A System of Indicators for Disaster Risk Management in the Americas

OMAR D. CARDONA[1]

[1] *Instituto de Estudios Ambientales, IDEA, Universidad Nacional de Colombia, Manizales*

ABSTRACT

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 accumulates. 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. The system of indicators proposed for the Americas permits a systematic and quantitative benchmarking of each country during different periods between 1980 and 2000, as well as comparisons across countries. 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* 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.

In this way, 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.

INTRODUCTION

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 that could 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 accumulates. 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.

The Disaster Risk Management Indicators Program in the Americas meets this need. The system of indicators proposed by IDEA for the Inter-American Development Bank (IDB) 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 (but also at the subnational and urban level to illustrate its application in those scales), allowing 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.

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 the program, 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 system of indicators, an outcome of the IDB-IDEA programme, provides a holistic approach to evaluation that is also flexible and compatible with other evaluation methods (Cardona 2001; 2004). As a result, it is likely to be increasingly used to measure risk and risk management conditions. The system's 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). Four components or composite indicators have been designed to represent the main elements of vulnerability and show each country's progress in managing risk. They are described in the following sections. Programme reports, technical details and the application results for the countries in the Americas can be consulted at the following web page: http://idea.unalmzl.edu.co (Cardona et al. 2003a/b, 2004a/b, 2005; Carreño et al. 2005c; IDEA 2005).

THE DISASTER DEFICIT INDEX (DDI)

The DDI 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. 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.

The DDI captures the relationship between the demand for contingent resources to cover the losses, L_R^P, caused by the Maximum Considered Event (MCE), and the public sector's economic resilience, R_E^P, (that is, the availability of internal and external funds for restoring affected inventories). Thus, DDI is calculated using the equation 1, as follows:

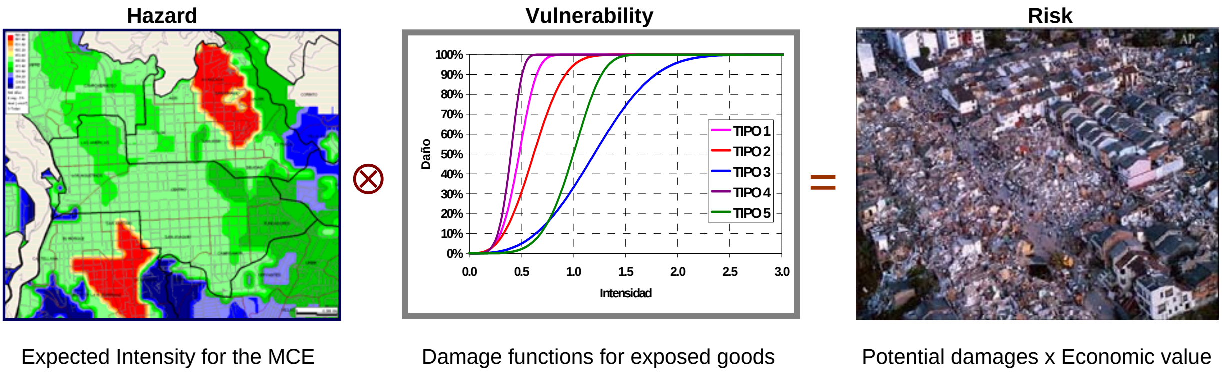
$$DDI = \frac{MCE\ loss}{Economic\,Resilience}\ ,\quad DDI = \frac{L_R^{\ P}}{R_E^{\ P}} \qquad (1)$$

$$\text{where } L_R^{\ P} = \varphi\, L_R \qquad (2)$$

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

$$L_R = E\,V(I_R F_S)\,K \qquad (3)$$

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; and K is a factor that corrects for uncertainty in the vulnerability function.



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

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

Fig. 1. Diagram for DDI calculation

Economic resilience, R_E^P (the denominator of the index), is defined in equation 4:

$$R_E^{\ P} = \sum_{i=1}^{n} F_i^{\ P} \quad (4)$$

where F_i^P represents the possible internal and external resources, that were available to the government, in its role as a promoter of recovery and as owner of affected goods, when the evaluation was undertaken. Access to these resources has limitations and costs that must be taken into account as feasible values according to the macroeconomic and financial conditions of the country. In this evaluation the following aspects have been taken 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 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.

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 DDI in context, we've developed a complementary indicator, DDI**'**, to illustrate the portion of a country's annual Capital Expenditure, E_C^P, that corresponds to the expected annual loss, L_y^P, 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.

$$DDI' = \frac{Expected\ annual\ loss}{Capital\ expenditures}, \quad DDI' = \frac{L_y^{\ P}}{E_C^{\ P}} \quad (5)$$

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. The DDI**'** was also estimated with respect to the amount of sustainable resources due to inter-temporal surplus.

Figure 2 and 3 show examples of the ranking of DDI_{500} (with a MCE with 500 years of return period) and DDI**'** for countries of Latin America and the Caribbean (LAC) in 2000.

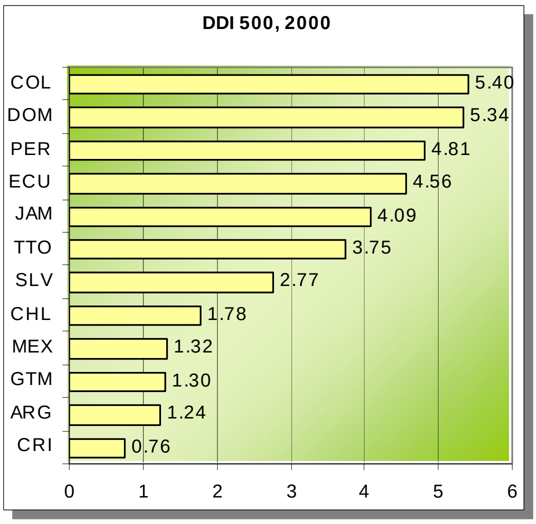


Fig. 2 DDI (500 year period of return) of countries of LAC, 2000

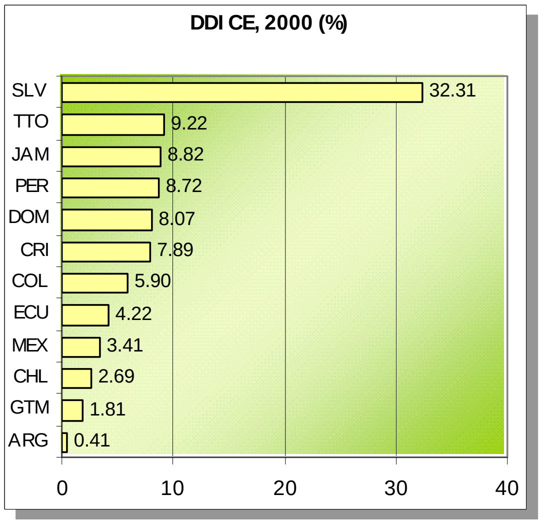


Fig. 3 DDI**'** based on capital expenditure for countries of LAC, 2000

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 decision makers 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. 2002). 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.

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 subindices that are calculated based on data from the DesInventar database (made by the Network of Social Studies in Disaster Prevention of Latin America, La RED in Spanish) for number of deaths K, number of people affected A, and losses L in each municipality, taking into account four wide groups of events: landslides and debris flows, seismo-tectonic, floods and storms, and other events. LDI is obtained from equation 6:

$$LDI = LDI_K + LDI_A + LDI_L \quad (6)$$

Figure 4 illustrates schematically how LDI is obtained for a country based on the information of events in each municipality.

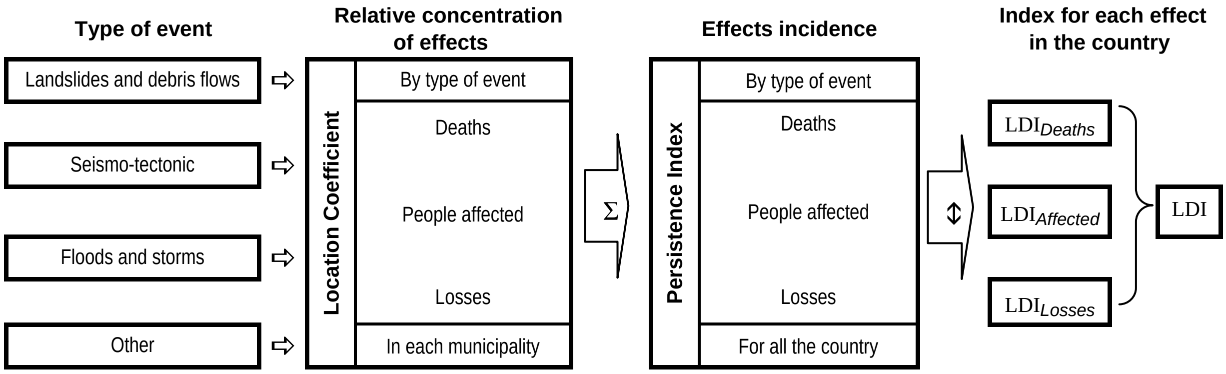


Fig. 4. Diagram for the calculation of the LDI

The local disaster subindicators for each type of variable (K, A,L) are obtained from equation 7.

$$LDI_{(K,A,L)} = \left(1 - \sum_{e=1}^{E} \left(\frac{PI_e}{PI}\right)^2\right) \lambda \,\Big|_{(K,A,L)} \qquad (7)$$

where $$PI_{(K,A,L)} = \sum_{e=1}^{E} PI_{e\,(K,A,L)} \qquad (8)$$

λ is a scaling coefficient and *PIe*, as expressed in equation 9, corresponds to the Persistence Index of effects (K,A,L) caused by each type of event *e*,

$$PI_{e\,(K,A,L)} = 100 \sum_{m=1}^{M} LC_{em\,(K,A,L)} \qquad (9)$$

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 (10)

$$LC_{em\,(K,A,L)} = \frac{x_{em}\, x_{eC}}{x_m\, x_C}\, \eta \,\Big|_{(K,A,L)} \qquad (10)$$

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.

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.

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.

Figure 5 shows an example of results of the LDI for countries of Latin America and the Caribbean region in the period 1996 to 2000.

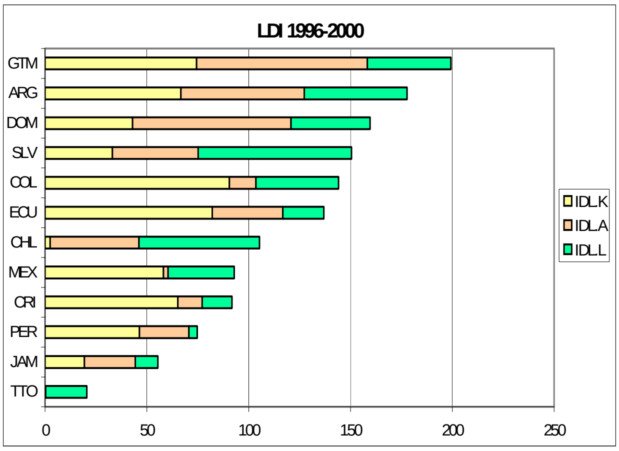


Fig. 5 LDI for countries of LAC, period 1996 to 2000.

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.

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 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 pro-posed are recognized as useful for measuring development (Holzmann and Jorgensen 2000; Holzmann 2001) their use here is intended to capture favourable conditions for direct physical impacts (exposure and susceptibility, ES), as well as indirect and, at times, intangible impacts (socio-economic fragility, SF, and lack of resilience, LR) of potential physical events (Masure 2003; Davis, 2003). The PVI, as shown in equation 11 is an average of these three types of composite indicators:

$$PVI = PVI_{ES} + PVI_{SF} + PVI_{LR} \tag{11}$$

The sub-indices for prevalent vulnerability conditions for each type of situation (ES, SF, LR) are obtained from equation 12

$$PVI^{t}_{c(ES,SF,LR)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Big|_{(ES,SF,LR)} \tag{12}$$

where, w_i is the weight assigned to each indicator, I^{t}_{ic} corresponds to each normalized indicator as expressed in equations 13 and 14. These represent the conditions of vulnerability for each situation (ES, FS, FR) respectively,

$$I^{t}_{ic} = \frac{x^{t}_{ic} - \min(x^{t}_{i})}{rank\,(x^{t}_{i})}, \text{ for (ES, SF)} \tag{13}$$

and

$$I^{t}_{ic} = \frac{\max(x^{t}_{i}) - x^{t}_{ic}}{rank\,(x^{t}_{i})}, \text{ for (LR)} \tag{14}$$

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

x^{t}_{i} is the variable considered jointly for all countries.

x^{t}_{M} it is the maximum value defined for the variable at *t* period

x^{t}_{m} it is the minimum value defined for the variable at *t* period

(x^{t}_{i}) rank it is the difference between the maximum and minimum value (x^{t}_{M} - x^{t}_{m}) at *t* period.

The weighting technique used to obtain the PVI was the Analytic Hierarchy Process (AHP); a widely used technique for multiattribute decision making proposed by Saaty (1980, 1987).

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. Figure 6 presents the structure of the PVI as a composite index.

Description	Indicator	Weight	Sub-index	Index
Population growth, average annual rate (%)	**ES1**	*w1*	PVI_{ES}	PVI
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*		
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*		
Human Development Index, HDI [Inv]	**LR1**	*w1*	PVI_{LR}	
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*		

Fig. 6. Diagram for the estimation of PVI_{ES}, PVI_{SF}, PVI_{LR} and the total PVI

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 6 shows the PVI_{ES} composition and participation in the PVI.

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.

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 2003). Figure 6 shows the PVI_{SF} composition and participation in the PVI.

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 unfavourable 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 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 6 shows the PVI_{LR} composition and participation in the PVI.

These indicators capture the capacity to recover from or absorb the impact of dangerous phenomena, whatever their nature and severity (Briguglio 2003). 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 2003) reflect a comparatively unfavourable position if natural hazards exist. The factors of lack of resilience are not very dependant or conditioned by the action of the event. As an example of application, figure 7 illustrates the results of the total PVI for countries of the LAC region in different periods from 1985 to 2000, each five years.

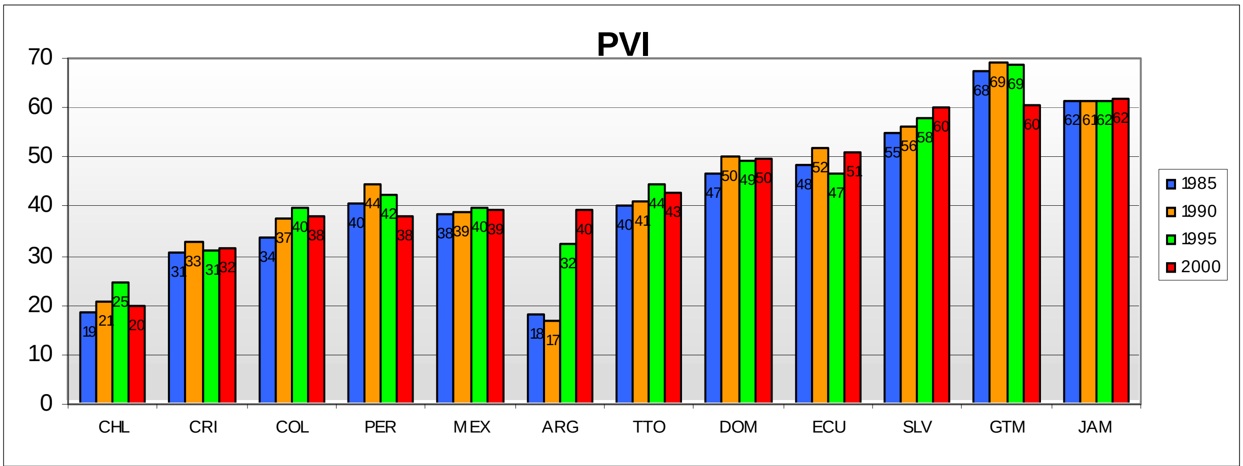


Fig. 7. Estimation of the total PVI for countries of LAC from 1985 to 2000, each 5 years

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

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.

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 crises 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, as indicated in equation 15, is defined as the average of the four composite indices:

$$RMI = (RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP}) / 4 \qquad (15)$$

The indicators for each type of public policy (RI, RR, DM, FP) are obtained through equation 16,

$$RMI^{t}_{c(RI,RR,DM,FP)} = \frac{\sum_{i=1}^{N} w_i \, I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Bigg|_{(RI,RR,DM,FP)} \qquad (16)$$

where, w_i is the weight assigned to each indicator, RMI^{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. 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). 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 that have a membership function of the bell or sigmoidal (at the extremes) type, given parametrically by the equations 17 and 18.

$$bell(x;a,b,c) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}} \qquad (17)$$

where the parameter b is usually positive.

$$sigmoidal(x;a,c) = \frac{1}{1+\exp\left[-a(x-c)\right]} \qquad (18)$$

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

These weights have been assigned using Analytic Hierarchy Process (AHP). Figure 8 shows the structure of the RMI as a composite index.

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; 2005a, for more details in the proceedings of this conference).

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 decision makers. 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 8 shows the RMI_{RI} composition and participation in the RMI.

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

RMI_{RI}

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

RMI_{RR}

Indicator	Description	Weight
DM1	Organization and coordination of emergency operations	w_{DM1}
DM2	Emergency response planning and implementation of warning systems	w_{DM2}
DM3	Endowment of equipments, tools and infrastructure	w_{DM3}
DM4	Simulation, updating and test of inter institutional response	w_{DM4}
DM5	Community preparedness and training	w_{DM5}
DM6	Rehabilitation and reconstruction planning	w_{DM6}

RMI_{DM}

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

RMI_{PF}

RMI

Fig. 8. Component indicators of the RMI

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 8 shows the RMI_{RR} composition and its participation in the RMI.

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 preparedness 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 8 shows the RMI_{DM} composition and its participation in the RMI.

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 8 shows the RMI_{FP} composition and its participation in the RMI. Lastly, figure 9 displays the results of the application of the RMI in countries of LAC region from 1985 to 2000, each five years.

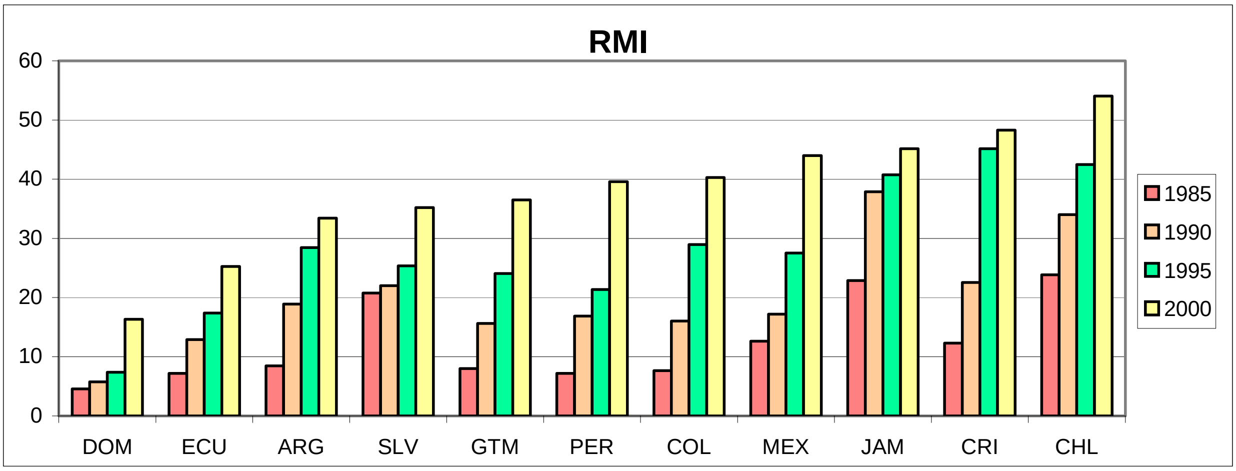


Fig. 8 Estimation of the total RMI for countries of the LAC region

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 that 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). 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.

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, RP, 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, RT, 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 9 illustrates an example of results of the total risk for the localities of Bogota, obtained using this holistic approach. Figura 10 shows how to obtain total risk indices for each analysis unit at urban level (Carreño et al. 2005b; for more details in the proceedings of this conference).

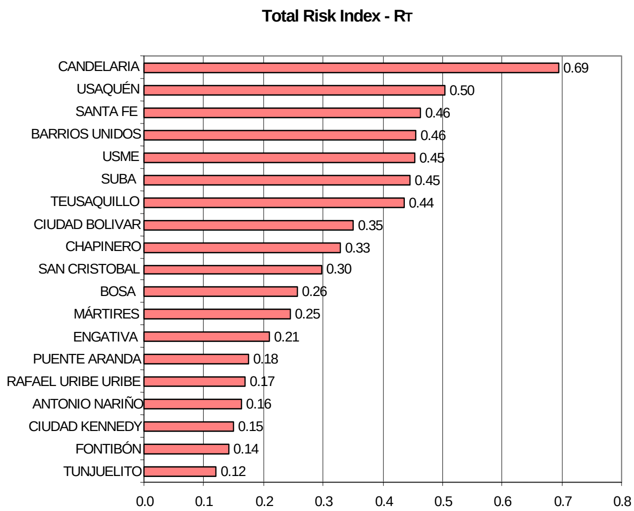


Fig. 9 Example of results of the RMI for localities in a urban centre

CONCLUSIONS AND FUTURE ANALYSIS

The IDB-IDEA program of indicators laid heavy emphasis on developing a language of risk that various kinds of decision makers understand. 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.

Ind	Description	w
F_{PR1}	Damaged area	*w1*
F_{PR2}	Number of deceased	*w2*
F_{PR3}	Number of injured	*w3*
F_{PR4}	Ruptures in water mains	*w4*
F_{PR5}	Rupture in gas network	*w5*
F_{PR6}	Fallen lengths on HT power lines	*w6*
F_{PR7}	Telephone exchanges affected	*w7*
F_{PR8}	Electricity substations affected	*w8*

R_P	**Physical risk**

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

Ind	Description	w
F_{SF1}	Slums-squatter neighbourhoods	*w1*
F_{SF2}	Mortality rate	*w2*
F_{SF3}	Delinquency rate	*w3*
F_{SF4}	Social disparity index	*w4*
F_{SF5}	Population density	*w5*
F_{LR1}	Hospital beds	*w6*
F_{LR2}	Health human resources	*w7*
F_{LR3}	Public space/shelter facilities	*w8*
F_{LR4}	Rescue and firemen manpower	*w9*
F_{LR5}	Development level	*w10*
F_{LR6}	Preparedness/emergency planning	*w11*

F	**Impact factor**

Fig. 10 Indicators of physical risk, social fragility and lack of resilience

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, decision makers 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 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. This index has the advantage of being composed of measures that more or less directly map sets specific decisions/actions onto sets of desirable outcomes. The indicators of risk and risk management described here 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 com-pare individual performance indicators for the period 1980–2000. The reports of the program also estimated the indicators at the subnational and urban level. This profile is a first 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.

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 favour of positive qualifications. The alternative, using scientists, informed independent persons and academics would resolve certain problems but may create others. Thus, maybe a cross check double entry approach is best where both types of sectors are taken into consideration.

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 programme. 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 programme and promoting its applicability at the decision maker level requires, amongst other things: a) Dissemination of the guidelines to easy analysis and indicator calculation; b) Transformation of indices into political indicators; c) The diffusion and acceptance of the indicators and the method by national decision makers in analyzed countries and in others, and d) An agreement as to procedures for future collection of information and analysis.

Lastly, perhaps the most important contribution of the programme 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.

REFERENCES

Barbat, A. (2003a). Vulnerability and Disaster Risk Indices from Engineering Perspective and Holistic Approach to Consider Hard and Soft Variables at Urban Level, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co

________. (2003b). Detailed application of the holistic approach for seismic risk evaluation on an urban centre using relative indices, IDB/IDEA Program of Indicators for Risk Management, National Uni-versity of Colombia, Manizales. http://idea.unalmzl.edu.co

Barbat, A.H, & Carreño, M.L (2004a). Indicadores de riesgo y gestión a nivel subnacional: Aplicación demostrativa en los departamentos de Colombia, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co

________. (2004b). Análisis de riesgo urbano utilizando indicadores: Aplicación demostrativa para la ciudad de Bogotá, Colombia, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

Briguglio, L. (2003). Methodological and practical considerations for constructing socio-economic indicators to evaluate disaster risk, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

Benson, C. (2003). Potential approaches to the development of indicators for measuring risk from a macroeconomic perspective, IDB/IDEA Program of Indicators for Risk Management, National Uni-versity of Colombia, Manizales. http://idea.unalmzl.edu.co

Cannon, T. (2003). Vulnerability Analysis, Livelihoods and Disasters Components and variables of vulnerability: modelling and analysis for disaster risk management, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

Cardona, O.D. (2001). “Estimación Holística del Riesgo Sísmico utilizando Sistemas Dinámicos Complejos” Technical University of Catalonia, Barcelona.
http://www.desenredando.org/public/varios/2001/ehrisusd/index.html

___________. (2004). "The Need for Rethinking the Concepts of Vulnerability and Risk from a Holistic Perspective: A Necessary Review and Criticism for Effective Risk Management", in Mapping Vulnerability: Disasters, Development and People, G. Bankoff, G. Frerks, D. Hilhorst (Ed), Earthscan Publishers, London.

Cardona, O. D. & Barbat, A. H. (2000). El Riesgo Sísmico y su Prevención, Cuaderno Técnico 5, Calidad Siderúrgica, Madrid, Spain.

Cardona, O.D., Hurtado, J.E., Duque, G., Moreno, A., Chardon, A.C., Velásquez, L.S. and S.D. Prieto. (2003a). The Notion of Disaster Risk: Conceptual framework for integrated management IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

____________. (2003b). Indicators for Risk Measurement: Methodological fundamentals IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

____________. (2004a). Disaster Risk and Risk Management Benchmarking: A Methodology Based on Indicators at National Level. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

____________. (2004b). Results of Application of the System of Indicators on Twelve Countries of the Americas. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

____________. (2005). Indicators of Disaster Risk and Risk Management: Program for Latin America and the Caribbean. Summary Report. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, http://idea.unalmzl.edu.co

Carreño, M.L, Cardona, O.D., Barbat, A.H. (2004). Metodología para la evaluación del desempeño de la gestión del riesgo, Monografía CIMNE IS-51, Technical University of Catalonia, Barcelona.

____________. (2005a). Evaluation of the risk management performance, 250th anniversary of the 1755 Lisbon earthquake. In this publication.

____________. (2005b). Seismic risk evaluation for a urban centre, 250th anniversary of the 1755 Lisbon earthquake. In this publication.

____________. (2005c). Sistema de indicadores para la evaluación de riesgos, Monografía CIMNE IS-52, Technical University of Catalonia, Barcelona.

Davis, I. (2003). The Effectiveness of Current Tools for the Identification, Measurement, Analysis and Synthesis of Vulnerability and Disaster Risk, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co

Freeman, P.K., Martin, L.A., Linneroot-Bayer, J., Mechler, R., Pflug G. & Warner, K. (2002). Disaster Risk Management: National Systems for the Comprehensive Management of Disaster Financial Strategies for Natural Disaster Reconstruction, SDD/IRPD, Regional Policy Dialogue, Inter-American Development Bank, IDB, Washington, D.C.

Holzmann, R. (2001). Risk and Vulnerability: The Forward Looking Role of Social Protection in a Globalizing World. SP Working Paper No. 0109. June. World Bank, Washington, D.C.

Holzmann, R. & Jorgensen, S. (2000). Manejo Social del Riesgo: un nuevo marco conceptual para la protección social y más allá. Social Protection, Working Paper No.0006 World Bank. Washington, D.C.

IDEA (2005). System of Indicators for Disaster Risk Management: Program for Latin American and the Caribbean. Main Technical Report. IDB/IDEA Program of Indicators for Disaster Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co

Lavell, A. (2003a). I. International Agency Concepts and Guidelines for Disaster Risk Management; II. The Transition from Risk Concepts to Risk Indicators, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co

_______. (2003b). Approaches to the construction of risk indicators at different spatial or territorial scales and the major components of indicator systems- conceptual bases, risk construction processes and practical implications, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

Masure, P. (2003). Variables and indicators of vulnerability and disaster risk for land-use and urban or territorial planning, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales. http://idea.unalmzl.edu.co

Munda, G. (2003). Methodological Exploration for the Formulation of a Socio-Economic Indicators Model to Evaluate Disaster Risk Management at the National and Sub-National Levels. A Social Multi-Criterion Model. IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co

Ordaz, M., and Santa-Cruz, S. (2003). Computation of physical damage to property due to natural hazard events . IDB/IDEA Program of Indicators for Disaster Risk Management, National Uni-versity of Colombia, Manizales. http://idea.unalmzl.edu.co

Saaty, T. L. (1980). *The Analytic Hierarchy Process*, McGraw-Hill Book Co., N.Y.

_________. (1987). The analytic hierarchy process- what it is and how it is used. *Mathematical Modelling*, 9, 161-176.

UNDP (2004). Reducing Disaster Risk: A Challenge for Development. A Global Report, Chapter 2th: International Patterns of Risk, The Disaster Risk Index, DRI, Geneva.

http://www.undp.org/bcpr/disred/rdr.htm

Wisner, B. (2003). Turning knowledge into timely and appropriate action: Reflections on IADB/IDEA program of disaster risk indicators, IDB/IDEA Program of Indicators for Risk Management, National University of Colombia, Manizales.

http://idea.unalmzl.edu.co