Evaluation of the risk management performance

M. L. CARREÑO[1], O. D. CARDONA[2], AND A. H. BARBAT[1]

[1]*Technical University of Catalonia, Barcelona, Spain*
[2]*Universidad Nacional de Colombia, IDEA, Manizales, Colombia*

ABSTRACT

The Risk Management Index, RMI, brings together a group of indicators that measure risk management performance and effectiveness. 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 or determining the "distance" between current conditions and an objective threshold or conditions in a reference country, subnational region, or city. 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, comprises the individual perception, social representation and objective assessment. Risk Reduction, involves the prevention and mitigation. Disaster Management, comprises response and recovery. And, governance and Financial Protection, related to institutionalization and risk transfer. In addition, this paper presents some results at the national, subnational and urban level to illustrate its application of the RMI in those scales.

INTRODUCTION

At present, no specific indicators exist in the countries, widely accepted, to valuate directly the performance 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. 2003a,b]. 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, 2003; Briguglio, 2003a,b; Mitchell, 2003] or using linguistic qualifications [Davis, 2003; Masure, 2003].

The method of the Risk Management Index RMI, herein described, was developed to evaluate risk management performance and effectiveness of countries of Latin America and the Caribbean in the framework of the Disaster Risk Management Indicators Program in Americas, led by the Institute of Environmental Studies, IDEA, of the National University of Colombia, in Manizales, for the Inter-American Development Bank, IDB. In addition, it was applied to the departments of Colombia and Bogota to illustrate its application at subnational and local level. Program reports, technical details and the application results for the countries in Americas can be consulted in the following web page: http://idea.unalmzl.edu.co

METHODOLOGICAL APPROACH USING INDICATORS

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. 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 (or multi-criteria) composite indicators 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.

THE RISK MANAGEMENT INDEX

The RMI was designed to assess risk management performance, and by this way, the effectiveness. 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. Risk Identification index, RMI_{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 index, RMI_{RR}, involves prevention and mitigation measures. Disaster Management index, RMI_{DM}, involves measures of response and recovery, and governance and Financial Protection, RMI_{FP}, measures the degree of institutionalization and risk transfer. The RMI is defined as the average of the four composite indicators:

$$RMI = \left(RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP}\right)/4 \qquad (1)$$

Six 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 is estimated based on five performance levels (*low, incipient, significant, outstanding*, and *optimal*) that correspond to a range from 1 (*low*) to 5 (*optimal*). 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. Alternatively, RMI can be estimated as the weighted sum of crisped numeric values (1 to 5, for example), instead of fuzzy sets of linguistic valuation (as in this method, using a Matlab application). However, this simplification eliminates risk management non-linearity, having outcomes less appropriated.

The sub-indices of risk management conditions for each type of public policy are obtained through equation 2

$$RMI^{t}_{c(RI,RR,DM,FP)} = \frac{\sum_{i=1}^{N} w_i I^{t}_{ic}}{\sum_{i=1}^{N} w_i} \Big|_{(RI,RR,DM,FP)} \qquad (2)$$

where, w_i is the weight assigned to each indicator, I^{t}_{ic} corresponding to each indicator for the territorial unity c in consideration and in 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 that have a membership function of the bell or sigmoidal (at the extremes) type, given parametrically by the equations 3 and 4.

$$bell(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \qquad (3)$$

where the parameter b is usually positive,

$$sigmoidal(x;a,c) = \frac{1}{1+\exp[-a(x-c)]} \qquad (4)$$

where a controls the slope at the crossing point, 0.5 of membership, $x=c$. Figure 1.a shows these membership functions.

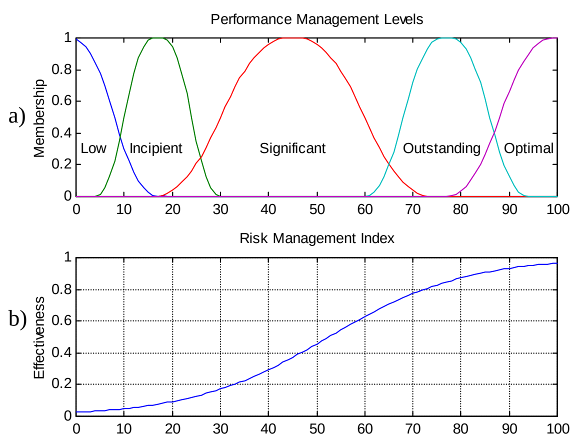

Fig. 1. a) Functions that represents the qualification level, b) Effectiveness degree of the risk management

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.

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, *significant*) and auto adaptive (innovating, creative, and spontaneous. That is to say, *outstanding* and *optimal*.)

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 Figure 1.a 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 in Figure 1.b, in which the effectiveness of the risk management is represented as a function of the performance level. Figure. 1.b 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 that experts, who know risk management progress in the place and according to their experience and knowledge, give qualifications for the indicators and assign relative importance between them for each public policy. These qualifications are processed using the Analytic Hierarchy Process (AHP) to assign weights, process which is explained in the Appendix A. 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" (see example of Figure 3).

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

$$\sum_{j=1}^{N} w_j = 1 \qquad (5)$$

where N is the number of indicators which intervene in each case. Qualification for each public policy (RMI_{IR}, RMI_{RR}, RMI_{DM} and RMI_{FP}) is the result of the union of the weighted fuzzy sets

$$\mu_{RMI\,P} = \max(w_1 \times \mu_C(C_1),\ldots, w_N \times \mu_C(C_N)) \qquad (6)$$

where w_1 to w_N are the weights of indicators indicated in Figure 2, $\mu_C(C_1)$ to $\mu_C(C_N)$ are the membership functions of the estimates made for each indicator and μ_{RMIi} is the membership function of RMI qualification of each public policy p. Risk management index value is obtained from the defuzzification of this membership function, using the method of centroid of area (COA).

$$RMI_P = [\max(w_1 \times \mu_C(C_1),\ldots, w_N \times \mu_C(C_N))]_{centroid} \qquad (7)$$

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 following equations

$$\text{Concentrated value} = \bar{X} = \frac{\sum A_i \bar{x}_i}{\sum A_i} \text{ or } COA = \frac{\int_X \mu_A(x)x\,dx}{\int_X \mu_A(x)\,dx} \qquad (8)$$

Finally the average of the four indexes provides the total risk management index, RMI.

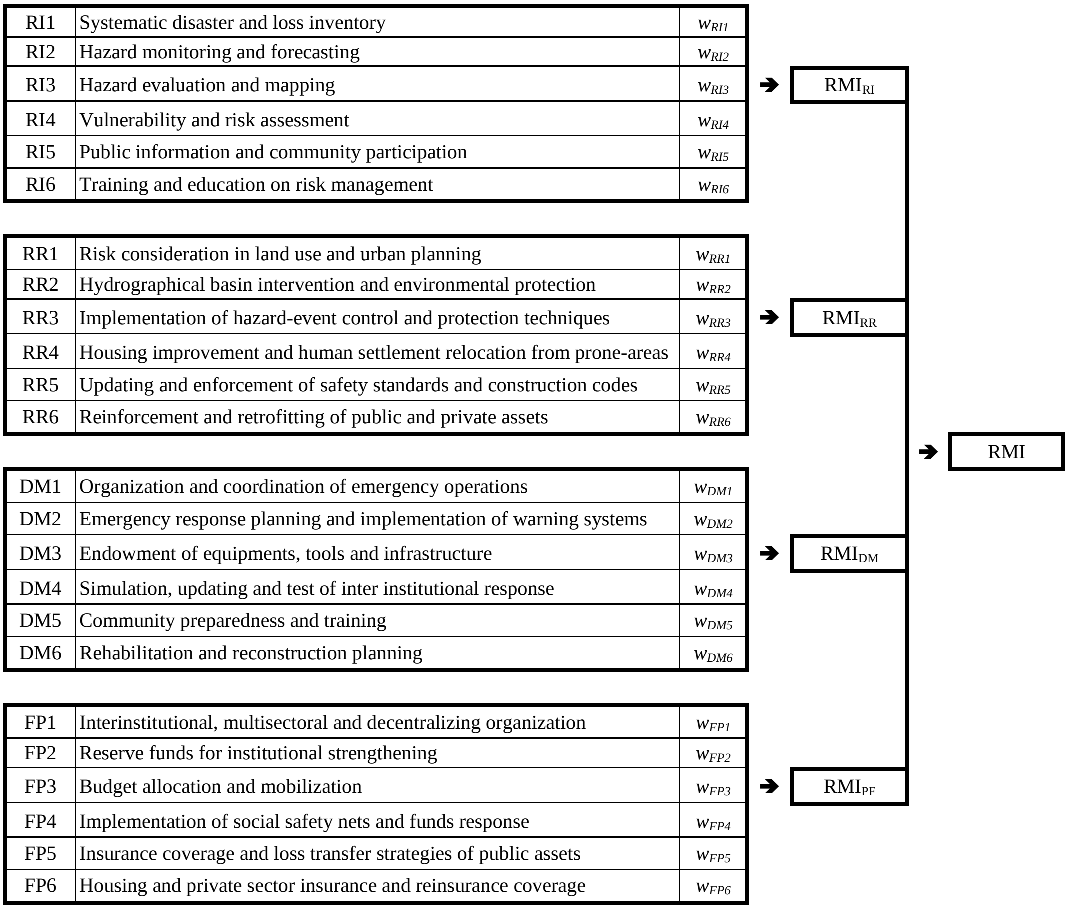

Fig. 2. Component indicators for RMI

INDICATORS FOR RISK IDENTIFICATION

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, risk identification 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 [Carreño et al., 2005] when the population recognizes and understands that risk. Figure 2 shows the RMI_{RI} composition for Risk Identification.

INDICATORS FOR RISK REDUCTION

The major aim of risk management is to reduce risk. 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 2. shows the RMI_{RR} composition for Risk Reduction.

INDICATORS FOR DISASTER MANAGEMENT

The goal of disaster management 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 2 shows the RMI_{DM} composition for Disaster Management.

INDICATORS FOR GOVERNANCE AND FINANCIAL PROTECTION

Adequate governance and financial protection 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 2 shows the RMI_{FP} composition for governance and Financial Protection.

Appendix B presents an example of the benchmark levels for an indicator. Tables of benchmarks for countries, subnational regions and cities are not the same but they are similar.

EXAMPLES OF APPLICATION

In the framework of the Disaster Risk Management Indicators Program in Americas, Colombia and other ten countries of Latin America and the Caribbean were evaluated. In addition the RMI for Bogota and 32 departments of Colombia was estimated with the participation of officials in charge of institutions related to risk management in each place. In this section some cases of study are presented to illustrate the application of RMI at local, national and subnational level.

URBAN LEVEL: BOGOTÁ, COLOMBIA

Risk management benchmarking and weights of each indicator were evaluated by officials of the Directorate for Risk Mitigation and Emergency Preparedness (DPAE in Spanish) and for academics of the city. Tables 1 to 4 show the qualifications made from 1985 to 2003 in different periods.

TABLE 1: Qualifications for risk identification indicators (RI)

Indicator	1985	1990	1995	2000	2003
RI1	1	1	2	3	3
RI2	1	1	2	3	3
RI3	1	2	3	4	5
RI4	1	1	1	3	4
RI5	1	1	2	2	3
RI6	1	1	1	2	4

TABLE 2: Qualifications for risk reduction indicators (RR)

Indicator	1985	1990	1995	2000	2003
RR1	1	2	2	3	4
RR2	1	1	1	1	2
RR3	1	1	1	3	4
RR4	1	2	2	3	4
RR5	2	2	2	4	4
RR6	1	1	1	2	3

TABLE 3: Qualifications for disaster management (MD)

Indicator	1985	1990	1995	2000	2003
MD1	1	2	2	3	3
MD2	1	1	1	2	3
MD3	1	1	1	2	2
MD4	1	1	1	1	3
MD5	1	1	1	2	3
MD6	1	1	1	1	2

TABLE 4: Qualifications for financial protection (FP)

Indicator	1985	1990	1995	2000	2003
PF1	1	2	2	3	3
PF2	1	4	4	4	4
PF3	1	1	3	3	4
PF4	1	1	1	1	1
PF5	1	1	1	2	3
PF6	1	1	2	2	3

The weights were also undertaken by risk management authorities of the city. Analytic Hierarchy Process (AHP) was applied to estimate these weights (See Appendix A). Table 5 shows the results obtained. Although it is also feasible to assign a weight to each composite subindex representing the performance of the city in each of the four policy areas, such weights were assumed equal.

TABLE 5: Weights for the set of indicators

Weight	RI	RR	MD	FP
w1	0.05	0.14	0.11	0.21
w2	0.22	0.09	0.11	0.46
w3	0.36	0.07	0.40	0.12
w4	0.22	0.31	0.22	0.05
w5	0.05	0.20	0.05	0.12
w6	0.12	0.19	0.11	0.04

Figure 3 shows an example of the calculation of an index using the Matlab application developed for the project. Table 6 shows the final results for Bogotá city.

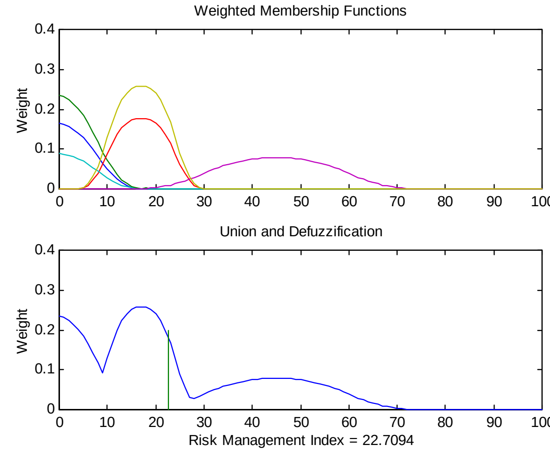

Fig. 3. Aggregation and defuzzification to calculate a RMI

TABLE 6: Risk management indices for Bogotá

Index	1985	1990	1995	2000	2003
RMI_{RI}	4.56	13.90	35.57	56.15	67.10
RMI_{RR}	11.03	13.90	13.90	46.14	56.72
RMI_{DM}	4.56	8.25	8.25	24.00	32.33
RMI_{FP}	4.56	57.49	54.80	57.64	61.44
RMI	6.18	23.38	28.13	45.98	54.40

These results reflect the performance of the risk management in Bogotá in the last twenty five years. They emphasize the aspects which it is necessary to improve in the four public policies. The public policy that had the lowest performance in Bogotá is the disaster management, whereas the policy with the greater performance is the risk identification followed by the financial protection.

Considering the localities or urban districts in which is divided the city, a detailed study was also achieved for 2004 by DPAE using the same methodology. Figure 4 shows the final results of the RMI by localities. From these results it is possible to assert that at urban level risk management should be performed mainly by the central administration of the city. Localities have not the possibility of developing independently some tasks because they are too small areas that have not sufficient capacity and autonomy to deal with some specialized activities.

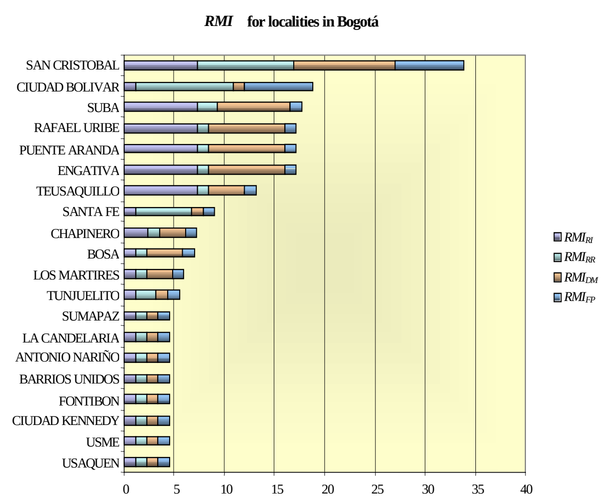

Fig. 4. Values of RMI for the localities of Bogotá, 2003.

NATIONAL LEVEL: COLOMBIA

Risk management benchmarking and weights of each indicator were evaluated by officials of the National Directorate for Disaster Prevention and Emergency Response and for academics of Center of Studies on Disasters and Risks (CEDERI in Spanish) of University of Los Andes. Tables 1 to 4 show the qualifications made from 1985 to 2003 in different periods.

TABLE 7: Qualifications for risk identification indicators (RI)

Indicator	1985	1990	1995	2000	2003
RI1	2	3	3	4	4
RI2	1	2	3	3	3
RI3	2	2	3	4	4
RI4	1	1	2	3	3
RI5	1	1	3	2	2
RI6	1	2	3	2	2

TABLE 8: Qualifications for risk reduction indicators (RR)

Indicator	1985	1990	1995	2000	2003
RR1	1	2	2	3	3
RR2	1	2	3	2	2
RR3	1	1	2	2	2
RR4	1	2	3	2	2
RR5	2	2	3	4	4
RR6	1	1	2	3	3

TABLE 9: Qualifications for disaster management (DM)

Indicator	1985	1990	1995	2000	2003
MD1	1	2	2	3	3
MD2	1	1	2	2	2
MD3	1	2	2	2	2
MD4	1	1	1	2	2
MD5	1	1	2	1	1
MD6	1	1	1	2	2

TABLE 10: Qualifications for financial protection (FP)

Indicator	1985	1990	1995	2000	2003
PF1	1	2	3	2	2
PF2	1	2	3	2	2
PF3	1	1	2	2	2
PF4	1	1	2	2	2
PF5	1	1	2	3	3
PF6	1	2	2	3	3

Table 11 displays the final results for the risk management indices for Colombia.

TABLE 11: Risk management indices for Colombia

Index	1985	1990	1995	2000	2003
RMI_{RI}	10.54	25.07	32.46	48.41	48.41
RMI_{RR}	10.97	13.96	39.28	44.46	44.46
RMI_{DM}	4.56	12.49	12.49	28.73	28.73
RMI_{FP}	4.56	12.49	31.50	39.64	39.64
RMI	7.66	16.00	28.93	40.31	40.31

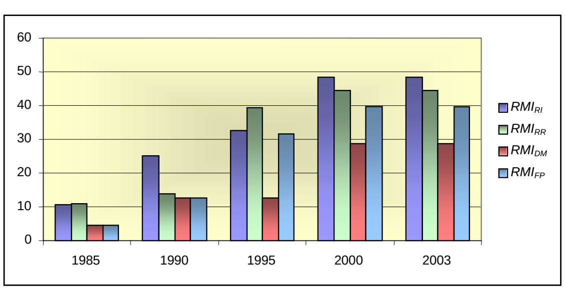

Fig. 5. Risk management indices for each public policy.

Figures 5 and 6 show risk identification and risk reduction have been intensive in Colombia during the period of analysis. According to this analysis, at present, the government of Colombia attempts to direct their efforts at formulation, implementation, and policy evaluation, according to these achievements and performance targets.

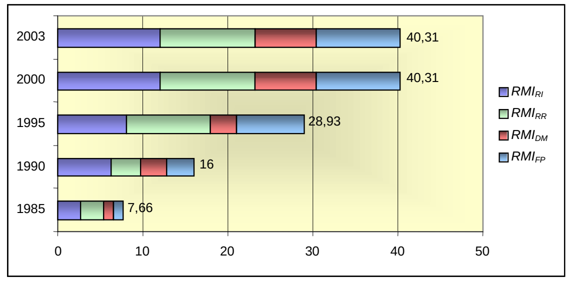

Fig. 6. RMI evolution from 1985 to 2003.

RESULTS FOR LATIN AMERICA AND THE CARIBBEAN

The risk management was evaluated for the following countries of Latin America and the Caribbean region (LAC): Argentina, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Jamaica, Mexico and Peru.

Risk management benchmarking and weights of each indicator were made by national advisors and officials of institutions related to disaster risk management of each country [Cardona et al., 2004, 2005]. Figure 7 to 10 illustrate the values of the components of RMI and Figure 11 presents the final results of the RMI for the countries every five years from 1985 to 2000.

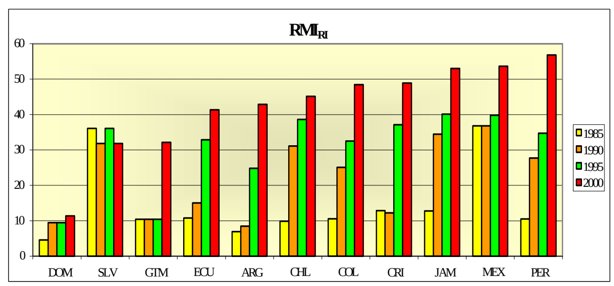

Fig. 7. RMI for Risk Identification in LAC, 1985 - 2000

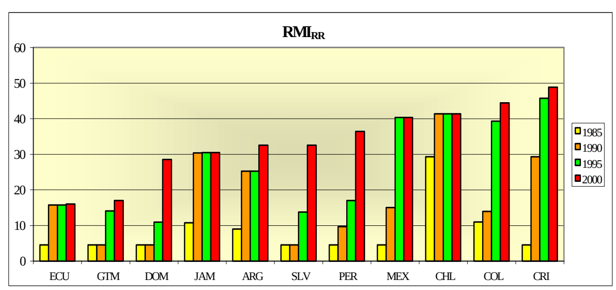

Fig. 8. RMI for Risk Reduction in LAC, 1985 - 2000

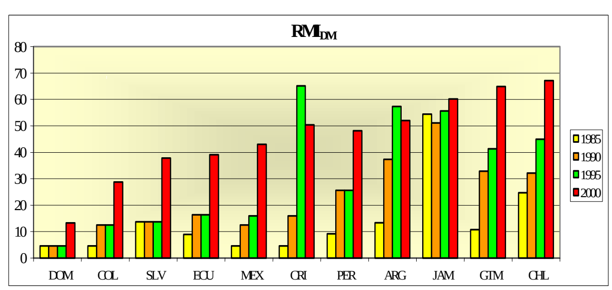

Fig. 9. RMI for Disaster Management in LAC, 1985 - 2000

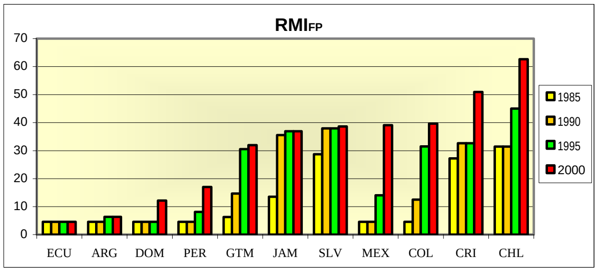

Fig. 10. RMI for Financial Protection, 1985 - 2000

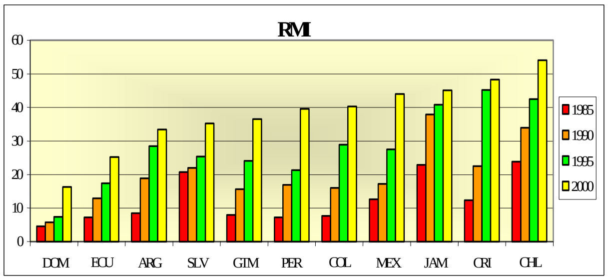

Fig. 11. RMI for the countries, 1985 - 2000

The analysis shows that Dominican Republic, Ecuador and Argentina 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 (feasible) 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.

SUBNATIONAL LEVEL: DEPARTMENTS OF COLOMBIA

The methodology was adapted to evaluate risk management performance at subnational level. The RMI was evaluated for the 32 departments of Colombia. Figure 12 shows a RMI map.

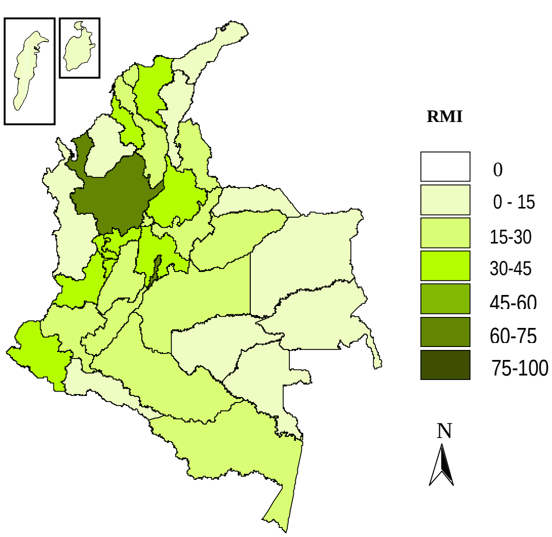

Fig. 12. RMI for the departments of Colombia at 2004

Risk management benchmarking of each indicator were evaluated by officials of the National Directorate for Disaster Prevention and Emergency Response and for academics of CEDERI. The RMI was evaluated only for 2004. Department of Antioquia and Bogota, capital district, posted the most significant advances in risk management practice. Valle del Cauca, Risaralda, Quindio, Nariño, Magdalena, Cundinamarca and Caldas, posted the same level in risk management. The lower values of RMI are shown by the departments of Vichada, Vaupes, Putumayo, Guajira, Guaviare, Guainía, Choco, Cordoba, Cesar and Arauca, which have made the least progress in the four public policies of risk management.

CONCLUSIONS

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. The RMI permits a systematic and quantitative benchmarking of each country during different periods, as well as comparisons across countries. This index enables the depiction of disaster risk management at the national level, but also at the subnational and urban level, allowing the creation of risk management performance benchmarks in order to establish performance targets for improving management effectiveness.

The RMI is novel and far more wide-reaching in its scope than other similar attempts in the past. 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 directly map sets specific decisions/actions onto sets of desirable outcomes. 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 feasible effectiveness.

ACKNOWLEDGEMENTS

This methodology was designed in the framework of the Disaster Risk Management Indicators Program in Americas, (ATN/JF-7907-RG Operation), led by IDEA for the Inter-American Development Bank, IDB. The authors would like to express their gratitude for the financial support to the IDB and to the Ministry of Education and Science of Spain, project "Desarrollo y aplicación de procedimientos avanzados para la evaluación de la vulnerabilidad y del riesgo sísmico de estructuras" – EVASIS – (REN2002-03365/RIES).

APPENDIX A

AHP is a technique is a widely used technique for multi-attribute decision making [Saaty 1980, 1987; Saaty and Vargas, 1991). 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 allows the application of data, experience, knowledge, and intuition of a logical and deep form.

The core of AHP is an ordinal pair-wise comparison of attributes, indicators in this context, in which preference statements are addressed. For a given objective, the comparisons are made per pairs of 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 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. The relative weights of the 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.

The matrices allowing the comparison of the assigned relative importance together with the respective index of consistency and the weights or priority vector obtained for the indicators of each policy for the example of Bogotá.

TABLE A.1: Matrix of comparisons for Risk Identification

	RI1	RI2	RI3	RI4	RI5	RI6
RI1	1	0.2	0.2	0.2	1	0.33
RI2	5	1	0.5	1	5	2
RI3	5	2	1	2	5	4
RI4	5	1	0.5	1	5	2
RI5	1	0.2	0.2	0.2	1	0.33
RI6	3	0.5	0.25	0.5	3	1

eigenvalue = 6.0877 CI = 0.018 CR = 0.014

TABLE A.2: Importance for Risk Identification

Indicator	Principal Eigenvector	Priority vector
RI1	0.0982	0.05
RI2	0.4441	0.22
RI3	0.7280	0.36
RI4	0.4441	0.22
RI5	0.0969	0.05
RI6	0.2381	0.12

TABLE A.3: Matrix of comparisons for Risk Reduction

	RR1	RR2	RR3	RR4	RR5	RR6
RR1	1	1	0.25	0.5	3	1
RR2	1	1	0.25	0.50	3	1
RR3	4	4	1	2	5	4
RR4	2	2	0.5	1	5	2
RR5	0.33	0.33	0.2	0.2	1	0.33
RR6	1	1	0.25	0.5	3.0	1

eigenvalue = 6.1343 CI = 0.027 CR = 0.022

TABLE A.4: Importance for Risk Reduction

Indicator	Principal eigenvector	Priority vector
RR1	0.3172	0.14
RR2	0.1896	0.09
RR3	0.1597	0.07
RR4	0.6900	0.31
RR5	0.4382	0.20
RR6	0.4122	0.19

TABLE A5: Matrix comparisons for Disaster Management

	MD1	MD2	MD3	MD4	MD5	MD6
MD1	1	2	2	5	4	5
MD2	0.5	1	1	5	2	5
MD3	0.5	1	1	5	2	5
MD4	0.2	0.2	0.2	1	0.33	1
MD5	0.25	0.5	0.5	3	1	3
MD6	0.2	0.2	0.2	1	0.33	1

eigenvalue = 6.0684 CI = 0,014 CR = 0.011

Table A6: Importance for Disaster Management

Indicator	Principal eigenvector	Priority vector
MD1	0.2272	0.11
MD2	0.2272	0.11
MD3	0.8023	0.40
MD4	0.4392	0.22
MD5	0.0923	0.05
MD6	0.2272	0.11

TABLE A7. Matrix of comparisons for Financial Protection

	PF1	PF2	PF3	PF4	PF5	PF6
PF1	1	0.33	2	5	2	5
PF2	3	1	5	6	5	6
PF3	0.5	0.2	1	3	1	3
PF4	0.2	0.167	0.33	1	0.33	1
PF5	0.5	0.2	1	3	1	3
PF6	0.2	0.167	0.167	1	0.33	1

eigenvalue = 6.0909 CI = 0.018 CR = 0.,015

TABLE A.8: Importance for Financial Protection

Indicator	Principal eigenvector	Priority vector
PF1	-0.3942	0.21
PF2	-0.8583	0.46
PF3	-0.2159	0.12
PF4	-0.0887	0.05
PF5	-0.2159	0.12
PF6	-0.0828	0.04

APPENDIX B

The following table presents an example of the benchmarks for the indicator RR5 of Risk Reduction policy. The tables for each indicator can be consulted in http://idea.unalmzl.edu.co and in Cardona et al. [2004, 2005].

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.

REFERENCES

Benson, C., Potential approaches to the development of indicators for measuring risk from a macroeconomic perspective, IDB/IDEA Program on Indicators for Disaster Risk Management, http://idea.unalmzl.edu.co Universidad Nacional de Colombia, Manizales. 2003.

Briguglio, L., Some Considerations with regard to the construction of an index of disaster risk with special reference to Islands and Small States, IDB/IDEA Program on Indicators for Disaster Risk Management, http://idea.unalmzl.edu.co Universidad Nacional de Colombia, Manizales. 2003a.

Briguglio, L., Methodological and practical considerations for constructing socio-economic indicators to evaluate disaster risk, IDB/IDEA Program on Indicators for Disaster Risk Management, http://idea.unalmzl.edu.co Universidad Nacional de Colombia, Manizales. 2003b.

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

Cardona, O.D., Hurtado, J. E., Duque, G., Moreno, A., Chardon, A.C., Velásquez, L. S. and Prieto, S. D., The Notion of Disaster Risk. Conceptual Framework for Integrated Risk Management. IDB/IDEA Program on Indicators for Disaster Risk Management, Universidad Nacional de Colombia, Manizales. http://idea.unalmzl.edu.co. 2003a.

Cardona, O.D., Hurtado, J. E., Duque, G., Moreno, A., Chardon, A.C., Velásquez, L. S. and Prieto, S. D., Indicators for Risk Measurement: Fundamentals for a Methodological Approach. IDB/IDEA Program on Indicators for Disaster Risk Management, Universidad Nacional de Colombia, Manizales. http://idea.unalmzl.edu.co. 2003b.

Cardona, O. D., Hurtado, J. E., Duque, G., Moreno, A., Chardon, A.C., Velásquez, L. S. and Prieto, S. D., Disaster Risk and Risk Management Benchmarking: A Methodology Based on Indicators at National Level, IDB/IDEA Program on Indicators for Disaster Risk Management, http://idea.unalmzl.edu.co, Universidad Nacional de Colombia, Manizales. 2004.

Cardona, O. D., Hurtado, J. E., Duque, G., Moreno, A., Chardon, A.C., Velásquez, L. S. and Prieto, S. D., System of Indicators for Disaster Risk Management: Program for Latin America and the Caribbean: Main Technical Report, IDB/IDEA Program on Indicators for Disaster Risk Management, http://idea.unalmzl.edu.co Universidad Nacional de Colombia, Manizales. 2005.

Carreño-Tibaduiza, M.L Sistema Experto para la Evaluación del Daño Postsísmico en Edificios, Thesis of Master, Department of Civil Engineering and Environment, University of Los Andes, Bogota. 2001.

Carreño, M.L, Cardona, O.D., Barbat, A. H., Metodología para la evaluación del desempeño de la gestión del riesgo, Monografías CIMNE, Technical University of Catalonia, Barcelona, Spain, 2004.

Carreño, M.L, Cardona, O.D., Barbat, A. H., Sistema de indicadores para la evaluación de riesgos, Monografías CIMNE, Technical University of Catalonia, Barcelona, Spain, 2005.

Comfort, L.K. Shared Risk: Complex Systems in Seismic Response, Pergamon, New York. 1999.

Davis, I., The Effectiveness of Current Tools for the Identification, Measurement, Analysis and Synthesis of Vulnerability and Disaster Risk, IDB/IDEA Program on Indicators for Disaster Risk Management, Universidad Nacional de Colombia, Manizales. 2003.

ISDR, A framework to guide and monitor disaster risk reduction, www.unisdr.org/dialogue/basicdocument.htm draft proposal, ISDR/ UNDP, 2003.

Mitchell, T An operational framework for mainstreaming disaster risk reduction, Benfield Hazard Research Centre Disaster Studies Working Paper 8, 2003.

Munda, G., 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 on Indicators for Disaster Risk Management, Universidad Nacional de Colombia, Manizales. http://idea.unalmzl.edu.co. 2003.

Masure, P., Variables and indicators of vulnerability and disaster risk for land-use and urban or territorial planning, IDB/IDEA http://idea.unalmzl.edu.co, Universidad Nacional de Colombia, Manizales. 2003 http://idea.unalmzl.edu.co,

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

Saaty, T.L. The analytic hierarchy process- what it is and how it is used. Mathematical Modelling, 9, 161-176., 1987.

Saaty, T.L., Vargas, L.G. Prediction, Projection, and Forecasting: Applications of the Analytical Hierarchy Process in Economics, Finance, Politics, Games, and Sports. Boston: Kluwer Academic Publishers, 1991.