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ORIGINAL PAPER

A disaster risk management performance index

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Abstract The Risk Management Index, RMI, proposed in this paper, 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 in a given area, to prepare for crisis and to recover efficiently from disasters. This index is designed to assess risk management performance. It provides a quantitative measure of management based on predefined qualitative *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, sub-national region, or city. The proposed RMI is constructed by quantifying four public policies, each of which is described by six indicators. The mentioned 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 policy is related to institutionalization and risk transfer. Results at the urban, national and sub-national levels, which illustrate the application of the RMI in those scales, are finally given.

Keywords Risk management · Performance of risk management index · Decision-making

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1 Methodological approach using indicators

Several methods based on indicators and other figures have been proposed to evaluate vulnerability and disaster risk issues. The contributions of Bates and Peacock (1992), Cutter (1994), Tucker et al. (1994), Davidson (1997), Puente (1999), Cardona et al. (2003a, b), UNDP (2004), World Bank (2004) and Carreño et al. (2005, 2006), among others, attempted to measure vulnerability and risk-related aspects using quantitative or qualitative indicators. In these studies, vulnerability or disaster risk is evaluated from different point of views, using techniques that are, certainly, similar in method but different in purpose and scope with that used in the present article. The mentioned studies have as an objective the evaluation of vulnerability and risk by means of indicators and not the assessment of the effectiveness or performance of risk management, which is the objective of the present paper.

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 regional and national levels (Mitchell 2003). However, in all cases, this type of initiative 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 quantitative 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 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 to dispose of evaluation methodologies facilitating management risk aggregation and comparison between countries, cities or regions, or any other territorial level. Also, the methodology should be easy to be applied in different time periods, in order to analyze the risk management 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 perfectly defined limits, 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.

2 The Risk Management Index, RMI

2.1 Description of the RMI

The RMI was designed to assess risk management performance and, by this way, its effectiveness. It provides a quantitative measure of management based on predefined qualitative 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 had six indicators. Risk identification index, RMI_{RI}, is a measure of individual perceptions, of 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 four public policies and their indicators were defined after an agreement with several stakeholders and evaluators. Any country or city could redefine them according to own specificities, whereas the parameters are maintained the same in the distinct evaluations over time, in order to make a consistent follow-up of the risk management. The RMI is defined as the average of the four composite indicators

$$\mathrm{RMI} = (\mathrm{RMI_{RI}} + \mathrm{RMI_{RR}} + \mathrm{RMI_{DM}} + \mathrm{RMI_{FP}})/4 \tag{1}$$

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 could 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 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 the proposed method, using a computer application. However, this simplification eliminates risk management non-linearity, having less appropriated outcomes.

The subindices of risk management conditions for each type of public policy are obtained as

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

where w_i is the weight assigned to each indicator, corresponding to each indicator for the territorial unity c taken into 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

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

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

where the parameter b is usually positive and a controls the slope at the crossing point, at 0.5 of membership, and $x = c$. Figure 1a shows these membership functions.

The shape of these membership functions follow a non-linear behavior described by a sigmoid, as proposed by Carreño et al. (2004), in order to characterize the performance 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, 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

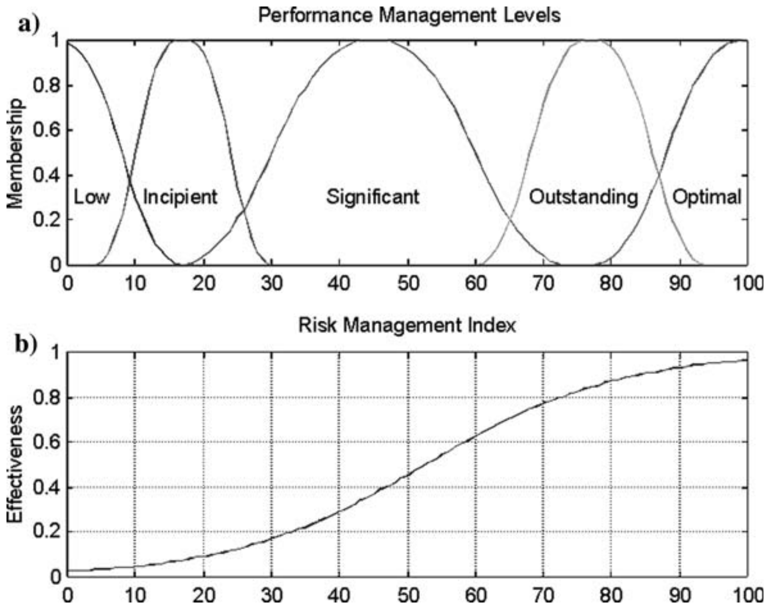

Fig. 1 (**a**) Functions that represents the qualification level; and (**b**) Effectiveness degree of the risk management

indicators is given in the x-axis of Fig. 1a 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 sigmoid function shows in Fig. 1b, in which the effectiveness of the risk management is represented as a function of the performance level. Figure 1b shows that increasing risk management effectiveness is non-linear, due to the fact that 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 the actual risk management progress in the studied area give qualifications of the indicators and assign relative importance between them for each public policy according to their experience and knowledge. These qualifications are processed using the Analytic Hierarchy Process (AHP) to assign weights, process which is explained in Appendix. Once these have been weighted and aggregated, they form a fuzzy set from which it is hoped to obtain a reply or result. In order to achieve this transformation we need to undergo a process of defuzzification of the obtained membership function and extract from this its *concentrated* or crisp value. This is the same as extracting an index.

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

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

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

$$\mu_{\mathrm{RMI_P}} = \max(w_1 \times \mu_C(C_1), \ldots, w_N \times \mu_C(C_N)) \quad (6)$$

where w_1 to w_N are the weights of the indicators of Fig. 2, $\mu_C(C_1)$ to $\mu_C(C_N)$ are the membership functions of the estimates made for each indicator and $\mu_{\mathrm{RMI}i}$ is the membership function of the RMI qualification of each public policy p. The RMI value is obtained from the defuzzification of this membership function, using the method of centroid of area, COA

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

This technique consists in estimating the area and the centroid of each set and obtaining a concentrated value by dividing the sum of the product amongst them by the sum of the areas

$$\bar{X} = \frac{\sum A_i \bar{x}_i}{\sum A_i} \quad (8)$$

or

$$\mathrm{COA} = \frac{\int_X \mu_A(x)x\mathrm{d}x}{\int_X \mu_A(x)\mathrm{d}x} \tag{9}$$

Finally, the average of the four indexes provides the total RMI

2.2 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 decision-makers. 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, 2006) when the population recognizes and understands that risk. Figure 2 shows the $\mathrm{RMI}_{\mathrm{RI}}$ composition for risk identification.

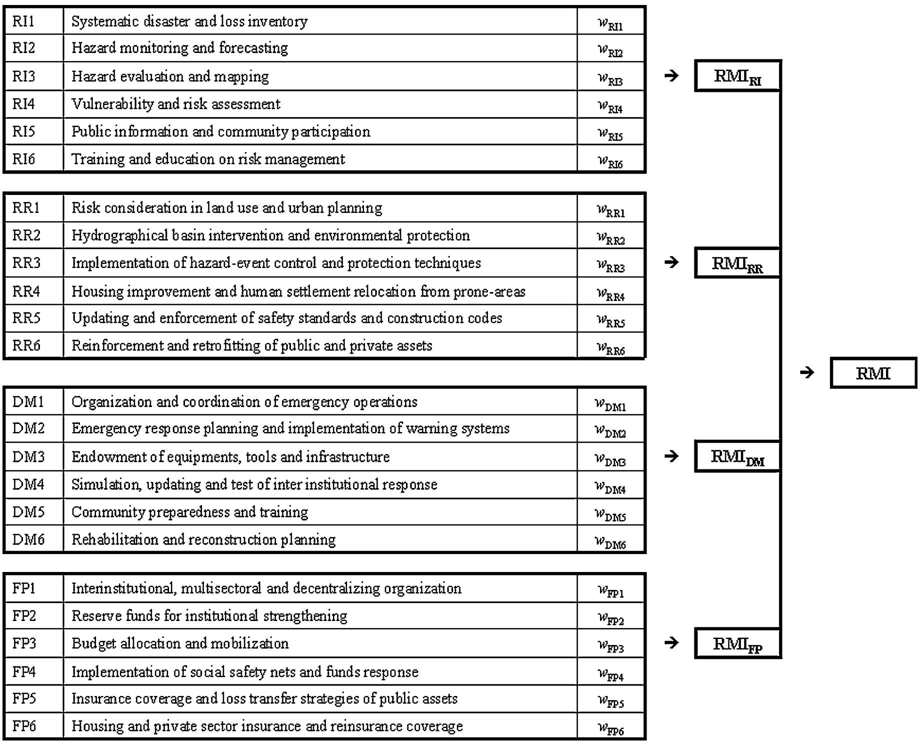

Fig. 2 Component indicators for RMI

2.3 Indicators for risk reduction

The major aim of risk management is to reduce risk. Reducing risk generally requires the implementation of structural and non-structural 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.

2.4 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.

2.5 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.

As an example, Table 1 presents the benchmark levels for the indicator RR5 of risk reduction policy. Tables of benchmarks for countries, sub-national regions and cities are not the same but, in general, they are basically similar. Some indicators may change due to scale issues and public responsibilities. The tables of benchmark for all the indicators used in the article can be consulted in http://www.manizales.unal.edu.co/ and in Cardona et al. (2004, 2005).

Table 1 Benchmarks for indicator RR5

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 microzonation, and their strict control and implementation.

3 Examples of application

In the framework of the Disaster Risk Management Indicators Program in the Americas, Colombia and other ten countries of Latin America and the Caribbean were evaluated (Cardona 2005). In addition, the RMI for Bogota and the 32 departments of Colombia was estimated with the participation of officials in charge of institutions related to risk management in each place. The indicators for each policy were obtained after a broad process of consultations and agreement, with the participation of local evaluators and of well-known international advisors. In this section some cases of study are presented to illustrate the application of RMI at local (urban), national and sub-national level.

3.1 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) of Bogotá, Colombia, and by academics of the city. Tables 2–5 show the qualifications made in different periods between 1985 and 2003 for the indicators shown in Fig. 2. These qualifications are according to the scale given in Sect. 2: (1) low, (2) incipient, (3) significant, (4) outstanding, and (5) optimal.

Table 2 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 3 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 4 Qualifications for disaster management (DM)

Indicator	1985	1990	1995	2000	2003
DM1	1	2	2	3	3
DM2	1	1	1	2	3
DM3	1	1	1	2	2
DM4	1	1	1	1	3
DM5	1	1	1	2	3
DM6	1	1	1	1	2

Table 5 Qualifications for financial protection (FP)

Indicator	1985	1990	1995	2000	2003
FP1	1	2	2	3	3
FP2	1	4	4	4	4
FP3	1	1	3	3	4
FP4	1	1	1	1	1
FP5	1	1	1	2	3
FP6	1	1	2	2	3

The weights were also obtained according to the opinion of the risk management authorities of the city of Bogotá. The AHP, which is explained in Appendix, was applied to estimate these weights. Table 6 shows the results obtained for the weights of each public policy. 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 to be equal.

Figure 3 shows an example of calculation of an index, in this case the RMI_{DM}. Figure 3a shows the membership functions for the qualifications of the disaster management indicators for the year 2003, which is shown in Table 4. Figure 3b shows the union of the fuzzy sets corresponding to the weighted qualifications, that is, their envelope according to Eq. 6. The defuzzification process corresponding to Eq. 7 is also illustrated in Fig. 3b. Table 7 shows the final results for Bogotá city.

The results obtained in this way for the RMI and the subindices corresponding to the four policies which have been considered, reflect the performance of the risk management in Bogotá in the last 25 years. They emphasize the aspects that 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 for 2003 performed starting from the qualifications made 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 significant tasks because they are too small areas that have not sufficient capacity and autonomy to deal with some specialized activities.

Table 6 Weights for the set of indicators

Weight	RI	RR	DM	FP
w_1	0.05	0.14	0.11	0.21
w_2	0.22	0.09	0.11	0.46
w_3	0.36	0.07	0.40	0.12
w_4	0.22	0.31	0.22	0.05
w_5	0.05	0.20	0.05	0.12
w_6	0.12	0.19	0.11	0.04

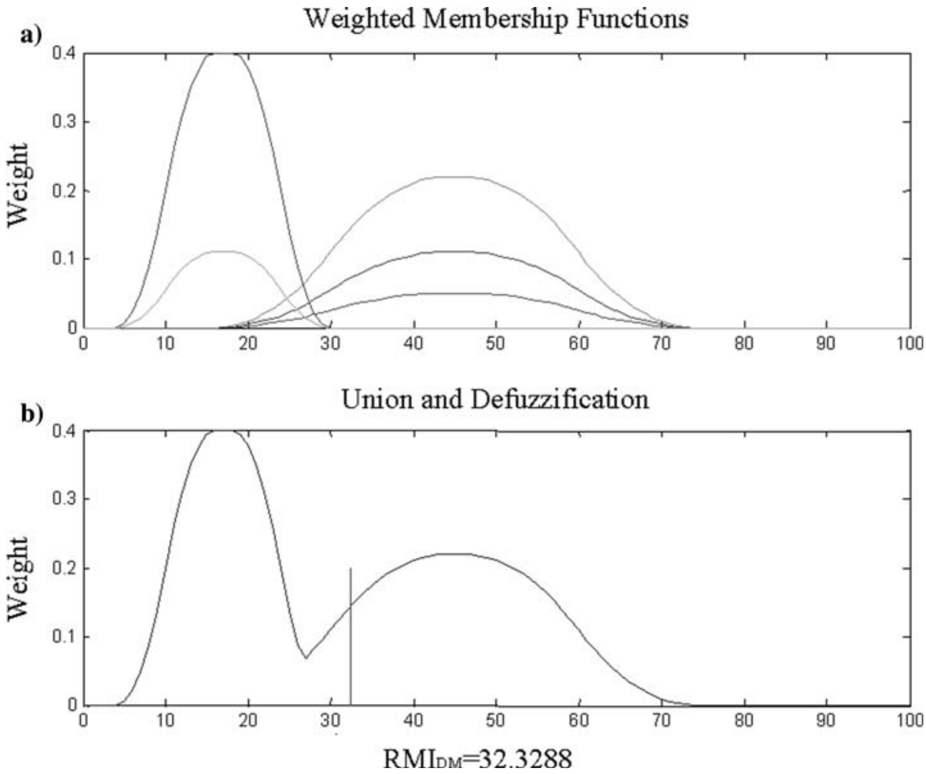

Fig. 3 Aggregation and defuzzification to calculate the RMI_{DM} for 2003

3.2 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 (DNPAD) and by academics of Centre of Studies on Disasters and Risks (CEDERI) of the University of Los Andes. Tables 8–11 show the qualifications made in different periods between 1985 and 2003, according to the given scale, for the indicators of the four public policies.

Again, the weights were obtained starting from the opinion of the authorities of the DNPAD of Colombia and by applying the AHP. Table 12 displays the final results of the risk management indices obtained for Colombia after the weighted union and the defuzzification of the qualifications for each public policy.

Table 7 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

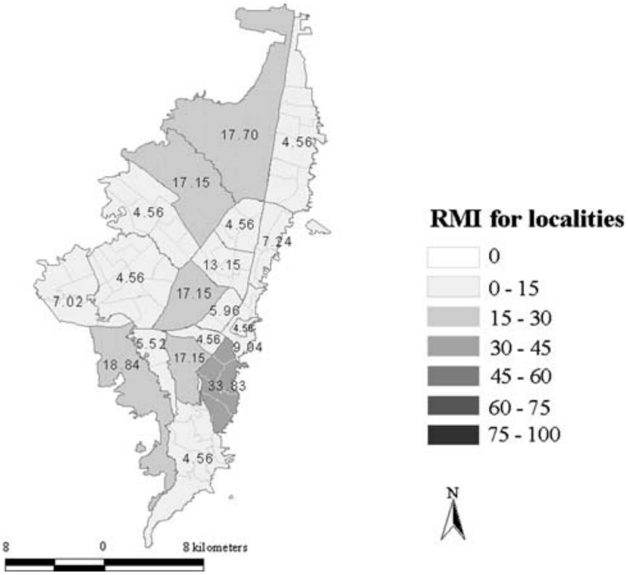

Fig. 4 Values of RMI for the localities of Bogotá, 2003

Table 8 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 9 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 10 Qualifications for disaster management (DM)

Indicator	1985	1990	1995	2000	2003
DM1	1	2	2	3	3
DM2	1	1	2	2	2
DM3	1	2	2	2	2
DM4	1	1	1	2	2
DM5	1	1	2	1	1
DM6	1	1	1	2	2

Table 11 Qualifications for financial protection (FP)

Indicator	1985	1990	1995	2000	2003
FP1	1	2	3	2	2
FP2	1	2	3	2	2
FP3	1	1	2	2	2
FP4	1	1	2	2	2
FP5	1	1	2	3	3
FP6	1	2	2	3	3

Table 12 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

Figures 5 and 6 show that 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 its efforts at formulating, implementing, and to the policy evaluation of risk management, according to these achievements and performance targets (SIRE 2005).

3.3 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). Figures 7–10 illustrate the values of the components of RMI and Fig. 11 shows the final results of the RMI for the countries every 5 years from 1985 to 2000.

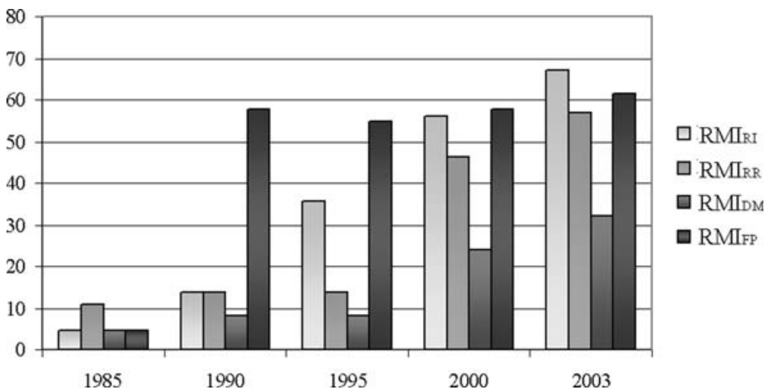

Fig. 5 Risk management indices for each public policy

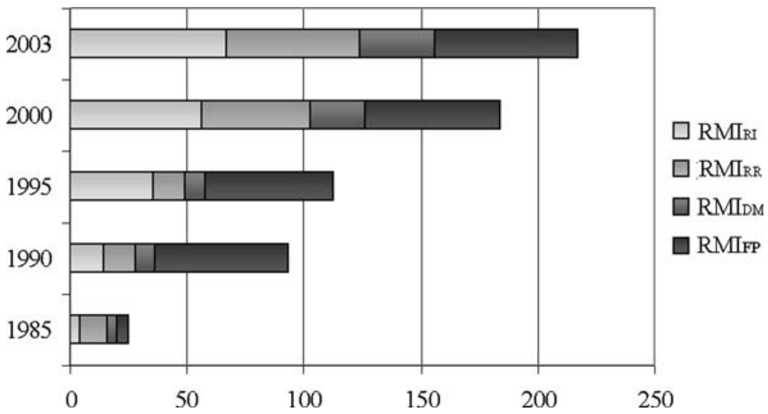

Fig. 6 RMI evolution from 1985 to 2003

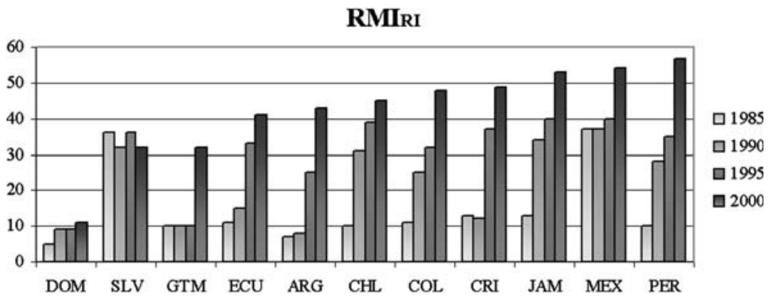

Fig. 7 RMI for risk identification in LAC, 1985–2000

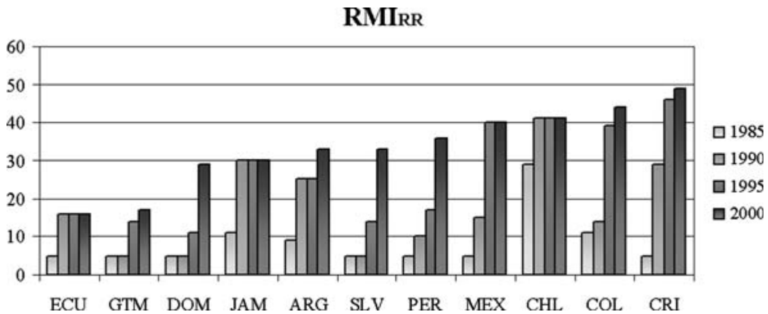

Fig. 8 RMI for risk reduction in LAC, 1985–2000

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

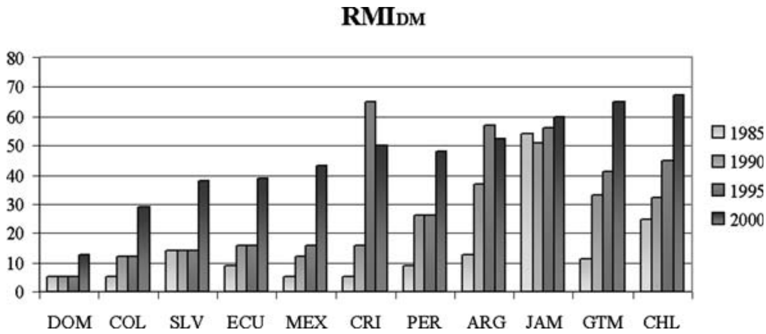

Fig. 9 RMI for disaster management in LAC, 1985–2000

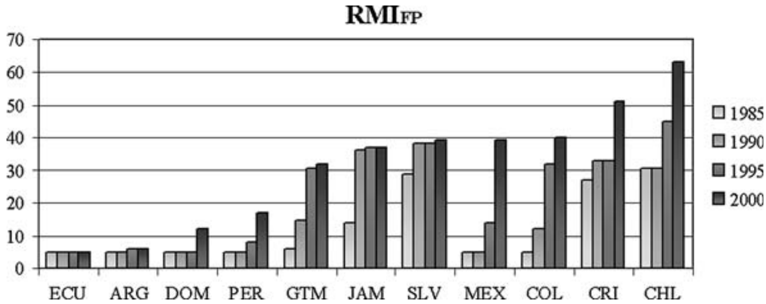

Fig. 10 RMI for financial protection, 1985–2000

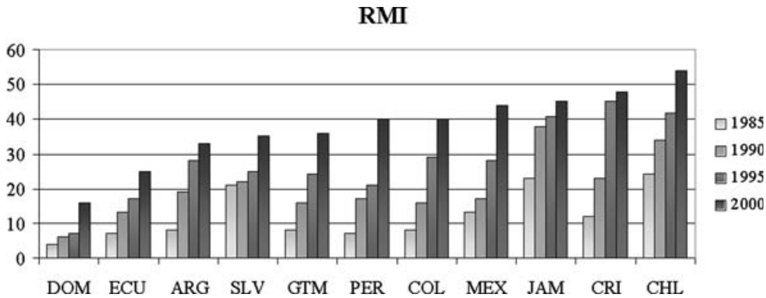

Fig. 11 RMI for the countries, 1985–2000

made has improved from "low" to "significant" in the majority of cases. On average, risk management performance is something better than "incipient" and the 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.

3.4 Sub-national level: Departments of Colombia

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

Risk management benchmarking of each indicator were evaluated by officials of the DNPAD, Colombia, and by 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.

4 Conclusions

The RMI is the first systematic and consistent international index 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 not only enables the depiction of disaster risk management at the national level, but also at the sub-national and urban level, allowing the creation of risk management performance benchmarks in order to establish performance targets for improving management effectiveness.

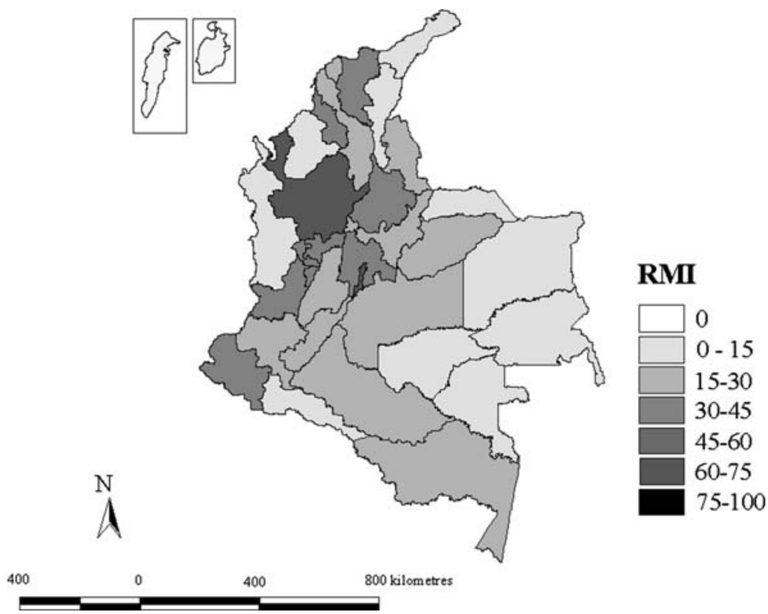

Fig. 12 RMI for the departments of Colombia at 2004

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. The RMI can show acute annual or biennial improvements due to political decisions and implementations of measures of risks management. That is important from the point of view of giving positive reinforcement to national or sub-national governments, as well as of providing for improved social protection, while slower, gradual socio-economic progress is being made. It is the reason why the RMI is a useful tool for organizations like the Inter-American Development Bank (IDB), which financed this study.

This index has the advantage of being composed of measures that directly map sets of 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. The new IDB Action Plan for disaster reduction in the Latin America and the Caribbean and the new country's strategy papers for development assistance made by decision-makers of the bank and of the countries, have been based on the outcomes and analyses of these evaluations.

Acknowledgements 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 (ATN/JF-7907-RG Operation), 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 sub-national 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://www.manizales.unal.edu.co/

Appendix

AHP is a technique widely used 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 pairwise 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 first posing the question "Which of the two is the more important?" and second "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, have been obtained for the indicators of each policy for the example of Bogotá (see Tables 13–20).

Table 13 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 14 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 15 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 16 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 17 Matrix comparisons for disaster management

	DM1	DM2	DM3	DM4	DM5	DM6
DM1	1	2	2	5	4	5
DM2	0.5	1	1	5	2	5
DM3	0.5	1	1	5	2	5
DM4	0.2	0.2	0.2	1	0.33	1
DM5	0.25	0.5	0.5	3	1	3
DM6	0.2	0.2	0.2	1	0.33	1

Eigenvalue = 6.0684; CI = 0,014; CR = 0.011

Table 18 Importance for disaster management

Indicator	Principal eigenvector	Priority vector
DM1	0.2272	0.11
DM2	0.2272	0.11
DM3	0.8023	0.40
DM4	0.4392	0.22
DM5	0.0923	0.05
DM6	0.2272	0.11

Table 19 Matrix of comparisons for financial protection

	PF1	PF2	PF3	PF4	PF5	PF6
FP1	1	0.33	2	5	2	5
FP2	3	1	5	6	5	6
FP3	0.5	0.2	1	3	1	3
FP4	0.2	0.167	0.33	1	0.33	1
FP5	0.5	0.2	1	3	1	3
FP6	0.2	0.167	0.167	1	0.33	1

Eigenvalue = 6.0909; CI = 0.018; CR = 0.015

Table 20 Importance for financial protection

Indicator	Principal eigenvector	Priority vector
FP1	–0.3942	0.21
FP2	–0.8583	0.46
FP3	–0.2159	0.12
FP4	–0.0887	0.05
FP5	–0.2159	0.12
FP6	–0.0828	0.04

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