Global Assessment Report
on Disaster Risk Reduction

GAR 2011

PROBABILISTIC MODELLING OF NATURAL RISKS AT THE GLOBAL LEVEL: THE HYBRID LOSS EXCEEDANCE CURVE

DEVELOPMENT OF METHODOLOGY AND IMPLEMENTATION OF CASE STUDIES

PHASE 1A: COLOMBIA, MEXICO AND NEPAL

ERN

Evaluación de Riesgos Naturales
- América Latina -
Consultores en Riesgos y Desastres

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1 Introduction

During recent decades, socio-economic impacts produced by disasters caused by natural phenomena are an indication of the high vulnerability of human settlements located in vulnerable areas in developing countries, as well as the levels of financial and social protection that must be provided in order to pay for associated economic losses, not only direct losses but also losses from a decrease in productivity of the agricultural and industrial sectors, a decline in tax revenues and a need to have resources available for dealing with emergencies.

Vulnerability in the face of natural phenomena has increased during recent decades primarily in the developing countries throughout the world. Population growth, poverty, the growth of cities and infrastructure projects in general have increased the assets exposed in regions that can be affected by a large diversity of dangerous natural phenomena. In addition, a high level of population migration because of various social problems, unemployment, violence, insecurity of many different types and other factors force people to occupy land that is less and less suitable for human habitation, which increases exposure under undesirable conditions, leading to a considerable increase in levels of vulnerability and risk.

Despite the research carried out on an international scale concerning the impact of disasters on development, formal incorporation of disaster risk in planning processes has been very timid up until now. Although most developing countries include in their budgets several allocations, primarily for preparation and dealing with emergencies, and in several cases efforts are being made to orient resources towards planning activities dealing with risk mitigation, in many countries do not calculate probabilistic losses from natural events as a permanent component of their budget process. However, if potential contingent losses are not accounted for, there is a lack of information required in order to consider and evaluate alternatives in order to reduce or pay for those losses. As a result, policies aimed at reducing risk do not really receive the attention that they require.

An absence of adequate models to quantify risk in objective and non-relative terms leads to a series of important implications. The most obvious implication is that by not accounting for contingent exposure to natural hazards a country's capacity to evaluate how desirable its planning tools are to deal with risk is limited. Planning tools require that risk is reasonably quantified as a pre-existing condition in order for those planning tools to be useful. Although it is possible to take policy decisions based on rough estimates or without probabilistic estimates[1], by not quantifying the risk when it is possible the decision-making process is handicapped for physical planning and for reducing and financing risk. If future losses are not a component of the planning and investment process in a country, it is almost

[1] Probabilistic: which permit the establishment of Probable Maximum Losses (PML) and expected annual losses (the basic risk premium) resulting from the estimated loss curves.

impossible to use budget resources in order to reduce potential losses. A lack of probabilistic disaster risk estimates has at least two very important serious implications: first, there is no contingency planning for the cost of future reconstruction and, second, which is the most important, the main incentive for promoting risk mitigation and prevention is lost.

Many recent applications and projects have been focus on evaluating hazards in terms of statistics, making reference to the frequencies of occurrence of various levels of phenomena such as earthquakes, tsunamis, hurricanes, flooding, landslides and volcanic eruptions. Meanwhile, the assessment of vulnerability has focused primarily on establishing indices based on the number of victims caused by each disaster. Using information at the worldwide level available in certain databases (e.g. EM-DAT of the Université catholique de Louvain), correlations have been established with information available on the same events in order to establish levels of vulnerability by correlating factors. Indices are based essentially on statistical correlations and not on actuarial or physical assessments obtained from the association between the degree of hazard, exposure and vulnerability, with which can be established measurements more appropriate or taking into account the risk to which each region or area of the world is exposed.

Although these indices are illustrative for effects of comparison, in general, they are deficient at the macro level for calculating risk in predictive terms. It can be stated that this type of focus is retrospective of what has occurred. In essence, they are indices of disaster and not of risk in the true sense of the word and, therefore, report indirectly and in a limited way what might occur in the future. These indices are inappropriate for determining frequency and intensity of hazards and potential losses. They do not facilitate the drafting of appropriate measures for intervention or risk mitigation, taking into account feasible and appropriate alternatives that can be described in function of their effectiveness and cost. Several of these indices developed at the global level, that have been established using indicators, illustrate the more advanced work carried out up until now of this type. A descriptive summary of the same is included in annex 1.

Taking that into account, the concept paper entitled *Global Assessment Report on Disaster Risk Reduction – GAR 2011* states the need to identify effective strategies for reducing various segments and strata of risk based on the application of instruments of probabilistic assessment and the availability of information on global, regional and national risks in order to identify and quantify the various strata of risk associated with various intensities and frequencies of possible consequences. In addition, it is proposed that the costs and benefits of the treatment of each of those segments and strata of risk be identified and examined, in order to sustain strategies of risk reduction taking into account the maximization of benefits for various groups of countries.

This report seeks to consider the possibility of meeting the challenge of GAR 2011, given the possibility of using information that until now has been used at a level and other, global a national and sub-national levels with greater resolution. Likewise, the possibility of using sophisticated and rigorous probabilistic models, a level state of the art, which make it possible to carry out appropriate risk assessments of effect, such as those used in the insurance and reinsurance industries, but adjusted by their authors in order to reflect not only catastrophic risk, as is usually the case, but also aggregated risk in terms of multi-hazard in relevant time frames for decision-makers in the public and private sector in order to create strata of the risk and propose activities for retention, mitigation, regulation, transfer and acceptability of the risk in accordance with what is feasible in terms of public investment and optimization of resources.

Bogota, February 2011
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2 Methodological aspects

One factor that can be considered common to the work carried out up until now at the global and regional levels is that rough assessments of all the variables are used, in statistical correlations and in hypotheses that can be considered acceptable only at the global level for illustrative purposes of issues in order to support the need to reduce the risk but that are inappropriate when the goal is to define pragmatic and realistic activities of reducing risk within the framework of the reality of individual countries. In general, of these approaches it can be said that:

a. They are not based on a rigorous scientific calculation in accordance with the state of the art in modelling risks from a probabilistic and actuarial perspective, making the final result tends to be preferentially and inevitably a comparative or relative measure for classification and not an objective measurement of risk, which is what is required in order to define intervention activities that must be defined in associated economic units and social justifications.

b. The resulting indicators can normally be used only for comparison and prioritization between areas, regions or countries. In certain cases, the indicators can be used for breaking down the result and attempt to prioritize possible general interventions at the level of parameters, but with which it is not feasible to establish well-defined policies, alternatives and priorities of risk mitigation.

c. They cannot, in general, be used to make prognosis or predictions of future risk, because there is no clear relationship between the parameters and the scaling of a given indicator, because it does not imply necessarily a proportional scaling with the existing level of risk. With a few exceptions, all describe retrospectively of disasters occurred and not those that could occur, estimated as the result of an analytical process that usually requires a probabilistic approach.

d. It is difficult to use those indicators in practical applications such as schemes for retention or transfer of risk, risk mitigation measures and their assessment, regulation of safety measures, information for land use plans and reasonable definitions of risk levels infeasible to take into account.

In light of the above, this type of approach usually makes reference to its limitations, taking into account the goal for which have been conceived and the need to be complemented with more rigorous risk assessments that allow application of more basic techniques in scientific terms that make it possible to assess sensitivity and future projections that are not feasible or are unreliable with the techniques mentioned earlier. This aspect is of special importance when not only changes are expected in the exposure and vulnerability but also changes in the levels of hazard, owing, for example, to climate change. Furthermore, in physical terms it is important to be able to describe change in the physical vulnerability over time, especially when changes or interventions can take place owing to successful mitigation programmes. In other words, the possible assessment of the effectiveness of risk management is more feasible when it is possible to measure risk more realistically taking into account concrete activities for reducing vulnerability in terms of potential damage in the long term. At the same time, it is desirable that the methodologies are multi-hazard or multi-risk in order to identify issues that are more the rule than the exception. In conclusion, the previous techniques are appropriate for certain types of activities whose goal is limited to communicating the risk and to recommend general activities. Therefore, in order to promote successively other more specific activities it will require dealing with the problem of risk differently than the case until now at the global or regional levels which requires a notable technical, scientific and operational challenge.

However, although there are actuarial and probabilistic models appropriate for evaluating catastrophic risk, usually proprietary, of businesses specialized in the field of insurance/ reinsurance and financial risk, such as RMS, AIR Worldwide, EQECAT, to mention only a few, apart from being black boxes these models are focused on capturing possible situations of insolvency undesirable for the insurance and reinsurance companies or operators on the capital market that “assume” risk. In other words, the models have not been designed and presented in function of the needs and realities of the parties seeking insurance for that risk, who must cover the risk of the first parts of losses—that are those that cause the most recurrent events—through the deductible or attachment point; otherwise premiums would be prohibitive. In other words, those models serve to help risk takers define strategies of financial protection in order to avoid their insolvency because of the catastrophic risk that they would have to pay. These models tend to ignore by definition small disasters that are not going to be paid because they would be retained by the insured party but, that lumped together in groups of several years—such as periods of government—not only are important but imply permanent attention and action by the parties seeking insurance.

That implies a change of the risk models in order to adjust them to the perspective and needs of the parties seeking insurance, such as, for example, governments at all levels. Clearly, the transfer of risk only makes sense at intermediary and high levels and retention of risk has serious implications not only financial (because they require reserve funds, contingency loans, reallocation of budgets) but also institutional, governmental and efficiency, and in general activities dealing with the inevitable recurrent events that exhaust institutions and communities and at the same vulnerable agents that suffer continuously events that affect their livelihoods. In conclusion, this project implies adjusting the existing models in order to determine what is required, what is stratification of the multi-hazard risk from the perspective of the policy holder and not the insurer. Therefore, this consultant group has made the specific adjustments to its models, on the basis of which has been developed the platform of open code and architecture multi-hazard ERN-CAPRA (*Comprehensive Approach for Probabilistic Risk Assessment*) developed by this consultant group for the countries with the support of the World Bank, the Inter-American Development Bank and UN-ISDR.

3 Objective

The main goal of this work is to develop an alternative methodology for assessing and analysing risk with probabilistic bases faced with various natural phenomena and apply it in various multi-hazard situations at the global, regional, national and local levels, in order to illustrate and facilitate stratification of risk in order to identify and maximize activities and interventions reasonable and effective of reducing risk. In addition, there are the following goals:

a. Production of a consistent, efficient and up-dated procedure for management of available information;

b. Development of an approximate and appropriate method for quantifying and characterizing the exposure of exposed elements susceptible of being affected and, therefore, of being included in risk assessments;

c. Assess appropriately the physical and human vulnerability of populations at various levels of aggregation to various considered hazards;

d. Implementation of a method for assessing risk with technical rigour, that makes possible carrying out prospective analysis with the definition of various levels of probability of occurrence of intensities or loss and that facilitates the multi-risk analysis rigorously;

e. Easy updating over time or in the event of a change of any of the model's parameters.

The assessments should be carried out on the basis of existing coarse grain information but with the capacity to be able to refine it as that information becomes available in greater detail. In other words, the assessment technique must be spatially scalable and make it possible to make assessments at the macro level—a regional or national scale—and a micro level—a subnational and local scale—where what changes is the resolution of the information. This permits inputting through various stages or versions of the GAR, demonstrative examples at any level, for any region, hazards, etc., in accordance with available information and convenience.

Assessment from an analytical point of view is backed up with an analysis of previous events based on information available in the database of events, DesInventar (www.desinventar.org), which provides information on effects and historical human losses for the countries over time and broken down by type of event; e.g. earthquakes, flooding, landslides, volcanoes, hurricanes and others. The information provided by the DesInventar database is fundamental for the following reasons:

a. It serves as a basis for calibration of the analytical models of risk assessment, using as a reference the largest events recorded.

b. It complements the results of an analytical assessment, making it possible to define empirically the loss exceedance curve for the range of events of minor intensity; segment of the curve in which the analytical assessments are unreliable.

c. It permits the inclusion of the effect or participation of various types of events and therefore makes it possible to establish which of them dominate or control maximum losses for a country or region in various segments of the loss exceedance curve.

This study proposes a methodology for risk analysis that uses, on the one hand, empirical estimates of occurrence based on information in the DesInventar database, with which can be estimated the occurrence of losses caused by recurrent minor events, and, on the other hand, probabilistic analytical assessments in order to estimate the occurrence of losses from major events, for which there is no information because of the absence of sufficient historical information. Information from the DesInventar database is limited for indicating the occurrence of losses through major events because of the short period of time it covers and the analytical assessment is fundamentally useful for estimating the consequences of extreme or catastrophic events.

It is proposed to construct a hybrid loss exceedance curve in order to represent the risk of disaster, in which its first segment of minor and modest losses correspond to an inductive analysis, in retrospective, and the second segment corresponds to a deductive and predictive analysis, in prospective, of the potential of major and extreme losses. The proposed methodology is used in Colombia, Mexico and Nepal in order to illustrate the advantages of this type of technique, considering that the first segment of the curve can be obtained for each type of hazard and as a total and that the second segment of the curve can be obtained for the hazards that have the potential of producing catastrophic events by correlation or occurrence of losses simultaneously. The results obtained in this way of assessing risk, using the hybrid loss exceedance curve, make it possible to make a series of approaches concerning various ways of risk reduction, illustrating that it is possible to classify them, in the sense that the manner of dealing with them, through activities and various measures of retention, mitigation, regulation, transfer and acceptability of the risk in light of technical, financial and social justifications.

3.1 The loss exceedance curve

In order to decide, it is necessary or very useful to measure. This work intent to contribute to have a quantitative notion of disaster risk in order to measure, in several cases reveal and bring to light or attempt to recognize a problem which may not have a true dimension. It seeks, if possible, to concern someone and identify focus of reasonable intervention, because the way of dealing with risk varies according to the level of risk that supposedly exists (stratification of risk to which there are alternative forms of replying).

There is a difference between probability (understood as frequency) and expectations or mathematical probability (in terms of possibility). One thing is the frequency of events (rate of occurrence) another is the possibility of consequences (potential loss). The expected consequences are obtained from the frequency and the severity and that expectation must be expressed in a window of time in order to be able to have a relevant reference for comparison. From that is derived the need to see the consequences and not the events in terms of a period of return (the inverse of the annual frequency) and in time periods that can be used as a reference and which can be called time of exposure.

From that, it can be concluded that it is possible to answer the question of how much can be the expectation or probability of loss (of reaching or surpassing) a certain level of consequences in a defined period of time: for example, a probability of loss of 0.1 (i.e. 10 per cent) in 50 years (which in passing is important to point out that it is the equivalent to a loss with an average return period of 500 years); case in which the following question is whether that percentage in that time of exposure is great or not. It should be pointed out that the probability that the loss of the X years of return period occurs in a time frame of X years is always 63 per cent (and not 100 per cent as would be thought). The probability that the maximum loss in 100 years occurs in 100 years is 63 per cent.

It should be mentioned that for a portfolio of exposed elements (of the responsibility or interest, for example, of a government) that loss and not the cause of the event of X years of return period (500, for the example, of a certain intensity). Possibly, for a set of elements distributed or dispersed, the loss of 500 years would be produced by an event of a much greater period of return; besides the vulnerability of each component of the portfolio would have significant influence also. Let's say that it would not be a constant vulnerability.

Given the above, and considering that a government would have a fiscal responsibility (risk economic for the consequences) to cover or pay for replacement of public infrastructure and the assets of a segment of the population (low incomes) it is necessary to quantify risk through a loss exceedance curve indicating which is the frequency (for example, annual) of each value (level) of possible losses for that government. Information that is relevant in order to be able to estimate whether it is feasible achieve a benefit if an investment is made to prevent or reduce that the expected losses (public investment) occur.

The loss exceedance curve (annual frequency with which is equal or greater than a level of loss) usually is obtained analytically by constructing a hypothetical model of the possible consequences for the exposed assets of a portfolio—to which is assigned a level (average) and a variability of vulnerability with reasonable technical criteria (analytical, observed and empirical) – considering the stochastic occurrence of multiple events of various intensities that can be feasible, result of the patterns of recurrence observed in history or the series of events occurred (seismic catalogue, frequency of rains, hurricane paths, etc.).

That loss exceedance curve (which also can be expressed as a curve of probable maximum losses with various periods of return) represents or “predicts” rather acceptably or robustly catastrophic risk, making the necessary reservations concerning the levels of epistemic and random uncertainty (for lack of information and inherent randomness). In other words, the annual frequency of losses very significant result of the correlation (simultaneousness of effects on the portfolio) of major events, which usually are of interest for the effects of negotiations between insurers and policy holders of the financial risk (insolvency, deficit, contingent liabilities) that are derived from extreme disasters and that are covered by contracts for transfer of losses. Figure 3-1 illustrates a typical loss exceedance curve.

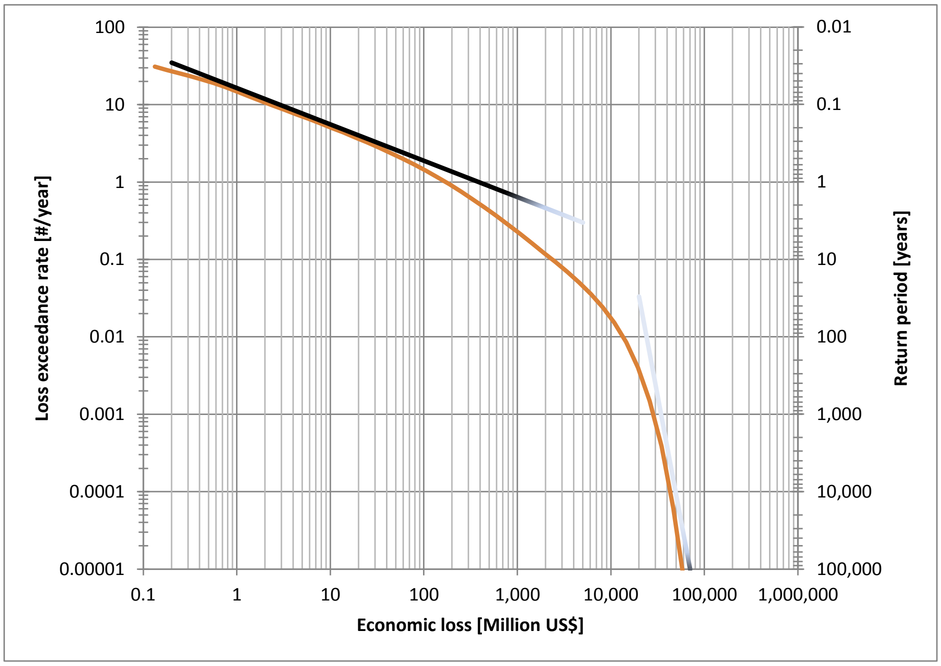


Figure 3-1 Loss exceedance curve for assessing disaster risk

From the above it can be concluded that the loss exceedance curve obtained analytically (i) usually covers only events such as earthquakes, hurricanes or phenomena that can cause serious consequences due to the correlation or simultaneousness of the effects on the exposed portfolio; (ii) is relevant and reliable only from a point of loss of a certain degree of importance, known as the attachment point (deductible), which is considered as defining a suitable value for the insurer after which transfer begins. That means that the consequences caused by events that difficultly can correlate losses (for example, minor flooding, landslides, minor events, etc.) or the consequences caused by events of less intensity (because the accumulation of losses over time are not taken into account) that must be assumed by the policy holder.

Not having an evaluation of losses for minor events has prevented until now that someone becomes interested in developing empirically a loss exceedance curve that illustrates what the curve does not capture analytically (for the reasons stated above), which has led to the rejection or underestimating of the consequences of those events. It is clear that the analytical curve has been proposed and used by insurers of risk whose interest is not to evaluate losses below the deductible (which would have to be in the interest of the policy holders) and not taking into account the accumulative effects and the implications of dealing repeatedly with events that can lead to administrative decline. In other words, events that should be in the interest of the governments and that in reality have not interested them nor have their true social and economic consequences been measured.

That could be one of the reasons for which several governments are not really covering minor events or for which there is no accurate information (evidence) or a justification to establish a well-defined strategy of mitigation according to the level of risk that these events present, despite their social effects, but also, economics when they are appropriately evaluated. Therefore, the successful empirical development using a series of assumptions about economic costs and a database with the characteristics of the DesInventar, the first segment of the loss exceedance curve, which, in general, would correspond to the deductible or most unreliable and even "insignificant" part of the analytical curve, is a step that can be of special interest for the adoption of a methodology that makes it possible to determine the consequences of minor events and the true costs that those events have and that are hidden or being assumed in general by the most vulnerable population.

The exercise carried out up until now with Colombia, Mexico and Nepal has made it possible to verify that assumption because a methodology has been developed making it possible to illustrate that the first segment of the loss exceedance curve (risk of recurrent minor events) can be obtained inductively empirically, using the DesInventar, and that there is the manner to connect it with the second segment that should be obtained analytically with the deductive and predictive approach of the probabilistic calculation of catastrophic risk. Both segments imply the development of an estimate of losses (with little developed criteria: assumptions of costs and a proxy of exposure) that until now have not been carried out (evaluation of effects of recurrent events and catastrophic risk profile of the portfolio of fiscal responsibility of the government).

In summary, this work opens a range of possibilities or a very broad of understanding of the behaviour of minor events using the approach of analysis of frequency and value of losses (or housing destroyed, or affected, deaths, wounded, etc.), which means extracting information from DesInventar that until now has not been explored and also this work defines how a complete risk profile can be made from a retrospective perspective (first segment) and predictive (second segment) that captures the fiscal responsibility, assuming that the small and moderate disasters correspond mostly to consequences of events that affect persons of lowest incomes of the population (losses that should entirely represent a cost for the Government) and that the losses associated with large disasters imply high costs for replacement of public infrastructure and of goods for the poorest strata. Risk calculations of this type have not been carried out before and their lack does not justify more explicitly (through stratification of risk) prevention and mitigation measures that could be proposed using an analysis of economic and social optimization.

4 Retrospective risk assessment

4.1 The DesInventar database

DesInventar[2] constitutes simultaneously a system of databases for preparing historic inventories of disasters and a methodology for their analysis. It is formed on the one hand, by a software that permits the gathering, systematization, organize and consult the information incorporated into the system, both from a spatial and temporal point of view, and on the other hand, by a methodology for gathering and analysing information that places special emphasis on the following aspects:

a. DesInventar deals with disasters taken as the group of adverse effects on life, property, infrastructure and social relations of a community. That includes events with very few effects as well as disasters in which there have been serious consequences.

b. In general, the level of resolution of the inventory of the records corresponds to the municipal territorial unit or equivalent division. However, local or regional inventories can be made with more detailed levels of resolution.

The information gathered in the DesInventar database, just like what occurs with any type of existing database on disasters, does not claim to make up the complete universe of disasters occurred historically. In the best of cases, it is a broad sample of them, limited by the very characteristics of the information and its sources, subjected permanently to refinement and amendments and therefore, not free of errors.

In DesInventar there are strong and robust variables: the type of event causing the disaster recorded; the date of its occurrence and geographical location, as well as other less robust but credible with a few verifications and that can serve for analysis: the number of deaths and wounded, the number of housing destroyed and affected and, taking certain criteria of information management in situations of disaster, the total number of victims and affected. To that can be added, with special attention: the number of hectares of crops affected.

In quantitative terms, the set of least robust variables presents various problems (in addition to the general “bias” against newspaper information) that requires permanent control and the resulting need for refinement before any analysis, in repeated treatment data from observation of journalists has been detected, but not of a specific verifiable source (in general an attempt has been made to contrast that information with another source, namely

[2] For details on the conception, methodology and use of DesInventar see: www.desinventar.org, especially the methodological and user manuals presented there. Consult also the work of LA RED-OSSO for UNDP-ISDR “Comparative Analysis of Databases de disasters EmDat-DesInventar” January 2003, at www.desenredando.org

"official"); official sources that "inflate" data depending on political circumstances, which can be difficult to correct but contrast with other unofficial sources; and errors of data entry.

Furthermore, not all the records contain the same information, either because of the type of damage (there is no damage to housing but in bridges, for example), or because there is no quantification of the damage (many damaged houses) either because the original information only include certain variables and not others (for example logically housing destroyed should have a corresponding number of affected, and that does not always appear).

As for the number of affected, there are records with a very high number of them. It has been detected that in most cases it is related to the inclusion as affected among the entire population that has been for one, two hours or one or two days without the provision of a basic service (two million affected by a lack of electricity).

Table 4-1 lists several of the countries that have established a database, the number of records and the period covered.

Table 4-1
Countries with DesInventar, number of records and period covered

Country	No. of records	Period covered	
Asia			
India	9,229	01/01/1970	30/12/2002
Nepal *	15,206	09/01/1971	30/12/2007
North America			
Mexico	23,432	03/01/1980	31/12/2009
South America – Andean region			
Bolivia	2,479	05/01/1970	23/12/2007
Colombia	28,352	15/11/1914	05/11/2009
Ecuador	4,521	07/01/1970	29/12/2007
Peru	21,090	01/01/1970	29/12/2009
Venezuela	5,047	09/01/1530	01/03/2010
South America – Southern Cone			
Argentina	15,466	01/01/1970	31/12/2004
Chile	12,340	01/01/1970	25/12/2009
Paraguay	255	01/01/1997	30/12/2008

Taken from DesInventar.org
* Taken de www.desinventar.net

Table 4-2 describes the main fields of records of the DesInventar database. This information has been taken from the DesInventar Methodological Guide, version 8.1.9, available on the Internet.

Table 4-2
Main fields of the DesInventar databases

Field	Description
Date	Date of the event
Geographical name	Location
Type of event	Type of event
Deaths	Number of persons killed as a direct result. When final official data are available, this value is included with appropriate observations, for example when there are differences between the officially accepted figures and those from other sources. Presumptions of deaths, not officially verified, are registered in the field observations of effects mention the source of information.
Missings	Number of persons whose whereabouts following a disaster are unknown. That includes persons who are assumed to be dead without physical evidence. Data on deaths and disappearances are mutually exclusive, therefore, they are not mixed.
Injured	Number of persons whose health or physical integrity is affected, without being mortal victims, as a direct result of the disaster. Should be included the persons who suffered wounds and those that fell ill, in the case of a plague or epidemic.
Victims	Number of persons that have suffered serious damage directly associated with the event to their individual or collective property and services. For example, partial or total destruction of their housing and property; losses of crops and warehouses, etc. The number of persons resettled should also be included.
Affected	Number of persons that suffered indirect or secondary effects associated with a disaster. This corresponds to the number of persons, different from victims, that suffer the impact of the secondary effects of disasters for reasons such as deficiencies in the provision of public services, business, or in employment, or by isolation. If the information appears by families, calculate the number of persons using available indicators.
Evacuated	Number of persons evacuated temporarily from their homes, work places, schools, hospitals, etc.
Resettled	Number of persons that have been displaced from their residences to new settlements.
Houses destroyed	Number of houses washed away, buried, collapsed or deteriorated, making them uninhabitable.
Housing affected	Number of houses with minor damage, not structural or architectural, that can continue being inhabited, even when they require repairs or cleaning.
Value of losses ($)	Amount of losses directly caused by the disaster in local currency
Value of losses (US$)	The equivalent in US$ of losses in local currency, using the exchange rate or local currency at the time of the disaster.
Hospital centres	Number of health centres, clinics, local and regional hospitals destroyed and directly or indirectly affected by the disaster.
Education centres	Number of daycare centres, primary schools, secondary schools, universities, training centres, etc. destroyed and directly or indirectly affected by the disaster. This includes those that have been used as temporary hotels.
Crops and forests (hectares)	Area of crops, grazing or forests destroyed and affected. If the information is expressed in other units of measure, they should be converted to hectares.
Livestock	Number of units lost (cows, pigs, goats, chickens) whatever the event (flooding, drought, epidemic, etc.).
Roads affected (metres)	Length of road networks destroyed or unusable (in metres).

4.2 Events with losses

For the effects of this report, the DesInventar records were submitted to a process of filtering, grouping together and amendment, in order to form a database on disasters that includes, in addition to the information already available, an estimate of the total value of losses associated with each event (which includes direct, indirect and macroeconomic effects of disasters, as well as providing that information in current US$). On that basis, a series of algorithms were developed for adjusting and preparing the database for processing the object of this analysis. Those algorithms are explained below.

4.2.1 *Algorithm for grouping events together*

Records in DesInventar are organized by municipality or another territorial unit. In other words, each event can have one or several records corresponding to damage observed in various municipalities, cities or regions. An algorithm was developed for analysing and unifying losses that can be considered to have been caused by the same event. For that grouping, the categories described in Table 4-3 are used.

Table 4-3
Categories

Category	Events included (as they appear in the database)	
Earthquake	Earthquake	Tsunami
Volcanic	Volcanic activity	
Landslide	Avalanche	Landslide
Hydro-meteorological	Deluge	Torrential flood
	Change in coastline	Hail
	Freezing	Hurricane
	Flooding	Rains
	High tide	Fog
	Blizzard	Heat wave
	Cold spell	Drought
	Storm	Electric storm
	Tornado	Heavy winds
Other events	Accident	Biological
	Change in coastline	Structural collapse
	Pollution	Epidemic
	Erosion	Escape
	Explosion	Famine
	Sinking	Fire
	Forest fire	Intoxication
	Shipwreck	Other
	Panic	Plague
	Rationing	Natural dams
	Sedimentation	

This algorithm makes it possible to define a series of parameters and criteria for grouping events together. The Table 4-4 shows the interval of time between records in order to consider them as having been produced by a single event.

Table 4-4
Interval between the triggering event and effects

Trigger	Category of the cause	Interval of time [days]
Earthquake	Earthquake	2
	Landslide	3
Hydro-meteorological	Hydro-meteorological	5
	Landslide	5
Landslide	Landslide	1
Volcanic	Volcanic	2
Other events	Other events	1

When two or more records are considered to be a single event, the various consequences recorded are grouped together and consolidated in the first record of that series.

4.2.2 *Algorithm for determining losses*

Information included in the database is used to produce an estimate of the total value of losses associated with each event resulting from the previous process. The model for evaluating losses takes into account the criteria established in the ECLAC *Manual for Assessment of the Socio-economic and Environmental Impact of Disasters* (2003). Annex 2 describes the criteria used and the results obtained for evaluating losses using data from DesInventar in Colombia, Mexico and Nepal. Table 4-5 summarizes the variables used in that evaluation, while Table 4-6 summarizes several of the parameters that a user can select in function of the physical and socio-economic conditions in the country or region that is being studied.

Table 4-5
Summary of elements used in evaluating losses

Houses and Urban Settlements			
Physical value	Value of contents	Indirect value	Macroeconomics
Drinking water and Sanitation			
Direct values		Indirect values	
Energy			
Direct values		Indirect values	
Telecommunications			
Direct values		Indirect values	
Transportation and Communications			
Direct values		Indirect values	

Table 4-6
Summary of parameters considered for evaluating losses

Sector	Parameter	Unit
Houses and urban settlements	Area of the typical house	m2
	Value per square metre	$
	Level of effect	per cent
	Per cent exposed (without land)	per cent
	Contents (furniture and equipment)	US$
	Demolition and removal of debris	$
	Vulnerability reduction	$
	Resettlement	$
	Temporary housing	$
	Rental housing	$
	Financial costs	$
	External sector effects	$
	Public sector effects	$
Public services (drinking water, energy and telecommunications)	Compromised infrastructure	$
	Decrease in production, increase in production costs and loss of income	$
Transportation and communications	Emergency repairs and cost of rehabilitating infrastructure	$
	Increased operating costs for vehicles	$

4.3 Steps for risk assessment

In order to carry out a retrospective risk analysis and the empirical construction of the first segment of the loss exceedance curve using DesInventar, the following steps have been carried out:

1. Selection of the DesInventar database;
2. General statistical analysis of that database;
3. Selection of the parameters for grouping together by event;
4. Unification of the effects through grouping together by event;
5. General statistical analysis by event;
6. Definition of parameters for loss assessment by event;
7. Calculation of losses by event;
8. Statistical analysis of losses by event;
9. Verification of results with events whose losses are recorded;
10. Tuning of the entire model for consistency and good estimates using existing information;
11. Classification of events by category;
12. Preparation of loss exceedance curves (number of events per year with losses greater or equal to each of the losses defined) for each type of event and for all events.

Figure 4-1 illustrates two segments of loss exceedance curves: one calculated following the previous steps (the one on the left) and the other through analytical evaluation (the one on the right), the calculation of which is explained further along.

Because the time covered by the database is very limited compared to that needed to record possible extreme losses, the segment of the curve obtained empirically with the DesInventar data shows an increase in the slope as a result of the lack of major events in the time covered by the database. In order to illustrate sensitivity to a lack of completeness of losses from major events of this segment of the loss exceedance curve, the figure shows how the segment “rises” as major hypothetical events that can happen and whose feasibility can be assessed using the probabilistic analytical technique described below are included in the database.

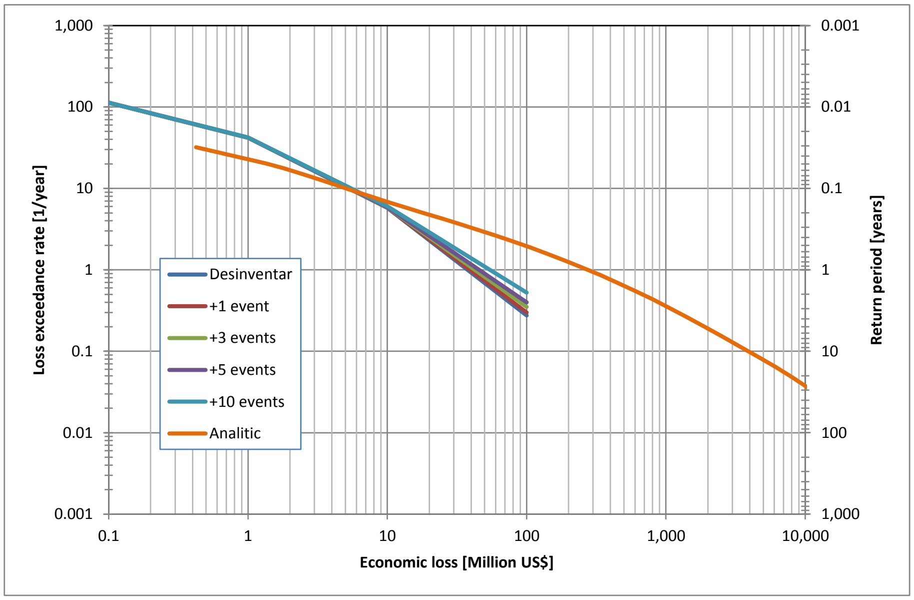


Figure 4-1
Effects of including large hypothetical events in the database

4.4 Results of empirical risk assessment

Three cases of study are included in this report Colombia, Mexico and Nepal; countries that have broad and refined DesInventar databases that make it possible to carry out the proposed analysis.

Annex 2 also presents interim results of the analysis made using the procedure for each country. The results presented below correspond to a summary of the results presented in that annex.

Table 4-7 summarizes the statistics of the DesInventar database for the countries, Colombia (since 1970 to 2009), Mexico (from 1980 to 2009) and Nepal (from 1971 to 2007), broken down by type of event after grouping events together.

Table 4-7
Summary of events grouped together

	Colombia		Mexico		Nepal	
Category	**No. of events**	**Cost [US$ millions]**	**No. of events**	**Cost [US$ millions]**	**No. of events**	**Cost [US$ millions]**
Landslides	2,401	711	442	1,707	1,173	173
Hydro-meteorological	5,565	10,449	3,608	66,499	3,207	1,506
Other events	2,771	771	4,228	6,533	2,837	10
Earthquakes	112	2,802	84	7,401	23	418
Volcanic activity	19	251	14	637	0	0
All events	10,868	14,983	8,376	82,778	7,240	2,109

Figure 4-2 to Figure 4-4 show the level of effects of the various phenomena within the countries studied.

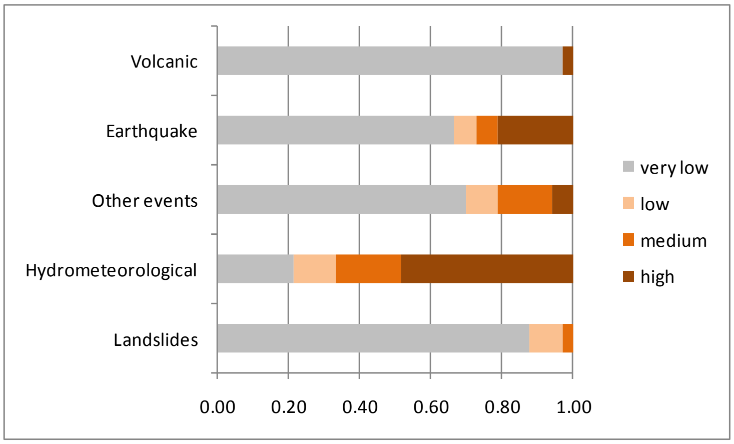


Figure 4-2
Effects of the phenomena in Colombia

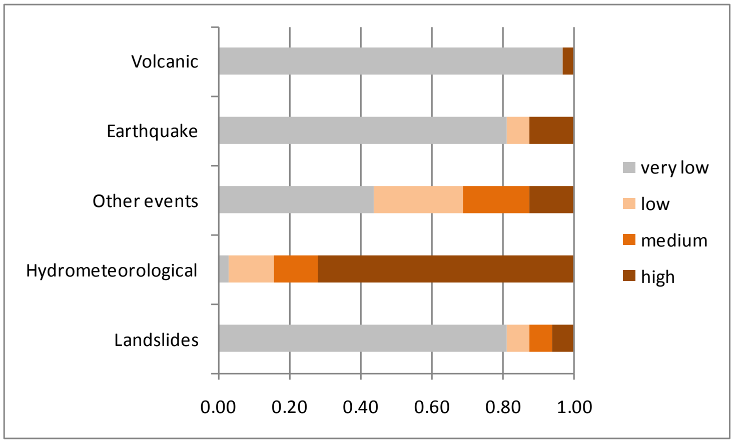


Figure 4-3
Effects of the phenomena in Mexico

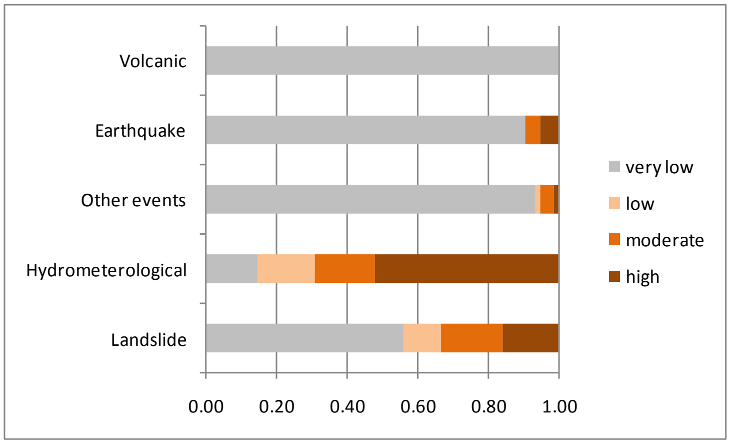


Figure 4-4
Effects of the phenomena in Nepal

Figure 4-5 to Figure 4-7 present diagrams of frequencies of the main variables available for the database of events grouped together.

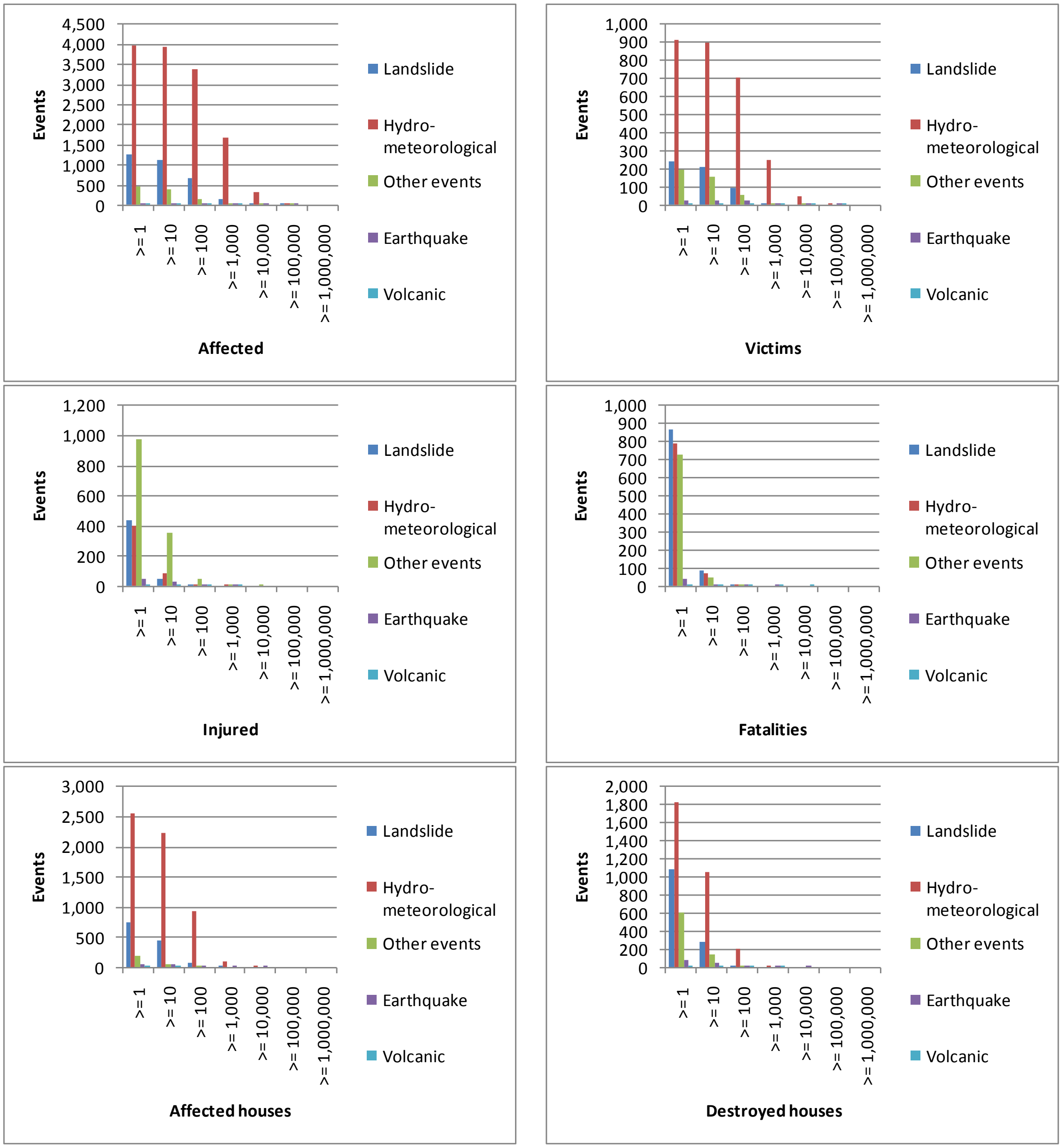


Figure 4-5
Frequency of events of the main variables in the database for Colombia

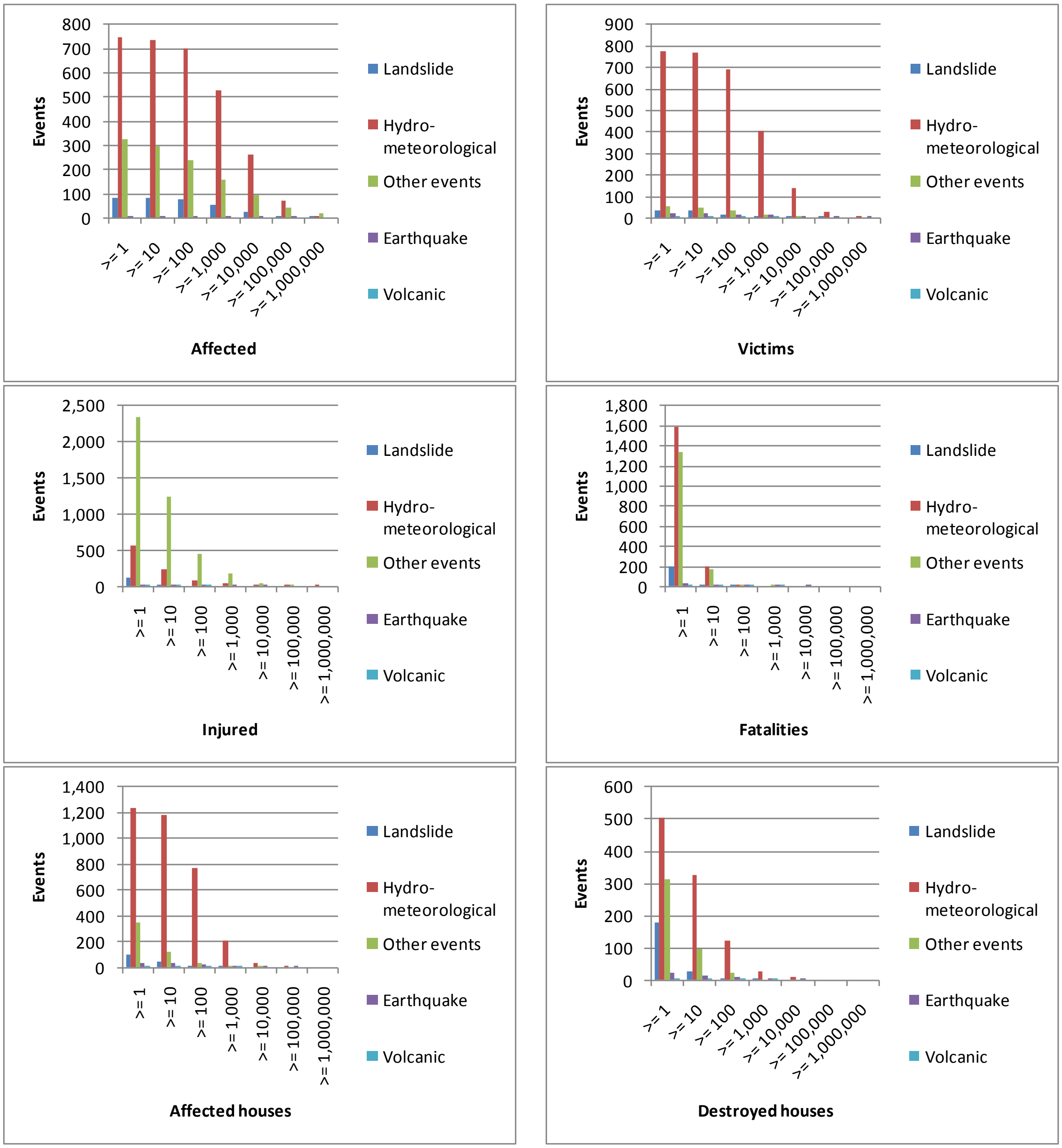


Figure 4-6
Frequency of events of the main variables in the database for Mexico

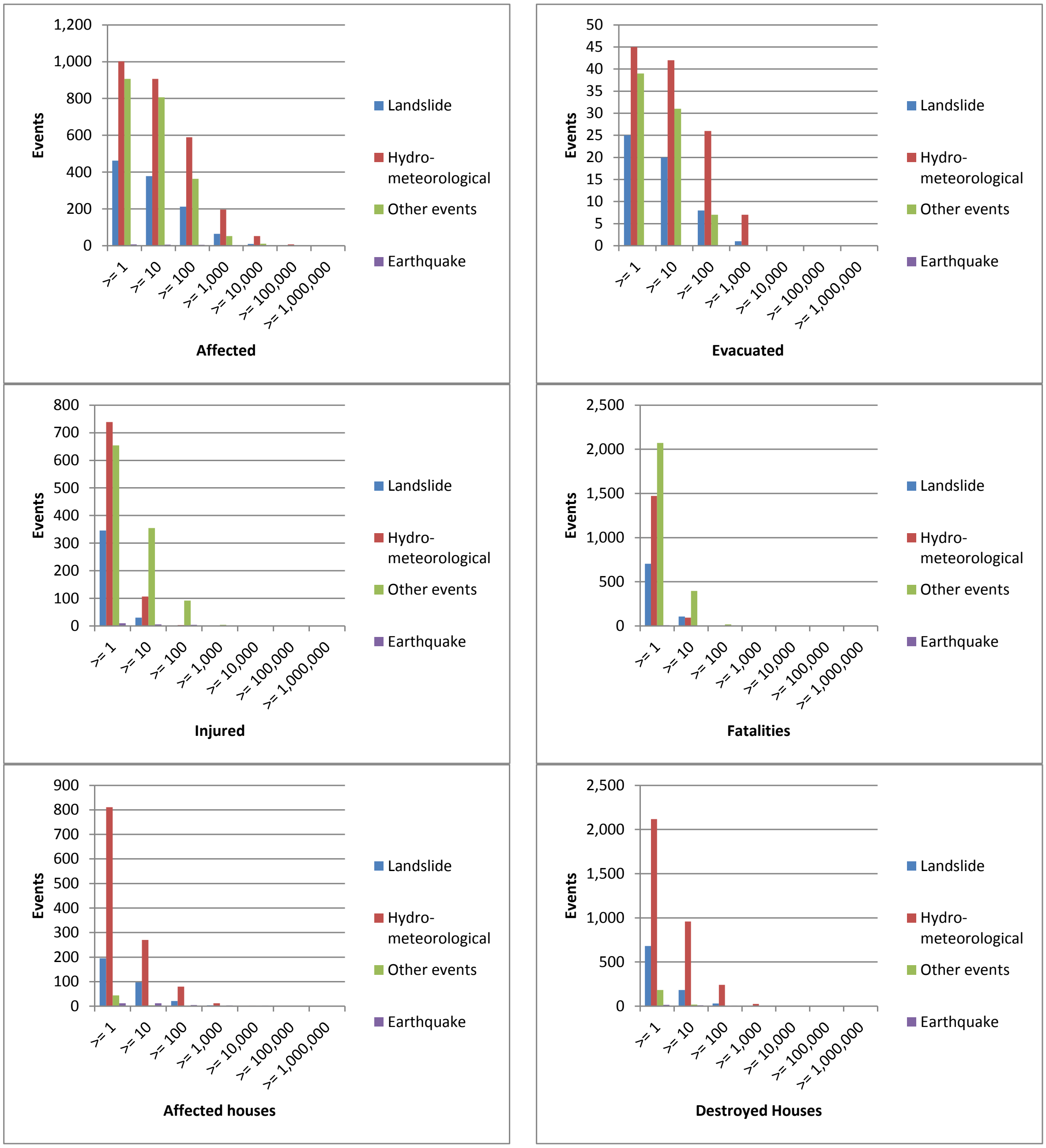


Figure 4-7
Frequency of events of the main variables in the database for Nepal

From Figure 4-8 to Figure 4-10 loss exceedance curves for each of the countries is presented, broken down by type of event and by the total number of events.

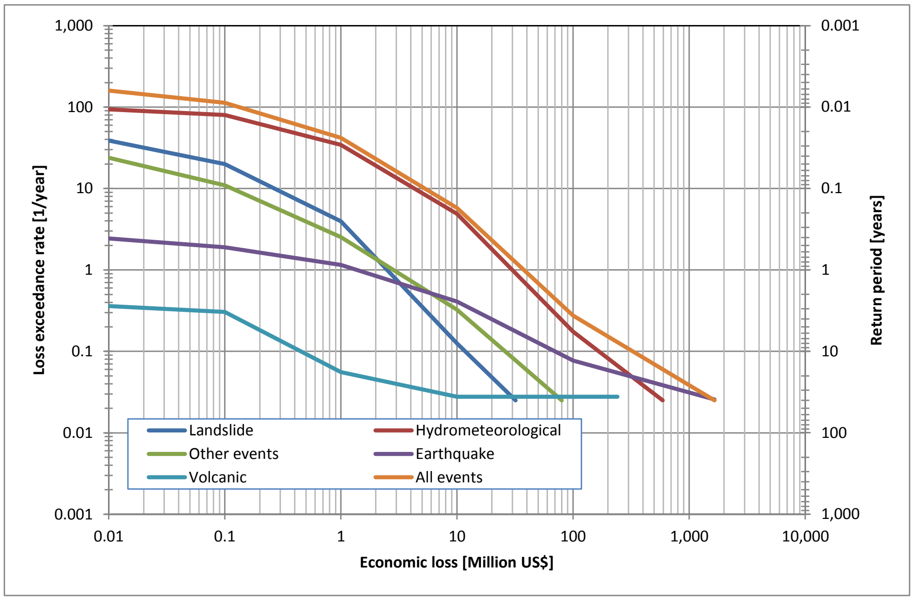


Figure 4-8
Economic losses by type of phenomena for Colombia

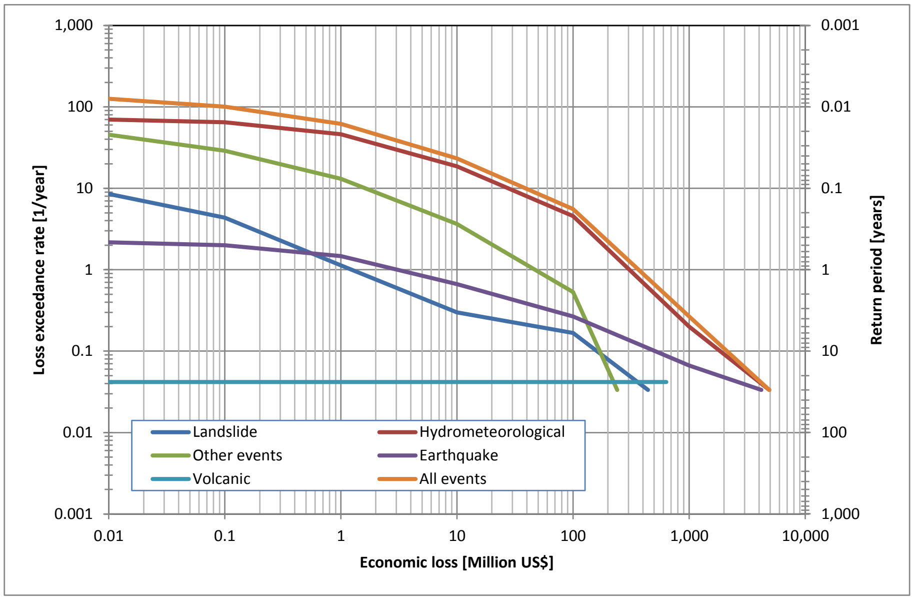


Figure 4-9
Economic losses by types of phenomena for Mexico

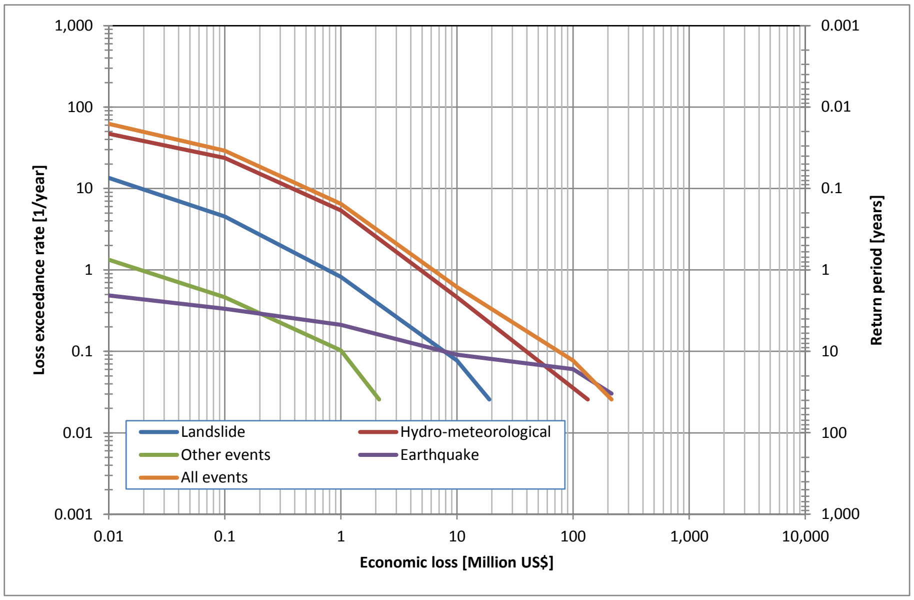


Figure 4-10
Economic losses by types of phenomena for Nepal

The economic loss exceedance curves using the DesInventar database in the case of Colombia show that losses caused by hydro-meteorological events (based on a retrospective evaluation) have been equal or greater than US$ 1 million at least 50 times per year, more than US$ 7 million at least 10 times per year, more than US$ 30 million at least once per year and more than US$ 100 million at least once every six years. Including all events, it can be said that losses have occurred equal to or greater than US$ 1 million at least 70 times per year, US$ 10 million at least 10 times per year, US$ 50 million once per year and US$ 1 billion at least once every 25 years.

In Mexico, economic loss exceedance curves using the DesInventar database indicate that losses caused by hydro-meteorological events have occurred equal to or greater than US$ 1 million at least 50 times per year, US$ 15 million at least 10 times per year, US$ 300 million at least once a year and US$ 1 billion at least once every six years. Taking into account all events, it can be said that losses equal to or greater than US$ 1 million have occurred at least 80 times per year, US$ 35 million at least 10 times per year, US$ 400 million once per year and US$ 1 billion at least once every three years.

Nepal show losses caused by hydro-meteorological events have been equal or greater than US$ 1 million at least 5 times per year, more than US$ 10 million at least once every 2 years and more than US$ 100 million at least once every 39 years. Including all events, it can be said that losses have occurred equal to or greater than US$ 1 million at least 6 times per year, US$ 10 million at least twice every three years and US$ 100 million at least once every 13 years.

The former obviously in the case of “someone” pays, which would mean to replace, repair or compensate the losses suffered. In any case, this type of assessment would make it possible to establish before anything else, as will be seen farther along, the order of magnitude of the resources that the government must spend every year (in a reserve fund, for example) to meet its fiscal responsibility (this under the supposition not far from the reality that the private parties affected have been the most disadvantaged persons in society). These losses correspond, in general, to losses that would not be covered by catastrophic risk insurance contracted by the government, if it had them; given that they correspond approximately to what deductible would be. Thus, those would be the losses that the governments should try to reduce through prevention-mitigation activities, except that its decision would be to assume them (pay them with its own resources every time that they occur), for example, through a reserve or disaster fund. In reality, governments currently do neither the one nor the other with adequate coverage, what they do is minimal if comparison is made between added disbursements that have been made from funds and the losses.

Likewise, curves that illustrate the effects on the population in terms of wounded and deaths for the various categories used in the case studies can be obtained. It should be noted that in this section the contribution of "other events" has been eliminated, because the present values (specifically in the database for Mexico) are off the scale that permits making comparisons and later analysis of the positive impact of the mitigation and prevention measures.[3]

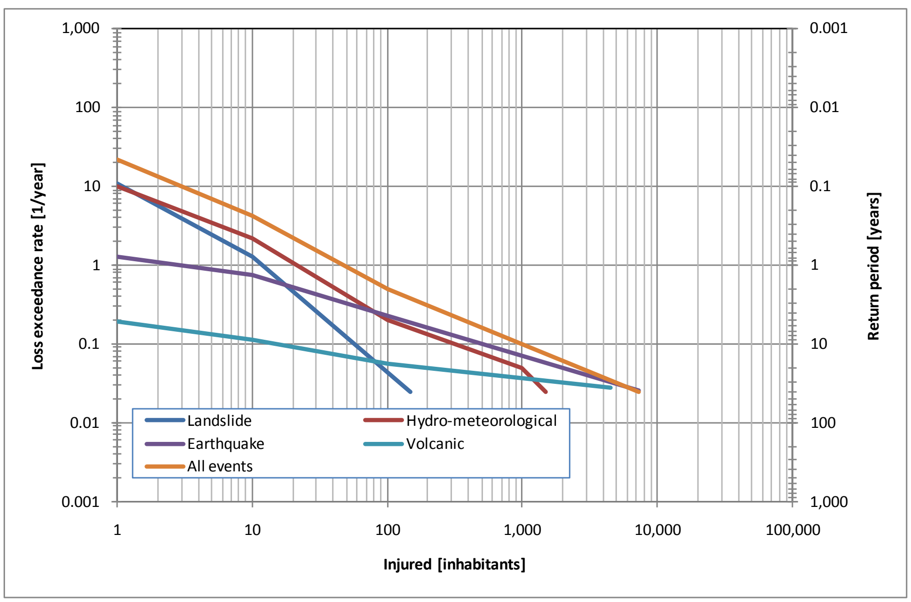


Figure 4-11
Recurrence of injured by type of event for Colombia

[3] The cost of prevention and mitigation measures in this case (for epidemics, plagues, technological or industrial events and fires, among others) cannot be estimated in a simplified way, and they were not taken into account for the cost-benefit analysis carried out later,.

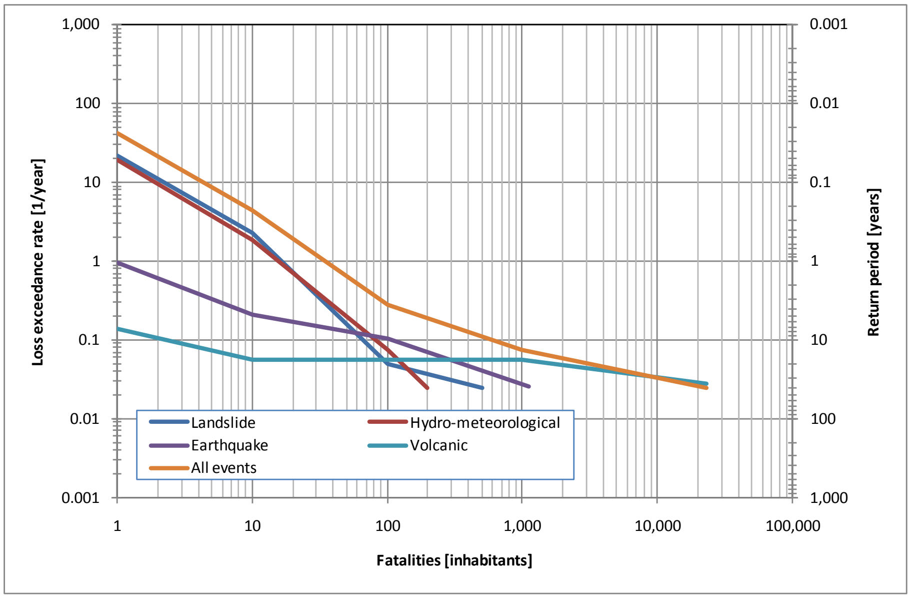


Figure 4-12
Recurrence of deaths by type of event for Colombia

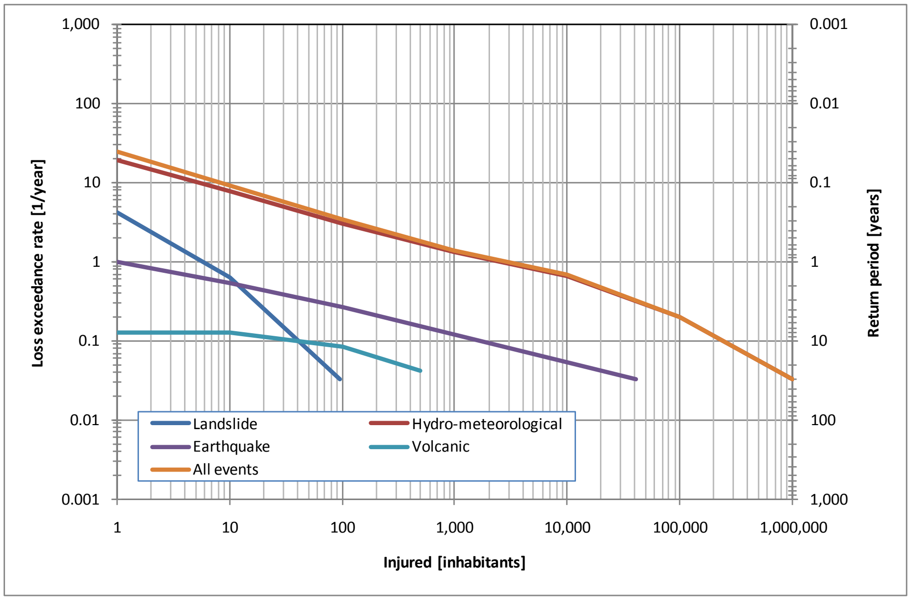


Figure 4-13
Recurrence of injured by type of event for Mexico

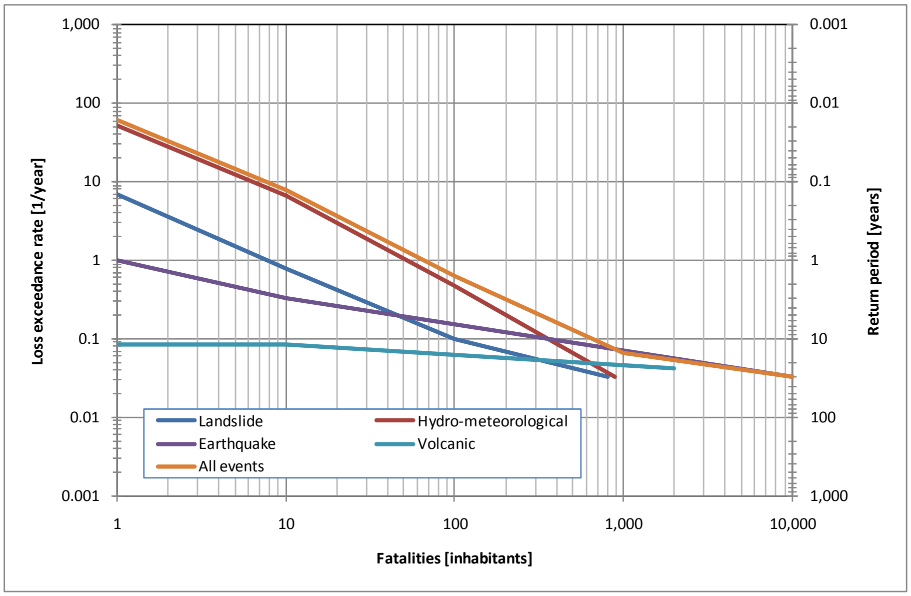


Figure 4-14
Recurrence of deaths by type of event for Mexico

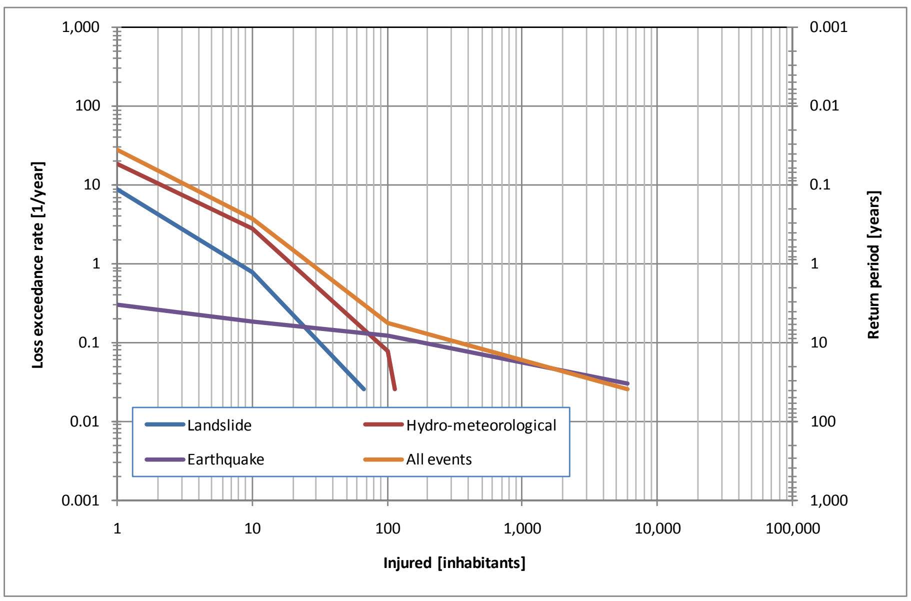


Figure 4-15
Recurrence of injured by type of event for Nepal

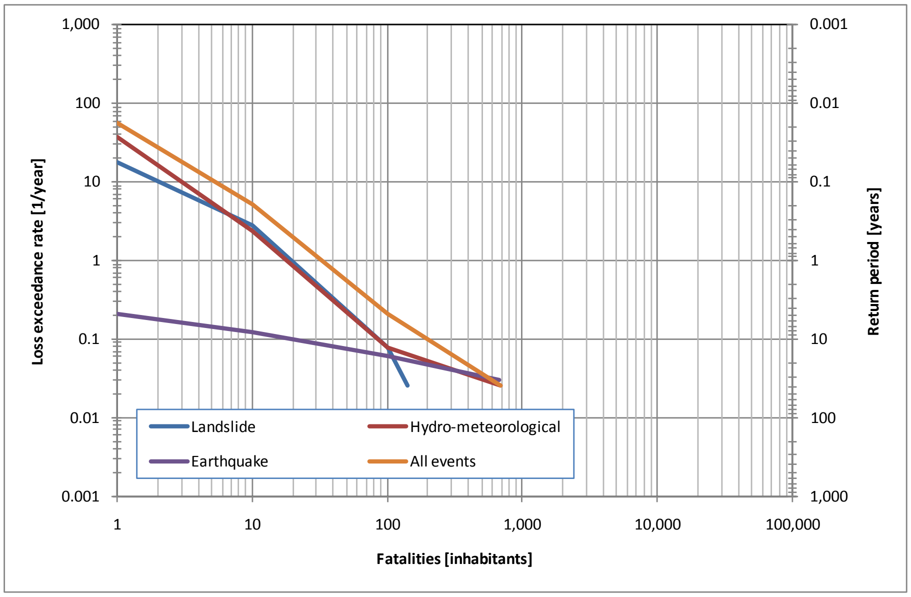


Figure 4-16
Recurrence of fatalities by type of event for Nepal

The loss exceedance curves of wounded and deaths using the DesInventar database in the case of Colombia show that at least one event has occurred annually with more than 45 wounded and 40 deaths (it is not necessarily caused by the same event), one event with more than 1,000 wounded every 10 years and one event with more than 10,000 deaths every 40 years. For the case of Mexico, the loss exceedance curves of wounded and deaths indicate that at least one event has occurred annually with more than 2,000 wounded and 70 deaths (it is not necessarily caused by the same event) and one event with more than 10,000 wounded and 10,000 deaths at least once every 40 years (it is not necessarily caused by the same event). Finally, Nepal shows at least one event per year with 25 injured and 30 fatalities (no has to be the same) and at least once every 20 years with 1,000 injured and 400 fatalities (it is not necessarily caused by the same event).

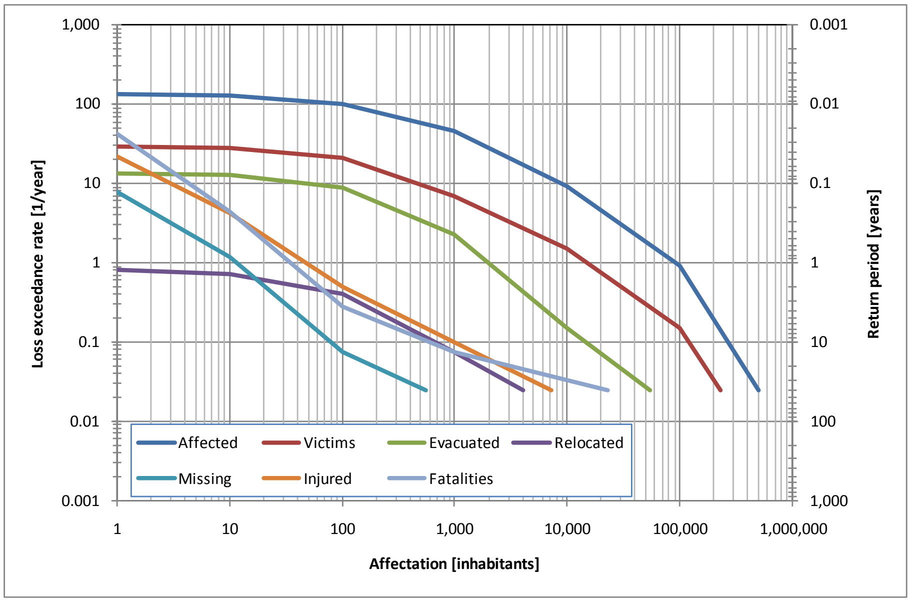


Figure 4-17
Recurrence of affected people for all events in Colombia

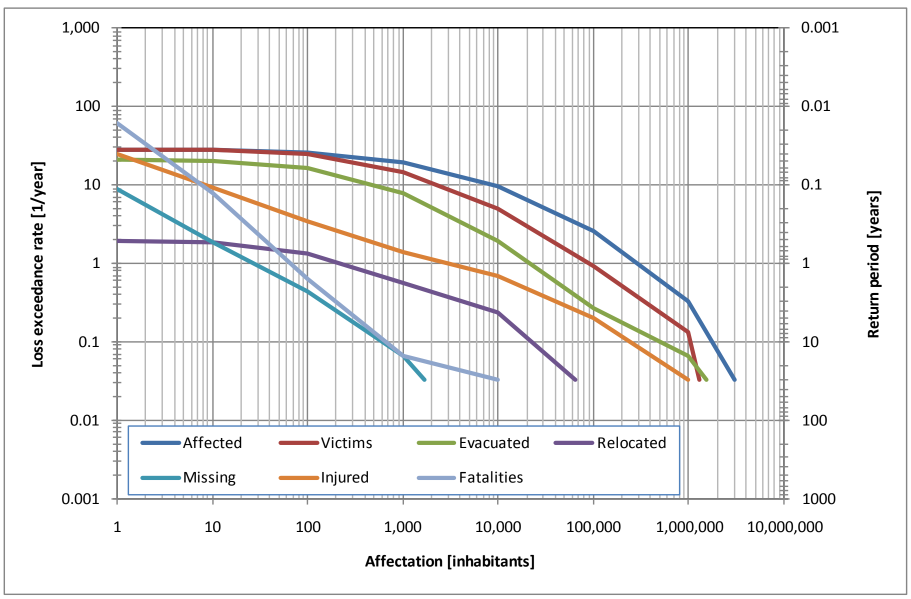


Figure 4-18
Recurrence of affected people for all events in Mexico

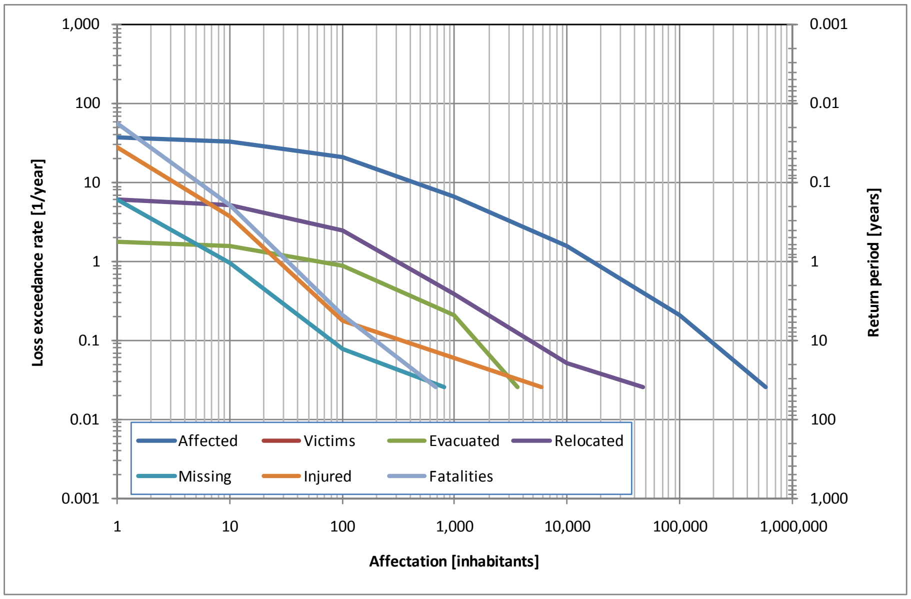


Figure 4-19
Recurrence of affected people for all events in Nepal

For the case of Colombia, loss exceedance curves of effects on the population indicate that at least one event has occurred annually with more than 40 deaths, 45 injured, 2,300 evacuated, 15,000 victims and 100,000 affected, not necessarily simultaneously. For the case of Mexico, an event has occurred at least once a year with more than 70 deaths, 2,000 injured, 200 displaced, 20,000 evacuated, 90,000 victims and 400,000 affected, without those effects having necessarily occurring in the same event. And for Nepal, events with 10 missing, 25 injured, 30 fatalities, 60 evacuated, 300 relocated and 16,000 affected happens at least every year (no has to happen in the same events).

From Table 4-8 through Table 4-13 are present values by year and for period of losses and effects that have occurred in Colombia (period of 4 years, the equivalent of a period of government), Mexico (period of 6 years, the equivalent of a period of government) and Nepal (period of 5 years).

Table 4-8
Value of losses per event in Colombia for a return period of one year

Phenomena	Affected [persons]	Evacuated [persons]	Victims [persons]	Injured [persons]	Deaths [persons]	Losses [US$]
Landslides	6,250	220	270	11	16	2,848,800
Hydro-meteorological	71,250	1,920	14,000	20	16	32,936,000
Other events	3,500	0	150	127	12	3,542,000
Earthquakes	10	0	0	3	1	1,716,000
Volcanic eruptions	0	0	0	0	0	0
All events[4]	100,000	2,350	15,240	175	40	36,972,000

[4] In the category "all events" are not included events from the category "other events". The values expressed in "all events" do not correspond to the sum of the other categories but to the results of the loss curve for all events.

Table 4-9
Value of losses per event in Colombia for a return period of four years

Phenomenon	Affected [persons]	Evacuated [persons]	Victims [persons]	Injured [persons]	Deaths [persons]	Losses [US$]
Landslides	40,000	900	1,360	31	51	7,894,800
Hydro-meteorological	270,000	5,000	40,000	86	40	77,377,600
Other events	35,000	62	864	894	33	16,000,000
Earthquakes	1,800	0	1,866	94	8	35,404,200
Volcanic eruptions	0	0	0	0	0	242,000
All events	300,000	5,000	55,496	1,120	197	129,578,000

Table 4-10
Value of losses per event in Mexico for return periods of one year

Phenomenon	Affected [persons]	Evacuated [persons]	Victims [persons]	Injured [persons]	Deaths [persons]	Losses [US$]
Landslides	6,000	140	18	5	6	1,200,000
Hydro-meteorological	300,000	16,000	88,380	2,000	53	400,000,000
Other events	300,000	5,000	250	15,000	50	60,000,000
Earthquakes	0	0	0	1	1	3,600,000
Volcanic eruptions	0	0	0	0	0	0
All events	800,000	21,000	91,610	23,000	101	439,296,000

Table 4-11
Values of losses per event in Mexico for return periods of six years

Phenomenon	Affected [persons]	Evacuated [persons]	Victims [persons]	Injured [persons]	Deaths [persons]	Losses [US$]
Landslides	60,000	800	1,600	28	60	118,809,600
Hydro-meteorological	1,544,481	120,000	500,550	200,000	193	1,450,000,000
Other events	5,000,000	21,000	3,500	135,000	153	168,000,000
Earthquakes	242	160	15,000	170	50	251,340,000
Volcanic eruptions	0	1,000	0	0	0	0
All events	5,000,000	120,000	510,000	400,000	800	1,474,088,000

Table 4-12
Value of losses per event in Nepal for a return period of one year

Phenomena	Affected [persons]	Evacuated [persons]	Victims [persons]	Injured [persons]	Deaths [persons]	Losses [US$]
Landslides	1,965	1	0	8	22	667,500
Hydro-meteorological	14,694	22	0	20	18	4,972,500
Other events	1,047	2	0	255	69	22,500
Earthquakes	0	0	0	0	0	0
Volcanic eruptions	0	0	0	0	0	0
All events[5]	25,004	104	0	270	79	7,023,000

[5] In the category "all events" are not included events from the category "other events". The values expressed in "all events" do not correspond to the sum of the other categories but to the results of the loss curve for all events.

Table 4-13
Value of losses per event in Nepal for a return period of five years

Phenomenon	Affected [persons]	Evacuated [persons]	Victims [persons]	Injured [persons]	Deaths [persons]	Losses [US$]
Landslides	14,353	100	0	25	59	3,688,500
Hydro-meteorological	80,081	500	0	51	45	31,026,000
Other events	30,000	93	0	517	143	300,000
Earthquakes	1	0	0	2	1	405,000
Volcanic eruptions	0	0	0	0	0	0
All events	200,000	1,000	0	559	198	59,190,000

From Figure 4-20 to Figure 4-22 the historical losses (in current dollars) are illustrated, in terms of accumulated, maximum and average value during recent periods every four years for Colombia (the equivalent of a period of government), every six years for Mexico (the equivalent of a period of government) and every five years for Nepal, which if the gradual increase continue, it could be expected that in the next periods the situation will continue to worsen.

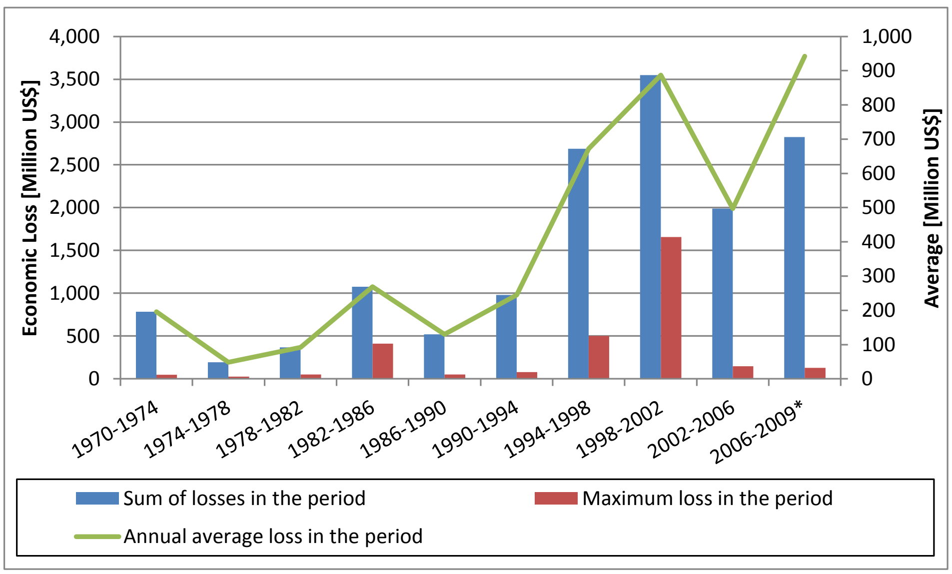


Figure 4-20
Economic losses per presidential period for Colombia

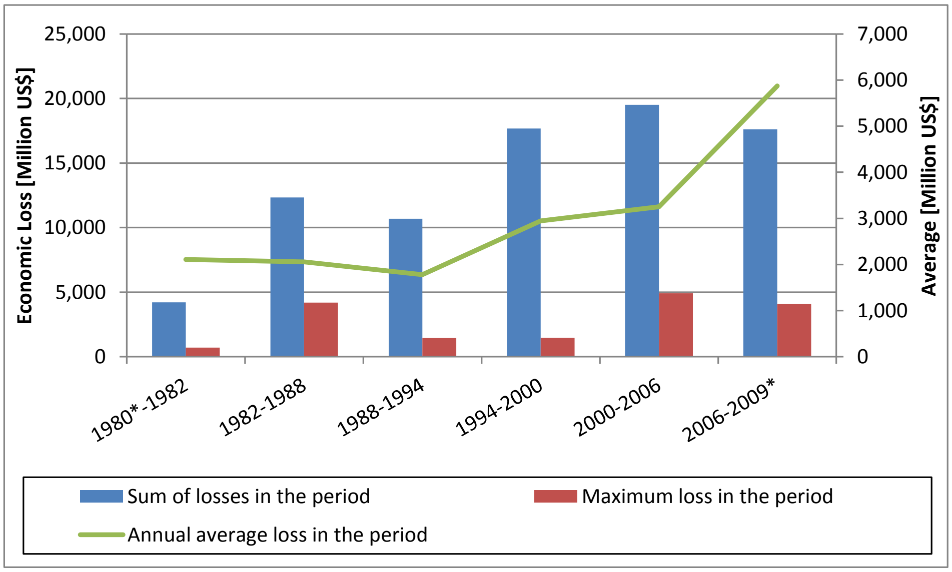


Figure 4-21
Economic losses per presidential period for Mexico

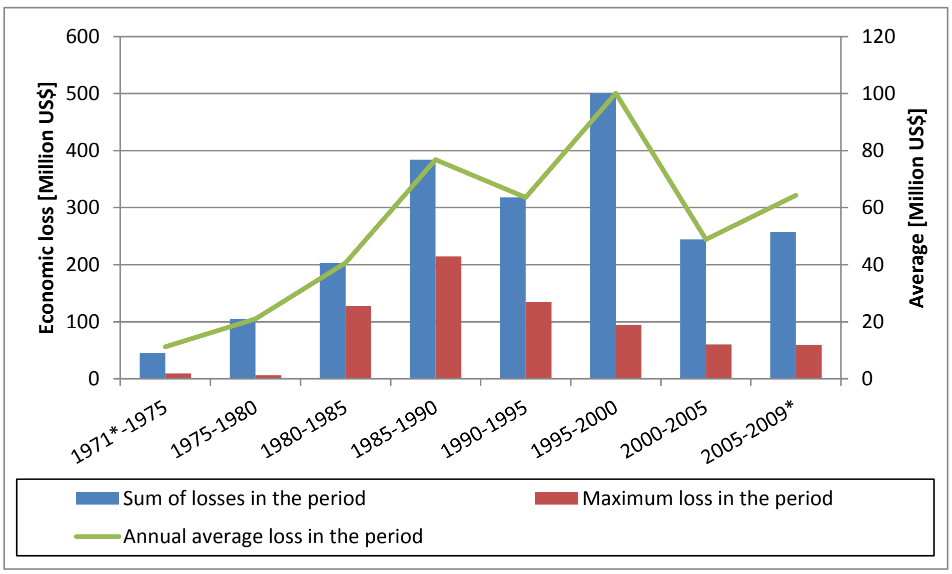


Figure 4-22
Economic losses per period of 5 years for Nepal

Figure 4-23 to Figure 4-25 shows adjusted estimated losses in each period, using purchasing power parity (PPP), which is based on the acquisitive capacity of a basket of basic goods, with which the economic and market effects would be taken into account.

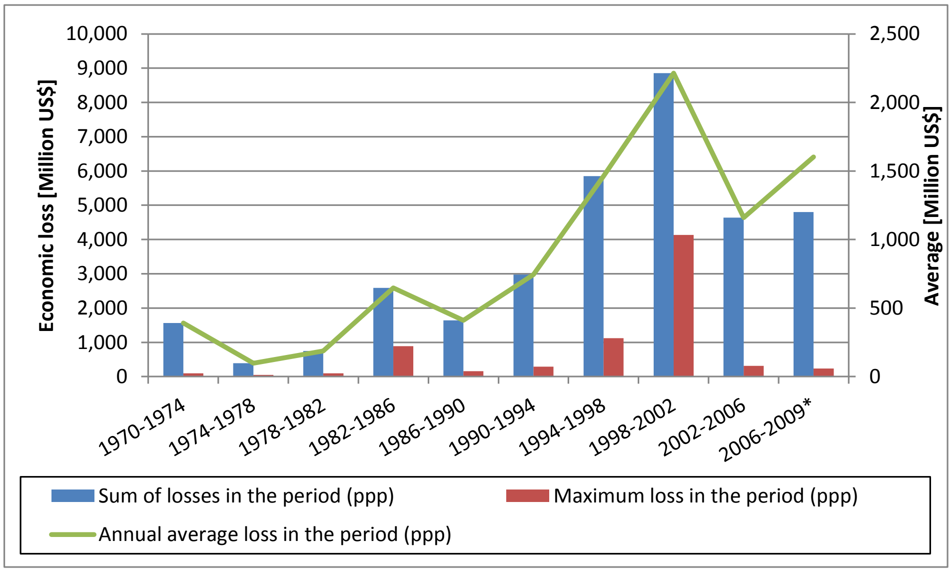


Figure 4-23
Economic losses (PPP) per presidential period for Colombia

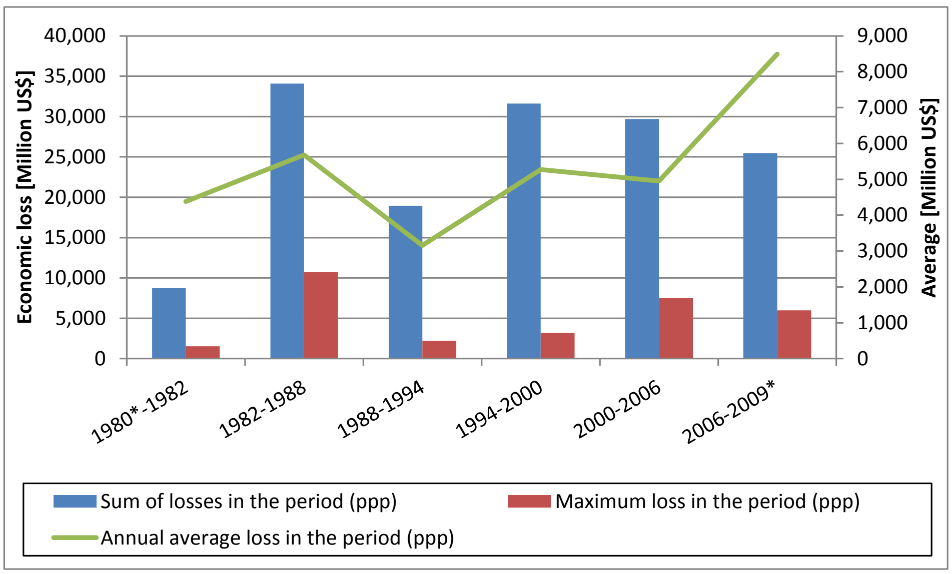


Figure 4-24
Economic losses (PPP) per presidential period for Mexico

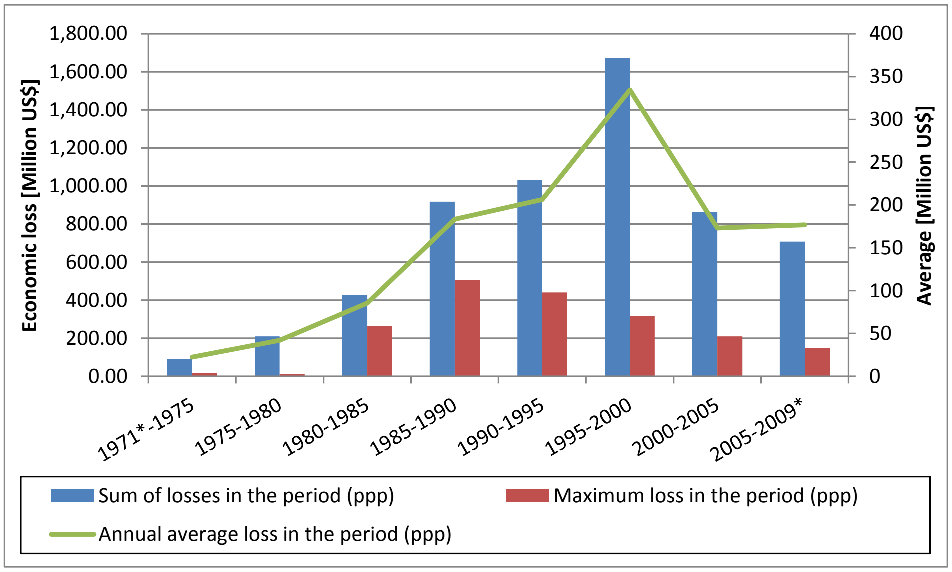


Figure 4-25
Economic losses (PPP) per 5 years period for Nepal

The above figures are significant and indicate that the social effects of disasters have been very high. This confirms the importance of implementing preventive activities and reducing risk in these countries within the framework of their economic and social development plans. Only in that way would be possible to avoid that these figures continue or increase as a result of the existing vulnerability or its increase, in particular, vulnerability of the low-income socio-economic strata, which are those that have been primarily affected according to the information from DesInventar database. It must be mentioned that given any increase in the occurrence and intensity of natural phenomena, such as that caused by climate change, the situation would be worse, owing to the existing degree of vulnerability and in several cases that are increasing, according to the results of the Prevalent Vulnerability Index. (See the programme of indicators of risk and risk management for the Americas (http://idea.unalmzl.edu.co).

5 Prospective risk assessment

5.1 Introduction

In general, it should be recognized that limited historical information is available (in most cases just several decades) about disasters and in particular catastrophic events, that can even not yet have happened. For this reason, it is impossible to predict the future consequences from extreme events based on the information available on effects. In other words, a database such as DesInventar is insufficient to record the occurrence of low frequency disasters and high consequences, because the window of opportunity covered for disasters that have occurred is very short.

Considering the possibility that highly destructive future events might occur, risk estimates must focus on using probabilistic analytical models that make it possible to use available information to predict possible catastrophic scenarios in which a high uncertainty involved in the analysis is taken into account. As a result, risk assessment must also follow a prospective approach, anticipating events of occurrence and scientifically possible consequences that can occur in the future, considering the great uncertainties associated with the assessment of severity and frequency. Figure 5-1 presents the general scheme of the probabilistic model for assessing risk and several of the possible direct applications that are derived from them at various scales.

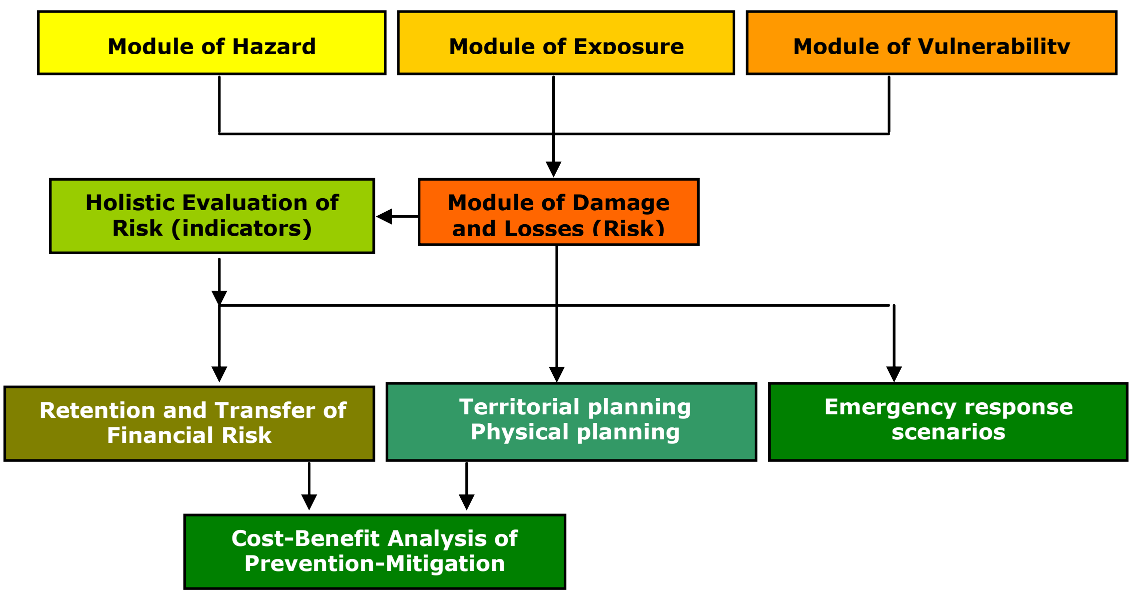


Figure 5-1
Probabilistic risk model and several applications

5.2 Hazard assessment

The identification and assessment of hazards that can affect a specific region constitutes a step prior to risk analysis and, therefore, it is a step of high relevance for that analysis. Knowledge about the occurrence of dangerous events and the characteristics of historically important events, provide an initial idea of the destructive potential of the phenomena that can represent a hazard for the region and makes it possible to establish the approximate return periods of the most significant intensity events. A summary of the methodology used for calculating the seismic hazard is included for the case of Colombia in the Annex 3, for Mexico in the Annex 4 and for Nepal Annex 8. Annex 5 presents a summary of the methodology used to assess the hazard of hurricane winds in Mexico. These assessment models correspond to models for hazard assessment used by the ERN-CAPRA system and are available at www.ecapra.org.

The hazard associated with a natural phenomenon is measured using frequency of occurrence and severity of events, characterized using some parameter of intensity of the danger at a specific geographical location. Hazard assessment is based on historical frequency of events with their various degrees of intensity. Once the parameters that characterize the occurrence of the phenomena from the technical and scientific point of view are defined, it is necessary to create a set of stochastic events—through the simulation of a series of random events, which analytically define the frequency and severity of the dangerous phenomenon, thus representing the hazard or probability of occurrence of events in the region studied.

Progress in development and presentation of the geographical and georeferenced information facilitate hazard analysis for recurrent events. The spatial distribution of intensities associated with adverse natural phenomena is a fundamental input for later assessment of risk. Management of this type of information through layers in raster[6] format makes it possible to render automatic processes of calculating risk, as well as a simple and convenient communication of the results. A series of probabilistic analytical models can be developed for the main natural phenomena of interest, such as earthquakes, tsunami, hurricanes, floods and landslides. In addition and given that each of these natural phenomena produce different types of associated events, the events that can produce losses are given in Table 5-1.

[6] A data structure represented through a rectangular grid of pixels or cells, each with a value.

Table 5-1
Modules of threat and parameters of intensity

Threat	Effect	Parameter of Intensity
Earthquake	Landslides	Acceleration, velocity and maximum land movement, and spectral values for various structural periods
Earthquake	Tsunami	Depth and area of flooding
Hurricane	Hurricane force winds	Distribution of peak wind velocities for gusts of 3 seconds
Hurricane	Storm surge	Depth and area of flooding
Flooding	Flooding	Depth and extension of the area of flooding

The hazard is characterized in each point of a territory by the expected value of the parameter of intensity that is considered appropriate, and by metrics of its dispersion, which shows the uncertainty associated with the occurrence of that value of the phenomenon's severity. It is important to point out that for the study of risk of catastrophic events it is relevant to study those cases of phenomena that can cause correlation of losses, in other words, simultaneous damage over a wide area. Usually, the phenomena that can create this situation are earthquakes and hurricanes. Landslides, flooding, tsunami and other events that cause serious damage over relatively small areas do not influence the maximum probable losses for a relatively large area, when the occurrence of earthquakes and hurricanes of great intensity in that area can be expected. This is the situation in the case studies of Colombia, Mexico and Nepal where earthquakes are highly relevant in all cases and hurricanes in the second.

The assessment of hazards for the case studies included in this report (see Annexes) allowed obtaining the loss exceedance curve of probability of the intensity both seismic as well as hurricane-force winds at each point of the country, which makes it possible to estimate demand or action of each phenomenon on exposed elements with events that can occur with various rates of occurrence; or which is the same, with different return periods. In that sense, the probabilistic hazard assessment permits development for each country of the following:

a. Maps at national level of seismic hazard in terms of peak ground acceleration for various return periods.

b. Maps at national level of hazard of hurricane winds in terms of maximum velocity of wind for various return periods.

This basic input for establishing a catastrophic risk profile from the probabilistic point of view of each country was evaluated with the ERN-CAPRA system developed by the consultant group for the World Bank, the Inter-American Development Bank and UN-ISDR.

5.3 Characterization of exposure

Exposure refers primarily to infrastructure components or to the population exposed that can be affected by a specific event. In order to characterize the exposure, it is necessary to identify the different individual components including their geographical location, their geometrical, physical and engineering main characteristics, their vulnerability to a dangerous event, their economic evaluation and the level of the possible human occupation in a specific scenario of analysis. The exposure values of goods at risk are normally estimated using sources of secondary information such as existing databases, or can be derived through simplified procedures based on general social and macroeconomic information, such as population density, construction statistics or more specific particular. Simplified models of exposure are used when specific information asset by asset is not available. Based on available information, a georeferenced database of exposure is created, in which all the specific information required for the study is included. Additional parameters with a high level of detail can be included, which contributes to improve the general reliability of the results. Special algorithms are used for visualizing the information contained in the database and for calculating indexes of general interpretation.

In certain specific cases, tools are used to gather information from satellite images or aerial photographs. These tools permit configuration of georeferenced databases with several basic characteristics, such as construction type, area, and number of floors or height of the component, which can then be complemented with statistics of the area of interest, with previous zoning of the construction types in the city or through information of local specialists in each case.

Characterization of the exposure at the global level is made using approximate models based on population distribution of 30-inch pixels, using what is available in databases of world population such as LandScan or SEDAC. This population distribution is used to generate a base of buildings exposure in the main cities of the areas under study. In addition, the information available from censuses and statistics of the various countries are used to categorize infrastructure in terms of types of construction, for which additional socio-economic information is used.

In addition to including in the model of exposure the buildings in the important cities in each country, other physical assets of special importance such as main infrastructure are also included in the exposure, taking into account a series of assumptions when aggregation is made from a local to a national scale. In general, the exposure model includes information about the following exposed components or elements:

a. Buildings in the main cities;
b. Important industrial installations;
c. Roads and bridges;
d. Electricity systems, including generation, substations and transmission;
e. Communications systems;
f. Important distribution systems;
g. Relevant infrastructure.

From this, a database that includes information related to the type of asset, its location and its approximate value is constructed.

Once the evaluation of each individual component of infrastructure is completed, verification of the values at risk based on general economic indicators must be made, for which indicators and values per capita or standardized with the GDP of the country or region, the capital stock, general evaluation of infrastructure for insurance, among others are used

Evaluation includes both the value of the property (main structural and non-structural elements) and the evaluation of contents susceptible to damage. For example, in the case of flooding the damage is usually associated with the contents and a portion of the structure that requires repair and maintenance after the disaster has occurred.

In order to estimate the effects on local inhabitants, an occupation is assigned to each of the components of the constructed exposure database The maximum occupation and the percentage of occupation at different times of the day are defined in order to analyse different situations of occupation, such as can be a typical daytime or night-time occupation. When no specific information is available on occupation the approximate density of occupation determined by construction type can be taken and used to project depending on its proportion in the portfolio of exposed elements in the area. This information and the distribution of areas of construction are calibrated using the original statistics of population distribution and information available from censuses.

For the analysis of the three case studies, Colombia, Mexico and Nepal, models of exposure have been prepared for the entire infrastructure at the country level. These exposure models, which are included in the annexes, describes the methodology, type and characteristics of the elements of infrastructure included and a summary of the values assigned by type of infrastructure; with a geographical resolution at department, state or district level. The tables and figures presented below are extracted from this information. .

Table 5-2 through Table 5-5 summarize the basic information of the exposure model for Colombia.

Table 5-2
Indicators and general parameters

Indicator	Unit	Value
Total population	Inhab	42,780,672
Urban population	Inhab	32,502,730
Rural population	Inhab	10,277,942
Minimum wage	US$	265
GDP (2008)	US$ Billion	328
GDP per capita (2008)	US$	7,400

Table 5-3
Areas and densities of construction

Constructions	Unit	Value	Unit	Value per capita
Urban built area	m^2	887,527 x10³	m^2/Inhab	20.7
Density of urban constructions	m^2/m^2 urban lands	0.44		-

Table 5-4
Economic evaluation of infrastructure

Infrastructure	Economic value [Million US$]	Economic value per capita [US$/Inhab]	Economic value per capita / GDP per capita	Relative share
Urban constructions	476,683	11,142	1.51	75.3%
Rural constructions	49,848	1,165	0.16	7.9%
Urban infrastructure	14,343	335	0.05	2.3%
National infrastructure	91,761	2,145	0.29	14.5%
Total Infrastructure of the country	**632,634**	**14,788**	**1.10**	**100.0%**
Government responsibility (fiscal)	173,210	4,049	0.55	27.4%

Table 5-5
Built area and economic evaluation of urban construction

Use group	Construction area [m^2x10^3]	Economic value [USx10^6$]	Construction area / population from use group	
			Unit	Value
Residential LP	81,123	17,259	m^2/Inhab LP	4.1
Residential MP	297,168	172,987	m^2/Inhab MP	13.7
Residential HP	27,700	25,572	m^2/Inhab HP	23.5
Commercial	234,469	129,370	m^2/WF	20.0
Industry	129,840	114,624	m^2/WF	50.0
Private Health	263	269	m^2/1000 Inhab	6.1
Private Education	27,844	16,603	m^2/Stud	2.2
Public Health	232	181	m^2/1000 Inhab	5.4
Public Education	84,111	47,031	m^2/Stud	6.8
Government	4,776.6	2,636	m^2/PE	5.0
Total	**887,527**	**526,531**	**m2/Urban Pop**	**27.3**

LP: Low-income population; MP: Medium-income population; HP: High-income population

Figure 5-2 through Figure 5-8 illustrate the main characteristics of the model of exposure developed for Colombia.

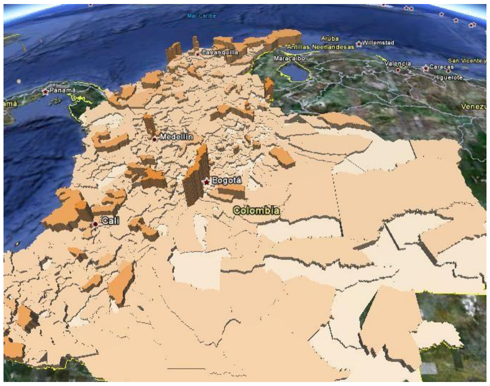


Figure 5-2 Distribution of rural population

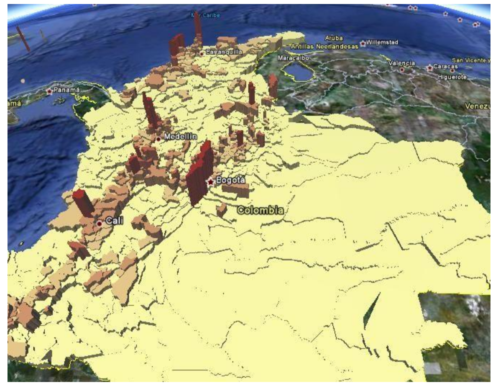


Figure 5-3 Population density

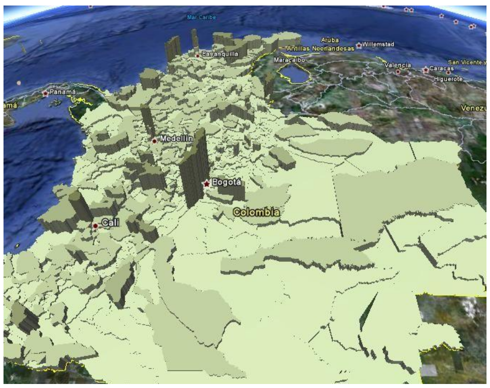


Figure 5-4 Distribution of exposed value of constructions

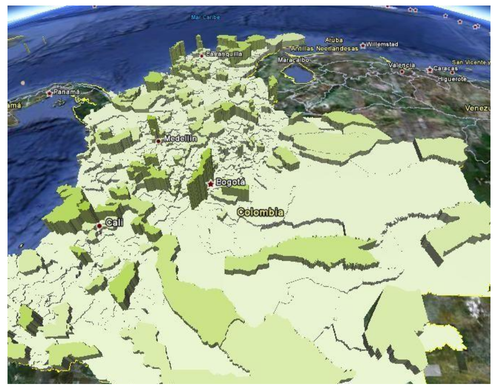


Figure 5-5 Distribution of exposed value of urban infrastructure

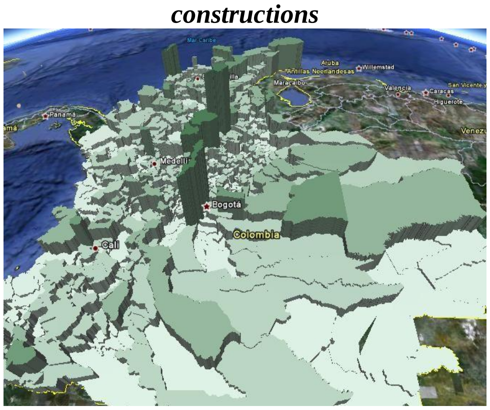


Figure 5-6 Distribution of exposed value of national infrastructure

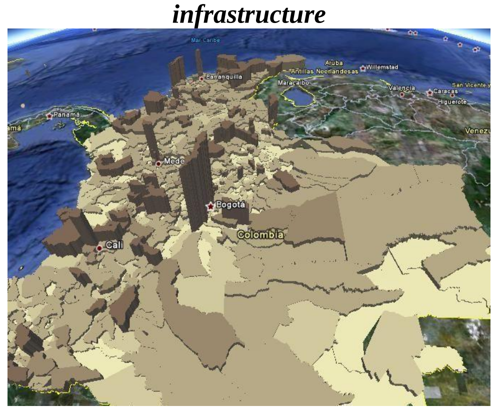


Figure 5-7 Distribution of exposed value of total physical components

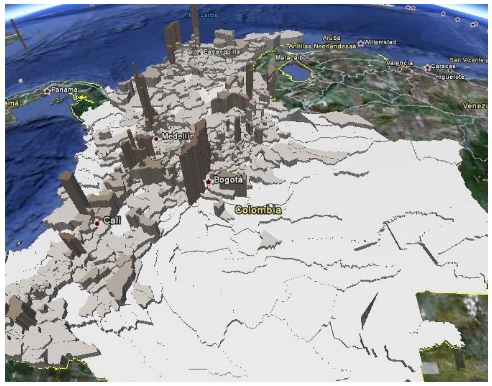


Figure 5-8 Density of exposed values

Table 5-6 through Table 5-9 summarize the basic information of the model of exposure for Mexico.

Table 5-6
Indicators and general parameters

Indicator	Unit	Value
Total population	Inhab	106,671,080
Urban population	Inhab	81,593,418
Rural population	Inhab	25,077,662
Minimum wage	US$	138
GDP (2008)	US$ Billion	1,353
GDP per capita (2008)	US$	12,400

Table 5-7
Areas and density of construction

Constructions	Unit	Value	Unit	Value per capita
Urban built area	m^2	2,298,991 x10³	m^2/Inhab	21.6
Density of urban constructions	m^2/m^2 urban lands	0.05	-	-

Table 5-8
Economic value of infrastructure

Infrastructure	Economic value [Million US$]	Economic value per capita [US$/Inhab]	Economic value per capita / GDP per capita	Relative share
Urban constructions	674,932	6,327	0.51	68.8%
Rural constructions	76,927	-	-	-
Urban infrastructure	33,780	317	0.03	3.4%
National infrastructure	195,455	1,832	0.15	19.9%
Total Infrastructure of the country	**981,094**	**9,197**	**0.68**	92.2%
Government responsibility (fiscal)	330,109	3,095	0.42	33.6%

Table 5-9
Built area and economic value of urban constructions

Use group	Construction area [m^2x10^3]	Economic value [US$x10^6]	Construction area / population from use group	
			Unit	Value
Residential LP	212,714	23,947	m^2/Inhab LP	4.1
Residential MP	678,280	210,066	m^2/Inhab MP	13.9
Residential HP	161,015	81,388	m^2/Inhab HP	24.1
Commercial	536,644	156,528	m^2/WF	20.0
Industry	401,059	187,786	m^2/WF	50.0
Private Health	359	192	m^2/1000 Inhab	3.4
Private Education	49,245	15,025	m^2/Stud	1.5
Public Health	359	154	m^2/1000 Inhab	3.4
Public Education	249,655	73,942	m^2/Stud	7.5
Government	9,662.7	2,832	m^2/PE	5.0
Total	**2,298,991**	**751,858**	**m^2/Urban Pop**	**28.2**

LP: Low-income population; MP: Medium-income population; HP: High-income population

Figure 5-9 through Figure 5-15 illustrate the main characteristics of the exposure model developed for Mexico.

Figure 5-9 Population distribution

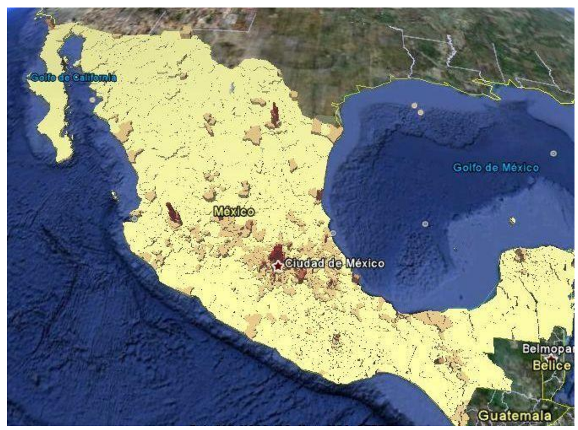


Figure 5-10 Population density

Figure 5-11 Distribution of exposed value of constructions

Figure 5-12 Distribution of exposed value of urban infrastructure

Figure 5-13 Distribution of the exposed value of national infrastructure

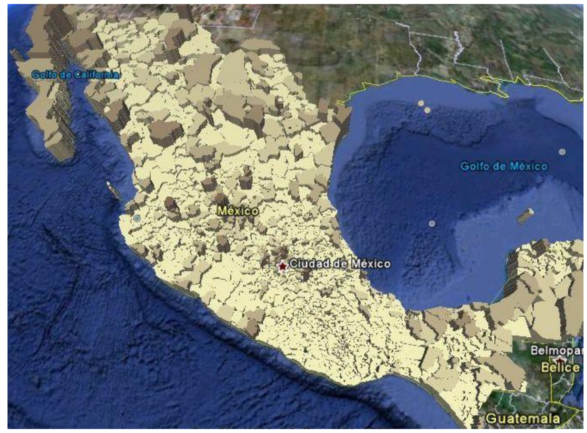


Figure 5-14 Distribution of the exposed value of total physical components

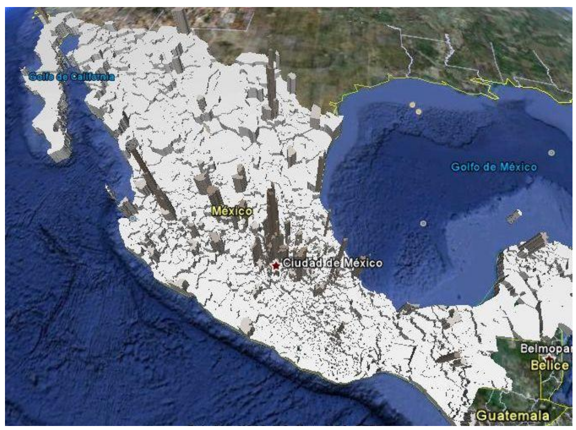


Figure 5-15 Density of exposed values

Table 5-10 through Table 5-13 summarize the basic information of the model of exposure for Nepal.

Table 5-10
Indicators and general parameters

Indicator	Unit	Value
Total population	Inhab	27,839,586
Urban population	Inhab	5,098,758
Rural population	Inhab	22,740,828
Minimum wage	US$	59
GDP (2008)	US$ Billion	29.29
GDP per capita (2008)	US$	1,144

Table 5-11
Áreas and density of construction

Constructions	Unit	Value	Unit	Value per capita
Urban built area	m^2	506,922 $x10^3$	m^2/Inhab	18.2
Density of urban constructions	m^2/m^2 urban lands	0.48		-

Table 5-12
Economic value of infrastructure

Infrastructure	Economic value [Million US$]	Economic value per capita [US$/Inhab]	Economic value per capita / GDP per capita	Relative share
Urban constructions	51,925	1,865	1.63	86.9%
Rural constructions	-	-	-	-
Urban infrastructure	1,889	68	0.06	3.2%
National infrastructure	5,957	214	0.19	10.0%
Total Infrastructure of the country	**59,771**	**2,147**	**1.88**	**100.0%**
Government responsibility (fiscal)	15,479	556	0.48	25.9%

Table 5-13
Built area and economic value of urban constructions

Use group	Construction area [m^2x10^3]	Economic value [$US\$x10^6$]	Construction area / population from use group	
			Unit	Value
Residential LP	37,211	1,805.1	m^2/Inhab LP	4
Residential MP	239,044	23,482.5	m^2/Inhab MP	13
Residential HP	22,606	3,447.0	m^2/Inhab HP	23
Commercial	59,760	5,896.2	m^2/WF	20
Industry	53,409	7,893.2	m^2/WF	50
Private Health	6	0.86	m^2/1000 Inhab	0.2
Private Education	33,057	3,572.0	m^2/Stud	4
Public Health	60	7.10	m^2/1000 Inhab	2
Public Education	54,810	5,156.6	m^2/Stud	6
Government	6,960	664.8	m^2/PE	7
Total	**506,922**	**51,925.5**	**m2/Urban Pop**	**99**

LP: Low-income population; MP: Medium-income population; HP: High-income population

Figure 5-16 through Figure 5-22 illustrate the main characteristics of the model of exposure developed for Nepal.

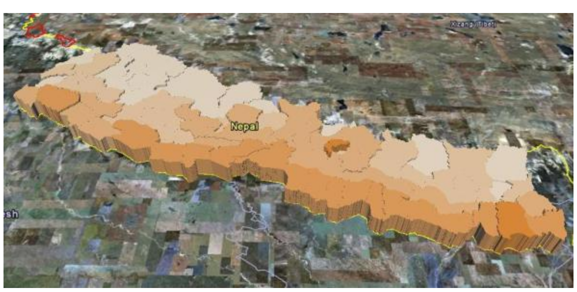


Figure 5-16 Distribution of rural population

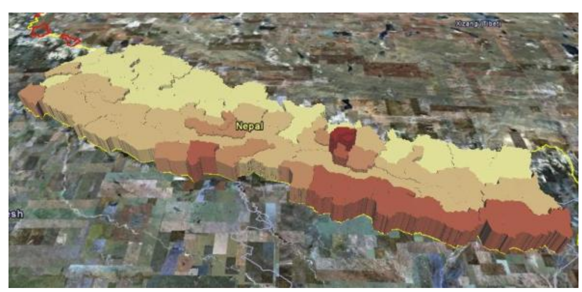


Figure 5-17 Population density

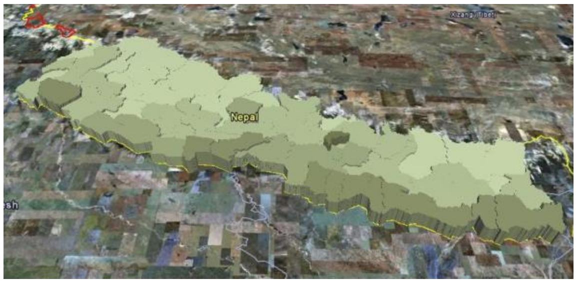


Figure 5-18 Distribution of exposed value of constructions

Figure 5-19 Distribution of exposed value of urban infrastructure

Figure 5-20 Distribution of exposed value of national infrastructure

Figure 5-21 Distribution of exposed value of total physical components

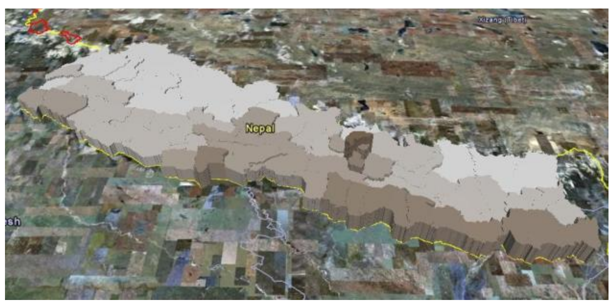


Figure 5-22 Density of exposed values

5.4 Vulnerability characterization

Characterization of physical vulnerability is determined by creating functions that relates the level of damage of each component with the intensity of the phenomenon that characterizes the hazard. The function of vulnerability must be calculated for each of the typical construction types so they can be assigned to each one of the elements of the database of exposure. Through the functions of vulnerability, it is possible to estimate the damage or the effects produced in each of the assets under the action of each event characterized by one of the parameters of intensity of the phenomenon that is being considered. Each vulnerability function is defined by a mean damage value and its variation, with which it is possible to estimate its respective probability function. The variation reveals the uncertainty associated in this process of calculating catastrophic risk.

Effects or damage estimations are measured in terms of the mean damage ratio, MDR which is defined as the ratio of the expected repair cost of the element affected to its replacement cost.

The vulnerability function or curve is defined relating the MDR to the parameter of intensity that characterizes the hazard and the probability distribution curve of loss obtained from the deviation of each of the loss values. As a result, a different value of vulnerability will be assigned for each exposed element, in probabilistic terms, for each event to which is subjected.

For the analysis carried out for Colombia, Mexico and Nepal a series of representative vulnerability functions of the dominant construction types in the main cities in each of the countries have been assigned.

Figure 5-23 and Figure 5-24 show several of the vulnerability functions used for risk analysis that are described below.

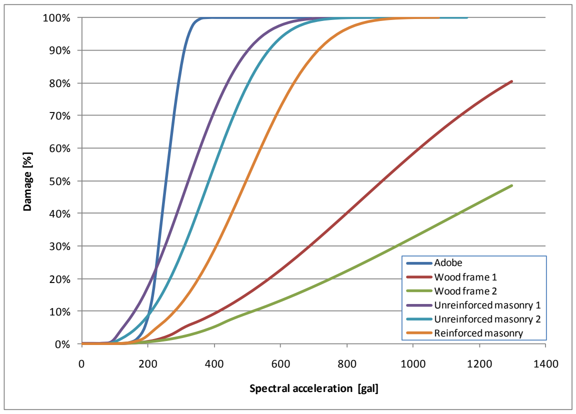


Figure 5-23 Seismic vulnerability functions for typical buildings

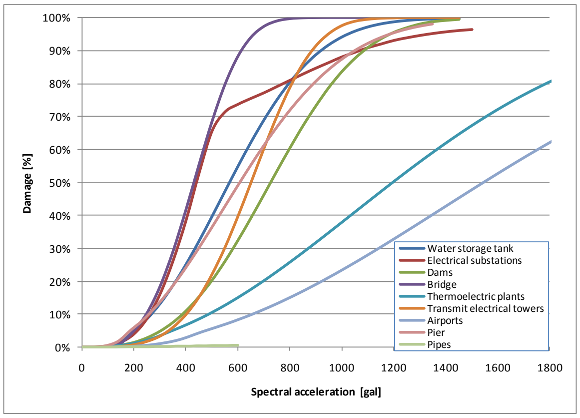


Figure 5-24 Seismic vulnerability functions for elements of infrastructure

5.5 Loss estimation

Based on the probabilistic hazard models proposed and on the inventory and evaluation of exposed assets with their corresponding vulnerability functions, modelling of probabilistic losses for the country or area of analysis is carried out.

In order to calculate the losses associated with a specific event, the mean damage ratio, MDR obtained from the vulnerability function is converted into economic loss by multiplying it by the replacement value of the component. This operation is repeated for each of the assets or elements in the inventory of exposed assets for each of the events analysed. During this evaluation process for the possible events and the vulnerability degree of each component of the portfolio the losses are added up, applying an appropriate calculation for treatment of the probability density functions associated with the events and the vulnerability, which makes it possible to calculate the exceedance probabilistic curve of the respective losses.

A similar analysis is made for the effects on the population, using in this case affectation functions defined for each component of physical infrastructure and the level of associated occupation.

The main risk measures in economic terms are described below:

- *Expected Annual Loss (EAL)*: The EAL is calculated as the sum of the product between the expected losses for a specific event and the frequency of occurrence of that event over the period of one year and for all stochastic events considered. In probabilistic terms, the EAL is the mathematical expectation of annual loss.

- *Pure Risk Premium (PRP):* The PRP corresponds to the value of the EAL divided by the replacement value of the asset. It indicates the cost that must be paid annually in order to cover expected losses in the future.

- *Loss exceedance curve (LEC):* The LEC represents the annual frequency with which determined economic loss will be exceeded. It is the most important and robust measurement of risk, given that it provides basic information for planning and assigning resources required in order to comply with specific management goals. The LEC can be calculated for a major probable event in one year or uniformly for all the possible events, in function of their return period. Generally, it is preferred the second approach, because it permits consideration of more than one catastrophic event per year.

- *Probable Maximum Loss*: The PML represents a value of loss for a specific level of loss. Depending on the capacity of a country, region or entity for risk management, it can be decided to intervene potential losses up to a specific return period considered appropriate.

In addition to the probabilistic assessment of economic losses, it is also relevant in an integral management of risk and reduction of vulnerability, to consider scenarios that determine natural events, such as historical events or individual events generated randomly on the basis of an evaluation of a hazard. This is particularly important in producing emergency response and attention plans and as an indicative analysis of the places of damage concentration and persons affected.
Normally and for the effects of adjustment and calibration of the models, stochastic events that represent representative historical events are used. This possibility permit simulation of specific events for which the parameters of the event itself are known, the geographical characteristics of location of the event and evaluations of reported economic and human losses are used. Assigning functions of physical vulnerability are calculated with the results of this type of specific event. For that purpose, recorded events are used (unfortunately not always well evaluated) in the countries, in the information available in the EM-DAT database (CRED, Université Catholique de Louvain) and several representative events existing in the DesInventar database.

5.6 Results of the analysis

5.6.1 *Physical losses*

The results of probable losses for the case studies are presented below. Table 5-14 through Table 5-17 summarize the results of annual expected losses and de maximum probable loss for the total exposure of Colombia, Mexico and Nepal. These values correspond to the losses that both the public sector and the private sector would have with zero per cent deductible for the case of seismic hazard in these countries and hurricane only for Mexico.

Table 5-14 Summary of the results of seismic risk for Colombia

Results		
Exposure value	US$ mill.	$632,772
Annual average loss	US$ mill.	$2,367
	‰	3.7
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$23,933	3.8%
250	$35,615	5.6%
500	$44,952	7.1%
1,000	$52,677	8.3%
1,500	$59,433	9.4%

Table 5-15 Summary of the results of seismic risk for Mexico

Results		
Exposed value	US$ million	$981,084
Annual average loss	US$ million	$1,166
	‰	1.2
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$7,275	0.7%
250	$15,307	1.6%
500	$25,463	2.6%
1,000	$38,198	3.9%
1,500	$45,014	4.6%

Table 5-16 Summary of results of seismic risk for Nepal

Results		
Exposure value	US$ x10^6	$59,771
Annual average loss	US$ x10^6	$1,493
	‰	25
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$7,855	13.1%
250	$9,609	16.1%
500	$11,058	18.5%
1,000	$12,176	20.3%
1,500	$12,566	21.0%

Table 5-17 Summary of results of hurricane risk for Mexico

Results		
Exposure value	US$ x10^6	$981,084
Annual average loss	US$ x10^6	$3,559
	‰	3.6
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$25,105	2.6%
250	$34,997	3.6%
500	$43,490	4.4%
1,000	$53,759	5.5%
1,500	$57,578	5.9%

Maximum Probable Loss (PML) values depend on the degree of dispersion of the assets evaluated. It should be kept in mind that the figures obtained for the various return periods correspond to the maximum probable losses for the entire country, which if evaluated for each department or state, or by cities, could significantly change because of the level of concentration of risk that occurs in both cases. Therefore, the relevance on defining for “whom” the risk is being evaluated.

Figure 5-25 through Figure 5-28 show the curves of probable maximum loss for each country.

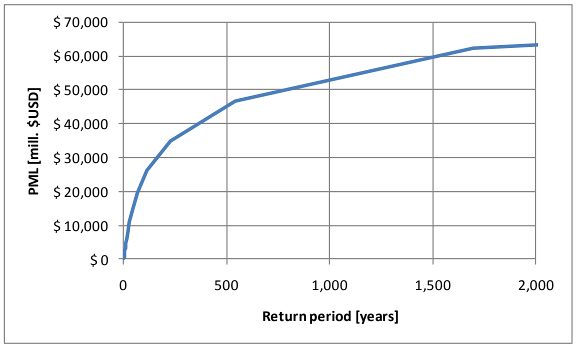


Figure 5-25 Curve of probable maximum loss from earthquakes for Colombia

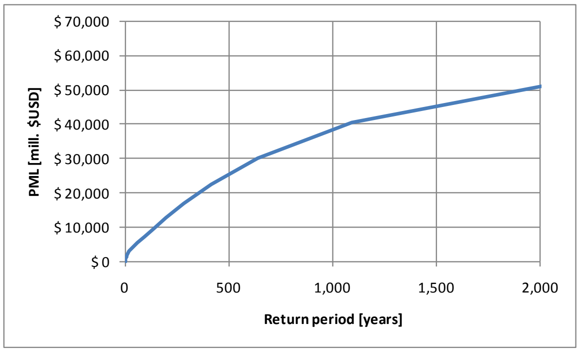


Figure 5-26 Curve of probable maximum loss from earthquakes for Mexico

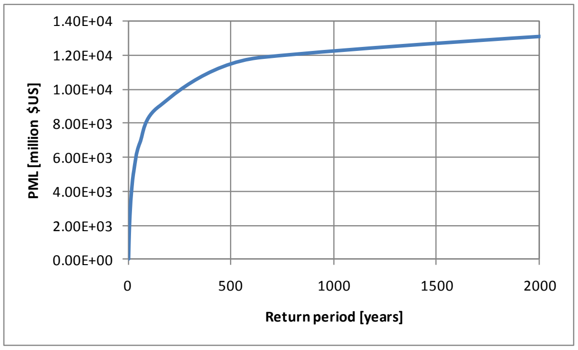


Figure 5-27 Curve of probable maximum loss from earthquakes for Nepal

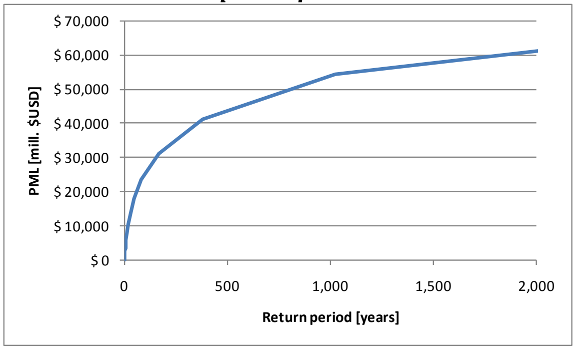


Figure 5-28 Curve of maximum probable loss from hurricanes for Mexico

Figure 5-29 through Figure 5-32 present loss exceedance curves for economic losses for each of the countries for the following portfolios:

- National, national infrastructure assets, also private and public buildings
- Fiscal, public and low income sector assets
- Public health, public assets devoted to medical care (medical centres, hospitals, and others)
- Public education, public assets devoted to educational services
- Government, public assets devoted to administrative and bureaucratic service
- Private, assets from moderate to high income population, industrial and commercial sectors

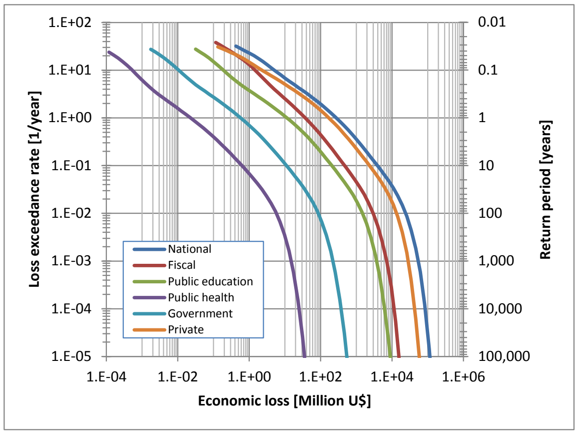


Figure 5-29 Loss exceedance curves for earthquake by portfolio for Colombia

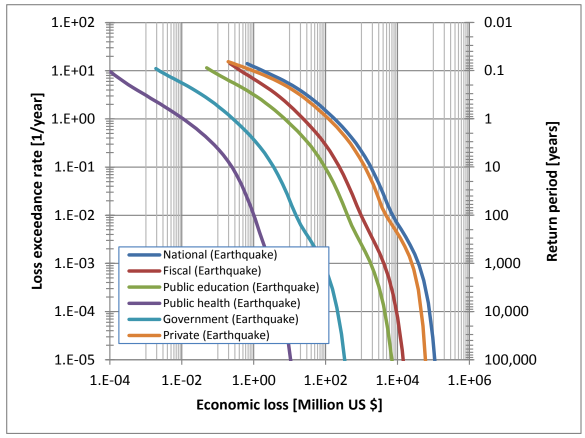


Figure 5-30 Loss exceedance curves for earthquake by portfolio for Mexico

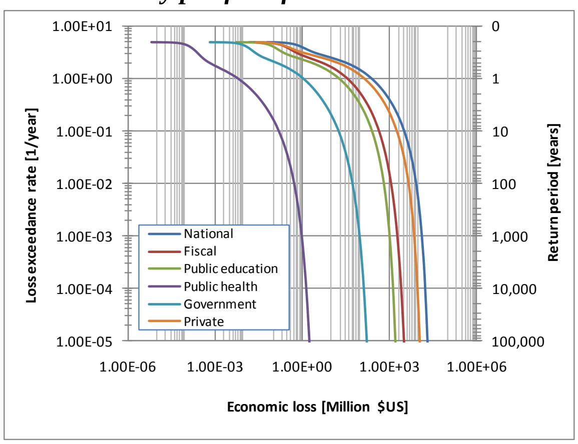


Figure 5-31 Loss exceedance curves for earthquake by portfolio for Nepal

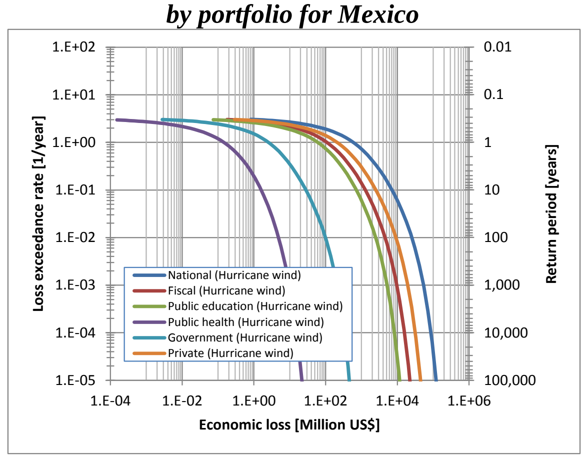


Figure 5-32 Loss exceedance curves for hurricanes by portfolio for Mexico

This type of curve is of special importance for defining strategies for reducing and transferring risk. Therefore, they are of special interest for each sector of government; for example, to determine reinforcement of existing structures in order to reduce their vulnerability and, as a result, their potential losses, and for negotiating insurance that covers possible or residual losses after investing in prevention. The value of the pure risk premium becomes an important measurement of the risk of each component and of an entire portfolio, given that it is the basis for defining the cost of risk transfer (commercial premium). That premium is usually calculated considering a deductible the owner must assume of the insured assets and that corresponds normally to minor losses (the most common), leaving the insurer the responsibility of covering larger or extreme losses that occur infrequently.

Table 5-18 Summary of seismic risk results for the fiscal portfolio of Colombia

Results		
Exposure value	US$ mill.	$173,226
Annual average loss	US$ mill.	$316
	‰	1.8
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$2,976	1.7%
250	$4,417	2.5%
500	$5,655	3.3%
1,000	$7,126	4.1%
1,500	$7,625	4.4%

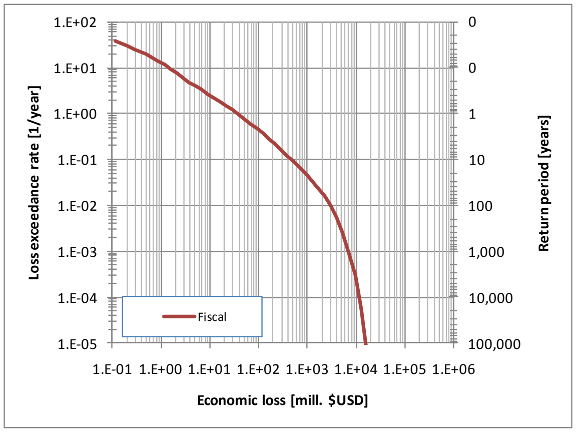


Figure 5-33 Loss exceedance curve for the fiscal portfolio of Colombia (Seismic risk)

Table 5-19 Summary of seismic risk results for the fiscal portfolio of Mexico

Results		
Exposure value	US$ mill.	$330,101
Annual average loss	US$ mill.	$157
	‰	0.5
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$972	0.3%
250	$1,773	0.5%
500	$2,769	0.8%
1,000	$4,168	1.3%
1,500	$4,990	1.5%

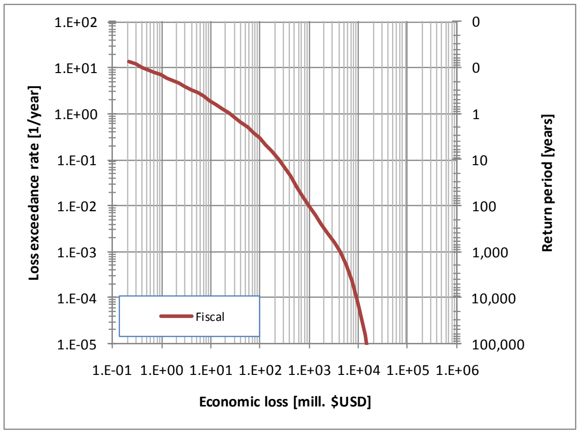


Figure 5-34 Loss exceedance curve for the fiscal portfolio of Mexico (Seismic risk)

Table 5-20 Summary of hurricane wind risk results for the fiscal portfolio of Mexico

Results		
Exposure value	US$ mill.	$330,101
Annual average loss	US$ mill.	$646
	‰	1.96
PML		
Return period	**Loss**	
years	**US$ mill.**	**%**
100	$4,481	1.4%
250	$6,373	1.9%
500	$7,824	2.4%
1,000	$9,443	2.9%
1,500	$10,412	3.2%

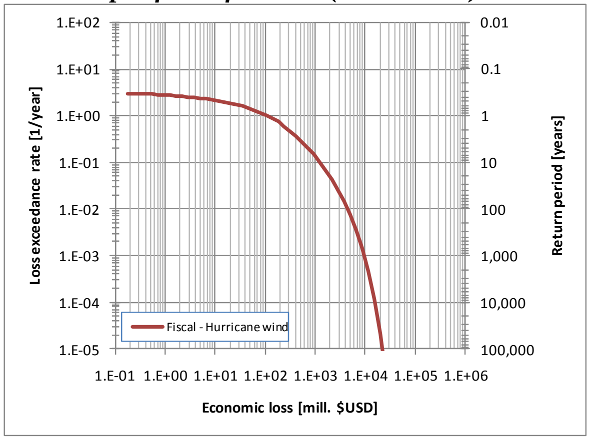


Figure 5-35 Loss exceedance curve for the fiscal portfolio of Mexico (Hurricane wind risk)

Table 5-21 Summary of risk results for the fiscal portfolio of Mexico

Results		
Exposure value	US$ mill.	$330,101
Annual average loss	US$ mill.	$803
	‰	2.43
PML		
Return period	Loss	
years	US$ mill.	%
100	$2,090	0.6%
250	$3,406	1.0%
500	$4,658	1.4%
1,000	$6,644	2.0%
1,500	$8,090	2.5%

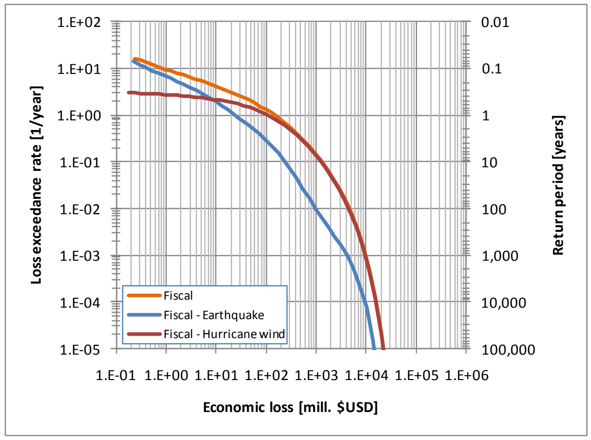


Figure 5-36 Loss exceedance curve for the fiscal portfolio of Mexico

Table 5-22 Summary of seismic risk results for the fiscal portfolio of Nepal

Results		
Exposed value	US$ mill.	$15,479
Average annual loss	US$ mill.	207
	‰	13‰
PML		
Return period	Loss	
years	US$ mill.	%
100	$1,071	6.9%
250	$1,365	8.8%
500	$1,512	9.7%
1,000	$1,784	11.5%
1,500	$1,829	11.8%

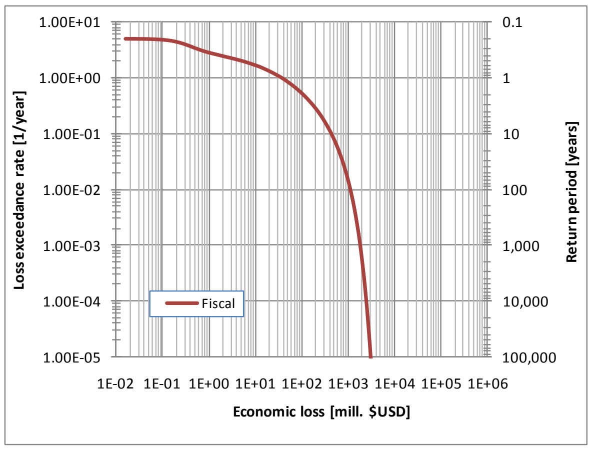


Figure 5-37 Loss exceedance curve for the fiscal portfolio of Nepal

Table 5-18 to Table 5-22 summarize the results of expected annual loss and maximum probable loss for fiscal responsibility of each government at the national level for Colombia, Mexico and Nepal with zero percent deductible. Those values correspond to the losses that the government would have for potential damage to public assets, or fiscal goods, and the low income strata of the private sector, which would have to be covered by the government in the event of a major disaster.

5.6.2 *Effects on the population*

Risk analysis at the country level is used to estimate the effects on the population in terms of lives lost and wounded. Those estimates for the two case studies of Colombia, Mexico and Nepal are presented below. Table 5-23, Table 5-24 and Table 5-25 summarize the results of the annual number of victims per 100,000 inhabitants in the cases of Colombia and Nepal and per million inhabitants in the case of Mexico.

Table 5-23 Summary of the results of risk for Colombia (victims)

Results		
Exposure value	[Inhab]	42,813,092
Annual average loss	[Inhab]	916
	[1/100,000 Inhab]	2.14
PML		
Return period	**Loss**	
years	**[Inhab]**	**%**
100	288	0.0%
250	11,680	0.0%
500	54,868	0.1%
1,000	163,056	0.4%
1,500	271,780	0.6%

Table 5-24 Summary of the results of risk for Mexico (victims)

Results		
Exposure value	[Inhab]	106,573,677
Annual average loss	[Inhab]	838
	[1/million Inhab]	7.87
PML		
Return period	**Loss**	
years	**[Inhab]**	**%**
100	4,875	0.0%
250	34,569	0.0%
500	85,476	0.1%
1,000	167,941	0.2%
1,500	232,850	0.2%

Table 5-25 Summary of the results of risk for Nepal (victims)

Results		
Exposure value	[Inhab]	26,057,400
Annual average loss	[Inhab]	4,526
	[1/100,000 Inhab]	17.37
PML		
Return period	**Loss**	
years	**[Inhab]**	**%**
100	39,260	0.15%
250	55,121	0.21%
500	67,170	0.26%
1,000	81,868	0.31%
1,500	86,375	0.33%

Table 5-26, Table 5-27 and Table 5-28 present a summary of the results of the annual number of wounded per 100,000 inhabitants in the cases of Colombia and Nepal and per million inhabitants in the case of Mexico.

Table 5-26 Summary of the results of risk for Colombia (injured)

Results		
Exposure value	[Inhab]	42,813,092
Annual average loss	[Inhab]	1,099
	[1/100,000 Inhab]	2.57
PML		
Return period	**Loss**	
years	**[Inhab]**	**%**
100	1,465	0.0%
250	23,634	0.1%
500	84,567	0.2%
1,000	216,313	0.5%
1,500	340,793	0.8%

Table 5-27 Summary of the results of risk for Mexico (injured)

Results		
Exposure value	[Inhab]	106,573,677
Annual average loss	[Inhab]	981
	[1/million Inhab]	9.21
PML		
Return period	**Loss**	
years	**[Inhab]**	**%**
100	9,419	0.0%
250	46,309	0.0%
500	101,339	0.1%
1,000	186,245	0.2%
1,500	251,333	0.2%

Table 5-28 Summary of the results of risk for Nepal (injured)

Results		
Exposure value	[Inhab]	27,900,500
Annual average loss	[Inhab]	5,570.16
	[1/100,000 Inhab]	19.96
PML		
Return period	Loss	
years	[Inhab]	%
100	49,205	0.18%
250	68,313	0.24%
500	84,719	0.30%
1,000	97,413	0.35%
1,500	108,604	0.39%

Figure 5-38, Figure 5-39 and Figure 5-40 present the loss exceedance curves for deaths and wounded for each country.

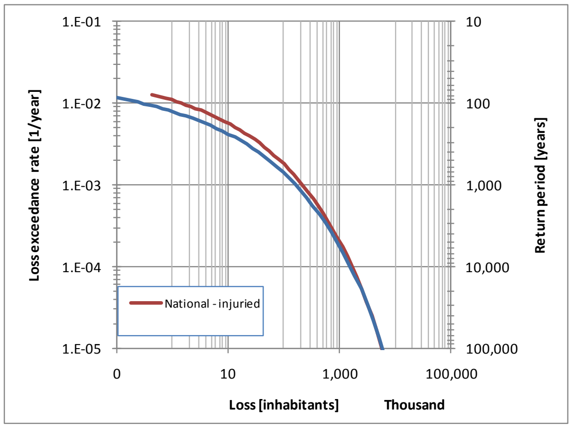


Figure 5-38 Loss exceedance curves of victims and wounded for Colombia

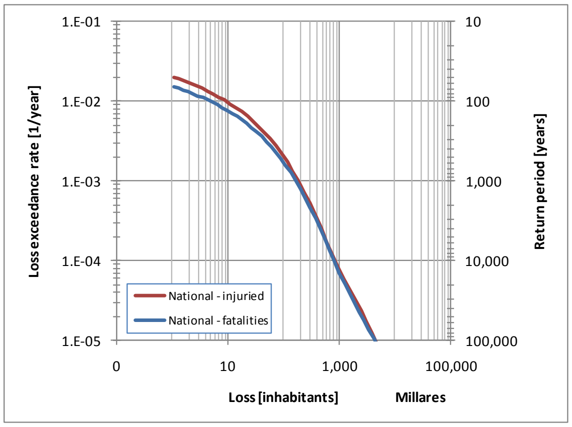


Figure 5-39 Loss exceedance curves for victims and wounded for Mexico

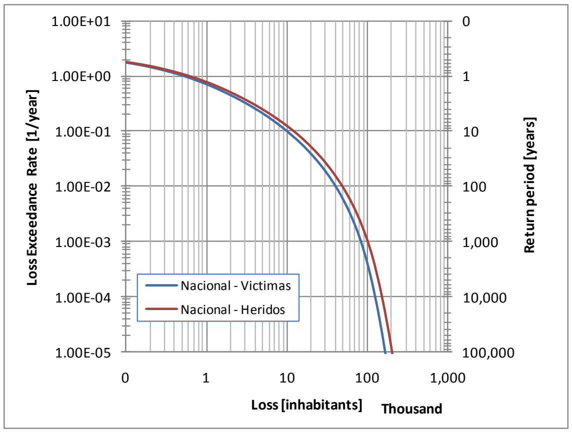


Figure 5-40 Loss exceedance curves of victims and wounded for Colombia

This type of probabilistic estimations shows that the loss of lives and the number of wounded in these countries can be very high in the case of extreme events such as those that have already occurred. In Colombia, for example, the return period of 20,000 deaths is of the order of 300 years and in Mexico it is 200 years.

6 Integration of risk assessments

6.1 Introduction

The results of the multi-hazard risk analysis can be visualized through the value of expected losses for each portfolio of elements exposed or through loss exceedance curves for a defined set of portfolios. For the effect, it is necessary to select the geographical unit of analysis, or purposes of aggregation, which should be established at the time of defining the portfolios for the analysis. The results of expected annual losses can be visualized and plotted for reference and comparison. Those values can be presented in terms of percentage (which indicates the relative level of effects) or in terms of the value of economic losses (which serves to categorize risk among portfolios and the areas evaluated). The effects on the population can be represented in the same way.

In this study, the geographical unit for the analysis has been each country. However, it is possible to make similar analyses for sub-national regions, cities or sectors of specific development for administrative units that can be considered responsible for meeting potential losses and/or reducing them. In general, risk analysis makes sense when it covers a portfolio or a region that has a responsibility of taking decisions on that risk; namely when the goal of the study is to stratify risk and define action for reducing it in accordance with the efficiency and cost of measures that are considered that should be implemented. In this study, for the case of Colombia and Mexico, risk is being considered a sovereign responsibility and although each sector (health, education, or the infrastructure of cities, for example) can be independent and decentralized, losses are not always assumed by those sectors or decentralized territorial levels because of an incapacity for dealing with them. In addition, as has been mentioned previously, neither national governments have really covered losses in the past, whether they are recurrent or extreme.

With the goal of establishing risk management strategies, it is necessary to represent conveniently the results of risk, or which in this study are presented in two different forms:

a. The loss exceedance curve that expresses the annual frequency (or the reverse: the return period) with which various levels of loss can be equalled or surpassed. These curves have been presented previously in empirical and analytical terms (using historical events) (in terms of hazard assessment and current vulnerability) for various types of events, sectors or portfolios of exposed elements.

b. The curves of accumulation of losses over time, in which case the expected annual loss corresponds to the slope of that curve and whose presentation results highly illustrative for representing hypothetical situations of risk reduction both for the case of the events that have already occurred as well as those expected to occur in the future.

An adequate representation of the results of risk analysis at the level of the selected geographical units permits estimating and visualizing risk, therefore, in order to take decisions, risk stratification is a very convenient way to express risk.

6.2 Proposal for a "hybrid" loss exceedance curve

In the previous sections were presented two complementary types of risk assessment:

a. Risk assessment based on the analysis of recorded historical events (using the DesInventar database) that covers relatively short periods of time (less than 40 years in general) and includes minor events with high frequency of occurrence, of effects relatively small and a few events with medium or large-sized effects. Information that has made possible to break down the results by type of phenomena (earthquake, hydro-meteorological, volcanic, landslide and others)

b. Analytical assessments using probabilistic models that make possible estimates of risk for medium-sized and extreme events with variable levels of uncertainty. In the case in point, only the analyses for earthquakes and hurricanes (in the case of Mexico) have been covered, with losses mainly from earthquakes.[7] This analysis has made it possible to calculate losses for various portfolios of exposed elements, including losses of government fiscal responsibility (over fiscal property and the private assets of low-income groups), in the health and public education sectors and in the private buildings of medium and high income strata.

The loss exceedance curves using the probabilistic models project losses that can occur in the future. They are the total losses that the country can have (depending on their exposure estimated with a proxy) or losses that would be of fiscal responsibility of the Government (in infrastructure and reconstruction of assets for the poorest people). These two curves obtained with predictive modelling in probabilistic terms are not reliable for the range of losses caused by minor events and are considered, in general, more robust (because of the type of assumptions made analytically) for the segment of major events (for example, starting at US$ 100 million).

The analyses presented in previous sections have been carried out so that the results of these two types of analysis are presented consistently in compatible formats for their adequate integration in a hybrid loss exceedance curve.

6.2.1 *Disaggregation of economic loss*

Using total loss exceedance curves for each of the countries, it is possible discriminate the participation of the various phenomena and sectors or portfolios. Figure 6-1 through Figure 6-6 illustrate the relative participation for various loss levels, expressed on the abscissa in terms of return periods.

[7] Analysis for second order and local hazard, such as landslides and flooding, can also be included, which require a considerable analytical effort and a high degree of resolution of information.

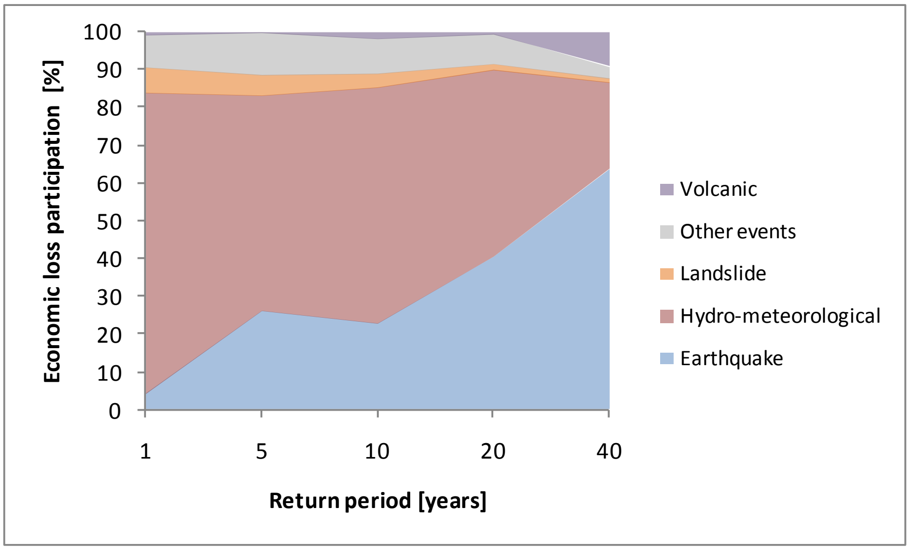


Figure 6-1
Participation of losses per phenomenon for Colombia (using historical events)

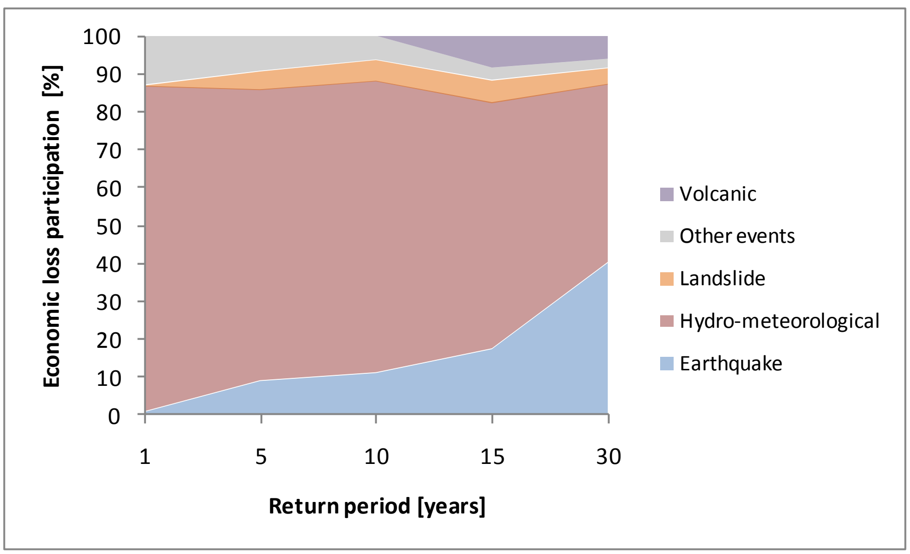


Figure 6-2
Participation of losses per phenomenon for Mexico (using historical events)

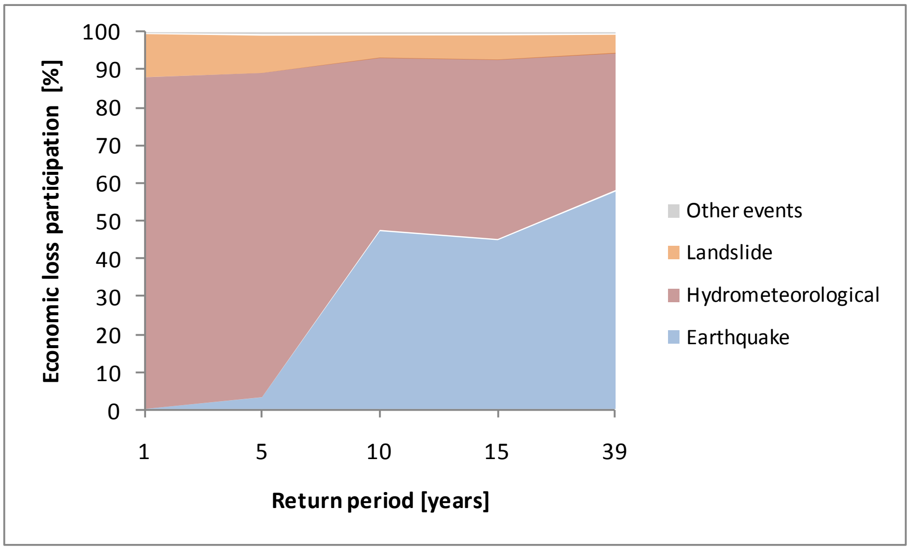


Figure 6-3
Participation of losses per phenomenon for Nepal (using historical events)

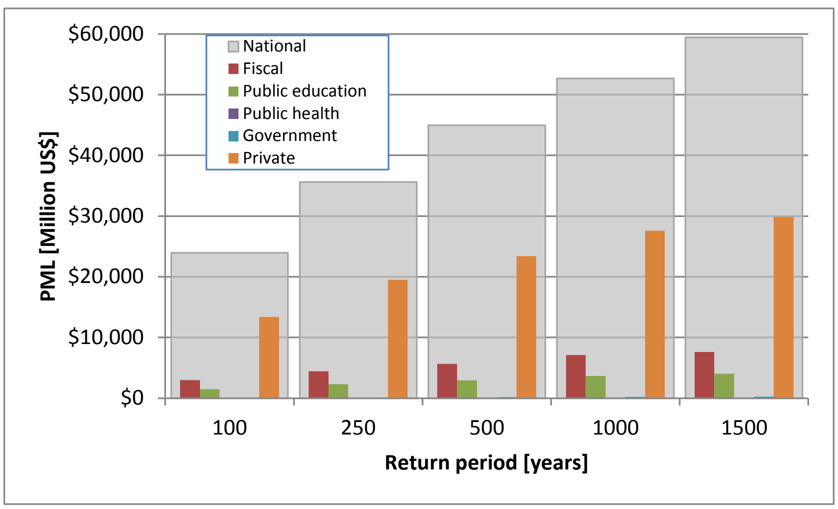


Figure 6-4
Participation of losses by sector for Colombia (using the probabilistic model)

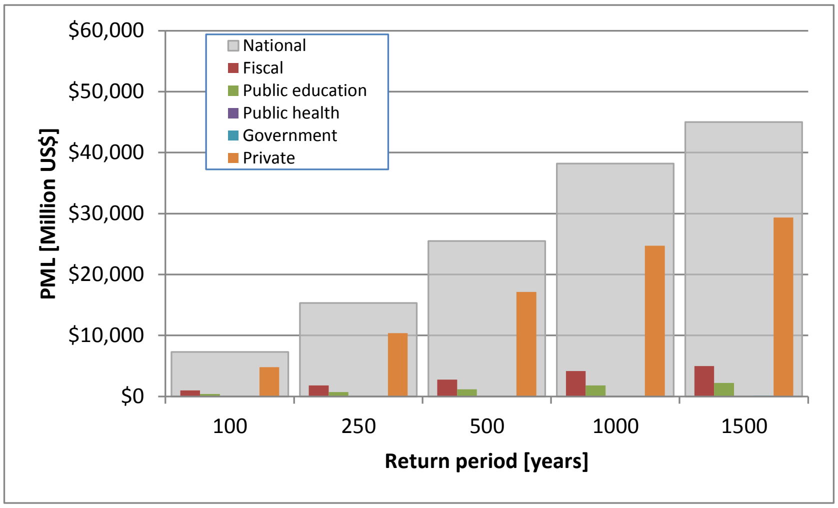


Figure 6-5
Participation of losses per sector for Mexico (using the probabilistic model)

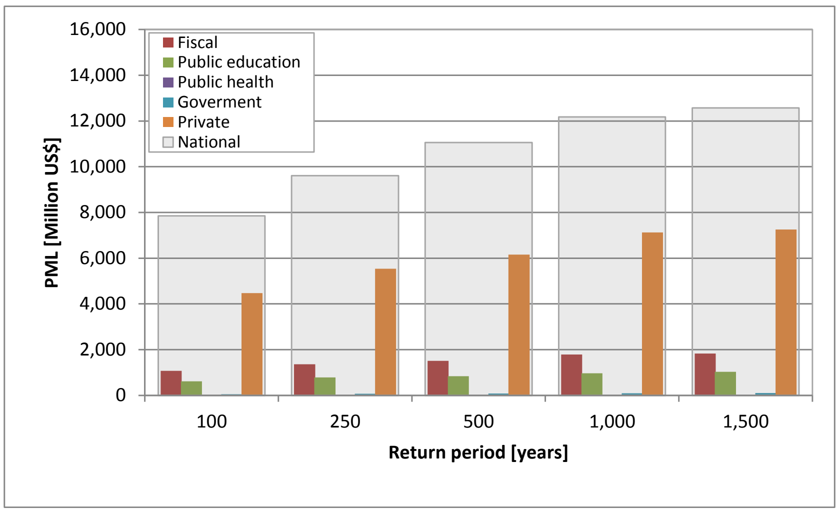


Figure 6-6
Participation of losses per sector for Nepal (using the probabilistic model)

6.2.2 *Cumulative economic loss curves over time*

Based on the information of the loss exceedance rate for a portfolio of analysis, it is possible to estimate the form in which losses accumulate over time for that portfolio, both for the case of the analysis of historical events and for a probabilistic analysis. Figure 6-7 to Figure 6-9 present for the case of Colombia, Mexico and Nepal the economic cumulative loss curves concerning the sequence of historical events occurred. The straight line joining the point of departure and the final point of the cumulative loss curve corresponds to the accumulation of annualized losses. As a result, its slope is the average (or expected) annual loss.

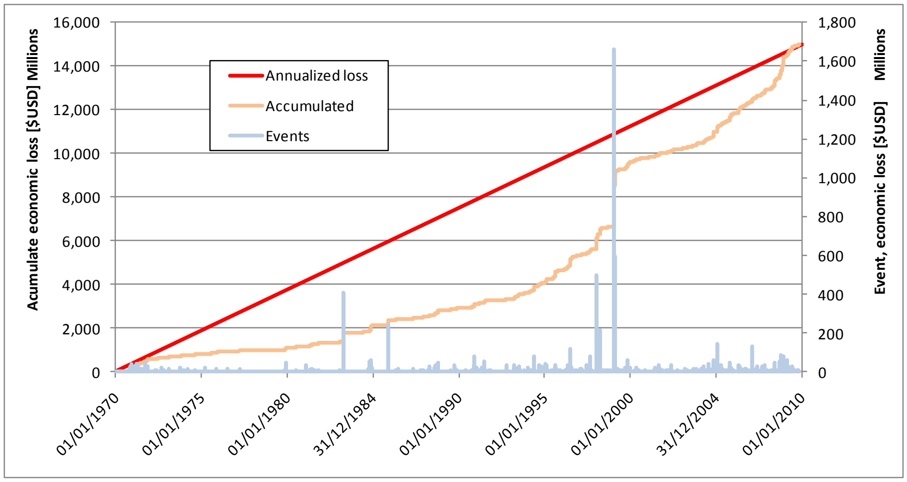


Figure 6-7
Historical events and annualized loss curve for Colombia (using historical events)

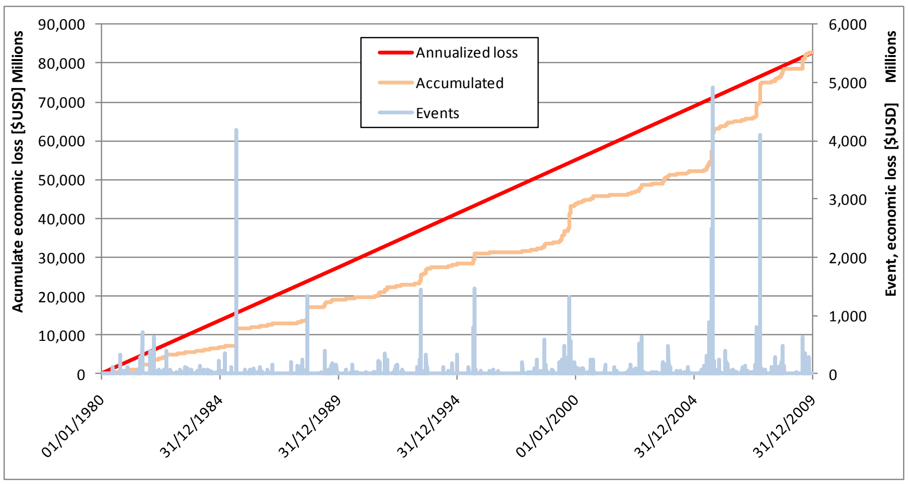


Figure 6-8
Historical events and annualized loss curves for Mexico (based on historical events)

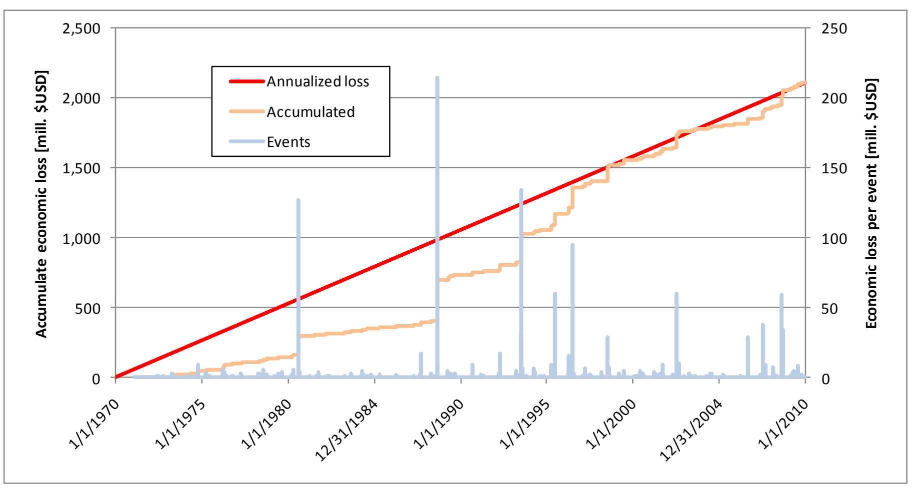
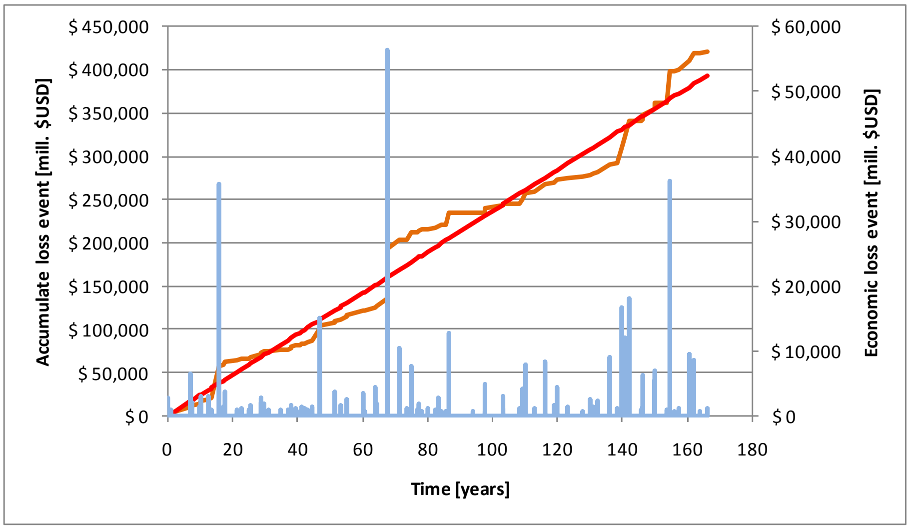


Figure 6-9
Historical events and annualized loss curves for Nepal (based on historical events)

Figure 6-10 to Figure 6-12 illustrate for the case of Colombia, Mexico and Nepal, respectively, the stochastic simulation of a series of events using the exceedance curve obtained from the probabilistic model and the Monte Carlo method it is possible to produce multiple cumulative loss curves that follow the same behaviour as that derived from the same expected annual loss. This simulation is important for illustrating that very short periods of historical events cannot appropriately reflect the behaviour of losses in the long term and can be insufficient for estimating extreme losses. Depending on the "run" of events of the historical period (with many or few major events) it is possible to be overestimating or underestimating very significantly risk, and for that reason the analytical evaluation of risk is essential, evaluating the hazard and the vulnerability.



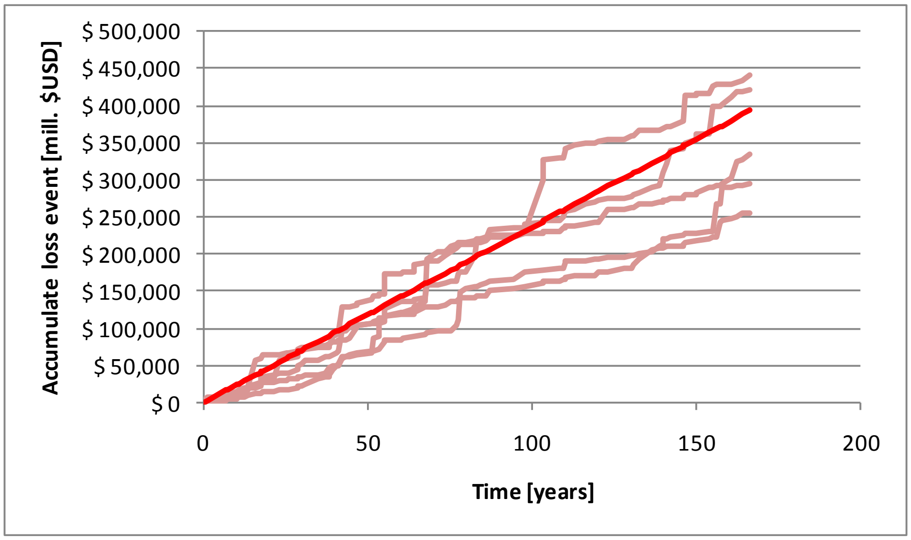


Figure 6-10
Simulation and accumulation of losses for Colombia (using the probabilistic model)

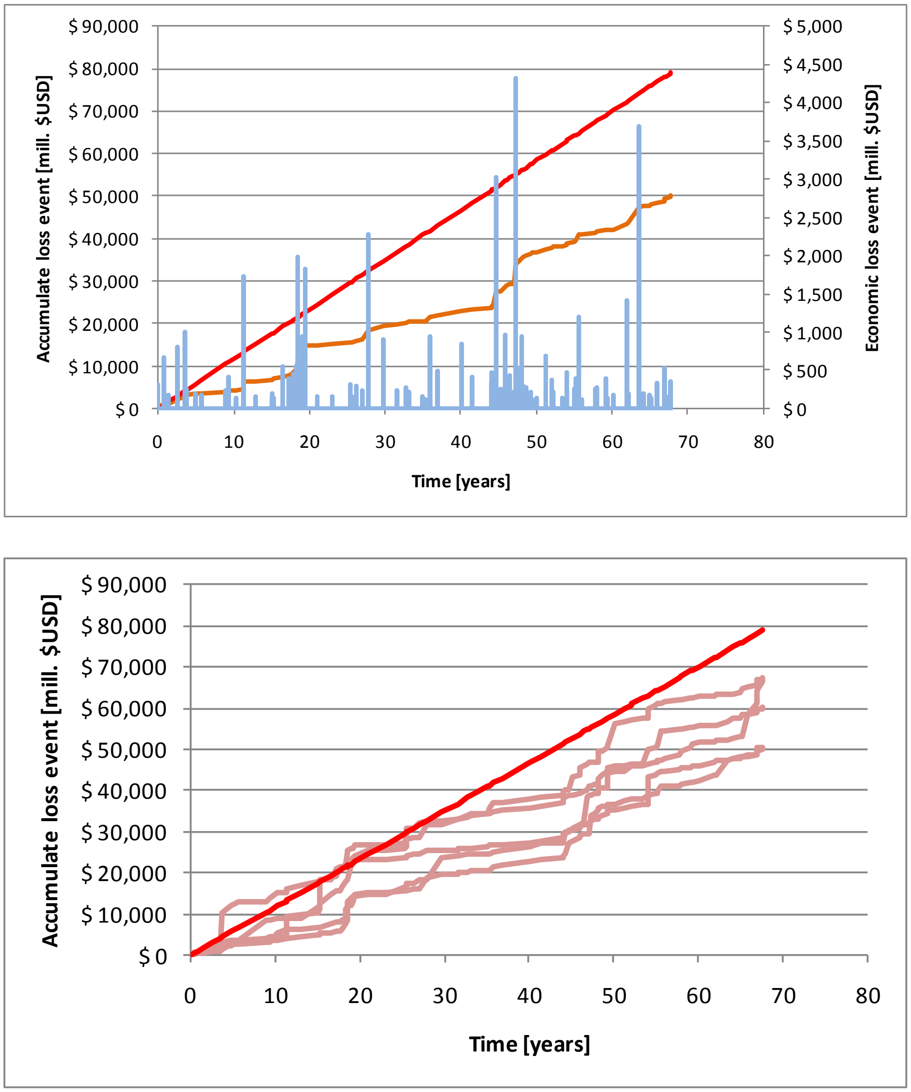


Figure 6-11
Simulation and accumulation of losses for Mexico (using the probabilistic model)

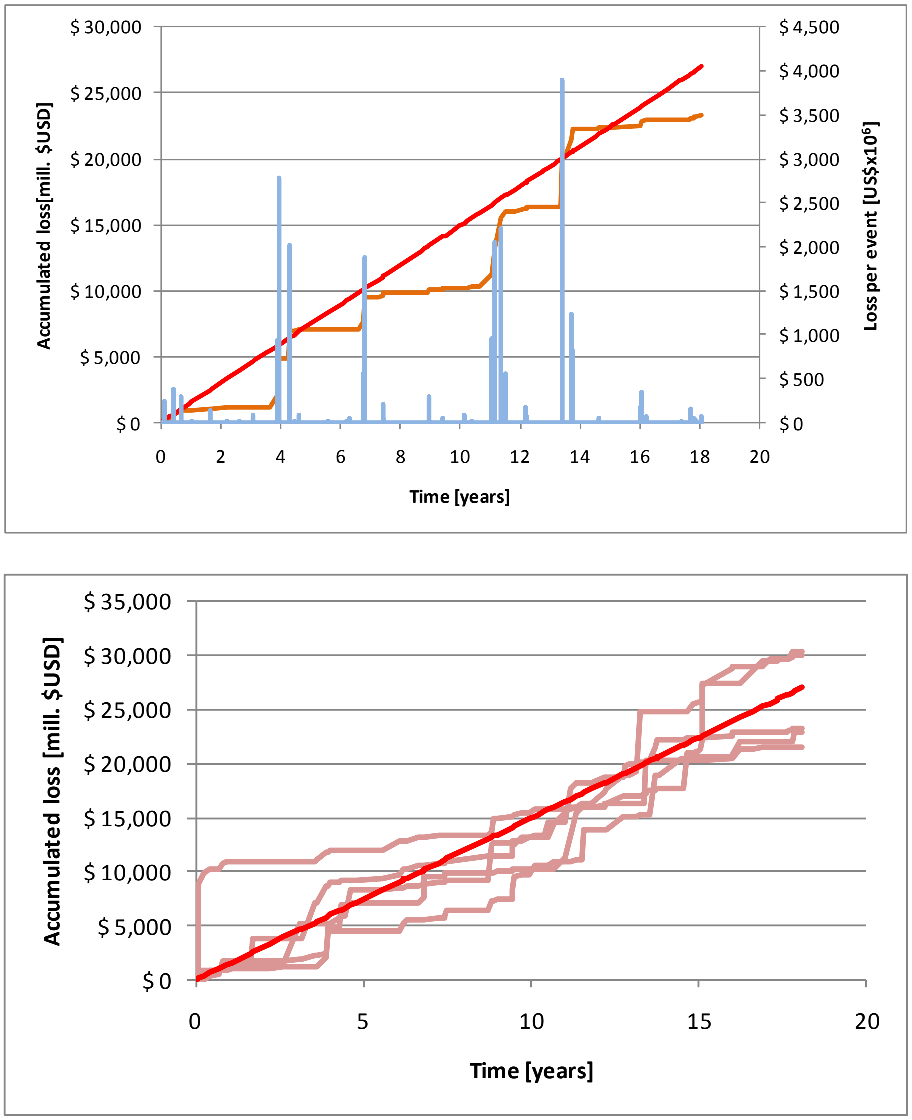


Figure 6-12
Simulation and accumulation of losses for Nepal (using the probabilistic model)

Figure 6-13 to Figure 6-15 show lines of accumulation over time of annual losses (average) for different types of phenomenon (earthquake, hydro-meteorological, volcanic, landslide, others and for the total). Figure 6-16 to Figure 6-18 include the results for various portfolios or sectors (fiscal, low income strata, health and public education, and private buildings) for each of the countries studied.

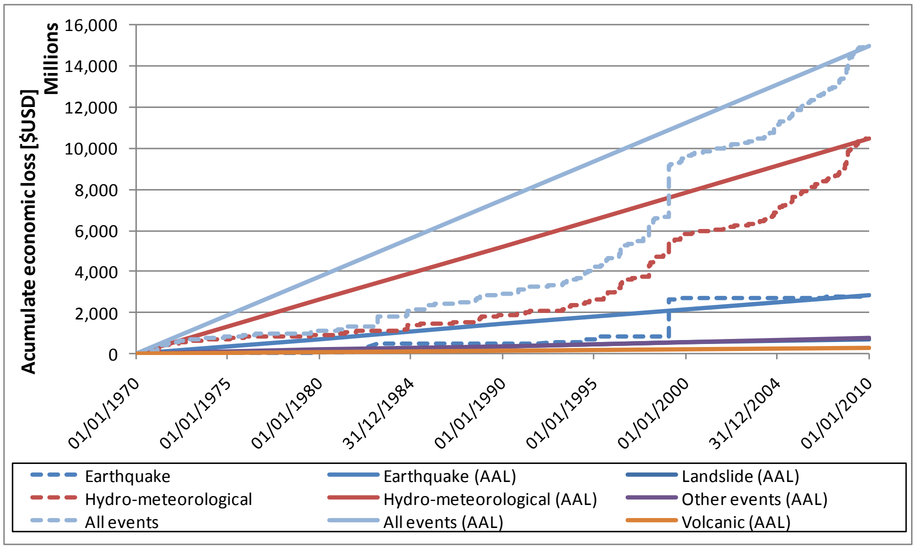


Figure 6-13
Accumulation over time of annual loss by event for Colombia (using historical events)

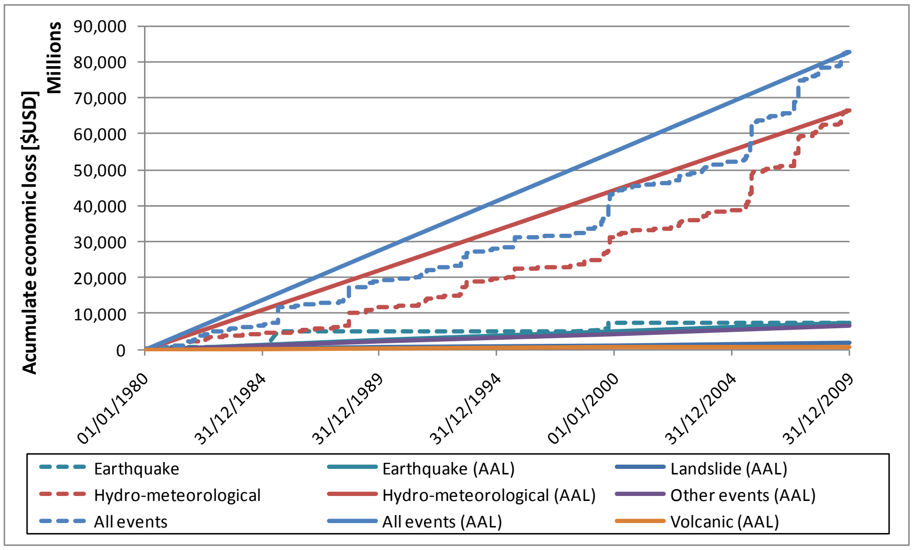


Figure 6-14
Accumulation over time of annual loss per event for Mexico (using historical events)

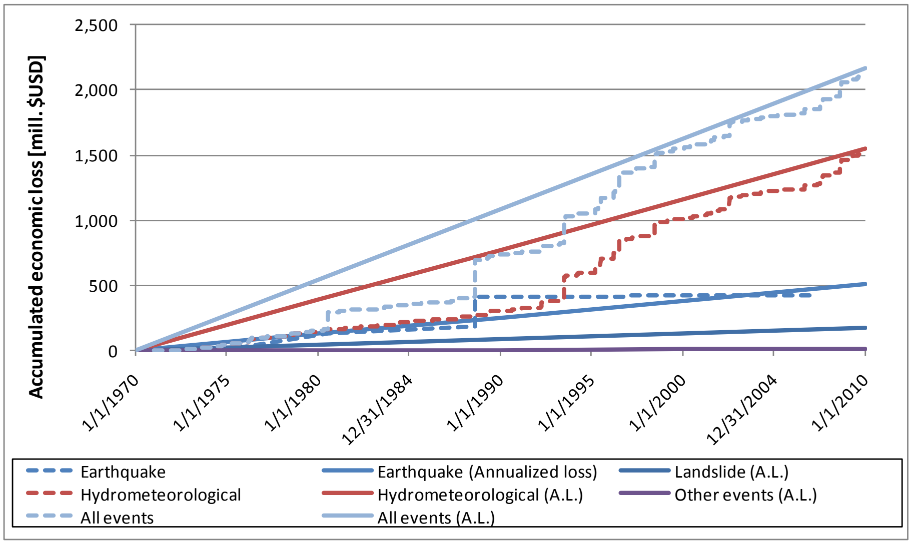


Figure 6-15
Accumulation over time of annual loss per event for Nepal (using historical events)

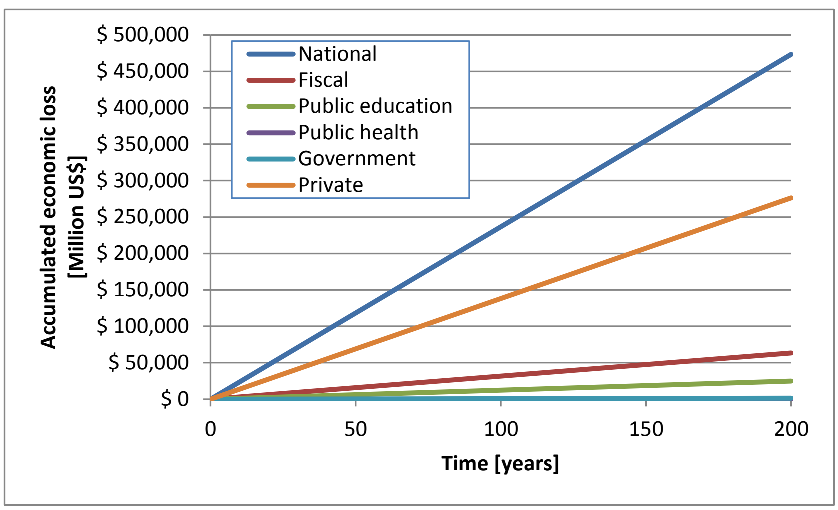


Figure 6-16
Accumulation over time of annual loss by sector for Colombia (using the probabilistic model)

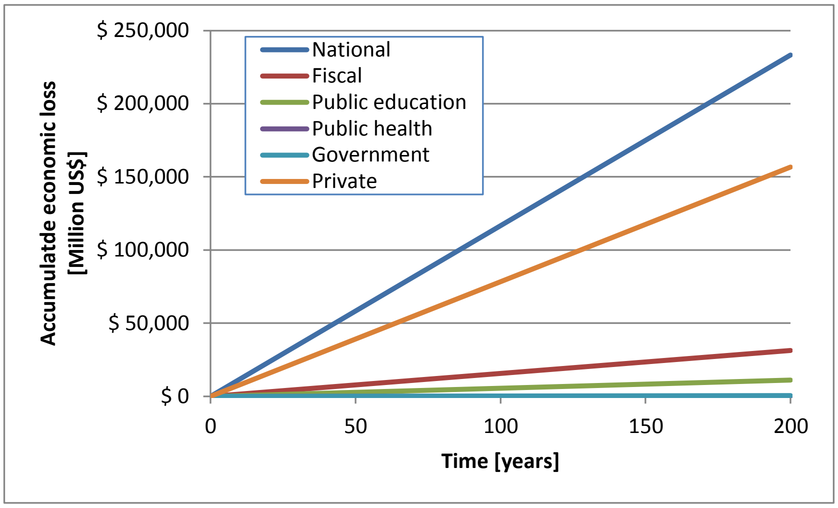


Figure 6-17
Accumulation over time of annual loss by sector for Mexico (using the probabilistic model)

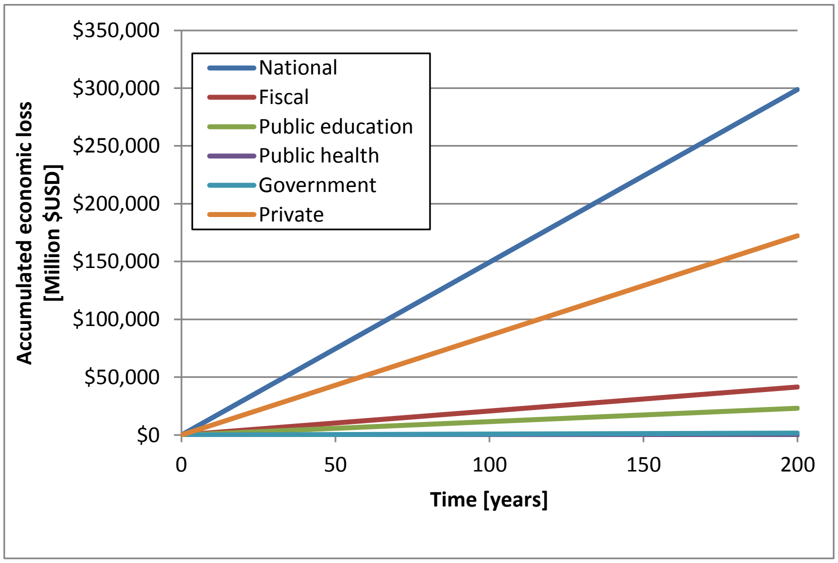


Figure 6-18
Accumulation over time of annual loss by sector for Nepal (using the probabilistic model)

This form of expressing losses over time facilitates visualization of the impact of mitigation measures, given that the annual loss would be reduced and given that over time would signify a flatter line. For the effects of stratifying risk and estimating how losses would be reduced, result, for example, from relocation of housing, the construction of protection works or by reinforcing structures (structural measures) both the loss exceedance curve and these graphs are especially useful. In addition, they can facilitate a cost-benefit analysis of prevention.

6.2.3 *Integration of economic loss exceedance curves*

Figure 6-19 to Figure 6-21 present economic loss exceedance curves for the two types of analysis mentioned (historical events and probabilistic model) for Colombia, Mexico and

Nepal. The figures show a single loss exceedance curve (for national or federal government); under the assumption that all historical events have affected primarily the socio-economic low income strata and that the responsibility of the Government in dealing with major disasters in the future corresponds to the assets of the public sector and low income socio-economic strata.

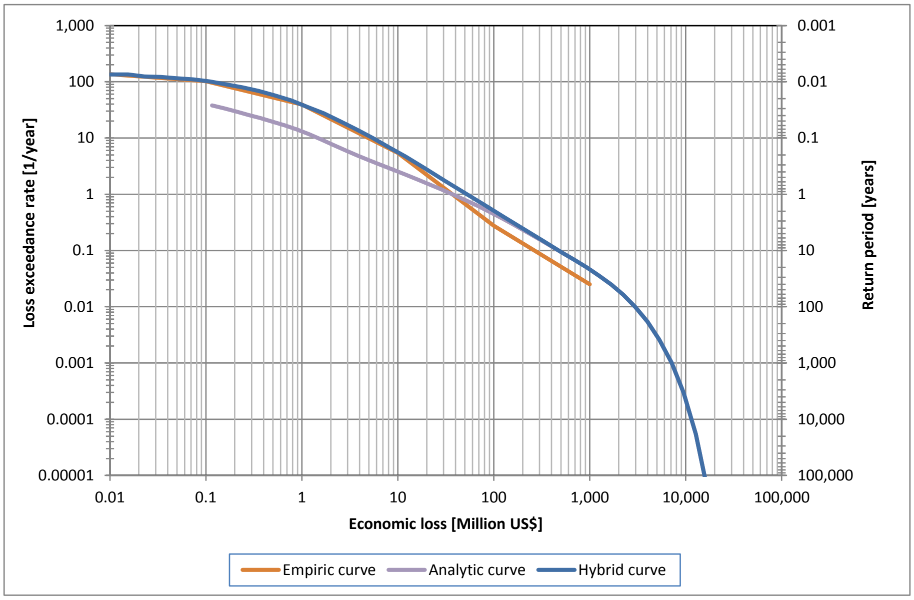


Figure 6-19 Hybrid loss exceedance curve for Colombia

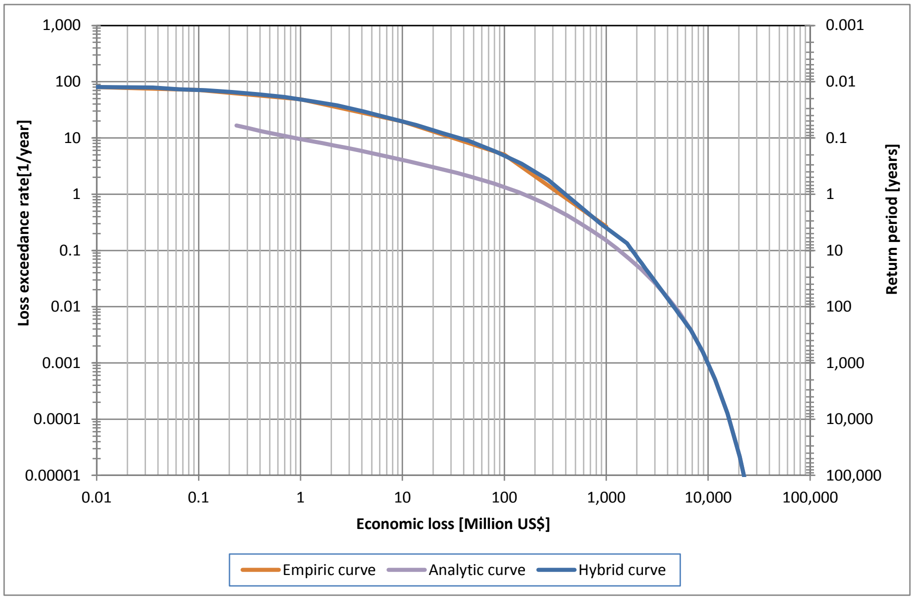


Figure 6-20 Hybrid loss exceedance curve for Mexico

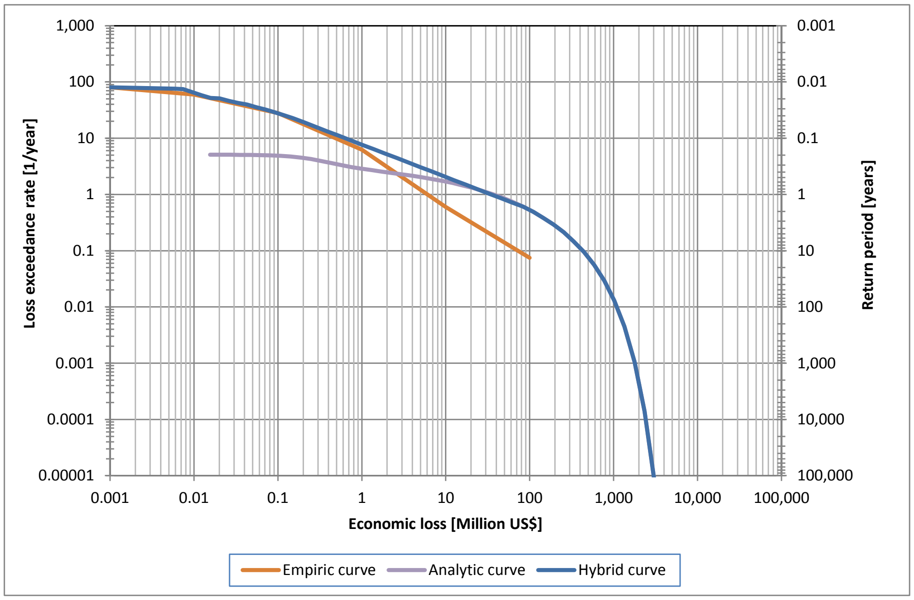


Figure 6-21 Hybrid loss exceedance curve for Nepal

The first segment of the new loss exceedance curve for each government corresponds to that of minor and medium-size losses obtained from the empirical/inductive analysis, or in retrospect, and the second segment corresponds to the deductive and predictive analysis, or in prospective, of the potential of major and extreme losses. In other words, the proposed technique for the risk analysis of other countries, regions or cities is based on merging the first segment of the curve for each type of hazard and for the total, with the second segment of the curve obtained only for hazards that have the potential of producing catastrophic events. The results of this hybrid curve facilitate hypotheses concerning the various forms of reduction of those catastrophic events, through stratification within the framework of this new loss exceedance curve.

Table 6-1 illustrates the differences in the values obtained from expected annual loss (pure risk premium[8]) considering the analysis of risk based on historical events, the probabilistic catastrophe of the fiscal responsibility of the Government and with the risk analysis result of the hybrid loss exceedance curve.

Table 6-1 Comparison of expected annual loss

	DesInventar All events [US$ millions]	DesInventar Without other events [US$ millions]	Catastrophic analysis Fiscal sector [US$ millions]	Hybrid curve [US$ millions]
Colombia	380	360	316	490
Mexico	2,760	2,540	810	2,424
Nepal	54	52	207	235

In the case of historical events, pure premiums for all events and excluding the category of "other events" have been estimated, which in the case of Mexico are very significant for

[8] This value is obtained by integrating the loss exceedance curve or maximum probable loss.

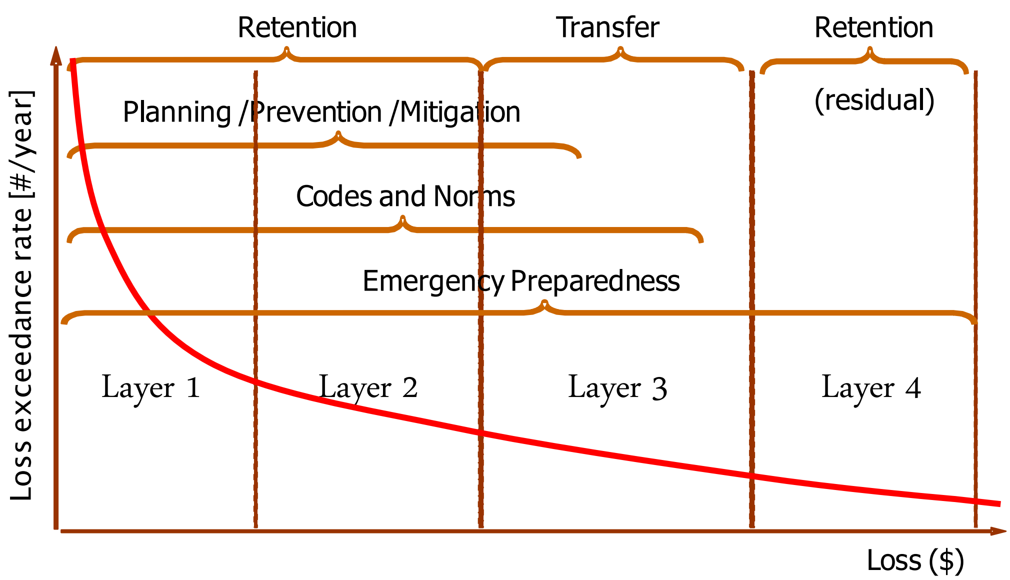
risk but that correspond primarily to biological events (illnesses, epidemics, plagues, etc.) and technological (explosions, fires, spills and leaks, etc.) whose mitigation is very specific, which in large part correspond to the private sector, and which should be the object of a study where the resolution is much greater in order to define the impact of the risk reduction measures described below.

It can be observed, in any case, an interesting situation given that the premium using the hybrid loss exceedance curve is greater, in the case of Colombia and Nepal, than the pure premium obtained with historical events, while in the case of Mexico it is smaller. However, this value corresponds to the annual value that each government would have to pay annually in order to cover all disasters in the future in the long run. In the case of taking out insurance, a portion of this value would be that which would have to be paid to insurance and reinsurance companies (which could well be the value of the premium to cover catastrophic risk), given that they cover losses only above a certain value, known as the attachment point or priority, leaving as deducible for each government the losses caused by small events. These events, as has been seen, correspond to very high values of losses and for which governments must have an explicit strategy of risk reduction, through effective mitigation and prevention, measures otherwise the losses due to minor events would continue to have a very high impact from the economic and social point of view in each country.

7 Stratification and optimal intervention of risk

7.1 Introduction

Once hybrid loss exceedance curves that shed light on the risk of each country have been obtained it is possible to make a “stratification of risk” in accordance with the various alternatives of feasible and viable intervention that permits to manage, reduce or transfer it ideally. In other words, stratification of risk is characterized by the fact that those measures are technically and economically viable, which will depend on their applicability in specific ranges or layers of risk. These layers, in general, correspond to a segment where the losses are smaller and occur very frequently, a segment that could be considered of greater losses whose frequency is moderate and a segment or layer of extreme losses that on the average occur very sporadically and that are considered losses of truly a catastrophic nature. Figure 7-1 illustrates the concept of stratification of risk by segments or layers based on the probability of occurrence of losses and the type of intervention measures that can be considered.



1 = High probability & low/moderate losses
2 = Medium probability & moderate/high losses
3 = Low probability & high losses
4 = Very low probability & very high losses

Figure 7-1
Example of risk stratification

In general, possible intervention measures of risk have associated costs whose justification depends on the benefits that each one of them can produce by reducing possible economic and social consequences. Cost-benefit analyses make possible comparison of various measures and thus define which of the risk layers result more or less appropriate for each of them. The alternatives of risk intervention, corrective and prospective, that can be considered in a study such as this, with the limitations of the absence of detailed information of historical events and the resolution that permits estimating risk analytically based on a proxy of exposure, are the following:

a. Use of reserve funds for compensation (retention);
b. Relocation of exposed elements in areas of risk (relocation);
c. Preventive works for reducing threatened areas (prevention);
d. Reinforcement of weak structures exposed to dangerous phenomena (mitigation);
e. Application of construction code and safety standards (regulation);
f. Preventing construction in areas exposed to dangerous phenomena (planning);
g. Instruments for transferring catastrophic risk (transfer).

There are other mitigation measures that should be adopted in all cases because they are related primarily to active non-structural measures that are in general of low cost, such as public information, education, training, community participation, warning systems, capacity building and improvement of governance in general. Therefore, these measures should be part of the permanent policies for risk management by the Government, however, if it is complicated to be able to identify, differentiate and justify those measures in the list of intervention measures possible for exploring, these are far from being correctly sustained through analysis such as those that can be made with risk assessment in physical terms or based on historical events and probabilistic analytical methods.

7.2 Determination of strata of risk

Stratification of risk for a country, a region or city depends on a series of variables that do not allow proposing a single form of establishing segments or layers of risk or their limits in a uniform way. Among these variables are the availability of economic resources for prevention, mitigation, regulation and planning, and the financial costs associated with the instruments of retention and transfer of risk. Furthermore, the current level of exposure (the number of exposed elements in dangerous areas) is very important, the possible intensity of possible dangerous phenomena, the degree of vulnerability of buildings and existing infrastructure, the demand or requirements for population safety and the policy implications of having or not certain levels of safety and to tolerate or accept certain levels of risk.

Figure 7-2 illustrates hypothetically the economic costs of each strategy that can be explored by a government, considering risk retention (capital) and risk transfer, (insurance/reinsurance and the capital market). In general, this scheme can be considered as feasible or appropriate in all cases. Nevertheless, what is impossible to define globally are limits (k1, k2, k3) up to retention and transfer instruments are optimal according to the cost of the sources of resources required for various levels of coverage.

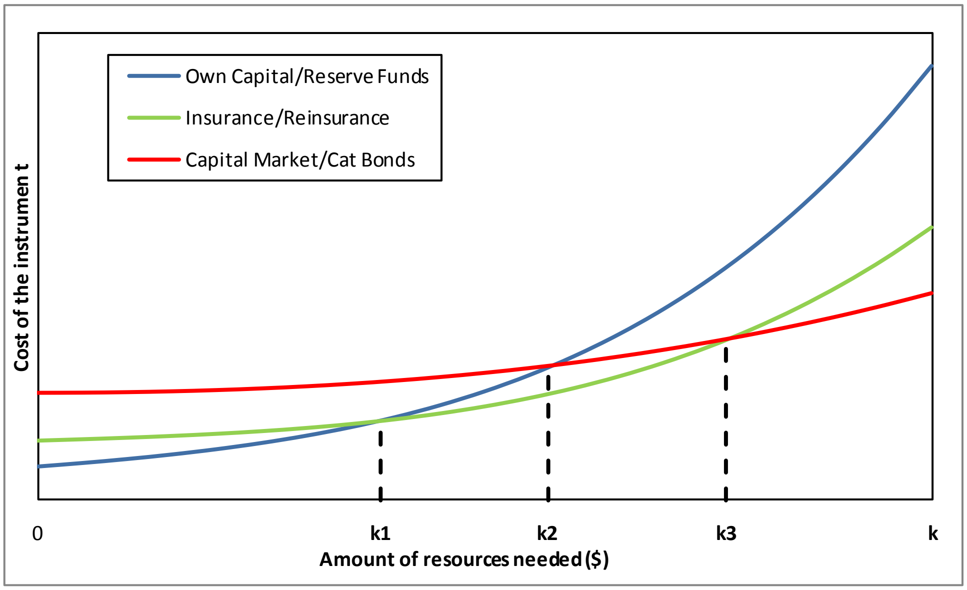


Figure 7-2
Financial costs according to the resources required or losses that must be covered

Considering the alternatives indicated, from the graph it can be deduced that it is not optimal to finance the entire loss from a single source of financing, and that at certain intervals there are other financing sources that can be less costly. For that reason, in theory, it is necessary, then, to construct a function of total costs that represent the weighted sum of financing sources and with algorithms of optimization to find the optimum cost (in this case the minimum) on the basis of that function.

In summary, stratification of risk depends on the loss exceedance probability, which can vary from one country to another or from one region to another. The alternatives or the strategy selected can have different options of measures or activities to implement in accordance with financial aspects and political and social realities. Clearly, there are levels of risk that because of their recurrence are subject to retention and which are obvious to intervene eliminating exposure through relocation of the exposed elements or constructing protection or prevention works that are justified in order to prevent that frequent events cause repeated damage. Above certain levels of risk, it is impossible to prevent the consequences but to reduce them with corrective or prospective mitigation measures of intervention. The regulation or promotion of safety standards such as construction codes or appropriate planning of land use implies defining a level of risk up to which these measures can be optimal and above which it would be desirable to transfer residual risk that, in turn, can be limited to a level of excess of loss up to which it is possible to have a strategy of financial protection.

From the above, it can be concluded that there are corrective and prospective intervention measures for reducing risk (that can be either structural or non-structural, active or passive)[9] and financial strategies for retention and transfer of economic losses that constitute the range of options that can be implemented in order to deal with various levels of risk and whose cost-benefit ratio is the basis for its economic, social and environmental justification.

7.3 Measures of physical intervention

Measures of physical or structural intervention involve the design and implementation of works or activities that make it possible to either decrease the level of hazard or reduce the level of vulnerability of the exposed elements. The type of structural intervention measures that should be adopted depends in general on the type of hazard that determines the risk that wants to be intervened.

For hazards such as earthquakes or hurricane-force winds, mitigation measures are oriented primarily to intervention of the vulnerability of the exposed components. For hazards such as tsunamis, storm surge, or volcanic hazard the intervention measures of risk are oriented primarily towards relocation or restrictive land use in land use plans. For hazards whose effects depend more on local conditions, such as flooding or landslides, structural intervention measures are oriented primarily towards prevention or intervention of the hazard through the construction of works such as contention walls and stabilization, improvements, dikes, embankments and others. These prevention works have a significant impact on all the exposed elements in the area of influence of the dangerous phenomena. Those improvements can range from very simple and low-cost interventions to costly large-scale works. In other words, the costs of the measures prevention are not necessarily related to the number or total cost of the exposed elements, nor with the level of associated risk.

The costs associated with the adoption of mitigation measures that imply reduction of vulnerability and relocation of the exposed elements depend directly on the level of economic risk because it is related to the number and conditions of the exposed elements. A greater number of exposed elements and as their conditions decline, namely a greater vulnerability and exposure, greater will be the investment required for countering risk. Furthermore, because there are various options of mitigation, there are various cost-benefit ratios of the mitigation measures on the basis of which those that present the most favourable ratios can be selected. In general, safety norms at each site define a minimum level of capacity or resistance for those elements in the face of those hazards. Therefore, it is possible to formulate a simplified model that makes it possible to calculate the investment needed to adopt mitigation measures that permit a reduction in the vulnerability to the required levels, in function of the type of element exposed.

The costs associated with this type of measure of intervention increase in function of the level of coverage or application on the exposed elements. Figure 7-3 illustrates

[9] In general, are considered to be structural measures physical interventions, and as non-structural passive activities such as planning and regulation, and active activities such as public information, warning systems, activities that involve the participation of local inhabitants and institutions.

hypothetically this type of behaviour.

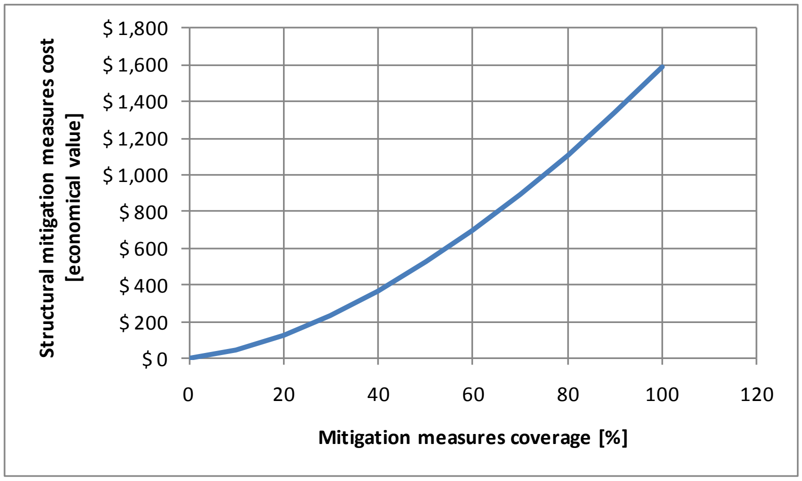


Figure 7-3
Costs associated with structural mitigation measures

On the other hand, the benefits that can be obtained by applying these mitigation measures can be represented in terms of future savings of losses associated with events of various types that can occur. For various levels of coverage (abscissa) the benefit can be calculated as the difference between the net present value of losses in the situation or original state (a certain degree of vulnerability or exposure) and the current net value in the new state (rehabilitated or without exposure), as illustrates Figure 7-4. The most representative cases of this type of expected intervention are the structural reinforcement (rehabilitation) or relocation of buildings and infrastructure.

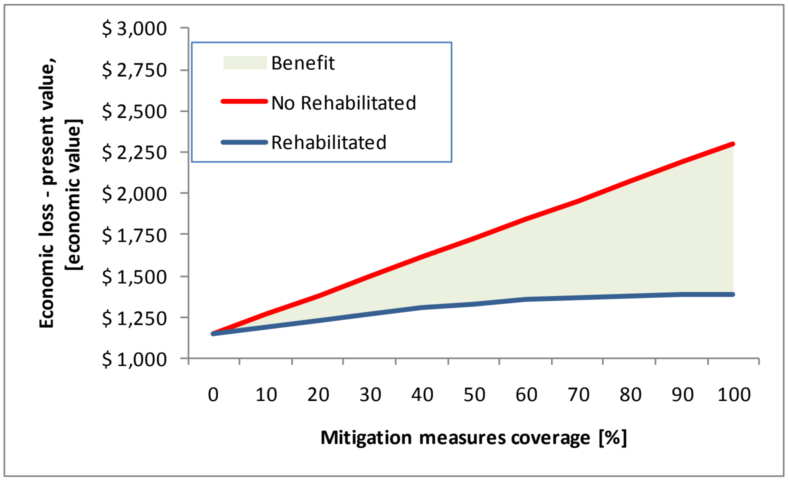


Figure 7-4
Benefit or savings in losses

In general, relocation of exposed elements is a relatively costly measure, which involves removing the exposed elements in areas considered to be of high risk. These measures are applied generally to situations of hazard in which it is not feasible to construct prevention or control works because of their high cost, as would be the case of areas of high hazard of tsunami, storm surge, flooding or by landslides.

Determination of the cost of intervention in this case depends on the number of components or elements to be relocated and these are in general associated with the components of greater risk in the portfolio. In this analysis, it should be taken into account that it is possible that only a limited number of components is in a non-mitigable high risk situation with prevention works. These exposed elements must be identified, independently from the models of risk assessment. Once identified it is relatively simple to propose a model for evaluation of relocation costs in function of the number of elements that have to be relocated.

Prevention works, on the other hand, are expensive measures that imply intervention in the general conditions of an area or a region. This type of interventions depends on the area to be protected and on the type of hazard. In general, it is considered that their implementation is viable in those cases in which this alternative is less expensive or more feasible than the relocation of the exposed elements in the area of influence of that hazard.

7.4 Retention and transfer of economic losses

Depending on the potential losses that can present in the future layers of loss, or strata of risk can be defined, which can be retained or that can be optimum transfer depending on the associated costs from the financial point of view. Figure 7-5 illustrates a structure of layers of loss and a possible strategy of retention and transfer of losses.

The various layers of the retention and transfer structure are established depending on the capacity of solvency of each of the participants and of the convenience in financial terms for the government of each of the various sources of available resources. The costs of each financing source vary in accordance with the level of risk or the amount of losses and the frequency or probability of the same.

Risk transfer is not a mitigation measure itself but, as the name indicates, it is an effective transfer of risk to the insurance and reinsurance sector or to the capital market. For the property-owner, that is surely an interesting alternative that allows him, for a certain annual cost, to cede or transfer the financial risk of their assets portfolio to an insurer.

The cost of this transfer is directly related to the maximum level of coverage. In addition, the transfer cost depends on the lower limit, also known as deductible for the insurer, because the transfer of the lower layers has generally a greater proportional value than for the higher layers because, precisely, of the high frequency of occurrence of this level of losses that involves high administrative and management costs.

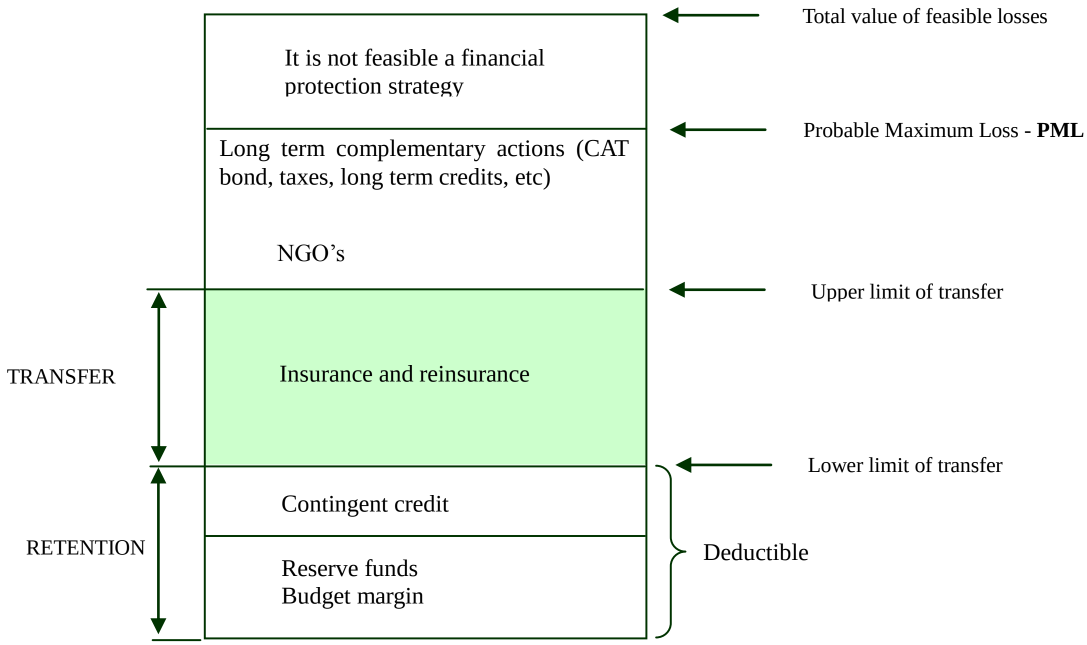


Figure 7-5
Example of the retention and transfer structure

The transfer costs of various layers can be quantified from the value of the expected annual loss that corresponds to the technical pure risk premium. This would be the base value that insurers (e.g. insurance companies) should use in order to calculate commercial premiums, which in addition to taking into account the value of the technical pure risk premium must consider additional costs such as the administrative, financial, indirect and other costs.

7.5 Stratification of risk in the cases of Colombia and Mexico

In the case of Colombia and Mexico it can be observed that if it is taken into consideration, as established by the Superintendencia Financiera and the Comisión de Seguros y Fianzas respectively, that the probable maximum loss (PML) for insurance effects must be that which corresponds to 1500 years of return period, that loss of the hybrid loss exceedance curve (chapter 6) corresponds to values of roughly US$ 7,600 and 10,400 million respectively, for Nepal correspond to 1,850 million. However, supposing a deductible of 1 per cent of fiscal exposure (chapter 5), which could well be what the insurance industry could establish—values that correspond approximately US$ 1,700 and 3,300 million (for Nepal correspond to 155 million), it is seen that those values are similar to the maximum obtained through the loss exceedance curve for historical events. From that, it can be concluded that losses owing to historical events would tend to be covered by the government as a result of the deductible that would be applied for contract insurance coverage for the fiscal responsibility of the Government.

That would mean that the first strata of risk that the government must retain would be, approximately, that corresponding to the first segment of the hybrid loss exceedance curve, obtained with the analysis of historical events. In the case of Colombia, could be considered that that corresponds up to losses of the order of US$ 1,500 million and for the case of Mexico of the order of US$ 3,000 million and Nepal about US$150 million. Above that figure, governments could cover their losses by transferring the risk to insurance and reinsurance (in order to cover the fiscal responsibility), which would be possibly limited by an excess of loss corresponding to the probable maximum loss for 1,500 years of return period, which as stated, corresponds approximately to US$ 7,600 and US$ 10,400 and US$ 1,850 million. Thus, above that value each government could opt for an instrument on the capital market, such as a cat bond or retain the risk again, not establishing an explicit strategy in order to cover greater losses. Keeping in mind that with zero percent deductible the value of the pure premium (chapter 5) in these cases is roughly US$ 300, US$ 800 and US$ 200 million, this would signify that the cost of the coverage abovementioned would be less than those figures because of the deductible that would be established.

It should be pointed out that the first layer that would be retained by the governments in which very high losses can appear would have to be covered with a reserve fund that would imply very high annual budgets. According to the hybrid loss exceedance curve, the annual costs would be of the order of US$ 490, US$ 2,400 and US$ 235 million respectively, where payment of the premiums to cover catastrophic events (between US$ 300, US$ 800 and US$ 200 million) is included. That means that some losses that would appear, in any case, must be reduced through prevention-mitigation measures, otherwise, retaining those losses, is totally inefficient and the social costs are too high as was already illustrated earlier. Given that prevention and mitigation imply costs, it is important, as it is illustrated below, to evaluate the cost-benefit ratio of the implementation of those measures based on the information of losses that could be reduced based on the prospective and retrospective analysis.

7.6 Cost-benefit ratios of physical intervention

Physical intervention, either mitigation or prevention measures, such as vulnerability reduction of the exposed elements, their relocation, the construction of control and protection works, or planning that prevents them from being exposed have a cost-benefit ratio. How this type of measure, fundamental for reducing risk in the various strata of risk, can be analysed and be justified in economic and social terms is illustrated below. Only was evaluated the benefit cost of interventions in the fiscal sector, due seismic events for Colombia and Mexico, Nepal was exclude because we do not know if there is a building code in the country.

The first case to consider consists in using the loss exceedance curve in order to evaluate the impact of the vulnerability reduction (one of the mitigation measures in the terminology used in this report) in dealing with extreme events of the portfolio of assets of the government's fiscal responsibility. It attempts to estimate in prospective terms what would happen if resources were used to intervene, rehabilitate or reinforce the portfolio of buildings that currently do not comply with earthquake-resistant norms and estimate the effect of this hypothetical mitigation measure in the loss exceedance curve. Figure 7-6 and Figure 7-7 illustrate earthquake loss exceedance curves for Colombia and Mexico, for the current state of buildings (fiscal) and considering the structural reinforcement of all buildings that do not comply with norms (i.e. Buildings of fiscal responsibility at the level of safety required by the building code).

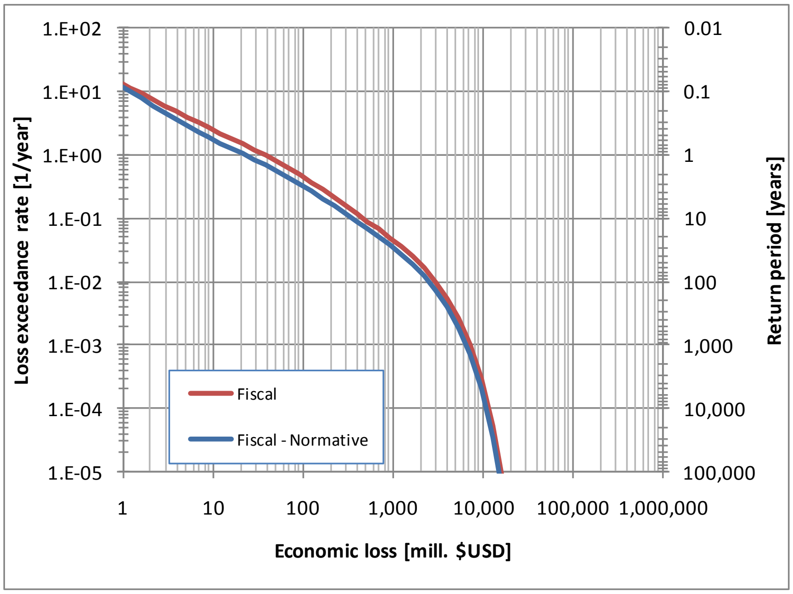


Figure 7-6
Loss exceedance curves for the current state and reinforced buildings of fiscal responsibility in the case of Colombia

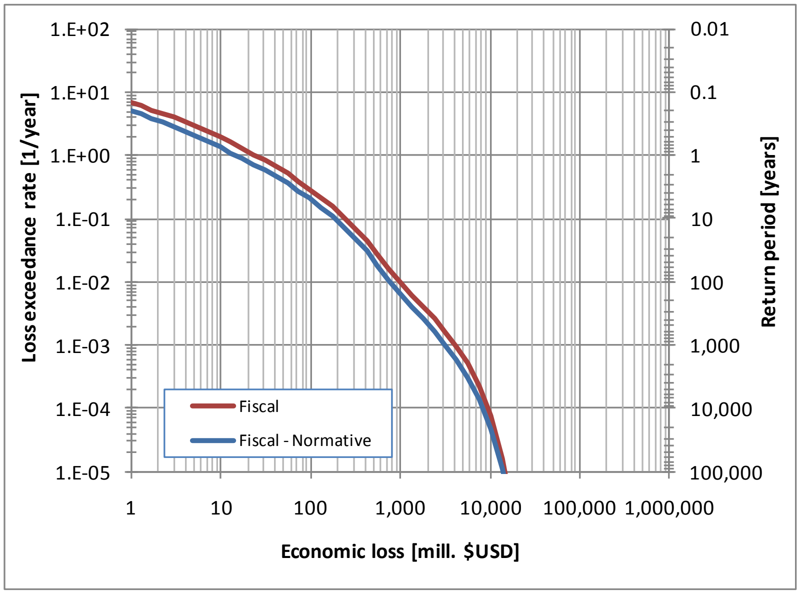


Figure 7-7
Loss exceedance curves for the current state and reinforced buildings of fiscal responsibility in the case of Mexico

A cost-benefit analysis of this mitigation measure is made by estimating the losses of the portfolio—i.e. different loss exceedance curves in order to determine from each one the expected annual loss, taking into account the hypothetical intervention of seismic vulnerability, carrying them to the level required by the code. This hypothetical intervention was made in accordance with the structural system for each type of building, for different percentages of the number of buildings of the portfolio of fiscal responsibility and thus estimate the costs associated with those interventions, beginning with the most vulnerable buildings. The net values of the expected annual loss and the associated cost of rehabilitation for each level of coverage or percentage of modified buildings are estimated.

Figure 7-8 and Figure 7-9 illustrate the reduction in the expected annual loss and the cost of their rehabilitation as more rehabilitated buildings are included, both for Colombia and Mexico. This estimation is made keeping in mind the criterion of prioritization of the risk estimation of the current state of buildings, being first hypothetically rehabilitated those that show greater expected annual loss in relation to their value. For that reason, stabilization both in the reduction of the annual expected loss as well as in the cost of rehabilitation can be seen in the graphs.

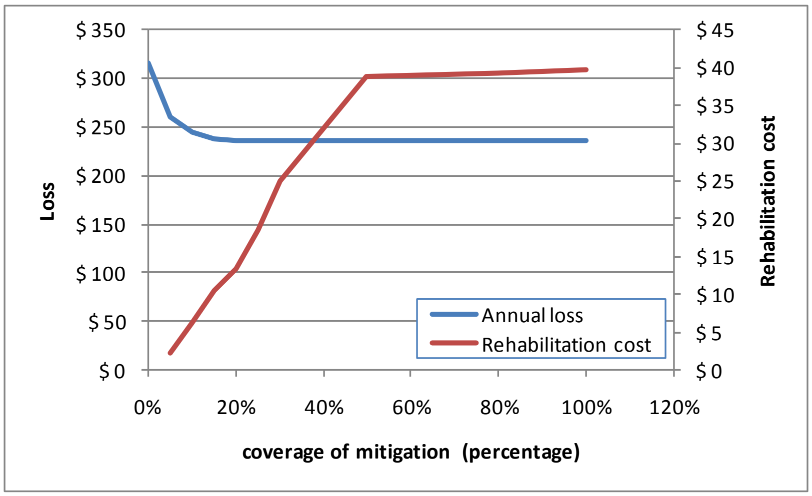


Figure 7-8
Reduction of expected annual loss and cost of rehabilitation of the portfolio of buildings of fiscal responsibility of Colombia

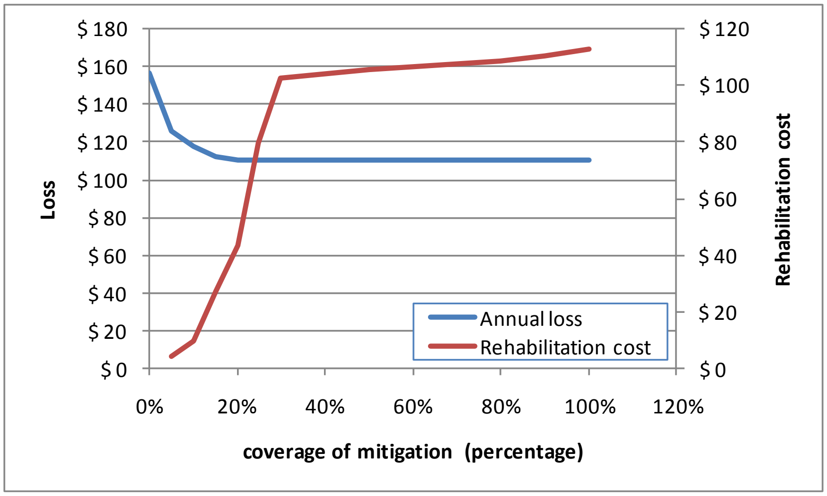


Figure 7-9
Reduction of expected annual loss and cost of the rehabilitation of the portfolio of buildings of fiscal responsibility of Mexico

Note that in both cases, the reduction of losses above a level of coverage of the order of 20 per cent is insignificant, decreasing from US$ 315 million in the current state of the buildings to US$ 235 million in the case of Colombia and US$ 157 to US$ 111 million in the case of Mexico, when coverage of this mitigation measure is 50 per cent of the buildings showing most risk in the portfolio. Likewise, it can be seen that the cost of those measures increases continuously and proportionally to coverage up to a percentage of 50 per cent in the case of Colombia and 30 per cent in the case of Mexico, resulting in a cost of rehabilitation of the order of US$ 40 and US$ 102 million respectively. On the basis of those values, the cost of rehabilitation of the portfolio does not increase significantly because the buildings either complies or what must be invested in order to achieve the same level of safety required by the construction code and earthquake-resistant construction is small. However, in the same graphs is shown that coverage of the investments in mitigation between 20 and 50 per cent of the portfolio of buildings, in the case of Colombia, and between 20 and 30 per cent in the case of Mexico, does not contribute to an effective reduction of the expected annual loss in each portfolio.

In these cases, the cost-benefit rate can be estimated by dividing the benefit, understood as the reduction of the expected annual loss through reduction of vulnerability (loss in the current state minus loss in the rehabilitated state) and the cost of the intervention or of the mitigation made. This cost-benefit ratio is shown for both countries in Figure 7-10 and Figure 7-11. In those graphs, it is shown again that the structural rehabilitation for a percentage greater than 20 per cent of the coverage of each portfolio of buildings of fiscal responsibility, beginning with the most vulnerable, the efficiency of mitigation is reduced significantly, although the cost-benefit ratio, in general, remains greater than 1.

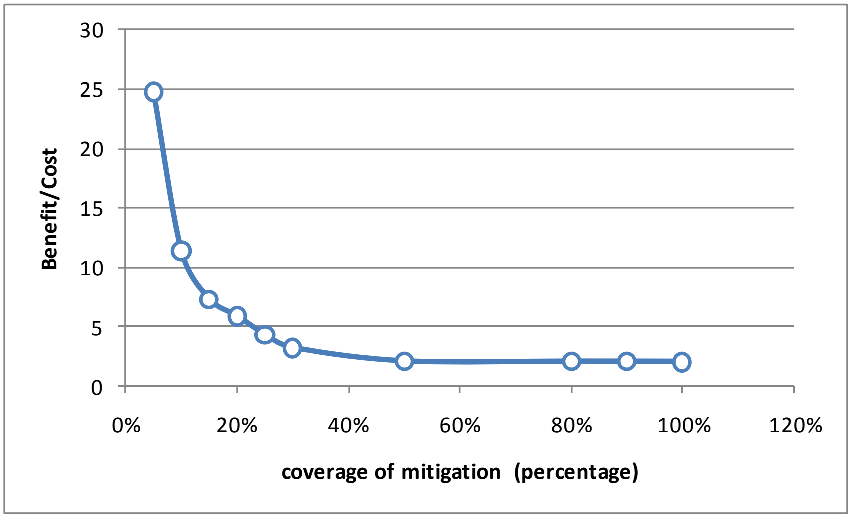


Figure 7-10
Cost-benefit ratio of the intervention of the vulnerability of the portfolio of buildings of fiscal responsibility of Colombia

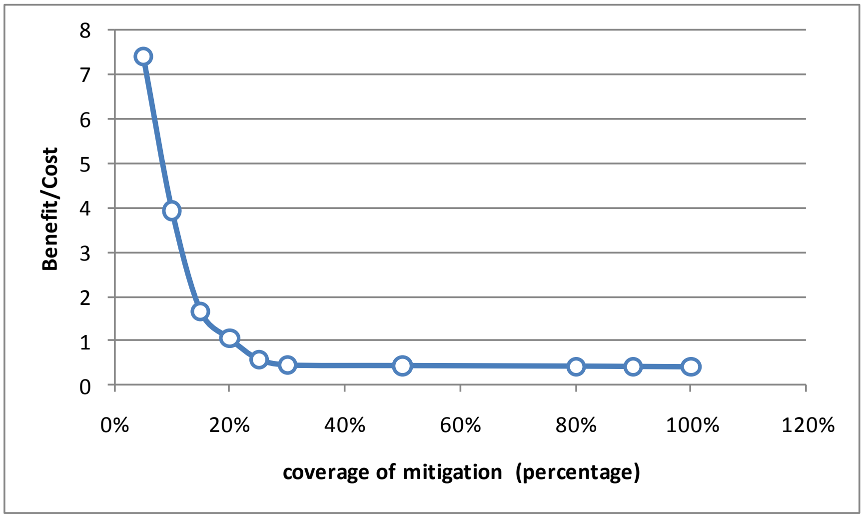


Figure 7-11
Cost-benefit relationship of the intervention of the vulnerability of the portfolio of buildings of fiscal responsibility of Colombia

In accordance with the abovementioned, it can be concluded that a careful and detailed analysis of the portfolios of buildings could be identified, with greater accuracy, up to which point would be justified to invest in structural reinforcement and after that cover the residual risk through a transfer instrument or financial protection.

However, using the available DesInventar databases also an analysis was made in retrospective analysis, considering that for each event some mitigation or prevention measure of risk could have been made. Specifically, there are four different options:

Restriction of exposure in risk areas which in this report have been referred to as:

"planning". This measure makes reference to what would have meant not having permitted that the houses destroyed in the events had been located or constructed at sites where they were. In this case, the cost of the houses that would have been constructed in another location without risk is not included, but is included as cost of mitigation, the investment that would have meant making the studies necessary to make a correct definition of dangerous area and the respective restrictions. This cost is estimated to be the equivalent of one third of the cost of protected housing (assuming that those were housing of priority interest), what could be approximately the value of the ground.

In the second case, the removal in advance of housing from areas at risk was postulated, which in this report are called "relocation". This mitigation measure has the same effect as the previous measure, but implies the demolition of exposed housing and construction of new basic housing for the owners previously located in areas of risk. In this case, the cost of mitigation does include the value of the new housing, which also is considered to be housing of priority interest. The value of this type of housing is a bit less that of housing of social interest.

The third case considered corresponds to the construction of protection and control, which in this report are referred to as "prevention". In this measure, it is assumed that a percentage of all affected and destroyed housing (90 percent) would be benefited by the works and the remaining (10 percent) is considered to be a fraction of the housing that would be affected without total destruction of the housing. The cost of these prevention measures corresponds to a percentage of the cost of housing of priority interest by the number of housing units protected.

Finally, in general, "intervention" in this report is defined as a combination of prevention measures and relocation, based on the protection of a segment of the housing through control works and complementing this measure with the relocation of the housing that is the most vulnerable.

For the effects of this study, the information obtained in the "Encuesta de calidad de vida 2003" of the Nacional Departamento Administrativo de Estadística (DANE) in Colombia was used, in which it is reported that 4 percent of the housing in Colombia is at non-mitigable risk and 10 percent in mitigable risk (through the construction of protection). That means that for hydro-meteorological and landslides events about 30 percent of the affected housing in the events recorded in the DesInventar database was at no mitigable high risk and the remaining 70 percent in mitigable high risk.

In the case of Mexico, although it is considered that a more favourable distribution exists, because of the lack of specific information it is considered appropriate and conservative to use the same percentages estimated in Colombia.

Figure 7-12 and Figure 7-13 illustrate for the case of Colombia and Mexico the accumulated value of the losses that occurred and that would have occurred during the time in which were recorded and the value of the investment of having carried out mitigation or prevention measures in each hydro-meteorological or landslide event occurred and recorded in the DesInventar databases.

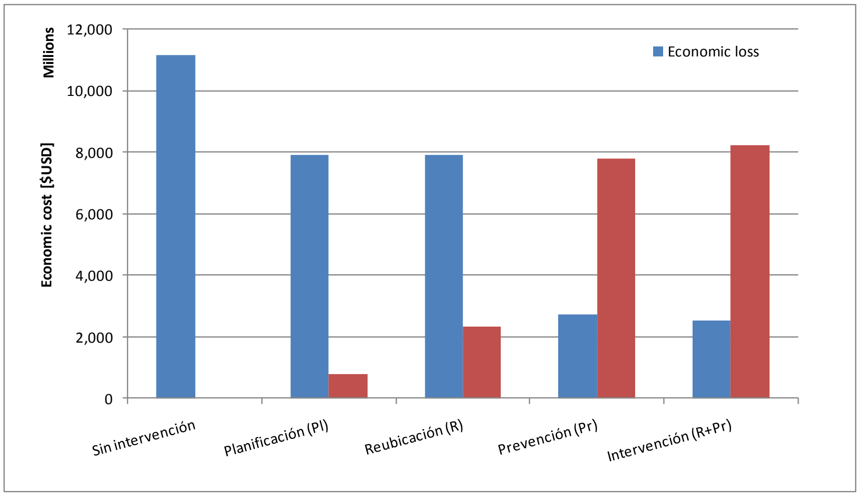


Figure 7-12
Comparison of the value of the losses and investment costs of various options for Colombia

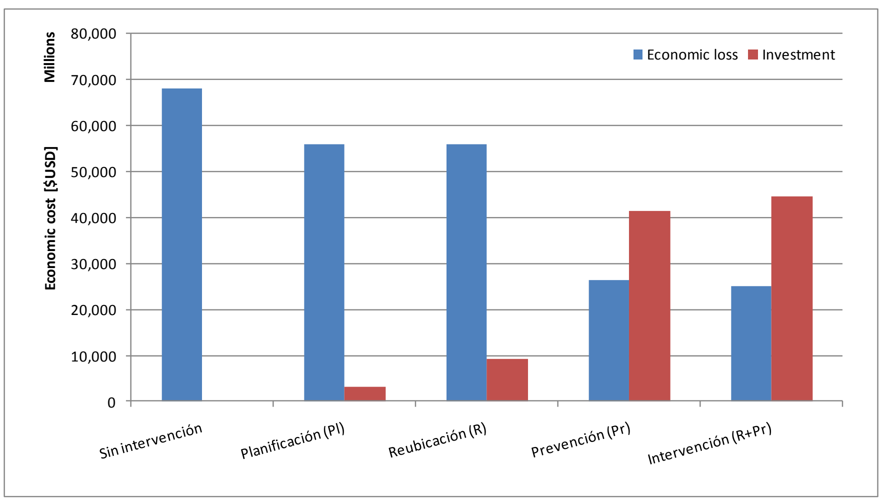


Figure 7-13
Comparison of the value of the losses and investment costs of the various options for Mexico

Figure 7-14 and Figure 7-15 illustrate the cost-benefit ratio of the various alternatives in the event that those measures had been carried out. These are obtained by dividing the difference of the losses by investment in the various alternatives. The rate is considered that in general should be higher because of the impact that would have had mitigation or prevention measures in disasters or later losses. The complexity of the analysis prevents making the analysis in any other way. A greater value of the index signifies a greater benefit.

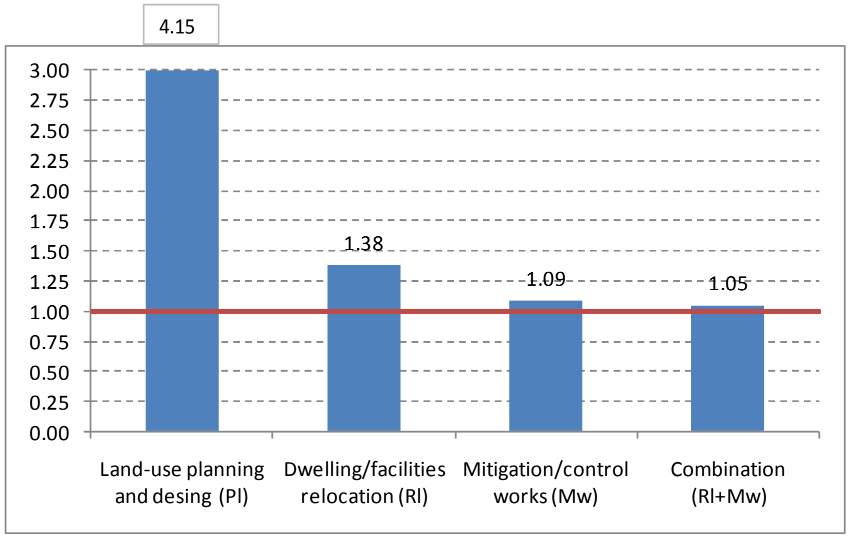


Figure 7-14
Comparison of the cost-benefit ratio of the various options used for Colombia

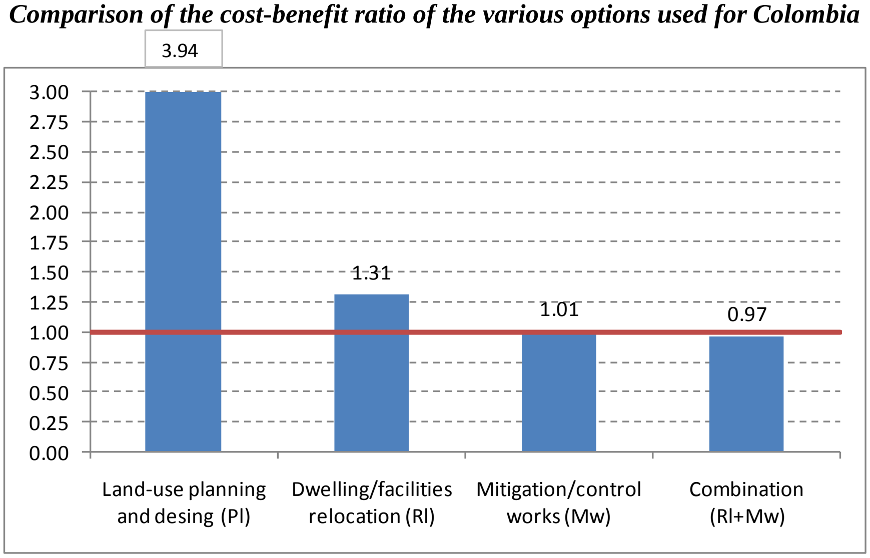


Figure 7-15
Comparison of the cost-benefit ratio of the various options used for Mexico

It should be observed that in general in both countries mitigation and prevention measures would have been justified from the economic point of view.

However, Figure 7-16 and Figure 7-17, present in a similar form the effects on the population with various proposed mitigation and prevention options for Colombia and Mexico. Events corresponding to the category "other events" are not included because in most cases they are not capable of improvement with the measures discussed here.

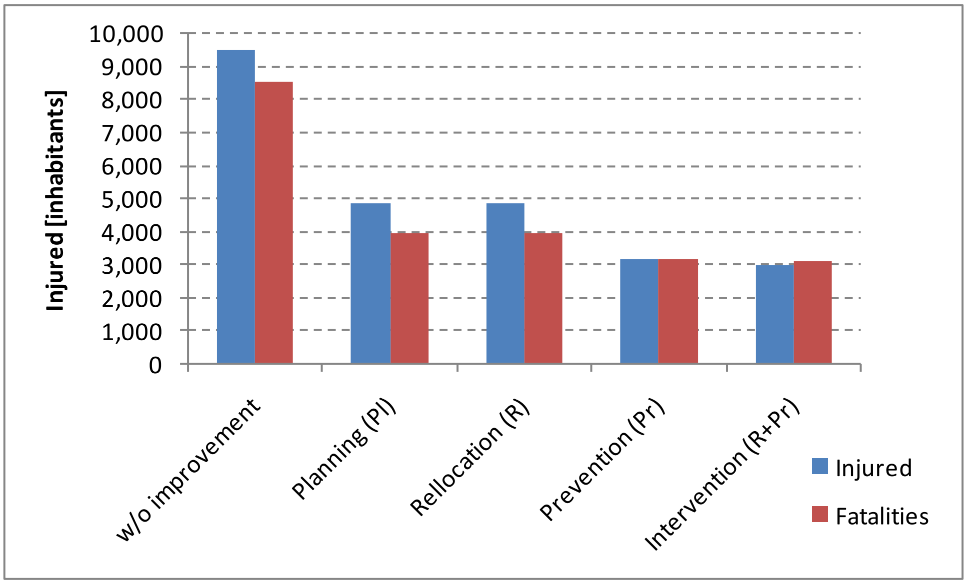


Figure 7-16
Comparison of the effects on the population for the various options used for Colombia

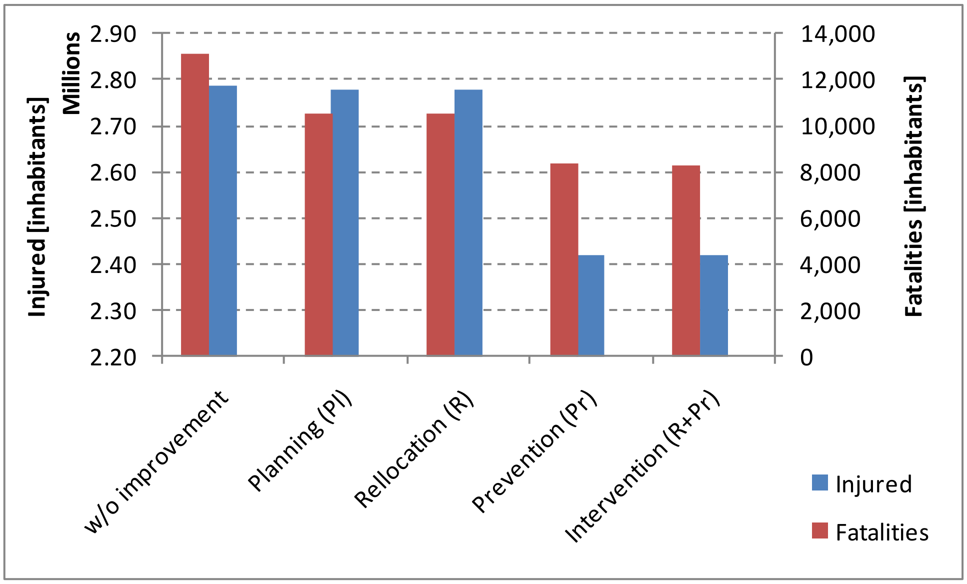


Figure 7-17
Comparison of the effects on the population for the various options used for Mexico

Figure 7-18 and Figure 7-19 illustrate the favourable social impact that would have been derived in social terms by reducing the number of wounded and deaths as a result of mitigation and prevention measures.

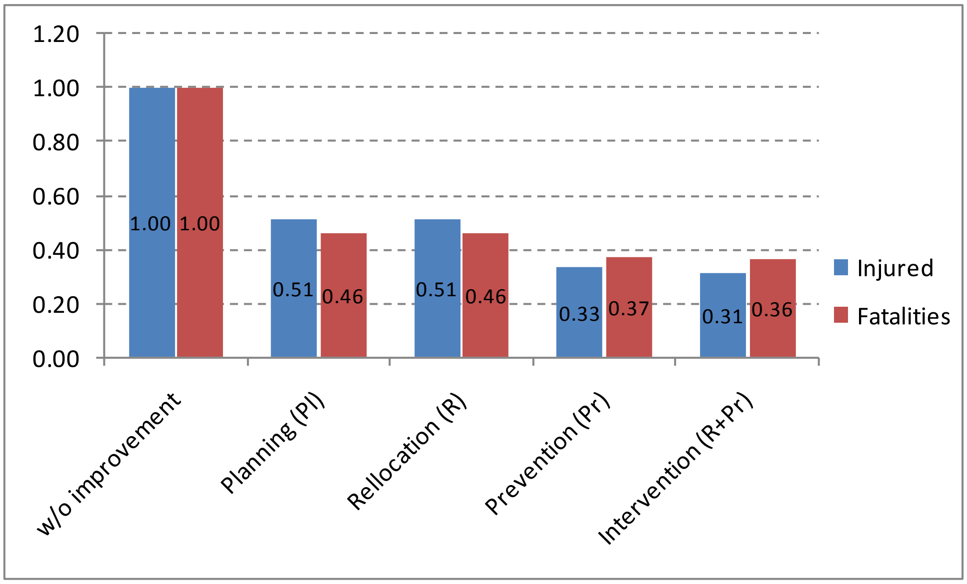


Figure 7-18
Reduction of the effects on the population for various options used for Colombia

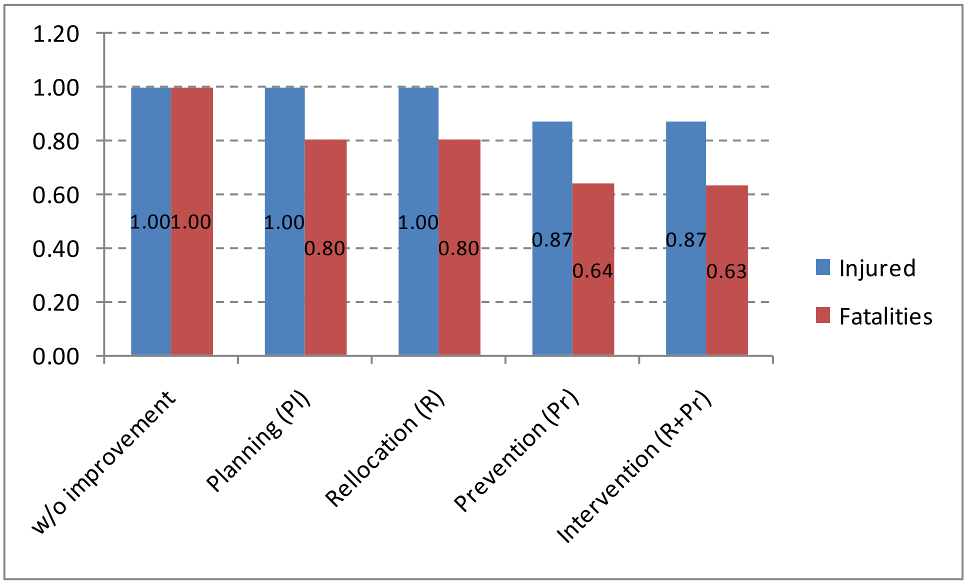


Figure 7-19
Reduction of the effects on the population for various options used for Mexico

Finally, in relation with the risk transfer, it is important to point out that the effect of transferring risk by layers creates changes in the value of the premium or premiums for each layer. Usually, analysis by layers must be carried out when insurance companies, for example, are not in a position to cover the entire expected loss defined for a given return period. In a case such as this, the company must pay for any losses above the priority (or lower layer of retention, if that has been set) to the established limit. That means that the premium that must be paid to the insurance company is reduced, but the part of the loss above that limit remains uncovered, that in turn can be another layer that must be negotiated either with another insurance company, reinsurance company or another type of instrument of transfer or financing. The figure of layers can also be used when the insured party is not interested in full protection because there are other more efficient financial instruments, for example, for the first layers of risk or for the last.

From an analysis of the hybrid loss exceedance curve, the value of the pure premium can be obtained for various initial values of coverage, which are shown in Table 7-1 to Table 7-3 for Colombia, Mexico and Nepal. This premium is reduced by increasing the initial value or less than the coverage (transferred layer). Both, the upper limit and the total exposed value used to indicate the percentage of the lower limit are obtained from the analysis of catastrophic risk, evaluated using the probabilistic model. One comment that can be made is that the maximum extreme events occurred up until now in these countries correspond approximately to a value of losses of the order of 1 percent of the exposed value.

Table 7-1
Expected annual loss for various values coverage for Colombia

Upper limit		AAL
[%]	[mill. US$]	[mill. US$]
0.10	173	341.05
0.30	433	387.37
0.50	866	420.72
0.80	1,299	439.45
1.00	1,732	451.93
2.00	3,465	476.13
3.00	5,197	484.59
5.00	8,661	489.34
7.00	12,126	490.22
9.00	15,590	490.37
10.00	17,323	490.39
41.90	72,542	490.41
100.00	173,226	490.41

Table 7-2
Expected annual loss for various values coverage for Mexico

Upper limit		AAL
[%]	[mill. US$]	[mill. US$]
0.10	330	1,750.73
0.30	825	2,110.83
0.50	1,651	2,291.74
0.80	2,476	2,354.43
1.00	3,301	2,381.05
2.00	6,602	2,413.50
3.00	9,903	2,421.27
5.00	16,505	2,424.11
7.00	23,107	2,424.40
9.00	29,709	2,424.43
10.00	33,010	2,424.44
24.80	81,700	2,424.44
100.00	330,101	2,424.44

Table 7-3
Expected annual loss for various values of initial coverage for Nepal

Upper limit		AAL
[%]	[mill. US$]	[mill. US$]
0.10	15	55.63
0.30	39	83.47
0.50	77	113.06
0.80	116	134.31
1.00	155	150.36
2.00	310	188.85
3.00	464	207.86
5.00	774	224.70
7.00	1,084	230.68
9.00	1,393	232.97
10.00	1,548	233.52
46.00	7,110	234.36
100.00	15,479	234.36

Figure 7-20 to Figure 7-22 present the graphs of the rate-on-line (ROL): pure premium of the layer divided by the value of the layer) for Colombia, Mexico and Nepal respectively. This type of measurement is fundamental for the design of financial protection instruments for the risk transfer that can include alternatives ranging from conventional and parametric insurance and reinsurance, to the securitization of risk or cat bonds, feasible in the capital market.

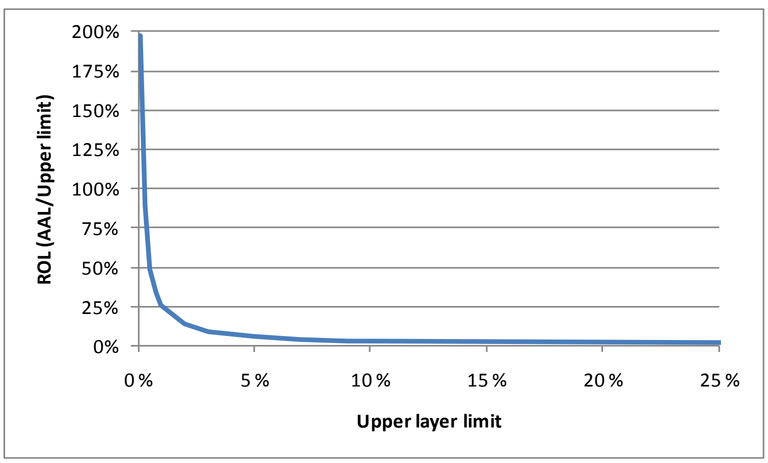


Figure 7-20
Rate-on-line curve for Colombia

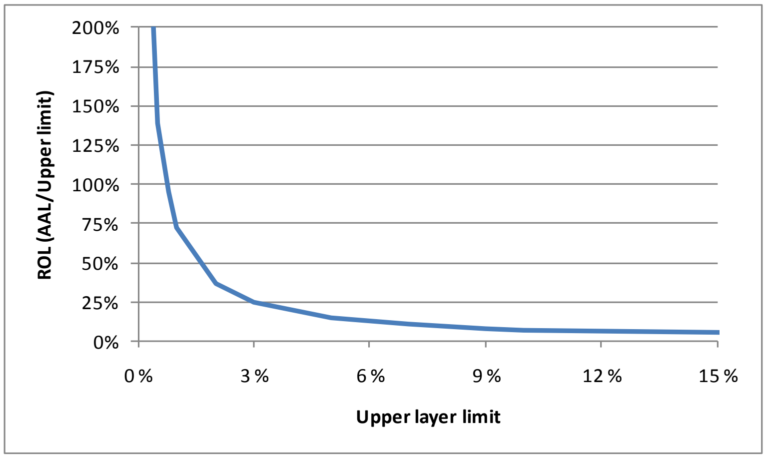


Figure 7-21
ROL curve for Mexico

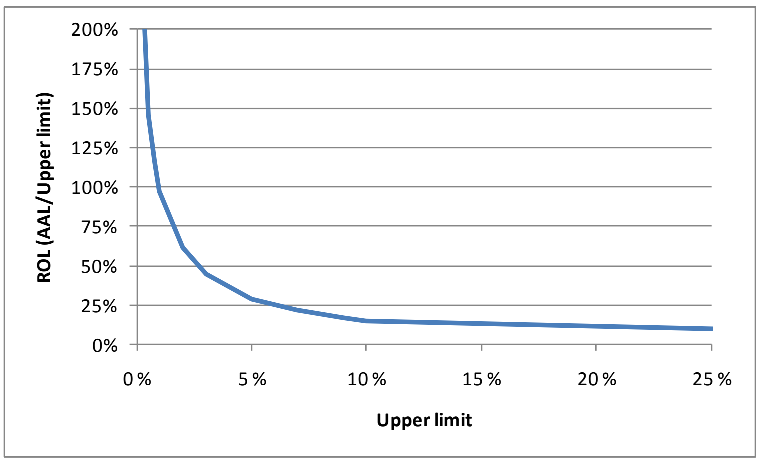


Figure 7-22
ROL curve for Nepal

With this type of information and an established deductible, the value of the premium that must be negotiated with the insurance and reinsurance industry or the capital markets to cover probable maximum losses can be determined. This strata of risk could well be considered as that of transfer, which in the case of Colombia, as already stated, would be between US$ 1,700 and US$ 7,600 million, in the case of Mexico between US$ 3,300 and US$ 10,700 million and the case of Nepal between US$ 155 and US$ 2,100 million. Without a deductible premiums of US$ 300 million, US$800 and US$ 200 million would be required, which would be reduced in a fraction of about one tenth part by having governments assume a first layer of losses between 0.5 and 1 percent of the exposed value. A future more detailed analysis of the portfolio of assets of fiscal responsibility of the Government would permit defining with greater precision the value of the premium for the layer to be transferred that would go from the deductible to the limit of excess of losses that the insurance and reinsurance companies are willing to assume.

Table 7-4
AAL for several coverages - Colombia

Lower limit [mill. US$]	Upper limit [mill. US$]	AAL [mill. US$]
0	1,700	451.16
1,700	7,600	26.63
7,600	173,226	0.70

Table 7-5
AAL for several coverages - Mexico

Lower limit [mill. US$]	Upper limit [mill. US$]	AAL [mill. US$]
0	3,300	2381.03
3,300	10,700	38.40
10,700	330,101	1.66

Table 7-6
AAL for several coverages - Nepal

Lower limit [mill. US$]	Upper limit [mill. US$]	AAL [mill. US$]
0	155	150.44
155	2,100	71.33
2,100	7,110	0.06

8 Conclusions and recommendations

It has been possible to propose and illustrate how risk can be stratified and how strategies can be defined for dealing with it using a cost-benefit analysis. Although this type of work clearly should be carried out at all territorial levels and with as much detail as possible. This innovative study at the country level, within the framework of the global vision of the GAR 2011, shows that it is indispensable to measure risk retrospectively, with an inductive or empirical focus, and at the same time prospectively, with a deductive and probabilistic focus. This work, using Colombia, Mexico and Nepal as case studies, has made it possible to propose and carry out for the first time a methodology of risk assessment with the goal of stratifying it, based on the hybrid construction of loss exceedance curves, using DesInventar, in order to take into account the extensive risk, and using a proxy of exposure, in order to take into account the intensive risk using an analytical technique.

The contribution, approach and case studies used in this study permit not only to illustrate but also to promote the interest of decision makers for an effective risk management through careful risk assessments. Assessment with an approach that makes it possible to demonstrate and measure the impact of the extensive risk, owing to the multiple minor events that when taken together imply considerable cost and significant social and environmental effects, which must be mitigated with efficient and effective intervention strategies, as well as measure the impact, often unexpected, of intensive risk, associated with the potential occurrence of extreme events, whose consequences can affect the fiscal sustainability and sovereignty of a country and which, therefore, are contingent liabilities that must be the object of wise strategies of financial protection.

Given that this is the first time that a work of this type has been made from a governmental perspective, especially with this focus, at the global level, ERN-AL, as consultant for the Global Assessment Report, recommends beginning a continuous process of studies with this same scope and resolution for those countries that have a DesInventar database and that through the CAPRA system can be evaluated using a proxy of exposure at the national level. Therefore, those countries that have DesInventar should begin by create this type of database. Also, the countries, in general, should begin to become familiar with platforms such as CAPRA in order to understand probabilistic approach to risk that in general very few persons have mastered and know in practice.