedure is described as are the alternatives for numeric treatment which have been taken into account for the estimation of the indices that make up the *PVI* for each country.

The third index of the indicator system, *PVI*, as shown in equation 2.3.1, is obtained by adding the three prevalent vulnerability sub-indices. These reflect exposure and susceptibility *ES*, socio-economic fragility *SF*, and lack of resilience *LR*:

$$PVI = PVI_{ES} + PVI_{SF} + PVI_{LR} \tag{2.3.1}$$

The sub-indices for prevalent vulnerability conditions for each type of situation (*ES,SF,LR*) are obtained from equation 2.3.2

$$PVI^{t}_{c(ES,SF,LR)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Bigg|_{(ES,SF,LR)} \tag{2.3.2}$$

where, w_i is the weight assigned to each indicator, I^{t}_{ic} corresponds to each normalized indicator as expressed in equations 2.3.3 and 2.3.4. These represent the conditions of vulnerability for each situation (*ES,FS,FR*) respectively,

$$I^{t}_{ic} = \frac{x^{t}_{ic} - \min(x^{t}_{i})}{rank\,(x^{t}_{i})}, \text{ for } (ES,SF) \tag{2.3.3}$$

y

$$I^{t}_{ic} = \frac{\max(x^{t}_{i}) - x^{t}_{ic}}{rank\,(x^{t}_{i})}, \text{ for } (LR)^{25} \tag{2.3.4}$$

x^{t}_{ic} is the original data for the variable for country *c* during time period *t*, and

[25] By means of this technique, resilience factors (which are inversely proportional to vulnerability) are converted into indicators of lack of resilience.

x_i^t is the variable considered jointly for all countries.
x_M^t it is the maximum value defined for the variable at *t* period
x_m^t it is the minimum value defined for the variable at *t* period
(x_i^t) rank it is the difference between the maximum and minimum value ($x^t{}_M$ - $x^t{}_m$) at *t* period

The choice of which method use for weighting is difficult, since each method has strengths and weaknesses. Such a choice depends on the objective of the composite indicator, the characteristics of the sub-indicators and also on the computational cost that the investigator can afford.

A typical feature of some weighting procedures is the identification of correlations in the set of indicators. However, the weights assigned by methods based on correlations bear no relation to the underlying analytical model that the composite indicator is trying to represent. As a result, a good strategy is to use several different analytical techniques to explore groups of indicators.

From the review of different methods presented in the Appendix 2.3-2 (JRC-EC 2002) it is possible to say the following:

a) *Equal weighting* can be applied after a proper scaling of the sub-indicators. Equal weighting works well if all sub-indicators are uncorrelated, or they are all highly correlated. However, when a few highly correlated indicators are involved, this method, albeit simple, may not provide the best means of aggregation.

b) *Multiple regression models* can handle a large number of indicators. This approach can be applied in cases where the sub-indicators considered as input to the model are related to various policy actions and the output of the model is the target. The regression model, thereafter, could quantify the relative effect of each policy action on the output, i.e. the single indicator. However, this means that there must be a "dependent variable" that accurately (and satisfactorily) measures the target in question. Measuring the influence of a number of independent variables on this policy target is a reasonable question. However, in such cases the dependent variable is not a composite indicator. Alternatively such an approach could be used for forecasting purposes. In a more general case of multiple output indicators, *canonical correlation analysis* that is a generalization of multiple regression could be applied. However, in any case, there is always the uncertainty that the relations, captured by the regression model for a given range of inputs and output, may not be valid for different ranges.

c) *Principal components analysis* is a very interesting exploratory technique to examine the correlation structure of groups of variables. In the development of composite indicators, it has been argued to apply PCA to identify the dimensions of the data and/or define the weights for the sub-indicators.

d) *Factor analysis* is usually employed as a supplementary method to the latter with a view to examine thoroughly the interrelationships of the base indicators. However, there are two crucial problems with these arguments. First, weights assigned to sub-indicators in both of these techniques are based on correlations which do not necessarily correspond to the underlying relationships between the sub indicators and the phenomena being measured. In other words there is confusion between correlation and causality. It is not possible to know (or estimate) the *real* weights since we would need a dependent variable. If there were a satisfactory dependent variable there would be no need for a composite indicator. It is further not advisable to use PCA when the base indicators have different cycles, as this would reduce the reliability of the composite indicator because some indicators perform better in one cycle and others in a different cycle (Nilsson 2000).

e) *The efficiency frontier* approach is extremely parsimonious as regards the weighting assumptions, because it lets the data decide on the weighting issue. It is argued, though, that such an empirical approach might not indicate the appropriate direction of a policy for a given country in order to improve its situation.

f) *The distance to target* is a way to avoid the immediate selection of weights, measuring the need for political intervention and the "urgency" of a problem. Using policy goals as targets convinces the policy makers for the "soundness" of the weighting method, as long as those policy makers have defined the policy targets themselves. This approach is technically feasible when there is a well-defined basis for a certain policy, such as a National Plan or similar reference documents. For international comparisons, such references are often not available, or they deliver contradictory results. Another counter-argument for the use of policy goals as targets is that the benefits of a given policy must be valued independently of the existing policy goals.

g) *Expert judgment* is adopted when a participatory method of evaluating the weights is sought. It is essential to bring together experts that have a wide spectrum of knowledge, experience and concerns, so as to ensure that a proper weighting system is found for a given application. The *budget allocation* is optimal for a maximum number of 10-12 indicators. If a too large number of indicators is involved, this method can give serious cognitive stress to the experts who are asked to allocate the budget.

h) *Analytic hierarchy process* is a widely used technique for multi-attribute decision making and as weighting method enables the decision-maker to derive weights as opposed to arbitrarily assign them. An advantage of AHP is that unlike many other methods based on Utility Theory, its use for purposes of comparisons does not require a universal scale. Furthermore, AHP tolerates inconsistency in the way people think through the amount of redundancy (more equations are available than the number of weights to be defined). This redundancy is a useful feature as it is analogous to estimating a number by calculating the average of repeated observations. The resulting weights are less sensitive to errors of judgment. These advantages render the weights derived from AHP defended and justified in front of public.

i) *Multi-criteria decision approach* allows the evaluator to highlight the fact that rankings are not always robust and thus uncertainty sometimes exists. Emphasis is made that transparency is put on such an uncertainty. This uncertainty, according with this approach, is completely ignored by the linear aggregation rule. Moreover, it is argued that the use of weights as importance coefficients can change the problem modeling significantly. However one has to note that the improvement of the mathematical aggregation procedure does not change the results spectacularly. The structuring process, and in this case above all, the input information used for the indicator scores determine clearly the ranking.

j) *Endogenous weighting* for the derivation of a composite indicator using linear programming is a very interesting method but it could be not very transparent. Firstly because endogenous weighting entails the impossibility of comparing countries' performance (since each country has its system of weights for each variable composing the indicator) and, ultimately, puts in danger the interpretability of the benchmarking exercise. Furthermore, endogenous weighting associates to high performances more weight. This means that a higher priority will be given to variables (or policies) in which a country has a comparative advantage. Munda (2003) considers that this is a questionable logic since an indicator should ideally be constructed with an "objective" view of the issue in mind.

Uncertainty analysis (UA) allows the analyst to assess the uncertainty associated with a composite indicator values (or model in a more general context) as the result of the propagation through the errors in the sub-indicators data, and uncertainties in the weights of the sub-indicators. Sensitivity analysis (SA) studies how the variation in the values of a composite indicator can be apportioned, qualitatively or quantitatively, to different sources of variation, and of how the given composite indicator depends upon the information fed into it. On this basis, we contend that UA and SA are prerequisites for building composite indicators (JRC-EC 2002).

The weights of the sub-indicators are considered as uncertain, due to the plurality of perspectives of the various stakeholders. For example, we may suppose a few surveys, each of different individuals informed about the objective of a composite indicator and the various sub-indicators composing it, resulted in a group of sets of weights, which were calculated using *budget allocation* and the *analytic hierarchy process.* For the purposes of the uncertainty analysis, the weights of the sub-indicators could be assumed uniformly distributed and sampled in their entire acceptable range, determined herein between the 10th and 90th percentiles of the weights.

In order to make the uncertainty analysis, the values of the composite indicator for each country could be obtained thousands times, using random sets of weights; each weight sampled within its acceptable range in a Monte Carlo-like procedure, applying a sampling method. Some methods have been used as it allows the analyst to perform both uncertainty and sensitivity analysis. The results of the uncertainty analysis for the countries could be displayed in the form of bars (the median, i.e. 50th percentile of the composite indicator values) and the associated confidence bounds, corresponding to the 5th and 95th percentile of the indicator values.

Once the system of sub-indicators is determined and used to obtain the composite indicator it is important to analyze how much the composite indicator values are influenced by uncertainty in the source data and/or uncertainty in the weights (due to the stakeholders' plurality of perspectives).

Sensitivity analysis (SA) complements uncertainty analysis in that it attempts to apportion quantitatively the variations in the indicator values to different sources of variation (e.g. weights, sub-indicator values). At a first stage, it is interesting to identify which weights are mostly responsible for the overlapping of countries, assuming that the values of the sub-indicators are error free. The sampling method allows for both uncertainty and sensitivity analysis. Sensitivity indices are calculated regarding the contribution of each weight to the difference in the indicator values between two countries. The higher the value of the sensitivity index for a given weight, the more sensitive the output to the variation of that weight

As an overall remark, it can be stated that uncertainty and sensitivity analysis can be used as tools to monitor the evolution of the discussion among the stakeholders. Abovementioned analysis can provide useful information on the identification of the most important weighting factors, which could guide a convergence process among the experts focusing on the important weights.

Appendix 2.3-1 Quality Guidelines for Composite Indicators

A mathematical combination (or aggregation as it is termed) of a set of indicators is most often called an 'index' or a 'composite indicator'. It is often a compromise between scientific accuracy and the information available at a reasonable cost. Composite indicators are based on sub-indicators that have no common meaningful unit of measurement and there is no obvious way of weighting these sub-indicators (Cardona *et al.* 2003b). It has been emphasized that the overall quality of a composite indicator depends crucially on the way this mathematical model is embedded in the social, political and technical structuring process (Munda 2003).

According to the Organization for Economic Co-operation and Development "…Composite indicators are valued for their ability to integrate large amounts of information into easily understood formats for a general audience. However, composite indicators can be misleading, particularly when they are used to rank country performance on complex economic phenomena and even more so when country rankings are compared over time. They have many methodological difficulties which must be confronted and can be easily manipulated to produce desired outcomes…The proliferation of composite indicators in various policy domains raises questions regarding their accuracy and reliability. Given the seemingly ad hoc nature of their computation, the sensitivity of the results to different weighting and aggregation techniques, and continuing problems of missing data, composite indicators can result in distorted findings on country performance and incorrect policy prescriptions… Despite their many deficiencies, composite indicators will continue to be developed due to their usefulness as a communication tool and, on occasion, for analytical purposes" (OECD, 2003, p. 3).

Experience shows that disputes over the appropriate method of establishing weights cannot be easily resolved. Cox *et al.* (1992) summarize the difficulties that are commonly encountered when proposing weights to combine indicators to a single measure, and conclude that many published weighting schemes are either arbitrary (e.g. based upon too complex multivariate methods) or unreliable (e.g. have a little social meaning). Wall *et al.* (1995) note that "the development of highly aggregated indicators is confronted with the dilemma that, although a high level of aggregation is necessary in order to intensify the awareness of problems, the existence of disaggregated values is essential in order to draw conclusion for possible courses of action". In spite of these purported shortfalls, composite indicators are nevertheless useful to provide experts, stakeholders and decision-makers with the direction of developments; comparison across places, situations and countries; assessment of state and trend in relation to goals and targets; early warning; identification of areas for action; anticipation of future conditions and trends; and communication channel for general public and decision-makers. A list of pros and cons on composite indicators (JRC-EC 2002) are the following:

Pros

- Composite indicators can be used to summarize complex or multi-dimensional issues, in view of supporting decision-makers.

- Composite indicators provide the big picture. They can be easier to interpret than trying to find a trend in many separate indicators. They facilitate the task of ranking countries on complex issues.
- Composite indicators can help attracting public interest by providing a summary figure with which to compare the performance across Countries and their progress over time.
- Composite indicators could help to reduce the size of a list of indicators or to include more information within the existing size limit.

Cons

- Composite indicators may send misleading, non-robust policy messages if they are poorly constructed or misinterpreted. Sensitivity analysis can be used to test composite indicators for robustness.
- The simple "big picture" results which composite indicators show may invite politicians to draw simplistic policy conclusions. Composite indicators should be used in combination with the sub-indicators to draw sophisticated policy conclusions.
- The construction of composite indicators involves stages where judgment has to be made: the selection of sub-indicators, choice of model, weighting indicators and treatment of missing values etc. These judgments should be transparent and based on sound statistical principles.
- There could be more scope for the countries about composite indicators than on individual indicators. The selection of sub-indicators and weights could be the target of political challenge
- The composite indicators increase the quantity of data needed because data are required for all the sub-indicators and for a statistically significant analysis.

Although science cannot provide an objective method for developing the one-and-only true composite indicator to summarize a complex system, it can help significantly in assuring that the processes of aggregation are as sound and transparent as possible. Among the steps to be followed in constructing composite indicators are:

1. Defining the phenomenon to be measured;
2. Selecting sub-indicators;
3. Checking data availability;
4. Pre-treatment of data
5. Assessing the relationships between the sub-indicators and their statistical properties;
6. Normalizing and weighting variables;
7. Testing for robustness and sensibility; and
8. Visualizing the composite.

According to the First Workshop on Composite Indicators of Country Performance held in Ispra, Italy (JRC-EC 2003) the following are issues that should be considered for the construction of composite indicators:

a) *Theoretical framework* – A theoretical framework should be presented as providing the basis for the selection and combination of variables into a meaningful composite indicator. This analytical underpinning will determine how sub-components and variables are weighted and should relate to a relevant policy process.

b) *Data selection* – Variables should be selected on the basis of their analytical soundness, measurability, country coverage, relevance to the phenomenon being measured, and relationship to each other. Issues to be addressed include dealing with missing values, the reliability of "soft data" from surveys and other sources, problems of over-aggregation of data and double-counting of phenomena, whether to include both static values and growth rates, and difficulties in using countries as the unit of measure.
c) *Correlation analysis of data* – A preliminary analysis of the data consists of application of Principal Components Analysis and Cluster Analysis, with a view to gain an insight into the relationships between the variables and an intuitive understanding of the phenomenon to be measured.
d) *Standardization methods* – Variables in a composite indicator should be standardized or normalized to render them comparable. Variables come in a variety of statistical units and sets with different ranges or scales which must be put on a common basis. The technique selected for standardization –standard deviation, categorical scale, minimum-maximum, etc.– should be based on the theoretical framework and the data set in question.
e) *Weighting approaches* – Variables in a composite indicator should be weighted according to an underlying theoretical framework or conceptual rationale. Greater weight should be given to components which are considered to be more significant in the context of the particular composite indicator. Weights may be assigned through expert opinion, techniques such as principal components analysis or factor analysis, or through correlations with dependent variables such as economic growth rates.
f) *Country groupings* – Composite indicators which compare country performance should avoid comparing disparate countries, particularly in terms of development levels. Countries should first be divided into like groups or peer groupings so as to be compared or ranked within their relevant reference groups.
g) *Sensitivity tests* – The robustness of composite indicators should be assessed in order to ensure their credibility and relevance to policy processes. Sensitivity tests should be conducted to assess the impact of including or excluding variables, changing weights, using different standardization techniques and selecting alternative base years, etc. Composite indicators should be easily decomposed or disaggregated in order to conduct such tests.
h) *Transparency/accessibility* – Composite indicators should be accompanied by detailed explanations of the underlying data sets, choice of standardization techniques, selection of weighting methods, and assessment of robustness of alternative approaches. To the extent possible, the components of composites should be available electronically to allow users to change variables, weights, etc. and to replicate sensitivity tests.
i) *Visualization* – The presentation of the results of composite indicators should acknowledge their limitations, show the results of sensitivity tests, and include confidence intervals for country rankings. Composite indicators should be acknowledged as simplistic presentations and comparisons of country performance in given areas to be used as starting points for further analysis.

Appendix 2.3-2 Statistical Treatment and Weighting Strategies for Building Composite Indicators

Composite indicators are based on sub-indicators that have no common meaningful unit of measurement and there is no obvious way of weighting these sub-indicators. A number of techniques are being analyzed herein and on the basis of their advantages and drawbacks a comparative presentation is given[¥]**.** These include: aggregation techniques, multiple linear regression analysis, principal components analysis and factor analysis, efficiency frontier, experts opinion (budget allocation), distance to targets, public opinion and Analytic Hierarchy Process.

2.3-2.1 Aggregation Techniques

Considering that x_{ic} is the value of indicator i for country c at time t, w_i is the weight given to indicator i in the composite indicator and that GC means the group of countries, the following descriptions give the equations for six different methods of calculating a composite indicator (Arundel and Bordoy 2002). These range from the simplest (Method 1) to the most complex (Method 6). Several variations on each method exist and there are others. However, they were chosen since they are the most representatives of the philosophy underlying the development of composite indicators as well as the most established in the literature.

<u>*Method 1. Sum of country rankings.*</u> This is the simplest aggregation method. It entails ranking the countries for each sub-indicator and then summing the country rankings. Method 1 is therefore based on ordinal levels. Its advantages are its simplicity and the independence to outliers. The disadvantage of this method is that it loses absolute level information.

$$I_c^t = \sum_{i=1}^{N} Rank_{ic}^t \qquad (2.3\text{-}2.1.1)$$

<u>*Method 2. Number of indicators above the mean minus the number below the mean.*</u> This method only uses nominal level data for each indicator. It simply takes the difference between the number of indicators that are above and below an arbitrarily defined threshold around the mean. Its advantages are its simplicity and the fact that this method is unaffected by outliers. The disadvantage of this method is that it loses interval level information. p is an arbitrarily chosen threshold above and below the mean.

$$I_c^t = \sum_{i=1}^{N} \cdot \operatorname{sgn}\left[\frac{x_{ic}^t}{x_{GCi}^t} - (1+p)\right] \qquad (2.3\text{-}2.1.2)$$

<u>*Method 3. Ratio or percentage differences from the mean.*</u> This method essentially takes the average of the ratios (or percentages) around the mean of the countries for each indicator. For example, assume that the mean of the countries for indicator x is 4, and the value is 6 for country A, 16 for country B, and 1 for country C. The ratios are: country A = 1.5, country B = 4, country C = 0.25. The ratios for all countries are then summed and divided by the number of indicators (if all weights = 1). The advantage of this method is that it can be used for calculating changes in the composite indicator over time. However, this method has one important disadvantage. It is less robust when there are outliers.

[¥] This appendix was mainly developed based on the review made by the Applied Statistics Group at JRC-EC (2002) of twenty-four published studies in different fields such as environment, economy, research, technology and health.

$$I_c^t = \frac{\sum_{i=1}^{N} w_i \cdot y_{ic}^t}{\sum_{i=1}^{N} w_i}, \text{ where } y_{ic}^t = \frac{x_{ic}^t}{x_{GCi}^t} \quad (2.3\text{-}2.1.3)$$

Method 4. Percentage of annual differences over consecutive years. The values of the sub-indicators are substituted by the differences in the values between the year in question and the previous year and divided by the value at the previous year.

$$I_c^t = \frac{\sum_{i=1}^{N} w_i \cdot y_{ic}^t}{\sum_{i=1}^{N} w_i}, \text{ where } y_{ic}^t = \frac{x_{ic}^t - x_{ic}^{t-1}}{x_{ic}^t} \quad (2.3\text{-}2.1.4)$$

Method 5. Standardized values. This method has been widely used (e.g. Environmental Sustainability Index of World Economic Forum, 2001). The composite indicator is based on the standardized scores (z-scores) for each indicator which equal the difference in the indicator for each country and the *GC* mean, divided by the standard error. This method is more robust when dealing with outliers than Method 3, but it does not entirely solve the problem. This is because the range between the minimum and maximum observed standardized scores will vary for each indicator. This characteristic of Method 5 is not necessarily undesirable. The method gives greater weight to an indicator in those countries with extreme values. This could be a desirable property if we wish to reward exceptional behavior, for example if we believe that a few exceptional indicators are worth more than a lot of average scores. With a view to allow comparisons between years, an alternative to this method is to calculate the composite indicator for each year using the values of the *GC* mean and standard deviation for a reference year.

$$I_c^t = \frac{\sum_{i=1}^{N} w_i \cdot y_{ic}^t}{\sum_{i=1}^{N} w_i}, \text{ where } y_{ic}^t = \frac{x_{ic}^t - x_{GCi}^t}{\sigma_{GCi}^t} \quad (2.3\text{-}2.1.5)$$

Method 6. Re-scaled values. This method is similar to Method 5, except that it uses re-scaled values of the constituent indicators. The result is that the standardized scores for all indicators have an identical range. This makes this method more robust when there are outliers. However, this characteristic introduces the opposite problem -the range for indicators with very little variation are increased. These indicators will therefore contribute more to the composite indicator than they would using Method 5. The result is that Method 6 is more dependent on the value of the weightings for each indicator than methods 3 and 5, where the contribution of each indicator to the composite indicator depends on both the weighting and the variance in the indicator.

$$I_c^t = \frac{\sum_{i=1}^{N} w_i \cdot y_{ic}^t}{\sum_{i=1}^{N} w_i}, \text{ where } y_{ic}^t = \frac{x_{ic}^t - \min(x_i^t)}{range(x_i^t)} \quad (2.3\text{-}2.1.6)$$

2.3-2.2 Multiple Linear Regression Analysis

One approach that has been used to combine a number of sub-indicators is to compute correlation coefficients between all of the sub-indicators. Linear regression models can tell us something about the 'linkages' between a large number of indicators $X_1, X_2,...,X_n$ and a single output indicator $\hat{U}$, but they deal only with linear correlation *per se*. Regression models can, however, stimulate research into new forms of conceptual models. In regression models, the set of indicators $X_1, X_2,...,X_n$ is combined on the one hand and an indicator $\hat{U}$ representing the objective to be attained on the other. A multiple regression model is then constructed to calculate the relative weights of the sub-indicators. Such models are essentially linear,

$$\hat{U} = a + b_1 X_1 + ... + b_n X_n \quad (2.3\text{-}2.2.1)$$

where $\hat{U}$ is the indicator, a is a constant, and b_1 to b_n are the regression coefficients (weights) of the associated sub-indicators $X_1, X_2,..., X_n$.

These models, although they can handle a large number of variables of different types, there is always the assumption of linear behavior and the uncertainty that the relations, captured by the regression model for a given range of inputs and outputs, may not be valid for different ranges. It is further argued that if the concepts to be measured could be represented by a single indicator $\hat{U}$, then there would be no need for developing a composite indicator (Muldur 2001). However, the set of sub-indicators considered as input in the regression model could be related to various policy actions. The regression model, thereafter, could quantify the relative effect of each policy action on the target, i.e. a suitable output performance indicator identified on a case-by-case basis. In a more general case where a set of input indicators of performance is sought to be related simultaneously with a set of output indicators, then canonical correlation analysis, that is a generalization of multiple regression, could be applied (Manly 1994).

2.3-2.3 Principal Components Analysis

Applications of Principal Components Analysis (PCA) related to the development of composite indicators are: a) to *identify the dimensionality* of the phenomenon, b) to *cluster* the indicators, and c) to *define the weights.* PCA decides which, amongst all possible projections, are the best for representing the structure of the data. Projections are chosen so that the maximum amount of information, measured in terms of variability, is retained in the smallest number of dimensions. The objective of the analysis is to take p variables $X_1, X_2,...,X_p$ and find linear combinations of these to produce principal components $Z_1, Z_2 ,..., Z_p$ that are uncorrelated, following

$$Z_j = \sum_{i=1}^{p} a_{ij} X_i \ , \ j = 1,2,...,p \quad (2.3\text{-}2.3.1)$$

The lack of correlation is a useful property because it means that the principal components are measuring different "statistical dimensions" in the data. When doing a PCA there is always the hope that some degree of economy can be achieved if the variation in the *p* original *X* variables can be accounted for by a small number of *Z* variables. It must be stressed that PCA does not always work in the sense that a large number of original variables are reduced to a small number of transformed variables. Indeed, if the original variables are uncorrelated then the analysis does absolutely nothing. The best results are obtained when the original variables are very highly correlated, positively or negatively.

The weights a_{ij} applied to the variables *X* in equation 15.8 are chosen so that the principal components *Z* satisfy the following conditions:

i. they are uncorrelated (orthogonal),
ii. the first principal component accounts for the maximum possible proportion of the variance of the set of *X*'s, the second principal component accounts for the maximum of the remaining variance and so on until the last of the principal component absorbs all the remaining variance not accounted for by the preceding components, and
iii. $a^2_{1j} + a^2_{2j} + ... + a^2_{pj} = 1 \quad , \quad j = 1,2,...,p$

In brief, PCA just involves finding the eigenvalues λ_j of the sample covariance matrix *C*,

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1p} \\ c_{21} & c_{22} & \cdots & c_{2p} \\ \cdots & & & \\ c_{p1} & c_{p2} & \cdots & c_{pp} \end{bmatrix} \qquad (2.3\text{-}2.3.2)$$

where the diagonal element c_{ii} is the variance of X_i and c_{ij} is the covariance of variables X_i and X_j. The eigenvalues of the matrix *C* are the variances of the principal components. There are *p* eigenvalues, some of which may be negligible. Negative eigenvalues are not possible for a covariance matrix. An important property of the eigenvalues is that they add up to the sum of the diagonal elements of *C*. This means that the sum of the variances of the principal components is equal to the sum of the variances of the original variables,

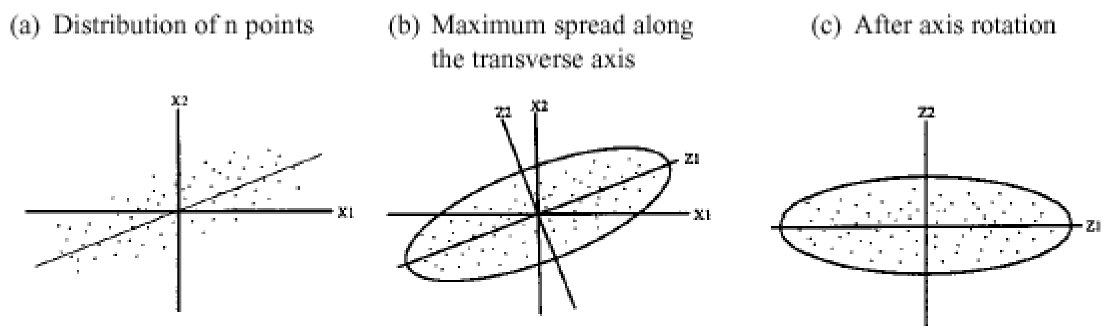
$$\lambda_1 + \lambda_2 + ... + \lambda p = c_{11} + c_{22} + ... + c_{pp} \qquad (2.3\text{-}2.3.3)$$

In order to avoid one variable having an undue influence on the principal components it is common to standardize the variables *X* to have means of zero and unit variances at the start of the analysis. The matrix *C* then takes the form of the correlation matrix. In that case, the sum of the diagonal terms, and hence the sum of the eigenvalues, is equal to *p*, the number of variables. The correlation coefficients of the principal components *Z* with the variables *X* are called *loadings*, $r(Z_j,X_i)$. In case of uncorrelated variables *X*, the loadings are equal to the weights a_{ij} given in equation 2.3-2.3.1.

Looking at PCA in a more concrete form, let us consider the case of two variables X_1 and X_2 and

n situations that are expressed by the two variables. A distribution diagram of n situations is shown in figure 2.3-2.3.1a. The variance of variable X_1 is 60% and the variance of X_2 is 40%. From the distribution of n points, it can be seen that there is some form of correlation between variables X_1 and X_2. If there is a proportional relationship between two variables, n points will be distributed along a straight line, and in this case one variable is sufficient. In figure 2.3-2.3.1a, the relationship is not perfectly proportional, although it is nearly proportional, so in approximations a single variable is sufficient.

Figure 2.3-2.3.1 Distribution Diagram of *n* Points Over Two Indicators and Axis Rotation



In figure 2.3-2.3.1b, an ellipse is drawn around the circumference of n points to show the shape of their distribution. In this case, a new variable Z_1 is inserted along the transverse axis, and Z_2 is inserted along the conjugate axis (right angles to the transverse axis). This corresponds to a change of coordinates. Here, the variance of Z_1 is 95% and the variance of Z_2 is 5%, that means that Z_1 is the first principal component and Z_2 is the second principal component. A rotation is applied to describe better the situation (figure 2.3-2.3.1c). At this point the following characteristics can be observed:

1) There is greater variance of n points on the Z_1 axis than on any other straight line drawn on this plane.
2) There is no correlation regarding the Z_1, Z_2 coordinates of n points.

In the distribution shown in the figure, n points are greatly dispersed along the Z_1 axis, so when observing data on n situations (samples), a considerable proportion can be understood solely through Z_1. Therefore if the information shown by the Z_2 axis is disregarded, the information contained in the two variables X_1 and X_2 can be summarized in Z_1. In the opposite case where the variables X_1 and X_2 are completely independent of the data on n situations, then the n points are distributed in the shape of a circle and not an ellipse, regardless of the direction of the new coordinate axes. In that case, Z_1 and Z_2 both contain an equal amount of information, so neither can be disregarded.

The PCA method has been widely used in the construction of composite indicators from large sets of sub-indicators, on the basis of correlation among the sub-indicators. In such cases, principal components have been used with the objective of combining sub-indicators into composite indicators to reflect the maximum possible proportion of the total variation in the set. The first principal component should usually capture sufficient variation to be an adequate representation of the original set. However, in other cases the first principal component alone does not explain more than 80% of the total variance of the sub-indicators and several principal components are combined together to create the composite indicator. As with the other techniques discussed here that are based on correlations, PCA has the disadvantage that correlations do not necessarily represent the *real (or even statistical!) influence* of those sub-indicators on the phenomenon the composite indicator is measuring.

2.3-2.4 Factor Analysis

FA has similar aims to PCA. The basic idea is still that it may be possible to describe a set of p variables $X_1, X_2, ..., Xp$ in terms of a smaller number of m factors, and hence elucidate the relationship between these variables. There is however, one important difference: PCA is not based on any particular statistical model, but FA is based on a rather special model.

The early development of factor analysis was due to Charles Spearman. He studied the correlations between test scores of various types and noted that many observations could be accounted for by a simple model for the scores (Manly 1994). For example, in one case he obtained the following matrix of correlations (table 15.1) for boys in a preparatory school for their scores on tests in Classics (C), French (F), English (E), Mathematics (M), Discrimination of pitch (D), and Music (Mu):

Table 2.3-2.4.1 Correlation Matrix

	C	F	E	M	D	Mu
C	1.00	0.83	0.78	0.70	0.66	0.63
F	0.83	1.00	0.67	0.67	0.65	0.57
E	0.78	0.67	1.00	0.64	0.54	0.51
M	0.70	0.67	0.64	1.00	0.45	0.51
D	0.66	0.65	0.54	0.45	1.00	0.40
Mu	0.63	0.57	0.51	0.51	0.40	1.00

He noted that this matrix has the interesting property that any two rows are almost proportional if the diagonals are ignored. Thus for rows C and E there are ratios:

$$\frac{0.83}{0.67} \cong \frac{0.70}{0.64} \cong \frac{0.66}{0.54} \cong \frac{0.63}{0.51} \cong 1.2$$

Spearmann proposed the idea that the six test scores are all of the form $X_i = F\, a_i + e_i$, where X_i is the i-th standardized score with a mean of zero and a standard deviation of one, a_i is a constant, F is a 'factor' value, which has mean zero and standard deviation of one, and e_i is the part of X_i that is specific to the i-th test only. He showed that a constant ratio between rows of a correlation matrix follows as a consequence of these assumptions and that therefore there is a plausible model for the data. In a general form this model is given by:

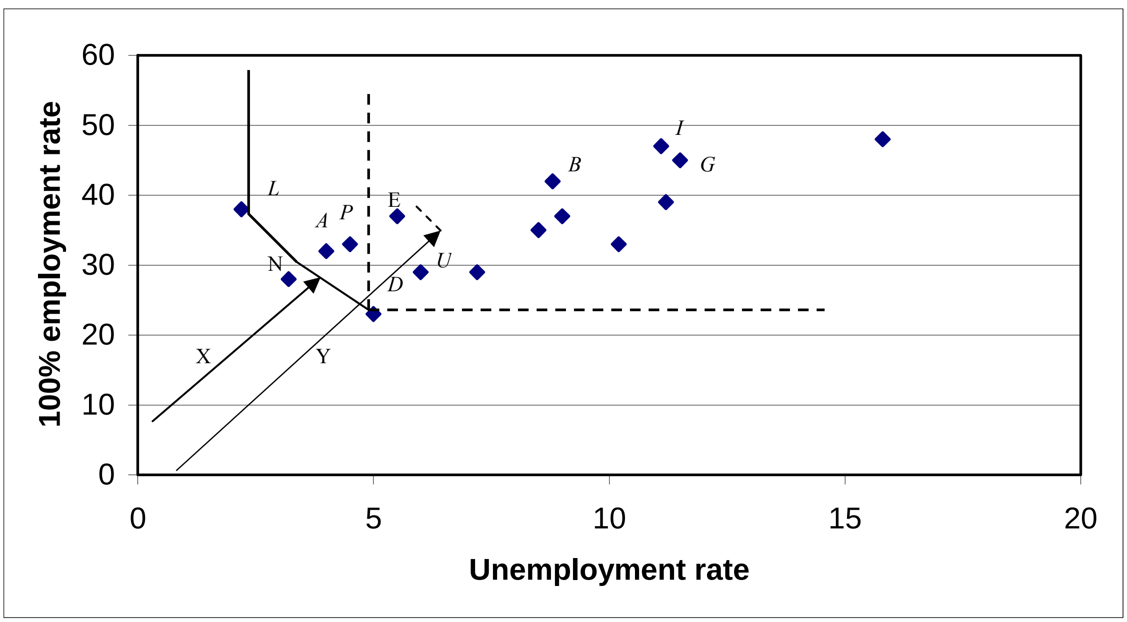
$$
\begin{aligned}
X_1 &= \alpha_{11}F_1 + \alpha_{12}F_2 + ... + \alpha_{1m}F_m + e_1 \\
X_2 &= \alpha_{21}F_1 + \alpha_{22}F_2 + ... + \alpha_{2m}F_m + e_2 \qquad (2.3\text{-}2.4.1) \\
&\;\;... \\
X_p &= \alpha_{p1}F_1 + \alpha_{p2}F_2 + ... + \alpha_{pm}F_{\mathrm{m}} + e_p
\end{aligned}
$$

where X_i is a variable with zero mean and unit variance; $\alpha i1, \alpha i2,...,\alpha im$ are the factor loadings related to the variable X_i; F_1, F_2,...,F_m are m uncorrelated common factors, each with zero mean and unit variance; and ei is the specific factor related only to the variable X_i, has zero mean, and it is uncorrelated with any of the common factors and the specific factors. The first stage to a FA is to determine provisional factor loadings α_{ij}. One way to do this is to do PCA and consider only the first m principal components, which are themselves taken to be the m factors. It is noted that there is an infinite number of alternative solutions for the factor analysis model.

2.3-2.5 Efficiency Frontier

A thorough description of the methodology may be found in Storrie and Bjurek (1999, 2000). The following paragraphs present the essence of the method, including a description of the necessary assumptions, and their implications, by creating a composite indicator of two sub-indicators for several countries. Figure 2.3-2.5.1 plots the two indicators, unemployment rate and employment rate. Best performance is found as we move towards the origin in both dimensions. We say that a country dominates another when it is best in both indicators. This is the first assumption of the methodology. Dominance is illustrated graphically by drawing an L-shape with the country in question at the intersection of the L (see dashed line). The country dominates all countries above and to the right of the L. For example *D* dominates *E*, *U*, and so on, but not *P* and *A*. *L* dominates *F*, *B*, *G*, *I* and *S.* The *N* dominates all countries except *L* and *D*. These three countries are not dominated by any other and constitute thus the frontier or the multi-dimensional benchmark, which passes through *L-N-D*. A further assumption is that a linear combination of two countries on the frontier is also on the frontier, i.e. convexity. The frontier is drawn with a solid line in figure 2.3-2.5.1.

Figure 2.3-2.5.1 The Construction of a Frontier



What remains now is to measure the extent to which the other countries deviate from the frontier. The procedure is exemplified with *E*. The length of the ray from the origin to *E* is marked as Y. The distance from the origin in the direction of *E* up to the frontier is denoted as X. The composite indicator for *E* is then equal to X/Y = 0.715. The values of the composite indicator for the remaining countries are calculated in a similar way. It is obvious that for countries on the frontier the composite indicator is equal to unit. Thus, in this methodology it is the benchmark countries that determine the weights. It is emphasized that different countries will be weighted differently depending upon where they are located in relation to the frontier.

The idea, illustrated graphically in two dimensions, may be extended in principle to any number of dimensions. The basic idea of a frontier and the distance to a particular segment remains. The efficiency frontier approach (objective method) is used for the calculation of the composite indicator. The first assumption of the methodology is that a country dominates another when it is best in both indicators. The weight assignment is not based on some value judgment but on the data. More precisely, after the frontier is identified (countries that perform best), the weighting depends upon on the location of the various countries relative to the countries that lie on the performance frontier and that exhibit a similar mix of the indicators. Different countries are weighted differently depending upon where they are located in relation to the frontier.

This method is extremely parsimonious with regard to the weighting assumptions because it lets the data decide on the weighting issue. McCarthy (2001) expresses however concern that such an empirical construct might not indicate the appropriate direction of a policy for a given country in order to improve its situation.

2.3-2.6 Distance to Targets

One way to avoid the immediate selection of weights is to measure the need for political intervention and the "urgency" of a problem by the distance to target approach. The urgency is high if we are far away from the goal, and low if the goal is almost reached. The weighting itself is realized by dividing the sub-indicator values by the corresponding target values, both expressed in the same units. The dimensionless parameters that are obtained in this way can be summarized by a simple average to produce the composite indicator.

Using policy goals as targets convinces the policy makers for the "soundness" of the weighting method, as long as those policy makers have defined the policy targets themselves. This approach is technically feasible when there is a well-defined basis for a certain policy, such as a National Plan or similar reference documents. For international comparisons, such references are often not available, or they deliver contradictory results. Another counter-argument for the use of policy goals as targets is that the benefits of a given policy must be valued independently of the existing policy goals. Alternatively to policy goals, sustainability levels, quantified effects on the environment, or best performance countries can be used as goalposts (e.g. Human Development Index, UNDP 1990, 2001).

2.3-2.7 Experts Opinion (Budget allocation)

A commonly used method is the assignment of weights to sub-indicators based on personal judgment (participatory method). This method, however, reaches its limits when some indicators have little (or no) meaning to the interviewed person. Obviously, in such cases the opinion of experts is sought. In some policy fields, there is consensus among experts on how to judge at least the relative contribution of physical indicators to the overall problem. There are certain cases, though, where opinions diverge. It is essential to bring together experts that have a wide spectrum of knowledge, experience and concerns, so as to ensure that a proper weighting system is found for a given application (Detlof von Winterfeld and Edward 1986).

Budget allocation is a participatory method in which experts are given a "budget" of *N* points, to be distributed over a number of sub-indicators, "paying" more for those sub-indicators whose importance they want to stress. The budget allocation method can be divided in four different phases:

- Selection of experts for the valuation;
- Allocation of budget to the sub-indicators;
- Calculation of the weights;
- Iteration of the budget allocation until convergence is reached (optional).

Different cases of study in which many experts have been asked to allocate a budget to several sub-indicators have showed very consistent results, in spite of the fact that the experts came from opposing social spheres (Moldan and Billharz 1997).

A counter argument against the use of the experts' opinion is on the weighting reliability. Local intervention cannot be evaluated without considering local strategies, so expert weighting may not be transferable from one area to another. Furthermore, allocating a certain budget over a too large number of indicators can give serious cognitive stress to the experts, as it implies circular thinking. The method is optimal for a maximum number of 10 indicators. Special care should be given in the identification of the population of experts from which to draw a sample, stratified or otherwise.

2.3-2.8 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was proposed in the 1970s and is a widely used technique for multi-attribute decision making (Saaty 1987). It enables decomposition of a problem into hierarchy and assures that both qualitative and quantitative aspects of a problem are incorporated in the evaluation process, during which opinion is systematically extracted by means of pair-wise comparisons. AHP is a compensatory decision methodology because alternatives that are efficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP allows for the application of data, experience, insights, and intuition in a logical and thorough way within a hierarchy as a whole. In particular, AHP as weighting method enables decision-maker to derive weights as opposed to arbitrarily assign them.

The core of AHP is an ordinal pair-wise comparison of attributes, sub-indicators in this context, in which preference statements are addressed. For a given objective, the comparisons are made per pairs of sub-indicators by firstly posing the question "Which of the two is the more important?" and secondly "By how much?." The strength of preference is expressed on a semantic scale of 1-9, which keeps measurement within the same order of magnitude. A preference of 1 indicates equality between two sub-indicators while a preference of 9 indicates that one sub-indicator is 9 times larger or more important than the one to which it is being compared. In this way comparisons are being made between pairs of sub-indicators where perception is sensitive enough to make a distinction. These comparisons result in a comparison matrix A (see table 2.3-2.8.1) where $A_{ii} = 1$ and $A_{ij} = 1 / A_{ji}$.

Table 2.3-2.8.1 Comparison Matrix A of Three Sub-indicators (Semantic Scale)

Objective	**Indicator A**	**Indicator B**	**Indicator C**
Indicator A	1	3	1
Indicator B	1 / 3	1	1 / 5
Indicator C	1	5	1

For the example shown in table 2.3-2.8.2, Indicator A is three times more important than Indicator B, and consequently Indicator B has one-third the importance of Indicator A. Each judgment reflects, in reality, the perception of the ratio of the relative contributions (weights) of the two indicators to the overall objective being assessed as shown in table 2.3-2.8.2.

Table 2.3-2.8.2 Comparison Matrix A of Three Sub-indicators (Weights)

Objective	Indicator A	Indicator B	Indicator C
Indicator A	**wA/wA**	**wA/wB**	**wA/wC**
Indicator B	**wB/wA**	**wB/wB**	**wB/wC**
Indicator C	**wC/wA**	**wC/wB**	**wC/wC**

The relative weights of the sub-indicators are calculated using an eigenvector technique. One of the advantages of this method is that it is able to check the consistency of the comparison matrix through the calculation of the eigenvalues.

AHP tolerates inconsistency through the amount of redundancy. For a matrix of size $n \times n$ only n-1 comparisons are required to establish weights for n indicators. The actual number of comparisons performed in AHP is $n(n-1)/2$. This redundancy is a useful feature as it is analogous to estimating a number by calculating the average of repeated observations. This results in a set of weights that are less sensitive to errors of judgment. In addition, this redundancy allows for a measure of these judgment errors by providing a means of calculating an inconsistency ratio (Saaty 1980; Karlsson 1998). According to Saaty small inconsistency ratios (less than 0.1 is the suggested rule-of-thumb, although even 0.2 is often cited) do no drastically affect the weights.

AHP is well suited to the type of complex decision-making problems involved and to the multiple goals related to the decision-making. The main advantage of AHP is that it is based on pairwise comparison; the human mind can easily handle two distinct problems and examine their differences. Another advantage of AHP is that unlike many other methods based on Utility Theory, its use for purposes of comparisons does not require a universal scale.

2.3-2.9 Multi-criteria Decision Approach

It is other multi-attribute decision technique in which Giuseppe Munda (2003) analyzes the assumptions underlying the linear aggregation rule and proves that the weights in linear aggregation rules have always the meaning of trade-off ratio. It denotes that in all constructions of a composite indicator, weights are used as importance coefficients, as a consequence, a theoretical inconsistency exists. He points out that the assumption of preference independence is essential for the existence of a linear aggregation rule. Then the use of a linear aggregation procedure implies that among the different aspects there is not synergy or conflict; assumption, indeed, that appears to be quite unrealistic. Finally, he said that in linear aggregation rules, compensability among the different individual sub-indicators is always assumed; this implies complete substitutability among the various components considered, but from a descriptive point of view, such a complete compensability is often not desirable.

A simple ranking algorithm, more consistent than the linear aggregation can be to consider the maximum likelihood ranking of countries as the ranking supported by the maximum number of individual indicators for each pair-wise comparison, summed over all pairs of countries considered. For more details and formal proofs see Munda and Nardo (2003). This mathematical aggregation convention can be divided into two main steps: i) pair-wise comparison of alternatives, and ii) ranking of alternatives in a complete pre-order. In this approach weights are never combined with intensities of preference, as a consequence the theoretical guarantee they are only importance coefficients. Since intensities of preference are not used the degree of compensability connected with the aggregation model is at the minimum possible level. Given that the summation of weights is equal to one, the pair-wise comparisons can be synthesized in an outranking matrix, which can be interpreted as a voting matrix.

2.3-2.10 Endogenous Weighting

In contrast to these *exogenous* weighting approaches, there is an *endogenous* approach where countries can be allowed to select their own weights for variables. This, according their authors, can promote greater political acceptance of composite indicators by allowing countries to discount variables on which they are weak while showing their revealed preferences.

The benchmarking practice is typically based on performance indicators, which aggregate various performance dimensions into a single numerical figure. These indicators generally provide imperfect proxies for what it would really like to measure. The evaluators inevitably have to trade-off alternative ‘proxy indicators’ in terms of multiple criteria such as reliability, relevance, validity, cost, and coverage of data. To resolve this weighting problem, Laurens Cherchye (2002; 2003) proposes a so-called “benefit-of-the-doubt” weighting method as a potentially useful aggregation method. In this method he endogenously selects those weights which maximize the composite indicator value for each country, subject to the constraint that no other country yields the indicator value greater than one when applying those same weights.

The interpretation of the benefit-of-the-doubt weighting (or the selection of *most favorable* weights for each country) is immediate: highest relative weights will be accorded to those indicators for which the country performs best (in relative terms) when compared to other countries in the sample. This prevents decision-makers from claiming that an unfair weighting scheme is employed for evaluating their country; any other weight profile can only worsen the position of the country *vis-à-vis* the other countries in the sample. In a way, the proposed methodology allows the decision-makers of each country to define their own weights; “the data speak for themselves” and determine the weights endogenously rather than to resort to specific *a priori* weights for each indicator.

2.4 The Risk Management Index (RMI)

The effort to measure risk management, when faced with natural phenomena, using indicators is a major challenge from the conceptual, scientific, technical and numerical perspectives. Indicators must be transparent, robust, representative and easily understood by public policy makers at national, sub-national and urban level. It is important that evaluation methodology have easy application to be used periodically, facilitating management risk aggregation and comparison between countries, cities or regions, or any other territorial level. Also, the methodology should be easy to apply in different time periods, in order to analyze its evolution.

At present, no specific indicators exist in the countries, widely accepted, to valuate directly the performance[26] of risk management or other relevant issues that reflect what we want to measure as risk management. Some initiatives have been taken at the regional and national levels (Mitchell 2003). However, in all cases this type of measure has been considered subjective and arbitrary due to their normative character. One of the principle efforts at defining those aspects that define risk management has been made within the action *framework* led by the ISDR (2003) where in draft form various thematic areas, components and possible performance evaluation criteria are proposed (Cardona *et al.* 2003b). In any case it is necessary to evaluate the variables in a qualitative way, using a scale that may run from 1 to 5 or from 1 to 7 (Benson 2003b; Briguglio 2003a/b; Mitchell 2003) or using linguistic qualifications (Davis 2003; Masure 2003).

In risk management assessment, it is necessary involving data with incommensurable units or information that only can be valuated using linguistic estimates. This is the reason why we are using multi-attribute composite indicators[27] and the fuzzy sets theory as tools to evaluate the effectiveness of risk management. Fuzzy sets have not limits perfectly defined, that is to say the transition between membership and non membership of a variable to the set is gradual. This property is useful when flexibility is needed in modeling, using linguistic or qualitative expressions, as *much, few, light, severe, scarce, incipient, moderate, reliable*, etc. Some basic aspects on fuzzy theory sets are widely treated in Appendix 2.4-2.

Indicators are proposed for each public policy. Together, these serve to characterize the risk management performance of a country, region or city. Using a larger number of indicators could be redundant and unnecessary and make the weighting of each indicator difficult. Following the performance evaluation of risk management method proposed by Carreño *et al.* (2004), the valuation of each indicator will be achieved using five performance levels: *low, incipient, significant, outstanding,* and *optimal*. From the numerical perspective these correspond to a range of 1 to 5, low to optimal. Tables 2.4.1 to 2.4.4 show the performance levels in a country for each public policy. Appendix 2.4-1 describes performance levels for a municipality.

[26] Other "performance" indicators exist at an international level to measure environmental sustainability, economic development, technological innovation etc. (OECD 2003; JRC-EC 2003).
[27] This is also known as multi-criteria techniques.

Table 2.4.1 Risk Identification Indicators

Indicator and Performance levels
RI1. Systematic disaster and loss inventory
1. Some basic and superficial data on the history of events.
2. Continual registering of current events, incomplete catalogues of the occurrence of some phenomena and limited information on losses and effects.
3. Some complete catalogues at the national and regional levels, systematization of actual events and their economic, social and environmental effects.
4. Complete inventory and multiple catalogues of events; registry and detailed systematization of effects and losses at the national level.
5. Detailed inventory of events and effects for all types of existing hazards and data bases at the sub-national and local levels.
RI2. Hazard monitoring and forecasting
1. Minimum and deficient instrumentation of some important phenomena.
2. Basic instrumentation networks with problems of updated technology and continuous maintenance.
3. Some networks with advanced technology at the national level or in particular areas; improved prognostics and information protocols established for principal hazards.
4. Good and progressive instrumentation cover at the national level, advanced research in the matter on the majority of hazards, and some automatic warning systems working.
5. Wide coverage of station and sensor networks for all types of hazard in all parts of the territory; permanent and opportune analysis of information and automatic early warning systems working continuously at the local, regional and national levels.
RI3. Hazard evaluation and mapping
1. Superficial evaluation and basic maps covering the influence and susceptibility of some phenomena.
2. Some descriptive and qualitative studies of susceptibility and hazard for principle phenomena at the national scale and for some specific areas.
3. Some hazard maps based on probabilistic techniques for the national level and for some regions. Generalized use of GIS for mapping the principle hazards.
4. Evaluation is based on advanced and adequate resolution methodologies for the majority of hazards. Microzonification of some cities based on probabilistic techniques.
5. Detailed studies for the vast majority of potential phenomena throughout the territory. Micro zoning of the majority of cities and hazard maps at the sub-national and municipal level.
RI4. Vulnerability and risk assessment
1. Identification and mapping of the principle elements exposed in prone zones in principle cities and river basins.
2. General studies of physical vulnerability when faced with the most recognized hazards, using GIS in some cities and basins.
3. Evaluation of potential damage and loss scenarios for some physical phenomena in the principal cities. Analysis of the physical vulnerability of some essential buildings.
4. Detailed studies of risk using probabilistic techniques taking into account the economic and social impact of the majority of hazards in some cities. Vulnerability analysis for the majority of essential buildings and life lines.
5. Generalized evaluation of risk, considering physical, social, cultural and environmental factors. Vulnerability analysis also for private buildings and the majority of life lines.
RI5. Public information and community participation
1. Sporadic information on risk management in normal conditions and more frequently when disasters occur.
2. Press, radio and television coverage oriented towards preparedness in case of emergency. Production of illustrative materials on dangerous phenomena.
3. Frequent opinion programs on risk management issues at the national and local levels. Guidelines for vulnerability reduction. Work with communities and NGOs.
4. Generalized diffusion and progressive consciousness; conformation of some social networks for civil protection and NGOs that explicitly promote risk management issues and practice.
5. Widescale participation and support from the private sector for diffusion activities. Consolidation of social networks and notable participation of professionals and NGOs at all levels.
RI6. Training and education in risk management
1. Incipient incorporation of hazard and disaster topics in formal education and programs for community participation.
2. Some curricular adjustments at the primary and secondary levels. Production of teaching guides for teachers and community leaders in some places.
3. Progressive incorporation of risk management in curricula. Considerable production of teaching materials and undertaking of frequent courses for community training.
4. Widening of curricular reform to higher education programs. Specialization courses offered at various universities. Wide ranging community training at the local level.
5. Generalized curricular reform throughout the territory and in all stages of education. Wide ranging production of teaching materials. Permanent schemes for community training.

Table 2.4.2 Risk Reduction Indicators

Indicator and Performance levels
RR1. Risk consideration in land use and urban planning
1. Consideration of some means for identifying risk, and environmental protection in physical planning.
2. Promulgation of national legislation and some local regulations that consider some hazards as a factor in territorial organization and development planning.
3. Progressive formulation of land use regulations in various cities that take into account hazards and risks; obligatory design and construction norms based on microzonations.
4. Wide ranging formulation and updating of territorial organization plans with a preventive approach in the majority of municipalities. Use of microzonations with security ends.
5. Generalized approval and control of implementation of territorial organization plans that include risk as a major factor, and the respective urban security regulations.
RR2. Hydrographic basin intervention and environmental protection
1. Inventory of basins and areas of severe environmental deterioration or those considered to be most fragile.
2. Promulgation of national level legal dispositions and some local ones that establish the obligatory nature of reforestation, environmental protection and river basin planning.
3. Formulation of some plans for organization and intervention in strategic water basins and sensitive zones taking into account risk and vulnerability aspects.
4. Appreciable number of regions and water basins with environmental protection plans, impact studies and ordering of agricultural areas and that consider risk a factor in determining investment decisions.
5. Intervention in a considerable number of deteriorated basins, sensitive zones and strategic ecosystems. Majority of municipalities have environmental intervention and protection plans.
RR3. Implementation of hazard-event control and protection techniques
1. Some structural control and stabilization measures in some more dangerous places.
2. Channeling works, water treatment in major cities all constructed following security norms.
3. Establishment of measures and regulations for the design and construction of hazard control and protection works in harmony with territorial organization dictates.
4. Wide scale intervention in mitigable risk zones using protection and control measures in the principle cities as required.
5. Adequate design and construction of cushioning, stabilizing, dissipation and control works in the majority of cities in order to protect human settlements and social investment.
RR4. Housing improvement and human settlement relocation from prone-areas
1. Identification and inventory of marginal human settlements located in hazard prone areas.
2. Promulgation of legislation establishing the priority of dealing with deteriorated urban areas at risk in the large cities.
3. Programs for upgrading the surroundings, existing housing, and relocation from risk areas in principal cities.
4. Progressive intervention of human settlements at risk in the majority of cities and adequate treatment of cleared areas.
5. Notable control of risk areas in all cities and relocation of the majority of housing constructed in non mitigable risk zones.
RR5. Updating and enforcement of safety standards and construction codes
1. Voluntary use of norms and codes from other countries without major adjustments.
2. Adaptation of some requirements and specifications according to some national and local criteria and particularities.
3. Promulgation and updating of obligatory national norms based on international norms that have been adjusted according to the hazard evaluations made in the country.
4. Technological updating of the majority of security and construction code norms for new and existing buildings with special requirements for special buildings and life lines.
5. Permanent updating of codes and security norms: establishment of local regulations for construction in the majority of cities based on microzonations, and their strict control and implementation.
RR6. Reinforcement and retrofitting of public and private assets
1. Retrofitting and sporadic adjustments to buildings and life lines; remodeling, changes of use or modifications.
2. Promulgation of intervention norms as regards the vulnerability of existing buildings. Strengthening of essential buildings such as hospitals or those considered indispensable.
3. Some mass programs for evaluating vulnerability, rehabilitation and retrofitting of hospitals, schools, and the central offices of life line facilities. Obligatory nature of retrofitting.
4. Progressive number of buildings retrofitted, life lines intervened, some buildings of the private sector retrofitted autonomously or due to fiscal incentives given by government.
5. Massive retrofitting of principal public and private buildings. Permanent programs of incentives for housing rehabilitation lead to lower socio-economic sectors.

Table 2.4.3 Disaster Management Indicators

Indicator and Performance levels
DM1. Organization and coordination of emergency operations
1. Different organizations attend emergencies but lack resources and various operate only with voluntary personnel.
2. Specific legislation defines an institutional structure, roles for operational entities and coordination of emergency commissions throughout the country.
3. Considerable coordination exists in some cities, between organizations in preparedness, communications, search and rescue, emergency networks, and management of temporary shelters.
4. Permanent coordination for response between operational organizations, public services, local authorities and civil society organizations in the majority of cities.
5. Advanced levels of interinstitutional organization between public, private and community based bodies. Adequate protocols exist for horizontal and vertical coordination at all territorial levels.
DM2. Emergency response planning and implementation of warning systems
1. Basic emergency and contingency plans exist with check lists and information on available personnel.
2. Legal regulations exist that establish the obligatory nature of emergency plans. Some cities have operational plans and articulation exists with technical information providers at the national level.
3. Protocols and operational procedures are well defined at the national and sub-national levels and in the main cities. Various prognosis and warning centers operate continuously.
4. Emergency and contingency plans are complete and associated with information and warning systems in the majority of cities.
5. Response preparedness based on analysis
DM3. Endowment of equipments, tools and infrastructure
1. Basic supply and inventory of resources only in the operational organizations and emergency commissions.
2. Centre with reserves and specialized equipment for emergencies at national level and in some cities. Inventory of resources in other public and private organizations.
3. Emergency Operations Centre which is well stocked with communication equipment and adequate registry systems. Specialized equipment and reserve centers exist in various cities.
4. EOCs are well equipped and systematized in the majority of cities. Progressive complimentary stocking of operational organizations.
5. Interinstitutional support networks between reserve centers and EOCs are working permanently. Wide ranging communications, transport and supply facilities exist in case of emergency.
DM4. Simulation, updating and test of inter institutional response
1. Some internal and joint institutional simulations between operational organizations exist in some cities.
2. Sporadic simulation exercises for emergency situations and institutional response exist with all operational organizations.
3. Desk and operational simulations with the additional participation of public service entities and local administrations in various cities.
4. Coordination of simulations with community, private sector and media at the national level, and in some cities.
5. Testing of emergency and contingency plans and updating of operational procedures based on frequent simulation exercises in the majority of cities.
DM5. Community preparedness and training
1. Informative meetings with community in order to illustrate emergency procedures during disasters.
2. Sporadic training courses with civil society organizations dealing with disaster related themes.
3. Community training activities are regularly programmed on emergency response in coordination with community development organizations and NGOs
4. Courses are run frequently with communities in the majority of cities and municipalities on preparedness, prevention and reduction of risk.
5. Permanent prevention and disaster response courses in all municipalities within the framework of a training program in community development and in coordination with other organizations and NGOs.
DM6. Rehabilitation and reconstruction planning
1. Design and implementation of rehabilitation and reconstruction plans only after important disasters.
2. Planning of some provisional recovery measures by public service institutions and those responsible for damage evaluation in some cities
3. Diagnostic procedures, reestablishment and repairing of infrastructure and production projects for community recovery are available at the national level and in various cities.
4. Ex ante undertaking of recovery plans and programs to support social recovery, sources of employment and productive means for communities in the majority of cities.
5. Generalized development of detailed reconstruction plans dealing with physical damage and social recovery based on risk scenarios. Specific legislation exists and anticipated measures for reactivation.

Table 2.4.4 Governance and Financial Protection (Loss Transfer)

Indicator and Performance levels

FP1. Interinstitutional, multisectoral and decentralizing organization

1. Basic organizations at the national level arranged in commissions, principally with an emergency response approach.
2. Legislation that establishes decentralized, interinstitutional and multisectoral organization for the integral management of risk and the formulation of a general risk management plan.
3. Interinstitutional risk management systems active at the local level in various cities. Inter-ministerial work at the national level in the design of public policies for vulnerability reduction.
4. Continuous implementation of risk management projects associated with programs of adaptation to climate change, environmental protection, energy, sanitation and poverty reduction.
5. Expert personnel with wide experience incorporating risk management in sustainable human development planning in major cities. High technology information systems available.

FP2. Reserve funds for institutional strengthening

1. Existence of a national disaster fund and some local funds in some cities.
2. Regulation of existing reserve funds or creation of new sources to co-finance local level risk management projects.
3. National economic support and search for international funds for institutional development and strengthening of risk management in the whole country.
4. Progressive creation of reserve funds at municipal level to co-finance projects, institutional strengthening and recovery in times of disaster.
5. Financial engineering for the design of retention and risk transfer instruments at the national level. Reserve funds operating in the majority of cities.

FP3. Budget allocation and mobilization

1. Limited allocation of national budget to competent institutions for emergency response.
2. Legal norms establishing budgetary allocations to national level organizations with risk management objectives.
3. Legally specified specific allocations for risk management at the local level and the frequent undertaking of interadministrative agreements for the execution of prevention projects.
4. Progressive allocation of discretionary expenses at the national and municipal level for vulnerability reduction, the creation of incentives and rates of environmental protection and security.
5. National orientation and support for loans requested by municipalities and sub national and local organizations from multilateral loan organizations.

FP4. Implementation of social safety nets and funds response

1. Sporadic subsidies to communities affected by disasters or in critical risk situations.
2. Permanent social investment funds created to support vulnerable communities focusing on the poorest socio-economic groups.
3. Social networks for the self protection of means of subsistence of communities at risk and undertaking of post disaster rehabilitation and reconstruction production projects.
4. Regular micro-credit programs and gender oriented activities oriented to the reduction of human vulnerability.
5. Generalized development of social protection and poverty reduction programs integrated with prevention and mitigation activities throughout the territory.

FP5. Insurance coverage and loss transfer strategies of public assets

1. Very few public buildings are insured at the national level and exceptionally at the local level.
2. Obligatory insurance of public goods. Deficient insurance of infrastructure
3. Progressive insurance of public goods and infrastructure at the national level and in some cities.
4. Design of programs for the collective insurance of buildings and publically rented infrastructure in the majority of cities.
5. Analysis and generalized implementation of retention and transfer strategies for losses to public goods, considering reinsurance groups, risk titles, bonds, etc.

FP6. Housing and private sector insurance and reinsurance coverage

1. Low percentage of private goods insured. Incipient, economically weak and little regulated insurance industry.
2. Regulation of insurance industry controls over solvency and legislation for insurance of house loan and housing sector.
3. Development of some careful insurance studies based on advanced probabilistic estimates of risk, using microzoning, auditing and optimum building inspection.
4. Design of collective housing insurance programs and for small businesses by the majority of local governments and insurance companies with automatic coverage for the poorest
5. Strong support for joint programs between government and insurance companies in order to generate economic incentives for risk reduction and mass insurance.

Alternatively, *RMI* can be estimated as the weighted sum of numeric values (1 to 5, for example), instead of fuzzy sets of linguistic valuation (as in this project, using a Matlab application). However, this simplification eliminates risk management non-linearity, having outcomes less appropriated.

This methodological approach permits the use of each reference level simultaneously as a "performance target" and therefore allows for comparison and identification of results or achievements. Governments should attempt to direct their efforts at formulation, implementation, and policy evaluation according to these performance targets.

A weight is assigned for each indicator which represents the relative importance of aspects that are evaluated in each of the four public policies. The values assigned to indicators and their respective are established via consultations with extern experts and representatives of institutions charged with the execution of public risk management policies in each country.

The *RMI*, as indicated in equation 2.4.1, is obtained by the average of four risk management indices. These represent four public policies: risk identification, *RI*, risk reduction, *RR*, disaster management, *DM*, and financial protection (risk transfer) and governance *FP*.

$$RMI = RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP} \tag{2.4.1}$$

The sub-indices of risk management conditions for each type of public policy (*RI,RR,DM,FP*) are obtained through equation 2.4.2,

$$RMI^{t}_{c(RI,RR,DM,FP)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Bigg|_{(RI,RR,DM,FP)} \tag{2.4.2}$$

where, w_i is the weight assigned to each indicator, I^{t}_{ic} corresponding to each indicator for the territorial unity in consideration c and the time period t –normalized or obtained by the defuzzification of the linguistic values. These represent the risk management performance levels defined by each public policy respectively. Such linguistic values, according to the proposal of Cardona (2001) and Carreño (2001) are the same as a fuzzy set[28] that have a membership function of the bell or sigmoidal (at the extremes) type, given parametrically by the equations 2.4.3 and 2.4.4.

$$bell(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \tag{2.4.3}$$

[28] A fuzzy set A in X is defined as $A = \{(x, \mu_A(x)) | x \in X\}$ where $\mu_A(x)$ is the membership function for the fuzzy set *A*. This function gives for each element of *X* a grade or value of membership in a range between 0 and 1, where 1 signifies maximum membership. If the value of this function was restricted only to 0 and 1, we would have a classic or non fuzzy set.

where the parameter b is usually positive.

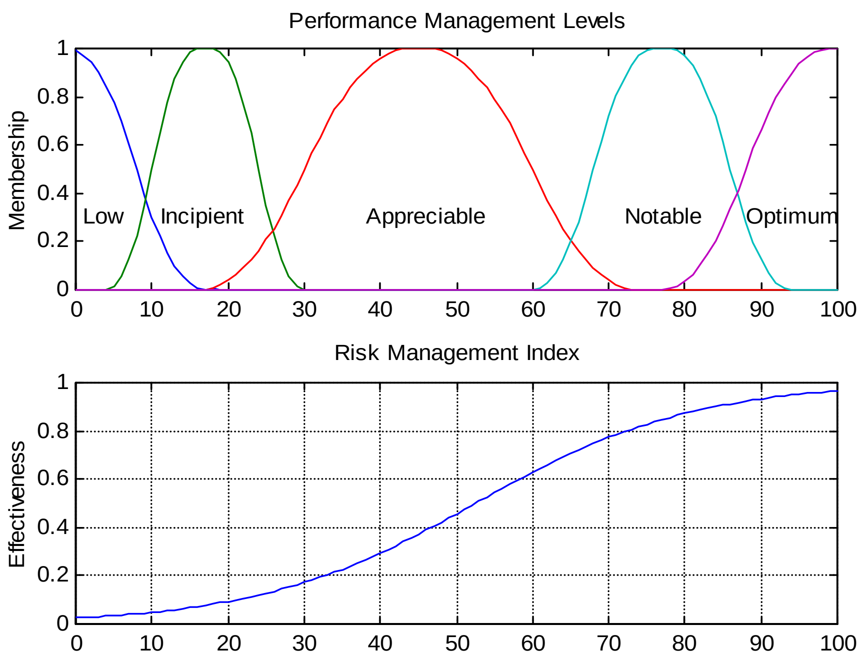
$$sigmoidal(x; a, c) = \frac{1}{1 + \exp[-a(x-c)]} \tag{2.4.4}$$

where a controls the slope at the crossing point, 0.5 of membership, $x = c$.

It is necessary that experts who know risk management progress in the place, according to their experience and knowledge, make the estimates of the different indicators in agreement to the qualification levels given for each one.

The form and coverage of these membership functions follow a non-linear behavior, in the form of a sigmoid, as proposed by Carreño *et al.* (2004) in order to characterize performance –or depth– of risk management and the level –or feasibility– of effectiveness,[29] as is illustrated in figure 2.4.1.[30]

Figure 2.4.1 Fuzzy Sets of Risk Management Performance Levels and Probability of Effectiveness



[29] The response of a socio technical system to risk is equivalent to a level of adaptation according to the level of effectiveness of its technical structure and its organization. These produce various patterns of action, inaction, innovation and determination when faced with risk. According to Comfort (1999) various types of response may occur depending on the technical structure, the flexibility, and the cultural openness to the use of technology. These types of response are: non adaptive response (inadequate for the existing level of risk and the performance is *low* or non existent); emergent adaptation (insufficient but *incipient*); adaptive operational (adequate management but with restrictions, *appreciable*) and auto adaptive (innovating, creative, and spontaneous. That is to say, *notable* and *optimal.*)

[30] Following the suggestions of peer reviewers, for a better distinction of the linguistic qualifications, it is possible to use “significant” instead of “appreciable” and “outstanding” instead of “notable”.

Membership functions for fuzzy sets are defined, representing the qualification levels for the indicators and are used in processing the information. The value of the indicators is given in the x-axis of upper graph of figure 2.4.1 and the membership degree for each level of qualification is given in the y-axis, where 1 is the total membership and 0 the non-membership. Risk management performance is defined by means of the membership of these functions, whose shape corresponds to the sigmoide function shows at the graphic below, in which the effectiveness of the risk management is represented as a function of the performance level. The lower graph shows that increasing risk management effectiveness is nonlinear, due to it is a complex process. Progress is slow in the beginning, but once risk management improves and becomes sustainable, performance and effectiveness also improve. Once performance reaches a high level, additional (smaller) efforts increase effectiveness significantly, but at the lower levels improvements in risk management are negligible and unsustainable and, as a result, they have little or no effectiveness.

It is necessary experts qualify indicators, but assign also their relative importance among the indicators of each public policy. These weights are assigned using Analytic Hierarchy Process (AHP), which is described in Appendix 2.4-3. Once these have been weighted and aggregated they form a fuzzy set from which it is hoped to obtain a reply or result. In order to achieve this transformation we need to undergo a process of defuzzification of the obtained membership function and extract from this its "concentrated" or crisp value. This is the same as extracting an "index".

Weights assigned sum 1 and they are used to weight (to give height to) membership functions of fuzzy sets corresponding to the qualifications made.

$$\sum_{j=1}^{N} w_j = 1 \tag{2.4.5}$$

where N is the number of indicators which intervene in each case. Qualification for each public policy is the result of the union of the weighted fuzzy sets.

$$\mu_{RMI_P} = \max\left(w_1 \times \mu_C\left(C_1\right), \ldots, w_N \times \mu_C\left(C_N\right)\right) \tag{2.4.6}$$

where w_i to w_N are the weights of component indicators, $\mu_c(C_1)$ to $\mu_c(C_N)$ are the membership functions of the estimates made for each indicator, and μ_{RMIp} is the membership function for the *RMI* qualification of each policy.

Risk management index value is obtained from the defuzzification of this membership function, using the method of centroid of area *(COA).*

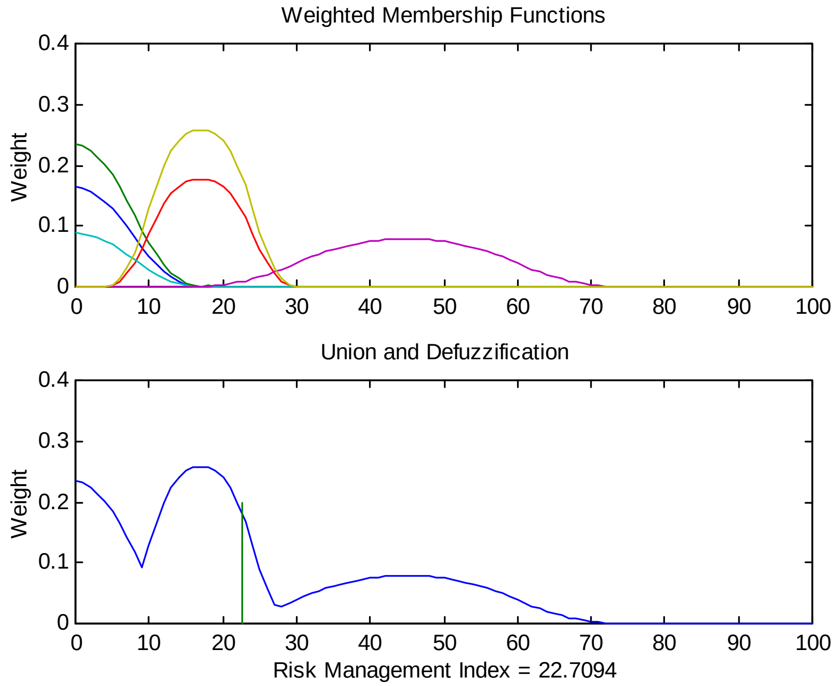
$$RMI_p = \left[\max\left(w_1 \times \mu_C\left(C_1\right), \ldots, w_N \times \mu_C\left(C_N\right)\right)\right]_{Centroid} \tag{2.4.7}$$

This technique consists in estimating the area and centroid of each set and obtaining a concentrated value by dividing the sum of the product amongst them by the sum of the areas, as is expressed in equation 2.4.8.

$$\text{Concentrated value} = \bar{X} = \frac{\sum A_i \bar{x}_i}{\sum A_i} \qquad \text{or} \quad COA = \frac{\int_X \mu_A(x)xdx}{\int_X \mu_A(x)dx} \tag{2.4.8}$$

Figure 2.4.2 illustrates an example of this procedure for extracting from the aggregation of membership weighted functions the *RMI* value for a public policy.

Figure 2.4.2 Example of Calculation of RMI (Carreño *et al.* 2004)



Finally, the four indices *(RI, RR, DM, FP)* average provide total index of risk management, *RMI*.

Appendix 2.4-1 Performance Levels in a City

Table 2.4-1.1 Risk Identification Indicators

Indicator and performance levels
RI1. Systematic disaster and loss inventory
1. Some basic and superficial data on the history of events that have affected the city
2. Continual registering of current events, incomplete catalogues of the occurrence of some phenomena and limited information on losses and effects.
3. Some complete catalogues at the national and regional levels, systematization of actual events and their economic, social and environmental effects.
4. Complete inventory and multiple catalogues of events; registry and detailed systematization of effects and losses at the local level.
5. Detailed inventory of events and effects for all types of existing hazards and data bases at the sub-national and local levels.
RI2. Hazard monitoring and forecasting
1. Minimum and deficient instrumentation of some important phenomena.
2. Basic instrumentation networks with problems of updated technology and continuous maintenance.
3. Some networks with advanced technology at the national level or in particular areas; improved prognostics and information protocols established for principal hazards.
4. Good and progressive instrumentation cover at the national level, advanced research in the matter on the majority of hazards, and some automatic warning systems working.
5. Wide coverage of station and sensor networks for all types of hazard in all the city; permanent and opportune analysis of information and automatic early warning systems working continuously at the local, regional and national levels.
RI3. Hazard evaluation and mapping
1. Superficial evaluation and basic maps covering the influence and susceptibility of some phenomena.
2. Some descriptive and qualitative studies of susceptibility and hazard for principle phenomena at the national scale and for some specific areas.
3. Some hazard maps based on probabilistic techniques for the national level and for some regions. Generalized use of GIS for mapping the principle hazards.
4. Evaluation is based on advanced and adequate resolution methodologies for the majority of hazards. Microzonation of the city based on probabilistic techniques.
5. Detailed studies for the vast majority of potential phenomena throughout the city using advanced methodologies; high technical capacity to generate knowledge on its hazards.
RI4. Vulnerability and risk assessment
1. Identification and mapping of the principle elements exposed in prone zones in the city.
2. General studies of physical vulnerability when faced with the most recognized hazards, using GIS having into account basins inside and near the city.
3. Evaluation of potential damage and loss scenarios for some physical phenomena in the principal cities. Analysis of the physical vulnerability of some essential buildings.
4. Detailed studies of risk using probabilistic techniques taking into account the economic and social impact of the majority of hazards in some cities. Vulnerability analysis for the majority of essential buildings and life lines.
5. Generalized evaluation of risk, considering physical, social, cultural and environmental factors. Vulnerability analysis also for private buildings and the majority of life lines.
RI5. Public information and community participation
1. Sporadic information on risk management in normal conditions and more frequently when disasters occur.
2. Press, radio and television coverage oriented towards preparedness in case of emergency. Production of illustrative materials on dangerous phenomena.
3. Frequent opinion programs on risk management issues at the national and local levels. Guidelines for vulnerability reduction. Work with communities and NGOs.
4. Generalized diffusion and progressive consciousness; conformation of some social networks for civil protection and NGOs that explicitly promote local risk management issues and practice.
5. Wide scale participation and support from the private sector for diffusion activities. Consolidation of social networks and notable participation of professionals and NGOs at all levels.
RI6. Training and education in risk management
1. Incipient incorporation of hazard and disaster topics in formal education and programs for community participation.
2. Some curricular adjustments at the primary and secondary levels. Production of teaching guides for teachers and community leaders in some localities or districts of the city.
3. Progressive incorporation of risk management in curricula. Considerable production of teaching materials and undertaking of frequent courses for community training.
4. Widening of curricular reform to higher education programs. Specialization courses offered at various universities. Wide ranging community training at the local level.
5. High technical capacity of the city to generate risk knowledge. Wide ranging production of teaching materials. Permanent schemes for community training.

Table 2.4-1.2 Risk Reduction Indicators

Indicator and performance levels
RR1. Risk consideration in land use and urban planning
1. Consideration of some means for identifying risk, and environmental protection in physical planning.
2. Promulgation of national legislation and some local regulations that consider some hazards as a factor in territorial organization and development planning.
3. Progressive formulation of land use regulations in various cities that take into account hazards and risks; obligatory design and construction norms based on microzonations.
4. Wide ranging formulation and updating of territorial organization plans with a preventive approach in the majority of municipalities. Use of microzonations with security ends. Risk management incorporation into sectorial plans.
5. Approval and control of implementation of territorial organization and development plans that include risk as a major factor and the respective urban security regulations.
RR2. Hydrographic basin intervention and environmental protection
1. Inventory of basins and areas of severe environmental deterioration or those considered to be most fragile.
2. Promulgation of legal dispositions that establish the obligatory nature of reforestation, environmental protection and river basin planning.
3. Formulation of the plan for organization and intervention in strategic water basins and sensitive zones taking into account risk and vulnerability aspects.
4. Environmental protection plans and impact studies, that consider risk a factor in determining investment decisions.
5. Intervention of deteriorated basins, sensitive zones and strategic ecosystems. Environmental intervention and protection plans.
RR3. Implementation of hazard-event control and protection techniques
1. Some structural control and stabilization measures in some more dangerous places.
2. Channeling works, sanitation and water treatment constructed following security norms.
3. Establishment of measures and regulations for the design and construction of hazard control and protection works in harmony with territorial organization dictates.
4. Wide scale intervention in mitigable risk zones using protection and control measures.
5. Wide implementation of mitigation plans and adequate design and construction of cushioning, stabilizing, dissipation and control works in order to protect human settlements and social investment.
RR4. Housing improvement and human settlement relocation from prone-areas
1. Identification and inventory of marginal human settlements located in hazard prone areas.
2. Promulgation of legislation establishing the priority of dealing with deteriorated urban areas at risk for improvement programs and social interest housing development.
3. Programs for upgrading the surroundings, existing housing, and relocation from risk areas.
4. Progressive intervention of human settlements at risk and adequate treatment of cleared areas.
5. Notable control of risk areas of the city and relocation of the majority of housing constructed in non mitigable risk zones.
RR5. Updating and enforcement of safety standards and construction codes
1. Voluntary use of norms and codes from other countries without major adjustments.
2. Adaptation of some requirements and specifications according to some national and local criteria and particularities.
3. Promulgation and updating of obligatory urban norms based on international or national norms that have been adjusted according to the hazard evaluations.
4. Technological updating of the majority of security and construction code norms for new and existing buildings with special requirements for special buildings and life lines.
5. Permanent updating of codes and security norms: establishment of local regulations for construction in the city based on urban microzonations, and their strict control and implementation.
RR6. Reinforcement and retrofitting of public and private assets
1. Retrofitting and sporadic adjustments to buildings and life lines; remodeling, changes of use or modifications.
2. Promulgation of intervention norms as regards the vulnerability of existing buildings. Strengthening of essential buildings such as hospitals or those considered indispensable.
3. Some mass programs for evaluating vulnerability, rehabilitation and retrofitting of hospitals, schools, and the central offices of life line facilities. Obligatory nature of retrofitting.
4. Progressive number of buildings retrofitted, life lines intervened, some buildings of the private sector retrofitted autonomously or due to fiscal incentives given by government.
5. Massive retrofitting of principal public and private buildings. Permanent programs of incentives for housing rehabilitation lead to lower socio-economic sectors.

Table 2.4-1. 3 Disaster Management Indicators

Indicator and performance levels

DM1. Organization and coordination of emergency operations

1. Different organizations attend emergencies but lack resources and various operate only with voluntary personnel.
2. Specific legislation defines an institutional structure, roles for operational entities and coordination of emergency commissions throughout the territory.
3. Considerable coordination exists in some localities or districts of the city, between organizations in preparedness, communications, search and rescue, emergency networks, and management of temporary shelters.
4. Permanent coordination for response between operational organizations, public services, local authorities and civil society organizations in the majority of localities or districts
5. Organization models that involve structures of control, instances of resources coordination and management. Advanced levels of interinstitutional organization between public, private and community based bodies.

DM2. Emergency response planning and implementation of warning systems

1. Basic emergency and contingency plans exist with check lists and information on available personnel.
2. Legal regulations exist that establish the obligatory nature of emergency plans. Articulation exists with technical information providers at the national level.
3. Protocols and operational procedures are well defined in the city. Various prognosis and warning centers operate continuously.
4. Emergency and contingency plans are complete and associated with information and warning systems in the majority of localities or districts.
5. Response preparedness based on probable scenarios in all localities or districts. Use of information technology to activate automatic response procedures.

DM3. Endowment of equipments, tools and infrastructure

1. Basic supply and inventory of resources only in the operational organizations and emergency commissions.
2. Centre with reserves and specialized equipment for emergencies at national level and in some localities or districts. Inventory of resources in other public and private organizations.
3. Emergency Operations Centre which is well stocked with communication equipment and adequate registry systems. Specialized equipment and reserve centers exist in various localities or districts.
4. EOCs are well equipped and systematized in the majority of localities or districts. Progressive complimentary stocking of operational organizations.
5. Interinstitutional support networks between reserve centers and EOCs are working permanently. Wide ranging communications, transport and supply facilities exist in case of emergency.

DM4. Simulation, updating and test of inter institutional response

1. Some internal and joint institutional simulations between operational organizations exist in the city.
2. Sporadic simulation exercises for emergency situations and institutional response exist with all operational organizations.
3. Desk and operational simulations with the additional participation of public service entities and local administrations in various localities or districts.
4. Coordination of simulations with community, private sector and media at the local level, and in some localities or districts.
5. Testing of emergency and contingency plans and updating of operational procedures based on frequent simulation exercises in the majority of localities.

DM5. Community preparedness and training

1. Informative meetings with community in order to illustrate emergency procedures during disasters.
2. Sporadic training courses with civil society organizations dealing with disaster related themes.
3. Community training activities are regularly programmed on emergency response in coordination with community development organizations and NGOs
4. Courses are run frequently with communities in the majority of cities and municipalities on preparedness, prevention and reduction of risk.
5. Permanent prevention and disaster response courses in all municipalities within the framework of a training program in community development and in coordination with other organizations and NGOs.

DM6. Rehabilitation and reconstruction planning

1. Design and implementation of rehabilitation and reconstruction plans only after important disasters.
2. Planning of some provisional recovery measures by public service institutions and those responsible for damage evaluation.
3. Diagnostic procedures, reestablishment and repairing of infrastructure and production projects for community recovery.
4. Ex ante undertaking of recovery plans and programs to support social recovery, sources of employment and productive means for communities.
5. Generalized development of detailed reconstruction plans dealing with physical damage and social recovery based on risk scenarios. Specific legislation exists and anticipated measures for reactivation.

Table 2.4-1.4 Governance and Financial Protection (loss transfer)

Indicator and performance levels

FP1. Interinstitutional, multisectoral and decentralizing organization

1. Basic organizations in commissions, principally with an emergency response approach.
2. Interinstitutional and multisectoral organization for the integral management of risk.
3. Interinstitutional risk management systems active. Work in the design of public policies for vulnerability reduction.
4. Continuous and decentralized implementation of risk management projects associated with programs of environmental protection, energy, sanitation and poverty reduction.
5. Expert personnel with wide experience incorporating risk management in sustainable human development planning in major cities. High technology information systems available.

FP2. Reserve funds for institutional strengthening

1. A reserve fund does not exist for a city. City depends of national disaster or calamity funds.
2. City depends on economic support from national level. International resources management is made. Incipient risk management strengthens.
3. Some occasional funds to co-finance risk management projects in the city exist in an interinstitutional way.
4. A reserve fund in the city exists, regulated for project co financing institutional strengthens and recovering in case of disaster.
5. A reserve fund operates in the city. Financial engineering for the design of retention and risk transfer instruments.

FP3. Budget allocation and mobilization

1. Limited allocation of national budget to competent institutions for emergency response.
2. Legal norms establishing budgetary allocations to local level organizations with risk management objectives.
3. Legally specified specific allocations for risk management at the local level and the frequent undertaking of interadministrative agreements for the execution of prevention projects.
4. Progressive allocation of discretionary expenses at the national and municipal level for vulnerability reduction, the creation of incentives and rates of environmental protection and security.
5. Local orientation and support for loans requested by municipalities and sub national and local organizations from multilateral loan organizations.

FP4. Implementation of social safety nets and funds response

1. Sporadic subsidies to communities affected by disasters or in critical risk situations.
2. Permanent social investment funds created to support vulnerable communities focusing on the poorest socio-economic groups.
3. Social networks for the self protection of means of subsistence of communities at risk and undertaking of post disaster rehabilitation and reconstruction production projects.
4. Regular micro-credit programs and gender oriented activities oriented to the reduction of human vulnerability.
5. Generalized development of social protection and poverty reduction programs integrated with prevention and mitigation activities throughout the territory.

FP5. Insurance coverage and loss transfer strategies of public assets

1. Very few public buildings are insured.
2. Obligatory insurance of public goods. Deficient insurance of infrastructure
3. Progressive insurance of public goods and infrastructure.
4. Design of programs for the collective insurance of buildings and publically rented infrastructure.
5. Analysis and generalized implementation of retention and transfer strategies for losses to public goods, considering reinsurance groups, risk titles, bonds, etc.

FP6. Housing and private sector insurance and reinsurance coverage

1. Low percentage of private goods insured. Incipient, economically weak and little regulated insurance industry.
2. Regulation of insurance industry controls over solvency and legislation for insurance of house loan and housing sector.
3. Development of some careful insurance studies based on advanced probabilistic estimates of risk, using micro-zoning, auditing and optimum building inspection.
4. Design of collective housing insurance programs and for small businesses by the city and insurance companies with automatic coverage for the poorest.
5. Strong support for joint programs between government and insurance companies in order to generate economic incentives for risk reduction and mass insurance.

Appendix 2.4-2 Fundamentals on Fuzzy Sets Logic and Application for Aggregation of Composite Indicators

Fuzzy sets logic, as its name indicates, works with sets that do not have perfectly defined limits. That is to say, the transition between membership and not membership of a variable to a set is gradual. It is characterized by the function of membership which gives flexibility to the modeling using linguistic or qualitative expressions such as *much, little, light, severe, scarce, incipient, moderate, reliable etc.* The technique arose out of the need to solve complex problems where imprecision, ambiguity, or uncertainty exists (Zadeh 1965). A fuzzy set A in X is defined as a set of ordered pairs:

$$A = \{(x, \mu_A(x)) | x \in X\} \qquad (2.4\text{-}2.1)$$

where $\mu_A(x)$ is the membership function for the fuzzy set A. This function gives for each element of X a grade or value of membership in a range between 0 and 1, where 1 signifies maximum membership. If the value of this function was restricted only to 0 and 1, we would have a classic or non fuzzy set. The more common membership functions of one dimension are those of triangular, trapezoidal, singleton, S, exponential and Π (bell shape) types. Some parametric expressions of these functions (Jang *et al.* 1997) are the following:

$$triangle(x;a,b,c) = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \qquad (2.4\text{-}2.2)$$

the parameters $\{a,b,c\}$ (with $a < b < c$) determine the coordinates of x for the three corners of the underlying triangular membership function.

$$trapezoid(x;a,b,c,d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right) \qquad (2.4\text{-}2.3)$$

the parameters $\{a,b,c,d\}$ (with $a < b \leq c < d$) determine the coordinates of x of the four corners of the underlying trapezoidal membership function. This function is reduced to triangle shape when b is equal to c

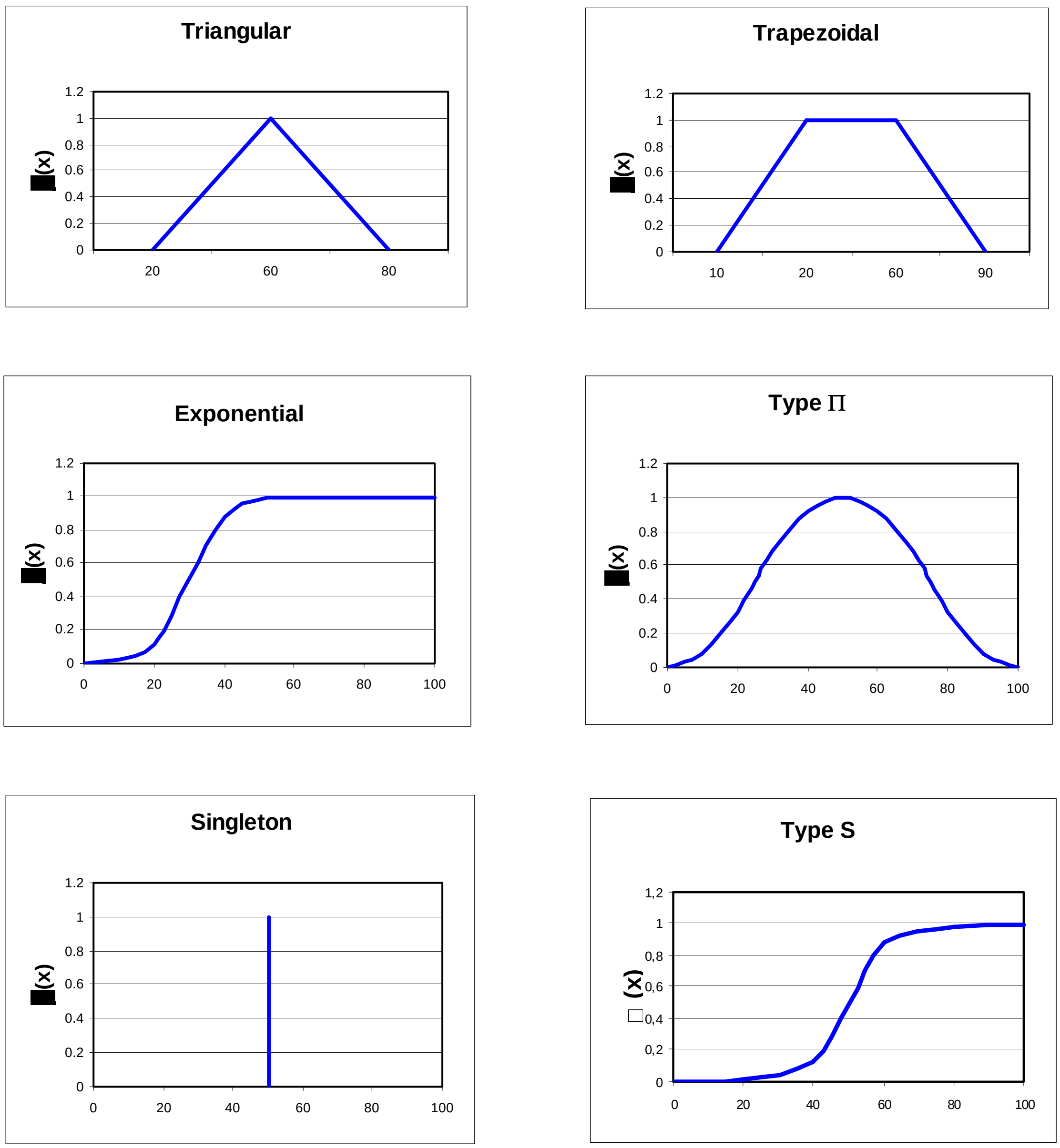
$$bell(x;a,b,c) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}} \qquad (2.4\text{-}2.4)$$

where the parameter b is usually positive.

$$sigmoidal(x;a,c) = \frac{1}{1 + \exp[-a(x-c)]} \qquad (2.4\text{-}2.5)$$

where *a* controls the slope at the crossing point, 0.5 of membership, $x = c$. In figure 2.4-2.1, taken from Carreño (2001), different types of membership functions are presented.

Figure 2.4-2.1 Types of Membership Functions



Basic operations of classic sets (union, intersection, and compliment) are also applicable in fuzzy sets. The result of the aggregation process of linguistic variables or fuzzy rules is a membership function that arises as result to develop the association of the component fuzzy sets using such operations. The table 2.4-2.1 describes some of these operations.

Table 2.4-2.1 Operations Among Fuzzy Sets

Operation	Definition
Containment or Subset	A is subset of B if and only if $\mu_A(x) \leq \mu_B(x)$, for all x. $A \subseteq B \Leftrightarrow \mu_A(x) \leq \mu_B(x)$
Union	Union of fuzzy sets A and B is the fuzzy set C, and is written as $C = A \cup B$ or C=A *OR* B, whose membership function is given by $\mu_C(x) = \max(\mu_A(x), \mu_B(x)) = \mu_A(x) \vee \mu_B(x)$
Intersection	Intersection of fuzzy sets A y B is the fuzzy set C, and is written as $C = A \cap B$ or C=A *AND* B whose membership function is given by $\mu_C(x) = \min(\mu_A(x), \mu_B(B)) = \mu_A(x) \wedge \mu_B(x)$
Complement (negation)	Complement of the fuzzy set A, denoted by $\bar{A}$ ($\neg A$, *NOT A*), it defined as $\mu_{\bar{A}}(x) = 1 - \mu_A(x)$

The fuzzy sets that originated in the use of linguistic terms (such as *low, incipient, appreciable, notable* and *optimal*) each constitutes a membership function to which a weight or importance factor may be assigned –according, for example, to expert opinion. Once these have been weighted and aggregated they form a fuzzy set from which it is hoped to obtain a reply or result. In many cases it is important that this reply is not fuzzy, but where it is we need to pass to another that is not so. In order to achieve this transformation we need to undergo a process of defuzzification of the obtained membership function and extract from this its "concentrated" or crisp value. This is the same as extracting an "index". Various defuzzification methods exist and these depend on the type of application required (Kosko 1992).

The most commonly used technique consists in estimating the area and centroid of each set and obtaining a concentrated value by dividing the sum of the product amongst them by the sum of the areas, as is expressed in equation 2.4-2.6

$$\text{Concentrated value} = \bar{X} = \frac{\sum A_i \bar{x}_i}{\sum A_i} \qquad \text{or} \qquad COA = \frac{\int_X \mu_A(x) x dx}{\int_X \mu_A(x) dx} \tag{2.4-2.6}$$

The maximum method can also be used. In this case we suppose that the membership function has only a simple maximum point and defuzzification takes place by taking the concentrated value at this point, as is expressed in equation 2.4-2.7

$$y_0(B) = \arg\max\{\mu_B(y) | y \in Y\} \tag{2.4-2.7}$$

However, if the aggregated membership or output function has various maximum points, we need to create a group (B_{max}) with these points (optimum solutions) as is indicated in equation 2.4-2.8

$$B_{\max} = \left\{ y \in Y \middle| \mu(y) = \max_{z \in Y} \mu_B(z) \right\} \tag{2.4-2.8}$$

then from this group of maximums we obtain a single point. This may be chosen in random form (one assumes that all solutions are equally valid), but it is preferable to obtain a point that is located in the middle of the solutions. The solution may also be obtained estimating the mean value of the set if this is a finite, as is shown in equation 2.4-2.9

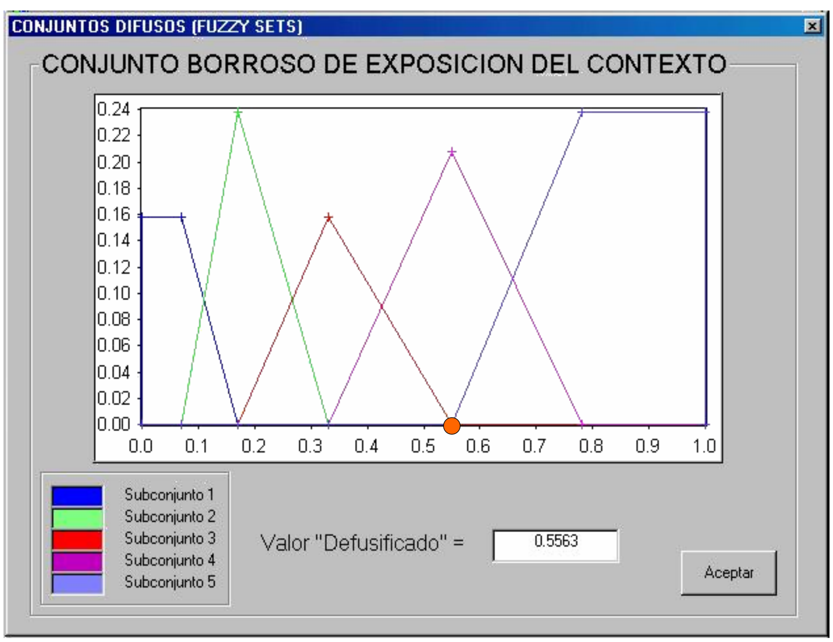
$$y_0(B) = \frac{1}{N} \sum_{y \in B_{\max}} y \qquad (2.4\text{-}2.9)$$

where N is the number of elements in the set. Using the centre of gravity method information related to membership function μ_B is taken into account. The medium of all the weights is taken as is expressed in equation 2.4-2.10

$$y_0(B) = \frac{1}{\sum \mu_B(y)} \sum_{y \in B_{\max}} y \mu_B(y) \qquad (2.4\text{-}2.10)$$

A graphic example of the weighted aggregation of a fuzzy set and of defuzzification of an index is illustrated in figure 2.4-2.2 (Cardona, 2001).

Figure 2.4-2.2 Example of Defuzzification of a Group of Aggregated Membership Functions or Weighted Fuzzy Sets



Appendix 2.4-3 Analytical Hierarchy Process, AHP Description

Analytical Hierarchy Process – AHP facilitates multi-criteria analysis based on relative importance. It is a useful technique to assign participation factors or importance of indicators components in a more rigorous way than direct appreciation using "judgement" or "feeling" from experts (Hyman 1998)

AHP is a technique is a widely used technique for multi-attribute decision making (Saaty 1987). It enables decomposition of a problem into hierarchy and assures that both qualitative and quantitative aspects of a problem are incorporated in the evaluation process, during which opinion is systematically extracted by means of pairwise comparisons. AHP is a compensatory decision methodology because alternatives that are efficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP allows for the application of data, experience, insights, and intuition in a logical and thorough way within a hierarchy as a whole.

The core of AHP is an ordinal pair-wise comparison of attributes, sub-indicators in this context, in which preference statements are addressed. For a given objective, the comparisons are made per pairs of sub-indicators by firstly posing the question "Which of the two is the more important?" and secondly "By how much?". The strength of preference is expressed on a semantic scale of 1-9, which keeps measurement within the same order of magnitude. A preference of 1 indicates equality between two sub-indicators while a preference of 9 indicates that one sub-indicator is 9 times larger or more important than the one to which it is being compared. Table 2.4-3.1 proposed by Saaty and Vargas (1991), shows the scores used for assignation of importances or relative preferences by pairs of indicators, having as reference in a comparative form, how much each indicator reflect the aspect that is desired to represent.

Table 2.4-3.1 Scale of Assignation of Comparative Importance Between Pairs

Importante judgement	Score
Extremely more important	9
	8
Very strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

In this way comparisons are being made between pairs of sub-indicators where perception is sensitive enough to make a distinction. These comparisons result in a comparison matrix A (see table 2.4-3.2) where $A_{ii} = 1$ and $A_{ij} = 1 / A_{ji}$.

Table 2.4-3.2 Comparison Matrix A of Three Sub-indicators (Semantic Scale)

Objective	Indicator A	Indicator B	Indicator C
Indicator A	1	3	1
Indicator B	1 / 3	1	1 / 5
Indicator C	1	5	1

Table 2.4-3.3 Comparison Matrix A of Three Sub-indicators (Weights)

Objective	Indicator A	Indicator B	Indicator C
Indicator A	**wA/wA**	**wA/wB**	**wA/wC**
Indicator B	**wB/wA**	**wB/wB**	**wB/wC**
Indicator C	**wC/wA**	**wC/wB**	**wC/wC**

The relative weights of the sub-indicators are calculated using an eigenvector technique. One of the advantages of this method is that it is able to check the consistency of the comparison matrix through the calculation of the eigenvalues.

AHP tolerates inconsistency through the amount of redundancy. For a matrix of size $n \times n$ only n-1 comparisons are required to establish weights for n indicators. The actual number of comparisons performed in AHP is $n(n-1)/2$. This redundancy is a useful feature as it is analogous to estimating a number by calculating the average of repeated observations. This results in a set of weights that are less sensitive to errors of judgment. In addition, this redundancy allows for a measure of these judgment errors by providing a means of calculating a consistency ratio.

AHP technique provides the consistency ratio *CR* as the ratio of a consistency index *CI* for the given pairwise comparison matrix to the value of the same consistency index for a randomly generated pairwise comparison matrix, as is expressed in the equations 2.4-3.1 and 2.4-3.2.

$$CR = \frac{CI}{CI_{random}} \leq 0.1 \qquad (2.4\text{-}3.1) \quad \text{where} \quad CI = \frac{\lambda_{\max} - n}{n-1} \qquad (2.4\text{-}3.2)$$

The $\lambda_{\max}$ term in equation 2.4-3.2 is the largest positive eigenvalue of the pairwise comparison matrix.

Hyman suggest that if consistency ratio *CR* exceeds 0.10 it is necessary modifying the elements of the pairwise comparison matrix with the aim of improving consistency. Once obtained an acceptable consistency it is necessary to calculate the principal eigenvector and standardize it, therefore the adjust values of the participation factors are determined.

2.5 Indicators at Sub-national and urban Level

Even though the development of an indicator for the sub-national level was not originally contemplated, as a demonstrative example also it was developed a system of indicators that allows a categorization of risk levels within a country.

Usually countries are divided administratively and politically into Departments, States or Provinces. These are subject to differential levels of autonomy depending on the levels of political, financial and administrative decentralization existing in different countries. The formulation of the system of indicators that allows individual or collective evaluation of sub-national levels can be achieved using the same concepts and approaches outlined for the national level.

The variables and indicators for this sub-national level would be similar to those at the national level, but may require modifications considered appropriate according to the spatial scale of the sub national and urban units. In the case of national level calculations of the *MCE* one would take the single most catastrophic event conceivable. However, this event is only the most critical of a series of events that could affect different areas of the country. Maximum probable impacts in these areas will not necessarily be associated with the same type of hazard event identified for the national level. This makes sub-national analysis even more difficult. On the other hand, such sub national events would not occur simultaneously.

Analysis at the sub-national level allows national decision makers to evaluate and compare the risk levels in different areas of the country. Most surely other critical contexts will be identified which though not reaching the levels implied in the *MCE* at the national level, could approach these and demand resources that the national level would have to assume to a great degree. On the other hand, this type of sub-national analysis is useful to sub-national decision makers helping them to identify key risk problems and identify actions that they must take on their own or in coordination with the national levels. Such sub-national level analysis requires greater effort and levels of information and scale resolution. However, it is convenient to undertake such analysis as it offers national and sub-national decision makers a tool that is useful in defining public policies and planning needs in order to reduce risk in the different regions of the country.

What might be different between *DDI* analysis at national and sub-national levels is that resources may exist at the sub-national level in order to cover response and reconstruction needs. To the extent greater fiscal decentralization exists and the *MCE* is smaller than at the national level the responsibility assumed by the sub-national level will possibly be greater. This type of evaluation is thus of great importance to decision makers in order for them to predict or plan for the social and economic implications faced by sub-national decision makers and those that need to be coordinated and agreed with national levels.

Such an index as *LDI* is of equal use at the sub-national level because it allows us to identify how susceptible the area is to lower level disasters and the impacts this signifies for local and municipal development. This index allows us to obtain a notion of the spatial variability and dispersion of risk within a sub-national unit resulting from smaller and recurrent events. From the risk management angle this type of information could contribute to orienting advisory capacities and support resources to municipalities, according to the history of past events and impacts. Many municipalities have not recovered from previous events when they are affected by another event which may not be considered relevant at the national or even sub-national levels, but which signifies a constant erosion of local development gains and opportunities. This type of context must be identified given that recurrent small scale disasters notably increase the difficulties of local development. Such events usually affect the livelihoods and means of subsistence of poor populations thus perpetuating their levels of poverty and human insecurity.

For the case of the *PVI* at the sub-national level it is necessary to propose a similar set of indicators like it was made for the national level, which should reflect analogous aspects. Usually each country has demographic, social and economic sets of indicators which make possible a representation of the vulnerability factors used at national level. Finally, *RMI* also can be applied to other territorial units, having the same criteria or referents for the performance levels used for national scale but adjusted consistently.

On the other hand, it is also possible to undertake risk analyses using indicators within urban metropolitan areas. These are usually made up of administrative units such as districts, municipalities, communes or localities which will have different risk levels.

Dropping down the spatial and administrative scale the need for evaluations within urban-metropolitan and large cities is also desirable. Taking into account the spatial scale at which urban risk analysis is undertaken, it is necessary to estimate or to have the scenarios of damage and loss that could exist for the different exposed elements that characterize the city (buildings, infrastructure, installations etc.). The *MCE* for the city would allow us to evaluate in greater detail the potential direct damage and effects and, then, prioritize the interventions and actions that are required in each area of the city in order to reduce risk.

The indicators to be used at this level of analysis are similar to those used at other levels but in this case we agree to estimate an index of physical risk (hard) and an impact factor, based on (soft) variables associated to the social fragility and the lack of resilience of the context, to obtain by this way an index of total risk, R_T, for each unit of analysis. These indicators require greater levels of resolution than those used at the national or regional level and they are oriented in favor of variables of particular interest at the urban level (Cardona and Barbat 2001; Barbat 2003a/b). In other words, it was developed a methodology that combines the representation made by the *DDI* and the *PVI,* used at national and sub-national levels.

It is important to indicate here that the most critical situation for the urban area as a whole could be related to a phenomenon that is different to that which could cause the most serious impacts in a particular area of the city. This makes analysis difficult because we would have to make estimations for various hazards given that risk and hazard could vary notoriously spatially (as is demonstrated by seismic microzonation and flooding studies). However, using historical information one can identify the hazard that in general would cause the most critical impact in the whole city and make comparisons of risk based on this point of reference.

Holistic evaluation at urban level (Cardona 2001) is formulated starting from input variables or descriptors which represent physical risk as well as risk of context (Appendix 2.5-2). Physical risk descriptors are obtained from physical risk scenarios. Risk of context descriptors are obtained from socioeconomic fragility and lack of resilience information. These factors "aggravate" physical risk or direct impact of events, which can be expressed by equation 2.5.1:

$$R_T = R_F(1 + F) \qquad (2.5.1)$$

This expression is known as Moncho's equation,[31] where R_T is the total risk, R_F is the physical risk and F is the impact factor –or aggravating coefficient–, which depends of socioeconomic fragility, FS, and lack of resilience FR

$$F = \sum_i w_{FSi} \times F_{FSi} + \sum_j w_{FRj} \times F_{FRj} \qquad (2.5.2)$$

The impact factor, F, is obtained from a weighted sum of aggravating factors for social fragility, F_{SFi}, and lack of resilience F_{LRj}, using weights that take into account their relative importance. These aggravating factors are calculated using a set of transformation functions (see Appendix 2.5-1), which relate gross values of variables that represent social fragility and lack of resilience, to corresponding aggravating factors. The weight, w_{FS} or w_{FR} , of each factor, F_{FSi} or F_{FR}, is calculated using Analytic Hierarchy Process (AHP).[32] The sum of the w_{FS} and w_{FR} is 1.

The physical risk R_F is evaluated in a similar way, using the abovementioned transformation functions. The factors F_{RFi} are obtained using the gross value of each descriptor that represents physical risk (number of deaths, destroyed area, etc). Consequently, these factors and, therefore, physical risk R_F, also take values between 0 and 1.

It is estimated that indirect impact of an event, represented by F in equation 2.5.1, could become equal at the direct impact. According to consultations to experts, it is estimated that indirect economic effects of a natural disaster depend on the phenomenon type. If it is a "wet" disaster (caused by a flood, for example) indirect economic effects could reach 0.5 to 0.75 times direct effects. In the case of a "dry" disaster (an earthquake, for example) indirect effects could become of 0.75 to 1.0 times direct effect. The difference is due to the kind of damages that they cause (destruction of crops, livelihoods, infrastructure, housing, etc.) This means that the total impact could become between 1.5 and 2.0 times the direct impact. In this case, direct impact value is used as maximum for indirect impact, what is reflect in equation 2.5.1, where aggravating coefficient F (impact factor) takes a final value between 0 and 1.[33]

Sigmoid functions were used in many cases to determine functions that give origin to values of the physical risk and the impact factor. On these figures are indicated, in the lower part of each curve, the maximum and minimum values from which the factor takes the maximum or minimum values

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[31] This denomination was given by an expert group at one of the workshops of the IDB-IDEA Project, realized in Barcelona in November 2003.

[32] This method has been explained previously in the *PVI* and *RMI* description.

[33] It is important to indicate that relation between direct and indirect impact is referred to gross estimation of direct and indirect economic effects. A study does not exist that empirically relates aggravation coefficients here proposed with indirect economic effects, nevertheless, these indicators are proxy of the aspects that aggravate the situation in case of a physical damage appears contributing to indirect socioeconomic impact, that in this case is valued with aims of relative evaluations.

(1 or 0). The limit values were determined considering information of disasters caused by natural phenomena and experts appreciations. A linear relation was assumed for descriptors on lack of resilience related to the level of development and emergency response planning. Table 2.5.1 shows how the impact factor is obtained considering social fragility and lack of resilience variables. In tables 2.5.2 and 2.5.3 are presented the units for each descriptor of social fragility and resilience, on the one hand, and for the physical risk, by another hand, for the application of curves to compute the factors i each case.

Table 2.5.1 Descriptors Used to Estimate F Coefficient

Aspect	Descriptor
Social Fragility	Slums-squatter neighbourhoods
	Mortality rate
	Delinquency rate
	Social disparity index
	Population density
Lack of Resilience	Hospital beds
	Health human resources
	Public space
	Rescue and firemen manpower
	Development level
	Emergency planning

Table 2.5.2 Aggravation Descriptors, their Units and Identifiers

Descriptor		Units
X_{FS1}	Slums-squatter neighbourhoods	Marginal settlements area / Locality area
X_{FS2}	Mortality rate	Number of deaths per 10,000 people
X_{FS3}	Delinquency rate	Number of crimes per 100,000 people
X_{FS4}	Social disparity index	Index between 0 and 1
X_{FS5}	Population density	Inhabitants / Km^2 of constructed area
X_{FR1}	Hospital beds	Number of beds per 1,000 people
X_{FR2}	Health human resources	Human resource in health per 1,000 people
X_{FR3}	Public space	Public space area/ Total area
X_{FR4}	Rescue and firemen manpower	Rescue personal per 10,000 people
X_{FR5}	Development level	Qualification from 1 to 4
X_{FR6}	Emergency planning	Qualification from 0 to 2

Table 2.5.3 Physical Risk Descriptors, their Units and Identifiers

Descriptor		Units
X_{RF1}	Damaged area	% (destroyed area / constructed area)
X_{RF2}	Dead people	Number of deaths per 1,000 people
X_{RF3}	Injured people	Number of people injured per 1,000 people
X_{RF4}	Damage in water mains	Number of breaks / Km^2
X_{RF5}	Damage in gas network	Number of breaks / Km^2
X_{RF6}	Fallen lengths on HT power lines	m of fallen length / Km^2
X_{RF7}	Electricity substations affected	Vulnerability index
X_{RF8}	Electricity substations affected	Vulnerability index
X_{RF9}	Damaged area	Damage index

Appendix 2.5-1 Transformation Functions

Descriptors are in x-axis and the respective factors are in the y-axis of the curves of figures 2.5-1.1 to 2.5-1.3.

Figure 2.5-1.1 Transformation Functions Used to Obtain the Aggravating Factors for Social Fragility

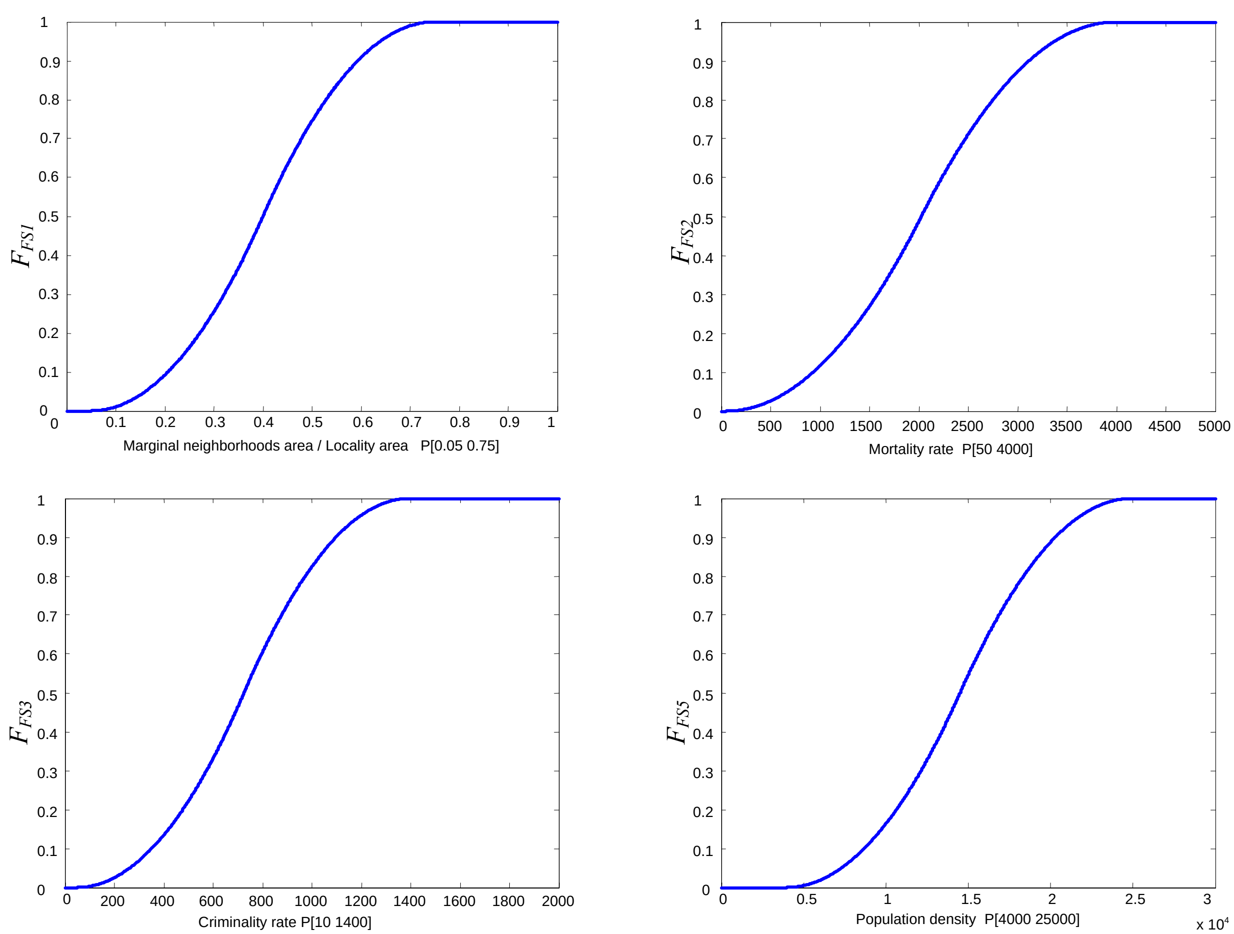


Figure 2.5-1.2 Transformation Functions Used to Obtain the Aggravating Factors for Lack of Resilience

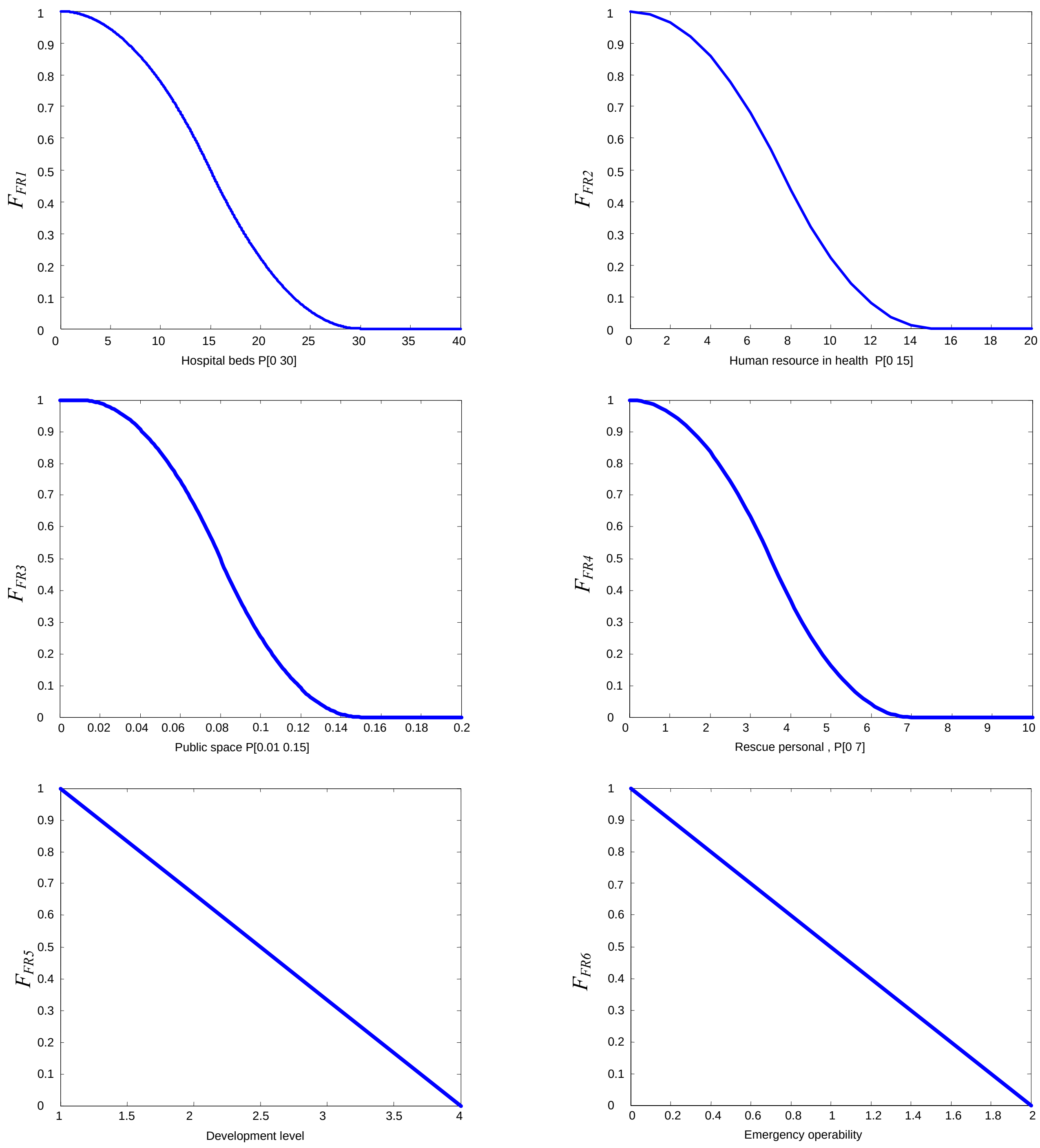
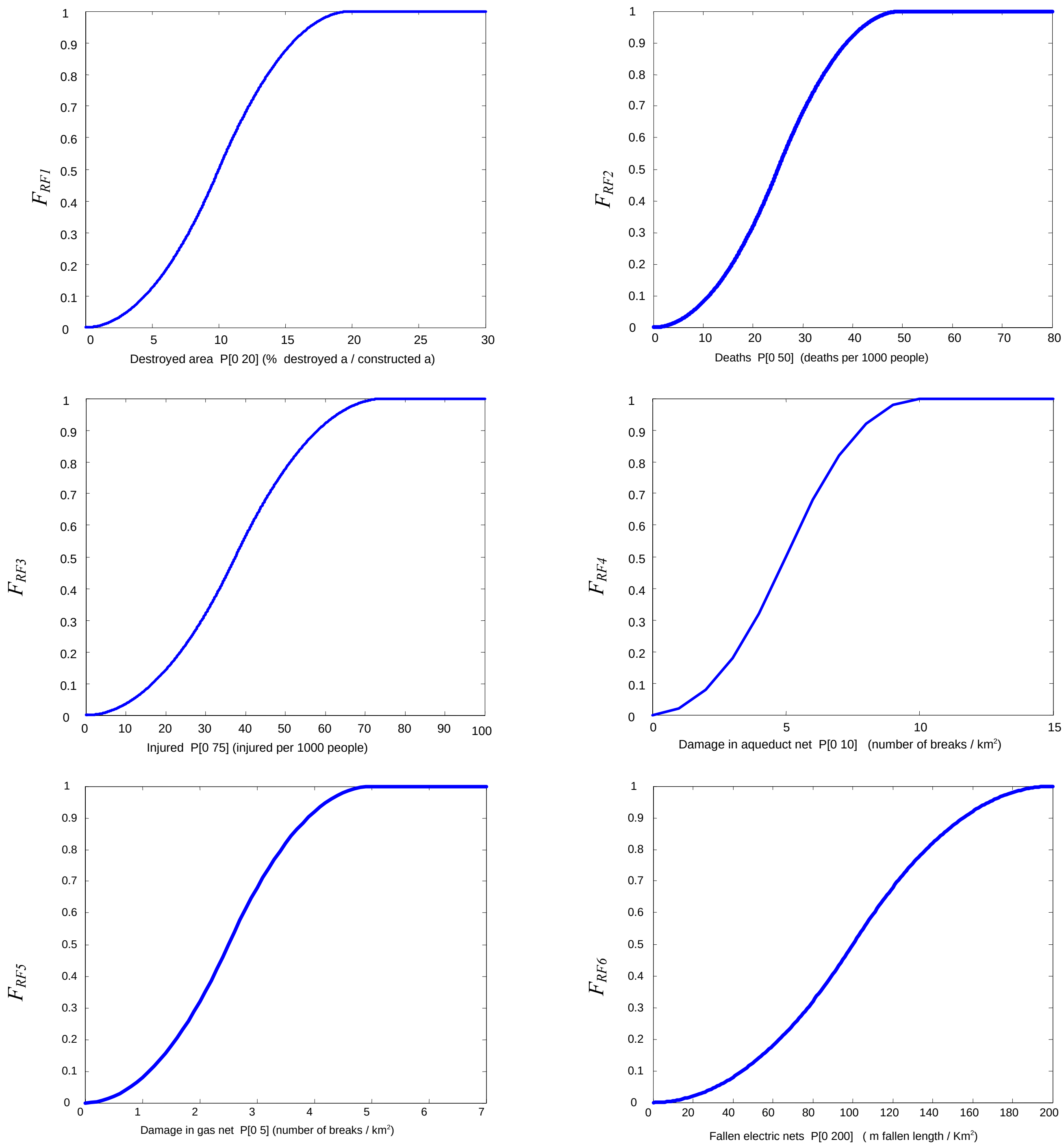


Figure 2.5-1.3 Transformation Functions Used to Obtain the Physical Risk Factors



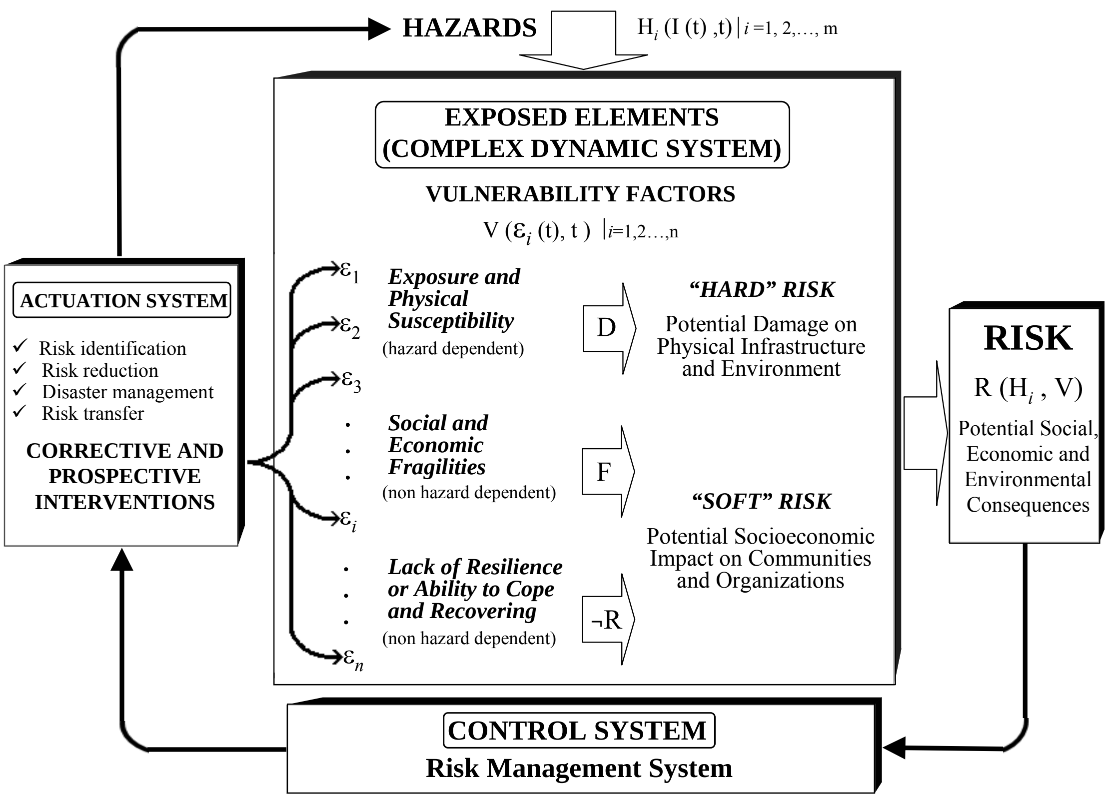
Appendix 2.5-2 Holistic Approach for Risk and Vulnerability Assessment

The conceptual framework and model for holistic approach to evaluate disaster risk was proposed by Cardona at end of 1990's (Cardona 2001) and applied with Hurtado and Barbat in 2000. In these works disaster risk was evaluated considering several dimensions or aspects of vulnerability, which are characterized by three categories or vulnerability factors:

a) Exposure and physical susceptibility, D, which is designated as "hard" risk, related to the potential damage on the physical infrastructure and environment,
b) Socio-economic fragilities, F, which contribute to "soft" risk, regarding the potential impact on the social context, and
c) Lack of resilience to cope disasters and recovery,¬R, which contributes also to "soft" risk or second order impact on communities and organizations.

Figure 2.5-2.1 describes the abovementioned theoretical framework (Cardona and Barbat 2000).

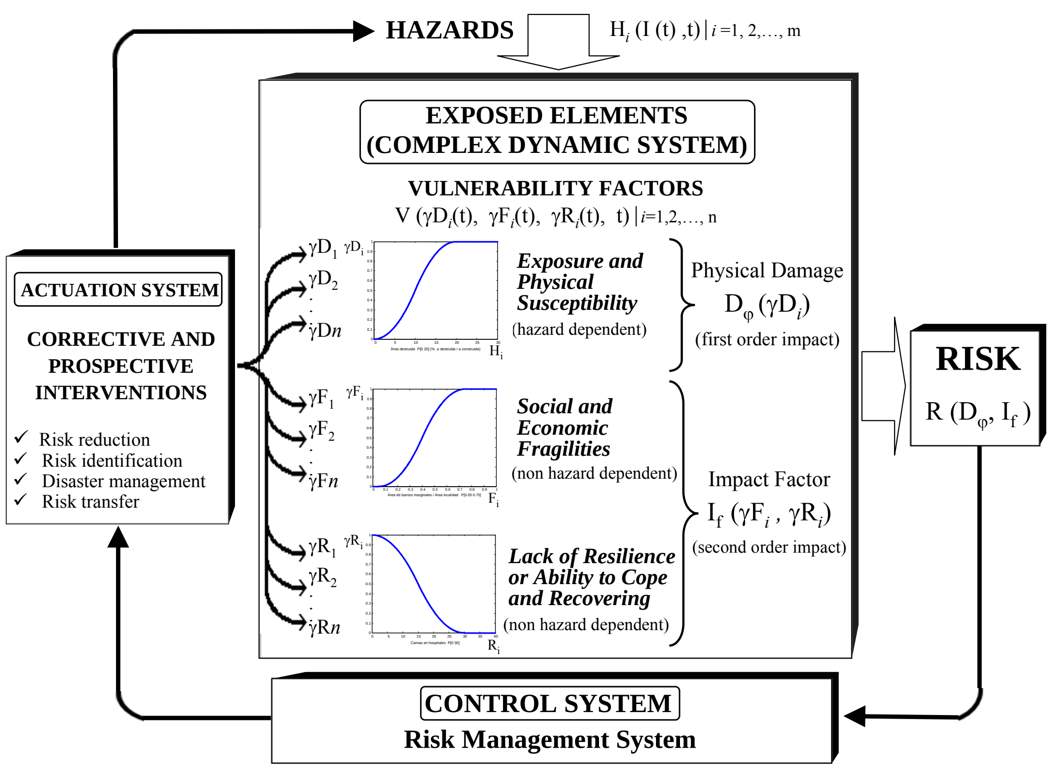
Figure 2.5-2.1 Theoretical Framework and Model for Holistic Approach of Disaster Risk Assessment and Management, After Cardona and Barbat (2000)



According to this model, vulnerability conditions in disaster prone areas depend on exposure and susceptibility of physical elements, the socioeconomic fragility and the lack of social resilience of the context. These factors provide a measure of direct as well as indirect and intangible impacts of hazard events. Vulnerability, and therefore, risk are the result of inadequate economic growth, on the one hand, and deficiencies that may be corrected by means of adequate development processes. Indicators or indices could be proposed to measure vulnerability[34] from a comprehensive and multidisciplinary perspective. Their use intend to capture favorable conditions for direct physical impacts (exposure and susceptibility), as well as indirect and, at times, intangible impacts (socioeconomic fragility and lack of resilience) of hazard events. Therefore, according this approach (Cardona 2001), exposure and susceptibility are necessary conditions for the existence of physical or "hard" risk, and these are hazard dependent. On the other hand, the propensity to suffer negative impacts, as result of the socioeconomic fragilities, and not being able to adequately face disasters are also vulnerability conditions for risk of the context, or "soft" risk, that usually are non hazard dependent.

Disaster risk, from a holistic perspective, means economic, social and environmental consequences of physical phenomena. These potential consequences are the result of the convolution of hazard events and the vulnerability. For risk management it is desired having a control and an actuation system that represent the risk management institutional organization and the corrective and prospective intervention measures. Carreño *et al.* (2004; 2005) developed an alternative version of the model, in which the evaluation of risk is achieved affecting the physical risk with an impact factor obtained from contextual conditions, such as the socio-economic fragilities and the lack of resilience; both conditions aggravate the physical loss scenario. Figure 2.5-2.2 shows the new version of the model from the holistic perspective originally proposed.

Figure 2.5-2.2 New Version of the Model (Carreño *et al.* 2004; 2005)



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[34] As the Prevalent Vulnerability Index, *PVI*, explained in this report.

The above diagram can be explained as follows. From a holistic perspective risk, R, is a function of the potential physical damage, D_{φ}, and an impact factor, I_f. The former is obtained from the susceptibility of the exposed elements, γD_i, to hazards, H_i, regarding their potential intensities, I, of events in a period of time t, and the latter depends on the social fragilities, γF_i, and the issues related to lack of resilience, γR_i, of the disaster prone socio-technical system or context. Using the meta-concepts of the theory of control and complex system dynamics, to reduce risk it is necessary to intervene in corrective and prospective way the vulnerability factors and, when it is possible, the hazards directly. Then risk management requires a system of control (institutional structure) and an actuation system (public policies and actions) to implement the changes needed on the exposed elements or complex system where risk is a social process. Public policies of risk management include decision-making regarding identification of risk, risk reduction, disaster management, and risk transfer. Risk identification entails the representation and objective assessment of risk, individual perceptions, and how those perceptions are understood by society as a whole. Risk reduction involves prevention and mitigation measures. Disaster management involves emergency response, recovery and reconstruction. And, finally, risk transfer means financial protection.

3. THE COLLECTING OF DATA

The necessary information for application of the system of indicators was acquired from each country and international databases. A description of instructive and forms used for that aim is presented in the next sections.

3.1 Data for the Estimation of the DDI

The *DDI* evaluation is made based on the physical risk modeling and in economic terms after the evaluation of Maximum Considered Event, *MCE*, as the maximum probable loss, PML, in the field of insurance is calculated. For this it is necessary to make some simplifications and assumptions using coarse grain and approximated figures that can be useful as a reference for the country.

Each country is evaluated for a team of specialists of an excellence center[35] that made the respective modeling according to the methodology. They needed direct support from people who collected the information to make said estimations. For this reason in addition of the information herein requested is useful to give information about the more relevant hazards, existing maps, location of the main cities, disaster prone areas and probable intensity of phenomena, among other existing or feasible data. It is requested, therefore, a permanent contact with the corresponding team with this objective.

From the historical information and considering the knowledge on hazards, in the most of the countries, it is possible to guess or estimate, without much debate, which of the extreme prone events in the country probably would cause the worst and critical disaster situation in case of thee likely event occurs in the future. Due to this is required to know:

3.1.1 Event that probably would cause the large impact to the country (hurricane, flood, earthquake, volcanic eruption) in a period of 500 years:

…………………………………………………………………………………………………

Other extreme events that could cause the most critical situations although not the maximum; in the likelihood order (include a qualitative factor of likelihood according the perception of experts):

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

[35] First application of the system of indicators was made with the technical support of the Engineering Institute of the UNAM, Mexico, were the modeling was made for Mexico, Guatemala, El Salvador, Dominican Republic, Jamaica, Trinidad and Tobago and Peru. In the Center of Studies of Disasters and Risks, CEDERI, from University of Los Andes, and in the Institute of Environmental Studies, IDEA, from National University of Colombia, Manizales, was made the modeling for Costa Rica, Colombia, Ecuador, Chile and Argentina.

It is requested a concise description (in other paper) of the main existing natural hazards in the country, that give information about their characteristics, prone area, representative events and their historical impacts. This information is useful as support and is included in the profile of each country. It is recommended that the extension of this summary be not longer than three pages at all, at single space.

For modeling of potential physical damage and value of the probable loss it has been proposed to assess the reposition cost (although surely all would not be reconstructed) of the properties of the public sector that could be affected. For that, it is necessary to estimate as better as possible the total constructed area (public and private) and the area of the public assets in thousand of m^2 and their approximate value in million of dollars in the main exposed cities to the phenomenon in each country (although the effects will not be in all cities simultaneously). It is proposed to include only the information of the main cities of the sub-national areas (states, provinces, departments, regions, etc, according is defined in each country) and the other settlements or exposed areas that should be considered according the event that could participate in the most critical effects. This aggregated information could be obtained from cadastral data and from construction in general.

This information is needed in a certain moments in the time, from 1980 to 2000 each five years. If it is possible, the more recent (200?) could be included. Probably in the most of cases projections must be made. The values must be converted to dollars of US according the average change in each year and if it is possible to obtain the cadastral values it will be necessary to estimate the possible factor between the cadastral and commercial value.

The valuation in the most of the countries has to be made following the proposed method of the Appendix 2.1-2 described previously, using the valuation of the aggregated capital stock of the economy and the sequence of the investment both public and private of each year, stating in a moment in the past.

In addition, it is necessary to estimate approximately the area of construction of the exposed poor human settlements or slums and their respective valuation in terms of reposition as social housing. All these values are gross and in some occasions it is necessary to use indirect methods to make the estimations, using the better possible criteria.[36]

3.1.2 Areas and valuations in the main cities or exposed areas

Table 3.1.1 illustrates values that are needed to obtain. Information of population of cities in each period can be added. These tables should be enlarged to include the relevant cities. In cases like floods, only make sense to include exposed prone areas of cities or basins that could be affected.

[36] For example, using information of population and population density by approximated constructed area. Areas by socioeconomic stratum according to categorization given by public services and values by m^2 of construction according to socioeconomic stratum.

Table 3.1.1 Values required for probable loss modelling

City	Total Constructed Area	Value US$	Public Sector Area	Value US$	Area of Slums	ValueUS$
City A						
1980						
1985						
1990						
1995						
2000						
200?						
City B						
1980						
1985						
1990						
1995						
2000						
200?						

In order to estimate the resources that the country can access in case of an extreme major event in the same years indicated it is necessary to assess a set of values that are transcribed below:

3.1.3 Estimation of losses that could be covered in each year by insurance in case of the disaster

F_1^P, corresponds to the *insurance and reassurance payments* that the country would approximately receive for goods and infrastructure insured by government. Insurance is a very incipient business in the developing countries and an insurance culture does not exist. The vast majority of insurance payments made after large scale events have been to the private sector, in particular to large industries. In various countries it is obligatory to insure public goods, but this legal requirement is not complied with thoroughly, particularly when dealing with decentralized territorial entities and local governments. A simple manner of estimating the value of insured physical wealth could be by calculating the expenses on insurance as a proportion of GDP. For example, if this is equivalent to 2% of GDP this means that 2% of losses will be covered by insurance companies.

Year	Value US$	Valor in %GDP
1980		
1985		
1990		
1995		
2000		
200?		

3.1.4 Estimation of available reserve funds for disaster in each year:

F_2^P, corresponds to the *reserve funds for disasters* that the country has available during the evaluation year. In various countries formally established calamity or disaster funds exist that have an annual budget and at times accumulated reserves from previous years. In various countries principal and sectoral funds may be found in different institutions and ministries, such as public works and infrastructure, health, civil defense, and others. Or, decentralized funds exist at the territorial levels. This sum must be estimated as the total of the reserves available to the nation for the affected zones.

Year	Value US$	Value in % National Budget
1980		
1985		
1990		
1995		
2000		
200?		

3.1.5 Estimation of likely aids and donations in case of the disaster in each year

F_3^P, represents the funds that may be received as *aids and donations*, public or private, national or international. Usually external aid is given for emergency response and few resources are available for rehabilitation and reconstruction. After a major event, help is generally received in the form of food, clothing, tents, and equipment, but little is received in cash. Although detailed information is not often available as to aid received from governments, NGOs and humanitarian aid agencies, in order to estimate this, an approximate and realistic analysis of such aid seen as a percentage of losses during previous events must be undertaken.

Year	Value US$	Value in % of the disaster
1980		
1985		
1990		
1995		
2000		
200?		

3.1.6 Estimation of likely new taxes in case of occurrence of the disaster in each year:

F_4^P, corresponds to the possible value of *new taxes* that countries could collect in case of disasters. Experiences exist that indicate that taxes have been imposed ranging between 2 and 3 per thousand and applied to financial and banking operations. But this type of tax may lead to contention and transfer of savings abroad. In general, severe doubts exist as regards the feasibility of imposing such taxes due to their unpopularity. This value should be calculated taking into account political feasibility. In Appendix 2.1-3 of previous section a simple method is presented for estimating taxes on financial transactions.

Year	Value US$	Value in %GDP
1980		
1985		
1990		
1995		
2000		
200?		

3.1.7 Estimation of the possible budgetary reallocation in each year

F_5^P, estimates the *margin for budgetary reallocations* in each country. In countries where limitations and constitutional controls on budget exist this value usually corresponds to the margin of discretional expenses available to government. In some countries this depends on the political decision of competent existing authorities. However, restrictions exist that impede larger reallocations due to the inevitable obligations of public spending on such things as salaries, transferences, social expenses, and debt servicing. Equally, there may be accumulated obligations related to previous budgets, as is explained in Appendix 2.1-4 of previous section. Reallocation of non executed loans from multilateral organizations may be considered here. If it is impossible to obtain a precise estimate of the margin for budgetary reallocation this may be very approximately calculated as a 60% of the investment in capital goods as a percentage of GDP.

Year	**Value US$**	**Value in %GDP**
1980		
1985		
1990		
1995		
2000		
200?		

3.1.8 Estimation of the possible external credit for the respective year

F_6^P, corresponds to the feasible value of *external credit* that the country could obtain from multilateral organisms and in the external capital market. Generally, loan conditions with multilateral organisms are more favorable but are restricted with regard to the level of sustainability of external debt and the relationship between debt servicing and exports. Interest rates in general depend on income per capita. Access to credits on the international capital market depends on internal and external financial risk calculations. This will determine the risk premiums and the commercial rates for debt titles. No matter what, access to credit signifies an increase in debt service obligations and the reduction of the countries capacity to absorb new debt. Therefore, the maximum value of external credit should be estimated through an analysis of the obligations and limitations for government. Appendix 2.1-5 of previous section presents how it is possible to make an analysis of the external financial situation of the country in case of lack of this specific data estimation.

Year	**Value US$**	**Value in %GDP**
1980		
1985		
1990		
1995		
2000		
200?		

3.1.9 Estimation of possible internal credit in the respective year

F_7^P, represents the *internal credit* a country may obtain from commercial and, at times, the Central Bank, when this is legal, signifying immediate liquidity. Also, it is at times possible to obtain resources from international reserves when a major disaster occurs, although this type of operation is generally complicated and may signify a risk for the balance of payments. Credit with commercial banks also has limitations and costs and depends on the workings of local credit markets. In general these will be scarce. In weak markets a large credit may affect internal consumption, local investment and interest rates. The additional available credit should be estimated taking into account the capacity to pay the loan and the capacity of national capital markets. Appendix 2.1-6 of previous section illustrates how access to internal credit may be approximately calculated if there are not specific values of this.

Year	Value US$	Value in %GDP
1980		
1985		
1990		
1995		
2000		
200?		

3.1.10 Estimation of annual capital expenditure in the respective year

For the purpose of *DDI'* evaluation, information of capital expenditure (fix investment) of annual budget of the country and amount of sustainable resources due to inter-temporal surplus are needed.

Year	Value US$	Value in % National Budget
1980		
1985		
1990		
1995		
2000		
200?		

3.1.11 Estimation of the sustainable amount of resources due to inter-temporal surplus

F_8^P, is an estimate of the *sustainable amount of resources due to inter-temporal surplus* which the government can employ, calculated over a 10 year period, in order to best attend the impacts of disasters. What we need to know is if the government, from an orthodox perspective, complies with its inter-temporal budgetary restriction. That is to say, if the flows of expenditures and incomes guarantee –in present value terms– that current and future primary surpluses allow a canceling of the present stock of debt. In order to estimate this annual amount of sustainable resources a method is proposed in Appendix 2.1-7 of previous section. After to solve the integral indicated then $d^* = (t\text{-}g\text{-}h) - b_0\,(r\text{-}\theta)$. Thus, for each year it is necessary to know the scenarios of deficit or primary surplus (t-g-h) en % of GDP that could be obtained usually from the Ministry of Finance. Using ten year period the average value is obtained and less the initial debt in % of

GDP times (r-θ), where r is the interest rate and θ is the growing rate of the GDP. The next table illustrates an example, with two scenarios one optimist and other pessimist.

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
-2.03%	-1.27%	-0.40%	-0.01%	0.31%	0.73%	0.95%	1.78%	2.52%	2.85%
-2.03%	-1.27%	-0.40%	-0.14%	0.08%	0.41%	0.56%	1.34%	1.98%	2.22%

In the first case the average is 0.54% and in the second 0.27%. Then, the d^* is equal to 0.13% and less -0.14% respectively taking into account that b_0 is 0.01 and (r-θ) is equal to 0.41.

For the years 1980, 1985, y 1990 values of surplus or deficit in the ten year period ahead shall be obtained from real values of the country in those years. For 1995 and 2000 some of them should be predicted with information of the Ministry of Public Finance or Macro-economy.

1980	1981	1982	1983	1984	1985	1986	1987	1988	1989

Initial debt b_0:_______ Rate (r-θ):____________ d^*: Opt: _________ Pess:________

1985	1986	1987	1988	1989	1990	1991	1992	1993	1994

Initial debt b_0:_______ Rate (r-θ):____________ d^*: Opt: _________ Pess:________

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999

Initial debt b_0:_______ Rate (r-θ):____________ d^*: Opt: _________ Pess:________

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004

Initial debt b_0:_______ Rate (r-θ):____________ d^*: Opt: _________ Pess:________

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009

Initial debt b_0:_______ Rate (r-θ):____________ d^*: Opt: _________ Pess:________

3.2 Data to Assess the LDI

Evaluation of LDI is made based on the review of the local disaster database DesInventar. This is an ongoing work in process of development by IDEA and with the support of La RED, in relation to the verification and adjustment of information. Periods of five years are used to evaluate LDI. LDI is obtained in 1985 using the information from 1981 to 1985 and so on. For index calculation it is required a few supplementary data to standardize existing information in DesInventar. It is necessary area and population of municipalities of each country in the years: 1985, 1990, 1995, 2000 and if it is possible the data of 200?. Information of surface of municipalities usually exists in all countries and population data is obtained from projections of the census made in each country.

Due to the name of a municipality could be equal to other in other sub-national area (state, department, etc.) it is required that the list uses the sub-national units and it is wished to have a code number in case of official codification. This information is needed in Excel.

3.2.1 Area and population of all municipalities (or equivalent administrative units) of the country.

Code	Name	Area Km^2	Population 1985	Population 1990	Population 1995	Population 2000	Population 2003
	State A						
	Munic 1						
	Munic 2						
	State B						
	Munic 1						
	Munic 2						
	Munic 3						

It is important to identify municipalities that did not exist in previous years. It is also necessary to identify from which municipality it was part before.

In addition, to obtain LDI it is necessary to have other supplementary values. For each period it is necessary the average cost per square meter of social housing constructions, the average number of square meters of a dwelling of social interest according to the standards of the country in each period, the value of the minimum monthly legal salary and the gross average of a hectare of "representative" crops (could be some) in areas of recurrent floods (weighted average obtained from expert opinion). These values are needed in dollars in each period.

Year	Value m2 social housing	Num. m^2 of one dwelling of social interest	Minimum monthly legal Salary	Average value of one hectare of crops in flood prone areas
1985				
1990				
1995				
2000				
200?				

3.3 Data to Estimate the PVI

PVI is a composite indicator that is evaluated based on identification of three categories or components of vulnerability: exposure and susceptibility, socioeconomic fragility, and lack of resilience. The intention is to characterize a situation or pattern of each country that may be understood as a prevalent vulnerability.

Indicators used for describing exposure, prevalent socioeconomic conditions and lack of resilience are proposed recognizing that their influence explains why adverse economic, social and environmental effects are consummated when a dangerous event occurs. Each aspect is a set of indicators that express situations, causes, susceptibilities, weaknesses or relative absences of each country under analysis and in favor of which risk reduction actions may be oriented. Due to among indicators is possible to detect correlations, dependencies and redundancy may be detected amongst indicators, information have to be treated with a set of statistical procedures to identify those situations. In addition, normalization, pondering and aggregation techniques are applied, reason why it is necessary to assign “weights” or importance factors by few methods that allow to make an analysis of sensitivity and uncertainty of the results.

Indicators proposed herein have been identified based on figures, indices, existing rates or proportions that derive from reliable data bases available worldwide or in each country.

Some of the indicators require to be estimated directly or indirectly, making some assumptions, based on existing data in each country. It is asked in those cases to describe the way as the estimation was carried out in an independent report of notes. Addittionally, these descriptions are requested when according to the criterion of the advisor a similar or alternative indicator is recommended, in the lack of one, which in most of the cases is not considered advisable for comparison effects, but that it can be useful when the situation of the country in the different periods of time is compared.

It is requested to use tables 3.3.1, 3.3.2 and 3.3.3 to provide values of the indicators. This information is needed at several moments in the time: 1985, 1990, 1995 and 2000. If it is possible include the most recent (200?). In each one of the mentioned tables it is requested to indicate the weight that in opinion of the advisor[37] could have each indicator like component of each index of prevalent vulnerability. This technique, well-known like the method of budgetary allocation, is the simplest one and it corresponds to the distribution of a score that in this case must sum 100.

[37] The allocation of weights is based on the opinion of experts, therefore it is subjective. It is recommended to do consultations to other expert people or officials of different institutions related to the subject using the herein contained formats. This, with the purpose of obtaining different opinions, which can in be in consensus or a result of an average, according to the criterion of the advisor. Also the delphi method or any technique that could be considered useful to obtain a representative vision of the weights or of the judgments can be used.

Table 3.3.1 Indicators of Exposure and Susceptibility

Indicator	1985	1990	1995	2000	Weight
ES1. Population growth, avg. annual rate (%)					
ES2. Urban growth, avg. annual rate (%).					
ES3. Population density, people/5 Km^2					
ES4. Poverty-population below US$ 1 per day PPP disposable income.[38]					
ES5. Capital stock, million US$ dollar/1000 km^2					
ES6. Imports and exports of goods and services, % of GDP					
ES7. Gross domestic fixed investment, % of GDP.					
ES8. Arable land and permanent crops, % land area.					

Table 3.3.2 Indicators of Socio-economic Fragility

Indicator	1985	1990	1995	2000	Weight
SF1. Human Poverty Index, HPI-1.					
SF2. Dependents as proportion of working age population (15-64)					
SF3. Social disparity, concentration of income measured using Gini index.					
SF4. Unemployment, as % of total labor force.					
SF5. Inflation, food prices, annual %					
SF6. Dependency of GDP growth of agriculture, annual %					
SF7. Debt servicing, % of GDP.					
SF8. Human-induced Soil Degradation (GLASOD)					

[38] Purchasing power parity: conversion to international dollars that have the same purchasing power that a dollar has in the USA (UNDP 2001).

Table 3.3.3 Indicators of (Lack of) Resilience

Indicator	1985	1990	1995	2000	Weight
LR1. Human Development Index, HDI [Inv]					
LR2. Gender-related Development Index, GDI [Inv]					
LR3. Social expenditure; on pensions, health, and education, % of GDP [Inv]					
LR4. Governance Index [Inv]					
LR5. Insurance of infrastructure and housing, % of GDP [Inv]					
LR6. Television sets per 1000 people [Inv]					
LR7. Hospital beds per 1000 people [Inv]					
LR8. Environmental Sustainability Index,[39] ESI [Inv]					

Tables 3.3.4, 3.3.5 and 3.3.6 allow allocation of importance factors for determination of weights by means of Analytic Hierarchy Process (AHP). This technique enables the decision-maker to derive weights as opposed to arbitrarily assign weights and does not require an universal scale. The core of AHP is an ordinal pair-wise comparison in which preference statements are addressed. Comparisons are made per pairs of indicators by firstly posing the question "Which of the two is the most important?" and secondly "By how much?" The strength of preference is expressed on a semantic scale of 1-9, which keeps measurement within the same order of magnitude. A preference of 1 indicates equality between two indicators while a preference of 9 indicates that one indicator is 9 times larger or more important than the one to which it is being compared. These comparisons result in a comparison matrix that is evaluated afterward. It is requested to select which of the indicators is perceived as more important and in which degree, pair by pair, using an X, according to the judgment of the advisor.[37]

[39] Some indices or indicators have not been estimated for all periods that may be evaluated with comparative ends. We will opt to maintain constant values that do not affect the aggregation when estimating the respective sub indices of prevalent vulnerability.

Table 3.3.4 Importance Factor Allocation to Indicators of Exposure and Susceptibility (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

	Indicator			Indicator	1	2	3	4	5	6	7	8	9
	ES1. Population growth, average annual rate (%)	*vs.*		ES2. Urban growth, average annual rate (%)									
	ES1. Population growth, average annual rate (%)	*vs.*		ES3. Population density, people per 5 km^2									
	ES1. Population growth, average annual rate (%)	*vs.*		ES4. Poverty-population below US$ 1 per day PPP disposable income									
	ES1. Population growth, average annual rate (%)	*vs.*		ES5. Capital stock, million US$ dollar/1000 km^2									
	ES1. Population growth, average annual rate (%)	*vs.*		ES6. Imports and exports of goods and services, % of GDP									
	ES1. Population growth, average annual rate (%)	*vs.*		ES7. Gross domestic fixed investment, % of GDP									
	ES1. Population growth, average annual rate (%)	*vs.*		ES8. Arable land and permanent crops, % land area									
	ES2. Urban growth, average annual rate (%)	*vs.*		ES3. Population density, people per 5 km^2									
	ES2. Urban growth, average annual rate (%)	*vs.*		ES4. Poverty-population below US$ 1 per day PPP disposable income									
	ES2. Urban growth, average annual rate (%)	*vs.*		ES5. Capital stock, million US$ dollar/1000 km^2									
	ES2. Urban growth, average annual rate (%)	*vs.*		ES6. Imports and exports of goods and services, % of GDP									
	ES2. Urban growth, average annual rate (%)	*vs.*		ES7. Gross domestic fixed investment, % of GDP									
	ES2. Urban growth, average annual rate (%)	*vs.*		ES8. Arable land and permanent crops, % land area									
	ES3. Population density, people per 5 km^2	*vs.*		ES4. Poverty-population below US$ 1 per day PPP disposable income									
	ES3. Population density, people per 5 km^2	*vs.*		ES5. Capital stock, million US$ dollar/1000 km^2									
	ES3. Population density, people per 5 km^2	*vs.*		ES6. Imports and exports of goods and services, % of GDP									
	ES3. Population density, people per 5 km^2	*vs.*		ES7. Gross domestic fixed investment, % of GDP									
	ES3. Population density, people per 5 km^2	*vs.*		ES8. Arable land and permanent crops, % land area									
	ES4. Poverty-population below US$ 1 per day PPP disposable income	*vs.*		ES5. Capital stock, million US$ dollar/1000 km^2									
	ES4. Poverty-population below US$ 1 per day PPP disposable income	*vs.*		ES6. Imports and exports of goods and services, % of GDP									
	ES4. Poverty-population below US$ 1 per day PPP disposable income	*vs.*		ES7. Gross domestic fixed investment, % of GDP									
	ES4. Poverty-population below US$ 1 per day PPP disposable income	*vs.*		ES8. Arable land and permanent crops, % land area									
	ES5. Capital stock, million US$ dollar/1000 km^2	*vs.*		ES6. Imports and exports of goods and services, % of GDP									
	ES5. Capital stock, million US$ dollar/1000 km^2	*vs.*		ES7. Gross domestic fixed investment, % of GDP									
	ES5. Capital stock, million US$ dollar/1000 km^2	*vs.*		ES8. Arable land and permanent crops, % land area									
	ES6. Imports and exports of goods and services, % of GDP	*vs.*		ES7. Gross domestic fixed investment, % of GDP									
	ES6. Imports and exports of goods and services, % of GDP	*vs.*		ES8. Arable land and permanent crops, % land area									
	ES7. Gross domestic fixed investment, % of GDP	*vs.*		ES8. Arable land and permanent crops, % land area									

Table 3.4.5 Importance Factor Allocation to Indicators of Socio-economic Fragility (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

					1	2	3	4	5	6	7	8	9
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF2. Dependents as proportion of working age population (15-64)									
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF3. Social disparity, concentration of income measured using Gini index.									
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF4. Unemployment, as % of total labor force									
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF5. Inflación, con base en el costo de los alimentos, en % anual.									
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF6. Dependency of GDP growth of agriculture, annual %									
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF7. Debt servicing, % of GDP									
	SF1. Human Poverty Index, HPI-1.	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									
	SF2. Dependents as proportion of working age population (15-64)	*vs.*		SF3. Social disparity, concentration of income measured using Gini index.									
	SF2. Dependents as proportion of working age population (15-64)	*vs.*		SF4. Unemployment, as % of total labor force									
	SF2. Dependents as proportion of working age population (15-64)	*vs.*		SF5. Inflación, con base en el costo de los alimentos, en % anual.									
	SF2. Dependents as proportion of working age population (15-64)	*vs.*		SF6. Dependency of GDP growth of agriculture, annual %									
	SF2. Dependents as proportion of working age population (15-64)	*vs.*		SF7. Debt servicing, % of GDP									
	SF2. Dependents as proportion of working age population (15-64)	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									
	SF3. Social disparity, concentration of income measured using Gini ndex	*vs.*		SF4. Unemployment, as % of total labor force									
	SF3. Social disparity, concentration of income measured using Gini ndex	*vs.*		SF5. Inflación, con base en el costo de los alimentos, en % anual.									
	SF3. Social disparity, concentration of income measured using Gini ndex	*vs.*		SF6. Dependency of GDP growth of agriculture, annual %									
	SF3. Social disparity, concentration of income measured using Gini ndex	*vs.*		SF7. Debt servicing, % of GDP									
	SF3. Social disparity, concentration of income measured using Gini ndex	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									
	SF4. Unemployment, as % of total labor force	*vs.*		SF5. Inflación, con base en el costo de los alimentos, en % anual.									
	SF4. Unemployment, as % of total labor force	*vs.*		SF6. Dependency of GDP growth of agriculture, annual %									
	SF4. Unemployment, as % of total labor force	*vs.*		SF7. Debt servicing, % of GDP									
	SF4. Unemployment, as % of total labor force	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									
	SF5. Inflation, food prices, annual %	*vs.*		SF6. Dependency of GDP growth of agriculture, annual %									
	SF5. Inflation, food prices, annual %	*vs.*		SF7. Debt servicing, % of GDP									
	SF5. Inflation, food prices, annual %	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									
	SF6. Dependency of GDP growth of agriculture, annual %	*vs.*		SF7. Debt servicing, % of GDP									
	SF6. Dependency of GDP growth of agriculture, annual %	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									
	SF7. Debt servicing, % of GDP	*vs.*		SF8. Human-induced Soil Degradation (GLASOD)									

Table 3.3.6 Importance Factor Allocation to Indicators of (Lack of) Resilience (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

					1	2	3	4	5	6	7	8	9
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR2. Gender-related Development Index, GDI [Inv]									
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR3. Social expenditure; on pensions, health, and education, % of GDP [Inv]									
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR4. Governance Index [Inv]									
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR5. Insurance of infrastructure and housing, % of GDP [Inv]									
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR6. Television sets per 1000 people [Inv]									
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR7. Camas hospitalarias por cada 1000 habitantes [Inv]									
	LR1. Human Development Index, HDI [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									
	LR2. Gender-related Development Index, GDI [Inv]	*vs.*		LR3. Social expenditure; on pensions, health, and education, % of GDP [Inv]									
	LR2. Gender-related Development Index, GDI [Inv]	*vs.*		LR4. Governance Index [Inv]									
	LR2. Gender-related Development Index, GDI [Inv]	*vs.*		LR5. Insurance of infrastructure and housing, % of GDP [Inv]									
	LR2. Gender-related Development Index, GDI [Inv]	*vs.*		LR6. Television sets per 1000 people [Inv]									
	LR2. Gender-related Development Index, GDI [Inv]	*vs.*		LR7. Camas hospitalarias por cada 1000 habitantes [Inv]									
	LR2. Gender-related Development Index, GDI [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									
	LR3. Social expenditure; pensions, health, and education, % GDP [Inv]	*vs.*		LR4. Governance Index [Inv]									
	LR3. Social expenditure; pensions, health, and education, % GDP [Inv]	*vs.*		LR5. Insurance of infrastructure and housing, % of GDP [Inv]									
	LR3. Social expenditure; pensions, health, and education, % GDP [Inv]	*vs.*		LR6. Television sets per 1000 people [Inv]									
	LR3. Social expenditure; pensions, health, and education, % GDP [Inv]	*vs.*		LR7. Camas hospitalarias por cada 1000 habitantes [Inv]									
	LR3. Social expenditure; pensions, health, and education, % GDP [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									
	LR4. Governance Index [Inv]	*vs.*		LR5. Insurance of infrastructure and housing, % of GDP [Inv]									
	LR4. Governance Index [Inv]	*vs.*		LR6. Television sets per 1000 people [Inv]									
	LR4. Governance Index [Inv]	*vs.*		LR7. Camas hospitalarias por cada 1000 habitantes [Inv]									
	LR4. Governance Index [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									
	LR5. Insurance of infrastructure and housing, % of GDP [Inv]	*vs.*		LR6. Television sets per 1000 people [Inv]									
	LR5. Insurance of infrastructure and housing, % of GDP [Inv]	*vs.*		LR7. Camas hospitalarias por cada 1000 habitantes [Inv]									
	LR5. Insurance of infrastructure and housing, % of GDP [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									
	LR6. Television sets per 1000 people [Inv]	*vs.*		LR7. Camas hospitalarias por cada 1000 habitantes [Inv]									
	LR6. Television sets per 1000 people [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									
	LR7. Hospital beds per 1000 people [Inv]	*vs.*		LR8. Environmental Sustainability Index, ESI [Inv]									

3.4 Data to estimate the RMI

The RMI is also a composite indicator that is evaluated based on a qualitative valuation of the performance of four aspects or public policies of disaster risk management. Eight indicators have been proposed for each public policy. Valuation of each indicator is achieved using five performance levels: *low, incipient, appreciable, notable,* and *optimum*.[40] This approach permits to use each reference level simultaneously as a "performance target" and therefore allows comparison and identification of results or achievements towards governments should attempt to direct their efforts of formulation, implementation, and policy evaluation according to these performance targets.

We assume that weights are equal for the four aspects: risk identification, risk reduction, disaster management, and financial protection (risk transfer) and governance. Nevertheless, if the advisor believes they can be different it is requested to indicate respective weights and a brief justification in a separated report.

Tables 3.4.1 to 3.4.4 present the indicators to evaluate, indicating by means of an X the performance level obtained by the country at different moments in the time.

For evaluation tables 2.4.1 to 2.4.4 from previous section are used. They describe respective levels of performance. It is important to review with well-taken care what is expressed as performance in each level. If it is partial, it is necessary to use the previous level. This information is needed at several moments in the time: 1985, 1990, 1995 and 2000. It is requested to include also present or more recent situation (200?). Although it is difficult to obtain objective appreciations or without biases in case of consulting other interested people, it is recommended to make that type of investigations with aims detect variations in the evaluation criterion.

[40] By experts suggestion for a better differentiation of linguistic qualification it can be used "significant" instead "appreciable" and "outstanding" instead "notable".

Table 3.4.1 Indicators of Risk Identification

Place an **X** in front of the performance level obtained in each year according to the table 2.4.1

Indicator	1985	1990	1995	2000	200?
RI1. Systematic disaster and loss inventory	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RI2. Hazard monitoring and foreca-sting	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RI3. Hazard evaluation and mapping	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RI4. Vulnerability and risk assessm-ent	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RI5. Public information and commu-nity participation	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RI6. Training and education in risk management	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*

Table 3.4.2 Indicators of Risk Reduction

Place an **X** in front of the performance level obtained in each year according to the table 2.4.2

Indicator	1985	1990	1995	2000	200?
RR1. Risk consideration in land use and urban planning	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RR2. Hydrographic basin interven-tion and environmental protection	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RR3. Implementation of hazard-event control and protection techniques	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RR4. Housing improvement and human settlement relocation from prone-areas	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RR5. Updating and enforcement of safety standards and construction codes	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
RR6. Reinforcement and retrofitting of public and private assets	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*

Table 3.4.3 Indicators of Disaster Management

Place an **X** in front of the performance level obtained in each year according to the table 2.4.3

Indicator	1985	1990	1995	2000	200?
DM1. Organization and coordination of emergency operations	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
DM2. Emergency response planning and implementation of warning systems	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
DM3. Endowment of equipments, tools and infrastructure	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
DM4. Simulation, updating and test of inter institutional response	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
DM5. Community preparedness and training	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
DM6. Rehabilitation and reconstruction planning	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*

Table 3.4.4 Indicators of Governance and Financial Protection (Loss transfer)

Place an **X** in front of the performance level obtained in each year according to the table 2.4.4

Indicator	1985	1990	1995	2000	200?
FP1. Interinstitutional, multisectoral and decentralizing organization	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
FP2. Reserve funds for institutional strengthening	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
FP3. Budget allocation and mobilization	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
FP4. Implementation of social safety nets and funds response	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
FP5. Insurance coverage and loss transfer strategies of public assets	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*
FP6. Housing and private sector insurance and reinsurance coverage	1. *Low*	1. *Low*	1. *Low*	1. *Low*	1. *Low*
	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*	2. *Incipient*
	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*	3 *Appreciabl.*
	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*	4. *Notable*
	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*	5. *Optimum*

Tables 3.4.5 to 3.4.8 are used for allocation of weights by means of the technique of budgetary allocation. In this case, also, distribution of the N points must sum 100. It is requested to assign in these tables the weights that each component indicator of each disaster management risk index could have, according to the opinion of advisor[37].

Tables 3.4.9 to 3.4.12 allow allocation of importance factors for determination of weights by means of the AHP. Comparisons are made by pairs. Also, the preference is expressed by means of a scale from 1 to 9. Preference 1 means equality between indicators while a preference of 9 means that an indicator is 9 times more important that the other. These comparisons result in a comparison matrix to which its consistency is processed by means of a numerical process later. It is requested to select which of the indicators is perceived as more important and in which degree, pair by pair, using an X, according to the judgment of the advisor[37].

Table 3.4.5 Budgetary Allocation (Weights) to Indicators of Risk Identification

Allocate 100 points among the eight indicators

Indicator	Weight
RI1. Systematic disaster and loss inventory	
RI2. Hazard monitoring and forecasting	
RI3. Hazard evaluation and mapping	
RI4. Vulnerability and risk assessment	
RI5. Public information and community participation	
RI6. Training and education in risk management	

Table 3.4.6 Budgetary Allocation (Weights) to Indicators of Risk Reduction

Allocate 100 points among the eight indicators

Indicator	Weight
RR1. Risk consideration in land use and urban planning	
RR2. Hydrographic basin intervention and environmental protection	
RR3. Implementation of hazard-event control and protection techniques	
RR4. Housing improvement and human settlement relocation from prone-areas	
RR5. Updating and enforcement of safety standards and construction codes	
RR6. Reinforcement and retrofitting of public and private assets	

Table 3.4.7 Budgetary Allocation (Weights) to Indicators of Disaster Management

Allocate 100 points among the eight indicators

Indicator	Weight
DM1. Organization and coordination of emergency operations	
DM2. Emergency response planning and implementation of warning systems	
DM3. Endowment of equipments, tools and infrastructure	
DM4. Simulation, updating and test of inter institutional response	
DM5. Community preparedness and training	
MD6. Rehabilitation and reconstruction planning	

Table 3.4.8 Budgetary allocation (weights) to indicators of Governance and Financial Protection

Allocate 100 points among the eight indicators

Indicador	Weight
FP1. Interinstitutional, multisectoral and decentralizing organization	
FP2. Reserve funds for institutional strengthening	
FP3. Budget allocation and mobilization	
FP4. Implementation of social safety nets and funds response	
FP5. Insurance coverage and loss transfer strategies of public assets	
FP6. Housing and private sector insurance and reinsurance coverage	

Table 3.4.9 Importance Factor Allocation to Indicators of Risk Identification (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

					1	2	3	4	5	6	7	8	9
	RI1. Systematic disaster and loss inventory	*vs.*		RI2. Hazard monitoring and forecasting									
	RI1. Systematic disaster and loss inventory	*vs.*		RI3. Hazard evaluation and mapping									
	RI1. Systematic disaster and loss inventory	*vs.*		RI4. Vulnerability and risk assessment									
	RI1. Systematic disaster and loss inventory	*vs.*		RI5. Public information and community participation									
	RI1. Systematic disaster and loss inventory	*vs.*		RI6. Training and education in risk management									
	RI2. Hazard monitoring and forecasting	*vs.*		RI3. Hazard evaluation and mapping									
	RI2. Hazard monitoring and forecasting	*vs.*		RI4. Vulnerability and risk assessment									
	RI2. Hazard monitoring and forecasting	*vs.*		RI5. Public information and community participation									
	RI2. Hazard monitoring and forecasting	*vs.*		RI6. Training and education in risk management									
	RI3. Hazard evaluation and mapping	*vs.*		RI4. Vulnerability and risk assessment									
	RI3. Hazard evaluation and mapping	*vs.*		RI5. Public information and community participation									
	RI3. Hazard evaluation and mapping	*vs.*		RI6. Training and education in risk management									
	RI4. Vulnerability and risk assessment	*vs.*		RI5. Public information and community participation									
	RI4. Vulnerability and risk assessment	*vs.*		RI6. Training and education in risk management									
	RI5. Public information and community participation	*vs.*		RI6. Training and education in risk management									

Table 3.4.10 Importance Factor Allocation to Indicators of Risk Reduction (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

					1	2	3	4	5	6	7	8	9
	RR1. Risk consideration in land use and urban planning	*vs.*		RR2. Hydrographic basin intervene-tion and environmental protection									
	RR1. Risk consideration in land use and urban planning	*vs.*		RR3. Implementation of hazard-event control & protection technique									
	RR1. Risk consideration in land use and urban planning	*vs.*		RR4. Housing improvement and human settlement relocation									
	RR1. Risk consideration in land use and urban planning	*vs.*		RR5. Updating and enforcement of safety standards & construction codes									
	RR1. Risk consideration in land use and urban planning	*vs.*		RR6. Reinforcement and retrofitting of public and private assets									
	RR2. Hydrographic basin intervene-tion and environmental protection	*vs.*		RR3. Implementation of hazard-event control & protection technique									
	RR2. Hydrographic basin intervene-tion and environmental protection	*vs.*		RR4. Housing improvement and human settlement relocation									
	RR2. Hydrographic basin intervene-tion and environmental protection	*vs.*		RR5. Updating and enforcement of safety standards & construction codes									
	RR2. Hydrographic basin intervene-tion and environmental protection	*vs.*		RR6. Reinforcement and retrofitting of public and private assets									
	RR3. Implementation of hazard-event control & protection technique	*vs.*		RR4. Housing improvement and human settlement relocation									
	RR3. Implementation of hazard-event control & protection technique	*vs.*		RR5. Updating and enforcement of safety standards & construction codes									
	RR3. Implementation of hazard-event control & protection technique	*vs.*		RR6. Reinforcement and retrofitting of public and private assets									
	RR4. Housing improvement and human settlement relocation	*vs.*		RR5. Updating and enforcement of safety standards & construction codes									
	RR4. Housing improvement and human settlement relocation	*vs.*		RR6. Reinforcement and retrofitting of public and private assets									
	RR5. Updating and enforcement of safety standards & constructn. codes	*vs.*		RR6. Reinforcement and retrofitting of public and private assets									

Table 3.4.11 Importance Factor Allocation to Indicators of Disaster Management (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

					1	2	3	4	5	6	7	8	9
	DM1. Organization & coordination of emergency operations	*vs.*		DM2. Emergency response planning & implementation of warning systems									
	DM1. Organization & coordination of emergency operations	*vs.*		DM3. Endowment of equipments, tools and infrastructure									
	DM1. Organization & coordination of emergency operations	*vs.*		DM4. Simulation, updating and test of inter institutional response									
	DM1. Organization & coordination of emergency operations	*vs.*		DM5. Community preparedness and training									
	DM1. Organization & coordination of emergency operations	*vs.*		DM6. Rehabilitation and reconstruction planning									
	DM2. Emergency response planning & implementation of warning systm	*vs.*		DM3. Endowment of equipments, tools and infrastructure									
	DM2. Emergency response planning & implementation of warning systm	*vs.*		DM4. Simulation, updating and test of inter institutional response									
	DM2. Emergency response planning & implementation of warning systm	*vs.*		DM5. Community preparedness and training									
	DM2. Emergency response planning & implementation of warning systm	*vs.*		DM6. Rehabilitation and reconstruction planning									
	DM3. Endowment of equipments, tools and infrastructure	*vs.*		DM4. Simulation, updating and test of inter institutional response									
	DM3. Endowment of equipments, tools and infrastructure	*vs.*		DM5. Community preparedness and training									
	DM3. Endowment of equipments, tools and infrastructure	*vs.*		DM6. Rehabilitation and reconstruction planning									
	DM4. Simulation, updating and test of inter institutional response	*vs.*		DM5. Community preparedness and training									
	DM4. Simulation, updating and test of inter institutional response	*vs.*		DM6. Rehabilitation and reconstruction planning									
	DM5. Community preparedness and training	*vs.*		DM6. Rehabilitation and reconstruction planning									

Table 3.4.12 Importance Factor Allocation to Indicators of Governance and Financial Protection (Loss Transfer) (AHP)

Which of the indicators is perceived as more important?
Place an **X** in front

In which degree?
Place an **X**

	Indicator			Indicator	1	2	3	4	5	6	7	8	9
	FP1. Interinstitutional, multisectoral and decentralizing organization	*vs.*		FP2. Reserve funds for institutional strengthening									
	FP1. Interinstitutional, multisectoral and decentralizing organization	*vs.*		FP3. Budget allocation and mobiliza-tion									
	FP1. Interinstitutional, multisectoral and decentralizing organization	*vs.*		FP4. Implementation of social safety nets and funds response									
	FP1. Interinstitutional, multisectoral and decentralizing organization	*vs.*		FP5. Insurance coverage and loss transfer strategies of public assets									
	FP1. Interinstitutional, multisectoral and decentralizing organization	*vs.*		FP6. Housing and private sector insurance and reinsurance coverage									
	FP2. Reserve funds for institutional strengthening	*vs.*		FP3. Budget allocation and mobiliza-tion									
	FP2. Reserve funds for institutional strengthening	*vs.*		FP4. Implementation of social safety nets and funds response									
	FP2. Reserve funds for institutional strengthening	*vs.*		FP5. Insurance coverage and loss transfer strategies of public assets									
	FP2. Reserve funds for institutional strengthening	*vs.*		FP6. Housing and private sector insurance and reinsurance coverage									
	FP3. Budget allocation and mobiliz-ation	*vs.*		FP4. Implementation of social safety nets and funds response									
	FP3. Budget allocation and mobiliz-ation	*vs.*		FP5. Insurance coverage and loss transfer strategies of public assets									
	FP3. Budget allocation and mobiliz-ation	*vs.*		FP6. Housing and private sector insurance and reinsurance coverage									
	FP4. Implementation of social safety nets and funds response	*vs.*		FP5. Insurance coverage and loss transfer strategies of public assets									
	FP4. Implementation of social safety nets and funds response	*vs.*		FP6. Housing and private sector insurance and reinsurance coverage									
	FP5. Insurance coverage and loss transfer strategies of public assets	*vs.*		FP6. Housing and private sector insurance and reinsurance coverage									

4. APPLICATION RESULTS

This section presents application results of the system of indicators in twelve countries of Latin America and the Caribbean. There are also presented results at sub-national and urban level, product of a demonstrative application made in order to illustrate how an adaptation of indices in other scales can be made and how an integrated estimation of risk at urban level can be achieved taking into account damage scenarios or potential losses. Some results for each one of the indices that compose the system of indicators are presented, compared and commented in this section.

4.1 The Disaster Deficit Index (DDI)

The *DDI* deals with the potential economic loss that the analyzed country could face in the case of the occurrence of the Maximum Event Considered, *MEC*, and its macroeconomic implications in terms of needed resources to confront reconstruction. Table 4.1.1 presents values of *DDI* in each period and by country.

Table 4.1.1 DDI in 1980 for 50, 100 and 500 years

Year	Índex	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER	TTO
1980	DDI_{50}	0.02	0.617	0.47	1.13	1.45	0.96	3.90	0.15	1.91	0.42	1.49	0.26
	DDI_{100}	0.08	1.24	1.04	2.18	2.80	2.21	5.61	0.35	3.82	0.66	3.99	0.67
	DDI_{500}	0.97	3.12	4.58	3.06	5.71	6.00	4.94	1.44	7.28	1.11	5.05	3.48
	DDI'_{CE}	0.30%	8.23%	4.40%	5.86%	9.70%	9.89%	40.28%	1.95%	16.47%	2.35%	9.29%	1.99%
	DDI'_{SI}	^D	8.49%	^D	26.44%	^D	7.53%	^D	^D	72.20%	4.33%	^D	^D
1985	DDI_{50}	0.04	0.43	0.80	1.97	2.87	1.76	5.15	0.17	1.33	0.49	1.93	0.39
	DDI_{100}	0.13	0.91	1.71	3.50	4.84	3.48	6.86	0.41	2.15	0.76	4.90	0.99
	DDI_{500}	1.49	2.75	6.36	3.97	7.08	6.83	5.43	1.64	3.04	1.23	5.57	4.48
	DDI'_{CE}	0.52%	11.59%	8.83%	11.36%	23.49%	21.89%	71.51%	2.97%	25.66%	3.66%	12.43%	3.01%
	DDI'_{SI}	^D	2.95%	^D	35.53%	29.67%	2.95%	81.35%	3.71%	7.13%	3.25%	9.91%	9.74%
1990	DDI_{50}	0.08	0.48	0.81	1.81	1.73	1.06	5.00	0.25	0.79	0.31	2.02	0.33
	DDI_{100}	0.27	1.00	1.73	3.28	3.26	2.40	6.82	0.58	1.64	0.49	5.05	0.85
	DDI_{500}	2.55	2.85	6.41	3.84	6.10	6.16	5.49	2.22	3.41	0.89	5.62	4.06
	DDI'_{CE}	1.12%	7.88%	9.49%	10.26%	12.05%	11.21%	67.62%	3.65%	22.24%	4.19%	20.79%	2.54%
	DDI'_{SI}	0.00%	5.34%	^D	16.30%	35.27%	5.88%	^D	16.08%	5.33%	1.78%	10.07%	5.10%
1995	DDI_{50}	0.02	0.11	0.46	0.13	0.96	0.46	1.23	0.15	0.94	0.95	1.06	0.20
	DDI_{100}	0.08	0.24	1.01	0.28	1.96	1.18	2.31	0.35	2.09	1.37	3.04	0.52
	DDI_{500}	1.00	1.25	4.50	0.59	4.75	4.65	3.16	1.45	5.08	1.77	4.43	2.85
	DDI'_{CE}	0.31%	2.90%	4.54%	8.43%	6.05%	4.31%	31.47%	1.90%	7.23%	5.70%	6.64%	10.26%
	DDI'_{SI}	^D	14.18%	^D	6.31%	62.98%	8.11%	^D	92.25%	14.95%	2.88%	^D	4.82%
2000	DDI_{50}	0.03	0.18	0.61	0.17	1.24	0.44	0.99	0.13	0.81	0.56	1.26	0.30
	DDI_{100}	0.10	0.41	1.33	0.37	2.45	1.14	1.90	0.31	1.77	0.86	3.53	0.76
	DDI_{500}	1.24	1.78	5.40	0.76	5.34	4.56	2.77	1.30	4.09	1.32	4.81	3.75
	DDI'_{CE}	0.41%	2.69%	5.90%	7.89%	8.07%	4.22%	32.31%	1.81%	8.82%	3.41%	8.72%	9.22%
	DDI'_{SI}	^D	^D	27.10%	9.96%	51.44%	6.19%	^D	^D	5.85%	5.35%	35.77%	2.80%

DDI'_{CE}: Index related to Capital Expenditure; DDI'_{SI}: Index related to Inter-temporal Surplus; ^D: Deficit increasing

A *DDI* greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the *DDI*, the greater the gap between losses and the country's ability to face them. If constrictions for additional debt exist, this situation implies the impossibility to recover. Figures 4.1.1 – 4.1.5 register the *DDI* for countries between 1980 and 2000 for 50, 100 and 500 years periods of return

In general, most of the countries have shown over the last two decades a high level of incapacity to face up the potential losses in the case of extreme events even if these are associated with 50 and 100 years periods of return. Even though the situation was more critical for most of the countries in the 1980s and beginnings of the 1990s (the *DDI* climbed to over 6.0), present situation is worrying given the increase of potential losses and the low economic resilience demonstrated by the majority of the countries. In 2000 all countries show a *DDI* greater than 1.0 except Costa Rica (CRI). The most critical situation can be seen in Colombia (COL) and Dominican Republic (DOM) which have a *DDI* over 5.0. Ecuador (ECU), Peru (PER), Chile (CHL) and Jamaica (JAM) follow them close with a DDI greater than 4.0.

Figure 4.1.1 DDI in 1980 for 50, 100 and 500 years

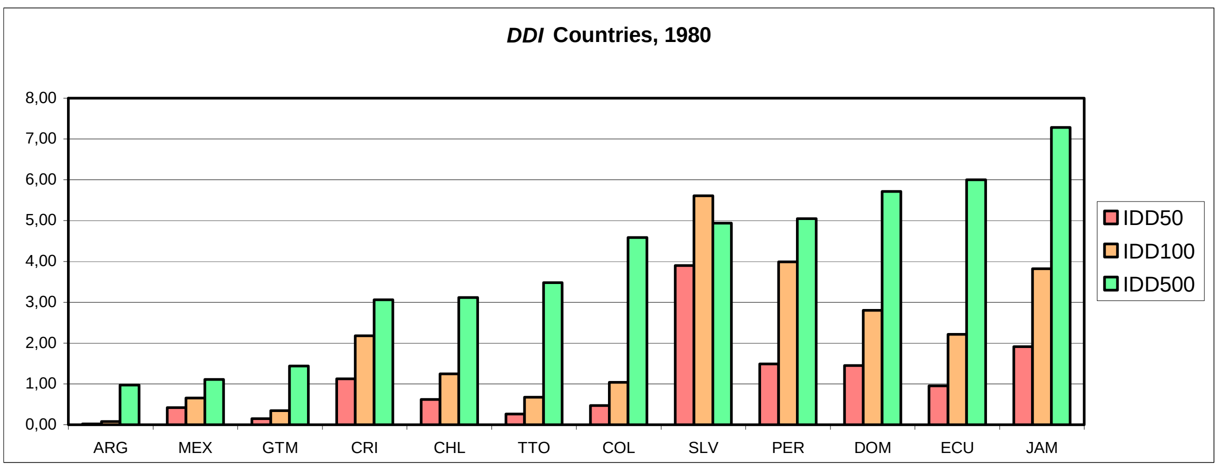


Figure 4.1.2 DDI in 1985 for 50, 100 and 500 years

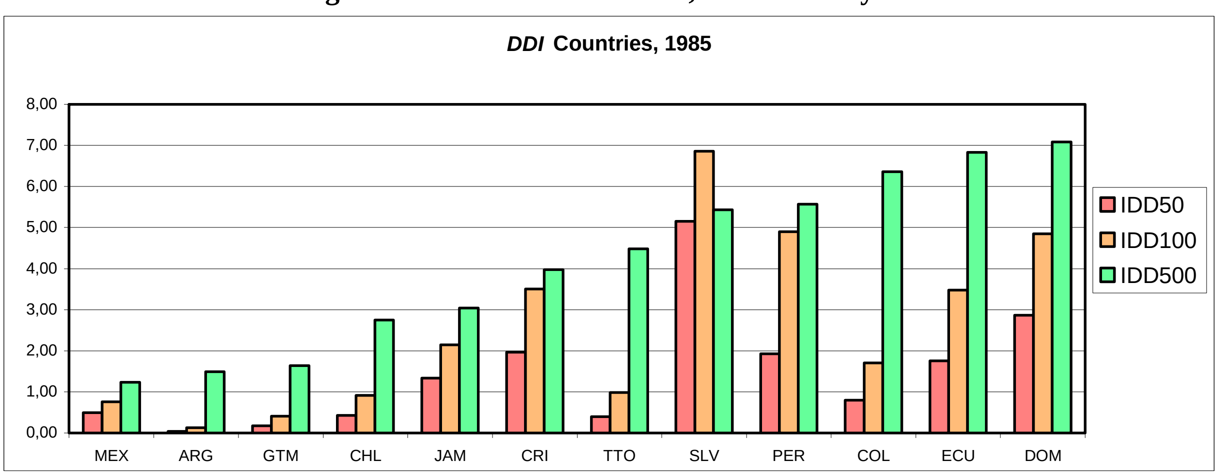


Figure 4.1.3 DDI in 1990 for 50, 100 and 500 years

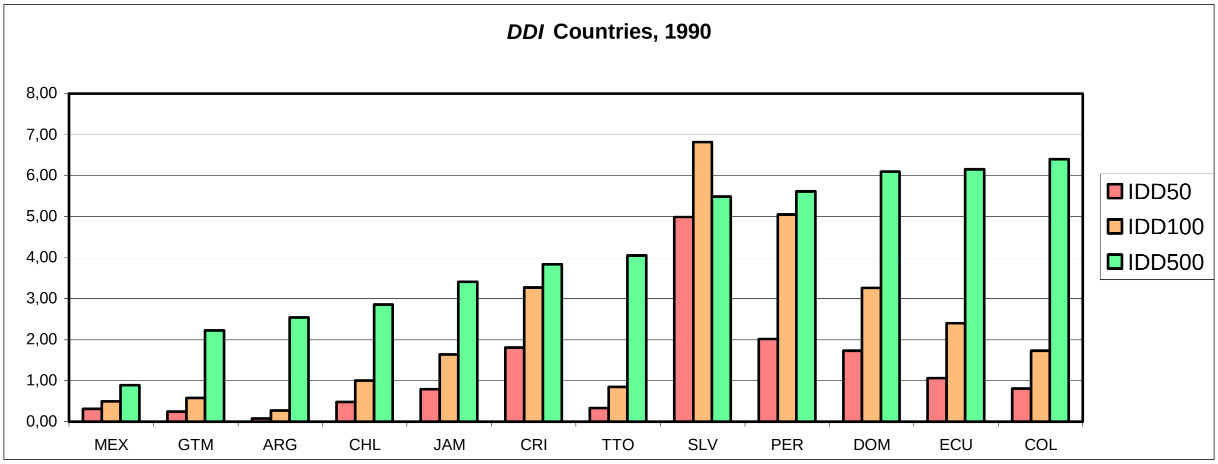


Figure 4.1.4 DDI in 1995 for 50, 100 and 500 years

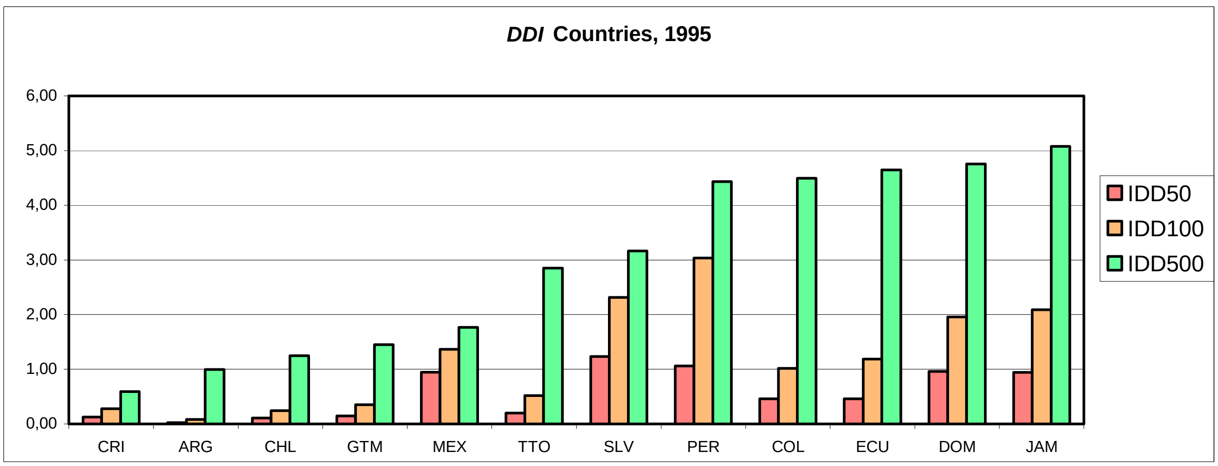
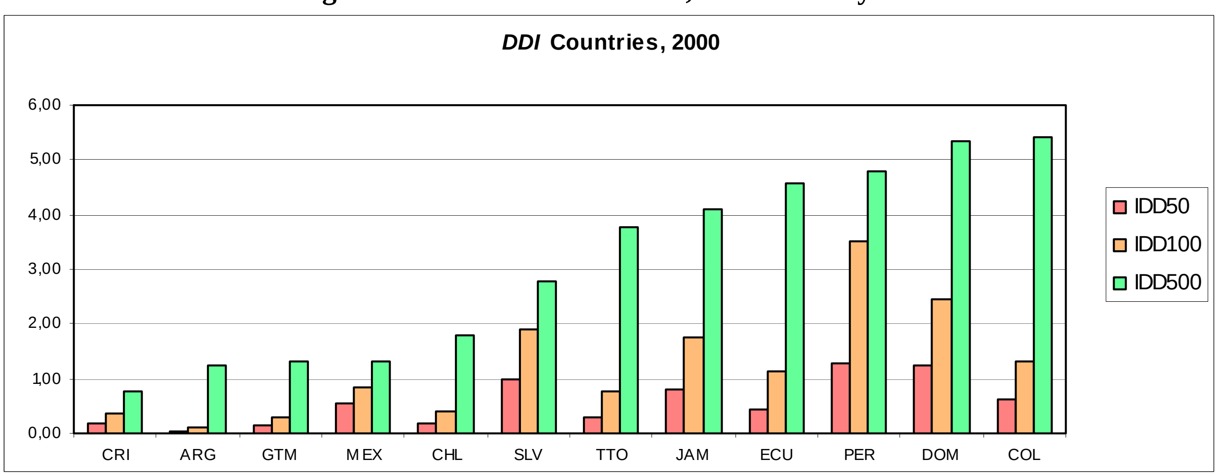
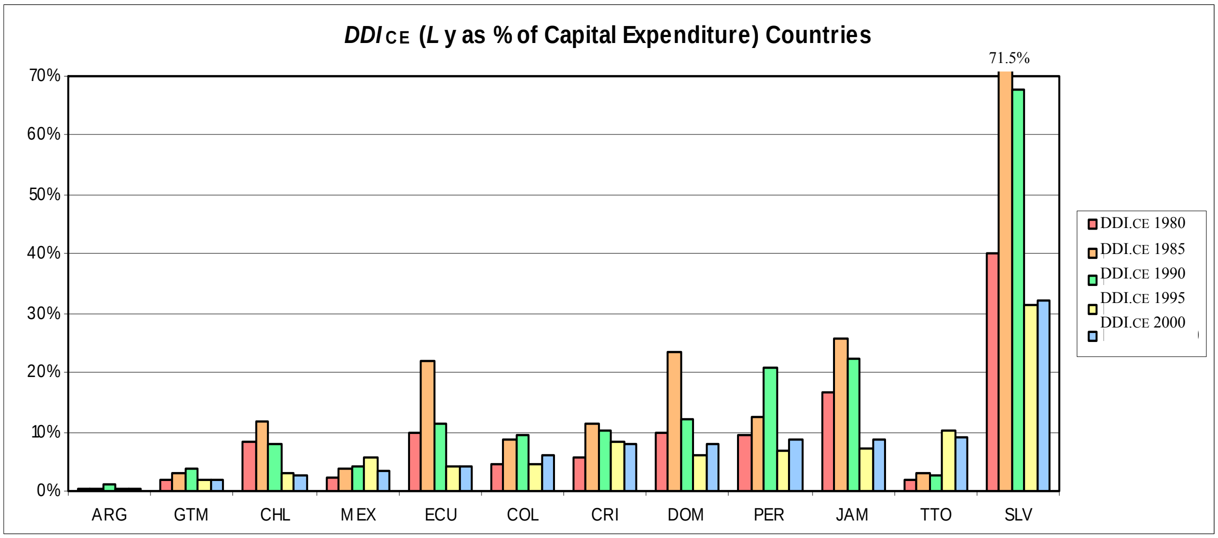


Figure 4.1.5 DDI in 2000 for 50, 100 and 500 years



In complementary way and in order to place *DDI* in perspective, an additional collateral indicator has been proposed, *DDI*', which represents the fraction that expected annual loss or technical premium signify to capital expenditure. That is, what percentage of the annual acquisition of fixed capital assets would be the annual payment for future disasters. Table 4.1.1 also includes figures of *DDI'* by country and period. Figure 4.1.6 shows evolution of this indicator in the last twenty years.

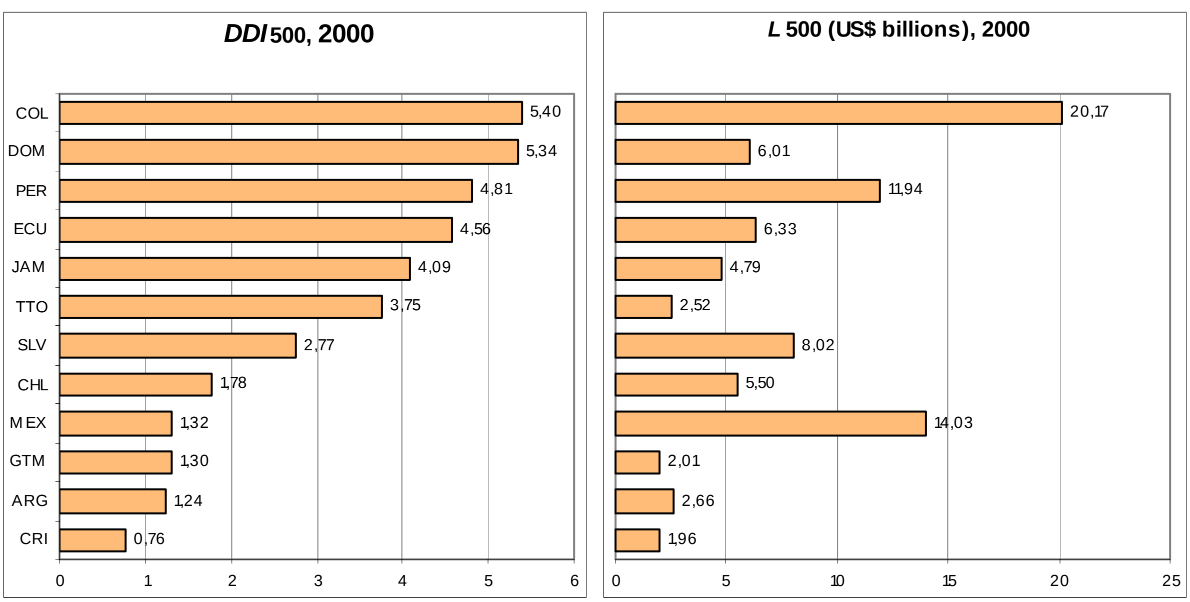
Figure 4.1.6 DDI' as Percentage of Capital Expenditure



Even though the situation for various countries was more critical in the 1980s and 1990s, a value of over 30% continues being excessive in the case of El Salvador (SLV). Only four countries have a *DDI'* below 5%.

The left side of figure 4.1.7 shows the *DDI* in 2000 calculated for an *MCE* with 500 years of return period (2 percent probability of occurrence in ten years). The right side of the figure shows the maximum loss, *L*, for the government during the same period.

Figure 4.1.7 DDI and Probable Maximum Loss in 500 Years



Government responsibility was restricted to the sum of losses associated with public sector buildings and housing for the lowest income population. With the exception of Costa Rica all countries have a DDI greater than 1.0. Colombia, with a DDI of 5.4, is in the most critical situation and could face a loss of US$20.2 million.

Figure 4.1.8 DDI and Probable Maximum Loss in 100 Years

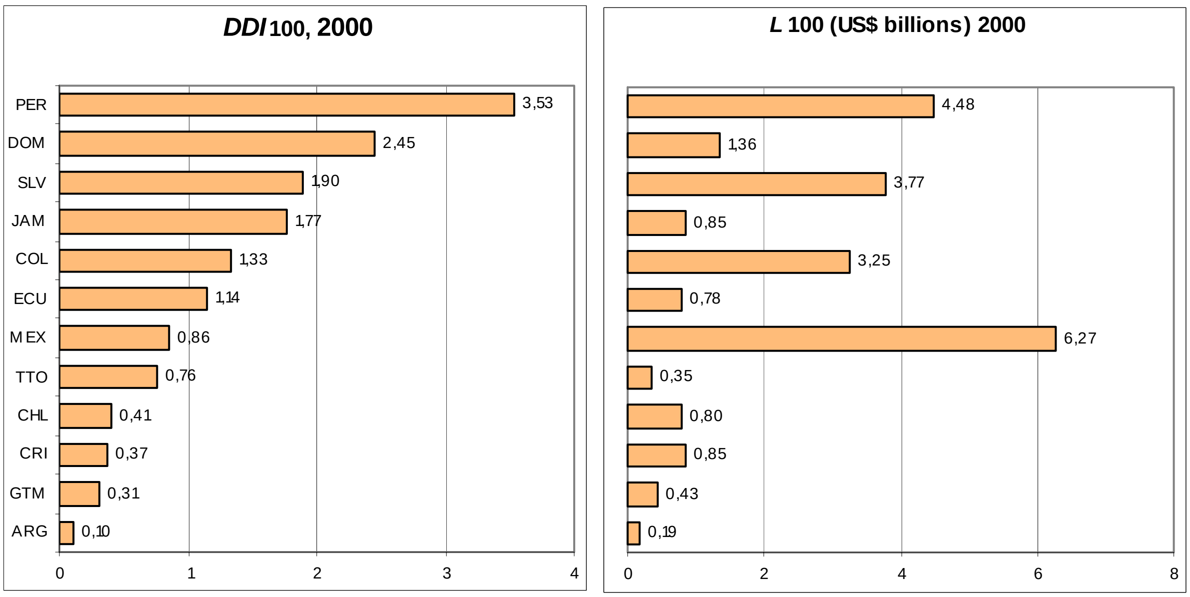


Figure 4.1.8 shows the Disaster Deficit Index and potential losses when faced with an event with 100 years of return period (5 percent probability of occurrence in ten years). In this case, access to reconstruction resources is critical for six of the twelve countries studied. The DDI for the other six countries is below 1.0. However, the impact for Mexico (MEX) could be very high even though its index is less than one.

Figure 4.1.9 DDI and Probable Maximum Loss in 50 Years

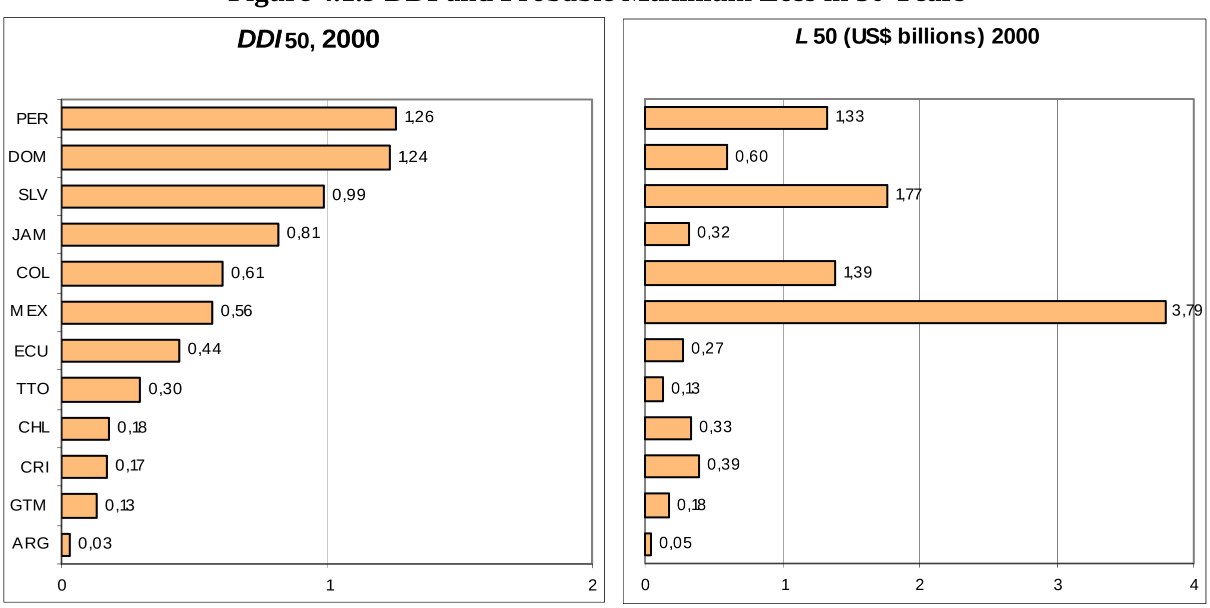
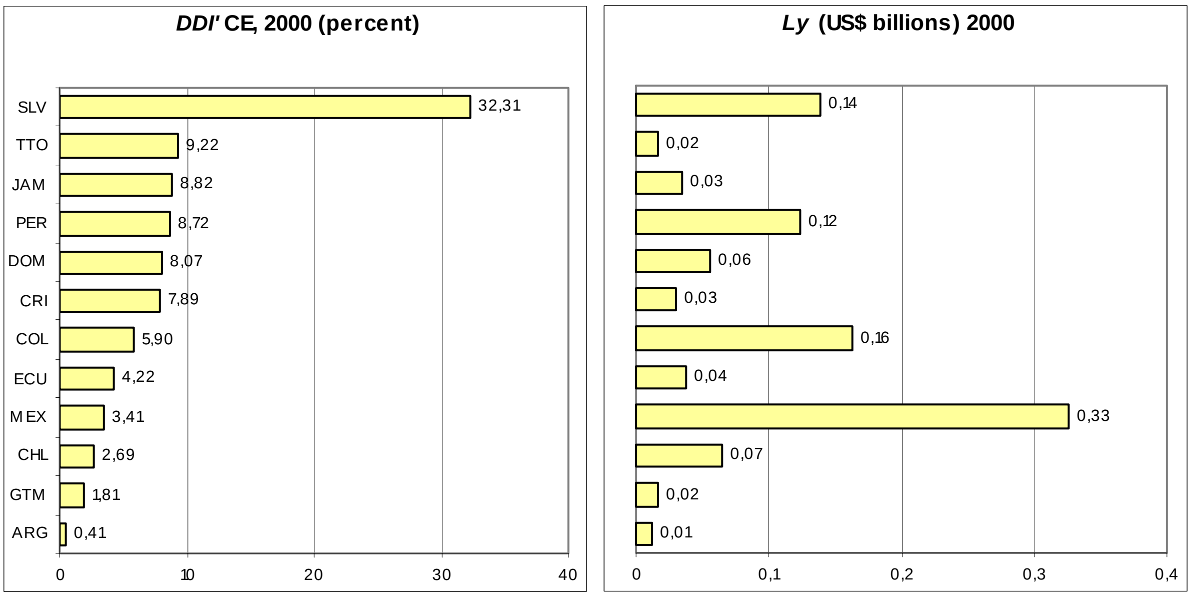


Figure 4.1.9 shows the DDI and potential losses when faced with an event with 50 years of return period (18 percent probability of occurrence in ten years). In four of the countries studied, the macroeconomic impact would be considerable if this high probability event should occur. The potential losses are particularly high even though some countries have a greater economic resilience.

Figure 4.1.10 DDI' and Annual Probable Loss



The left side of figure 4.1.10 shows the DDI'$_{CE}$ for 2000. The right side shows the annual expected loss, *Ly*. El Salvador shows the highest DDI' relative to capital expenditures. The annual cost of future disasters represents 32 percent of capital investment. Trinidad and Tobago (TTO) follows in importance with 9.2 percent. Only four countries have values below 5 percent of the investment budget (capital expenditure of fixed assets)

4.1.1 Estimating Probable Losses

Potential losses (the numerator of the index) were calculated using a model that takes into account different hazards (which are calculated in probabilistic form according to historical data on the intensity of past phenomena) and the actual physical vulnerability of the elements exposed to such phenomena. This analytical and predictive model is not based on historical measures of losses (deaths and number of people affected), but rather on the intensity of the phenomena. Actuarial requirements imply that we must avoid making estimates of risk based on previous damage statistics over short time periods. Modeling must be done by inference, by evaluating the likelihood of high-impact, low-probability events, as well as the vulnerability of infrastructure and other elements that are exposed to hazard (see previous section of this document and the methodology (Cardona *et al.* 2004a), for additional details of the technical bases of the models used). Table 4.1.1.1.1 presents all the probable loss values for all return periods and Table 4.1.2 presents the annual expected loss for the countries between 1980 and 2000.

Table 4.1.2 Summary of Figures of Probable Losses (US$ millions)

		L50					L100					L500				
Country	SECTOR	1980	1985	1990	1995	2000	1980	1985	1990	1995	2000	1980	1985	1990	1995	2000
ARG	TO	211	234	266	319	401	508	565	640	769	966	3926	4371	4954	5954	7486
	GO	1	1	1	1	2	3	4	4	5	6	96	107	121	146	184
	PO	25	28	32	39	49	94	105	119	143	180	1292	1442	1634	1968	2478
CHL	TO	1169	1107	1043	1127	1249	2984	2827	2662	2878	3188	23199	21951	20652	22329	24734
	GO	62	58	55	59	66	194	184	173	187	208	2344	2218	2088	2257	2500
	PO	251	238	224	242	268	555	526	495	535	592	2817	2665	2507	2711	3004
COL	TO	1715	2242	2785	3962	4619	3745	4898	6083	8654	10090	19537	25550	31731	45143	52632
	GO	429	561	697	991	1155	901	1178	1463	2081	2426	3982	5208	6467	9201	10728
	PO	88	115	143	203	237	307	402	499	710	827	3504	4582	5691	8096	9439
CRI	TO	361	381	424	464	734	778	821	915	999	1581	3155	3327	3707	4050	6408
	GO	86	90	101	110	174	163	172	192	210	332	578	609	679	742	1174
	PO	105	111	123	135	213	256	270	301	329	520	388	410	456	499	789
DOM	TO	705	804	917	1047	1194	1488	1698	1937	2210	2521	7731	8820	10061	11478	13094
	GO	186	212	242	276	315	346	395	450	514	586	1504	1716	1958	2233	2548
	PO	167	190	217	248	283	458	522	596	680	775	2043	2331	2659	3033	3460
ECU	TO	622	673	699	785	882	1536	1659	1722	1928	2165	10502	11303	11720	13037	14600
	GO	69	75	78	88	99	149	162	169	190	214	823	894	934	1047	1180
	PO	122	132	136	153	171	406	438	453	508	569	3690	3975	4120	4598	5151
SLV	TO	1862	2202	2497	2906	3279	3790	4484	5087	5923	6685	13170	15672	17847	20860	23642
	GO	433	512	581	676	762	772	914	1037	1207	1362	2401	2857	3253	3802	4309
	PO	573	677	768	894	1008	1367	1617	1835	2136	2411	2068	2460	2802	3275	3711
GTM	TO	151	176	227	295	312	335	391	502	653	692	1665	1942	2497	3247	3440
	GO	37	43	55	71	75	69	80	103	134	142	284	331	426	554	587
	PO	50	59	76	98	104	140	163	210	273	289	688	803	1032	1342	1422
JAM	TO	573	595	619	644	676	1393	1447	1505	1565	1643	7758	8059	8381	8716	9156
	GO	166	172	179	186	195	353	367	381	397	416	1470	1527	1588	1651	1735
	PO	102	106	110	115	120	364	378	393	409	429	2586	2686	2794	2905	3052
MEX	TO	7366	8067	8824	9567	10291	15409	16859	18424	19918	21382	64215	70022	76264	81305	86623
	GO	1300	1425	1559	1692	1823	2575	2819	3084	3345	3599	8209	8958	9765	10439	11140
	PO	1342	1479	1628	1808	1972	1821	2006	2208	2452	2674	1988	2189	2407	2660	2894
PER	TO	1212	899	1322	1688	1769	4109	3048	4482	5722	5995	20539	15237	22403	28601	29967
	GO	21	15	23	29	30	82	61	90	115	120	1165	865	1271	1623	1700
	PO	890	660	971	1240	1299	2987	2216	3259	4160	4359	7017	5206	7654	9772	10238
TTO	TO	269	272	276	281	287	654	660	669	682	698	4342	4380	4436	4513	4617
	GO	80	81	82	83	85	172	174	176	179	184	825	833	843	858	878
	PO	43	43	44	45	46	156	157	160	162	166	1546	1559	1579	1607	1644

TO: Total; GO: Government sector; PO: Poor sector

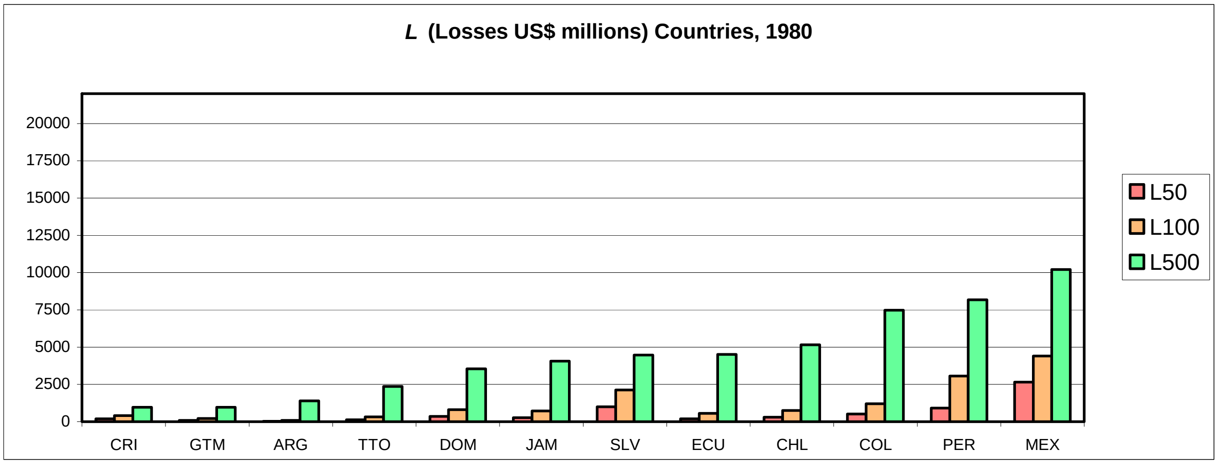
Table 4.1.3 Figures of Expected Annual Loss (US$ millions)

		Ly				
Country	SECTOR	1980	1985	1990	1995	2000
ARG	TO	37.0	41.2	46.7	56.2	70.6
	GO	1.4	1.6	1.8	2.1	2.7
	PO	4.7	5.3	6.0	7.2	9.0
CHL	TO	267.7	253.3	238.3	257.7	285.5
	GO	27.3	25.8	24.3	26.3	29.1
	PO	33.9	32.0	30.1	32.6	36.1
COL	TO	207.8	271.8	337.5	480.2	559.8
	GO	44.3	57.9	71.9	102.3	119.3
	PO	16.3	21.3	26.4	37.6	43.8
CRI	TO	33.9	35.7	39.8	43.5	68.8
	GO	7.2	7.6	8.5	9.3	14.7
	PO	7.4	7.8	8.7	9.5	15.0
DOM	TO	80.8	92.2	105.1	119.9	136.8
	GO	18.1	20.6	23.6	26.9	30.7
	PO	15.1	17.3	19.7	22.5	25.6
ECU	TO	91.9	99.1	102.9	114.8	128.8
	GO	9.5	10.3	10.7	12.0	13.5
	PO	17.9	19.3	20.0	22.3	24.9
SLV	TO	173.7	205.7	233.4	271.9	307.0
	GO	37.2	44.1	50.0	58.2	65.7
	PO	41.3	48.8	55.4	64.5	72.8
GTM	TO	17.3	20.1	25.9	33.7	35.7
	GO	3.6	4.2	5.4	7.0	7.4
	PO	4.7	5.5	7.0	9.1	9.7
JAM	TO	75.8	78.8	81.9	85.2	89.5
	GO	17.0	17.7	18.4	19.1	20.1
	PO	12.4	12.9	13.4	13.9	14.6
MEX	TO	801.1	875.5	956.0	1026.9	1099.0
	GO	125.0	136.8	149.4	161.0	172.6
	PO	104.7	115.4	127.1	141.1	153.8
PER	TO	187.1	138.8	204.1	260.6	273.1
	GO	10.0	7.4	10.9	13.9	14.5
	PO	74.7	55.4	81.4	104.0	108.9
TTO	TO	40.0	40.3	40.9	41.6	42.6
	GO	8.9	9.0	9.1	9.2	9.5
	PO	6.1	6.2	6.2	6.3	6.5

TO: Total; GO: Government sector; PO: Poor sector

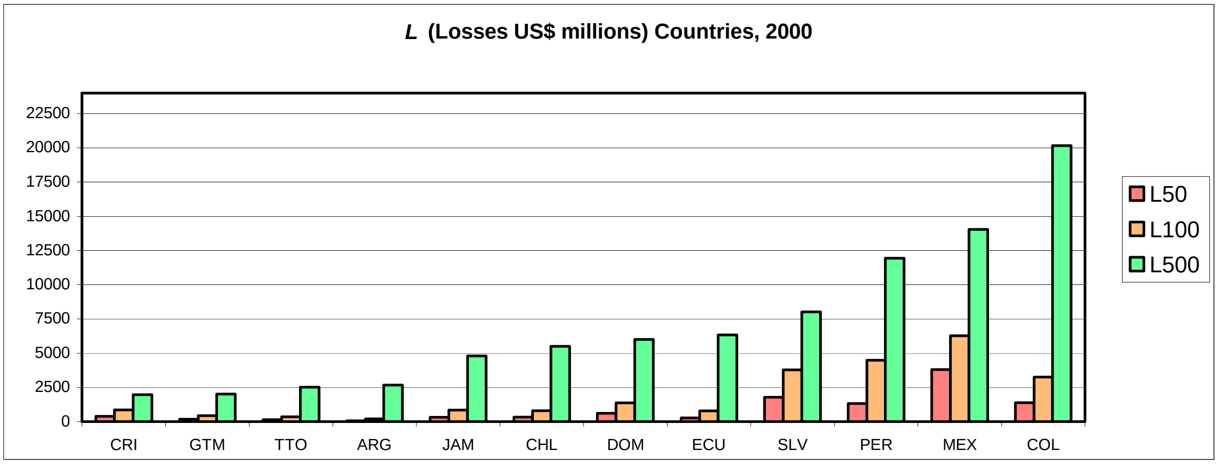
Figures 4.1.11 and 4.1.12 register the maximum probable losses for 50, 100 and 500 year periods of return calculated for 1980 and 2000. These evaluations were made every five years. The figures show that there is an increase in losses over time due to the increase in capital stocks and physical vulnerability (Ordaz and Yamín 2003).

Figure 4.1.11 Probable Maximum Loss in 1980



The calculation of losses was undertaken for extreme events which would cause several losses in simultaneous form according to the hazards which in each country may be considered the cause of the *MCE*. Consequently, the case of hurricanes was studied in countries such as Mexico, Guatemala (GTM) Jamaica, Trinidad and Tobago, and Dominican Republic. Calculations included wind and storm surges. In the case of volcanic eruptions it was confirmed that these would cause relatively located losses in countries such as Ecuador, Colombia, and Central American countries. Flooding is important in Argentina (ARG) and Peru. However, earthquakes were the type of phenomenon that dominated the *MCE* in all countries and for all return periods.

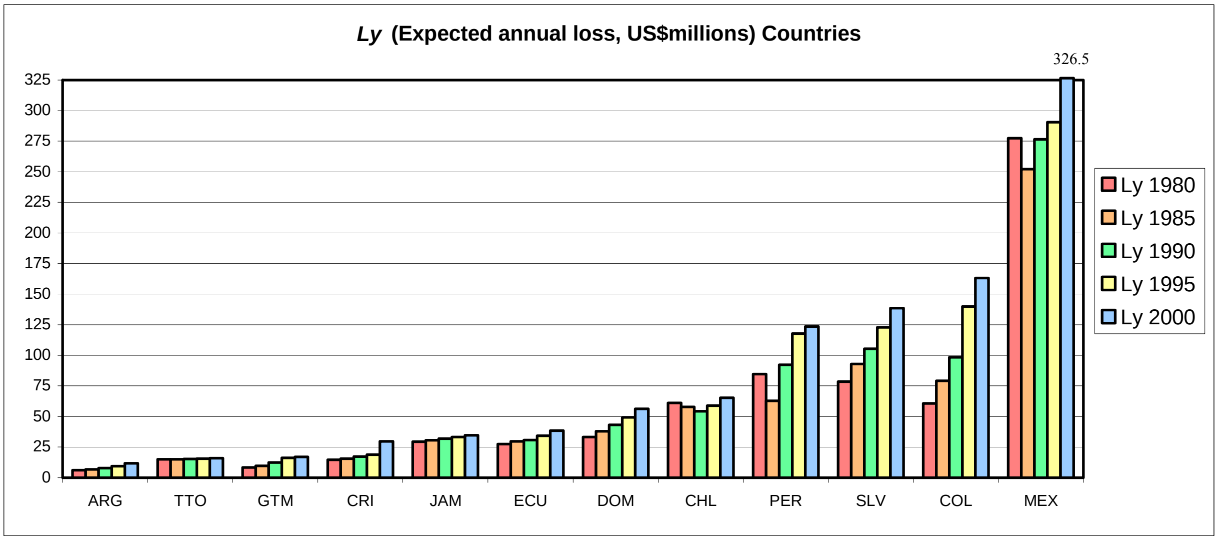
Figure 4.1.12 Probable Maximum Loss in 2000



One piece of data that is very useful for risk assessment is the expected annual loss, L_y^P, which is defined as the expected loss value in any one year. Also it is known as the pure or technical premium. This value is equivalent to the annual average investment or saving that a country would have to make in order to cover approximately losses associated with future major events. Figure

4.1.13 registers evolution of this value during the last 20 years (in millions of dollars). The means for estimating expected annual loss is detailed in the methodological document (Cardona *et al.* 2004a).

Figure 4.1.13 Technical Premium, each five years, between 1980 y 2000



4.1.2 Potentially Available to the Government

In this study (the denominator of the index) following constraints are explicitly taken into consideration: *Insurance and reinsurance payments* for insured government-owned goods and infrastructure (F_1^P); d*isaster reserve funds* (F_2^P); public, private, national or international *aid and donations* (F_3^P); n*ew taxes* (F_4^P); b*udgetary reallocations*, which usually corresponds to the margin of discretional expenses available to the government (F_5^P); e*xternal credit* that the country could obtain from multilateral organizations and in the external capital market (F_6^P); and i*nternal credit* the country may obtain from commercial banks as well as the central bank (F_7^P). Table 4.1.4 registers the value of feasible accessible funds for governments for each period.

In the case of insurance the participation of the "non life" sector in GNP was evaluated and this proportion of loss was considered covered by insurance companies. The disaster funds were obtained from the reserves laid aside by governments in its annual budget with this end in sight. Few countries have this type of reserve. The value of the possible real money donations was estimated as being 5% of total loss (Freeman *et al.* 2002a). This is considered very conservative estimate.

Table 4.1.4 Possible Funds Available to Government in Each Period (US$ millions)

Year	Funds	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER	TTO
1980	$F1p_{50}$	0.37	28.55	6.11	1.57	2.87	2.58	23.73	0.95	4.07	30.35	5.28	0.68
	$F1p_{100}$	1.39	60.81	14.28	3.46	6.53	7.50	50.48	2.27	10.90	50.49	17.80	1.82
	$F1p_{.500}$	19.86	208.09	88.49	7.97	28.82	61.02	105.45	10.60	61.68	117.15	47.46	13.18
	F2p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.50	0.00	13.97	0.00	0.00
	$F3p_{50}$	10.54	390.61	42.87	18.06	35.25	31.09	93.10	7.56	28.65	368.32	60.61	13.46
	$F3p_{100}$	25.38	791.98	93.63	38.92	74.42	76.80	189.48	16.74	69.64	770.43	205.43	32.69
	$F3p_{500}$	196.29	3092.66	488.42	157.74	386.56	525.11	658.51	83.25	387.88	3210.76	1026.95	217.11
	F4p	0.00	0.00	229.85	0.00	0.00	0.00	24.30	276.81	0.00	0.00	0.00	0.00
	F5p	1213.84	445.53	826.12	149.82	205.62	166.16	116.91	254.24	107.20	5869.63	546.29	451.60
	F6p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F7p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	R_{E50}	1224.75	864.69	1104.95	169.45	243.73	199.83	258.04	590.06	139.92	6282.26	612.17	465.74
	R_{E100}	1240.61	1298.32	1163.88	192.20	286.57	250.46	381.18	600.57	187.74	6704.52	769.52	486.12
	R_{E500}	1429.98	3746.29	1632.88	315.53	620.99	752.28	905.18	675.40	556.76	9211.50	1620.69	681.90
1985	$F1p_{50}$	0.42	26.32	8.11	1.68	3.32	2.83	21.52	2.06	56.75	33.85	2.84	0.70
	$F1p_{100}$	1.58	56.06	18.95	3.70	7.56	8.23	45.81	4.94	151.97	56.27	9.56	1.87
	$F1p_{.500}$	22.48	192.00	117.45	8.53	33.37	66.83	96.24	23.02	859.90	129.99	25.50	13.50
	F2p	0.00	0.00	5.38	0.00	0.00	0.00	0.00	33.67	0.00	187.19	0.00	0.00
	$F3p_{50}$	11.72	369.30	56.06	19.04	40.21	33.65	110.10	8.82	29.76	403.36	44.96	13.59
	$F3p_{100}$	28.25	748.70	122.45	41.04	84.90	82.96	224.21	19.53	72.35	842.94	152.41	33.01
	$F3p_{500}$	218.55	2923.22	638.74	166.34	440.98	565.14	783.60	97.12	402.94	3501.11	761.87	219.00
	F4p	0.00	0.00	240.14	0.00	0.00	0.00	21.18	341.57	0.00	0.00	0.00	0.00
	F5p	795.34	299.41	537.99	81.51	96.85	81.04	77.94	194.92	71.47	4138.75	303.11	301.07
	F6p	0.00	164.86	0.00	0.00	0.00	0.00	0.00	0.00	25.20	553.42	0.00	0.00
	F7p	0.00	164.86	0.00	0.00	0.00	0.00	0.00	0.00	25.20	553.42	0.00	0.00
	R_{E50}	807.49	1024.75	847.68	102.23	140.38	117.52	230.74	581.03	208.38	5869.99	350.91	315.36
	R_{E100}	825.17	1433.88	924.91	126.25	189.31	172.23	369.14	594.62	346.20	6331.98	465.08	335.94
	R_{E500}	1036.37	3744.34	1539.71	256.38	571.19	713.01	978.96	690.29	1384.72	9063.87	1090.47	533.56

Year	Funds	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER	TTO
1990	$F1p_{50}$	0.49	28.67	10.22	1.90	3.84	2.99	18.88	1.62	37.57	37.71	5.17	0.72
	$F1p_{100}$	1.81	61.03	23.89	4.19	8.75	8.67	40.20	3.88	100.62	62.63	17.41	1.92
	$F1p_{.500}$	25.86	209.20	148.06	9.64	38.64	70.40	84.77	18.08	569.36	144.06	46.41	13.88
	F2p	0.00	112.09	5.60	0.00	0.00	0.00	0.00	40.40	0.00	4.25	0.00	0.00
	$F3p_{50}$	13.29	347.22	69.62	21.22	45.87	34.95	124.86	11.33	30.95	441.21	66.11	13.78
	$F3p_{100}$	32.02	703.87	152.07	45.74	96.85	86.10	254.37	25.11	75.23	921.18	224.08	33.46
	$F3p_{500}$	247.71	2747.95	793.28	185.37	503.06	586.01	892.36	124.84	419.05	3813.21	1120.14	221.80
	F4p	0.00	0.00	329.26	0.00	0.00	0.00	32.69	268.78	0.00	0.00	155.13	0.00
	F5p	415.29	414.09	621.40	100.55	215.29	164.35	93.53	203.39	85.76	3957.15	266.40	361.28
	F6p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.62	2889.81	0.00	0.00
	F7p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.62	2889.81	0.00	0.00
	RE_{50}	429.06	902.06	1036.11	123.68	265.00	202.28	269.97	525.53	365.52	10219.93	492.81	375.78
	RE_{100}	449.12	1291.08	1132.22	150.48	320.89	259.11	420.79	541.56	472.86	10724.82	663.02	396.66
	RE_{500}	688.86	3483.33	1897.60	295.57	756.98	820.76	1103.35	655.49	1285.41	13698.29	1588.09	596.96
1995	$F1p_{50}$	0.60	35.79	14.83	2.12	4.47	3.42	19.15	1.85	12.38	42.26	3.68	0.75
	$F1p_{100}$	2.23	76.21	34.66	4.66	10.19	9.90	40.78	4.43	33.15	69.98	12.40	2.00
	$F1p_{.500}$	31.76	261.93	214.85	10.75	44.96	80.21	86.34	20.66	187.54	158.13	33.04	14.40
	F2p	0.00	275.97	17.50	158.93	0.00	0.00	0.00	101.00	0.00	0.00	43.44	0.00
	$F3p_{50}$	15.95	375.64	99.05	23.18	52.33	39.24	145.31	14.74	32.19	478.37	84.40	14.03
	$F3p_{100}$	38.45	761.60	216.35	49.96	110.49	96.41	296.14	32.65	78.25	995.92	286.08	34.08
	$F3p_{500}$	297.72	2977.94	1128.58	202.49	573.89	651.83	1042.99	162.33	435.78	4065.25	1430.07	225.67
	F4p	0.00	0.00	636.63	1423.90	0.00	4.97	874.60	514.93	0.00	0.00	0.00	0.00
	F5p	1788.70	1218.63	1847.72	133.77	488.89	477.54	233.96	508.49	274.30	3180.04	1064.71	91.19
	F6p	0.00	652.16	0.00	82.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	266.46
	F7p	0.00	652.16	0.00	82.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	266.46
	RE_{50}	1805.25	3210.35	2615.73	1905.92	545.69	525.16	1273.01	1141.01	318.86	3700.67	1196.23	638.89
	RE_{100}	1829.38	3636.73	2752.86	1935.25	609.56	588.82	1445.48	1161.50	385.69	4245.94	1406.63	660.18
	RE_{500}	2118.18	6038.78	3845.28	2093.85	1107.74	1214.55	2237.88	1307.42	897.62	7403.42	2571.27	864.18
2000	$F1p_{50}$	0.77	32.71	17.69	3.43	5.22	3.93	25.85	1.87	25.27	46.86	2.66	0.78
	$F1p_{100}$	2.87	69.64	41.34	7.55	11.89	11.38	55.08	4.48	67.67	77.47	8.96	2.09
	$F1p_{.500}$	40.93	239.79	256.26	17.40	52.46	92.02	117.10	20.89	383.19	173.32	23.88	15.07
	F2p	0.00	343.83	4.77	165.47	0.00	0.00	0.00	111.10	0.00	421.11	110.61	0.00
	$F3p_{50}$	20.04	416.27	115.48	36.68	59.69	44.10	163.94	15.62	33.79	514.54	88.43	14.37
	$F3p_{100}$	48.31	844.05	252.24	79.06	126.04	108.25	334.25	34.59	82.14	1069.10	299.74	34.88
	$F3p_{500}$	374.30	3303.69	1315.80	320.42	654.69	729.99	1182.10	172.02	457.82	4331.13	1498.36	230.83
	F4p	0.00	0.00	496.66	1854.38	0.00	18.62	1343.99	671.53	0.00	0.00	0.00	0.00
	F5p	1735.21	1453.84	1659.12	226.07	418.50	546.38	257.26	564.71	236.06	5736.41	850.04	103.80
	F6p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.25	0.00	0.00	161.09
	F7p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.25	0.00	0.00	161.09
	RE_{50}	1756.02	2246.65	2293.73	2286.03	483.41	613.03	1791.04	1364.83	387.62	6718.91	1051.73	441.14
	RE_{100}	1786.39	2711.37	2454.13	2332.53	556.43	684.63	1990.57	1386.41	478.38	7304.08	1269.34	462.97
	RE_{500}	2150.44	5341.15	3732.61	2583.73	1125.65	1387.01	2900.45	1540.25	1169.57	10661.96	2482.88	671.89

The feasible value of new taxes was obtained by a specific procedure described in the methodology. Few countries considered the charging of new taxes feasible in cases of disaster. On the contrary, in many cases it is suggested that these should be reduced. The margin of budgetary reallocation was calculated as 60% of capital expenditures or fixed assets of government in the year for which calculations were made.

One of the aspects that impeded the use of the external debt indicator originally proposed in the methodology (Cardona *et al.* 2004a) was its high level of sensitivity to erratic changes in the real exchange and interest rates. In effect, during the 1980s Latin America countries suffered a large scale of external shocks that generated considerable macroeconomic instability. Additionally, external debt crisis and hyperinflation must be taken into account. In this context the real interest rates were negative and exchange rates were extremely volatile. As indicators are valid approximations when such variables are “normal”, results were not trustworthy.

In the same way, the originally proposed internal credit indicator could not be used given that during the same period institutional changes were implemented and those made any reasonable supposition as regards access to internal debt resources invalid. As regards it is important to point out that the Central Banks are independent and this impedes government accedes to direct monetary credit.

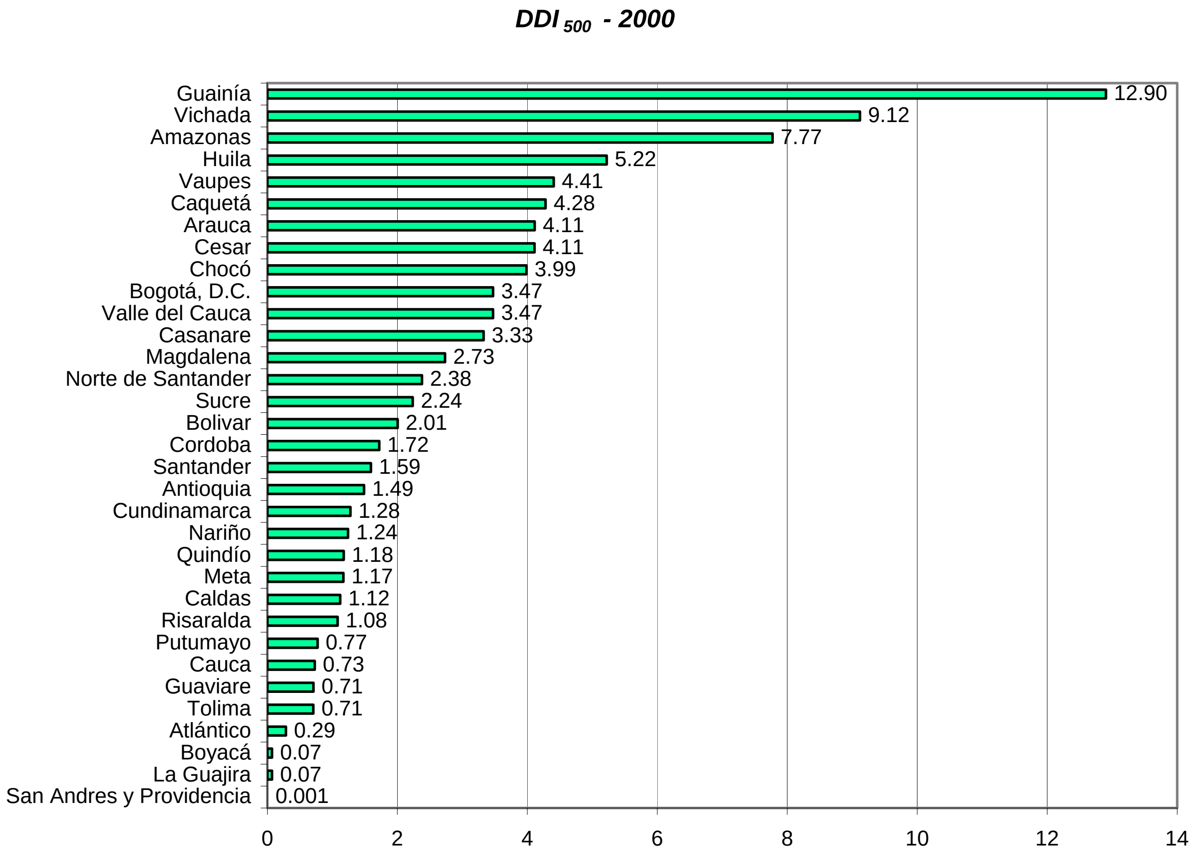
Methods originally proposed for estimating possibility of internal and external credit are adequate only when the macroeconomic conditions are relatively stable. Due to this we opted to use a new indicator known as the “sustainability frontier”. If a country is outside of this frontier it is impossible to obtain new credits. These evaluations were made under the hypothesis of the present situation even though in reality they were retrospective analysis (for the 1980s and 1990s). Most of the countries fell outside the debt sustainability frontier in all periods analyzed.

4.1.3 Sub-national Level Evaluation

DDI can be estimated to the interior of a country for sub-national units such as states, departments or provinces. Barbat and Carreño (2004b) and Carreño *et al.* (2005) present application results for Colombia in a detailed form, as a demonstrative example within present study frame. In order to estimate the *DDI*, loss caused by *MEC* of each department was calculated and economic resilience was obtained based on available resources for disasters prevention and attention and reassignment of investment budget of each department.

Figure 4.1.14 shows the *DDI* for year 2000 and for a *MCE* of 500 years of return period in 32 departments of Colombia. This example of the evaluation of *DDI* was obtained taking into account only the economic resilience of each department and without participation of national government.

Figure 4.1.14. DDI_{500} for Colombia, by Department (2000)



4.2 The Local Disaster Index (LDI)

LDI was estimated for each country by means of an especial numerical treatment of aggregation that was explained in the previous section, taking into account deaths (k), affected people (A) and economic losses (L) by four types or groups of events. The total *LDI* is the sum of these individual sub-indexes. Each sub-index captures incidence and uniformity of effect distribution at local level, gives the idea of the relative weight of the effects caused by different class of events in each municipality, and reflects the persistency of the effects on livelihoods and local development.

The value of the local disaster sub-indices, *LDI* (K,A,L) increases if an uniform distribution of the variable (effects) exists amongst municipalities and the different types of event. Thus the lowest values signify a high level of disparity and that the variable is concentrated. The maximum value of the sub-index is 100. This means that the variable is similar for all types of event and that there is a similar distribution between municipalities.

Table 4.2.1 shows the accumulated figures of deaths, affected people and economic losses in thousands of dollars in each period and for each country. Also the table includes the figures of the calculated indices to which reference is made further on.

Table 4.2.1 Accumulated Values and Indices for Each Period and Country

Period	Unit	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER	TTO
1981-1985	Deaths	562	627	25,390	42	105	723	674	No data	29	5,416	1,502	27
	Affected	294,926	278,698	1,876,213	4,495	23,350	8,654	62,122	No data	60,086	588,540	775,745	62
	Losses	168,808	282,336	384,976	11,692	8,347	15,393	6,123	No data	394	635,557	252,398	17
	LDIK	64.7	14.4	14.1	48.2	41.5	68.6	49.1	--	17.1	17.3	55.0	8.7
	LDIA	7.0	59.0	4.1	67.4	5.0	3.4	56.6	--	6.5	72.3	20.3	18.1
	LDIL	6.9	59.7	8.0	40.3	45.3	11.4	72.4	--	39.4	59.5	0.6	87.4
	LDI	78.7	133.1	26.1	155.8	91.8	83.4	178.0	--	63.0	149.1	75.9	114.3
	LDI'	0.89	0.92	0.97	0.92	0.83	0.92	0.84	--	0.78	0.94	0.92	0.58
1986-1990	Deaths	343	663	1,864	101	89	806	57	372	48	1,333	1,513	4
	Affected	1,637,503	481,594	1,300,795	8,907	90	185,761	9,923	380,041	194	2,042,818	464,013	2,951
	Losses	58,868	102,974	200,832	3,266	38,222	3,255	731	8,576	9,527	527,271	39,667	41
	LDIK	63.9	1.2	60.1	10.4	40.9	32.4	24.6	49.6	40.7	47.0	29.5	24.0
	LDIA	31.5	53.8	8.4	38.9	0.0	66.5	11.3	3.4	0.9	6.9	54.4	0.0
	LDIL	8.1	65.9	13.0	21.1	57.6	87.0	61.9	33.7	0.2	1.0	56.5	2.1
	LDL	103.5	120.9	81.5	70.5	98.5	185.8	97.8	86.7	41.8	54.9	140.4	26.1
	LDI'	0.88	0.95	0.91	0.82	0.91	0.89	0.88	0.76	0.84	0.98	0.87	0.63
1991-1995	Deaths	325	620	1,626	138	418	888	118	507	23	520	1,794	7
	Affected	2,252,716	510,088	1,676,522	75,949	123,665	15,381	55,935	47,852	2,301	95,272	655,272	154
	Losses	72,816	113,017	417,849	27,655	55,712	16,535	2,715	17,049	293	17,594	374,515	8,523
	LDIK	40.5	5.9	81.7	80.2	49.4	67.0	43.8	11.4	66.6	28.5	27.0	0.0
	LDIA	0.9	26.2	9.2	74.4	11.0	23.7	66.2	34.2	81.7	48.3	31.7	61.5
	LDIL	1.7	63.9	15.9	48.8	33.0	65.9	37.4	89.7	57.3	33.7	41.8	0.0
	LDL	43.1	95.9	106.8	203.4	93.5	156.6	147.5	135.3	205.6	110.5	100.6	61.5
	LDI'	0.86	0.93	0.91	0.92	0.89	0.90	0.90	0.79	0.69	0.78	0.92	0.75
1996-2000	Deaths	418	344	2,540	116	101	1,048	126	604	18	1,826	1,980	3
	Affected	6,867,980	321,079	4,573,352	44,223	1,663	61,845	53,055	1,078,718	2,114	573,801	1,229,281	2,972
	Losses	74,783	78,366	985,085	26,756	40,340	89,654	598	738,919	80	329,937	546,818	232,875
	LDIK	66.7	2.5	90.5	65.2	42.9	82.1	33.0	74.3	19.3	58.1	46.3	0.0
	LDIA	60.7	43.6	13.0	12.0	77.9	34.7	42.2	83.9	24.9	2.3	24.4	0.3
	LDIL	50.4	59.2	40.6	14.6	38.8	20.1	75.3	41.1	11.1	32.5	4.0	20.2
	LDL	177.7	105.3	144.1	91.8	159.6	136.8	150.5	199.3	55.4	92.9	74.7	20.5
	LDI'	0.88	0.91	0.91	0.83	0.83	0.93	0.84	0.89	0.64	0.89	0.92	0.52

Losses (US$ 000)

Figures 4.2.1 – 4.2.3 illustrate variation of the accumulated values of losses, affected people and number of killed people in each country from 1980 to the 2000, in periods of five years. Figure 4.2.2 does not include the total number of affected people in Argentina and Colombia in the period 1996-2000, that surpass the 4.5 and 6.8 million people respectively. Also, the total number of deaths in Colombia and Mexico are not included in figure 4.2.3 for the period 1980-1985. These surpass 25,000 and 5,000 respectively. Figures 4.2.4 – 4.2.6 illustrate the sub-indices calculated taking into account independently losses, affected people and deaths.

Figure 4.2.1 Economic Losses in Periods of 5 years

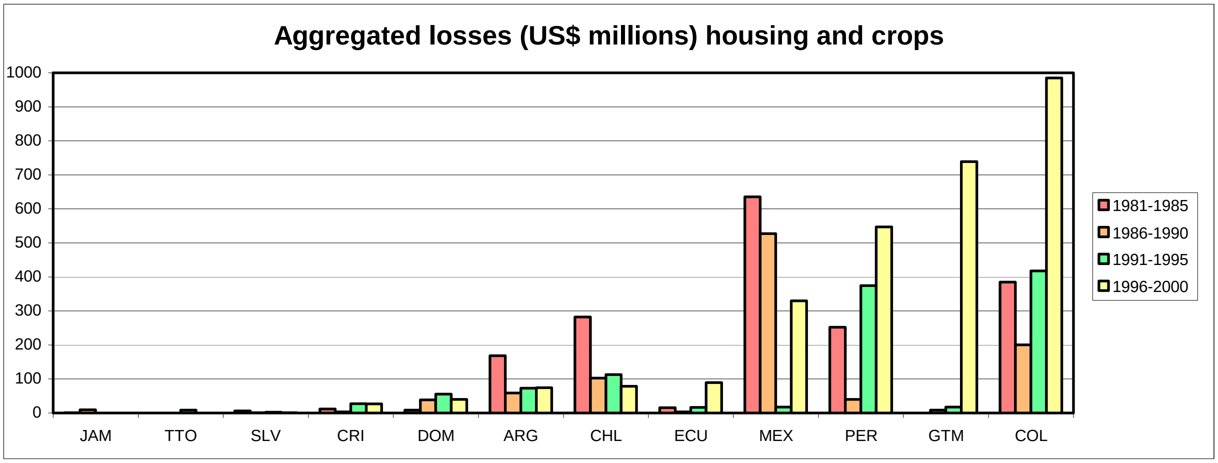


Figure 4.2.2 Affected Persons in Periods of 5 years

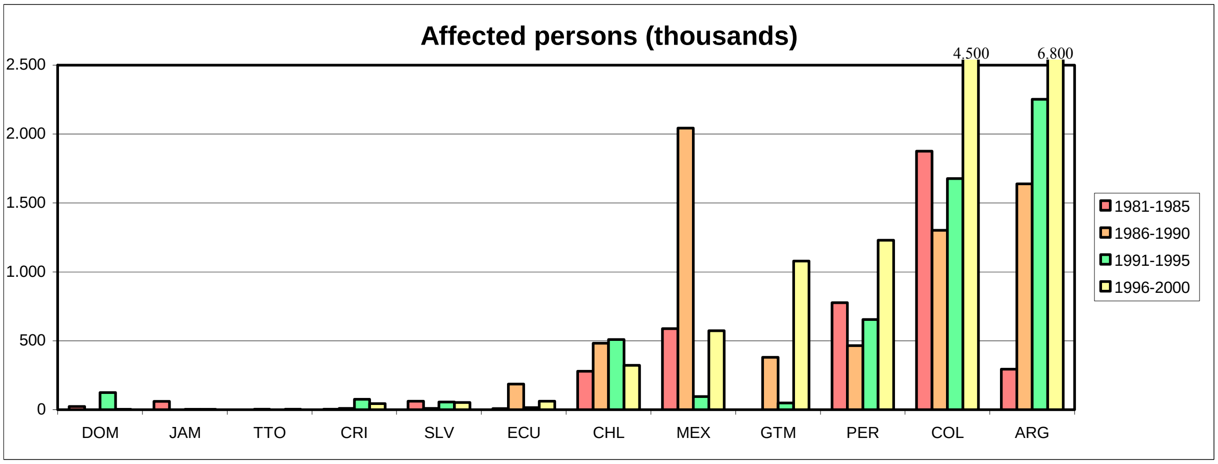


Figure 4.2.3 Deaths in Periods of 5 years

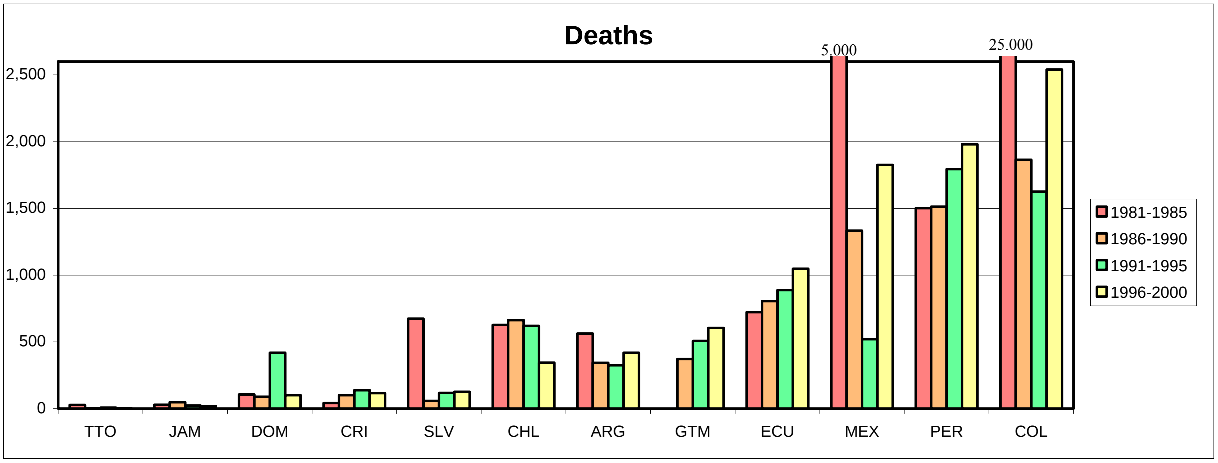


Figure 4.2.4 LDI_L for Losses in Each Period and Country

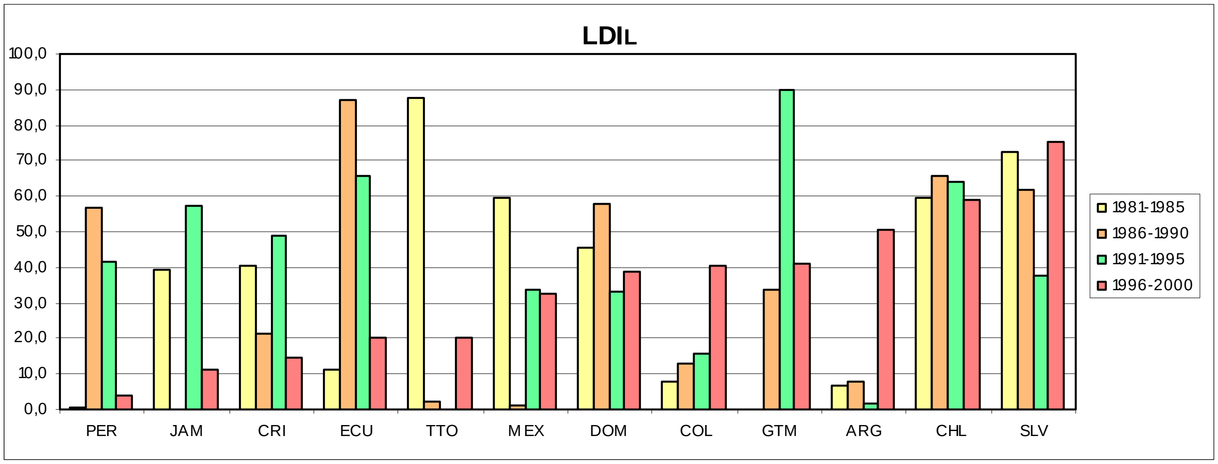


Figure 4.2.5 LDI_A for Affected People in Each Period and Country

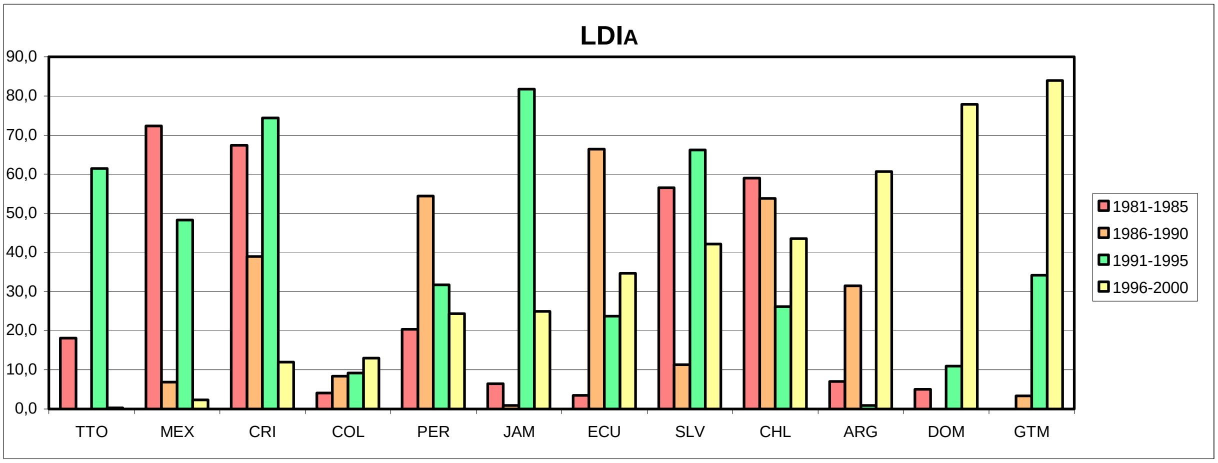


Figure 4.2.6 LDI_K for Deaths in Each Period and Country

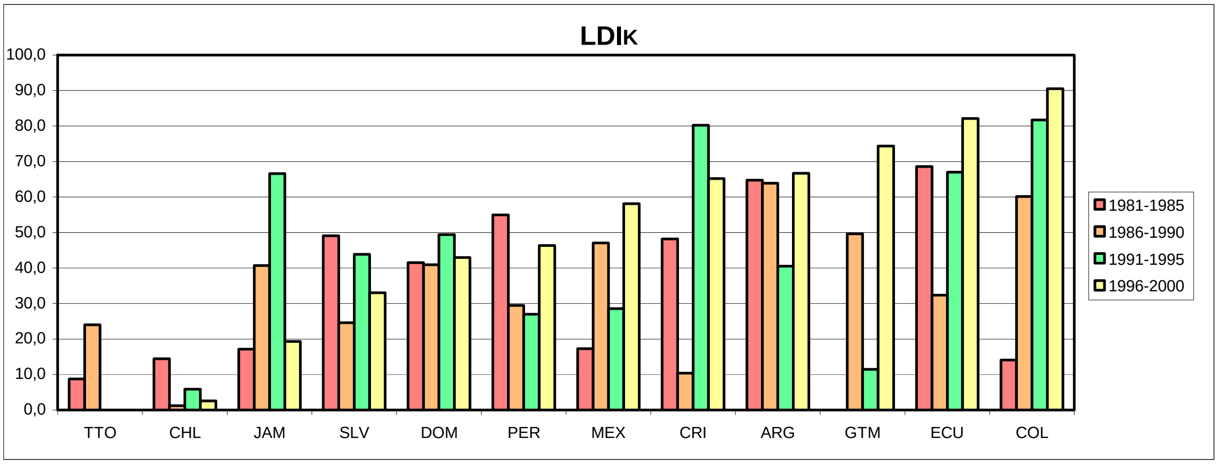
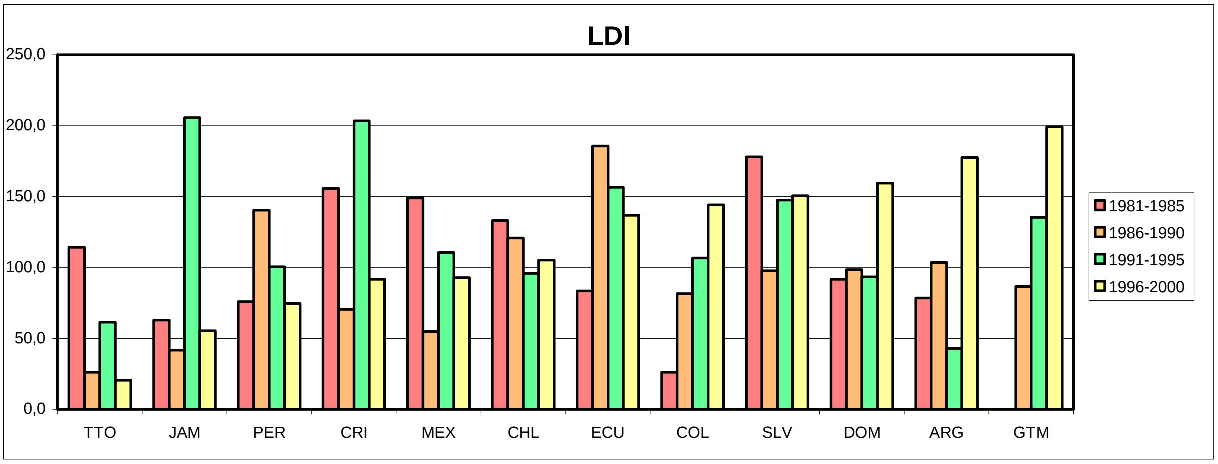


Figure 4.2.7 shows the total *LDI* for countries in each period as obtained by summing the three components (sub-indices) or *LDI*s related to losses, affected persons and deaths.

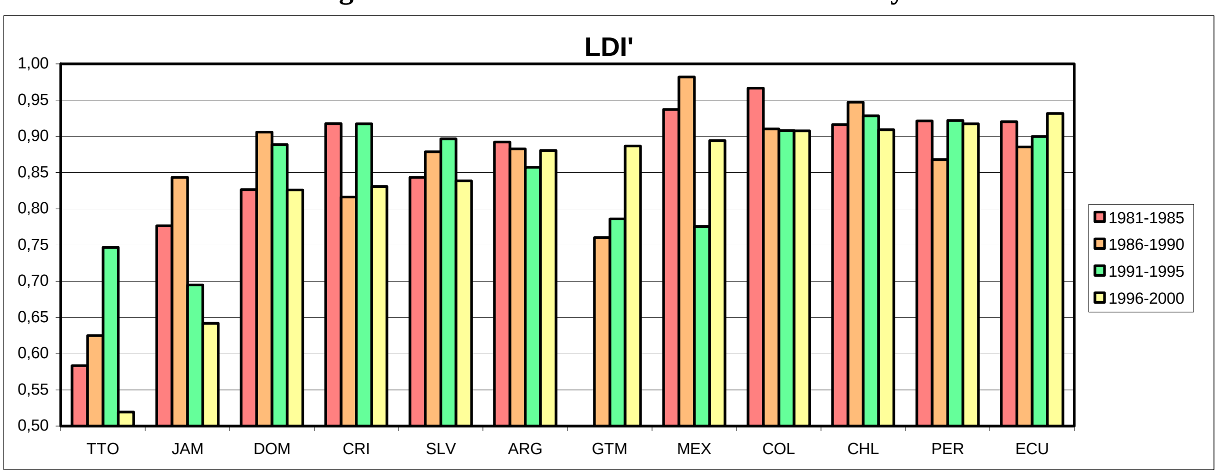
Figure 4.2.7 Aggregated LDI for each period and country



The higher the *LDI*, the greater the relative regularity in the magnitude and distribution of effects between all municipalities, due to the different types of hazard. Guatemala, Argentina, Dominican Republic, Colombia and El Salvador, in general, show a tendency for the *LDI* to increase over the years. On the other hand, Ecuador, Chile, Mexico and Peru show a tendency for the *LDI* to decrease. These tendencies could be associated with positive and negative processes of environmental deterioration.

In addition, a *LDI*' has been formulated which indicates the level of concentration of effects and summed losses (direct physical damage) for all events in each country, at the municipal level. Table 4.2.1 presents the *LDI*' and figure 4.2.8 shows the value of this index for each country in the different periods.

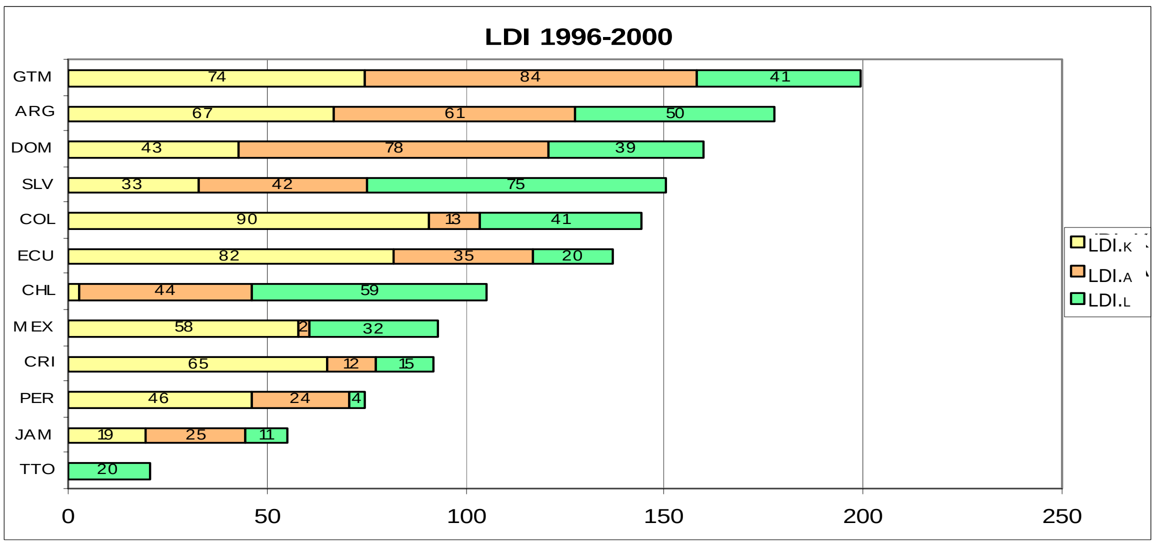
Figure 4.2.8 LDI' for Each Period and Country



The *LDI'* indicates that in countries such as Ecuador, Peru, Chile, Colombia, and even in Argentina, it has been constant that a smaller percentage of municipalities concentrates most of the losses in the period. A *LDI'* between 0.90 and 0.95 means that 10% of the municipalities of the country concentrates between 80% and 90% of the losses that have appeared, respectively. See previous section and methodology (Cardona *et al.* 2004). Values in Mexico and Colombia stand out when extreme disasters have affected many municipalities simultaneously.

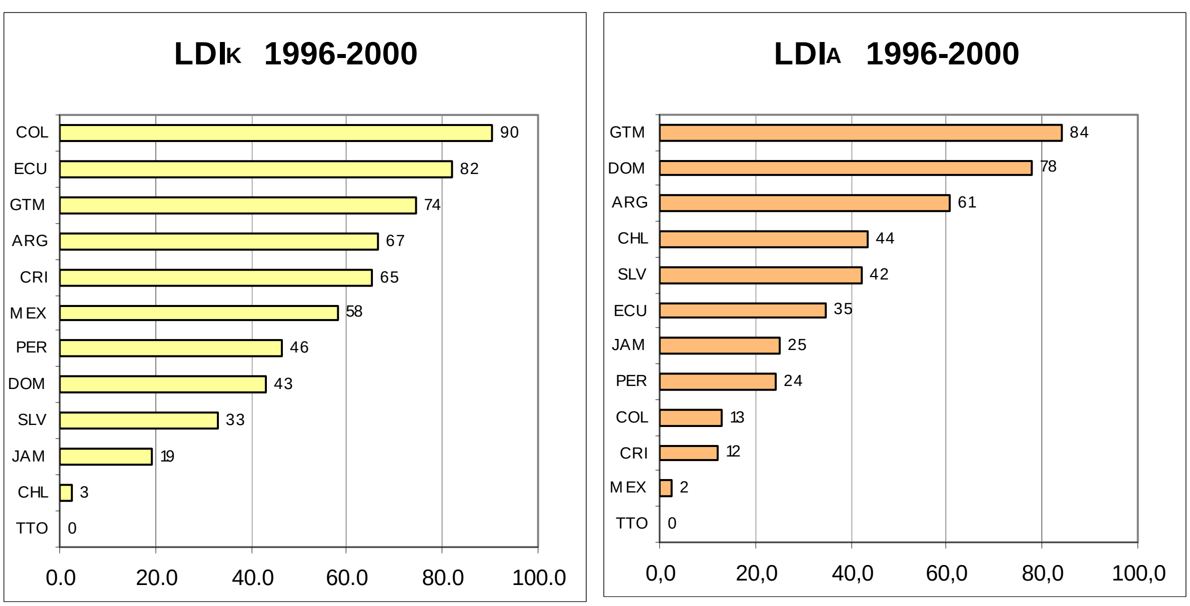
Figure 4.2.9 shows the total *LDI* in 2000, which was obtained by adding its three components: the *LDI* related to the number of deaths (K), the number of people affected (A), and total losses (L).

Figure 4.2. 9 Total LDI



The left side of figure 4.2.10 shows the *LDI* for 1996 - 2000 based on number of deaths, LDI_K. The right side of the figure shows the indicator for the number of persons affected, LDI_A.

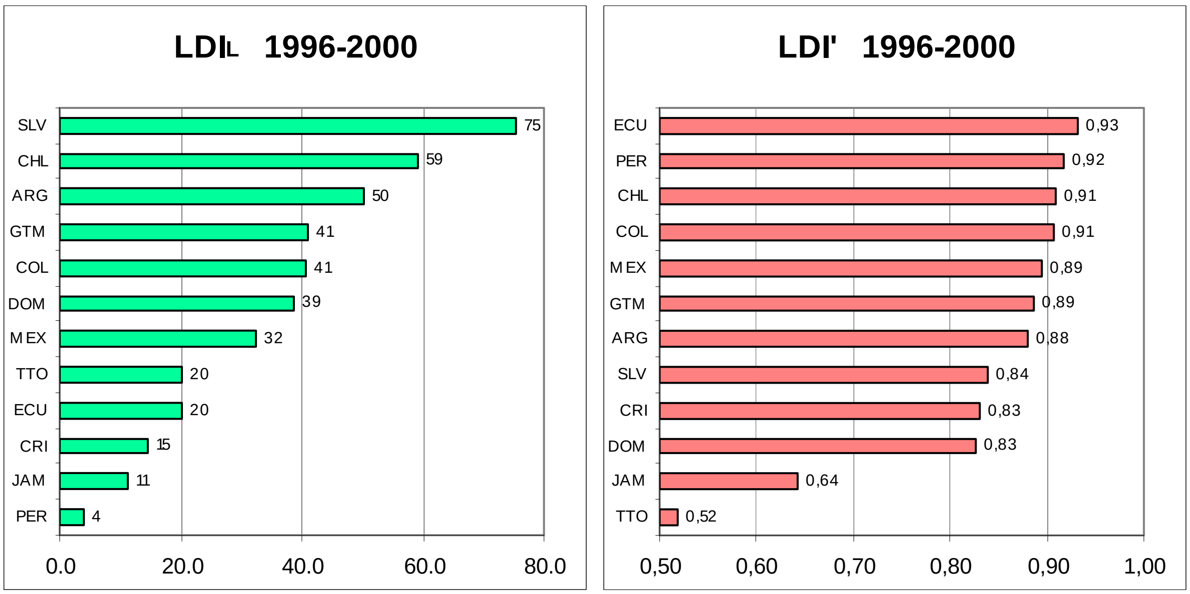
Figure 4.2.10 LDI_K and LDI_A



The data for Colombia and Ecuador show that, during this period, there was a greater incidence and persistence in the distribution of deaths among municipalities. However, data for Guatemala (GTM) and the Dominican Republic show a greater incidence and persistence in the distribution of the number of people affected. Disasters between 1996 and 2000 generated numerous landslides and floods in many municipalities in these four countries. Colombia was affected by an earthquake in coffee growing areas in 1999, and by extensive flooding in the north in 1995 and 2000. Guatemala suffered the consequences of hurricane Mitch, while the Dominican Republic was buffeted by hurricane Georges in 1998.

The left side of figure 4.2.11 shows the *LDI* for 1996-2000. The right side of the figure shows *LDI'* for the same period.

Figure 4.2.11 LDI_L and LDI'

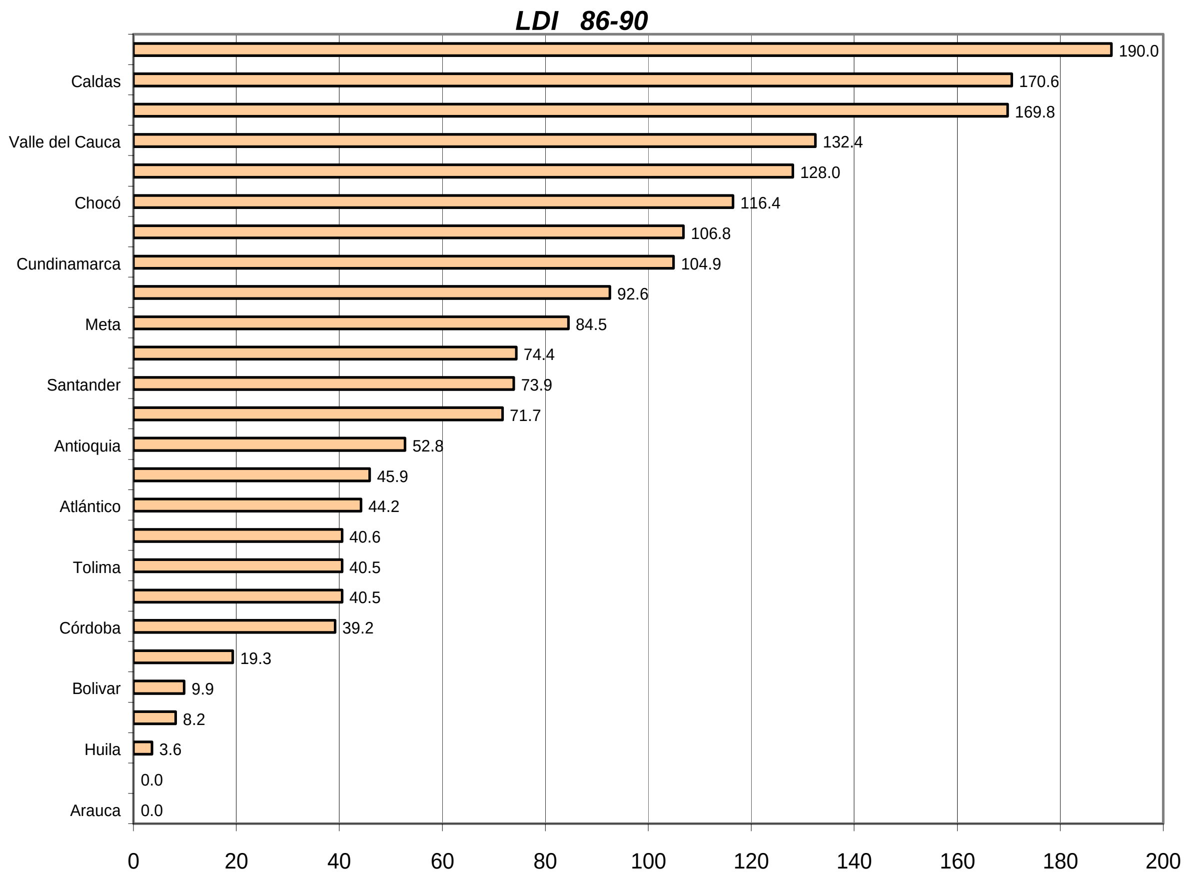


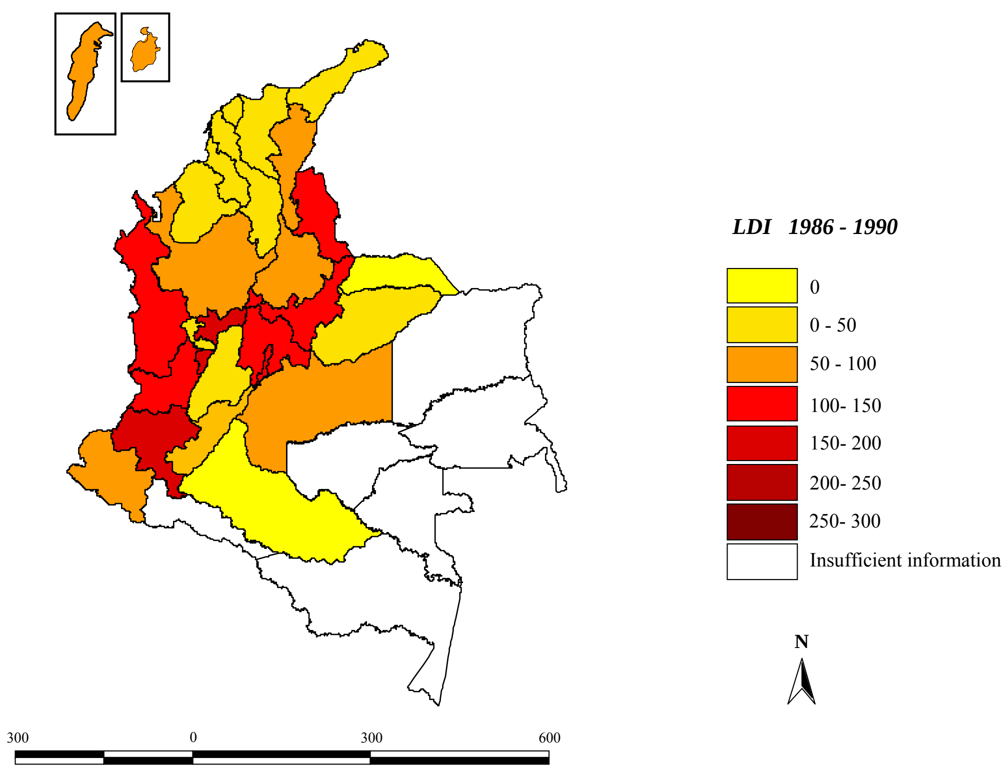
LDI_L shows relative losses in El Salvador were more similar and more evenly distributed among all municipalities than in other countries. This means that there is a lower variability of risk in the country. *LDI'* shows that in countries such as Chile, Colombia, Ecuador and Peru, losses during the period studied were concentrated in a few municipalities. An *LDI'* of 0.93, 0.92 and 0.91 signifies that 10 percent of the municipalities concentrate 82, 78 and 75 percent of losses, respectively (see methodology: Cardona *et al.* 2004a, 2004b, and 2005). This aspect is explained in more detail at the previous section.

4.2.1 Sub-national Level Evaluation

LDI can be estimated to the interior of a country for sub-national units such as states, departments or provinces. Barbat and Carreño (2004b) and Carreño *et al.* (2005) present application results for Colombia in a detailed form, as a demonstrative example within present study frame. Figure 4.2.12 shows an example of the *LDI* aggregated value for departments of Colombia between 1986 and 2000.

Figure 4.1.2.1. 1 Aggregated LDI for for Colombia, by Department (1986-1990)





4.3 The Prevalent Vulnerability Index (PVI)

On the whole, the *PVI* reflects susceptibility due to exposure degree of the physical goods and people; this favors direct impact. Besides, it reflects the social and economic fragility conditions that favor indirect and intangible impact. And, also, it reflects the lack of capacity to absorb the consequences, for responding efficiently and for recovering. A reduction of these types of factors as a result of a sustainable process of human development and explicit policies of risk reduction are one of the aspects that must be given special attention. Table 4.3.1 shows the values of the *PVI* and the indices that compose it.

Table 4.1.3.1 PVI composite sub-indicators for each country and period

Year	Ind	Weights[41]	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER	TTO
1985	ES	Equal	15.56	19.00	26.05	46.06	45.92	50.38	39.46	36.18	56.70	30.85	29.24	53.91
		AHP	13.08	14.82	23.33	40.03	47.66	66.03	39.62	43.91	71.79	28.11	28.66	51.48
		Budget	12.97	23.06	25.94	40.55	48.10	53.20	32.63	43.30	49.31	30.10	29.88	50.14
		Unify	14.96	16.95	23.33	37.86	38.90	56.38	36.76	40.82	54.10	28.48	28.97	52.31
	SF	Equal	29.44	26.47	27.65	27.85	31.68	26.08	51.18	52.09	48.18	23.48	22.88	24.44
		AHP	23.39	18.89	26.56	29.51	31.61	25.99	49.66	63.44	54.23	25.05	22.00	25.36
		Budget	23.80	18.66	28.03	29.50	30.84	26.23	50.54	57.62	47.68	22.28	22.02	23.88
		Unify	28.28	27.72	26.56	23.67	31.76	24.59	49.37	57.64	44.48	20.76	22.50	28.48
	LR	Equal	13.77	20.71	53.93	31.49	63.31	60.48	74.58	92.11	55.77	62.26	66.44	41.04
		AHP	17.65	21.99	51.47	22.81	60.46	52.55	74.97	95.47	58.67	61.87	70.71	43.38
		Budget	18.00	20.14	53.14	22.50	59.98	59.00	75.39	91.40	60.29	66.27	70.06	43.63
		Unify	13.16	15.91	51.47	24.99	60.88	57.93	74.27	92.11	54.60	57.95	63.81	44.25
	PVI	Equal	19.59	22.06	35.88	35.13	46.97	45.65	55.07	60.13	53.55	38.86	39.52	39.80
		AHP	18.04	18.57	33.79	30.78	46.58	48.19	54.75	67.61	61.56	38.34	40.46	40.07
		Budget	18.26	17.64	35.70	30.85	46.31	46.14	52.85	64.11	52.43	39.55	40.65	39.21
		Unify	18.80	20.19	33.79	28.84	43.85	46.30	53.46	63.52	51.06	35.73	38.43	41.68
1990	ES	Equal	12.00	30.55	28.16	52.59	55.06	54.63	50.47	43.89	56.08	33.49	24.98	45.65
		AHP	13.36	24.49	23.87	48.33	54.08	69.67	50.31	46.77	70.65	31.76	22.66	42.34
		Budget	12.59	23.06	27.66	48.64	55.00	57.26	52.46	49.39	49.09	33.41	22.91	41.81
		Unify	12.21	27.84	23.87	44.02	47.87	60.19	45.23	46.71	53.78	32.75	24.13	44.77
	SF	Equal	23.23	24.23	34.47	26.45	32.18	30.22	44.00	54.22	43.90	19.12	31.70	37.52
		AHP	23.55	12.56	33.14	27.80	31.83	29.74	47.16	64.83	50.35	25.25	35.43	36.59
		Budget	23.32	14.09	34.83	27.55	30.42	30.49	46.16	59.23	42.78	21.38	35.09	36.27
		Unify	23.05	25.03	33.14	22.35	32.75	27.89	44.60	59.47	40.53	18.77	29.86	39.13
	LR	Equal	9.49	24.19	58.46	30.40	66.54	63.72	72.85	91.98	60.92	62.76	75.02	42.04
		AHP	14.18	25.70	55.38	22.22	64.69	55.59	70.80	95.40	62.90	60.04	74.98	44.58
		Budget	14.89	24.58	57.25	21.76	64.24	62.10	73.04	91.42	63.77	66.83	74.58	44.89
		Unify	8.08	20.64	55.38	26.47	64.26	60.98	70.85	91.79	58.79	57.83	70.80	45.78
	PVI	Equal	14.91	26.32	40.37	36.48	51.26	49.52	55.77	63.36	53.63	38.46	43.90	41.74
		AHP	17.03	20.92	37.46	32.78	50.20	51.67	56.09	39.00	61.30	39.02	44.36	41.17
		Budget	16.93	20.57	39.91	32.65	49.89	49.95	57.22	66.68	51.88	40.54	44.19	40.99
		Unify	14.44	24.50	37.46	30.95	48.29	49.69	53.56	65.99	51.03	36.45	41.60	43.23

[41] Variables have been pondered according to expert criteria in each country. Weights were assigned in order to grant each component a relative importance in the context of each particular composite indicator. Three techniques have been used to compare results and evaluate their pertinence: Equal weighting, Budget allocation, Analytic Hierarchy Process, AHP, and one more –Unify– using an average of AHP allocations of all countries (Cardona *et al.* 2004).

Year	Ind	Weights	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER	TTO
1995	ES	Equal	22.38	21.56	30.62	41.61	45.56	42.36	60.52	46.41	53.46	25.75	26.62	50.23
		AHP	39.29	16.57	27.77	38.85	49.03	49.59	63.88	45.89	66.02	26.15	23.97	48.69
		Budget	35.98	13.71	30.55	38.97	50.19	46.26	65.81	52.47	45.23	25.75	25.66	46.14
		Unify	32.76	18.30	27.77	36.52	38.38	41.25	57.46	48.74	48.54	26.06	25.39	52.49
	SF	Equal	33.69	34.42	41.15	26.97	41.56	38.70	44.46	59.64	52.86	40.97	28.77	43.97
		AHP	35.99	31.84	40.04	28.21	37.84	35.29	44.69	63.99	57.57	37.21	28.94	41.65
		Budget	33.03	21.01	41.43	27.90	36.73	37.94	43.90	65.40	51.92	39.78	29.74	40.95
		Unify	33.60	33.86	40.04	25.96	40.50	35.23	44.51	62.78	47.91	38.22	29.27	44.92
	LR	Equal	15.92	23.98	52.68	34.87	64.64	60.40	68.34	92.86	57.77	54.39	69.14	39.12
		AHP	21.70	25.22	51.46	25.64	60.68	55.06	64.77	95.78	60.97	55.50	73.73	42.95
		Budget	22.51	23.23	53.22	25.51	60.30	59.93	69.03	92.74	62.36	58.37	73.45	42.70
		Unify	13.48	19.53	51.46	30.32	61.82	59.84	66.39	92.35	56.32	51.52	66.37	44.36
	PVI	Equal	24.00	26.65	41.48	34.48	50.59	47.16	57.77	66.30	54.70	40.37	41.51	44.44
		AHP	32.32	24.54	39.76	30.90	49.18	46.65	57.78	37.70	61.52	39.62	42.21	44.43
		Budget	30.51	19.32	41.74	30.79	49.07	48.04	59.58	70.20	53.17	41.30	42.95	43.26
		Unify	26.61	23.90	39.76	30.93	46.90	45.44	56.12	67.96	50.92	38.60	40.34	47.25
2000	ES	Equal	21.75	18.59	21.28	44.20	49.85	38.55	59.70	44.92	56.06	30.04	22.75	52.19
		AHP	38.84	14.42	18.01	45.01	50.15	42.64	57.63	28.48	67.67	30.26	22.28	50.35
		Budget	35.58	10.67	21.32	44.95	51.57	41.51	61.68	43.41	47.37	28.16	23.12	47.76
		Unify	32.36	15.78	18.01	41.11	43.48	36.08	54.55	37.58	52.12	29.27	22.10	55.85
	SF	Equal	39.26	34.95	47.29	23.35	36.91	51.85	42.99	51.69	48.05	30.78	24.92	31.24
		AHP	46.50	21.36	48.73	23.29	40.53	51.41	59.18	60.11	55.55	32.07	25.24	32.10
		Budget	46.33	22.98	52.29	23.14	39.68	52.35	52.62	56.40	49.78	36.39	24.92	30.77
		Unify	40.62	34.94	48.73	20.71	40.31	50.10	48.75	56.58	48.00	30.32	25.48	36.42
	LR	Equal	20.47	20.21	44.59	34.15	62.08	62.31	66.54	90.31	59.42	51.27	62.37	41.31
		AHP	33.16	23.23	47.33	26.36	58.69	58.63	63.53	92.25	61.76	55.40	66.88	45.76
		Budget	34.30	21.52	47.24	25.60	58.28	62.72	66.64	90.20	61.37	57.53	66.46	45.46
		Unify	20.61	18.30	47.33	31.75	58.85	63.70	66.48	89.60	58.00	50.16	60.37	48.09
	PVI	Equal	27.16	24.59	37.72	33.90	49.61	50.91	56.41	62.31	54.51	37.36	36.68	41.58
		AHP	39.50	19.67	38.03	31.55	49.79	50.90	60.11	31.01	61.66	39.24	38.14	42.73
		Budget	38.74	18.39	40.28	31.23	49.85	52.19	60.31	63.34	52.84	40.70	38.17	41.33
		Unify	31.20	23.01	38.03	31.19	47.55	49.96	56.59	61.25	52.71	36.59	35.98	46.79

Indicators used for describing exposure, prevalent socio-economic conditions and lack of resilience have been formulated in a consistent fashion (directly or in inverse fashion, accordingly), recognizing that their influence explains why adverse economic, social and environmental effects are consummated when a dangerous event occurs.

Figure 4.3.1 shows the PVI_{ES}, figure 4.3.2 shows the PVI_{SF} and figure 4.3.3 shows the IVP_{LR} by country and period, using AHP weighting.

Figure 4.3.1 PVI for Exposure and Susceptibility

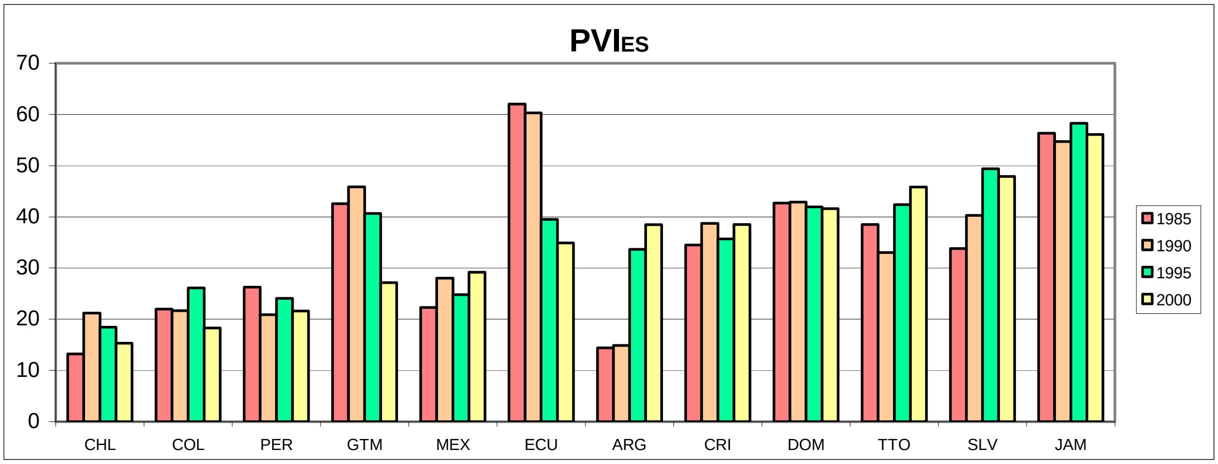


Figure 4.3.2 PVI for Socio-economic Fragility

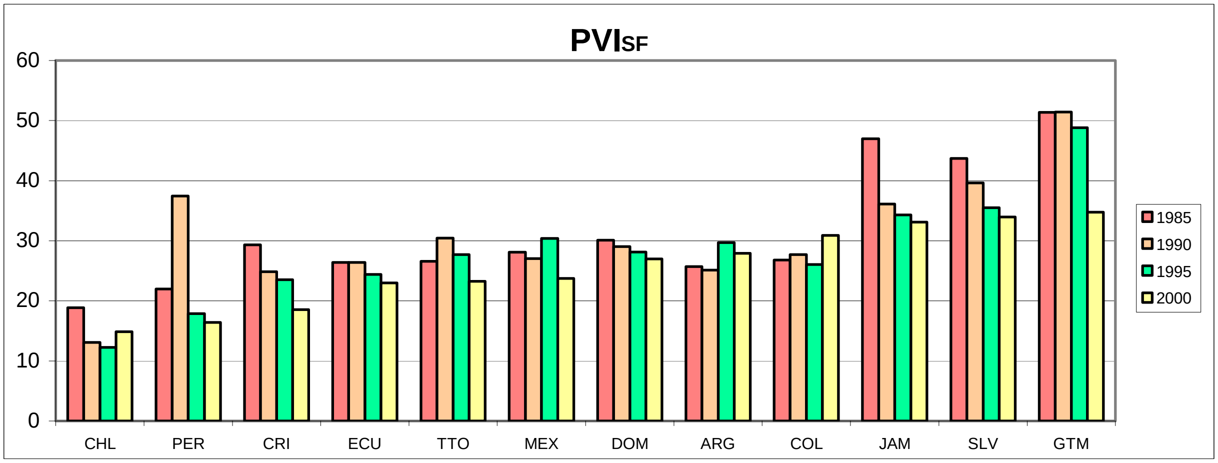
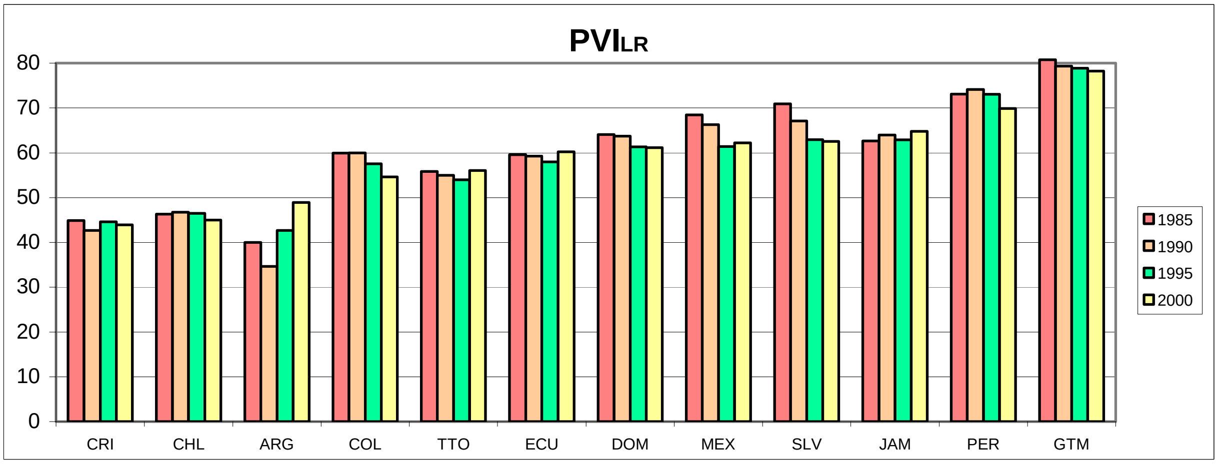


Figure 4.3.3 PVI due to Lack of Resilience



From the data in table 4.3.1 and figures 4.3.1-4.3.3 one may conclude that the smallest countries, such as Jamaica, El Salvador, Trinidad and Tobago, Dominican Republic, and Costa Rica systematically present greater PVI_{ES}. In Mexico, Argentina, Costa Rica, Trinidad and Tobago, and El Salvador all present a relative increase of exposure and susceptibility in the last years. In Chile and Colombia one may conclude that there has been a slight decrease and this is very remarkable in Guatemala and Ecuador. Guatemala, El Salvador, Jamaica and Colombia present a PVI_{SF} relatively high, although in most of the countries the socio-economic fragility has been decreased over time, with exception of Colombia and Chile in the last period. The values of PVI_{SF} are very high, on the whole, and they are particularly remarkable in Guatemala, Peru, Jamaica, although the value has diminished slightly during the last few years, with exception of Jamaica, Ecuador and Argentina. Costa Rica and Chile present the greater resilience.

Figure 4.3.4 shows the Prevalent Vulnerability Index for each country studied for the period 1985 through 2000. The Prevalent Vulnerability Index increased between 1985 and 2000 for every country except Peru and Guatemala (where it declined), and Jamaica (where it remained unchanged). The countries with the highest PVI are Guatemala, Jamaica and El Salvador; however, each paints a different picture of vulnerability. While the index for Guatemala has been consistently higher than that of any of the other countries, it posted a significant decline between 1995 and 2000. However, the PVI for El Salvador is not only one of the highest, it also increased steadily during the period studied. Finally, while Jamaica has a relatively high Prevalent Vulnerability Index, it has remained relatively unchanged since 1985.

The situation between 1995 and 2000 changed significantly. Most countries show a declining trend in vulnerability from 1995 to 2000. The exceptions are Costa Rica, the Dominican Republic, El Salvador, and Ecuador where vulnerability increased slightly, and Argentina, which posted a significant increase in vulnerability. The case of Argentina is particularly noteworthy because, in 1985 and 1990, it had the lowest PVI of any of the countries studied. However, vulnerability had increased markedly by 1995 and posted another increase in 2000. The countries with the lowest relative PVI are Chile, Costa Rica and Colombia.

Figure 4.3.4 PVI for Studied Countries

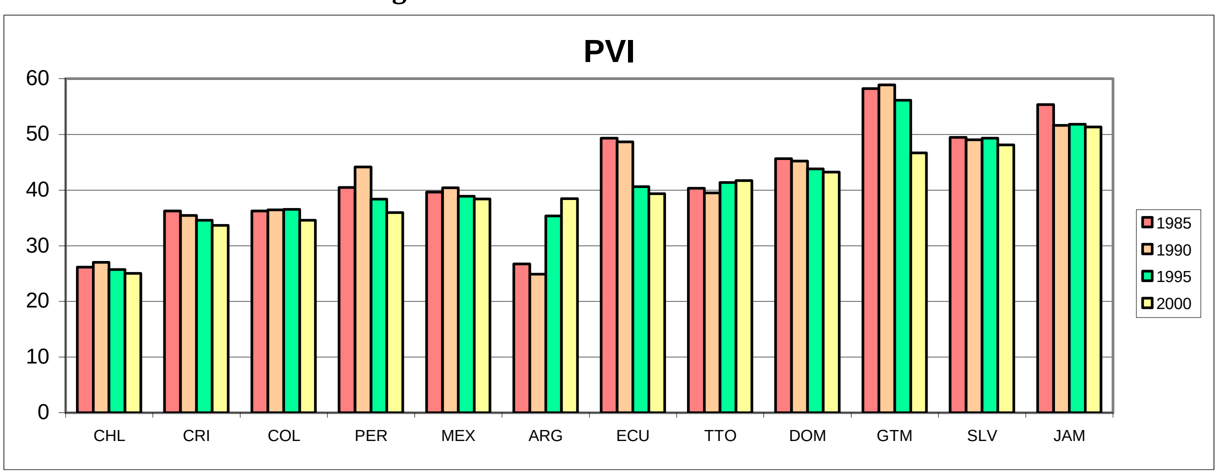
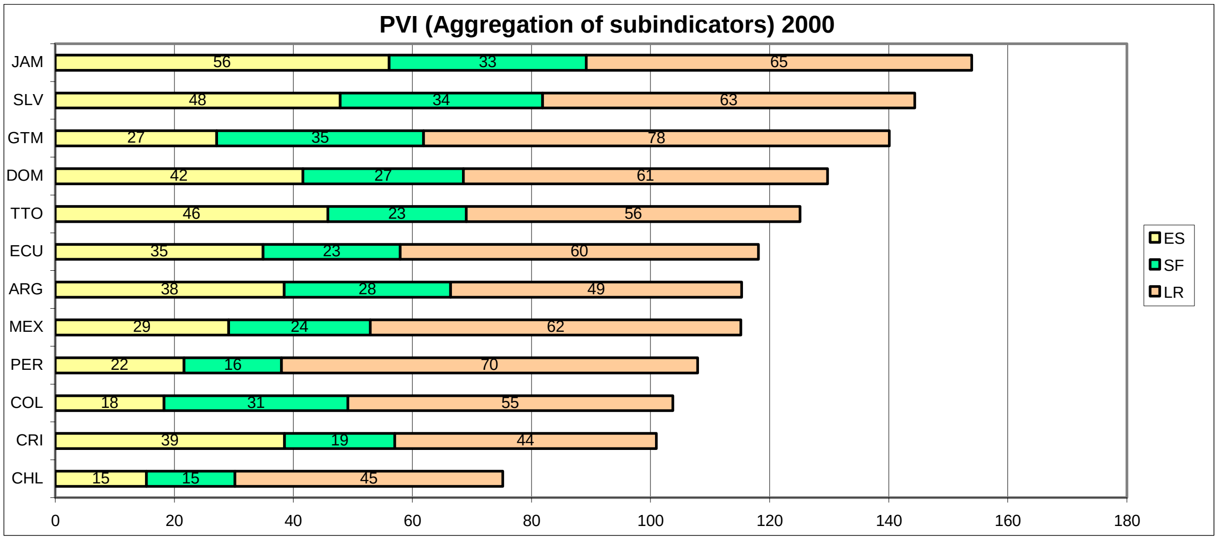


Figure 4.3.5 shows the aggregated Prevalent Vulnerability Index for all the countries in 2000. The values in this graph are obtained by adding the three components: exposure and susceptibility, social fragility and lack of resilience.

Figure 4.3.5 Aggregated PVI



The alternatives for numerical treatment taken into account for the estimation of the indexes that comprise the *PVI* in each country are described in the previous section. Procedure for formulating the *PVI* using composite indicators is the following:

a) Data selection – Variables were selected based on their analytical sufficiency, their availability or possibility to be measured and their relevance or logic in terms of representing the underlying vulnerability factors. The fact that some variables would not have a full coverage was taken into account and also that it would thus be necessary to estimate the lacking values by means of adequate statistical techniques and expert criteria attempting to avoid in some cases the problem of over summing and double accounting.

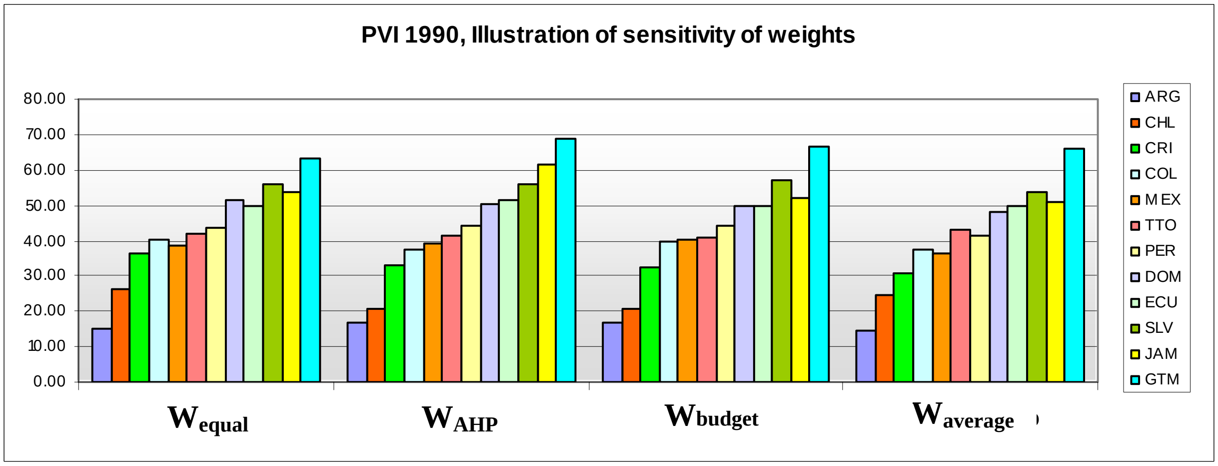
b) *Standardization methods* – Variables were normalized to make them comparable. The minimum-maximum technique was used to scale them to a common base and absolute minimums and maximums were defined for each variable. They kept constant for all evaluation periods.[42] With this technique the normalized scores for all indicators have an identical range. This makes this method more robust when there are outliers and increases the range for indicators that have little variation.

c) *Sensitivity tests* – The robustness of the indicators was calculated by making multiple evaluations, including and excluding indicators, modifying weights (equals, averages, allocation of points and AHP).The weights of the indicators are considered uncertainties given the plurality of perspectives of the experts. Result variation was minimal and in making comparisons the greatest change of position involved one scale place on the classification. Figure 4.3.6 shows the classification of the countries with weighting alternatives for one analysis period. Tables

[42] We proceed by this way to avoid changes in scaled values of all countries when a new one gets into evaluation. By this way if there are new countries in the analysis, the relative values do not have any modification due to the ranks keep constant between maximum and minimum of each variable.

4.3.2 and 4.3.3 show the scores obtained using budget and AHP alternatives. The *IVP* was arrived at finally using the weights obtained by the AHP in each country.

Figure 4.3.1 Estimations of PVI Using Different Weights



d) *Correlation analysis of data* – Possible relationships between variables were identified. Results of this analysis are registered in tables 4.3.4, 4.3.5 and 4.3.6. Very few variables were found to be correlated (at a 0.01 significance level). For example, ES.3 and ES.8 (population density and arable land); SF.1 and SF.2 (human poverty and dependency of vulnerable population); and LR.1 and LR.2 (human development and gender development). With the exception of this last case, which was taken into account in the weighting procedure, it was not necessary to eliminate any of the indicators given their importance in the intuitive understanding of vulnerability. There were other cases that showed correlations in certain years (the majority at a 0.05 significance level). This was the case with ES.1 and ES.2 (population growth and urban growth), SF.2 and SF.6 (dependency of vulnerable population and dependency of the population on agriculture), LR.1 and LR.3 and LR.6 (human development, social expenditure and televisions per thousand people). These were not eliminated as they represent relevant and different aspects.

e) *Transparency/accessibility and Visualization* – The estimation of the *IVP* has been achieved with data accompanied by explicatory notes as regards the data used. All data, graphs and electronic processes are available and permit easy changes of variables, weights etc. and the reproduction of sensibility tests. A wide range of additional graphs exist not used in this report that may be easily used and up-dated.

4.3.1 Evaluation at Sub-national Level

PVI can be estimated to the interior of a country for sub-national units such as states, departments or provinces. Barbat and Carreño (2004b) and Carreño *et al.*. (2005) present application results for Colombia in a detailed form, as a demonstrative example within present study frame. In order to express the same components of the *PVI* similar available sub-indicators for each department of the country were used. Figure 4.3.7 shows an example of the *PVI* valued for each department of Colombia for 1995.

Table 4.3.2 Weights Assigned Using Budget alternative

Ind	ARG	CHL	COL	CRI	ECU	SLV	GTM	JAM	MEX	PER	DOM	TTO
ES.1	2	10	9	5	8	25	10	9	10	3	8	9.2
ES.2	16	20	16	10	20	25	15	10	15	19	20	16.8
ES.3	3	10	10	10	8	15	10	10	15	6	8	9.8
ES.4	30	30	21	20	14	20	24	25	15	11	14	20.2
ES.5	14	10	14	10	10	7	10	17	15	22	10	12.9
ES.6	15	5	11	20	15	3	8	10	10	14	15	11.2
ES.7	8	5	11	15	5	3	15	10	10	17	5	9.7
ES.8	12	10	8	10	20	2	8	9	10	8	20	10.2
SF.1	30	30	20	20	25	25	19	20	15	10	25	21.1
SF.2	14	10	10	5	10	6	9	5	10	13	10	9.3
SF.3	16	5	17	10	20	27	19	15	20	12	20	15.8
SF.4	15	20	16	10	4	28	14	17	10	15	4	14.5
SF.5	2	10	9	10	8	6	14	10	5	18	8	9.4
SF.6	12	10	9	15	12	5	9	10	5	4	12	9.5
SF.7	8	5	10	10	6	2	7	15	15	21	6	10.1
SF.8	3	10	10	20	15	1	9	8	20	7	15	10.4
LR.1	14	30	19	20	25	30	20	20	15	15	25	20.6
LR.2	12	5	8	8	7	3	15	10	5	5	7	8.4
LR.3	11	10	15	15	10	15	10	20	15	20	10	14.0
LR.4	27	10	14	20	20	4	10	10	15	10	20	13.9
LR.5	4	20	10	7	13	5	10	7.5	15	23	13	11.3
LR.6	8	5	5	5	4	1	5	5	5	3	4	4.9
LR.7	13	10	12	5	6	15	15	7.5	15	16	6	11.4
LR.8	11	10	17	20	15	27	15	20	15	8	15	15.4

Table 4.3.3 Weights Obtained Using AHP Technique

Ind	ARG	CHL	COL	CRI	ECU	SLV	GTM	JAM	MEX	PER	DOM	TTO
ES.1	2.18	1.97	5.01	4.83	6.23	13.31	4.95	3.03	2.41	2.58	8.59	5.01
ES.2	16.64	4.81	12.37	10.58	21.72	12.91	1.93	6.31	5.38	22.37	21.01	12.37
ES.3	2.63	3.40	8.99	9.56	14.22	19.65	6.96	10.17	10.72	4.73	7.84	8.99
ES.4	33.36	24.97	25.39	20.38	29.85	36.22	36.03	16.67	32.60	8.42	15.40	25.39
ES.5	13.74	10.95	12.35	11.39	3.59	8.53	13.79	3.03	22.67	26.18	9.59	12.35
ES.6	14.11	7.31	11.71	20.38	11.71	3.58	3.01	20.26	7.30	14.07	15.32	11.71
ES.7	7.45	16.36	12.38	14.34	3.53	3.47	23.50	20.26	15.63	14.07	5.14	12.38
ES.8	9.89	30.24	11.82	8.54	9.15	2.31	9.83	20.26	3.29	7.59	17.10	11.82
SF.1	27.39	4.70	20.91	19.05	26.78	34.58	22.76	19.12	21.73	8.99	23.96	20.91
SF.2	12.51	7.10	8.50	6.13	8.88	6.52	3.08	4.57	14.89	13.80	7.54	8.50
SF.3	16.29	1.96	16.40	10.92	8.59	21.54	32.61	12.08	30.56	9.54	19.92	16.40
SF.4	18.45	24.67	12.52	9.53	3.76	14.12	7.87	13.27	13.66	13.80	6.05	12.52
SF.5	2.12	29.93	9.44	9.53	8.42	3.31	4.74	7.97	1.84	19.41	7.16	9.44
SF.6	12.83	12.48	9.58	14.44	19.02	5.40	1.99	8.89	5.31	3.39	12.06	9.58
SF.7	7.27	3.05	9.63	11.18	9.90	1.97	11.10	18.19	3.25	24.81	5.63	9.63
SF.8	3.15	16.10	13.02	19.23	14.66	12.57	15.85	15.91	8.75	6.26	17.67	13.02
LR.1	15.46	24.90	21.91	21.39	27.56	26.72	16.09	20.79	28.41	13.17	24.58	21.91
LR.2	15.46	3.24	10.53	7.62	19.81	3.60	32.69	6.84	3.73	4.94	7.37	10.53
LR.3	11.59	7.46	13.56	15.74	6.41	14.24	22.90	16.56	9.67	21.27	9.79	13.56
LR.4	26.19	18.98	15.05	19.49	14.17	16.91	11.46	11.63	2.84	8.50	20.29	15.05
LR.5	2.45	30.16	12.90	7.62	8.63	8.03	3.06	10.45	18.82	27.63	12.18	12.90
LR.6	6.84	2.05	3.70	4.87	3.70	5.16	1.97	4.43	1.85	2.42	3.71	3.70
LR.7	12.72	9.02	9.17	5.05	8.69	2.17	4.71	10.05	18.82	14.30	6.23	9.17
LR.8	9.29	4.21	13.18	18.24	11.04	23.18	7.12	19.25	15.86	7.76	15.85	13.18

Table 4.3.4 Value and Correlation Matrices for the ES

1985	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ARG	1.490	1.956	55.368	9.000	124.174	18.009	17.589	0.804
CHI	1.624	1.950	80.442	6.400	113.185	53.860	16.845	0.304
COL	2.037	2.996	152.397	11.000	151.763	26.340	16.714	1.430
CRI	2.935	3.734	258.715	6.400	163.377	63.199	19.321	4.661
DOM	2.072	3.744	665.668	3.200	287.732	65.255	17.264	7.338
ECU	2.529	4.236	164.337	57.800	200.190	47.623	16.060	4.082
SLV	1.581	1.341	1.151.062	20.000	282.226	52.211	12.024	12.403
GTM	2.520	2.690	356.820	53.300	117.074	24.932	10.956	4.473
JAM	1.063	2.340	1.066.990	13.100	569.035	121.555	22.110	9.695
MEX	2.035	3.034	197.688	13.100	385.957	25.749	19.093	0.891
PER	2.127	2.912	76.141	22.000	43.127	39.424	18.203	0.281
TTO	1.024	2.253	1.148.148	12.400	1.860.150	60.978	18.764	8.967

	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ES.1								
ES.2	0.72145							
ES.3	-0.5817	-0.3829						
ES.4	0.404	0.27733	-0.1326					
ES.5	-0.5842	-0.1982	0.65801	-0.165				
ES.6	-0.3764	-0.0149	0.63385	-0.2323	0.31764			
ES.7	-0.2951	0.20566	0.01861	-0.5538	0.29301	0.51705		
ES.8	-0.3601	-0.2396	0.94882	0.00833	0.47902	0.62195	-0.1189	

1990	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ARG	1.322	1.711	59.428	15.000	154.019	14.991	13.997	0.804
CHI	1.671	1.893	87.467	11.000	163.763	65.972	23.142	0.330
COL	1.961	2.829	168.335	9.100	222.073	35.386	16.591	1.632
CRI	2.623	3.695	298.570	6.200	263.173	75.956	22.388	4.896
DOM	1.674	2.926	729.744	3.200	459.893	77.518	24.941	9.301
ECU	2.256	3.708	185.378	57.800	271.408	60.115	18.435	4.772
SLV	1.866	2.311	1.233.591	20.000	417.859	49.785	13.712	12.548
GTM	2.593	2.526	403.440	53.300	159.174	45.869	12.982	4.473
JAM	0.669	2.094	1.103.416	13.100	739.878	99.940	25.346	9.234
MEX	1.866	2.693	218.019	23.300	525.134	38.306	17.880	0.995
PER	1.966	2.482	84.254	22.000	62.994	29.598	16.131	0.328
TTO	0.912	1.154	1.184.211	12.400	2.054.188	73.951	12.597	8.967

	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ES.1								
ES.2	0.74352							
ES.3	-0.5142	-0.3675						
ES.4	0.4499	0.29322	-0.2013					
ES.5	-0.5993	-0.5346	0.67023	-0.2117				
ES.6	-0.3089	0.0672	0.58621	-0.2202	0.42907			
ES.7	-0.1333	0.34237	-0.0164	-0.3927	-0.1948	0.66956		
ES.8	-0.2868	-0.0774	0.93257	-0.0961	0.48619	0.61231	0.07448	

1995	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ARG	1.292	1.707	63.522	44.300	213.112	19.724	17.938	0.804
CHI	1.456	1.675	94.888	4.200	267.215	59.277	23.872	0.374
COL	1.868	2.686	185.607	11.000	319.012	35.734	22.396	1.955
CRI	2.092	2.984	335.879	9.600	414.884	77.921	18.995	5.680
DOM	1.745	2.915	795.473	3.200	641.280	65.218	19.185	10.335
ECU	2.056	3.451	206.979	20.200	339.686	58.318	18.556	5.155
SLV	2.060	2.768	1,368.243	25.300	681.057	59.395	18.606	13.176
GTM	2.642	3.105	460.020	39.800	222.684	44.689	14.515	5.119
JAM	0.785	1.863	1,144.968	3.200	1,309.346	113.679	28.947	9.234
MEX	1.545	2.016	238.763	17.900	719.988	58.174	16.152	1.100
PER	1.919	2.203	93.113	15.500	89.656	30.705	24.074	0.363
TTO	0.645	1.403	1,230.019	12.400	2,735.669	92.989	20.781	9.162

	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ES.1								
ES.2	0.83432							
ES.3	-0.3487	-0.09736						
ES.4	0.35635	0.117559	-0.198332					
ES.5	-0.7227	-0.48817	0.7113096	-0.28997				
ES.6	-0.5188	-0.17257	0.6823054	-0.60325	0.704427			
ES.7	-0.5553	-0.43102	0.1685153	-0.64885	0.20598	0.4216409		
ES.8	-0.0963	0.239681	0.9233161	-0.18158	0.514624	0.6142768	0.01335	

2000	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ARG	1.224	1.519	67.658	54.000	379.403	22.405	16.193	0.804
CHI	1.246	1.446	101.571	2.000	459.362	58.513	21.021	0.425
COL	1.725	2.430	203.617	8.200	428.638	39.500	12.738	1.663
CRI	1.640	3.127	373.090	12.600	624.870	93.870	17.397	5.484
DOM	1.567	2.612	865.337	3.200	907.225	65.170	23.690	10.335
ECU	1.826	2.996	228.399	15.600	297.024	73.230	16.174	5.155
SLV	1.957	2.656	1,514.479	21.000	1,029.339	69.790	16.884	12.066
GTM	2.581	3.388	525.007	10.000	325.113	49.511	17.922	5.026
JAM	0.659	2.506	1,187.904	3.200	1,721.713	100.549	27.444	9.234
MEX	1.473	1.713	256.632	15.900	984.383	64.071	21.258	1.310
PER	1.561	2.217	101.324	14.800	130.961	33.839	20.123	0.398
TTO	0.660	1.286	1,268.031	12.400	3,930.164	106.304	18.533	9.162

	ES.1	ES.2	ES.3	ES.4	ES.5	ES.6	ES.7	ES.8
ES.1								
ES.2	0.6984							
ES.3	-0.2272	0.09344						
ES.4	-0.0055	-0.27375	-0.22675					
ES.5	-0.6463	-0.42628	0.679421	-0.15609				
ES.6	-0.4325	0.09237	0.644458	-0.47366	0.704101			
ES.7	-0.4745	-0.11188	0.323164	-0.42262	0.243146	0.39736		
ES.8	-0.0785	0.32683	0.93057	-0.25783	0.530101	0.66149	0.2881	

Table 4.3.3 Value and Correlation Matrices for the SF

1985	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
ARG	22.3	0.653	42.000	5.300	600.000	7.634	6.925	2.860
CHI	5.400	0.587	56.200	12.100	28.322	7.636	13.778	2.350
COL	8.600	0.719	48.000	14.000	31.471	17.452	5.650	1.330
CRI	6.600	0.689	37.400	6.800	12.259	21.808	13.436	8.410
DOM	14.400	0.737	47.400	15.800	43.533	13.100	5.991	5.930
ECU	15.200	0.823	43.730	7.330	30.699	13.332	6.881	2.660
SLV	20.600	0.898	49.000	16.900	18.869	26.912	6.812	12.170
GTM	58.800	0.973	59.600	2.650	21.863	25.851	3.443	3.930
JAM	13.600	0.776	36.400	25.000	25.491	7.516	24.345	18.170
MEX	10.400	0.852	42.500	4.420	59.814	10.072	8.290	2.770
PER	23.000	0.783	41.400	5.200	145.455	10.226	5.827	0.530
TTO	7.900	0.648	40.300	15.500	8.458	2.435	3.585	18.610

	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
SF.1								
SF.2	0.7681							
SF.3	0.5556	0.27376						
SF.4	-0.3992	-0.20967	-0.22148					
SF.5	0.088	-0.27441	-0.176998	-0.333				
SF.6	0.5382	0.63649	0.423917	-0.1972	-0.28521			
SF.7	-0.3457	-0.2224	-0.37205	0.52589	-0.13182	-0.21256		
SF.8	-0.1691	-0.05907	-0.410763	0.71505	-0.2896	-0.15666	0.38922	

1990	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
ARG	16.500	0.655	43.000	7.300	2,129.406	8.124	4.357	2.860
CHI	5.400	0.567	55.400	5.700	25.953	8.709	9.140	2.350
COL	8.600	0.676	53.000	10.200	27.196	16.748	9.657	1.330
CRI	6.600	0.685	37.400	4.600	18.245	17.889	8.774	8.410
DOM	14.400	0.682	47.400	15.800	49.609	13.423	3.281	5.930
ECU	15.200	0.756	43.730	6.100	47.516	13.407	10.142	2.660
SLV	20.600	0.818	53.000	10.000	25.873	17.102	4.329	12.170
GTM	58.800	0.965	59.600	3.900	47.133	25.879	2.793	3.930
JAM	13.600	0.740	36.400	15.700	22.285	7.112	14.405	18.170
MEX	10.400	0.740	46.900	2.750	25.388	7.848	4.306	2.770
PER	23.000	0.731	41.400	8.300	6,782.312	8.538	1.810	0.530
TTO	7.900	0.658	40.300	20.000	17.115	2.541	8.861	18.610

	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
SF.1								
SF.2	0.8722							
SF.3	0.4873	0.33951						
SF.4	-0.273	-0.25238	-0.35474					
SF.5	0.1362	-0.03738	-0.25312	-0.0858				
SF.6	0.6383	0.66245	0.572636	-0.4535	-0.240835			
SF.7	-0.4984	-0.34409	-0.37027	0.2985	-0.466518	-0.2622		
SF.8	-0.1651	0.02621	-0.43411	0.7123	-0.355837	-0.3006	0.46923	

1995	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
ARG	15.400	0.621	44.000	18.800	2.835	5.698	3.445	2.860
CHI	4.200	0.564	57.500	4.700	8.314	9.239	7.611	2.350
COL	8.600	0.637	57.100	8.700	19.449	15.284	4.697	1.330
CRI	6.600	0.643	45.900	5.200	-49.154	13.696	5.547	8.410
DOM	14.400	0.642	47.400	15.800	14.526	12.578	3.426	5.930
ECU	16.800	0.689	43.730	6.900	20.749	11.916	7.890	2.660
SLV	20.600	0.724	50.800	7.700	6.671	13.371	2.991	12.170
GTM	62.400	0.939	55.800	2.650	8.800	24.151	2.387	3.930
JAM	13.600	0.633	36.400	16.200	20.334	8.518	11.797	18.170
MEX	10.400	0.661	51.900	5.700	39.220	5.474	9.157	2.770
PER	23.100	0.675	46.200	6.970	9.383	8.606	2.313	0.530
TTO	7.900	0.577	40.300	17.200	16.816	2.313	7.877	18.610

	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
SF.1								
SF.2	0.954							
SF.3	0.2381	0.3166						
SF.4	-0.334	-0.4866	-0.67358					
SF.5	0.0551	0.0043	0.06401	0.1665				
SF.6	0.7037	0.79809	0.52643	-0.5632	-0.2521			
SF.7	-0.4813	-0.451	-0.40325	0.167	0.31217	-0.4827		
SF.8	-0.1606	-0.1856	-0.63053	0.4961	-0.0617	-0.2863	0.4465	

2000	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
ARG	14.300	0.595	45.000	15.000	-2.624	4.971	9.622	2.860
CHI	4.200	0.548	58.000	8.300	1.366	8.538	8.164	2.350
COL	9.100	0.595	58.000	20.500	9.040	13.421	6.136	1.330
CRI	4.000	0.604	41.200	5.200	9.775	9.554	4.063	8.410
DOM	14.400	0.608	47.400	15.800	0.379	11.168	2.659	5.930
ECU	16.800	0.620	43.730	9.000	120.309	9.978	9.378	2.660
SLV	18.300	0.674	53.000	7.000	0.172	9.778	2.846	12.170
GTM	23.800	0.856	55.800	1.400	4.339	22.826	2.127	3.930
JAM	13.600	0.614	37.910	18.970	7.004	6.479	8.327	18.170
MEX	9.500	0.605	48.110	1.600	6.289	4.097	10.084	2.770
PER	12.900	0.630	40.300	7.400	0.777	8.641	4.787	0.530
TTO	7.900	0.468	40.300	12.200	8.145	1.658	6.344	18.610

	SF.1	SF.2	SF.3	SF.4	SF.5	SF.6	SF.7	SF.8
SF.1								
SF.2	0.77796							
SF.3	0.1152	0.3449						
SF.4	-0.1373	-0.4375	-0.1242					
SF.5	0.18826	-0.0145	-0.1758	-0.0553				
SF.6	0.55912	0.8464	0.562	-0.2206	0.0414			
SF.7	-0.3289	-0.4876	-0.2079	0.17427	0.346	-0.6116		
SF.8	-0.0452	-0.2721	-0.4626	0.24526	-0.1553	-0.3709	-0.1113	

Table 4.3.4 Value and Correlation Matrices for LR

1985	LR.1	LR.2	LR.3	LR.4	LR.5	LR.6	LR.7	LR.8
ARG	0.799	0.824	11.430	1.144	1.452	215.443	4.594	61.667
CHI	0.785	0.817	17.800	1.415	0.989	144.916	3.406	57.233
COL	0.695	0.767	6.630	0.901	1.200	92.500	1.564	56.300
CRI	0.785	0.813	14.060	1.265	0.837	75.700	3.314	59.667
DOM	0.680	0.712	3.970	0.927	1.372	78.419	1.700	46.900
ECU	0.694	0.761	3.530	0.838	1.141	65.941	1.907	54.367
SLV	0.614	0.694	6.550	0.916	0.812	73.855	1.471	46.800
GTM	0.554	0.609	4.240	0.759	0.675	25.995	1.100	48.450
JAM	0.690	0.736	8.520	1.035	1.166	93.033	3.333	41.200
MEX	0.753	0.782	7.720	0.956	0.702	113.688	0.700	47.400
PER	0.690	0.724	3.960	0.897	0.825	76.852	1.684	53.600
TTO	0.780	0.789	10.160	1.150	0.564	275.862	3.800	43.250

	LR.1	LR.2	LR.2	LR.4	LR.5	LR.6	LR.7	LR.8
LR.1								
LR.2	0.9675							
LR.3	0.7183	0.70696						
LR.4	0.7981	0.76239	0.96539					
LR.5	0.1539	0.23527	-0.0328	0.02909				
LR.6	0.7051	0.62709	0.49124	0.55868	-0.0209			
LR.7	0.6796	0.63541	0.69406	0.75823	0.283	0.702143		
LR.8	0.4228	0.50392	0.39252	0.35325	0.3566	0.014891	0.28776	

1990	LR.1	LR.2	LR.3	LR.4	LR.5	LR.6	LR.7	LR.8
ARG	0.808	0.824	20.040	1.150	1.474	249.023	4.594	61.667
CHI	0.780	0.817	16.480	1.421	1.004	206.107	3.159	57.233
COL	0.720	0.767	6.270	0.838	1.218	108.665	1.367	56.300
CRI	0.791	0.789	14.310	1.355	0.849	221.429	2.500	59.667
DOM	0.680	0.712	3.970	0.920	1.393	83.682	1.881	46.900
ECU	0.704	0.761	3.530	0.845	1.158	85.737	1.644	54.367
SLV	0.653	0.694	6.550	1.068	0.824	91.841	1.471	46.800
GTM	0.577	0.609	4.060	0.868	0.685	53.099	1.100	48.450
JAM	0.720	0.736	8.270	1.004	1.184	135.592	2.200	41.200
MEX	0.785	0.782	7.600	0.968	0.712	149.534	0.800	47.400
PER	0.702	0.612	4.050	0.952	0.837	96.350	1.413	53.600
TTO	0.790	0.789	8.050	1.222	0.573	330.891	4.000	43.250

	LR.1	LR.2	LR.2	LR.4	LR.5	LR.6	LR.7	LR.8
LR.1								
LR.2	0.8508							
LR.2	0.7078	0.69859						
LR.4	0.6331	0.5528	0.77999					
LR.5	0.1117	0.29258	0.25633	-0.1826				
LR.6	0.8226	0.70384	0.68441	0.75578	-0.1463			
LR.7	0.6334	0.61002	0.7543	0.66688	0.24655	0.84682		
LR.8	0.3653	0.34806	0.58019	0.29839	0.3566	0.15601	0.2803	

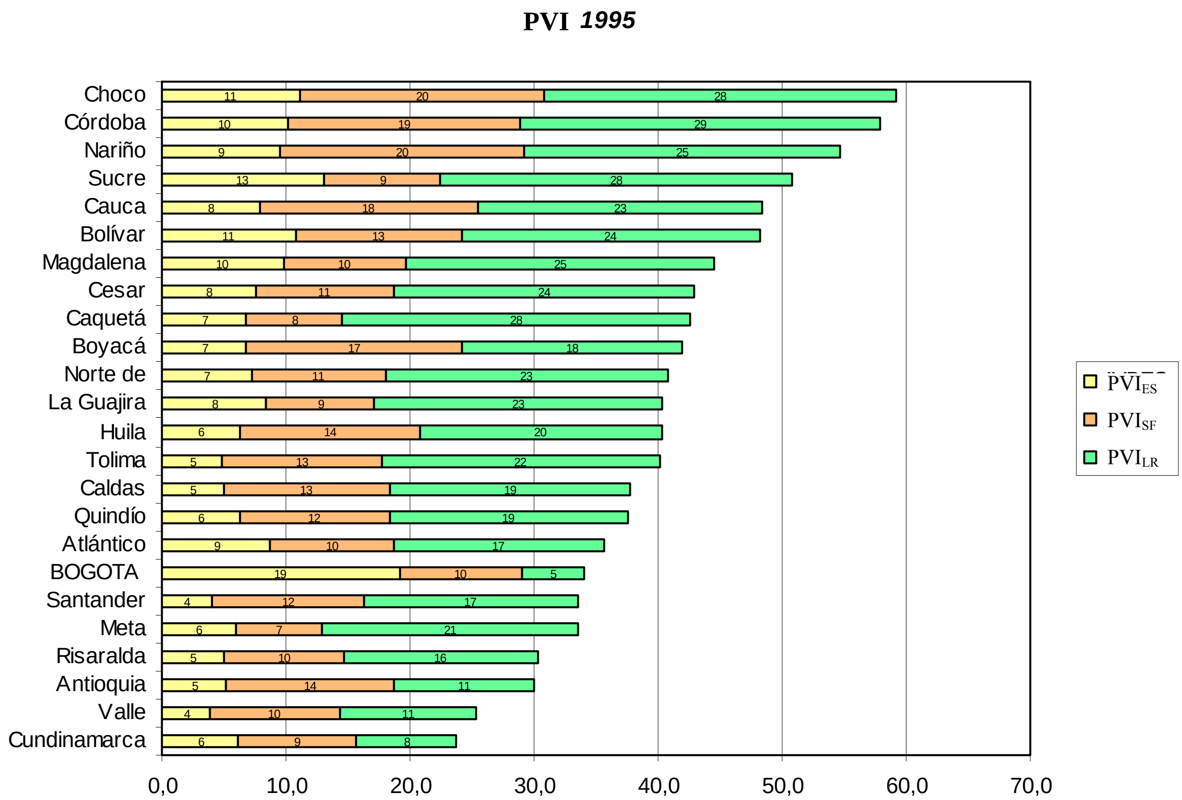
1995	LR.1	LR.2	LR.3	LR.4	LR.5	LR.6	LR.7	LR.8
ARG	0.830	0.824	16.764	1.098	1.503	276.100	2.200	62.500
CHI	0.819	0.817	13.855	1.466	1.024	224.168	2.200	60.000
COL	0.746	0.767	9.652	0.771	1.242	189.767	1.200	55.000
CRI	0.810	0.763	13.299	1.401	0.866	225.225	1.784	57.000
DOM	0.700	0.712	4.259	1.034	1.421	89.869	1.600	46.900
ECU	0.720	0.761	4.548	0.728	1.181	148.342	1.554	57.000
SLV	0.692	0.694	8.063	1.082	0.841	132.509	1.234	48.000
GTM	0.608	0.609	4.376	0.824	0.699	60.120	0.966	47.300
JAM	0.740	0.736	7.429	1.065	1.207	160.000	2.216	41.200
MEX	0.793	0.770	9.234	1.019	0.726	213.290	1.200	51.000
PER	0.730	0.724	5.341	0.948	0.854	140.236	0.900	50.000
TTO	0.790	0.789	9.933	1.217	0.584	332.601	3.900	43.250

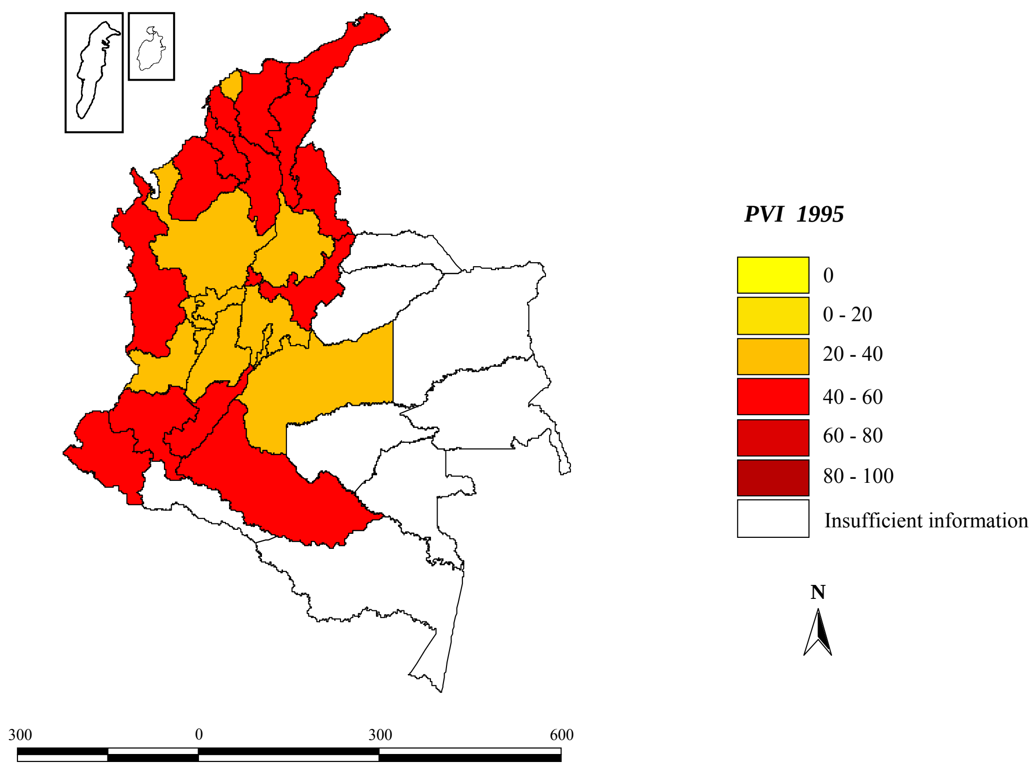
	LR.1	LR.2	LR.2	LR.4	LR.5	LR.6	LR.7	LR.8
LR.1								
LR.2	0.9434							
LR.3	0.8382	0.74314						
LR.4	0.637	0.45596	0.65783					
LR.5	0.1492	0.30503	0.15894	-0.1695				
LR.6	0.8651	0.83568	0.76672	0.52499	-0.102			
LR.7	0.5141	0.53698	0.41442	0.51703	-0.075	0.75889		
LR.8	0.5125	0.55466	0.61926	0.1658	0.3832	0.28389	-0.151	

2000	LR.1	LR.2	LR.3	LR.4	LR.5	LR.6	LR.7	LR.8
ARG	0.844	0.824	16.891	0.682	1.538	320.781	2.200	61.500
CHI	0.830	0.817	15.766	1.393	1.047	282.690	2.747	55.100
COL	0.746	0.767	10.747	0.670	1.271	282.026	1.498	59.100
CRI	0.783	0.789	14.271	1.204	0.886	231.171	1.493	63.200
DOM	0.740	0.712	4.724	0.842	1.453	96.000	1.547	48.400
ECU	0.731	0.761	2.760	0.656	1.208	218.251	0.760	54.300
SLV	0.719	0.694	9.154	0.843	0.860	200.765	0.760	48.700
GTM	0.634	0.609	4.862	0.722	0.715	61.484	0.700	49.600
JAM	0.760	0.736	9.213	0.888	1.235	194.093	1.115	40.100
MEX	0.820	0.782	9.416	0.958	0.743	283.169	1.100	45.900
PER	0.747	0.724	5.612	0.821	0.873	148.079	1.332	56.500
TTO	0.800	0.789	10.632	1.032	0.598	339.934	3.900	40.100

	LR.1	LR.2	LR.2	LR.4	LR.5	LR.6	LR.7	LR.8
LR.1								
LR.2	0.938283							
LR.3	0.741973	0.70309						
LR.4	0.483951	0.4147	0.5229					
LR.5	0.194856	0.2601	0.12323	-0.3547				
LR.6	0.814274	0.87296	0.70168	0.28102	0.0064			
LR.7	0.615132	0.59285	0.53784	0.48867	-0.1077	0.63022		
LR.8	0.146953	0.30347	0.36314	-0.0346	0.3482	0.10575	-0.115	

Figure 4.3.7 Aggregated PVI for the Colombia, by Department (1995)





4.4 The Risk Management Index

In risk management assessment, it is necessary involving data with incommensurable units or information that only can be valuated using linguistic estimates. This is the reason why we are using multi-attribute composite indicators and the fuzzy sets theory. Table 4.4.1 presents the *RMI* values and the levels of the sub indices that make them up. They are obtained from valuations indicated in tables 4.4.2 – 4.4.5. Figure 4.4.1 shows the RMI_{RI}, figure 4.4.2 shows the RMI_{RR}, figure 4.4.3 shows RMI_{DM} and figure 4.4.4 shows the RMI_{FP} by country and period, using AHP weighting.

Table 4.4.1 RMI Composite Sub-indicators for Each Country and Period

Year	Ind	Weight[43]	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER
1985	RI	AHP	6.98	9.90	10.54	12.85	4.56	10.73	36.07	10.39	12.74	36.80	10.45
		Budget	9.40	11.89	11.14	12.49	4.56	12.37	42.83	11.54	10.61	38.91	11.02
		Equal	12.49	12.49	12.49	12.49	4.56	12.49	36.07	12.49	12.49	31.83	12.49
	RR	AHP	9.01	29.32	10.97	4.56	4.56	4.56	4.56	4.56	10.76	4.56	4.56
		Budget	11.40	38.73	11.14	4.56	4.56	4.56	4.56	4.56	13.17	4.56	4.56
		Equal	12.49	36.40	12.49	4.56	4.56	4.56	4.56	4.56	12.49	4.56	4.56
	DM	AHP	13.36	24.72	4.56	4.56	4.56	8.90	13.70	10.75	54.44	4.56	9.17
		Budget	12.90	34.95	4.56	4.56	4.56	12.20	12.49	11.83	51.20	4.56	9.40
		Equal	12.49	36.40	4.56	4.56	4.56	12.49	12.49	12.49	48.82	4.56	12.49
	FP	AHP	4.56	31.42	4.56	27.26	4.56	4.56	28.69	6.27	13.53	4.56	4.56
		Budget	4.56	31.64	4.56	26.11	4.56	4.56	33.51	11.54	13.05	4.56	4.56
		Equal	4.56	36.40	4.56	31.83	4.56	4.56	36.07	12.49	12.49	4.56	4.56
	RMI	AHP	8.48	23.84	7.66	12.31	4.56	7.19	20.75	7.99	22.87	12.62	7.19
		Budget	9.57	29.30	7.85	11.93	4.56	8.42	23.35	9.87	22.01	13.15	7.38
		Equal	10.51	30.42	8.52	13.36	4.56	8.52	22.30	10.51	21.57	11.38	8.52
1990	RI	AHP	8.42	31.10	25.07	12.26	9.43	15.02	31.83	10.39	34.45	36.80	27.68
		Budget	11.76	35.23	23.92	12.49	10.15	12.97	41.35	12.49	30.99	38.91	29.00
		Equal	12.49	36.40	31.83	12.49	12.49	12.49	31.83	12.49	31.83	31.83	31.83
	RR	AHP	25.22	41.36	13.96	29.29	4.56	15.73	4.56	4.56	30.40	15.02	9.65
		Budget	29.90	41.64	13.68	30.72	4.56	12.95	4.56	4.56	34.60	15.19	10.78
		Equal	31.83	36.40	12.49	31.83	4.56	12.49	4.56	4.56	31.83	12.49	12.49
	DM	AHP	37.37	32.15	12.49	15.94	4.56	16.28	13.70	32.90	51.10	12.49	25.61
		Budget	34.24	36.40	12.49	13.35	4.56	14.04	12.49	35.10	49.31	12.49	26.06
		Equal	31.83	36.40	12.49	12.49	4.56	12.49	12.49	36.40	43.52	12.49	31.83
	FP	AHP	4.56	31.42	12.49	32.65	4.56	4.56	37.90	14.69	35.55	4.56	4.56
		Budget	4.56	36.70	12.49	31.64	4.56	4.56	32.27	13.35	34.93	4.56	4.56
		Equal	4.56	36.40	12.49	36.40	4.56	4.56	31.83	12.49	31.83	4.56	4.56
	RMI	AHP	18.89	34.01	16.00	22.54	5.78	12.90	22.00	15.64	37.87	17.22	16.87
		Budget	20.11	37.49	15.64	22.05	5.96	11.13	22.67	16.38	37.46	17.79	17.60
		Equal	20.18	36.40	17.32	23.30	6.54	10.51	20.18	16.48	34.75	15.34	20.18

[43] The variables were pondered according to expert criteria in each country. Weights were assigned in order to grant each component a relative importance in the context of each particular composite indicator. Three techniques were used to compare results and evaluate their pertinence: Analytic Hierarchy Process, AHP, Budget allocation and Equal weighting (Cardona *et al.* 2004).

Year	Ind	Weight[43]	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER
1995	RI	AHP	24.83	38.61	32.46	37.11	9.43	32.85	36.07	10.39	40.08	39.78	34.67
		Budget	30.43	41.64	33.70	36.40	10.15	36.17	42.83	13.35	40.73	43.22	34.83
		Equal	31.83	36.40	36.40	36.40	12.49	36.40	36.07	12.49	36.40	31.83	36.40
	RR	AHP	25.22	41.36	39.28	45.74	10.92	15.73	13.71	14.02	30.46	40.31	17.00
		Budget	29.90	41.64	38.73	45.74	11.14	12.95	9.40	12.49	36.73	36.84	17.00
		Equal	31.83	36.40	36.40	48.13	12.49	12.49	12.49	12.49	31.83	31.83	17.00
	DM	AHP	57.31	45.00	12.49	65.09	4.56	16.28	13.70	41.31	55.64	15.91	25.61
		Budget	52.74	45.00	12.49	56.82	4.56	14.04	12.49	38.97	51.24	15.90	26.06
		Equal	48.82	45.00	12.49	56.82	4.56	12.49	12.49	36.40	44.20	12.49	31.83
	FP	AHP	6.35	45.00	31.50	32.65	4.56	4.56	37.90	30.54	36.90	14.05	8.11
		Budget	10.02	45.00	32.95	31.64	4.56	4.56	32.27	32.92	35.81	13.05	9.40
		Equal	12.49	45.00	36.40	36.40	4.56	4.56	31.83	31.83	31.83	31.83	12.49
	RMI	AHP	28.43	42.49	28.93	45.15	7.37	17.36	25.35	24.07	40.77	27.51	21.35
		Budget	30.78	43.32	29.47	42.65	7.60	16.93	24.25	24.43	41.13	27.25	21.82
		Equal	31.24	40.70	30.42	44.44	8.52	16.48	23.22	23.30	36.07	26.99	24.43
2000	RI	AHP	42.85	45.13	48.41	48.93	11.34	41.32	31.83	32.15	52.98	53.66	52.64
		Budget	43.65	52.23	49.01	45.82	11.89	37.34	36.40	36.40	56.36	59.31	53.66
		Equal	48.82	48.13	48.13	48.13	12.49	36.40	31.83	36.40	48.13	43.52	56.82
	RR	AHP	32.53	41.36	44.46	48.83	28.52	16.00	32.55	17.00	30.46	40.31	34.88
		Budget	43.07	41.64	44.91	47.41	29.11	13.95	17.00	17.00	36.73	36.84	34.95
		Equal	43.52	36.40	48.13	48.13	31.83	12.49	31.83	17.00	31.83	31.83	36.40
	DM	AHP	51.97	67.12	28.73	50.35	13.28	39.05	37.84	64.84	60.15	42.99	44.26
		Budget	46.61	58.57	30.64	56.82	13.17	34.11	33.88	60.43	57.47	42.98	44.47
		Equal	43.52	56.82	31.83	56.82	12.49	31.83	31.83	56.82	49.28	36.40	48.13
	FP	AHP	6.35	62.64	39.64	43.13	12.17	4.56	38.60	31.95	36.90	39.11	17.00
		Budget	10.02	60.05	39.26	43.13	14.73	4.56	32.92	32.92	35.81	36.69	17.00
		Equal	12.49	56.82	36.40	48.13	12.49	4.56	36.07	31.83	31.83	31.83	17.00
	RMI	AHP	33.43	54.06	40.31	47.81	16.33	25.23	35.20	36.49	45.12	44.02	37.20
		Budget	35.84	53.12	40.96	48.29	17.23	22.49	30.05	36.69	46.59	43.96	37.52
		Equal	37.09	49.54	41.12	50.30	17.32	21.32	32.89	35.51	40.27	35.89	39.59
2003	RI	AHP	42.56	59.86	48.41	48.93	34.11	41.32	48.13	32.15	60.06	53.66	54.87
		Budget	41.51	65.58	49.01	45.82	35.23	37.34	63.89	38.10	61.58	59.31	55.03
		Equal	43.52	56.82	48.13	48.13	36.40	36.40	48.13	36.40	54.97	43.52	56.82
	RR	AHP	38.53	58.11	44.46	50.96	33.25	17.00	38.23	17.00	30.46	40.31	45.00
		Budget	43.07	48.76	44.91	49.47	33.70	17.00	25.40	17.00	36.73	36.84	45.00
		Equal	43.52	48.13	48.13	48.13	36.40	17.00	36.40	17.00	31.83	31.83	45.00
	DM	AHP	55.81	67.12	28.73	50.35	43.31	28.13	45.00	72.07	63.04	42.99	44.26
		Budget	47.73	58.57	30.64	56.82	43.65	33.04	45.00	67.44	59.25	42.98	44.47
		Equal	42.36	56.82	31.83	56.82	48.82	31.83	45.00	63.65	59.25	36.40	48.13
	FP	AHP	6.35	62.64	39.64	43.13	14.50	4.56	40.44	41.71	41.32	39.11	36.40
		Budget	10.02	60.05	39.26	43.13	14.73	4.56	34.18	44.60	4.57	36.69	36.40
		Equal	12.49	56.82	36.40	48.13	12.49	4.56	31.83	43.52	43.52	31.83	36.40
	RMI	AHP	35.81	61.94	40.31	48.34	31.29	22.75	42.95	40.73	48.72	44.02	45.13
		Budget	35.58	58.24	40.96	48.81	31.82	22.99	42.12	41.79	40.53	43.96	45.23
		Equal	35.47	54.65	41.12	50.30	33.53	22.45	40.34	40.14	47.39	35.89	46.59

Table 4.4.2 Qualification of the RMI Sub-indicators in 1985 [44]

1985	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER
RI1	2	2	2	1	1	1	1	1	2	1	1
RI2	1	2	1	2	1	2	3	2	1	3	1
RI3	1	2	2	2	1	2	1	1	2	2	1
RI4	1	1	1	1	1	2	1	1	1	1	2
RI5	1	1	1	1	1	1	1	1	2	1	1
RI6	1	1	1	1	1	1	1	1	1	1	1
RR1	1	2	1	1	1	1	1	1	1	1	1
RR2	1	2	1	1	1	1	1	1	1	1	1
RR3	1	2	1	1	1	1	1	1	2	1	1
RR4	1	2	1	1	1	1	1	1	1	1	1
RR5	2	3	2	1	1	1	1	1	2	1	1
RR6	1	2	1	1	1	1	1	1	1	1	1
DM1	2	2	1	1	1	2	2	2	4	1	1
DM2	1	2	1	1	1	1	2	1	3	1	1
DM3	1	2	1	1	1	1	1	1	1	1	1
DM4	1	2	1	1	1	1	1	2	1	1	2
DM5	2	2	1	1	1	1	1	2	1	1	1
DM6	1	3	1	1	1	1	1	2	1	1	1
FP1	1	2	1	1	1	1	1	1	2	1	1
FP2	1	2	1	2	1	1	1	1	1	1	1
FP3	1	2	1	2	1	1	1	1	1	1	1
FP4	1	2	1	2	1	1	1	1	1	1	1
FP5	1	3	1	2	1	1	1	1	1	1	1
FP6	1	3	1	3	1	1	3	2	2	1	1

Table 4.1.3 Qualification of the RMI Subindicators in 1990

1990	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER
RI1	2	3	3	1	1	2	1	1	3	1	1
RI2	2	3	2	2	1	2	3	2	2	3	2
RI3	2	2	2	2	1	2	2	2	2	2	2
RI4	1	2	1	1	1	2	1	2	2	1	3
RI5	1	2	1	1	2	2	1	2	3	1	2
RI6	1	2	2	2	1	1	1	1	1	1	1
RR1	1	3	2	2	1	2	1	1	2	1	1
RR2	2	2	2	2	1	2	1	1	2	2	2
RR3	2	3	1	1	1	1	1	1	3	1	2
RR4	1	3	2	2	1	2	1	1	1	1	1
RR5	3	3	2	2	1	1	1	1	3	2	1
RR6	1	2	1	3	1	2	1	1	1	2	1
DM1	3	3	2	2	1	2	2	3	4	2	2
DM2	1	2	1	2	1	2	2	2	3	1	1
DM3	1	2	2	2	1	1	1	2	1	1	1
DM4	2	2	1	2	1	2	1	2	2	1	3
DM5	3	2	1	2	1	2	1	3	2	1	2
DM6	1	3	1	1	1	2	1	2	1	1	1
FP1	1	2	2	2	1	1	1	1	3	1	1
FP2	1	3	2	2	1	1	1	1	2	1	1
FP3	1	3	1	2	1	1	2	2	2	1	1
FP4	1	3	1	3	1	1	3	2	1	1	1
FP5	1	3	1	2	1	1	1	1	1	1	1
FP6	1	3	2	3	1	1	3	2	3	1	1

[44] Valuation of each indicator is made using five performance levels: 1.*low, 2.incipient, 3.significant, 4. outstanding,* and *optimal*.

Table 4.4.4 Qualification of the RMI Sub-indicators in 1995

1995	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER
RI1	3	3	3	3	1	2	1	1	3	2	2
RI2	3	3	3	3	1	3	3	2	3	3	3
RI3	3	3	3	3	1	3	3	2	3	3	3
RI4	2	2	2	2	1	3	1	2	2	1	3
RI5	1	3	3	2	2	2	1	2	3	1	3
RI6	1	3	3	3	1	2	1	2	2	1	2
RR1	1	3	2	3	1	2	2	2	2	1	2
RR2	2	2	3	2	2	2	2	1	3	2	2
RR3	2	3	2	2	1	1	2	1	3	2	2
RR4	1	3	3	4	1	2	1	2	2	1	2
RR5	3	3	3	4	1	1	1	2	3	3	2
RR6	1	2	2	3	1	2	1	1	1	3	2
DM1	4	3	2	4	1	2	2	3	5	2	2
DM2	3	3	2	3	1	2	2	3	3	2	1
DM3	3	3	2	3	1	1	1	3	2	2	2
DM4	3	3	1	4	1	2	1	3	3	2	3
DM5	4	3	2	3	1	2	1	3	3	1	2
DM6	1	3	1	3	1	2	1	2	1	1	1
FP1	1	3	1	2	1	1	1	1	3	2	1
FP2	1	3	3	2	1	1	1	2	3	2	1
FP3	1	3	3	2	1	1	2	2	2	1	1
FP4	2	3	2	3	1	1	3	3	2	1	2
FP5	1	3	2	2	1	1	1	1	1	1	1
FP6	1	3	2	3	1	1	3	2	3	1	1

Table 4.4.5 Qualification of the RMI Sub-indicators in 2000

2000	ARG	CHL	COL	CRI	DOM	ECU	SLV	GTM	JAM	MEX	PER
RI1	4	4	4	3	2	2	2	2	4	2	3
RI2	3	4	3	3	2	3	3	3	4	4	3
RI3	3	3	4	4	2	3	3	3	3	3	3
RI4	3	2	3	2	2	3	1	3	2	2	4
RI5	1	3	2	3	2	3	1	3	4	2	3
RI6	1	3	2	3	1	2	1	2	3	1	3
RR1	2	3	3	3	1	2	2	2	2	1	3
RR2	3	3	2	3	3	2	3	2	3	2	3
RR3	2	3	2	2	1	1	2	2	3	2	3
RR4	1	3	2	4	2	2	1	2	2	1	3
RR5	4	3	4	4	2	2	1	2	3	3	2
RR6	2	2	3	2	1	2	1	2	1	3	2
DM1	4	4	3	4	2	2	3	4	5	3	3
DM2	2	4	2	4	2	2	3	4	3	3	2
DM3	3	3	2	3	2	1	3	4	3	3	2
DM4	3	3	2	3	2	2	2	4	3	3	4
DM5	4	3	1	3	2	3	2	4	3	2	3
DM6	1	3	2	4	1	2	1	3	2	2	2
FP1	1	4	2	3	1	1	1	2	3	2	2
FP2	1	3	2	3	1	1	1	3	3	3	2
FP3	1	3	2	3	1	1	3	2	2	1	2
FP4	2	3	2	4	1	1	3	3	2	2	2
FP5	1	3	3	2	1	1	1	1	1	2	2
FP6	1	3	3	3	2	1	3	2	3	2	2

Figure 4.4.1 RMI Related to Risk Identification

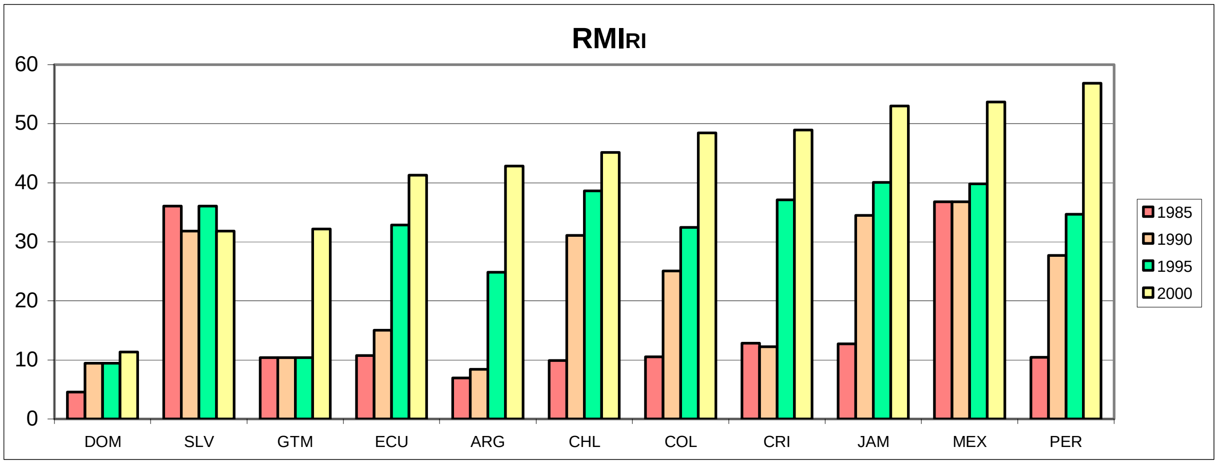


Figure 4.4.2 RMI Related to Risk Reduction

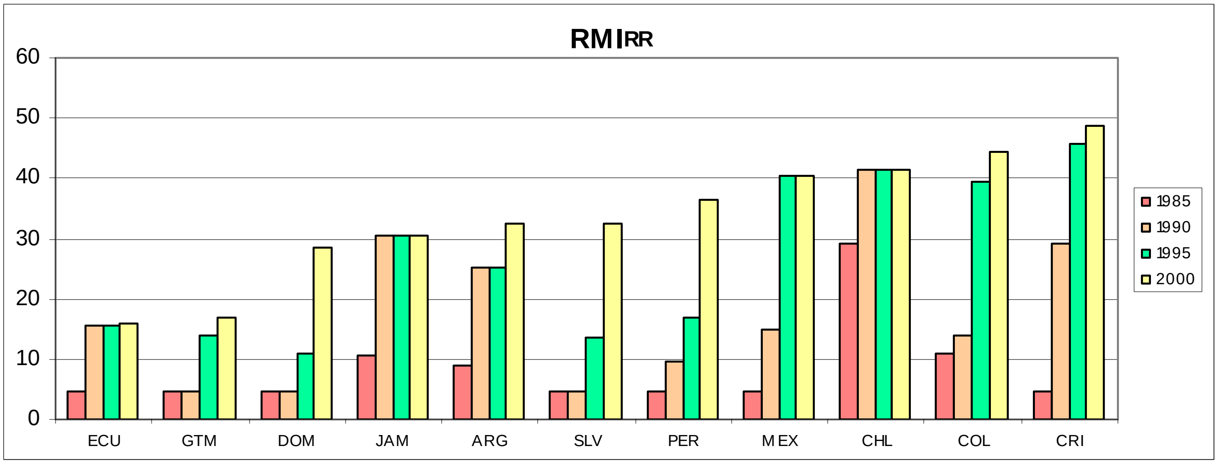


Figure 4.4.3 RMI Related to Disaster Management

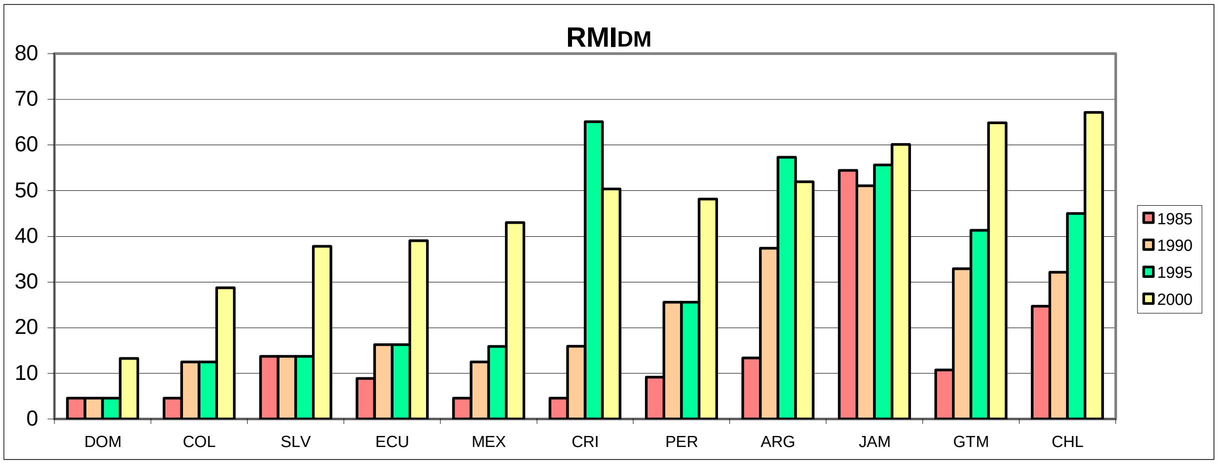


Figure 4.4.4 RMI Related to Financial Protection and Governance

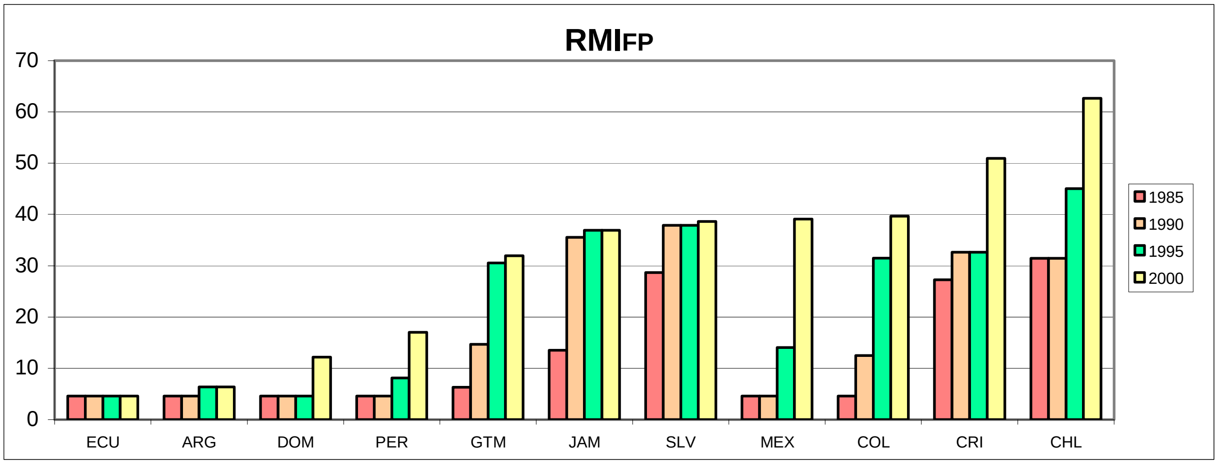


Table 4.4.1 and figures 4.4.1 – 4.4.4 show that most countries have made adequate progress in identifying risks, particularly Mexico, Peru and Jamaica. Costa Rica, Colombia, Chile and Mexico show the greatest advances in risk reduction. The largest improvements in the region were made in the indicator for disaster management. Chile, Guatemala and Jamaica posted the strongest showing in 2000; however, in the mid-1990s, Costa Rica, Argentina and Jamaica posted relatively strong indicators. The least relative improvement in the region was in financial protection and governance. The best postings for this indicator were in Chile, Costa Rica, Colombia and Mexico. It is with regard to this aspect that countries in general show least advance.

Figure 4.4.5 RMI for Each Country

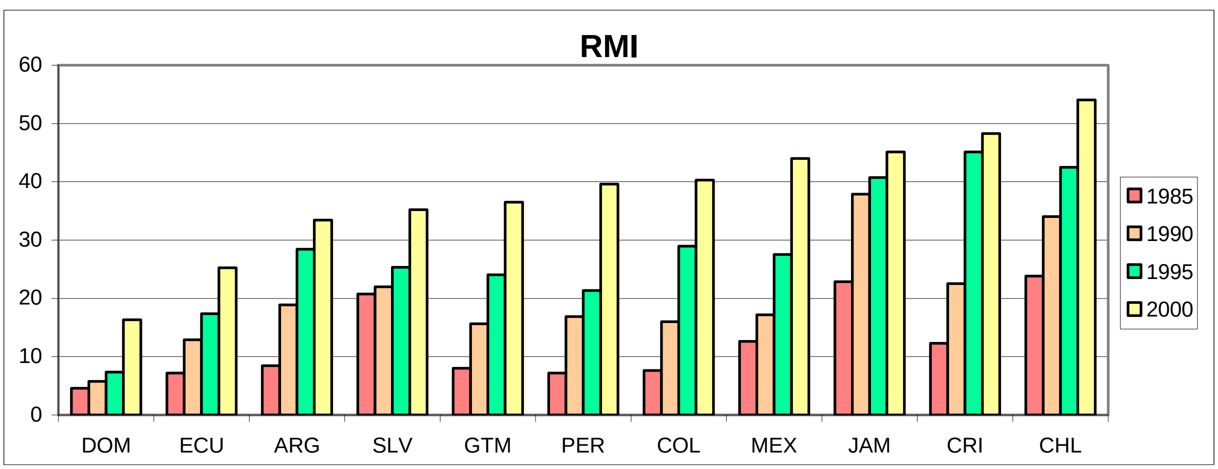
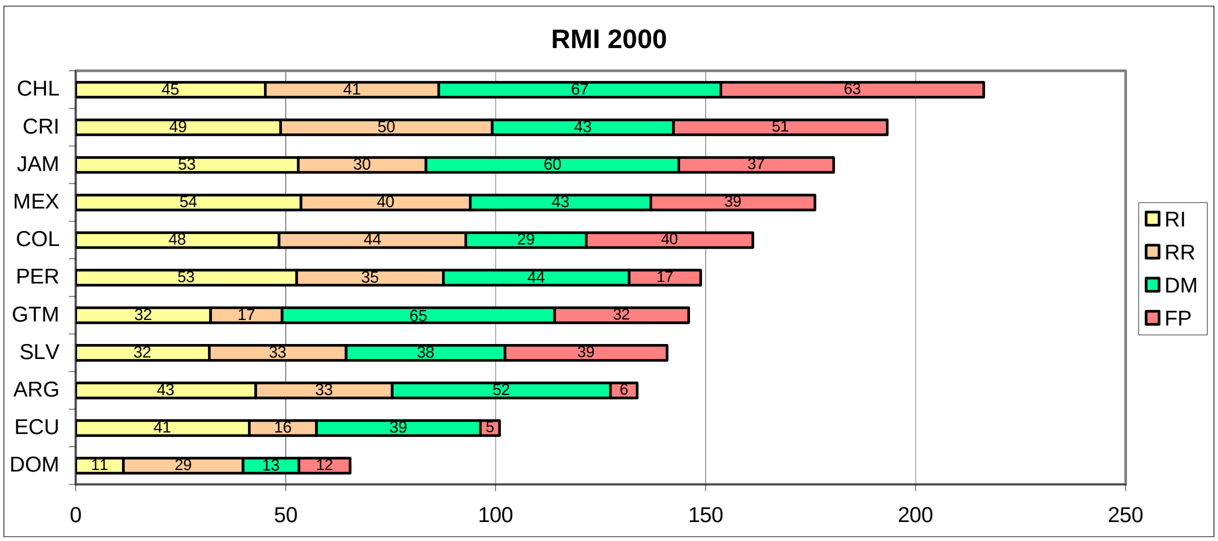


Figure 4.4.5 shows that the *RMI* for most countries studied has improved. All the countries started in the 1980's at a very low performance and in the 2000 the average *RMI* remains almost incipient. The countries with the largest improvement in the index, Costa Rica and Chile, only reach the "significant" level. The Dominican Republic and Ecuador posted the lowest index.

According to the theory that supports the method used here (Carreño *et al.* 2004), the probable effectiveness of risk management in the majority of cases does not rise above 60 percent. Most countries generally reach a level of effectiveness of between 20 and 30 percent. This is very low when compared to required effectiveness. Effectiveness was even lower in the past. The low level of effectiveness of risk management that may be inferred from the *RMI* values for this group of countries is confirmed by the high risk levels represented in the *DDI,* the *LDI* and the *PVI* over the years. In part, the high risk levels are due to the lack of effective risk management in the past. Figure 4.4.6 shows *RMI* values for 2000 obtained by adding the four components related to risk identification, risk reduction, disaster management and financial protection.

Figure 4.4.6 Aggregated RMI



The indicators that make up each public policy were weighted according to expert criteria in each country. Weights were assigned in order to give each component its significance in the context of each particular composite indicator. Three techniques were used to compare the results and analyze its pertinence:

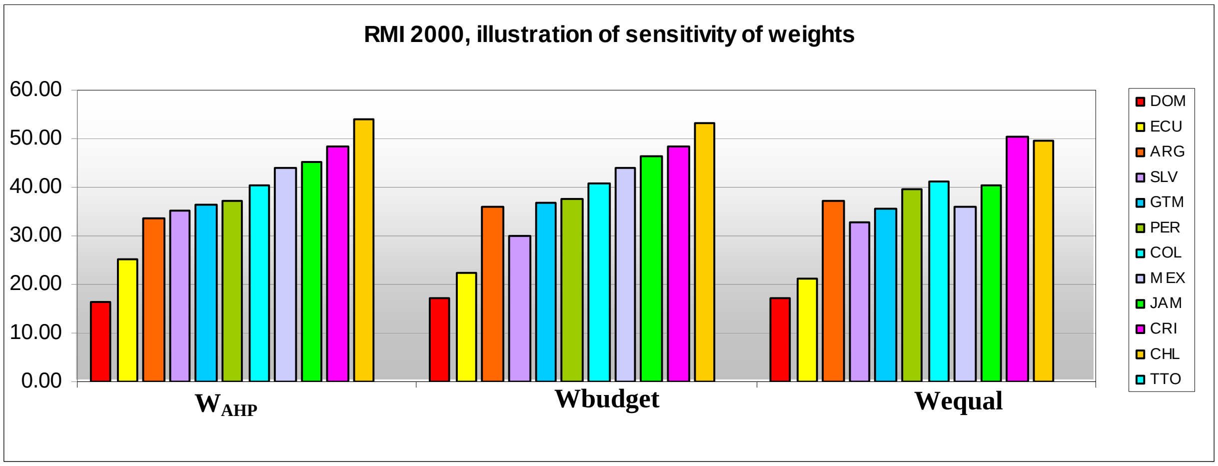
a) *Equal weighting*- This method, albeit simple, may not provide the best means of aggregation.

b) *Judgment of experts*- Experts were selected in each country with an ample spectrum of experience, knowledge and interest in the topic. The method is very useful given that the budgetary allocation of weights was undertaken for six indicators in each case (less than ten) as is recommended in the specialized literature.

c) *Analytic Hierarchy Process. AHP*- This method enables to derive weights as opposed to arbitrarily assignments. An advantage of AHP is that unlike many other methods, its use for purposes of comparisons does not require a universal scale. Furthermore, AHP tolerates inconsistency in the way people think through the amount of redundancy (more equations are available than the number of weights to be defined). Although an average of these allocations was obtained in order to have another unified pondering, it was decided to leave the weights obtained in each country, following adjustments in some cases in order to achieve consistency (see the methodology in Cardona *et al.* 2004a).

d) *Sensitivity tests* – The weights of the indicators are considered uncertainties given the plurality of perspectives of the experts. Result variation was minimal and in making comparisons the greatest change of position involved one scale place on the classification. Figure 4.4.7 shows the classification of the countries with weighting alternatives for one analysis period. Tables 4.4.6 and 4.4.7 show the weights obtained using the budget alternative and the AHP. The *RMI* was arrived at finally using the weights obtained by the AHP in each country.

Figure 4.4.1 Estimations of RMI using Different Weights



The weights and evaluations were undertaken in the majority of countries by risk management authorities. These evaluations would appear to be overly generous when compared to those undertaken by local external experts. The latter would appear to be more objective and sincere. The first type of evaluation was adhered to here but external evaluations are considered to be very pertinent and perhaps over time are the more desirable if undertaken in coordinated and concerted fashion, thus eliminating status quo factors in evaluations. Although it is also feasible to assign a weight to each composite index representing the performance of the country in each of the four policy areas, we assume in principle that such weights are equal.

4.4.1 Evaluation at Sub-national Level

RMI can be estimated within a country for sub-national units such as states, departments or provinces. Barbat and Carreño (2004b) and Carreño *et al.* (2005) present application results for Colombia and Bogota in a detailed form, as a demonstrative example within present study frame.

In the case of Bogota, for the estimation of the *RMI* we convened the participation of people of the Directorate of Prevention and Attention of Emergencies of Bogotá and external experts. The sub-indicators on risk identification (RI), risk reduction (RR), disaster management (DM) and financial protection and governance (FP), as well as the weights using the AHP were described according to their experience and knowledge. Table 4.4.8 presents the results of the *RMI* for Bogota.

Table 4.4.6 Weights Obtained Using Budget al.ternative

Ind	ARG	CHL	COL	CRI	ECU	SVL	GUA	JAM	MEX	PER	DOM	TTO
RI.1	10	25	10	10	10.75	10	15	5	5	28	5	n/a
RI.2	15	20	10	20	15.25	50	15	35	52	14	20	n/a
RI.3	20	5	20	15	14.75	10	20	15	30	22	5	n/a
RI.4	25	10	30	20	20.25	10	20	15	5	18	25	n/a
RI.5	10	10	15	15	21	10	10	20	5	12	15	n/a
RI.6	20	30	15	20	18	10	20	10	3	6	30	n/a
RR.1	25	15	13	25	19.5	10	20	20	10	20	30	n/a
RR.2	20	10	12	20	20	0	20	20	20	15	20	n/a
RR.3	9	15	5	10	12	20	15	25	10	10	5	n/a
RR.4	12	20	30	15	17.5	50	20	15	5	18	15	n/a
RR.5	18	30	20	15	17.25	10	15	15	30	25	25	n/a
RR.6	16	10	20	15	13.75	10	10	5	25	12	5	n/a
DM.1	24	25	15	20	19	33	18	30	25	30	20	n/a
DM.2	21	25	15	20	18.25	6	22	30	20	20	25	n/a
DM.3	17	10	20	20	12	9	14	20	20	7	10	n/a
DM.4	14	5	20	5	12.75	2	14	5	25	12	10	n/a
DM.5	11	15	15	20	20.75	17	18	10	5	25	15	n/a
DM.6	13	20	15	15	17.25	33	14	5	5	6	20	n/a
FP.1	27	30	10	20	26	25	15	10	20	15	35	n/a
FP.2	21	15	15	20	12	0	15	10	30	5	5	n/a
FP.3	15	10	15	20	16.25	10	20	25	5	20	15	n/a
FP.4	13	20	10	10	14.75	5	20	15	5	10	10	n/a
FP.5	18	10	25	20	15.25	35	15	10	15	25	5	n/a
FP.6	6	15	25	10	15.75	25	15	30	25	25	30	n/a

Table 4.4.7 Weights Obtained Using AHP Technique

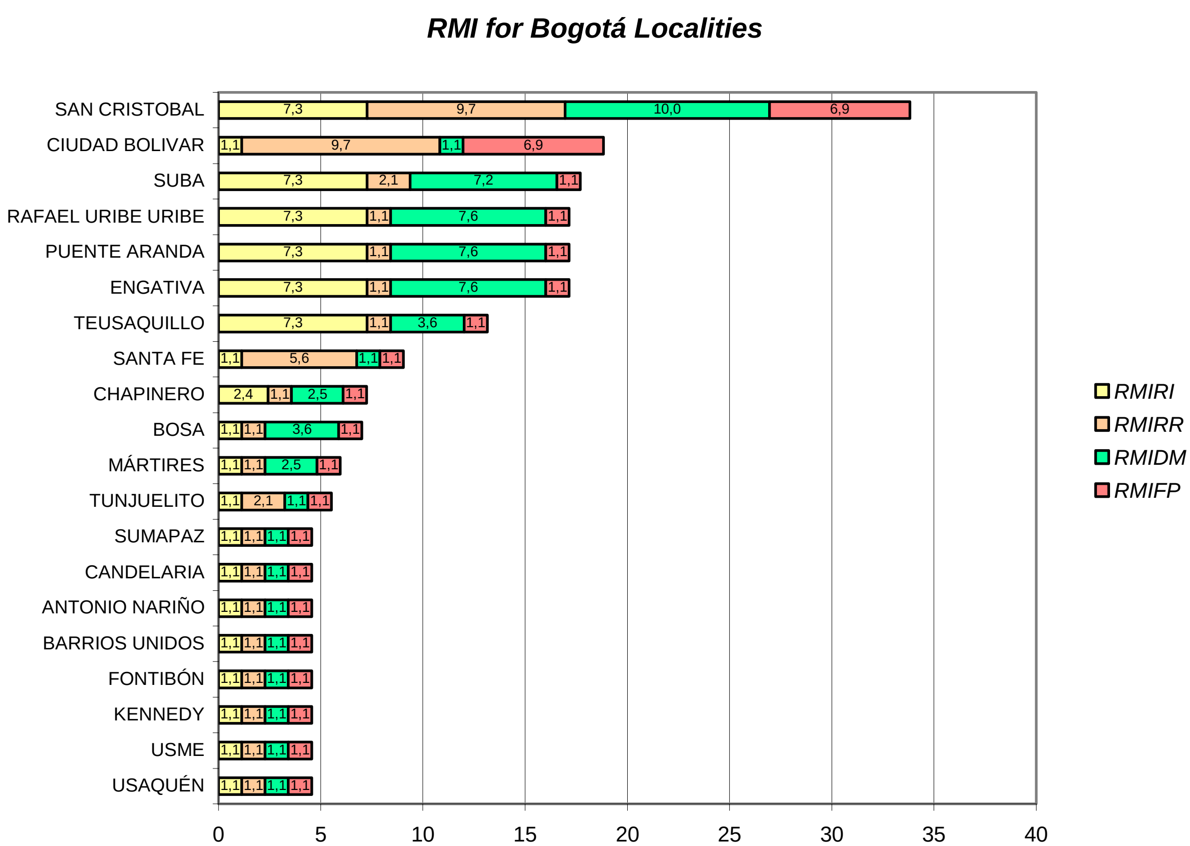
Ind	ARG	CHL	COL	CRI	ECU	SVL	GUA	JAM	MEX	PER	DOM	TTO
RI.1	7.65	9.33	11.54	9	3.21	16.67	43.55	5.78	6.37	31.22	4.87	n/d
RI.2	7.34	17.9	11.54	20	10.05	16.67	23.36	23.29	41.24	14.16	13.8	n/d
RI.3	13.4	2.92	17.66	20	6.77	16.67	14.78	20.35	24.08	23.97	4.87	n/d
RI.4	46	26.3	31.52	18	24.17	16.67	9.40	12.63	3.13	17.05	25.7	n/d
RI.5	3.45	5.15	13.86	15	40.83	16.67	5.88	25.26	17.74	8.31	14.6	n/d
RI.6	22.1	38.5	13.86	18	14.96	16.67	3.03	12.69	7.44	5.29	36.2	n/d
RR.1	44.1	43.2	14.37	26	40.95	24.3	46.38	30.01	5.97	24.81	30.3	n/d
RR.2	19.5	4.01	8.59	22	23.32	21.92	27.05	16.85	9.82	13.49	19	n/d
RR.3	4.45	5.97	7.24	9.2	7.46	17.8	11.23	8.66	14.89	3.41	4.95	n/d
RR.4	5.95	15.6	31.27	14	13.28	8.8	7.30	13.46	4.51	18.18	15.2	n/d
RR.5	15.6	15.6	19.86	16	9.47	15.99	4.80	17.88	24.23	31.33	25.6	n/d
RR.6	10.4	15.6	18.68	12	5.52	11.19	3.24	13.14	40.58	8.79	4.95	n/d
DM.1	42.2	24.6	12.50	14	13.80	5.85	5.46	31.51	30.51	30.60	19.5	n/d
DM.2	31.5	45.9	12.50	14	13.80	37.24	41.09	22.12	15.32	19.84	25.3	n/d
DM.3	8.67	5.33	25.00	14	5.25	15.84	10.67	11.94	15.32	6.61	9.09	n/d
DM.4	6.21	3.58	25.00	38	5.25	24.57	3.22	13.64	30.51	11.39	9.09	n/d
DM.5	4.56	12.4	12.50	14	40.39	10.09	24.47	14.78	2.27	28.33	17.5	n/d
DM.6	6.79	8.17	12.50	7.3	21.51	6.41	15.09	6.01	6.07	3.23	19.5	n/d
PF.1	45.3	45.9	10.52	20	51.70	24.24	18.08	9.71	19.12	10.03	33.9	n/d
PF.2	25.6	5.11	13.23	20	4.62	4.292	2.83	9.71	40.83	2.93	4.99	n/d
PF.3	14	10.2	14.96	18	20.15	5.909	41.55	22.57	2.58	18.20	16.1	n/d
PF.4	5.46	13.5	7.35	10	4.623	36.52	24.98	16.8	3.35	7.97	9.33	n/d
PF.5	6.37	3.01	26.97	20	4.78	13.72	7.77	9.13	10.6	30.4	4.99	n/d
PF.6	3.17	22.3	26.97	12	14.13	15.31	4.78	32.1	23.6	30.4	30.7	n/d

Table 4.4.8 RMI for Bogota

Indicator	1985	1990	1995	2000	2003
RMI_{RI}	4.6	13.9	35.6	56.2	67.1
RMI_{RR}	11.0	13.9	13.9	46.1	56.7
RMI_{DM}	4.6	8.3	8.3	24.0	32.3
RMI_{FP}	4.6	57.5	54.8	57.6	61.4
$RMI_{average}$	6.2	23.4	28.1	46.0	54.4

In addition, it was made the same study to evaluate the *RMI* in each locality of the city, following and using the same functions. Figure 4.4.8 shows the results obtained for 2003.

Figure 4.4.8 Ranking of the Localities According to the RMI



4.5 Indicators at Urban Level

The type of evaluation proposed for the urban level was applied as a demonstrative way in Bogotá, Colombia, with the idea of illustrating the type of results that could be obtained and, consequently, the type of risk management activities that are most appropriate. For this type of example it was necessary to identify a case where the information required was easy to obtain and where hazard and physical risk studies have been made in advance and with an adequate level of refinement and resolution. A summary of the results is included in the report of Barbat and Carreño (2004b).

For the illustrative example the seismic hazard was considered the worse threat. Seismic risk evaluation of Bogota, from a holistic perspective, was obtained starting from the potential scenario of losses. This allowed defining indicators of damage and direct effects for each unit of analysis, in this case called locality or district.

An indicator of physical risk (R_P) was obtained for each locality by taking into account potential deaths, number of persons injured, the extent of the area destroyed and the impact on vital infrastructure and services, including water, electricity, roads, and housing. A direct impact factor (F) was determined for each unit of analysis on the basis of indicators of social fragility and lack of resilience. The direct impact factor ranges between 0 and 1. The values to evaluate the factor of indirect impact are computed for each locality of the city, using functions that are described in the previous section whereby the net values of the indicators are related to an impact factor. Each factor is also assigned a weight consistent with the Analytic Hierarchy Process (AHP).

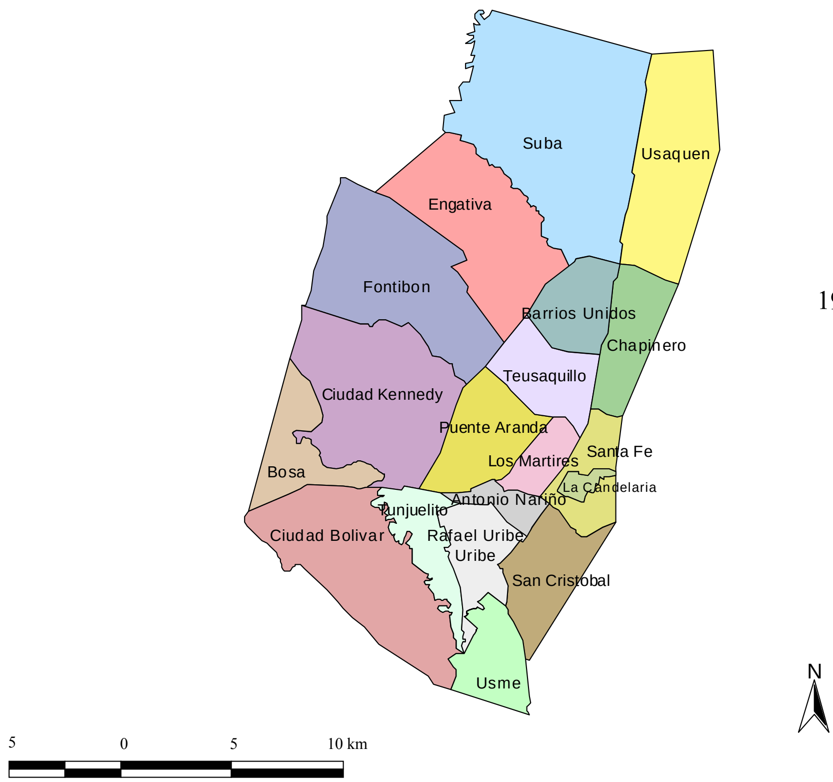
Bogota, capital of Colombia, is divided in localities or districts. A locality is a political, administrative and territorial municipal division, with clear competitions, financial and resources application criteria. Localities were established with the aim to attend in a more effective way necessities of this part of territory. From 1992, Bogota is divided in 20 localities thus: Usaquén, Chapinero, Santafé, San Cristóbal, Usme, Tunjuelito, Bosa, Kennedy, Fontibón, Engativa, Suba, Barrios Unidos, Teusaquillo, Mártires, Antonio Nariño, Puente Aranda, Candelaria, Rafael Uribe, Ciudad Bolívar y Sumapaz. This study has into account only 19 of these due to Sumapaz locality corresponds to rural area fundamentally. Figure 4.5.1 shows the map of Bogota's localities or areas.

Tables 4.5.1 and 4.5.3 show descriptor values used in the proposed model. They represent physical risk, social fragility and lack of resilience of the city respectively.

Tables 4.5.2 and 4.5.4 show values of the physical risk factors and aggravation values, because of social fragility and lack of resilience obtained with application of the curves from figures 2.5-1.1 a 2.5-1.3, as physical risk index, R_p and the impact factor, *F*.

Additionally, standardize average values are shown, using population density for the city. Table 4.5.5 shows physical risk, the impact factor, the total risk results of each locality and also shows average values of the city.

Figure 4.5.1 Map of Localities of Bogotá



19 localities

Table 4.5.1 Values of Physical Risk Descriptors, R_p

Locality	X_{Rp1}	X_{Rp2}	X_{Rp3}	X_{Rp4}	X_{Rp5}	X_{Rp6}	X_{Rp7}	X_{Rp8}
Usaquen	15.1186	4	27	2	0	24	0.7	0.83
Chapinero	5.0302	5	27	5	0	81	0.77	0.9
Santafe	6.6070	3	16	7	0	63	0.62	0.9
San Cristóbal	4.9278	2	13	4	0	34	0.68	0.9
Usme	10.5870	0	1	1	1	14	0.67	0.9
Tunjuelito	3.5494	0	1	1	0	7	0.58	0.7
Bosa	4.2461	2	12	3	1	42	0.73	0.9
Ciudad Kennedy	4.8198	0	2	1	0	11	0.54	0.7
Fontibón	5.3163	1	7	1	0	5	0.64	0.7
Engativa	6.8777	1	5	1	0	3	0.66	0.8
Suba	13.8449	2	13	1	0	19	0.66	0.77
Barrios Unidos	12.2659	4	27	2	1	45	0.75	0.9
Teusaquillo	10.2985	8	41	4	0	36	0.74	0.9
Mártires	7.0283	6	30	2	0	18	0.66	0.7
Antonio Nariño	4.0287	0	2	2	0	17	0.67	0.8
Puente Aranda	5.7006	1	6	2	0	20	0.69	0.7
Candelaria	8.9515	9	44	6	0	81	0.67	0.9
Rafael Uribe Uribe	3.2433	1	11	2	0	29	0.65	0.9
Ciudad Bolívar	8.8908	1	11	1	1	21	0.64	0.9

Table 4.5.2 Factors, F_{RP}, and Physical Risk, Rp

Locality	F_{RP1}	F_{RP2}	F_{RP3}	F_{RP4}	F_{RP5}	F_{RP6}	F_{RP7}	F_{RP8}	R_P
Usaquen	0.881	0.0128	0.259	0.08	0	0.0288	0.70	0.83	0.386
Chapinero	0.127	0.02	0.259	0.50	0	0.328	0.77	0.90	0.264
Santafe	0.218	0.0072	0.091	0.82	0	0.198	0.62	0.90	0.314
San Cristobal	0.121	0.0032	0.0601	0.32	0	0.0578	0.68	0.90	0.175
Usme	0.557	0	0.000356	0.02	0.08	0.0098	0.67	0.90	0.253
Tunjuelito	0.063	0	0.000356	0.02	0	0.00245	0.58	0.70	0.076
Bosa	0.090	0.0032	0.0512	0.18	0.08	0.0882	0.73	0.90	0.152
Ciudad Kennedy	0.116	0	0.00142	0.02	0	0.00605	0.54	0.70	0.092
Fontibón	0.141	0.0008	0.0174	0.02	0	0.00125	0.64	0.70	0.105
Engativa	0.237	0.0008	0.00889	0.02	0	0.00045	0.66	0.80	0.139
Suba	0.811	0.0032	0.0601	0.02	0	0.0181	0.66	0.77	0.326
Barrios Unidos	0.701	0.0128	0.259	0.08	0.08	0.101	0.75	0.90	0.350
Teusaquillo	0.529	0.0512	0.589	0.32	0	0.0648	0.74	0.90	0.366
Mártires	0.247	0.0288	0.32	0.08	0	0.0162	0.66	0.70	0.186
Antonio Nariño	0.081	0	0.00142	0.08	0	0.145	0.67	0.80	0.116
Puente Aranda	0.162	0.0008	0.0128	0.08	0	0.02	0.69	0.70	0.126
Candelaria	0.401	0.0648	0.658	0.68	0	0.328	0.67	0.90	0.426
Rafael Uribe U.	0.053	0.0008	0.043	0.08	0	0.042	0.65	0.90	0.103
Ciudad Bolívar	0.395	0.0008	0.043	0.02	0.08	0.022	0.64	0.90	0.206
Bogota	0.41	0.0039	0.0536	0.0924	0.0486	0.0379	0.6645	0.8630	0.2246

Table 4.5.3 Values of Aggravating Descriptors due to Social Fragility and Lack of Resilience, SF and LR

Locality	X_{SF1}	X_{SF2}	X_{SF3}	X_{SF4}	X_{SF5}	X_{LR1}	X_{LR2}	X_{LR3}	X_{LR4}	X_{LR5}	X_{LR6}
Usaquen	0.311	1260	433	0.33	12720.00	0.17937	28	0.0496	0.844	4	2
Chapinero	0.161	1786	1282	0.00	9655.00	0.49088	89	0.0129	3.231	4	1
Santafe	0.370	1082	1034	0.36	19223.00	0.62909	143	0.0032	3.382	3	2
San Cristóbal	0.614	1511	216	0.82	32242.00	0.10353	19	0.0148	3.882	1	2
Usme	1.476	421	74	1.00	353106.00	0.06368	2	0	7.323	1	2
Tunjuelito	0.738	715	322	0.45	33095.00	0.17567	13	0.0978	4.504	2	2
Bosa	1.076	664	258	0.51	17383.00	0.04872	3	0.0359	7.837	1	1
Ciudad Kennedy	0.501	1433	380	0.44	22352.00	0.06875	8	0.0202	3.454	2	1
Fontibón	0.340	1000	275	0.39	9795.00	0.02736	4	0.0109	3.870	3	2
Engativa	0.257	2789	278	0.41	22488.00	0.06770	7	0.0005	3.371	2	2
Suba	0.326	1880	316	0.41	12658.00	0.08701	15	0.0257	4.202	2	2
Barrios Unidos	0.001	950	509	0.29	16908.00	0.15437	33	0.1170	6.175	4	1
Teusaquillo	0.166	0	888	0.05	11536.00	0.51755	20	0.1126	1.540	4	2
Mártires	0.201	570	831	0.33	11902.00	1.14030	103	0.0271	25.426	3	1
Antonio Nariño	0.112	534	513	0.20	20414.00	0.09494	5	0.0131	8.884	4	1
Puente Aranda	0.058	1147	448	0.37	15203.00	0.03858	4	0.0030	1.488	3	2
Candelaria	0.775	0	904	0.34	11422.00	0.00000	0	0	0	3	0
Rafael Uribe U.	0.532	927	288	0.50	23125.00	0.01863	11	0.00133	3.696	1	2
Ciudad Bolívar	0.418	970	162	0.92	28058.00	0.07044	3	0	5.880	1	2

Table 4.5.4 Impact Factor, *F*, due to Social Fragility and Lack of Resilience Factors, F_{SF} y F_{LR}

Locality	F_{SF1}	F_{SF2}	F_{SF3}	F_{SF4}	F_{SF5}	F_{LR1}	F_{LR2}	F_{LR3}	F_{LR4}	F_{LR5}	F_{LR6}	F
Usaquen	0.278	0.0150	0.1610	0.327	0.345	1	0	0.840	0.969	0	0	0.309
Chapinero	0.0503	0.1370	0.985	0.000	0.145	0.999	0	0.999	0.575	0	0.5	0.245
Santafe	0.418	0.00149	0.853	0.362	0.849	0.999	0	1	0.533	0.3	0	0.478
San Cristóbal	0.925	0.0580	0.030	0.816	1.000	1	0	0.998	0.396	1	0	0.707
Usme	1.000	0	0.000632	1.000	1.000	0.999	0.964	1	0.000	1	0	0.797
Tunjuelito	0.999	0	0.0812	0.449	1.000	1	0.0356	0.278	0.255	0.6	0	0.587
Bosa	1.000	0	0.0475	0.515	0.737	1	0.92	0.932	0.000	1	0.5	0.701
Ciudad Kennedy	0.747	0.0417	0.120	0.440	0.968	1	0.436	0.989	0.513	0.6	0.5	0.643
Fontibón	0.343	0.0000	0.056	0.385	0.152	1	0.858	1	0.399	0.3	0	0.358
Engativa	0.175	0.6740	0.057	0.409	0.971	1	0.564	1	0.536	0.6	0	0.521
Suba	0.311	0.1720	0.078	0.415	0.340	0.998	0	0.975	0.321	0.6	0	0.369
Barrios Unidos	0.000	0	0.231	0.290	0.703	1	0	0.111	0.030	0	0.5	0.302
Teusaquillo	0.0549	0	0.712	0.050	0.258	0.999	0	0.143	0.904	0	0	0.193
Mártires	0.0931	0	0.645	0.331	0.283	0.997	0	0.97	0.000	0.3	0.5	0.325
Antonio Nariño	0.0157	0	0.235	0.198	0.905	1	0.778	0.999	0.000	0	0.5	0.407
Puente Aranda	0.000261	0.0048	0.174	0.373	0.565	1	0.858	1	0.911	0.3	0	0.391
Candelaria	1.000	0	0.730	0.340	0.250	1	1	1	1.000	0.3	1	0.631
Rafael Uribe U.	0.806	0	0.0622	0.503	0.984	1	0.142	1	0.445	1	0	0.635
Ciudad Bolívar	0.550	0	0.0138	0.920	1.000	1	0.92	1	0.049	1	0	0.700
Bogota.	0.762	0.032	0.111	0.736	0.880	0.999	0.670	0.922	0.188	0.774	0.089	0.663

Table 4.5.5 Total Risk for Bogotá City

Locality	R_P	F	R_T
Usaquen	0.386	0.309	0.505
Chapinero	0.264	0.245	0.329
Santafe	0.314	0.478	0.464
San Cristóbal	0.175	0.707	0.298
Usme	0.253	0.797	0.454
Tunjuelito	0.076	0.587	0.121
Bosa	0.152	0.701	0.258
Ciudad Kennedy	0.092	0.643	0.150
Fontibón	0.105	0.358	0.142
Engativa	0.139	0.521	0.211
Suba	0.326	0.369	0.446
Barrios Unidos	0.350	0.302	0.456
Teusaquillo	0.366	0.193	0.436
Mártires	0.186	0.325	0.246
Antonio Nariño	0.116	0.407	0.163
Puente Aranda	0.126	0.391	0.175
Candelaria	0.426	0.631	0.694
Rafael Uribe Uribe	0.103	0.635	0.169
Ciudad Bolivar	0.206	0.700	0.350
Bogota	0.225	0.663	0.374

Figures 4.5.2 to 4.5.6 presents the results of the holistic estimation of seismic risk in Bogotá using indicators. These figures show how the locality of La Candelaria presents the most critical situation with regard to physical risk and total risk, because its impact factor is significant, although it is not the highest in the city. Localities with high impact factor (due to social fragility and lack of resilience) are Usme, San Cristóbal, Bosa and Ciudad Bolívar, whereas the lower values belong to Barrios Unidos, Chapinero and Teusaquillo. In addition, the localities of La Candelaria, Usaquén, Barrios Unidos and Teusaquillo present the greater physical risk, whereas Ciudad Kennedy and Tunjuelito have the lower physical risk. As result, La Candelaria, Usaquen, Santafe and Barrios Unidos present the higher total risk values, and Ciudad Kennedy, Fontibón and Tunjuelito have the lower values.

In general, results obtained for Bogotá are similar using both the approach orginally proposed by Cardona (2001) and this model of holistic evaluation of risk. Nevertheless, this model corrects methodological and conceptual issues and refines the technic, turning it into a more versatile tool. The conceptual improvements give to the model a more solid theoretical and analytical support and eliminate unnecessary and questionable aspects of the original model that, in some cases, have reduced its transparency and applicability. Keeping the approach based on indicators and the use of fuzzy sets or membership function alternatives, proposed originally, this model is proposing a technique where these two approaches are merging and simplifiying, improving the scaling procedure, the determination of indicators and final indices; making easier the comparison even between cities.

Figure 4.5.2 Physical Risk Index for the Localities of Bogotá

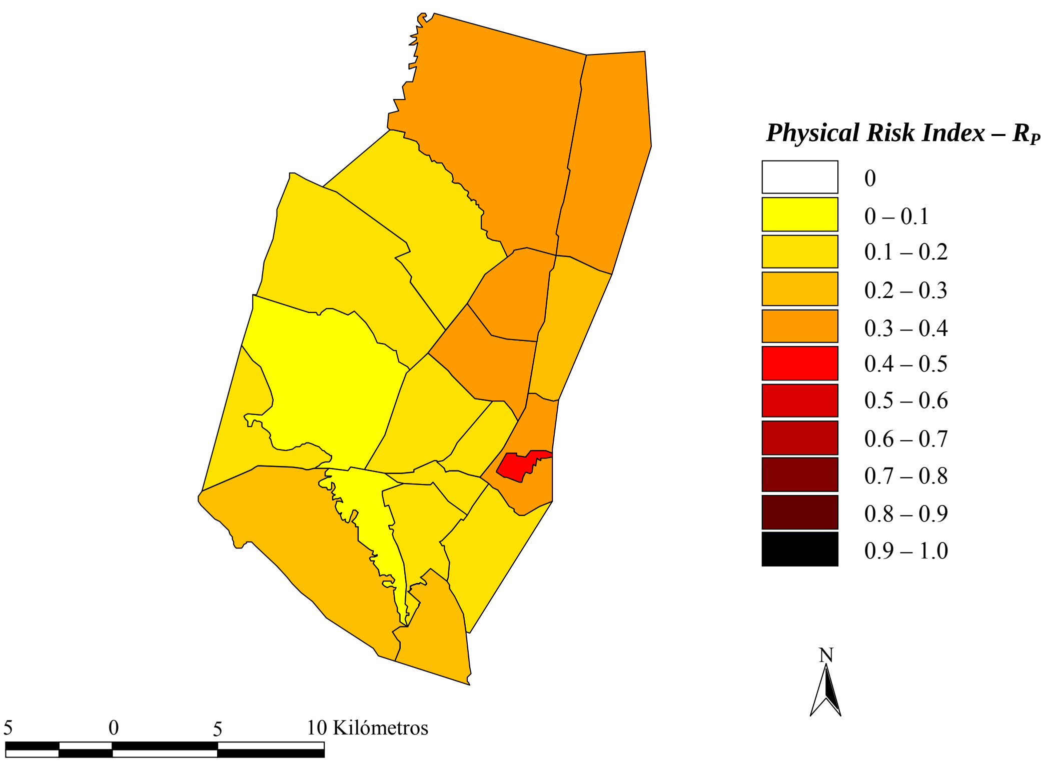


Figure 4.5.3 Values and Ranking of the Localities According to the Physical Risk Index

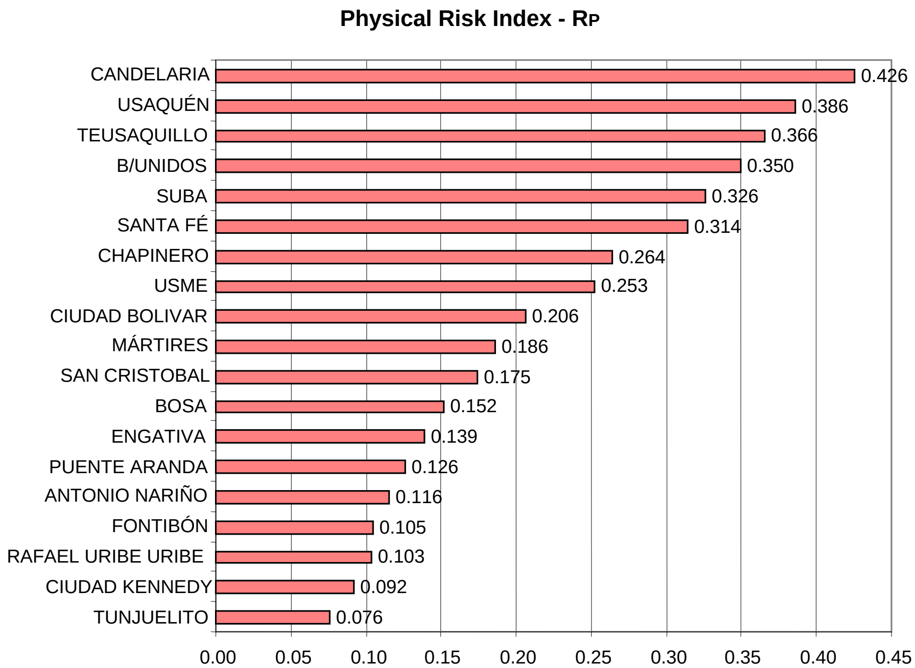


Figure 4.5.4 Values and Ranking of the Localities According to the Impact Factor

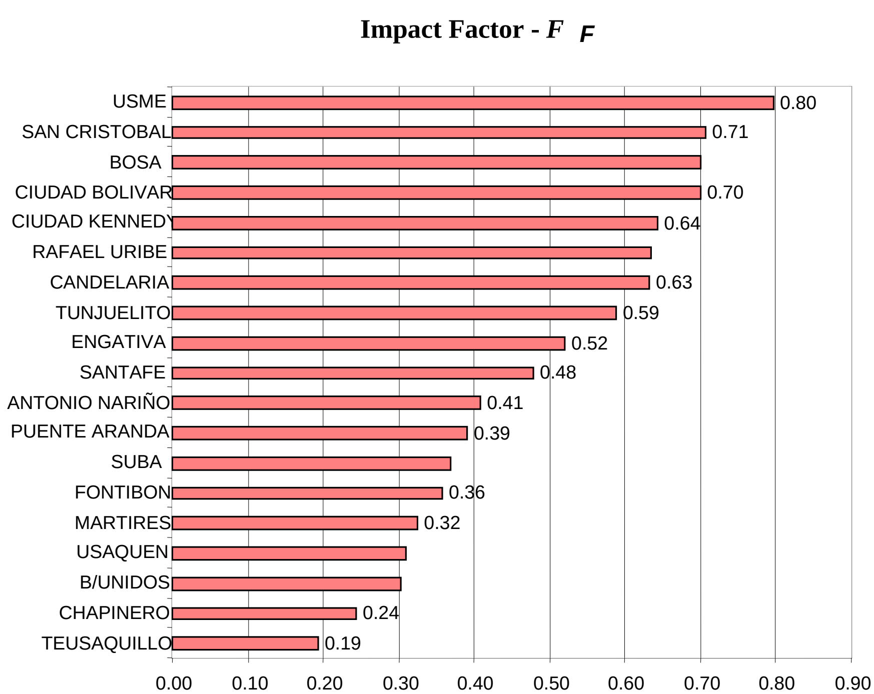


Figure 4.5.5 Total Risk Index for the Localities of Bogotá

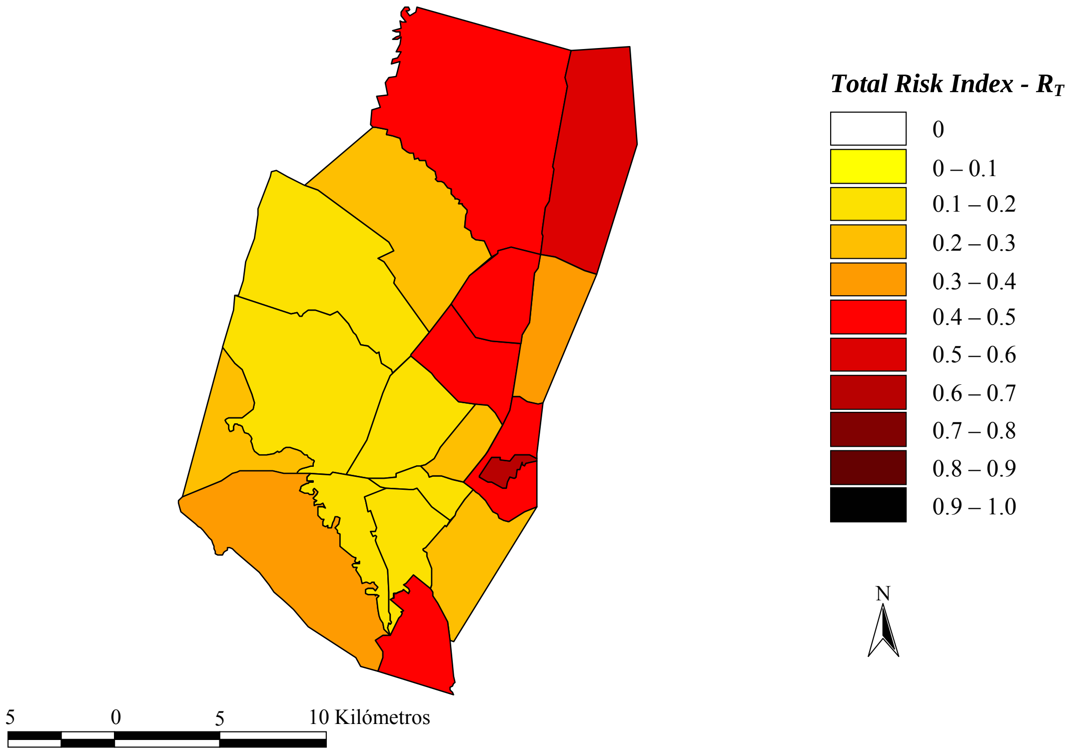
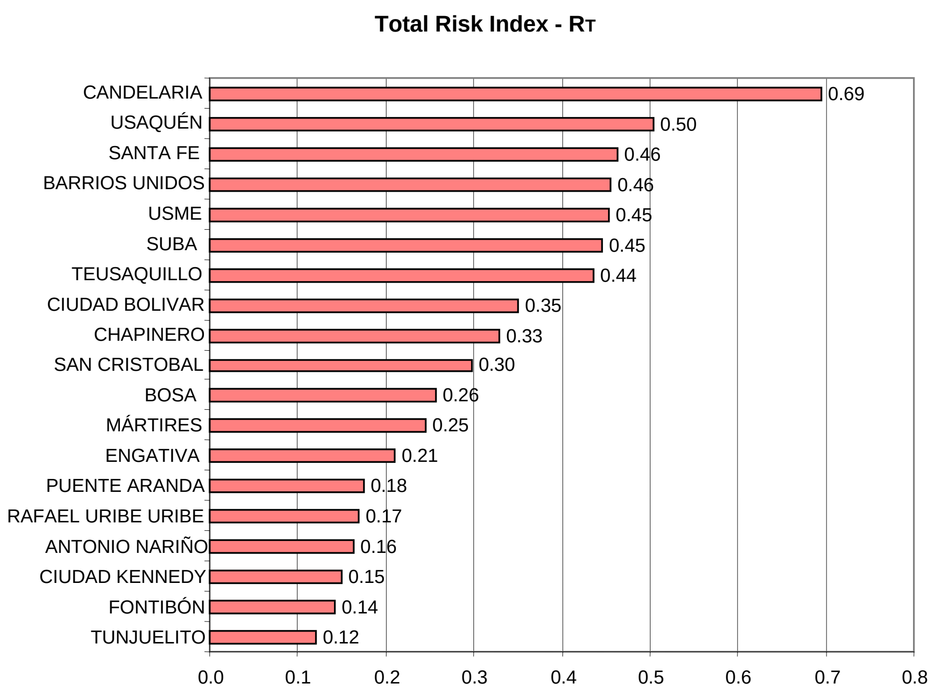


Figure 4.5.6 Values and Ranking of the Localities According to the Total Risk Index



4.6 Conclusions

The indicators of risk and risk management presented in this report have permitted an evaluation of twelve Latin American and Caribbean countries based on integrated criteria. The results show that it is possible to describe risk and risk management using coarse grain measures and classify countries according to a relative scale. An evaluation of individual countries allowed us to compare individual performance indicators for the period 1980–2000.[45] The report also estimated the indicators at the subnational and urban level.

The Disaster Deficit, Local Disaster and Prevalent Vulnerability indices (DDI, LDI and PVI) are risk proxies that measure different factors that affect overall risk at the national and subnational levels. By depicting existing risk conditions, the indicators highlight the need for intervention. This study indicates that the countries of the region face significant risks that have yet to be fully recognized or taken into account by individuals, decisionmakers and society as a whole. These indicators are a first step in correctly measuring risk so that it can be given the priority that it deserves in the development process. Once risk has been identified and measured, activities can then be implemented to reduce and control it. The first step in addressing risk is to recognize it as a significant socioeconomic and environmental problem.

The results obtained for the period 1995 to 2000, using an ordinal ranking scale, are as follows: Peru, the Dominican Republic and El Salvador are most prone to future extreme disaster risk based on evaluations for the year 2000. These countries are likely to suffer significant losses and lack the economic resilience to address them adequately. Jamaica and Colombia also face relatively high risk, particularly in the case of low probability, high consequence events. Trinidad and Tobago, Ecuador and Mexico are in the mid-range of countries. The first two countries have a relatively poor ability to obtain reconstruction assistance, while Mexico may suffer high losses but its economic resilience is relatively high. Chile, Costa Rica, Guatemala and Argentina have minor relative risk profiles for extreme events, but this does not mean that risk is low. Large-scale losses are not expected in these countries, and their capacity to deal with losses is relatively good. In general, the risk associated with extreme events has increased over time in all the countries.

Local data for the last two decades indicate that Guatemala, Argentina and El Salvador face relatively high risk in the event of recurrent and highly spatially dispersed, low scale events. They are followed by Colombia and the Dominican Republic where events that could pose a hazard occur with less regularity and dispersion at the municipal level. Ecuador, Chile, and Mexico rank between these countries and Costa Rica, Peru, Trinidad and Tobago, and Jamaica where there is a lower relative incidence of smaller scale dispersed events.

Ecuador, Peru, Chile and Colombia have the highest relative concentration of economic losses associated with recurrent events, with losses concentrated in a limited number of municipalities. There is no clear regional tendency of the risk associated with smaller scale events. The effects in terms of deaths, affected population, and destruction of housing and crops do not follow an easily

[45] For obvious space limitations the results for each country cannot be included in this report.

identified pattern. However, the low level of awareness of events that have cumulative national and local impacts is worrisome.

Toward the end of the 1990s, Jamaica, El Salvador, and Guatemala had the highest prevalent vulnerability indices. Social and economic conditions in the Dominican Republic and Ecuador also presage that a hazard event could easily become a disaster. The Prevalent Vulnerability Index for Trinidad and Tobago, Peru, and Argentina is much better than that of the previous countries, but not quite as robust as that of Chile, Costa Rica, Mexico and Colombia, which have the lowest levels of vulnerability and lack of resilience. With the exception of Trinidad and Tobago and Argentina, prevalent vulnerability has dropped over the last 20 years. However, vulnerability is still very high in the vast majority of countries.

The Risk Management Index is the first systematic and consistent international technique developed to measure risk management performance. The conceptual and technical bases of this index are robust, despite the fact that it is inherently subjective. Although the method may be refined or simplified in the future, its approach is quite innovative because it allows the measurement of risk management and its probable effectiveness. The analysis shows that Ecuador, Argentina and the Dominican Republic have made the least progress over the last few years. El Salvador and Guatemala posted a slightly better performance. Peru and Colombia showed even more improvement, while Chile, Costa Rica, Jamaica and Mexico posted the most significant advances in risk management practice. The overall tendency since the 1980s has been one of increased concern for risk management. As a result, the evaluation of advances made has improved from "low" to "significant" in the majority of cases. On average, risk management performance is something better than "incipient," and (probable) effectiveness is still very low (0.2 - 0.3). This suggests that considerable efforts are required to promote effective and sustainable risk management, even in the more advanced countries. In general the greatest advances have been made in risk identification and disaster management. Risk reduction, financial protection and institutional organization have as yet been approached very timidly.

Taking into account relative positions in the ranking of indicators, the Dominican Republic, El Salvador, Ecuador and Guatemala face the greatest risk and have achieved the lowest levels of development in risk management. Colombia, Peru, Jamaica and Argentina are in an intermediate position. However, the latter two countries are special cases. In Jamaica, risk is high but risk management performance is good. In Argentina, while risk is low, so is risk management performance. Costa Rica, Chile and Mexico exhibit relatively low risk levels and acceptable risk management performance.

5. COMMENTS, CRITICISMS AND SUGGESTIONS FOR FUTURE DEVELOPMENTS

5.1 Overall Strengths and Benefits from the Perspective of the Peer Reviewers

According to the peer reviewers the proposed system of indicators is undoubtedly the most thorough, conceptually well substantiated, varied and critically constructed in existence on the topic. The conceptual framework will inevitably become a frame of reference for many academics and practitioners in the area and in it self generate new advances and attempts at analysis and indicator construction. The basic design of the system of indicators has been carefully constructed, logical, and comprehensive in its review of applicable methodologies and techniques of measurement. The project team undertook a difficult and ambitious task in seeking to integrate multiple measures for key dimensions of disaster risk into a single, comprehensive profile of risk and performance. The members have reviewed and considered the major existing methodologies for assessing risk, and have developed innovative means of integrating quantitative and qualitative measures for different characteristics of risk and exposure. These methods balance quantitative with quantitative measures, and seek to capture the essential dimensions underlying risk in both theory and practice.

Taking a holistic view of risk, the program has managed to bring a multidisciplinary perspective to bear on the analysis and the integration of what the project team call "soft" and "hard" variables. The combination of "hard" and "soft" analysis and variables is not common and almost unique in our predominantly still segregated disciplinary environment. The program has produced (with what ever doubts and short comings one may identify) a very well structured argument and proposal for four different types of indicator on risk and risk management, introducing unquestionably valid and varied variables to construct these (independently of the fact that arguments may be provided for the inclusion of other variables), combining different quantitative and qualitative methods for aggregating and valorizing components.

The four indicators have different qualities in relation to hazards at different scales, and different relevance for various actors/agents. A major benefit is that it can make transparent the policy areas in which interventions can be made by key actors in a much more specific way than has been possible so far. There is of course no guarantee that relevant actions will be taken because of the existence of the indicators. And it must be asked whether the inadequacy of disaster management up to now has been significantly affected by the absence of such indicators. But one of the most useful aspects of the indices may be the way that they make it more difficult for the relevant actors to avoid their responsibilities (including perhaps increasing the resources available). The indicators may also point to ways in which existing resources can be used more effectively.

The four indicators are complementary and also comprehensive. Used together, they provide guidance for a society-wide program of risk reduction from "top down" and "bottom up" that, in principle would include all relevant actors, decision makers, and socio-economic groups at national to local scale. However, written up as a scientific report, the full power and vision of the IDB-IDEA project does not come across. The comprehensive and complementary nature of its four indicators provides the basis for making risk reduction "an essential and integral component of sustainable human development."[46] It could be that as a follow up a more "journalistic" version of the report should be produced with narrative examples of how the indicators could be used together to achieve desirable change.

One of the reviewers said that he was very impressed with the national delegates from the participating countries whom he heard speak and met in the regional workshop of the project in Manizales. It seems that a true epistemic community[47] has been formed through the hard struggle to generate data for the indicators project. Countries seem to have taken full ownership of the indicators. It is highly likely that one of the benefits of this project beyond the existence of this set of indicators is the initiation of a process of sharing and exchange that will support national advocates for risk reduction in the future.

Unique other attempts to bring science to the service of risk reduction, the IDB-IDEA indicators project laid heavy emphasis on *developing a language of risk* that various kinds of decision makers understand. One would think after some experiences it would be hard to find a senior government official who denies the *developmental significance* of disaster. Yet facing a variety of demanding priorities and rapid changes, the political leadership tends to focus on what is immediate. The past is too soon forgotten. These indicators are a bell of mindfulness. This is a very important advance that will have repercussions throughout the Hemisphere, and perhaps the world. The project amounts to an enormous contribution. In sum, the basic formulation of the system of indicators seems fine for the purpose in mind however some criticisms are relevant to take into account for future developments or to identify the weaknesses or the inherent limitations of each index or their components. The main criticisms of the peer reviewers, the replies of the project team and the suggestions of both sides are described in the following paragraphs for each indicator for future improvements.

5.2 Critiques, Comments and Project Team Replies on the DDI

One of the great strengths of the IDB-IDEA approach, according to the peer review, is to develop language that decision makers recognize and use. They consider this is particularly true in the case of the *DDI*, because it is a real innovation in the disaster risk arena, and is potentially a very valuable tool for governments, international agencies, and also in relation to civil society engagement and good governance. Financial planners and senior officials concerned with financial affairs will be find the *DDI* and *DDI'* immediately useful, assuming that the logic is that the *MCE* approach will give a basis for dealing with the most challenging events in financial terms and that there will be some strong correlation between the impact of *MCE* and the overall risk faced by a country. This, however, does not remove the difficulty of contending priorities in nations and municipalities that face numerous short term crises. In addition, even well educated people do not fully understand concepts from probability analysis, such as "return period". Thus some interpretations will still be necessary in making sure that decision makers do not think that a "500 year event" is so remote as not to matter to them or their fixed term administration.

[46] A statement produced by the Inter-American Conference on Risk Reduction directed to the World Conference on Disaster Reduction, produced on 19 November 2004.

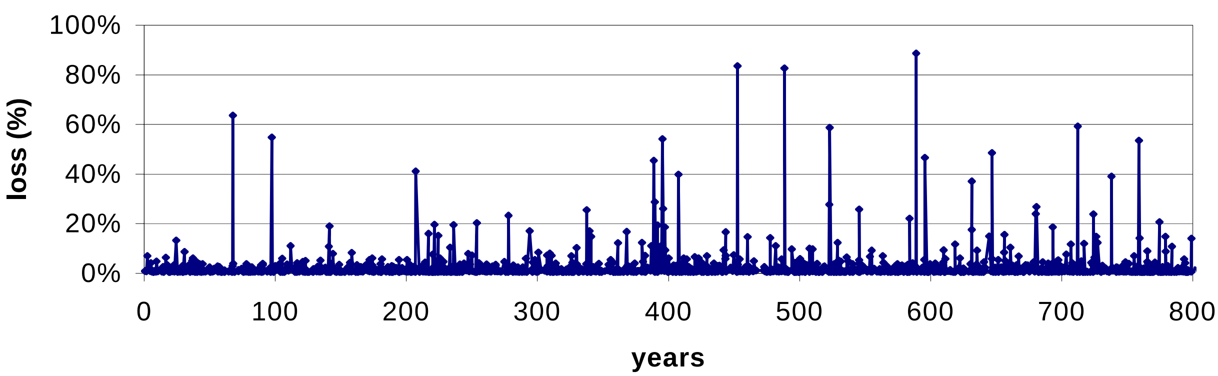
[47] "An epistemic community consists of those who accept one version of a story, or one version of validating a story." See http://en.wikipedia.org/wiki/Epistemic_community .

5.2.1 Loss Estimation and Return Period Concept

Some reviewers think it would also be helpful to re-calculate the *DDI* for losses occurring 1-in-10 year events or for shorter return period because politically, it is much easier to persuade a government that it needs to plan for and mitigate against the impact of a hazard event "that may well occur within its term of office. Most governments are unlikely to feel too concerned about *DDI*s for a 1-in-500 event, or even about *DDI*s for 1-in-100 and 1-in-50 year events." The perception is that *DDI* is calculated taking into account losses for long return periods (based on the *MCE*), whereas in reality a more normal distribution including smaller hazard events could produce serious damage in successive years. Some peers think that there is evidence that hazard frequency expectations, and the concept of "predictable" return periods is being severely challenged by real life events. Examples include the series of hurricanes in the Caribbean and the Philippines in 2004, the sequence of extreme riverside and rainwater floods in Bangladesh in the late 1980s and late 1990s, and in China in the late 1990s and the past few years. For Latin America this complexity is made worse by the unpredictability of El Niño/La Niña events. In essence, some believe that in each country there will be many events and it is quite likely that smaller events will be extremely damaging and therefore financially crippling as well, especially when aggregated and their greater frequency is taken into account.

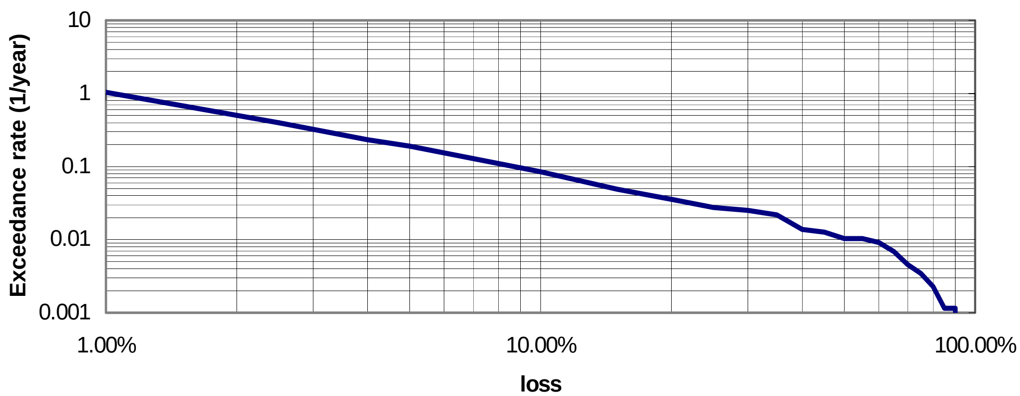
In reply to the above criticisms and comments to the *DDI* and *DDI***'**, first of all it is necessary to say that, certainly, the numerator of the *DDI* is an estimator of the losses associated to given return periods (see further discussion on the concept of return period). These estimators are sometimes called "probable losses" or "probable maximum losses" or losses produced by the "maximum considered or credible event", and perhaps a few more names. However, their precise meaning is the following.

Figure 5.2.1 Hypothetical Loss History in a City.
Losses are Expressed as a fraction of the total exposed value



Consider the process of occurrence of disasters in time, illustrated in Figure 5.2.1, where we have plotted the direct losses due to disasters in a city, as a function of time, for the last 800 years. It can be noted that there are many small losses and a few large ones. A convenient representation of the sizes and frequencies of occurrence of losses can be made by counting how many times a given loss value has been exceeded during the 800 years and then dividing these numbers by the observation time (800 years in this case). These figures would then be the number of events per year in which a given loss value has been exceeded. These quantities are known as *exceedance* *rates* or *frequencies of exceedance*, which are usually denote with ν. For the loss history of Figure 5.2.1, Figure 5.2.2 shows the corresponding exceedance rate.

Figure 5.2.1 Exceedance Rate of the Losses of the Process Shown in Figure 5.2.1



Which value of loss could be a good estimator of a "large" loss? Perhaps one that takes place very infrequently. For instance, for some applications, once every 100 years (that is, ν=0.01/year) could be deemed infrequent enough. Then, a good estimator of a "large" loss, in this example, would be 55%, which is the loss that, on average, would be exceeded once every 100 years. This is exactly the meaning of these loss estimators: losses that are associated to given return periods (50, 100 and 500 years in most of the herein computations), that is, losses that, on average would be exceeded every 50, 100 or 500 years.

Traditions, lack of rigor, difficulties in the communication process, among other factors, contribute to darken the precise meaning of some key concepts. For computation of indices *DDI* and *DDI'* it has been used estimators of losses which, regardless their various names, have a precise mathematical meaning. These estimators are sometimes called "probable maximum losses" or "probable losses". Although the names are well known, and come from solid backgrounds, its use is very unfortunate: the only precise word in these names is "losses". How should these estimators be called? The answer is open to debate. However, the precise meaning of these estimators should be kept in mind.

Let us now assume that we have computed the loss estimators associated to our selected return period (or periods). Are these losses produced by a single, identifiable natural event? Sometimes they are and sometimes they are not. For instance, in a city that is affected by earthquakes originated in a limited set of seismic sources, it could be easy to identify "the" event that produces the loss associated to a return period of, say, 100 years. In other cases it might be impossible to associate the loss with a single event, because the losses are produced, following the seismic example, by events coming from a variety of sources. But say that one can associate the 100-year loss value with a single event. In some portions of the reports of this project we have called these events the *MCE*. Again, the name is well known and originated in respectable traditions, but incredibly imprecise. How should these events be called? This is another open question.

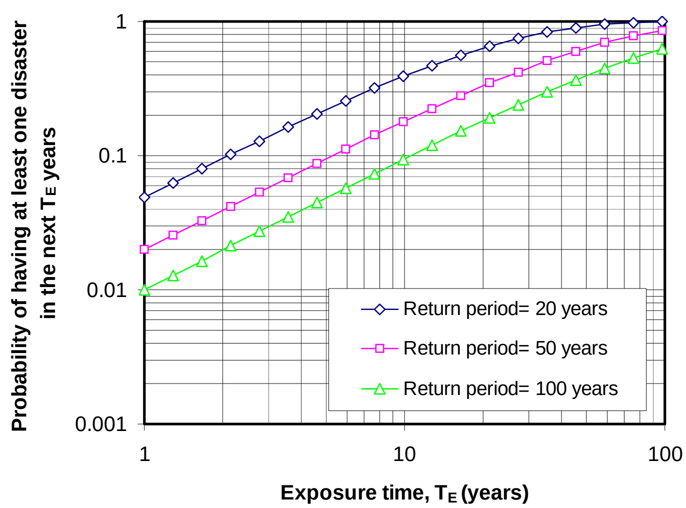
On the other hand, taking into account other experiences, it is fully accepted that the concept of return period[48] has proven to be a tricky one. According to its definition, the return period of a disaster with a loss L is the average time between events that produce losses equal or higher than L. For example, if we say that the return period of a disaster producing losses of 1,000,000 USD is 100 years, we mean that, on average, we should expect one disaster with losses equal or higher than 1,000,000 every 100 years. Note that <u>we imply nothing about how much time we would have to wait to see the next disaster of this kind</u> (the kind of disasters that produce losses above 1,000,000 USD); we are only specifying the average waiting time.

However, perhaps due to psychological factors related with risk perception, people seem to believe that if a given disaster is associated to return period T_R, it is almost impossible to have a disaster of this kind in the next year, or within two years, or, in general, relatively near in the future. The concept of return period seems to imply the notion of periodicity, so people act as if they believed that the probability of having a disaster of the kind examined grows as the waiting time approaches the return period. Although models of some waiting processes have this peculiarity, empirical evidence shows that, for most cases, a Poisson model is a better representation of the process of occurrence of disasters in time.

If the time occurrences are Poissonian, then the times between events are independent and exponentially distributed with parameter λ; this quantity is exactly the exceedance rate of the disaster or, in other words, the inverse of its return period. Hence, the probability, P_F, of having at least one disaster of the kind analyzed in the next T_E years (often called the *exposure time*) can be computed with the following expression:

$$P_F = 1 - e^{-\frac{T_E}{T_R}} \qquad (5.2.1)$$

Figure 5.2.2 Probability of Having at Least One Disaster of Different Return Periods in the Next T_E Years



[48] This portion of text was, with some differences, is included in the appendices of *DDI* en section two.

Results are somehow surprising. Figure 5.2.3 shows P_F as a function of return period and exposure time. For instance, even when talking about a relatively infrequent disaster –the one with a return period of 100 years– the probability of having at least one of these events the next year is about 1% (it is, obviously, not impossible), and the probability of having this disaster within the next 10 years is close to 10%. For a more frequent disaster (T_R=20 years), the probability of experiencing one of its kind (or larger) the next year is 5%, while, with a 40% chance, we will suffer it within 10 years. For reference, we have included in Table 5.2.1 some of these values.

Table 5.2.1 Probability of Having at Least One Disaster of Return Period T_R in the Next T_E years

Exposure time, T_E (the next N years)	**Return period of the event, TR (years)**		
	20	50	100
1	5%	2%	1%
5	22%	10%	5%
10	39%	18%	10%
20	63%	33%	18%
50	92%	63%	39%
100	99%	86%	63%
200	100%	98%	86%

Indeed, risk seems it is better perceived when expressed in terms of probabilities of exceedance in given time spans (the "probability of ruin" of classic probabilistic analysis) than when specified in terms of the return period of the "ruin". In this sense, in the context of this project, it would have been better to characterize the events associated to return periods of 50, 100 and 500 years (all of which, to some reviewers, seem very far in the future) with their corresponding probabilities of exceedance in a given time span or "window". An exposure time of, say 10-20 years, seems adequate, because it is close enough in the future. Table 5.2.2 gives these probabilities of exceedance for two cases: T_E=10 and 20 years. We have included return periods of 10, 50, 100 and 500 years. It must be noted that we did not use an event of T_R=10 years in the original study. However, judging from the numbers of Table 5.2.2, we now believe that this return period would have been better, because a probability of exceedance of 86% makes the event "likely·" to occur in the next 20 years, while a probability of 4% makes the 500-year return-period event "unlikely". The 100-year return-period event is somewhere in between.

Table 5.2.2 Probability of Having at Least One Disaster of Return Period T_R in the Next T_E Years for Several Combinations of T_R and T_E.

Exposure time, T_E (the next N years)	**Return period of the event, T_R (years)**			
	10	50	100	500
10	63%	18%	10%	2%
20	86%	33%	18%	4%

In boldface we have marked our preferred values of a likely, moderately likely and unlikely event in the next 20 years.

In conclusion and thinking in the future developments, it would have been better to use the 10, 100 and 500 year return-period events but marking them as "likely", "moderately likely" and "unlikely" in the next 20 years. In addition, although it is important to have different scenarios of PML or *MCE*, perhaps it is desirable to define one period of return to standardize the *DDI*. In any case, if the loss is calculated for short return periods the losses would be very small if they are compared with the economic coping capacity or resilience of the countries; therefore *DDI* should be used only for return periods of extreme hazard events.

It is important to remember that the *DDI* scores are based on historical levels of capital stock and its actual degrees of vulnerability. Therefore a disaster occurring in, say, 20 years time is likely to be associated with a far higher *DDI*, unless the new stock or infrastructure comply with the hazard proofing standards to withstand the different types of natural hazards and there are substantial increases in insurance coverage and other use of financial risk transfer mechanisms.

By other way, it is also important to underline the relevance of the ***DDI'*.** This index uses the expected annualized loss (or premium), which is a very important estimator, because it measures the average yearly amount of loss when one accounts for the frequency and severity of various levels of loss. *MCE* is a scenario value, not an in-going cost that can be reflected in a cashflow financial analysis. If decision-makers know the expected annual loss, they can include this supplementary estimator as an operating expense in the financial analysis. Therefore, the *DDI'*, certainly is relevant for usual planning periods.

In principle, it seems reasonable to think that the cost of money has to be considered in the computation of *DDI* and *DDI'*. It seems reasonable because the amounts paid in the future should be taken to the present with an adequate discount rate, as it is done in financial evaluation of projects. The expected annual loss, *p*, can be calculated as the annual payment in a very long period which, on the long run, equals the sum of the present value of the losses, *X*. However, if one assume Poissonian occurrences of disasters, as we have done throughout this project, it turns out (Rosenblueth, 1976) that the present value of the total losses, *X*, can be computed as

$$X = E(L)\frac{\nu_0}{\gamma} \tag{5.2.2}$$

where ν_0 is the number of events in a year, γ is the discount rate and L is the loss in an event. On the other hand, it is known that the annual discount factor, f, tends to γ as the number of payments tends to infinitum. In consequence, the premium is:

$$p = fX = \gamma X = \nu_0 E(L) \tag{5.2.3}$$

which is exactly the expression used to compute the annual expected losses for the estimation of *DDI'*.

The cost of money in time has no effect in the estimation of the premium if the loss-occurrence process is Poissonian. We can not extrapolate this result to other occurrence models, but we can say that, since the Poisson hypothesis is good enough for our purposes, the cost of money is a minor issue. Notice that the exceedance rate used for the estimation of the loss with a given return period, is by definition the number of times in which such amount is exceeded per unit time.

Given that it is an instantaneous rate, the project team considers that it is correct to express these amounts in "constant value". That means that the loss for a return period is expressed in present value, so it is not necessary to discount it. But we know that cities are not static. In view of this, estimation of risk indexes must be done periodically in order to take into account changes in risk variables. It is highly beneficial for the country that governments establish sustainable mechanisms in order to record future losses and damages with consistency and reliability. We recognize that cost of money in time can be relevant in financial analysis of schemes for the generation of funds to face the disaster. The *DDI* gives a measure of the amount that would be required after a great event with a low probability of occurrence, but the *DDI'* is proportional to the average of the whole history of losses. We can see that there is not a unique way to measure the risk. For this reason there is a need to consider both indexes, in order to give enough information to decision makers.

Other possibility to explore in future developments of DDI is related to the evaluation of a "probable frequent loss", similar to the latter (Porter *et al*. 2004). It could be expressed as the mean loss associated with the hazard event intensity that has 10% exceedance probability in 5 years, which corresponds to a return period of approximately 50 years (more accurately, 47.5 years, assuming Poisson arrivals of events). Any way, it is necessary for convenience, as above, to let an event with the intensity be referred to as the economic-basis event. The mean loss given this event could be used in contract with the traditional PML approach. It is other depiction, perhaps more understandable, of the above EMC loss estimators for the DDI. Any way, there are other good ways to define indices aimed to expressing the risk.

5.2.2 Empirical Verification and Indirect Losses

One of the main criticisms to the loss estimation method proposed is that it is almost impossible to verify it with historical data. One of the reasons is that the countries have been recording losses for a very short time in comparison with the return periods of great events. From table 5.2.2 we can say that the probability of having an event with return period T_R= 100 years in a period of observation T_E=20 years, is 18%. It is almost sure that the 100-year events have not occurred in the last 20 years. In consequence, empirical estimation of probability is restricted to low values of losses. Empirical verification can also fail because of changes in the amounts exposed or the construction technologies over the time. On the other hand, it is fair to remember the fact that the project team is using stochastic (or "catastrophic") models to predict future losses instead of making (empirical) extrapolations of past events, a technique that also faces difficulties, of a very different nature, but not of easy solution.

In addition, as it can be noted, in the computation of *DDI* and *DDI'* only direct economic are accounted for. Some peer reviewers have argued, with reason, that there are cases in which indirect economic losses can be similar, or even larger, than direct economic losses. Indeed, the effects of losing infrastructure, buildings or factories could propagate throughout the economy in such a way that the final losses are much larger than those due to the direct impact of the disaster. However, measurement of the indirect loses has proven to be extremely difficult. This issue was amply discussed during the development of the project, and it was agreed that, even when they are an incomplete measurement of the effects of disasters, direct losses are good indicators of total losses. Furthermore, a correction to direct losses was proposed in order to obtain a better estimator of the impacts. The equation, now known as Moncho's equation, used in the project at urban level (Carreño *et al.*, 2005) gives a relation between direct and total losses:

$$L_T = L + FL = L(1 + F) \qquad (5.2.4)$$

where L_T s for total loss, L stands for direct loss, and F is a coefficient (or impact factor) that varies with the kind of hazard event, socio-economic prevalent issues, and resilience (the degree of preparedness and ability to absorb and cope with indirect effects). Conceivably, F could be estimated for different hazards and regions, resorting to the (scarce) collected data on losses during disasters. In any case, the proposed indices are indicators to depict the risk profile of the countries and the levels of losses need to be understood in the context of each country.

5.2.3 Limitations of the Loss Estimation Method

The process of evaluation of economical losses due to natural events is, in general, very complex. In this project we have used an approximate method aimed to estimating losses in cities. As in all approximations, there is a compromise between precision and simplicity. In general, the more precise a method is, the more difficult its application. In this project, it was intended to develop an estimation method that could be applied, with relatively small efforts, by local consultants or government officials. With these restrictions in mind, we developed the proposed method. In the following paragraphs we will discuss some of its main limitations, as well as some of its strengths.

Cities are considered points in space. In this analysis, cities are considered dimensionless objects in space. In other words, we assume that when a disturbance takes place, it hits the whole city with the same intensity. Moreover, an implicit assumption is that not only intensities throughout the city, but also losses, are perfectly correlated. These are very conservative assumptions. First, for cities of the size of Bogotá, Mexico or Santiago, it is very likely that intensities during an event vary (perhaps widely) for different points in the same city,[49] so not all buildings are hit with the same intensity at the same time. Second, even if intensities at all points were the same, it is extremely unlikely that all buildings would suffer the same level of damage. How conservative are these assumptions is presently unknown, but it could be explored by simulation or by comparison with results of more refined models, which could be done for a few cities in the region.

Losses associated to a given return period are considered (almost) equal to losses produced by an event whose intensity has the given return period. Our loss estimation method is based in the following equation:

$$L_R = E\,V(I_R F_S)\,K \qquad (5.2.4)$$

where:

- L_R is the loss associated to a selected return period, R;

[49] Note that the variability that we are referring to is the intensity variability for a given set of site conditions. The differences due to site effects can, also with some approximations, be accounted for.

- E is the economical value of all the property exposed;
- $V(\,)$ is the *vulnerability function*, which relates the intensity of the event with the fraction of the value that is lost if an event of such intensity takes place;
- I_R is the intensity of the event associated to the selected return period;
- F_R is a factor that corrects intensities to account for local site effects;
- K is a factor that corrects for uncertainty in the vulnerability function.

In other words, except for factor K, L_R is the loss produced by an event whose intensity I_R is associated to the selected return period. This, in general, is not true. Since intensities and losses are not deterministically related, losses associated to a given return period are produced by events with a whole range of intensities, and not only by those with intensity exactly equal to I_R. We tried to correct this limitation by introducing factor K. But it must be kept in mind that this is only an approximate correction, which could be too imprecise for certain applications. However, a more realistic loss computation would have turned the method inapplicable for most local groups. Again, the compromise between simplicity and precision requires paying a price. It is also important to bear in mind that the public expenditure on post-disaster response may include humanitarian assistance (provision of food, clothing, temporary housing etc.) and support for restoration of livelihoods (e.g., provision of seeds and agricultural implements; cancellation of outstanding agricultural loans etc.). It would be overly complicated to include these in the calculation of the *DDI* but it is worth pointing out that estimates of required expenditure post-disaster are only a loose estimate of actual expenditure.

Wide generalization of types of buildings. In these analyses, we split the large number of buildings in a city in only three types: private sector, public sector and property of the poor. Later, we used the same vulnerability function for all buildings that belonged to the same sector. This is, obviously, an extremely broad characterization of buildings. Clearly, for instance, not all buildings of the private sector are equal, and the constructions of the poor sector comprise, in most cases, several types of buildings. In this case, however, this simplification does not come from limitations on the proposed method, but from limitations in the availability of information. In fact, if we had had information about the number of buildings that belonged to a variety of structural types, we would have been able to construct vulnerability functions for each type. How many different structural types? Perhaps they are not many, maybe not more than ten. But in any case, it would have been better that the broad classification we used which comes, as mentioned, from the lack of detailed information.

Rules to combine losses in different cities. As it can be recalled, the method herein proposed estimates individually, losses for each city and, in a second step, to combine these losses with given rules in order to produce a national loss estimator. The need of using these rules comes from the fact that, for an extended area of a given size, cities are very unlikely to be affected simultaneously by the same event. The size of the areas, of course, is hazard-dependent. In general, it is impossible to construct a simple set of combination rules that yields good approximations in all cases. The ones we have proposed rely on two main assumptions: a) that cities (or groups of cities) are not affected simultaneously by the same event; and b) that the hazard curves for all cities are parallel in a log-log scale. Condition a) depends on the judgment exercised to group cities. We carried out this grouping the best way we could, but the truth is that we did not perform sensitivity analyses in order to examine other possibilities. Condition b) was generally fulfilled although, as with condition a) we did not examine the implications of those cases in which the "parallelism" of the hazard curves was far from perfect.

5.2.4 Concerns Related to the Estimation of the Economic Resilience

The economic resilience or denominator of the *DDI* was calculated making some assumptions, that were applied in the same way to all countries, but some hypothesis could be not the better in all cases. It means that for the evolution of the *DDI* in the future it is necessary to review both the information of each country about the figures on the possible funds available for disaster reconstruction and the underlying assumptions made to compute those figures. Inspection of the data on possible funds raises some issues, for example:-

- There seems to be a very wide variation in estimated levels of aid that would flow in response to a disaster. As a matter of interest, the implied per capita aid receipts based on the 2000 value of for a 1 in 500 year event, admittedly crude calculation, indicated that Guatemala and Argentina expected to receive under US$16 per capita compared to estimates of over US$170 per capita for Chile, El Salvador, Jamaica and Trinidad and Tobago. Some estimates may be overly optimistic/pessimistic.

- The possibility of new taxes looks extremely high for Costa Rica, El Salvador and Guatemala relative to total value of the economic resilience. Using World Bank figures on total current revenue (in US$ and excluding aid receipts) for Costa Rica and Guatemala, it is possible to estimate that new taxes was equivalent to 59% of total current revenue for Costa Rica and 75% for El Salvador (data for Guatemala were not available). This seems very high and perhaps politically implausible.

- Amounts allowed for budgetary reallocations are quite probably too high too. It is also important to point out the opportunity costs of reallocated resources – i.e., diverting away resources from planned investments, with implications for longer-term growth and development. Certainly, this is by no means 'free' money.

Therefore, it would be useful to include in future some sensitivity analysis, recalculating *DDI* assuming other realistic/pessimistic hypothesis. For example if budgetary reallocations are only half of current estimates. It means *DDI* would be greater and then worse than the current valuations of the indicator that in several cases scores in excess of 1 ($DDI > 1$).

A high potential loss or a high *DDI* score has relevant implications and it is important for the governments understand quite what it means. It could be implications for GDP growth for example. More details and analyses are required in the future dialogues with and among the countries in a new phase of this program. This discussion should also note that there is no direct linear relationship between the scale of physical losses and economic consequences. For example, heavy infrastructure losses (roads, power, etc.) will have less impact in a small island specializing in financial services than one dependent on agriculture or tourism. Thus, levels of losses need to be understood in the context of the affected area.

Lastly, new evaluations might consider other potential funds for the economic resilience, for example, the relief remittances. Some of the most significant funding available to a country after a major disaster comes from migrants living abroad. Sending home money to family, friends and relatives has been a major factor in many disasters. Even if this does not contribute directly to the funds available for public expenditure, in effect it acts to reduce some of the demands that might be otherwise put on governments. It is in effect an informal "tax" on émigrés that is contributed voluntarily.

5.3 Remarks and Criticisms to the LDI, IVP and RMI

5.3.1 Appreciations on LDI

Latin America and the Caribbean are, after all, highly urbanized. Nevertheless, work with DesInventar has revealed the kinds of small and medium sized events that cripple economic development and endanger livelihoods in rural areas. An effort was made to take these events into account with the *LDI*. In the case of this index we are presented with a novel and unique scheme never considered previously in index construction but taking up on one of the principle points of discussion in the disaster community to date. That is to say, when is a disaster a disaster and what is the role of the thousands of generally unaccounted for smaller and medium scale events in the risk and disaster equation? The *LDI* is innovative and important and the effort to construct an index to represent this, both interesting and relevant. The construction of indices and analysis based on small and medium scale events may even serve to stimulate more concern and information collection on such events. However, a series of analytical and methodological points may be made with regard to this indicator. These may require modification or extension of the analytical model.

DesInventar registers all physical events (natural, socio natural and technological-anthropogenic) for which information is available and which can be associated with some reported level of social and economic damage and loss. Some of these events are small or medium scale with restricted o very restricted spatial impacts, covering parts of municipalities, districts or small towns for example. However, on the other hand, DesInventar also registers large or very large disasters that have at times a very wide spatial coverage. But, these events are registered in the data base according to the information available municipality by municipality, or district by district, as multiple local events. That is to say an event such as the earthquake in the Coffee Axis of Colombia in 1999 or Hurricane Mitch in Honduras in 1998 will be registered in DesInventar with tens if not far more registries of losses and damage at a municipal or district level. The sum of these gives us a global picture of the damage and loss associated with a single earthquake or hurricane that has had multiple effects in numerous communities and localities. Part of the logic of this type of register is that a large physical event leads in the end to an innumerable series of small local disasters. But, in the end, the physical event is a single phenomenon with at times a very large spatial coverage.

The analysis undertaken to get to the *LDI* does not separate off very small, small or medium scale, local events, from large impact events with multiple local effects. This may be justified at one level but not at another. If we assume that all disasters are essentially local disasters such that small events with restricted local impacts are the same in essence as large events with multiple local impacts, then the index is correct in its assumptions and conclusions. However, when justifying the index the report states that the index attempts to represent the impacts of small and medium disasters, as opposed to the large well reported disasters. Thus, by combining both types of event this criteria does not seem to be satisfied and the index in fact represents a measure of the local effects, their concentration etc. irrespective of the size of the disaster as such.

Thus, in order to diversify the index and possibly arrive at some very interesting results it may be interesting to first undertake an analysis and arrive at an indicator where the large disasters are removed. Secondly, one could undertake an analysis where only the large events are considered, but seen as numerous local disasters. And, thirdly, one could undertake an analysis using all events, large and small-as has been done in calculating the existing indicator. In the case that the results of all three analyses are similar, weight would be given to the hypothesis that small events have in the end a similar long term distribution of effects as do the large one off events. This has important policy implications. On the other hand, if the results were to be very different, weight would be given to the counter hypothesis that small events have a wider and more varied scope of impact than large events and this in it self also has important policy conclusions. In the case of analysis undertaken incorporating all events this maybe needs to be called a Local Impact Index as opposed to a Local Disaster Index. And, the term Local Disaster Index reserved for the product of calculations made using information only from small and medium level restricted local impact events.

A reviewer believes that it would be far more useful if the *LDI* were able to show to what extent changes in levels of losses over time were due to natural fluctuations or trends in frequency in the occurrence of natural hazard events and to shifts in vulnerability, both for countries as a whole and for particular municipalities. Unfortunately, this would involve ranking the intensity of hazard occurring and obviously it is a potentially major stumbling block because the DesInventar database does not contain any information on this. It would also imply that it might be difficult to integrate different types of hazard in a single, multi-hazard *LDI*. Perhaps in future, if it were possible, it could provide some very interesting results, including highlighting areas potentially facing rapidly rising vulnerability and so where urgent action is required.

From other points of view, the *LDI* involves a potentially serious methodological problem in that it uses data for *affected people*. Certainly, the project team spent a long time discussing this. One issue is that the definition of *affected* is likely to vary tremendously according to rather subjective judgments of different types of people who make the assessment. It is especially prone to the self-interest of certain types of agents who are likely to be providing such information: for instance, local government officials may be interested in higher figures in order to gain more assistance. There is also the phenomenon of the perpetuation of initial estimates from one source (e.g. a reporter on the scene, or a rescue organization). Once this figure has been cited in one publication, it is repeated endlessly by others without gaining any greater accuracy. This data from DesInventar may be collected with an attempt to apply certain rules or guidelines, but with twelve countries and by definition many local interpreters of the figures, it may be rather inadequate. There is also a problem with estimates of *deaths*, which is not as simple as at first seems. For instance, do the data include those who were initially declared missing? After how long (and who makes the calculations?) are those still missing declared as dead – and is this the same in every country? And what about those who succumb to illness or injury many months after the event? They should be included as victims of that disaster, but this is going to be very difficult. Of course we could assume that there is a valid and reasonably consistent ratio between initial deaths and those that follow later through the missing and illness categories. But the reporting may vary enormously between localities, types of disaster, and of course between countries.

Certainly, *number affected*, exists in several databases. Figure for *affected* is similar to *number of people affected* + *number of victims* in DesInventar. From the project team point of view *number of deaths*, constitutes the robust indicator (in other databases as EmDat, this figure is similar to *deaths* + *number of missing persons*). Any way, the project team suggests that the data for people affected could be omitted in future, and that some care be given to the compilation of the data for deaths. The project team realizes this would be a major change in this index, and that the number of deaths may not be an adequate measure of the impact of a particular event, but we would need to be reasonably certain that the number of deaths correlates reasonably well with other measures that convey the measurement of total impact.

Lastly, one of the reviewers make this question: Do *LDI*s really tell us much more than would be revealed by an examination of the raw data, which would immediately reveal types of hazard causing highest deaths and losses and whether impacts were or were not relatively evenly spread across a country? The project team think that the *LDI*s measures, indeed, simultaneously frequency and uniformity of the effects of small and medium hazard events at local level. It is to say, this is a measure of the variability of risk in a country or sub-national region. Whether or not the "language" of the *LDI* speaks directly to municipal and sub-national decision makers will depend on the extent to which they are familiar with DesInventar. If that accounting system remains a "black box" to them, then it will be difficult for these decision makers wholly to take ownership of the method and use it properly. Some do not know to what extent DesInventar has been diffused as a tool of local and sub-national government as opposed to an academic research tool. It could be that this valuable tool needs to be further "marketed" in government circles.

5.3.2 Appreciations on PVI

Some peer reviewers think that the *PVI* is a potentially very powerful index because the contributory data under the three headings (Exposure & Susceptibility; Socio-economic Fragility; Resilience) includes many factors that can be considered "causal" in relation to risk. There is a significant theoretical argument underlying this, for instance about how significant poverty is as a causal factor. It is well known that there some disasters have affected the wealthy, e.g. when high incomes have led them to construct large homes that are unsafe in earthquakes. So poverty is not the same as hazard vulnerability, although it is generally understood to be an 'explanatory factor' of high significance in most cases. The inclusion of poverty and wealth indicators, governance and gender factors, unemployment levels etc. suggests that the project accepts these as contributory causes of risk. This makes it possible to promote the *PVI* as a policy tool for vulnerability reduction in quite a powerful way. This is really important because it suggests areas in which actors can make relevant interventions. And it is also in these areas that civil society can be involved in advocacy and the use of the *PVI* in particular as a means to direct claims for rights-based approaches to vulnerability reduction.

Composed mostly of four large, complex "black boxes", the resilience side of the *PVI* is quite different. Conceptually it is not as crisp and clear. Unable to pin down "resilience" to more discrete and specific decisions/actions, the project settled for more diffuse and general measures. This mirrors the general state-of-the-art in the world today. The understanding of vulnerability and resilience is simply not far enough advanced. On the other hand, some peers are also some-what uneasy that the IDB-IDEA project imports wholesale into its measure of resilience four large, pre-existing indices: the UNDP's human development index (HDI) and gender development index (GDI), the World Bank's Governance Index, and the World Economic Forum's Environmental Sustainability Index (ESI). Therefore, some reviewers believe that the *PVI* should be welcomed as a solid first approximation, but more work needs to be done to improve it in the future.

Certainly, from the point of view of project team, *PVI* is useful as a first approximation. In order to have directly resonance with its potential users it is necessary to identify who in government is responsible for vulnerability reduction and it means in the future dialogues with the countries to work by sectors as Ministry of Health, Social Welfare, Employment, Environment, Agriculture, and so on. The method adopted is also cost-free since some indices as abovementioned are produced routinely for most countries in the world. That is not a trivial point because of the challenge of sustainability. On the other hand, by doing so, the project also imports, together with these indexes, all their assumptions and weaknesses.

It is perhaps surprising to see quite so little change in *PVI*s over the 20-year period examined, but reassuring to see that there is a bit more variation within each of PVI_{SF} and PVI_{ES} over time, as would be expected. The fact that the overall *PVI* for a particular country does not change much is interesting. It concurs with some country-specific analysis other researchers have undertaken, revealing that the nature of vulnerability can shift significantly over time without necessarily rising or falling overall.

There are also doubts of the reviewers on some variables or sub-indicators of the *PVI*. ES6 (imports and exports of goods and services as % of GDP), for example, used as proxy of exposure. There is no clear correlation across countries between trade as a % of GDP and vulnerability. As it stands, ES6 makes an inference that the more open an economy is, the more sensitive it is to disaster shocks. To some extent, this is true but this is may be in part because it is acting as a proxy for size. Smaller economies, especially really small ones, are often most open (basically reflecting economies of scale and thus concentration of production in relatively few goods/crops) and by implication potentially highly vulnerable if the activities they specialize in (often agriculture) are themselves highly vulnerable. For larger countries, the relationship between level of openness and vulnerability to natural hazards is in part dependent on the composition of trade, including how diversified exports are. For countries with a few key exports, vulnerability of those exports needs to be considered. If most exports are agricultural then exports can plummet post disaster (though obviously depending on the type and area of impact of the disaster itself). Manufacturing exports often stand up much better, especially when one is looking at performance for a whole year, ignoring short-term disruptions to transport routes etc.

It would be desirable to see something linked on composition of the economy –relative importance of agriculture, industry, etc. Typically, countries with larger agricultural sectors are more sensitive. Arable land and permanent crops as percentage of land area is included (ES8) but this is not the same as looking at the economic significance of the agricultural sector. It would have been relatively simple to go a stage further in measuring macroeconomic vulnerability but as an absolute minimum it would be sensible to include agriculture as a percentage of GDP as a variable.

From the perspective of the project team, the *PVI* brings together a series of relevant and pertinent variables for measuring vulnerability and resilience, or lack of it. There are, however, others that may be equally valid in certain cases and circumstances. But this is not a real problem given the method proposed would allow substitution of certain variables for others. The type of adaptation of variables could be done according to the type of country, type of hazard context etc. given the generic and specific nature of many vulnerability and resilience variables related to different risk contexts.

Lastly, the question of conceptual clarity is important because policy makers are being asked to do many things. Currently, besides the priorities set out in the World Bank's Poverty Reduction Strategy Papers in a number of countries, they are being asked to implement the Millennium Development Goals. A danger of asserting that risk reduction is an "essential and integral component" of development is that decision makers may think that by focusing on the MDGs (or on raising the HDI, GDI, ESI, etc.) they will *automatically* reduce risk. However, a lot depends on *how* these goals are pursued and implemented.

5.3.3 Appreciations on RMI

According to peer reviewers, the *RMI* is also novel and far more wide-reaching in its scope than other similar attempts in the past. In some ways this is the most sensitive and interesting indicator of all. It is certainly the one that can show the fastest rate of change given improvements in political will or deterioration of governance. While *DDI* and *PVI* will take decades to shift, especially in nations and in sub-national zones with long histories of marginality and heavy poverty burdens, *RMI* is likely to show sharp annual or bi-annual improvements given the right policy decisions and implementation. That is important from the point of view of giving national governments positive reinforcement, as well as providing for improved social protection while slower, gradual socio-economic progress is being make. The *RMI* has the advantage of being composed of measures that more or less directly map sets specific decisions/actions onto sets of desirable outcomes.

From the perspective of some reviewers the main critique and expected future improvement of *RMI* may lie with the use of the Analytic Hierarchy Process (AHP). This method served as a means of consolidating expert opinion on critical issues for which little empirical data existed. However, this method has the unfortunate effect of yielding different results, given differing selections of experts. Consequently, the validity of the results from AHP depends very much on the selection process used in identifying the "experts" who render the judgments regarding the phenomena under review, and the subjective allocation of weights by these. When no empirical data regarding a set of indicators exist for the *RMI*, for example, AHP serves as a means of gathering informed judgment regarding problematic situations. In the system of indicators AHP is used for *PVI* and *RMI*; to weight the underlying concepts of the former and the areas of performance of the latter about which experienced administrators could reasonably be expected to form judgments based upon their observations and knowledge about a given city, district, state, or nation. But these judgments, made by human experts, may in fact vary significantly.

From this perspective of the project team, the AHP serves as a useful methodology for estimating risk indicators at the present time, when there are few consistent means of empirical data collection across all jurisdictions in the study. However, as cities and governments improve their information infrastructure, AHP could effectively be replaced by more sophisticated methods of modeling and analysis of disaster risk indicators.

5.4 Problems with the Quality, Accessibility and Reliability of the Information

Reliability of the indices depends on the information provided by the institutions involved in the program and the local consultants of each country. In the process of obtaining information the project team found that it was a difficult task, more than it was expected.

In the case of the estimation of the losses for the *DDI*, the main problem turned out to be the lack of information about the exposed values and its distribution in the different categories considered in the project (public, private and poor sectors). Some monetary values obtained from each country were incongruent and the project team had to reject them. Other monetary indicators, such as the construction cost per square meter (USD/m^2) exhibited variations in time that were far from what was expected and difficult to believe. The cost associated to construction in each group (poor, public and private sectors) showed gross differences from one country to another; this may have happened because consultants had to give best-guess estimates because in very few cases information was available and reliable, and no common initial criteria was established for this estimation process.

The population data in each country seemed to be consistent and in most cases was obtained from reliable sources, so it was decided to compute the rest of information from this data. The distribution of exposed values in each city, and its evolution in time, were obtained in such a way that they were consistent with the evolution of the corresponding size of their economies. In many cases, the information received from local consultants only covered some cities in each country (the more important in terms of population and values). It must be made clear that results obtained from this information are restricted to those cities, and extrapolation to the national case has to be made with caution. Although the information related to natural hazards requested was very specific, local consultants had trouble recovering it, and, in most cases, the information delivered was limited to a brief description of the hazard, the way it can affect people and sometimes a list of past events. Because of this, website pages and good judgment were required to complete hazard information in order to be able to perform the loss estimations for *DDI*.

The *LDI* is based DesInventar database, hence the quality of the *LDI* figures depends on the quality of the information of the DesInventar. Some think that there are many problems in the disaster databases due to the type of sources and the criteria used to collect the information. A critique of the DesInventar database also is useful, including to cover: a) Whether, over time, the database has reported an increasing percentage of events that occur; b) Whether the percentage of disasters reported in the database varies significantly between countries and between municipalities within a particular country; c) Whether accuracy of reporting has improved over time (in terms of deaths, people affected, etc.); and d) How accurate reported figures are believed to be.

Certainly, the sources used for the DesInventar are varied. In general newspaper sources have been used, sometimes in combination with official data from the various governments, and in some countries the specific database has been constructed using official information gathered at local, provincial and national level by civil defense or similar bodies. The official sources used do not necessarily imply that these are primary or correct in terms of quality of information. Newspaper information may present problems, but so do other sources. In most cases the various sources, including the official sources when there is more than one for a given disaster, report different information that is often contradictory and needs to be analyzed and assessed in each case. (La Red, 2002). Like in other databases one needs to be cautious in examining trends over time because coverage is increasing, however it has been very similar in all countries since 1970's and therefore for the periods considered in the project (1980-2000). Perhaps there are problems in comparing some figures on, say, numbers of deaths or people affected between countries, because the disasters reported in the database varies between countries particularly before 1980`s. However, taking into account the sources, the reporting has improved over time in the same way in all countries during the period used in the project.

In sum, like any database, the information contained in the DesInventar raises problems in relation to the sources of information, particularly regarding verification of the information (at least in terms of order of magnitude) and with the information on certain variables, especially socio-economic ones. In this sense the DesInventar methodology includes a categorization of variables, depending on the level of reasonable certitude concerning the information (date, geography, type of event, deaths, people injured, homes destroyed and homes affected, for example, are fairly robust variables, whereas information on the number of people affected, the number of victims or economic evaluations tends to be less robust). In spite of this, the process of gathering information involves a detailed review of the information and attempts, inasmuch as it is possible or information exists, to corroborate or check it against other sources. *LDI*s were estimated using the more robust variables of the database on exception of the *LDI* based on people affected. Perhaps in future developments this figure might be changed or missed.

In order to provide comparable data sets for *PVI*, gaps in time series were filled in using statistical techniques and surrogates were found in some cases for missing data. In future analyses it is necessary to avoid doing it if it is possible, because there is simply no substitute for good data. Statistical methods may be sophisticated, indeed, but they do not change reality. In addition, there are large parts of some of the participating countries from which there simply is not available data. This problem is related to the very large degree of "informality" in the region. Urban squatter settlement is only one of many manifestations of informality. Much economic activity is not "formal" and is never recorded. Livelihoods of the poor and marginal –both urban and rural– are often opaque to researchers because there are components that are illegal or quasi-legal. Informality also characterizes the service sector with illegal electricity connections, unlicensed medical practice, and many other kinds of "adaptations" by the poor and marginal to their situation. Some elements of informality are also beginning to appear in nominally "middle class" groups because of the stress of economic crisis. The strategic question, then, is whether the program should lobby with governments and international organizations to extend data acquisition to these "blank" zones or not in the future developments or phases of the project. Information comes at a cost and it is could be an inconvenient for the sustainability of the program.

In the case of *RMI*, it is important to indicate that risk management officials established the weights applied to the sub-indicators and carried out the evaluations of performance for most countries. These evaluations would appear to be overly generous when compared to those undertaken by local external experts. The latter evaluations appear to be more objective. While the project team has used the evaluations of national officials in this study, external evaluations are considered to be very pertinent. Perhaps, with time, they will become more desirable, particularly if undertaken in coordinated and concerted fashion, thus eliminating *status quo* factors in the evaluations.

In conclusion, undoubtedly, the construction of the indicators is methodologically complex for run of the mill professionals whilst the demands for information are relatively onerous in some cases, given access and identification problems. Certain variables or types of information are not readily available and require research as opposed to rote collection where such information exists as a normal part of data systematization at the national or international levels. Doubts exist as to the veracity and accuracy of some items of information, although overall the procedures used to "test" the information assure a very reasonable level of accuracy and veracity. In the same way, weighting procedures and decisions could be questioned at times but again, overall, the decisions taken seem to be well justified and lead to adequate levels of accuracy. The use of official employees of risk management institutions at the national level in order to undertake the qualitative analyses is open to revision given the clear bias, in some cases, in favor of positive qualifications. The alternative, using scientists, informed independent persons and academics would resolve certain problems but may create others. So, maybe a cross check double entry approach is best where both types of sectors are taken into consideration.

5.5 Future Analysis and Interpretation of Results

The results of the indicator exercise, as they stand at present, provide a single statement of the situation and levels of efficacy and efficiency of the analyzed countries, with all the caveats as to the accuracy of the data that could be made. When it comes to convincing policy makers of the virtues of the system of indicators this is not only a matter of convincing them as regards the method and the veracity of results on a comparative or individual basis, but also as to the pertinence of the results in terms of opening up or "inviting" policy change and actions, as is made explicit in the discussion of program objectives. Given this, it could be interesting for the results, in the future, to be submitted to scrutiny by trained risk and disaster specialists in each country and concrete policy recommendations derived from such an examination in order to demonstrate to policy makers the real and final utility of the system of the indicators. This could be achieved through existing centers and professionals.

To date the system of indicators has been opened up to scrutiny and discussion by international advisors, academics, risk professionals and a limited number of national technical and professional staff, but to few policy makers as such. In the short term it would thus be very wise to organize a series of national dialogues where the derived indicator results and implications are presented to a selected number of national level policy and decision makers. This would allow a testing of relevance and pertinence and offer conclusions as regards future work on the program.

Given this context one recommendation could be that the indicator process be seen as part of a wider research and academic initiative based at the university level or in a university level centre. In Latin America there are very few if any multidisciplinary or holistic type research and teaching center dedicated to the analysis of risk, risk patterns and risk management initiatives. This is sorely needed and could perhaps be promoted by a multi agency initiative creating a regional centre or a series of national initiatives linked to existing centers or, where necessary, creating new centers. The objectives of such centers would be to provide an "observatory" type institution dedicated to analysis and monitoring, research and practice in risk management. The indicator program would be one of the components of such a centre, constantly offering information and analysis to government and research personnel, whilst being linked to centers in other countries, thus guaranteeing standardized approaches to analysis (if a single research centre was assigned for each of Central, South and Caribbean America, this would not be as difficult to achieve).

The product of this effort is the construction of comprehensive profile of disaster risk indicators for twelve nations in Latin America and the Caribbean. This profile is a beginning step for creating a "common operating picture" of disaster risk reduction for the region. That is, it represents a common knowledge base that can be accessed, viewed, and understood by all of the different policy makers responsible for disaster risk reduction in the region. Any group that is not included or that fails to comprehend the level and frequency of risk will likely fail to engage actively in the risk reduction process. Consequently, the construction of an effective common knowledge base for the system of decision makers responsible for disaster risk reduction is fundamental to achieving change in practice.

According to the peer reviewers, the value of this common knowledge base in terms of formulating public policies and designing appropriate means of intervention at local, state/provincial, national, and international levels of decision making cannot be underestimated. The graphs produced from this first implementation vividly showed the change over time in exposure to disaster risk, the losses incurred by each nation from disaster, and the level of disaster management practices that have –or have not– been instituted in each country. The indicators also show the extent to which disaster risk reduction is related to development, as the rankings of the twelve nations change over time, exposure to risk, and degree of loss.

In the opinion of one of the reviewers the indicators and the variables utilized are probably what may be called "technical" or "academic", product of a relatively thorough research process that goes beyond what may be considered possible to repeat regularly in a normal indicator construction process. With the use of the concept of "technical" indicators this peer wish to express the idea that these will probably be of more direct use and concern to technical and professional staff working in risk reduction organizations or to university researchers, than to high level decision makers as such. Put in more clear and vivid terms, he believes the indicators and their component variables could clearly be used by technical and professional staff to identify problems and capacities and thus to help establish priorities for intervention given the resources now available to them. But, they would not necessarily serve to persuade hard pressed and short term oriented decision makers to increase budgetary allocations and stimulate further work in the area. Thus, he concludes that a further step exists in the decision making process which requires that risk professionals and technical staff take such indicators and convert them into what one specialist called, "fear and ego indicators". That is to say, indicators based on the existing method and information but which are far more incisive and conclusive in terms of the economic, social and political consequences of doing nothing in the future.

Reviewed critically, and based on the evidence from the twelve-nation implementation process, from the perspective of the peer reviewers, the comparative report of results by country demonstrates that the initial objectives of the program have been met successfully. The results were reported graphically, in color, so that public administrators untrained in statistical methods could easily see and understand the basic findings from the survey. The sobering findings from the survey document the extent of disaster risk that characterizes the twelve participating nations. While there are instances of improvement, and in some nations, steady evidence of investment and attention to disaster risk reduction, there are also clear examples of increasing vulnerability in a subset of nations. This tool provides the comparative assessment that has been lacking in previous disaster risk reduction efforts. Visual representation of complex data is critical in communicating the results of this survey effectively to busy policy makers. This is an essential component of initiating a process of change. However, it is very important to take into account the set of "next steps" that might be taken to improve the reliability and validity of the data collected and the analyses undertaken. In the future sustainability for the program and promoting its applicability at the decision maker level requires, amongst other things:

- Dissemination of the guidelines to easy analysis and indicator calculation
- Transformation of indices into political indicators
- The diffusion and acceptance of the indicators and the method by national decision makers in analyzed countries and in others
- An agreement as to procedures for future collection of information and analysis

In sum, the final products include a wealth of data that, due to time constraints, has yet to be properly analyzed. Assuming there is consensus agreement that the basic methodology is sound and that data provided is reasonable, there are many more interesting comparisons that could be made between countries and over time, hopefully indicating countries where improved risk management is essential, ones that are already doing well and lessons to be learned. Although some of these comparisons have been made (in the final reports and the country papers), in the future a new qualitative examination of results should be undertaken and more detailed policy inferences drawn for each country. These examinations should include the underlying disaggregated scores and a qualitative analysis of the meaning of those results within the political/economic/social environmental context prevailing. This sort of discussion could be critical in drawing out policy implications of the indicator scores, not only in saying, for instance, that a particular country needs to be doing more to reduce risk but in suggesting how vulnerability could be reduced.

The project lacked efforts to link the different indicators (although this was done partially in the individual country papers). Certainly, to compare the scores according to the different indicators could be meaningfully. For instance, some countries have a high *DDI* but a low *PVI*. It is possible to conclude from this that those countries are already doing a lot, as compared with other countries, to reduce vulnerability and that it has few further options for reducing its *DDI* other than by increasing insurance coverage (given that it is difficult to increase funding raised from other sources included in the *DDI*). In contrast, other countries have a relatively high *PVI* but very low *DDI*. One can conclude that their governments do not need to worry too much about high vulnerability –even despite the fact that the value of its *PVI* is increasing, because they can meet disaster related costs with relative ease. Are such comparisons meaningless? In the analysis, for example, it is also possible to conclude it is totally meaningless because the *PVI* is based on a wider definition of vulnerability, and by the way to think also that this wider vulnerability still costs a country, in terms of development foregone, higher poverty etc., placing additional indirect demands on public finance too. The effort to link the different indicators is certainly an activity to develop in the future in the dialogues with the countries. A new phase of the project should include additional explicit comparisons and provide additional guidance on how to interpret the results, including whether or not such comparisons are meaningful and valid given the criteria and data underlying each indicator.

Within the twelve participating countries, an effort could be made to reach out to civil society. So far the indicators project seems to have made great strides in developing a common pool of experience and common risk management language among government and academic workers. However, civil society experiences disaster differently and works locally in different ways. Local citizen based groups, NGOs, teachers associations, faith-based organizations, human rights activists, trade unionists, professional associations (engineers, health workers, architects, foresters, etc.), etc. be drawn into the process for many reasons. The private sector also has, apparently, provided some of the data (e.g. the insurance industry). However, industry, large scale agriculture, privatized utilities all have a large role to play in risk reduction.

A useful follow up to the IDB-IDEA project would be to commission teaching material for high schools and colleges that explain the indicators. At high school level it is possible that the *DDI* might prove more difficult. However, material dealing with *PVI*, *LDI*, and *RMI* could be integrated into geography or environmental studies, or social studies, curricula with an active local field work component. At college of university level, the indicators could be integrated into a number of curricula: economics, planning, sociology, politics and public administration, public health, architecture, engineering, etc. Outreach and work-shopping among representatives of the mass media would also help to make the indicators more familiar to the public. It is reasonable to suppose that among the four, the *RMI* is likely to gather most attention by the media and the public. It is also one that can change most dramatically on an annual basis. Linked to an annual review of *RMI* in the municipalities of one of the participating countries, it is possible to imagine a corporation and media-sponsored competition for the "safest city" or the "city with greatest improvement in *RMI*".

Lastly, perhaps the most important contribution of the program was to initiate a systematic procedure of measuring and documenting disaster risk across the twelve nations engaged in this project. Once initiated, however, the program itself becomes a process in which the participants learn by engaging in data collection, analysis, and interpretation of findings. Some of the methods, adopted because no other measures existed, may now be re-examined and redesigned as cumulative data show new possibilities for refining the measures, or as data collection methods yield new possibilities for more complete and comprehensive documentation of risk and risk reduction practices. A likely source of improving both data collection and analysis, especially at the sub-national level, is the potential for integrating information technology more systematically into governmental operations. As better information becomes available, more systematic and more reliable methods of analysis can be adopted. There is a consensus among the peer reviewers that risk is local and it is important for effectiveness to face it at local level in many issues. The project produced interesting applications at sub-national and urban level showing how it is possible to develop indicators of disaster risk and risk management for decision-makers in those scales. For example, the financial implications for local governments and communities of the 'disaster deficit' are of great significance. In aggregate, the imbalance between costs of hazard events and available resources is also probably very significant even at the national level; hence a supplementary local equivalent *DDI* might be very useful. In other words, it is very important to extend and supplement this type of applications in several cities and sub-national regions in all countries.

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