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

ERN

CAPRA

CENTRAL AMERICA PROBABILISTIC RISK ASSESSMENT

EVALUACIÓN PROBABILISTA DE RIESGOS EN CENTRO AMÉRICA

BELIZE

TASK III
RISK EVALUATION

<u>TECHNICAL REPORT SUBTASK 3.2</u>
PROBABILISTIC RISK MODELS

CEPREDENAC

Estrategia Internacional para la Reducción de Desastres EIRD

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1 Probabilistic risk analysis

1.1 General

A probabilistic risk analysis is basically intended to determine the distribution of probability of loss which exposed assets may suffer over a given period of time, as a consequence of the occurrence of natural hazards, rationally integrating the uncertainties which exist in different parts of the process. The basic question that a probabilistic analysis attempts to answer is, given that there is a set of assets exposed to the effects of one or more natural hazards, how often will losses over a certain value occur?

Given that the frequency of catastrophic events is particularly low, it is not possible to answer that question by constructing purely empirical models of the process of occurrence of such events. This means that we must construct probabilistic models such as that described here.

The procedure for probabilistic calculation is therefore, an evaluation of losses that will affect a group of exposed assets during each of the scenarios which collectively describe the hazard, and then probabilistically integrating the results obtained using the frequency of occurrence of each scenario as a weighting factor.

The probabilistic analysis of risk involves uncertainties which cannot be ignored, and which should be propagated throughout the process of calculation. This section describes the general basis of calculation that can be used to achieve the objective proposed.

1.2 Risk analysis

1.2.1 *Procedure for analysis*

The evaluation of risk requires three analytical steps, as follows:

- *Hazard assessment:* For each of the risks considered, a set of events is defined along with their respective frequencies of occurrence, which are an integral representation of the related hazard. Each scenario contains spatial distribution parameters which will permit the construction of the distribution of probability of intensities produced by the occurrence.

- *Definition of the inventory of exposed elements*: An inventory of the exposed elements must be made, and this should specify their geographical location, and the following parameters to classify them:
    - o Physical valuable cost of replacement
    - o Human value, or number of occupants estimated
    - o Structural class to which the assets belongs

- *Vulnerability of the constructions*: Each class of structure must be allocated at a function of vulnerability for each type of hazard. This function characterizes the comportment of the asset during the occurrence of the hazard phenomena. The functions of vulnerability define the distribution of probability of loss as a function of the intensity produced during a specific scenario. This is defined through curves which relate the expected value of damage and standard deviation of damage with the intensity of the phenomenon.

1.2.2 *Basic equation*

Given the basic objective of the probabilistic analysis of the risk mentioned, a specific method must be found to calculate in order to calculate the frequencies of occurrence of specific levels of loss associated with the exposed assets over defined periods of time, and with the occurrence of natural hazards.

The risk of natural hazards is commonly described as an exceedance curve or loss curve, which specifies frequencies, usually annually, with which events will occur that exceed a specified value of loss. This annual loss frequency is also known as the exceedance rate, and it can be calculated using the following equation, which is one of the many ways adopted by the theorem of total probability:

$$\nu(p) = \sum_{i=1}^{Eventos} \Pr(P > p \mid Evento\ \mathrm{i}) F_A(Evento\ \mathrm{i}) \qquad \textbf{(Ec. 1)}$$

In this equation *v(P)* is the rate of exceedance of loss *p*, and F_A *(Event i)* is the annual frequency of occurrence of the *Event i*, while *Pr(P>p(Event i)* is the probability that the loss will be higher than *p,* given that the i-th event occurred. The sum of the equation is made for all potentially damaging events. The inverse of *v(p)* is the return period of loss *p*, identified as *Tr.*

As will be seen later, the loss curve contains all the information required to describe the process of occurrence of events which produce loss in terms of probability.

The loss *p* referred to in the equation 1 is the sum of the losses that occur to all the assets exposed. The following should be borne in mind:

- The loss *p* is an uncertain quantity, whose value given the occurrence of an event, cannot be precisely known. Therefore, it must be seen and treated as a random variable, and mechanisms should be constructed to discover the distribution of probability in it, conditional on the occurrence of a certain event.

- The loss *p* is calculated as the sum of the losses which occur in each of the exposed assets. Each of the items in the sum is a random variable, and there is a certain level of correlation between them, which should be included in the analysis.

A careful approach to equation (1), the probabilistic calculation has the following sequence:

1. For a scenario, to determine the distribution of probabilities of loss in each of the assets exposed.
2. Based on the distribution of probability of each of the losses of each asset, to determine the distribution of probability from the sum of these losses, taking account of the correlation which exists between them.
3. Once the distribution of probability is determined from some of the losses in this event, calculate the probability that this will exceed a given value p.
4. The probability determined in (3), multiplied by the annual frequency of occurrence of the event, is the contribution of this event to the rate of exceedance in the loss p.

The calculation is repeated for all events, and this obtains the result indicated by equation 1.

It is also interesting to note that in equation 1 there is no distinction between events which belong to different hazards. In effect, the sum in this equation may include, for example, earthquakes and hurricanes or earthquakes and volcanic eruptions. This is so because the supposition is that both the events associated with the same hazard and the events associated with different hazards do not occur simultaneously. However, some phenomenal which are potentially damaging do occur simultaneously, and in such cases special care should be taken in determining the distribution of the probability of p, as analyzed in the next section.

1.2.3 *The temporality of hazards*

Some natural phenomena produce losses of different kinds, and they occur simultaneously. For example, the occurrence of a hurricane generates strong winds, and flooding due to higher sea levels, and intense rain associated with the precipitation; the damage due to wind and flood, therefore occur almost simultaneously and cannot be considered as independent events.

The case mentioned above can be considered as one in which three different hazards (wind, flooding from storm-surge, and flooding due to excess rain) occur simultaneously, associated with the same *temporality.*

With this in mind, the hazards studied in this phase of the project can be grouped into temporalities indicated in Table 1-1.

Table 1-1
Temporality of the hazards

ANALYSIS OF THE TEMPORALITIES OF THE HAZARDS	TEMPORALITY			
Type of hazard	**1**	**2**	**3**	**4**
Earthquake				
Tsunami				
Hurricane - Wind				
Hurricane – Storm-surge				
Hurricane - rain				
Non-hurricane rain				
Flooding				
Landslide				
Volcano – Ash fall				
Volcano – Pyroclastic flows				
Volcano – Lava Flows				

According to the table above, the earthquake, understood as a movement of the ground induced by seismic waves, the tsunami and landslides which can be induced by the movement will occur in the same temporality (1, according to Table 1-1), but in a temporality which is different from that in which damage due to wind, storm-surges and floods will occur.

The evaluation of the loss during a given scenario is therefore made by considering that the hazards which belong to the same temporality occur simultaneously. There is no simple or unambiguous way of evaluating losses in such conditions (several hazards occurring simultaneously). For the purposes of this project, the following expression has been proposed to evaluate the loss to each of the exposed assets, which corresponds to a model of damage as a cascade, in which the order of exposure of different intensities is irrelevant:

$$P_i = \prod_{j=1}^{M} (1 - P_{ij}) \quad \textbf{(Ec. 2)}$$

where P_i is the loss associated with a scenario I, P_{ij} is the loss associated with scenario I because of the hazard j., and M is the number of simultaneous hazards considered in the timeframe to which scenario i belongs.

It should be remembered that P_{ij} are random variables, and therefore, Pi is also a random variable. However, if the distribution of probability of P_{ij} is known, and reasonable assumptions are made as to their level of correlation (that they are perfectly correlated, for example), the moments of the distribution probability of P_i can be determined based on equation 2.

1.2.4 *Uncertainties*

As observed in equation 1, and as proposed above, the loss suffered in a group of exposed assets during a given scenario is an uncertain quantity, which should be treated as a random variable.

Generally, it is not practical to make a direct determination of the distribution of the probability of loss in the exposed assets, conditional on the occurrence of a given scenario. In other words, for example, it is not practical to determine addition the distribution of the probability of the loss in a building, given that, a force six earthquake occurs at a place 60 miles away.

For methodological reasons, the probability of exceeding of the loss *p*, given that an event occurs, common is commonly expressed as follows:

$$\Pr(P > p \mid Evento) = \int_I \Pr(P > p \mid I) f(I \mid Evento) dI \qquad \textbf{(Ec. 3)}$$

The first term of the items to be integrated, Pr(P>p|I),P, is the probability that the loss will exceed the value *p* given that the local intensity was *I*; this term, therefore takes account of the uncertainty which varies in relations of vulnerability. Further, the term f(I|Event) is the density of probabilities of the intensity, conditional on the occurrence of the event. This term takes account of the fact that, given the accounts of an event, the intensity at the place of interest is uncertain.

1.2.5 *Specific risk estimators*

As indicated above, the curve calculated by applying equation 1 contains all the information required to characterize the process of occurrence of events which produce losses. However, it is sometimes not practical to use a complete curve, and therefore it is convenient to use specific estimators of risk which will allow it to be expressed by a single number. The two specific estimators most commonly used described here described as follows:

(a) *Average annual loss (AAL)*: this is the expected value of the annual loss. It is an important quantity, since it indicates, for example, whether that if the process of occurrence of the damaging event is stationary between here and eternity, its cost will be the equivalent of having AAL paid annually. Therefore, in a simple insurance system, the annual expected loss would be the pure annual premium. AAL can be obtained by integrating *v(p)*, or by the following expression:

$$AAL = \sum_{i=1}^{Eventos} E(P|Evento\ \text{i}) F_A(Evento\ \text{i}) \quad \textbf{(Ec. 4)}$$

(b) *Probable maximum loss (PML)*: This is a loss which does not occur that frequently, that is, it is associated with a very long return period (or, alternatively, a very low exceedance rate). There are no universally accepted standard to define what is meant by "not very frequently". In fact, the choice of a return period or the other to take some decision depends on the risk aversion of who are deciding. In the insurance industry, for example, the return periods used to define the PML range from 200 to at least 2500 years.

1.2.6 *Probability of loss exceedance*

The loss curve, *ν(p)*, calculated with equation 1, indicates the frequency with which events will occur to produce losses equal to or higher than a given loss *p*. If we suppose that the process of occurrence of events in time follows a Poisson process, then it will be possible to calculate the probability that the loss *p* will be exceeded in a period of time T, that is, in the next T years, with the following expression:

$$Pe(p,T) = 1 - e^{-\nu(p)T} \quad \textbf{(Ec. 5)}$$

where *Pe(p,T)* is the probability that the loss *p* will be exceeded in the next T years.

1.2.7 *Analysis for a single scenario*

The probabilistic risk analysis is normally conducted for an entire set of specific scenarios of different hazards. However, if desired, the analysis can be made for a single scenario (only one of the elements to be added in equation 1). If the annual frequency of occurrence of the scenario is taken as 1, the application of equation 1 would lead us to the probabilities of exceedance (and not annual frequencies of occurrence) of loss, given that the scenario in question happened.

This case has important applications in the field of land-use planning, since results mapped for example in terms of expected loss values, are easily incorporated into land use-plans.