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Natural disasters mitigation in the world and sustainable development: a Risk Analisys approach

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ABSTRACT

The problem of natural disasters in the world is analysed, not from the common approach, that of Hazard Assessment, but from the Risk Analysis approach, risk being the expected loss, to achieve a Sustainable Development.

During the period 1990-1999, these natural phenomena have produced, in events with at least ten mortal casualties, more than 407.682 dead & missing, with an annual mean 28% lower than that for the period 1965-1999. Cyclones, earthquakes and floods, in this order, have produced more than 90% of the casualties. The interannual coefficient of variation of casualties 1990-1995 was 1,02, almost double the one for economic losses, 0,55. For the same period, these losses reached an annual average of 65.099 USD million, 0,33% of Gross World Product. Most of casualties have been in undeveloped countries, contrary to the economic losses, of which the Kobe (Japan) 1995 earthquake, stands out as the biggest economic disaster of the century, resulting in a for 100 billion USD loss. At a world level, 20% of losses were insured. In GNP terms, economic impacts were much higher in undeveloped countries.

It is shown that the real significance of natural disasters comes from the fact that they are the main disasters at societal and economic levels, not from the absolute figures of losses. This fact focuses mitigation efforts on the Preparedness: the identification and Risk Analysis of potential scenarios of disasters and the postdisaster research with Multidisciplinary Commissions of Investigation in order to better learn the lessons of Nature.

To apply Risk Analysis, it is necessary to differentiate Societal and Economic Risk, because they do not coincide in different hazards and environments, and priority in government action might focus, in application of the Subsidiary Principle, more on protection of human life than on minimization of economic losses. For the latter there are tools such as insurance with penalties for risk exposure, from hazard maps, the best and first investment in any mitigation strategy. It is shown also how to rationally design Mitigation Strategies by using Societal Risk Acceptability Criteria and cost-benefit analysis. A general Technical-Administrative Procedure of Population Risk Assessment, similar to the Environmental Impact Assessment, is proposed. This procedure might be the best tool to achieve a higher level of human development measured according the UN Human Development Index.

Key words: International Decade for Natural Disaster Reduction, mitigation strategies, natural disasters, risk analysis, sustainable development

Desarrollo sostenible y mitigación de desastres naturales en el mundo: una aproximación desde el Análisis de Riesgos

RESUMEN

Se presenta un análisis del problema de los desastres naturales en el mundo, no desde la aproximación usual, la Evaluación de Peligros o Amenazas, sino desde la perspectiva del Análisis de Riesgos, entendiendo el Riesgo como la pérdida esperada, al servicio del Desarrollo Sostenible.

Durante el período 1990-1999, estos fenómenos naturales han producido, en sucesos con al menos diez víctimas mortales, al menos 407.682 muertos, un 28 % menos en media anual que la del período 1965-1999. Los fenómenos que han producido más del 90 % de las víctimas, han sido las tormentas ciclónicas, los terremotos y las inundaciones. El coeficiente de variación interanual ha sido de 1,02, el doble que el de las pérdidas económicas, 0,55, que para el período 1990-1995, han sido evaluadas en una media anual de 65.099 millones de $ USA (76.587 millones de euros), el 0,33 % del Producto Bruto Mundial. La inmensa mayor parte de las víctimas se han producido en países en vías de desarrollo, al revés que las económicas, destacando el terremoto de Kobe (Japón) de 1995, el mayor evento siniestral del siglo XX, con 100.000 millones de $ USA (117.647 millones de euros). El 20 % de las pérdidas en el mundo estaban aseguradas. El impacto económico en términos relativos al PIB, fue sin embargo mucho mayor en los países poco desarrollados.

Se demuestra como la importancia de los desastres naturales no proviene de las cifras absolutas de víctimas o pérdidas económicas sino de ser los principales desastres a nivel social y económico a nivel mundial. Este hecho focaliza el objetivo de la filosofía clave de miti-

gación, la preventiva, que busca la Mitigación del Riesgo, tanto en la identificación y Análisis de Riesgos de escenarios de posibles catástrofes como en la investigación, con Comisiones Pluridisciplinares de Investigación, de los desastres, para aprender las lecciones de la Naturaleza.

Con vistas a la aplicación del Análisis de Riesgos, se muestra la necesidad de diferenciar el análisis del Riesgo Social del Económico, ya que aparte de su no coincidencia en diversos fenómenos y entornos sociales, la prioridad de la acción gubernamental debería pivotar, en aplicación del Principio de Subsidiariedad, sobre la protección de la vida más que la de la propiedad, que cuenta con mecanismos como los seguros, con penalizaciones a la exposición al riesgo basadas en mapas de riesgos, la mejor y primera inversión en cualquier estrategia de mitigación. Se muestran también las vías para un diseño racional de las Estrategias de Mitigación basándose en Criterios de Aceptabilidad Social del Riesgo y en el análisis coste-beneficio. Se propone asimismo el establecimiento de un Procedimiento Técnico-Administrativo de Evaluación de Riesgos para la Población, similar al de Evaluación de Impacto Ambiental pero con el objetivo de proteger la vida humana. Este procedimiento podría ser la herramienta para lograr un mayor desarrollo humano medido a través del Indice de Desarrollo Humano de la ONU.

Palabras claves: análisis de riesgos, Decenio Internacional para la Reducción de Desastres Naturales, desastres naturales, desarrollo sostenible, estrategias de mitigación

Introduction

Natural disasters represent a widespread problem in the world. They also pose an increasing problem for a sustainable World in absolute terms, both social and economic, as will be shown below. This is the reason why the United Nations has declared the International Decade for Natural Disaster Reduction (IDNDR) 1990-2000.

The main objective of scientific and technological research in natural disasters is mitigation. Mitigation, "the measures taken independent from an emergency situation or actual disaster" (National Research Council, 1994), must emphasize preventive measures because emergency measures, in general, are very limited in their ability to avoid human and economic losses.

The theoretical tool for a rational preventive mitigation is called Risk Analysis. Risk Analysis, as shown in the Figure 1, has three stages: a) Risk Factor Analysis b) Risk Assessment c) Risk Reduction Analysis.

Natural Risk is the expected loss due to the action of a natural hazard. If we consider expected human losses, we have the so-called societal risk, with several types according with the expected dead, injured, homeless and unemployed; if we consider expected economic losses, we have the economic risk, with several kinds according to structural damage, content damage, benefit loss and so on.

The existence of natural risks is a consequence of the existence of all the risk factors (Ayala-Carcedo, 1993): Hazard (with a severity or intensity and a probability of occurrence), Exposure(of people or goods) and Vulnerability to this exposure, a degree of loss from 0(no damage) to 1(destruction or dead). Only when all the risk factors exist is there risk, a conceptual reality (Figure 2). In a simplified quantitative way, Risk may be expressed as:

$$R=\Sigma P\cdot V\cdot E$$

R: Risk (Expected Annual Losses); P: Annual Probability of occurrence; V: Vulnerability (0-1); E: Exposure

Obviously, preventive measures intend risk mitigation, the best way to limit the effects of disasters.

The use of the results of Risk Analysis, with organisational, financial and management measures, is called Risk Management (see for instance Kauf, 1978).

Most of the approaches taken from Natural Sciences and Engineering to the problem are hazard approaches, studying both Severity and Probability. Risk Analysis is a global approach, which includes Social Sciences. This approach is more convenient from the point of view of decision-makers because people are interested in the mitigation of damages.A good national study carried out in the USA from this point of view was published in 1984 by Petak & Atkisson.

In the history of Mankind the main disasters from natural causes have been those produced by great epidemics such as those in the XIV Century from bubonic plague, ("Black Death"), killing around one fourth of the European populations (McNeill, 1984). The impact of these natural biohazards has been, and is, several thousand times greater than the impact of violent physical natural hazards, meteorological and geological (Ayala-Carcedo, 2000 a), analysed in this paper. Famines produced by drought, often coincident with war, are another cause of death much more important than violent disasters in semiarid and arid poor countries, producing some 8,2 million casualties during the XXth Century (German IDNDR-Committee, 1994).

It is important to differentiate an event resulting from a hazard and that resulting from a disaster. All disasters are events but not all events are disasters. An event may or may not produce damages in a com-

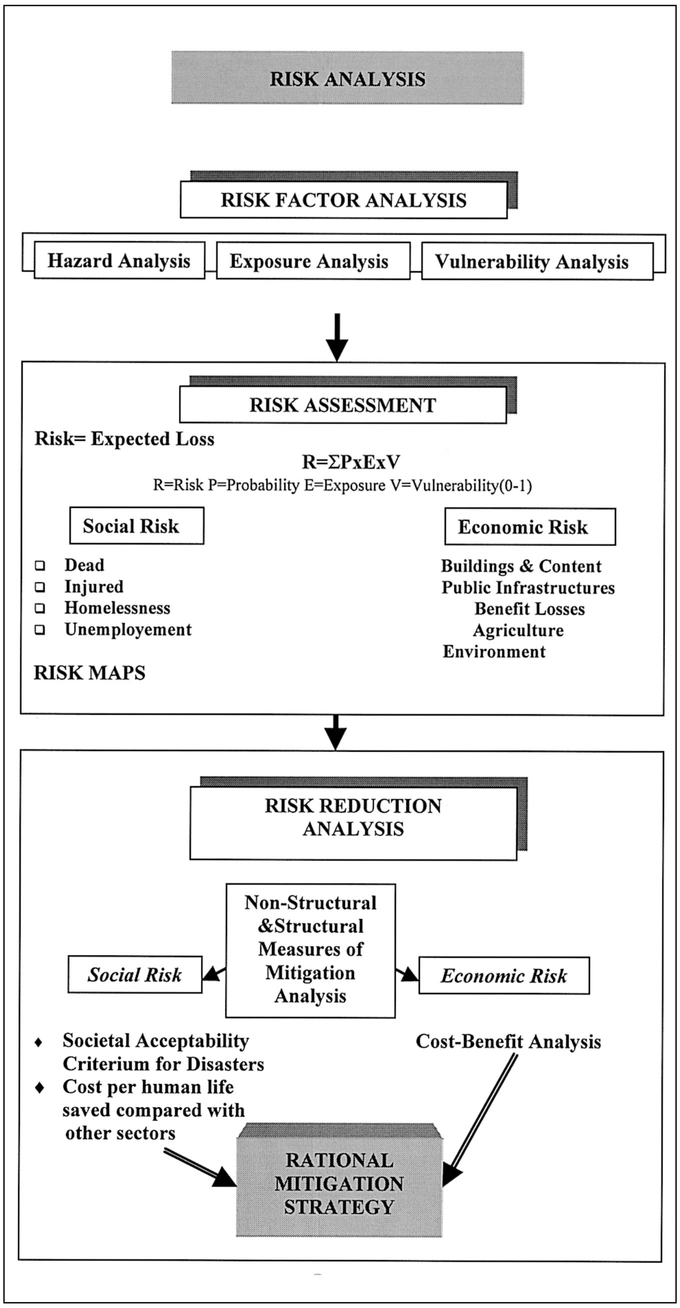

Fig. 1. The Risk Analysis
Fig. 1. El Análisis de Riesgos

munity; a disaster always produces damages over a given threshold. For operational purposes the criterion used here is that a societal disaster is an event causing at least 10 deaths; this is the approximated threshold used at national, and sometimes, global media, an index of potential interest of people in these events. It is very difficult to find one single criterion to define economic disasters, because the importance is different at local, regional and global scales or at the level of insurance or industrial companies.

There is a problem in the attribution of human and economic losses between floods and meteorological hazards with intense rainfall. Many times the immediate cause of damage is flooding produced by the meteorological event, the triggering phenomenon. In this paper we have differentiated between cyclone phenomena of different sizes with severe winds such as hurricanes, typhoons and tornadoes, and floods triggered by other meteorological phenomena such as frontal rainfalls and monsoons.

Societal impacts of violent natural disasters

The societal impacts are at the individual level: dead, injured (short and long duration), sufferers (including the individuals directly impacted by the emergency, mainly people suffering evacuation and often psychological disorders) and unemployed produced by the disaster. At the societal level, the global societal structure may be changed in a good or, in general, a bad way, but the family structure suffers serious disorders.

Data reliability of societal impacts is in general good for developed countries and not very good for undeveloped ones; reliability decreases with the size of the disaster. This means that casualties assessment for great catastrophes in undeveloped countries

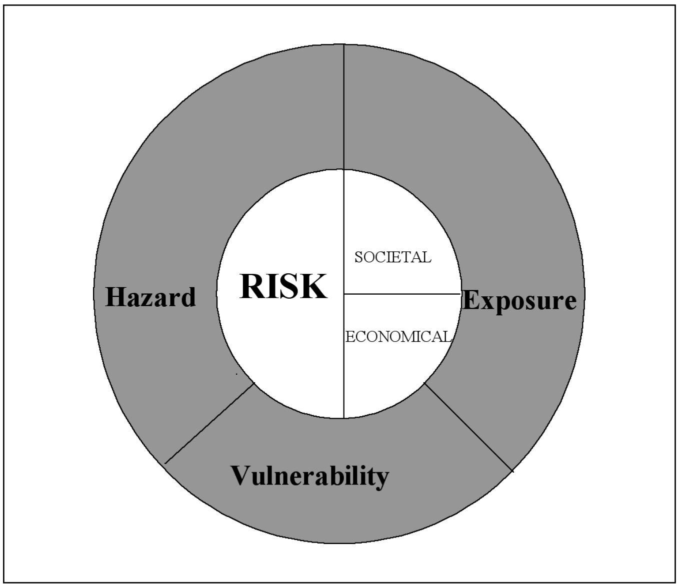

Fig. 2. Factors of Risk and Risk types
Fig. 2. Factores de Riesgo y tipos de Riesgo

may have serious errors, perhaps around 50 to 100 %, sometimes due to governments trying to minimise the figures, sometimes resulting from the difficulties of getting to the catastrophic zones and thus realising the true dimensions of the catastrophe.

The main data sources are the database of the Centre pour la Recherche de l´Epidemiologie des Disastres (CRED) at the University of Louvaine in Belgium, reports of reinsurance companies such as Swiss Re or Munich Re, databases of the U.S. Geological Survey or U.S. NOAA, specialised papers on different hazards and national reports. After ten years of IDNDR, most countries, even some that are developed, do not have reliable statistics.

During the period 1965-1999, a total of 1.995.000 mortal casualties due to violent natural disaster were recorded in the world, according to data from cited sources and our own data. Around 1.100.000 (55 %) resulted in disasters with 1.000 or more dead & missing. Moreover, some 1.850.000 people died in famines produced by drought. The most destructive events during the period 1965-1999 were the Bangladesh cyclone of 1970 with some 500,000 dead & missing and the Tienshin (China) earthquake of 1976, with an official figure of 242,000 dead (other estimate go as high as 650.000). During the IDNDR 1990-1999, there was a total of 407.682 mortal casualties (Figure 3) according with data of Swiss Re (1990-99), Munich Re (1990-99) and our own sources (Ayala-Carcedo, 1990-1995). This means an average of 40.768 casualties/year versus 57.000 during the whole period of 1965-1999, 28 % lower, perhaps a sign of improved prevention.

A distribution by hazard for the period 1990-95 is shown in the Figure 4, which indicates that cyclonic storms followed by earthquakes and floods are the most dangerous hazards.

The distribution of societal disasters with time has a high variability. During the period 1990-99, the standard deviation of total annual dead was 41.658 dead, the coefficient of variation (standard deviation/mean) CV was 1,02 and the casualties relationship between the most and the least catastrophic year was of 11,2. For the period 1990-95, as Figure 5 shows, higher inter-annual variability of hazards were associated with cyclonic storms with a CV of 1,99, earthquakes with 1,29 and volcanoes with 1,24; the figure for floods, 0,29 is clearly underestimated because the 1999 flood in Venezuela with some 35.000 dead is not included.

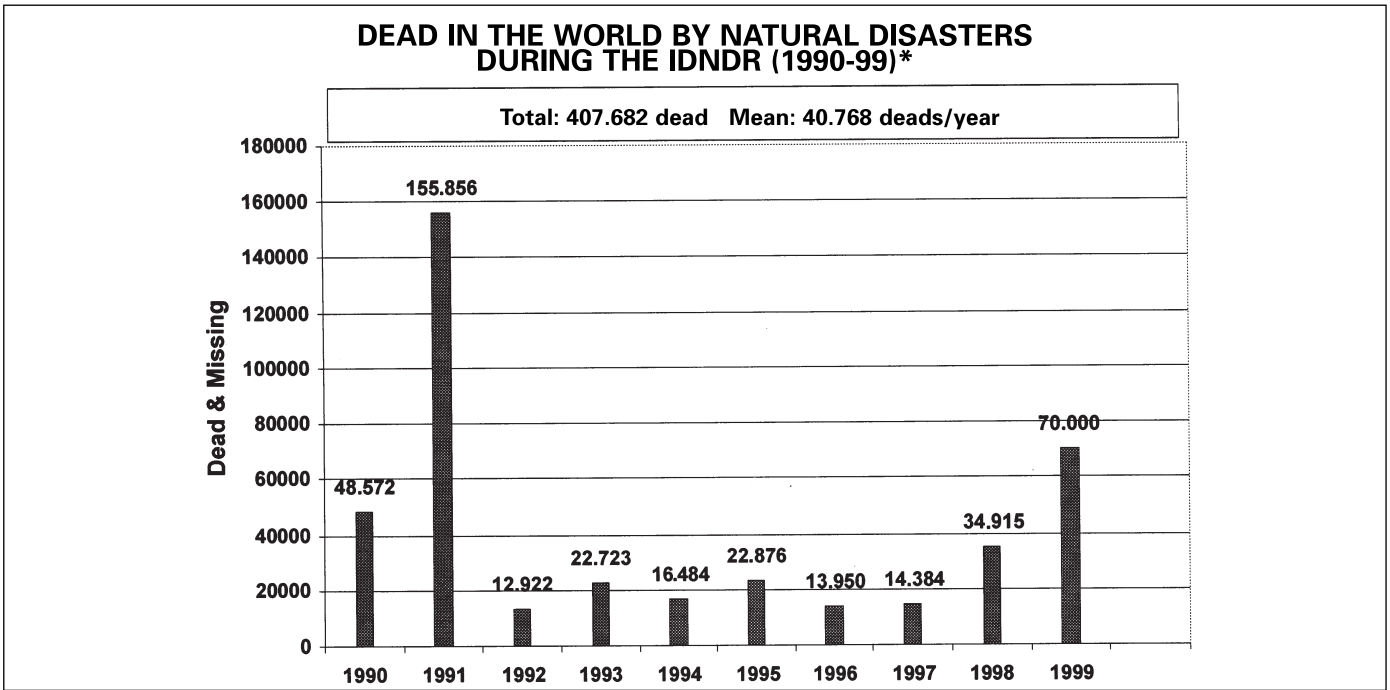

Fig. 3. Dead during The International Decade for Natural Disaster Reduction 1990-2000 [with data of Swiss Re, Munich Re (1996-1999) and Ayala-Carcedo (1990-1995)]

Fig. 3. Víctimas mortales durante el Decenio Internacional para la Reducción de Desatres Naturales 1990-2000 (con datos de Swiss Re, Munich Re (1996-1999) y Ayala-Carcedo(1990-1995))

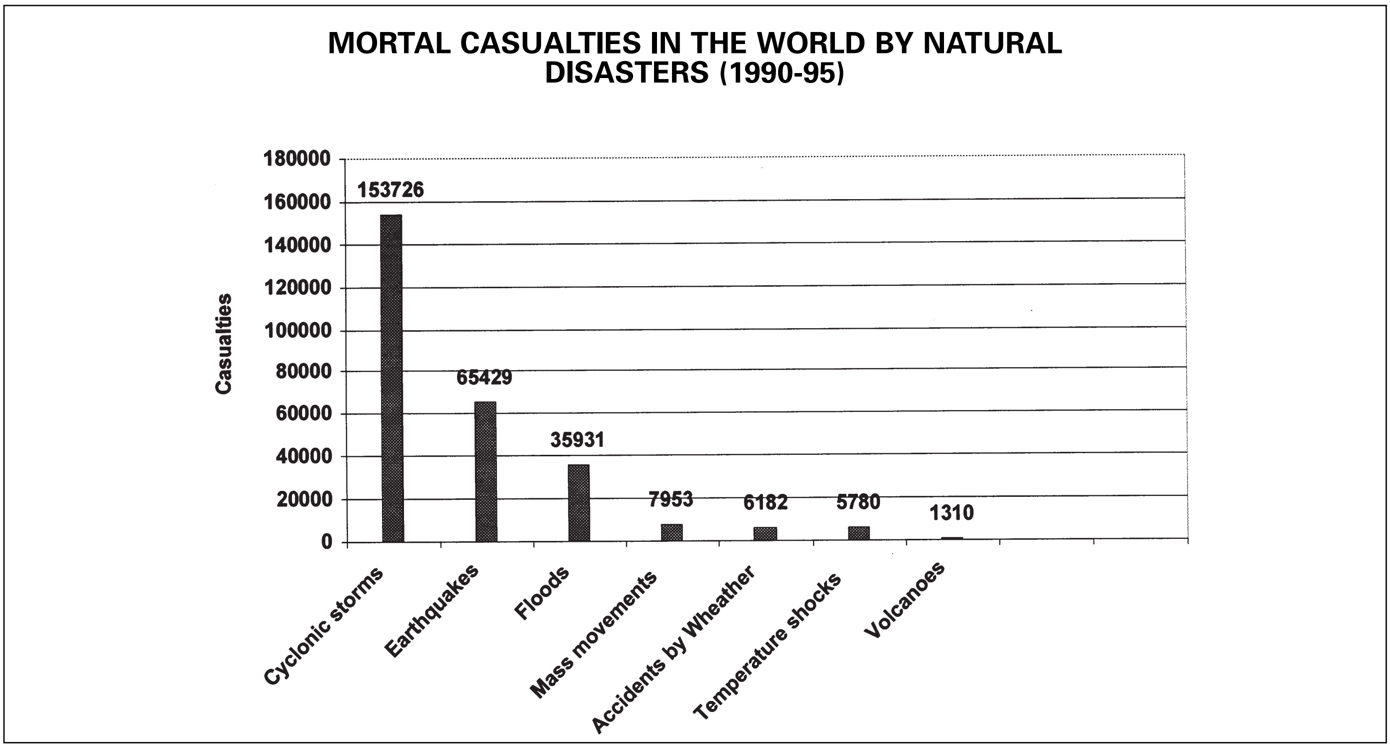

Fig. 4. Dead produced by Natural Violent Hazards, 1990-1995 (Ayala-Carcedo, 1990-95)
Fig. 4. Víctimas mortales producidas por Desastres Naturales Violentos, 1990-1995 (Ayala-Carcedo, 1990-1995)

The classification used in this paper for societal disasters size is: small (10-99 dead), medium (100-999), big (1.000-9.999), huge (10.000-99.999), megadisater (100.000-999.999) and gigadisaster (equal or greater than 1.000.000).

Statistical size distribution of disasters measured by casualties, shows a similar trend to the one of extreme values statistics (Figures 6 and 7): the greater the disaster size, the lower the number of disasters. Obviously this must be related with extreme statistics of hazards, and probably with the pattern in size of populations, all probably following fractal patterns.

There are several injured people by dead, variable with hazard type.

The number of sufferers is two to three orders of magnitude greater than dead. For the period 1991-1994, with 205.649 dead, there was a total of 36.112.000 homeless around the world (Ayala-Carcedo ed., 1994). The main hazards for sufferers are meteorological, floods and earthquakes.

Regarding unemployed, during 1970, in the USA, for a total of 979 dead, there was a total unemployment estimated in 89.643 employee-years (Petak & Atkisson, 1984).

The geographical distribution of disasters during the period 1900-1987 may be seen in Figure 8. Causal research about this distribution may be conducted through Risk Analysis. Asia, with the 85 % of the dead, has all kinds of hazards with higher severity and greater geographical areas, the highest population exposed and also the highest vulnerability; this means higher risk factors, and higher risk produces higher casualties. On the other hand, Africa has violent hazards limited in geographical area and severity, with medium exposure and high vulnerability; this means much lower risk than in Asia, and, according to the data, much lower casualties (in droughts, due to semiarid or arid climate, widely spread in Africa, the casualties are much more higher). The geographical distribution of disasters is closely related with socio-economic distribution at a world level: disasters concentrate in undeveloped countries. This is also the pattern at national levels, due mainly to higher vulnerability of dwellings in lower income zones. Developed countries are not totally safe as revealed the Kobe earthquake of 1995 with 5.426 dead (Braunner & Cochrane, 1995).

Disaster distribution in time increased in the period 1963-1992: the number of disasters with 100 or more dead increased from 89 in 1963-67 to 205 in

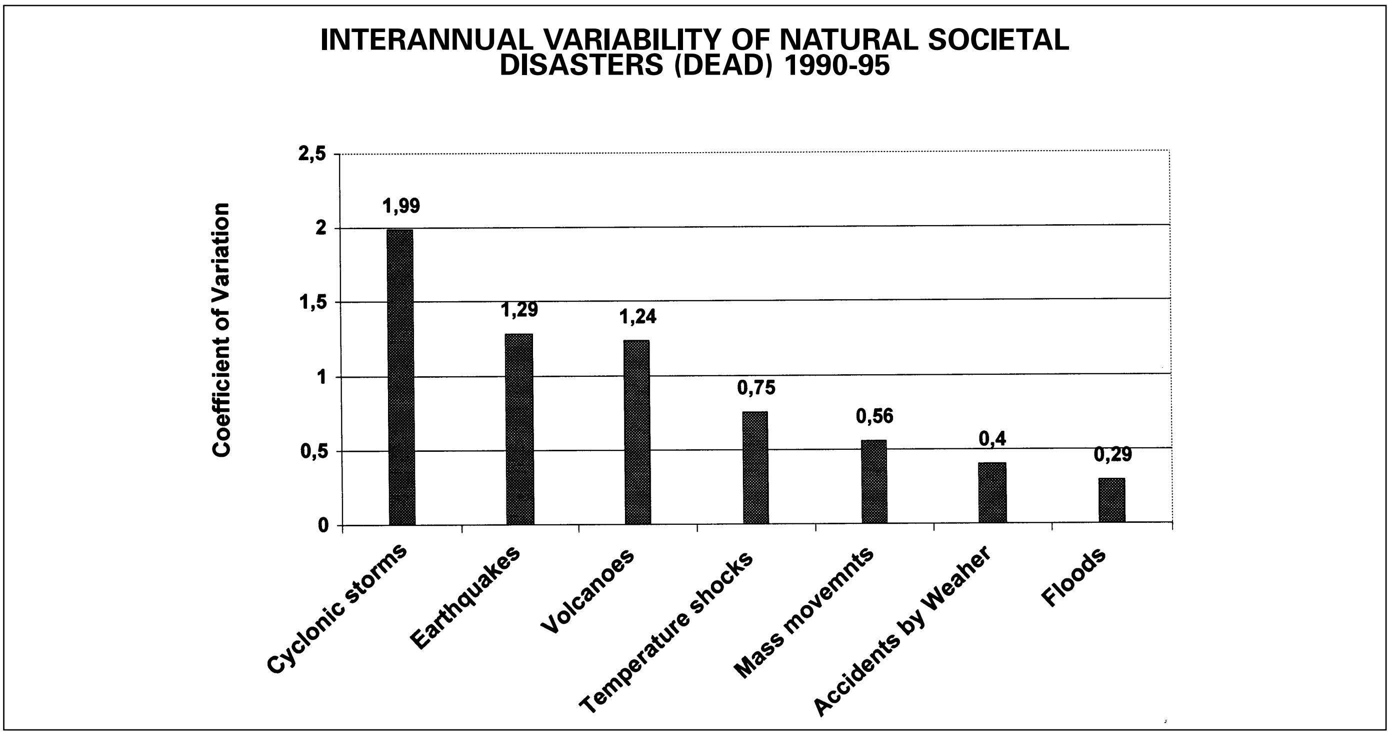

Fig. 5. Variability of annual dead toll of Natural Violent Disasters 1990-95 (Data: Ayala-Carcedo, 1990-1995)
Fig. 5. Variabilidad interanual de las víctimas mortales en Desatres Naturales Violentos, 1990-1995 (Datos: Ayala-Carcedo, 1990-1995)

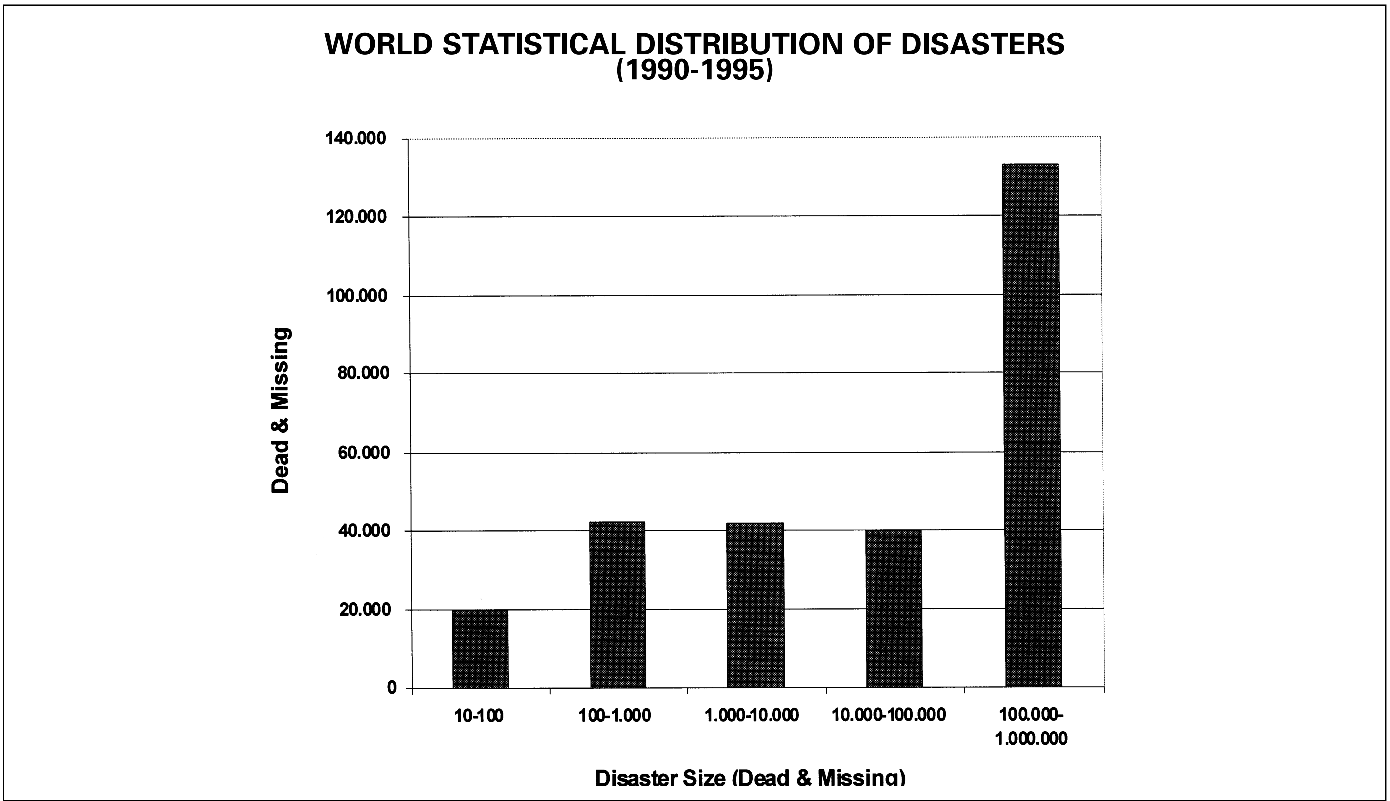

Fig. 6. Accumulated dead in Natural Disasters during 1990-1995 period by disaster size
Fig. 6. Víctimas mortales acumuladas durante el período1990-1995, por tamaño de desastre

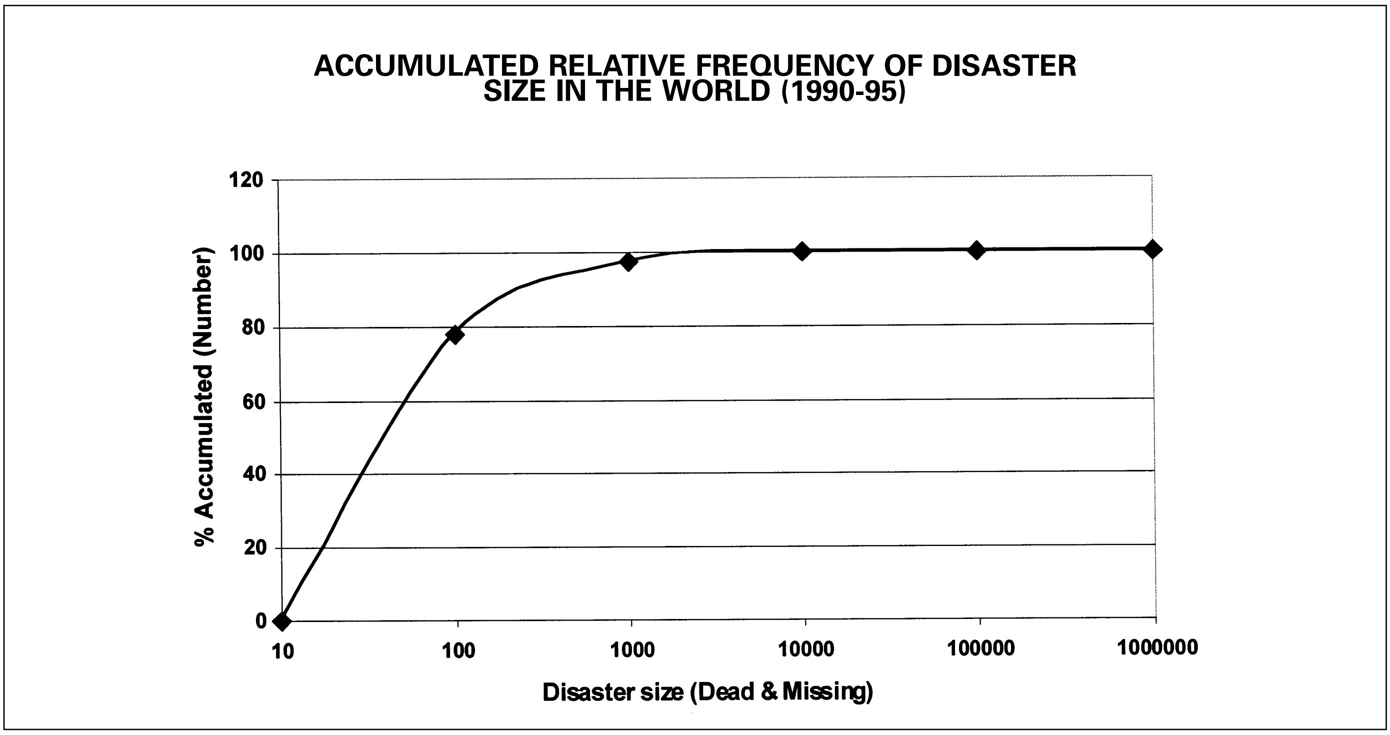

Fig. 7. Accumulated % of Natural Disasters during 1990-1995 period, according to disaster size, showing a much higher frequency of small and medium disasters

Fig. 7. Frecuencia acumulada de los Desastres Naturales durante el período 1990-1995 según el tamaño del desastre, mostrando frecuencias mucho más altas de los desastres pequeños y medios

1988-92 (IDNDR, 1994); but this trend was broken during the period 1992-1998.

Economic impacts of violent natural disasters

Assessment of economic impacts is a difficult task due to the various types of damages in a disaster, the obvious problems of work in a devastated region and the individual, societal and governmental hurdles that must be overcome for an objective appraisal. My personal experience in Spain is that assessments coming from sufferers at political (regional or local levels, associations) or individual levels are often overestimated by 2,5 to 5 times.

The most accurate assessment comes from insurance appraisers, but insured impacts are only a part of total losses. This all means that figures of total economic losses are in general of limited reliability, clearly less than that of casualties, and the only reliable data are those from insured losses.

Losses may be classified as direct (mainly structural loss of dwelling and public infrastructures, building contents, agricultural and emergency costs) and indirect (attention to injured, loss of benefits, unemployment and so on). Losses may be public or private, industrial, agricultural, etc... Appraisal of indirect losses is very difficult; direct losses must be appraised according to the actual, residual value of goods and not according to the replacement value.

The main and most reliable sources of economic losses are the reports of insurance companies such as Swiss Re or Munich Re. The conversion from insured losses to total losses has a doubtful reliability; an objective and reproducible way may be to take into account the insurance level, greater for developed countries and lower for undeveloped ones.

During the period 1990-1995, which had the worst economic disaster in history, the Kobe earthquake of 1995, the mean total annual losses were 65.099 US $ million, 0,33 % of the World Gross Product, and the coefficient of interannual variation (standard deviation/mean) was 0,55, around half that of societal disasters (Ayala-Carcedo, ed.,1990-95).

According to Munich Re data, during the period 1986-1995, floods caused 31% of world total losses, wind storms 30%, and earthquakes 29%. Total losses from floods of all origins accounted for 250.658 US $ million for the period 1987-96 according with data of CRED.

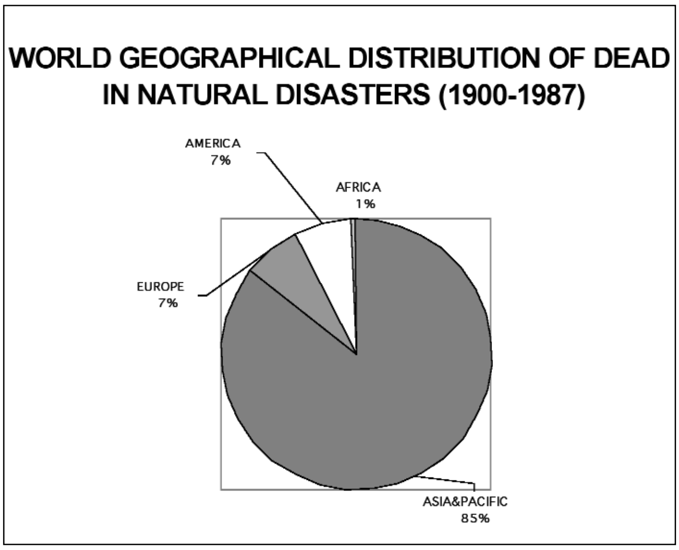

Fig. 8. World geographical distribution of fatalities shows Asia is the continent most affected by Natural Disasters in absolute number (with data of Japan IDNDR)

Fig. 8. Distribución geográfica mundial de víctimas mortales, mostrando que Asia es el continente más golpeado en términos absolutos (con datos de la IDNDR, Japón)

In a developed country such as Spain, with some 40 million inhabitants, total losses during the period of 1990-95 for natural violent disasters, were 3.610 US $ million, an annual mean of 602 million, 0.15 % of GNP. Some 58 % of that loss was due to meteorological damages in agriculture (Ayala-Carcedo, ed., 1995).

The worst economic disasters were the mentioned Kobe earthquake with total losses ranging from 82.400 US $ million to 100.000 (http://www.kanados.com/kobe-quake/); the Andrew hurricane of 1992 in USA with 30.000, and the Northridge earthquake of 1994 in California, also with 30.000 US $ total losses, all in the IDNDR.

Insurance rate (insured/total losses) was 3 % in Kobe (Braunner & Cochrane, 1995), 35 % in the Northridge earthquake (Swiss Re, 1990) and 52 % in the hurricane Andrew (German IDNDR, 1994). For the period 1990-95, total insured losses in the world were 81.373 US $ million, 20,8 % of total losses. The trend in total losses for a single risk such as floods in the USA is increasing (Figure 9), probably as a result of the increased economic value of exposure. From 1987 there is a trend of rapidly rising in insurance losses according with data of Swiss Re and Munich Re. Probably, Climate Change, introducing more energy through temperature increases in the atmospheric and oceanic systems, will progressively increase the frequency and severity of all climate related risks as has been suggested by several authors (Ayala-Carcedo, 1999 a; Ayala-Carcedo & Piserra, 2000 b) and has been shown for Europe by the ACACIA project of the European Union (Parry, Parry & Livermore, 2000).

The geographical distribution of %GNP losses clearly shows a greater impact for undeveloped countries (Figure 10). The main reason may probably be a higher structural vulnerability and also a greater reliance on agriculture, which is strongly affected by meteorological risks. Most of the total losses are in developed countries due to higher exposure values in spite of the lower economic vulnerability; this is especially true for insured losses. This trend of more intense damage for lesser development is also probably true inside each nation: the social impact of economic losses is probably higher for low income groups.

The awareness of the fact that places with lower income levels per capita at national and World scales are the most affected at both the natural disasters at human and economic levels is the key to understanding the contribution of natural disaster reduction to Sustainable Development along the lines of the Yokohama Declaration (IDNDR, 1994). Mitigation strategies contribute to Global Sustainability by increasing safety and societal cohesion at both the national and global levels.

From a societal perspective mortal casualties by natural hazards as opposed to other hazards such as traffic and general mortality is very low, as may be seen in Figures 11 and 12. In Spain, for instance, industrial accidents affecting workers during the period 1996-99 accounted for an annual mean of 1,460 dead and 10,837 severe injured for a workers population of 13,076.,.000 in 1998, a probability of dead at work over a period of 35 years (work active period), of $4x10^{-3}$, and an annual probability of death at work of $1x10^{-4}$. Nevertheless, natural hazards, with a probability of death in Spain during a lifetime of $1,7x10^{-4}$ and an annual probability of death of $2x10^{-6}$, 50 times less than for industrial accidents, have a greater societal impact, as media news space shows, compared to other risks such as industrial or traffic accidents. If we perform a deeper analysis of casualties over time, a new insight emerges from an examination of the relationship between the events and disasters discussed before. Traffic or industrial accidents with 10 or more dead are very rare; events with 10 or more dead produced by natural hazards and natural disasters are much more common. This distinction is even more evident when the death toll of events is 100 or higher.

If we review all the events worldwide resulting in

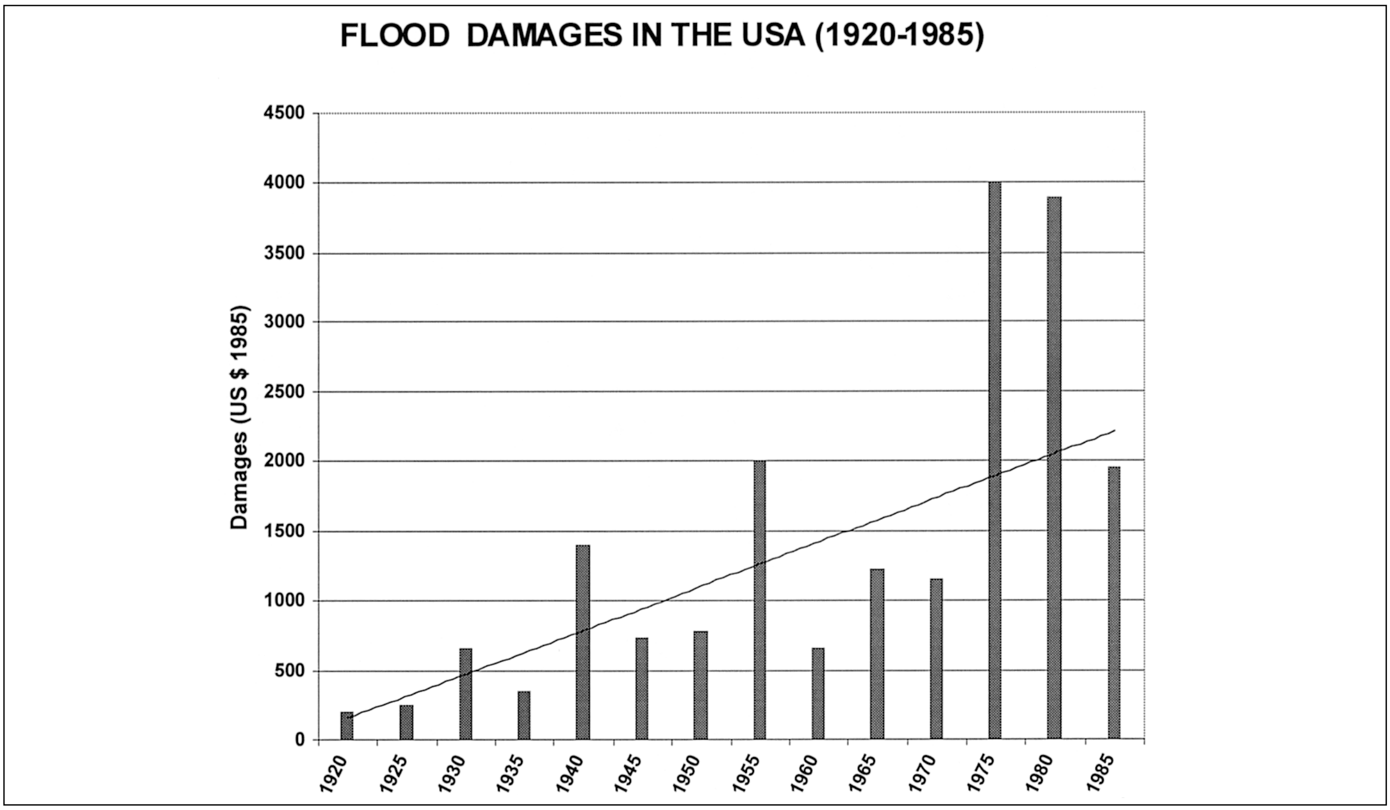

Fig. 9. Rising trend of flood losses in the USA, probably related to increasing economic exposure (with data of NOAA)
Fig. 9. Tendencia creciente de las pérdidas por inundaciones en EE.UU., probablemente ligada a la creciente exposición económica (con datos de la NOAA)

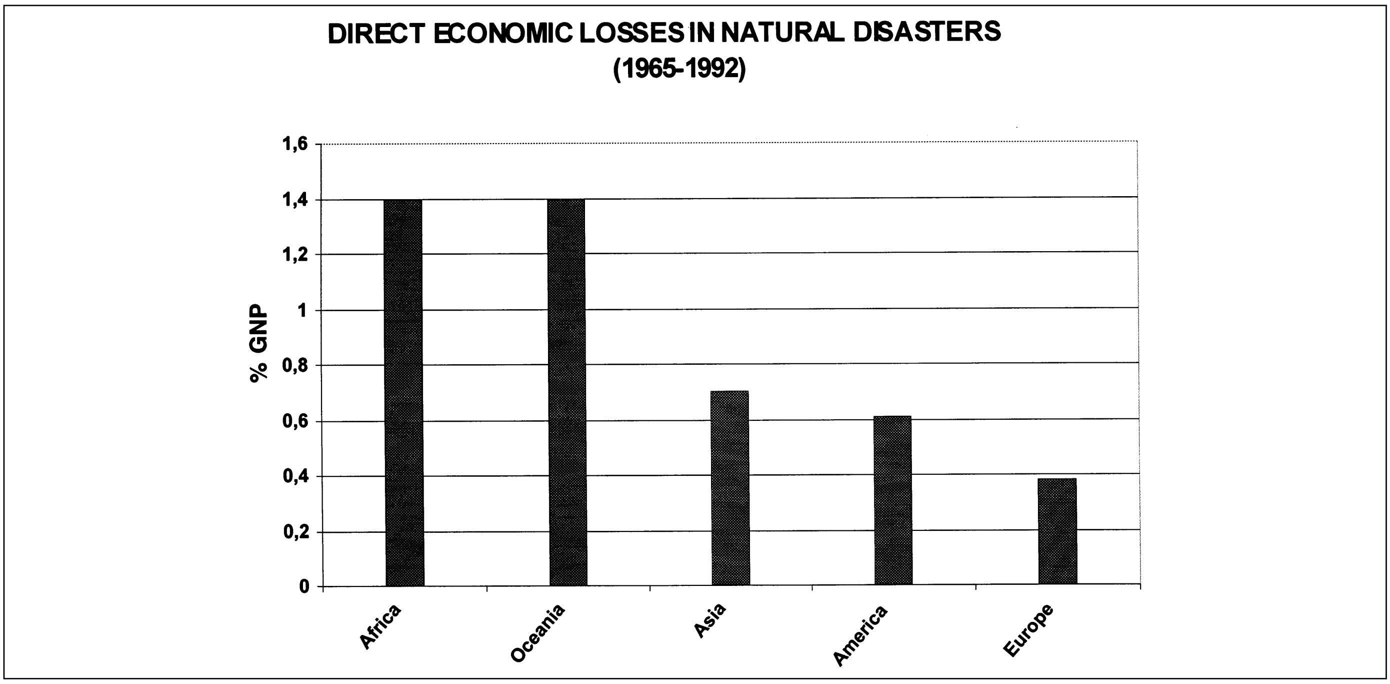

Fig. 10. Economic Vulnerability to Natural Disasters at the country level is clearly higher in undeveloped continents (with data of CRED, partly modified by IDNDR of Japan)
Fig. 10. La vulnerabilidad económica a los Desastres Naturales a nivel de país es claramente más alta en países subdesarrollados (con datos de CRED, parcialmente modificados por la IDNDR de Japón)

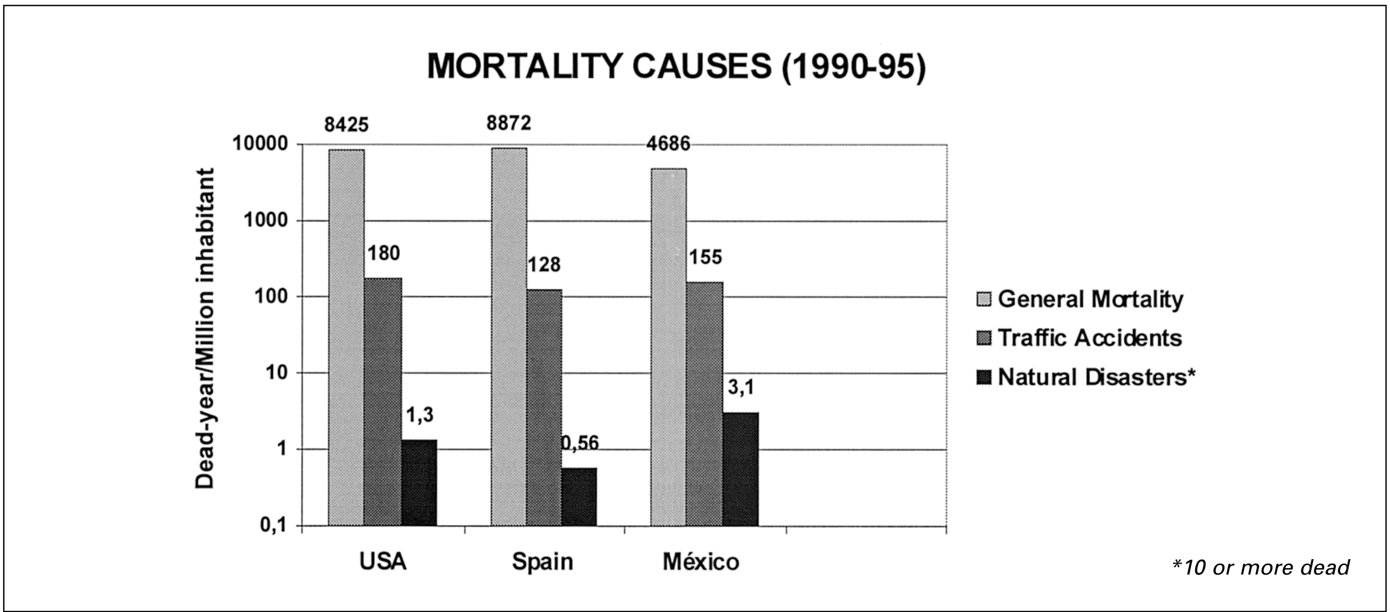

Fig. 11. Comparison of total death tolls of Natural Disasters with deaths from other causes doesn´t give an adequate idea of the real importance of Natural Disasters, which is leaned only from a comparison of death tolls in events with 10 or more dead, the disasters [with data of Hewitt (1997) and own data]

Fig. 11. La comparación de víctimas mortales en Desastres Naturales con otras causas de muerte, no da una idea adecuada de la importancia real de los Desastres Naturales, importancia que proviene de la comparación de víctimas en sucesos con 10 o más víctimas, los desastres [con datos de Hewitt (1997) y datos propios]

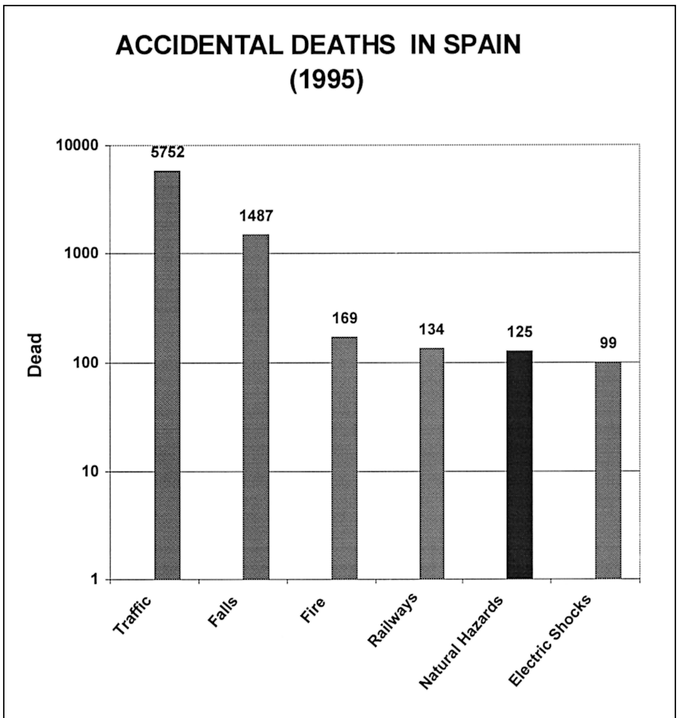

Fig. 12. Total death toll of Natural Hazards in Spain compared with other accidental death (with data of National Institute of Statistics, 1999)

Fig. 12. Víctimas mortales totales en España de los Peligros Naturales comparada con otras muertes accidentales (con datos del Instituto Nacional de Estadística, 1999)

the death of 20 or more individuals, the conclusion is very clear: at a world level natural disasters are the main source of disasters, that is, events with a high incidence of death (Figure 13). And this fact is enhanced when we consider historical disasters size (Figure 14). Epidemics, as pointed out by Foster (1994) and may be seen in the Figure 14, must be considered as disaster, in fact the main source of giant disasters.

Disasters, unlike common accidental events, have an increased capacity to affect simultaneously the conscience of a great number of people. A good test of this assertion is the amount of media coverage when there is a disaster. Hurricane Mitch in Central America (1998), and the Turkey earthquake and Venezuela flash-floods of 1999, with a total death toll of some 80.000, come to mind. They all made newspaper headlines for two weeks. Forty five thousand mortal casualties in traffic accidents each year in the USA do not have such a concentrated impact. People almost take for granted traffic risk and everyday traffic deaths but, without a clear awareness of natural risk, with relatively long recurrence periods, most don't think about natural disasters until they occur and usually claims government responsibilities (Ayala-Carcedo, 2000 c).

In developed countries such as Spain, this is not the pattern because during the last 50 years techno-

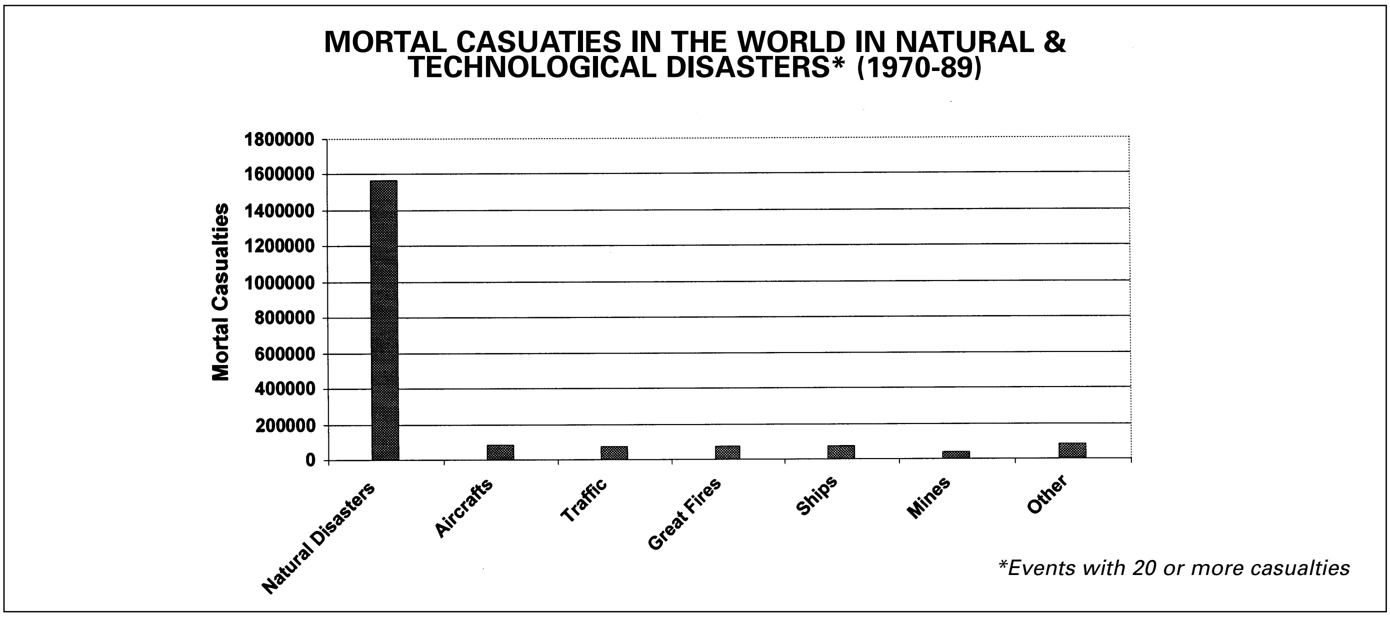

Fig. 13. Analysis at a world level of death tolls in disastrous events shows that Natural Disasters are the main source of death in societal disasters, and this is the main reason for their importance (Swiss Re, 1990)
Fig. 13. El análisis a nivel mundial de las víctimas mortales en eventos desastrosos muestra que los Peligros Naturales son la principal fuente de desastres sociales en el mundo, y esa es la principal razón de su importancia (Swiss Re, 1990)

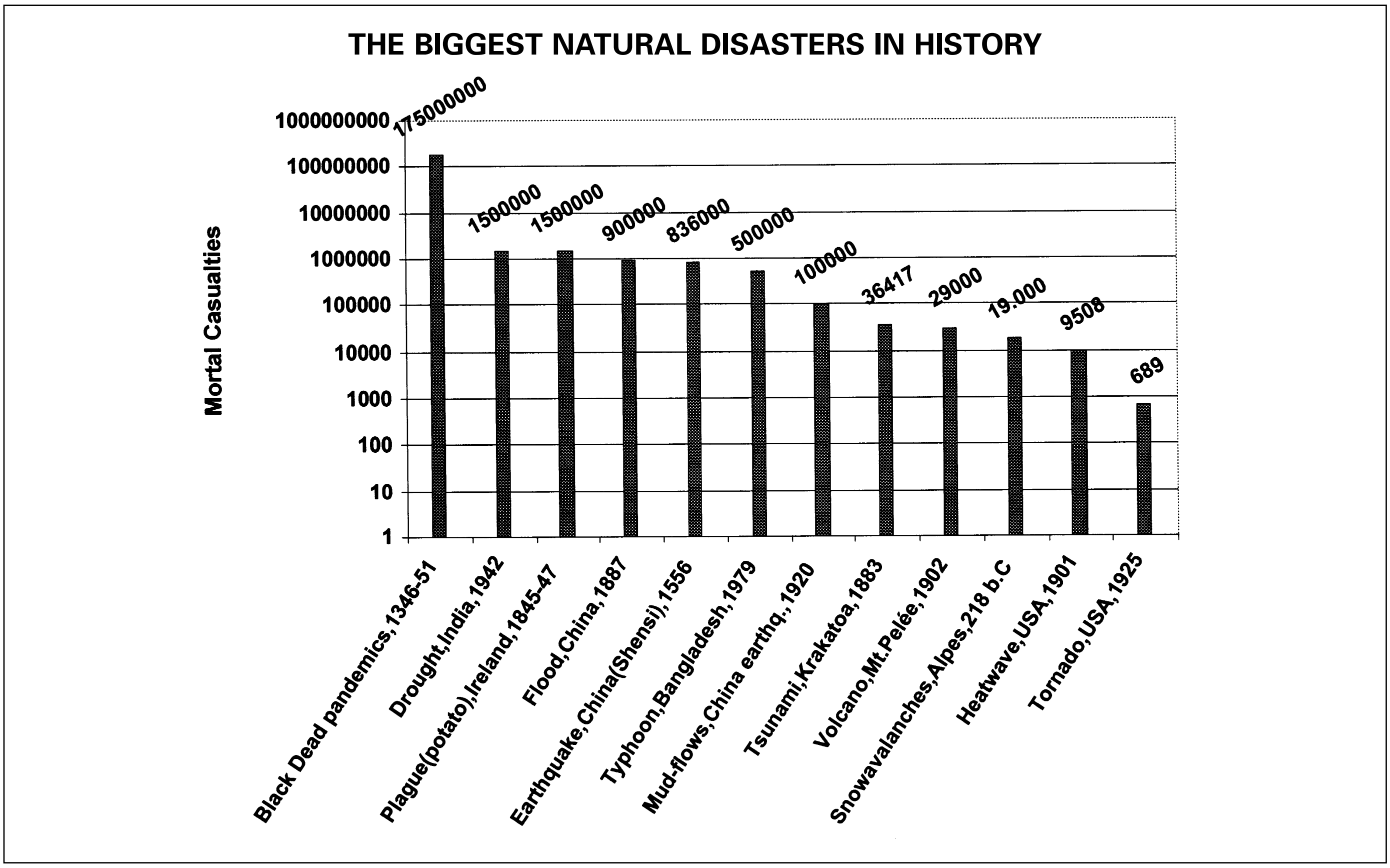

Fig. 14. Epidemics and droughts have been the biggest Natural Disasters
Fig. 14. Las epidemias y sequías han sido los principales Desastres Naturales

logical disasters with 10 or more mortal casualties have produced greater human losses than have natural disasters (Ayala-Carcedo and Silva, 1999 b). They also have been the worst single disasters in terms of death tolls. Despite this fact, developed countries may be hit by great societal disasters with low recurrence periods such as the Kobe earthquake in 1995, with 5.426 dead (Braunner & Cochrane, 1995).

At an economic level, the main victims are population of undeveloped countries and reinsurance companies.

As it has been shown, undeveloped countries have higher impacts in terms of GNP, and some great disasters can impact their economies for several years. Developed countries have, due to higher economic exposure, higher total economic impacts, but suffer lesser impacts on GNP. Besides, insurance coverage of damages is about ten times higher in developed countries, which have far fewer social problems associated with economic losses and also with the economic claims to governments in relative terms.

An analysis from the reinsurance business point of view performed by Swiss Re in 1990 for the period 1970-89, showed that natural disasters are also the great economic disasters, the great simultaneous concentration of economic losses, for insurers (Figure 15).

From these facts, the answer to the question of why Natural disasters are important might be: Natural disasters are important in a societal sense because they are the most important disasters at a world level, specially for undeveloped countries, and at economic level, they have a strong impact on GNP for undeveloped countries and also for reinsurance business.

Philosophy and keys formitigation strategies

The design of an optimum mitigation strategy in accordance the with Figure 1, must be preceded by Risk Factor Analysis and Risk Assessment.

Hazard Analysis has been broadly performed by Natural Sciences and Technologies, but despite the early development of Severity Scales (such as the Beaufort Scale for wind at the beginning of XIXth Century, Gil Olcina & Olcina Cantos, 1999) and also Severity-Vulnerability Scales (such as the Rossi-Forel Scale for earthquakes in 1880 and the Mercalli one in 1902; Bolt, 1981), important fields like those of mass movements (despite works such as Varnes, 1978) and floods (there are some works on curves of standardised floods to the mean annual one return period, Miller, 1997), have not had adequate scales devel-

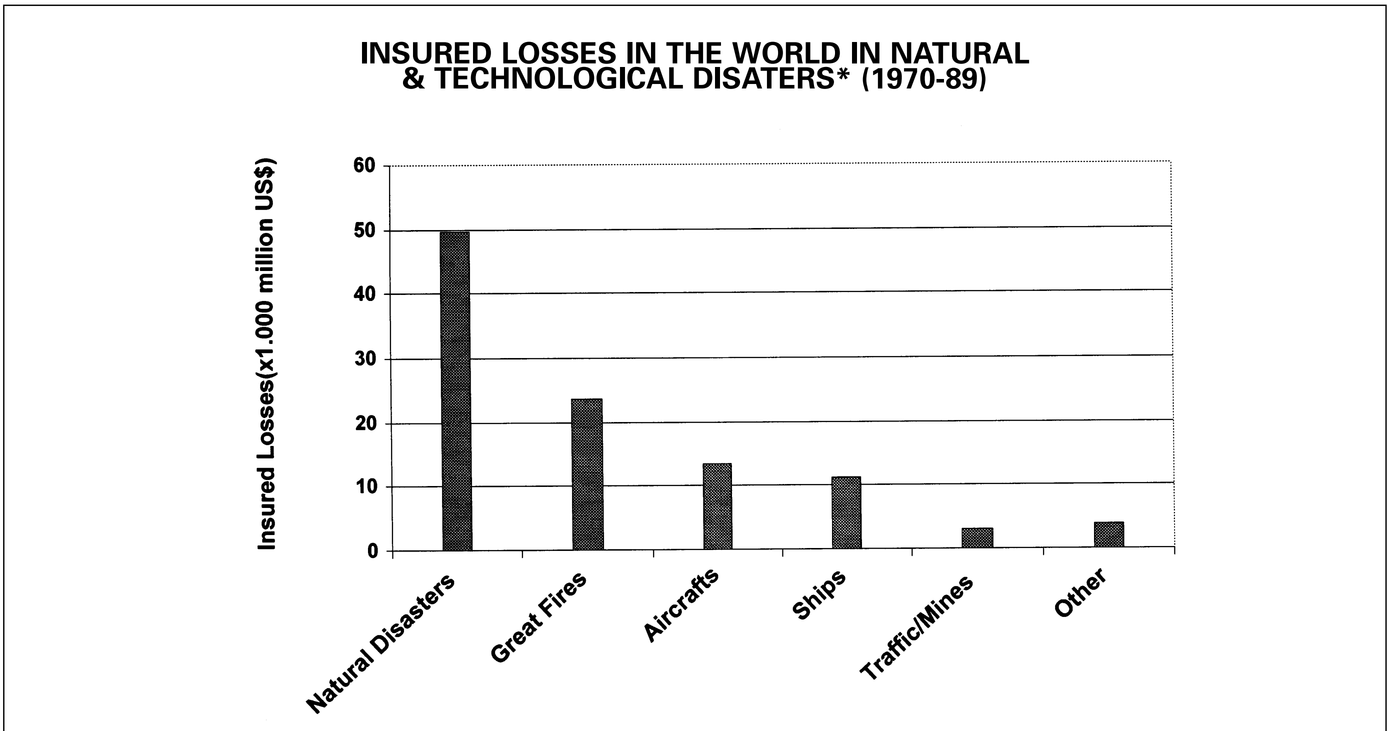

Fig. 15. Natural Disasters at world level are also the bigger economic disasters (Swiss Re, 1990)
Fig. 15. Los Desastres Naturales han sido también los principales desastres económicos a nivel mundial (Swiss Re, 1990)

oped, which are necessary for Risk Analysis. Volcanoes have an Explosivity Index Scale (see Tiedemann, 1992).

Science and Technology have also investigated structural vulnerability, especially for earthquakes (MSK scale, published on1964). Economic vulnerability for floods was investigated by Grigg & Helweg (1975); tsunamis by Lee *et al.* (1978); wind by Hart (1976); earthquakes by Lee & Eguchi (1977); and earthquakes and volcanoes by Tiedemann (1992) among others. Human vulnerability for floods has been investigated by the U.S. Bureau of Reclamation (1989), which has shown the great importance of warning time: when it is less than 1.5 hours, vulnerability increases exponentially. Human and economic vulnerability in mass movements has been investigated by the author (Ayala-Carcedo, 1994). Problems related to increase of population in cities and megacities has been analysed by Cunning (1994) and Solway (1994). Use of MDR (Mean Death Rate or Mean Damage Rate) may be a good option in disaster analysis (Tiedemann, 1992).

Exposure is also an insufficiently studied risk factor, although it is often the key factor. For example, from the study of Lee *et al.* (1978), it is clear that flood risk, due to higher rate of exposures in flood plain, is greater for small communities in the USA than for bigger ones. Sometimes, the change of exposure with time is the key risk factor to explain the evolution of damage with time, because exposure, as vulnerability, is an anthropogenic factor. Thus, the evolution of fatalities due to lightning in Spain, is well explained by changes in the population of farmers, the most exposed group as they work outdoors (Figure 16).

Much more work must yet be done in these fields to have reliable risk assessments. Disaster Analysis is the best way to increase our understanding of risk. Accordingly, Post-Disaster Analysis by interdisciplinary ad-hoc Investigation Commissions is a key prerequisite of Sustainable Development.

Disaster mitigation means risk (expected loss) mitigation, and this requires preparedness, analysed by UNDRO (1987). This is the corner-stone of any strategy for disaster mitigation.

Preparedness must be based on the 3Ws, what, where, when. They are closely related, as shown below.

What is related with hazard typology forecasting at different geographic scales, including the different classes of hazard and its severity. An area, for instance, may be affected by earthquakes and floods, with severity (the set of factors that may make the hazard more dangerous) amplification related with

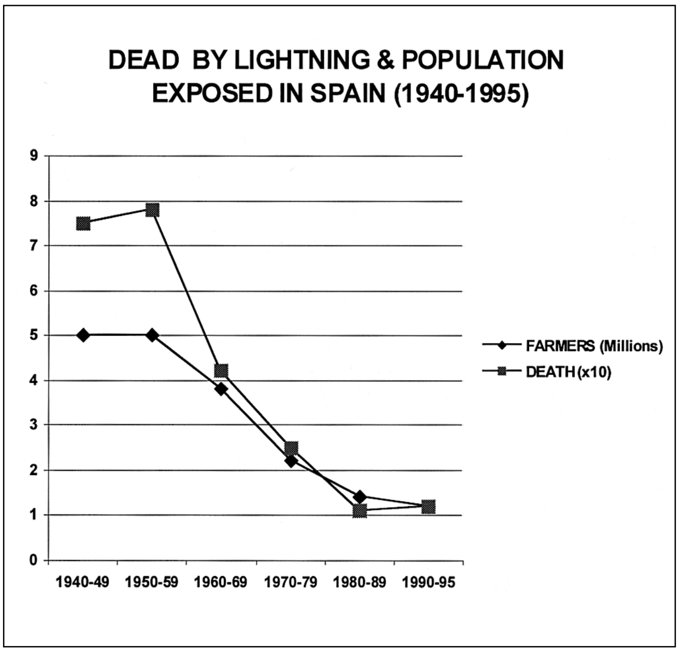

Fig. 16. The decrease of farmers population in Spain is the key to understanding the decline in deaths by lightaing (data of National Institute of Meteorology and National Institute of Statistics)

Fig. 16. El declive de la población de agricultores en España, es la clave para comprender la caída del número de víctimas por rayos observada (datos de víctimas del Instituto Nacional de Meteorología e Instituto Nacional de Estadística)

earthquake-triggered liquefaction and flash-flooding due to a small river basin. A subject to analyse is the triggering cause of risk, clearly related with mitigation, as may be seen in Figure 17 for landslides.

Where refers to the spatial forecasting of hazard and risk with various types of risk maps (Ayala-Carcedo, 1990).

When means temporal forecasting of hazard ocurrence, with two intervals: short term and long term. Long-term forecasting is in general possible and is directly related to hazard probability for risk assessment, which requires records of events, especially those of catastrophic ones. Short-term forecasting with practical effects on alarm and evacuation is not reliable for earthquake and near-coast triggered tsunamis, about a half of volcanic eruptions, small and medium-size convection storms, flash-floods, tornadoes, droughts, most landslides, snow-avalanches and most extraterrestrial impacts. On the other hand, short-term forecasting is possible for distantly triggered tsunamis, most storms with lightning, medium and large river basin floods, about a half of volcanic eruptions and most epidemics and plagues. A subject to investigate related with temporal forecasting is the

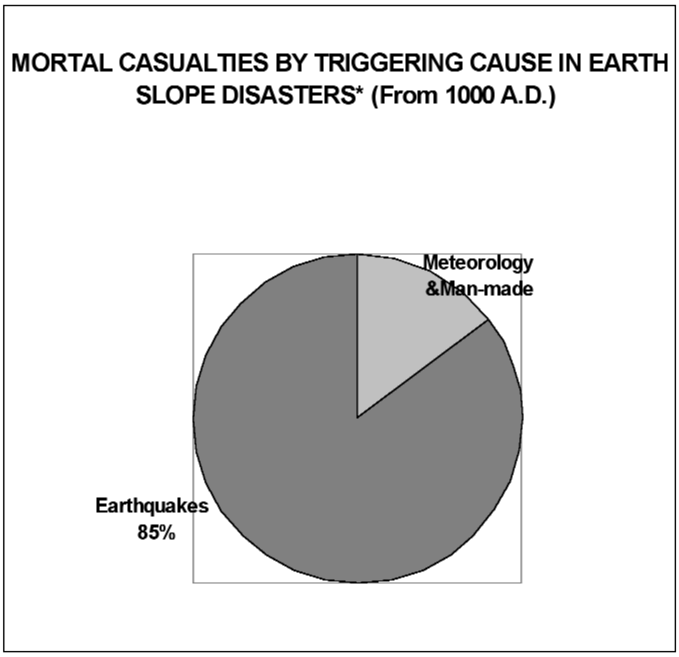

Fig. 17. Death Analysis of landslides shows that earthquake triggering accounts for most deaths (Ayala-Carcedo, 1994)
Fig. 17. El análisis de víctimas mortales en movimientos de ladera muestra como el desencadenamiento por terremotos es la causa de la mayor parte (Ayala-Carcedo, 1994)

monthly distribution of risk, necessary to forecast the monthly distribution of mitigation measures, as may be seen in Figure 18 for meteorological events in China, which are clearly related to the summer monsoon (Ayala-Carcedo & Llorente, 1991).

The severe problems with short-term forecasting, highlights the need for preparedness over the long run, especially through land-use planning and construction codes.

Mitigation strategies may be of several kinds, according to the related risk factors, as may be seen in Figure 22 (Ayala-Carcedo, 1993).

How do we choose between different strategies to mitigate economic risk? There are two criteria: efficiency and economy. Efficiency means better capacity to diminish risk. Economy means greater risk reduction (avoided loss) with the same investment in preparedness.

For economic risk, if we rank the set of possible preparedness actions from greater to lower economic risk reduction, as may be seen in Figure 19, a diminishing yields curve appears (Ayala-Carcedo, 1993). This curve has three zones: a) Zone I: all the actions have benefit (risk reduction) greater than cost thus they are economically interesting to private owners; the cut-off point is where the tangent to the curve equals 1; b) Zone II: actions are not economically advantageous but may benefit from the positive balance of actions when governmental action is taken into account; c) Zone III: all the actions are not profitable from both the private and public point of views (but may be necessary from a societal perspective). For societal risk strategy choice, there are three criteria. We saw that natural hazard importance from a societal point of view rests mainly on its capacity to generate disasters. Then, the first criterion must be to start with the maximum disaster. When we have forecasted disasters similar in size for different hazards, the criterion must be economic: the minimum cost per avoided death. From this point of view, Petak & Atkisson (1984) showed in a comparative analysis the differences among natural hazards in terms of dead by million US $ loss in USA (Figure 20). Risks with a lower ratio of dead /economic loss are in general more economically amenable to mitigation.

Along these lines the general government strategy against morbidity vs. mortality may be oriented. Petak & Atkisson (1984) show how cost by avoided dead in natural risk mitigation is greater than for other public life-saving strategies and there is an

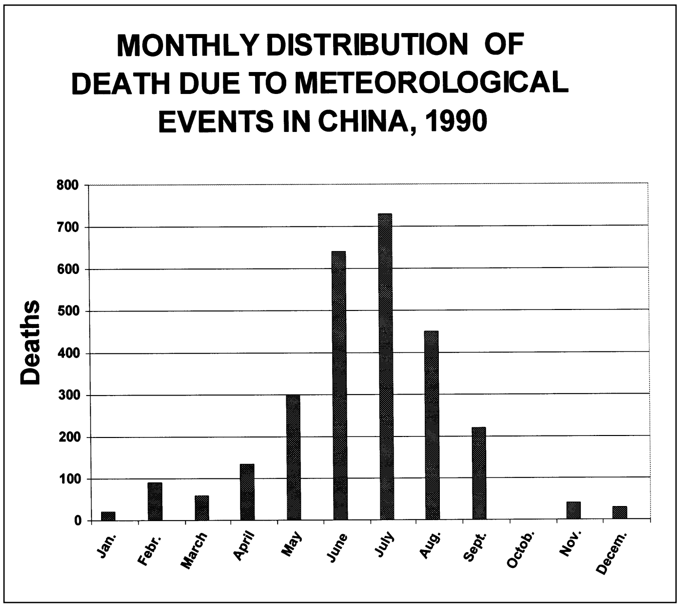

Fig. 18. Analysis of deaths over time, necessary for emergency organization, shows in the case of China, a strong influence on the part of the summer monsoon (Ayala-Carcedo & Llorente, 1991)
Fig. 18. El análisis de la distribución de víctimas mortales en el tiempo, necesario para la organización en emergencias, muestra en el caso de China un control ligado al monzón veraniego (Ayala-Carcedo y Llorente, 1991)

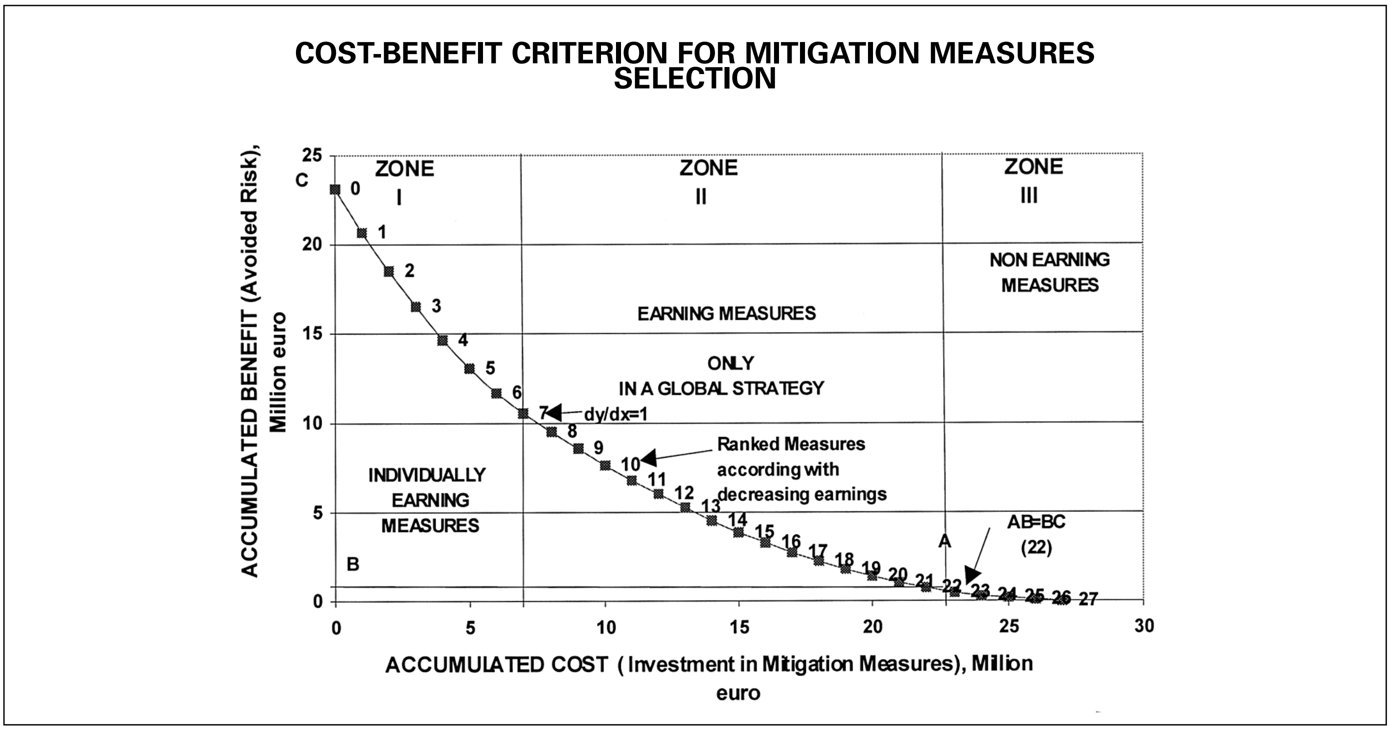

Fig. 19. Ranking of possible mitigation measures according to cost and benefit criteria, shows a decreasing yields curve that may be used to make a rational choice (Ayala-Carcedo, 1993)
Fig. 19. La ordenación de las medidas de mitigación posibles de acuerdo con criterios costo-beneficio, muestra una curva de rendimientos decrecientes que puede usarse para realizar una elección racional (Ayala-Carcedo, 1993)

opportunity cost associated with natural risk mitigation investments. Despite this assertion being substantially true, one might well want to take into account how the disaster generation capacity of natural hazards seriously affects public opinion.

The third criterion is societal risk acceptability, sometimes called "group risk acceptability" (Mark, 1995). Society loathes disasters and there is a non-linear mathematical relationship with disaster size expressed with a log-log, a potential relationship; people only accepts larger disasters when their probability is much lower. Besides, the probabilities of individual death for many kinds of events is known. For example the current mean annual probability of immediate death for individual in Spain for lightning is $0,3x10^{-6}$ and $0,5x10^{-6}$ for floods; actual probabilities for exposed people are about 10-20 times greater, and lifetime individual probabilities are the former times life expectancy.

These studies on immediate individual death risk (hicken, 1975) are the basis for individual risk-acceptability risk criteria such as the VRJ, with the limits 10^{-4} for annual probability of dead for intolerable risk and 10^{-6} for tolerable risk; cases between these limits are in the ALARP zone, that is, the zone where risk must be diminished as low as reasonable in practice (Higson, 1990).

For groups exposed to risk, a societal approach is needed due to the probability of a catastrophe. The criteria are called F-N, with F being the frequency (in fact probability) of one event with N or more fatalities, and the relationship is log-log or potentially so. Figure 21, shows the criterion of the Hong Kong Government (Wrigley & Tromp, 1995), a criterion where catastrophes with 1,000 or more fatalities are not acceptable. The philosophy of risk acceptability has been analysed in a critical approach by Dubreil (2000), showing the negative aspects associated with normalcy in view of post-disaster rehabilitation.

All these facts lead to the conclusion that the main venue of disasters associated with earthquakes or cyclic storms, where all the population is exposed, is megacities in undeveloped countries, settlements that will be increasingly vulnerable. Then it is probable that earthquake risk, opposite to no change in earthquake hazard, is increasing.

Aversion to economic risk follows the same pattern, a log-log relationship between annual probabili-

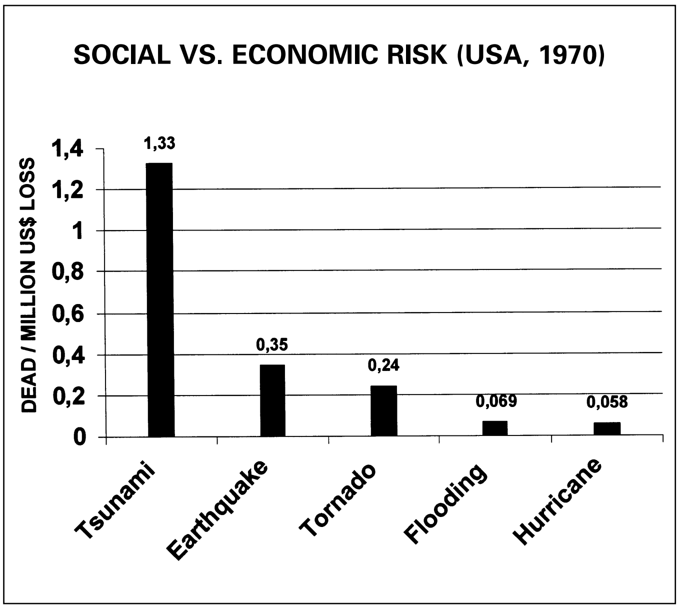

Fig. 20. Rate dead/economic loss varies greatly for different hazards, and sometimes, the deaths and economic losses don´t coincide in space (Petak & Atkisson, 1984)

Fig. 20. El ratio víctimas mortales/pérdidas económicas es muy diferente para diferentes peligros y, algunas veces, víctimas mortales y pérdidas económicas no coinciden a nivel espacial (Petak y Atkisson, 1984)

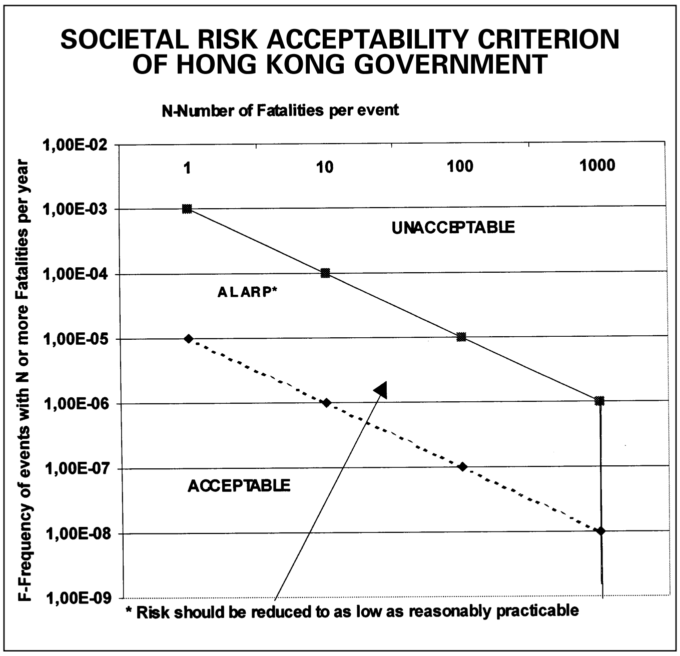

Fig. 21. Hong Kong Government´s Societal Risk Acceptability Criterion, type F-N (Frequency-Fatalities Number)

Fig. 21. Criterio de Aceptabilidad Social del Riesgo del Gobierno de Hong Kong, tipo F-N o P-N (Frecuencia, o mejor, Probabilidad-Número de Víctimas Mortales)

ty of failure and economic potential losses (Withman, 1984), the foundation for insurability criteria.

Structural and non-structural mitigation measures: a rational approach

Mitigation strategies may be classified according to the risk factor mitigated as may be seen in Figure 22 (Ayala-Carcedo, 1993).

Antihazard and antivulnerability, structural measures, may be classified as active (antihazard) or passive (antivulnerability); antiexposure measures are considered non-structural.

Structural measures include, for different risks:

*Volcanoes: Reinforced roofs to support ash weight, blasting to open new lava channels, tunnels for drainage of crater lakes to avoid freatomagmatic eruptions.

*Earthquakes: Earthquake-resistant design of foundations and structures.

*Mass movements: Stabilisation with groundwater drainage, geometry corrections, bolts, anchors, etc...

*Cyclone storms and tornadoes: Wind-resistant structures and walls and shelters.

*Floods: Dams, channels, fluvial dykes, dwellings with basement, etc...

Main non-structural measures are:

*Warning for evacuation or avoidance of risk.

*Land-use planning based on risk maps or special procedures as explained below.

*Training for risk.

*Insurance.

There is a traditional controversy about the choice of structural vs. non-structural measures. Natural and social scientists are prone to support non-structural measures, and engineers are more likely to support structural ones. Before, we have provided the main criteria for a rational choice, but it seems that a deeper insight is needed.

Insurance and training of the population exposed to risk are feasible, and are always necessary measures; Brauner & Cochrane (1995) showed the importance of training the population in the Kobe earthquake of 1995 for first-aid due to the accessibility problems of the civil defence teams and Lachman *et al.* (1961) analysed the human behaviours during a tsunami.

Enough warning to produce practical effects is feasible in only some cases, as has been shown before.

Land-use planning is feasible and useful for: vol-

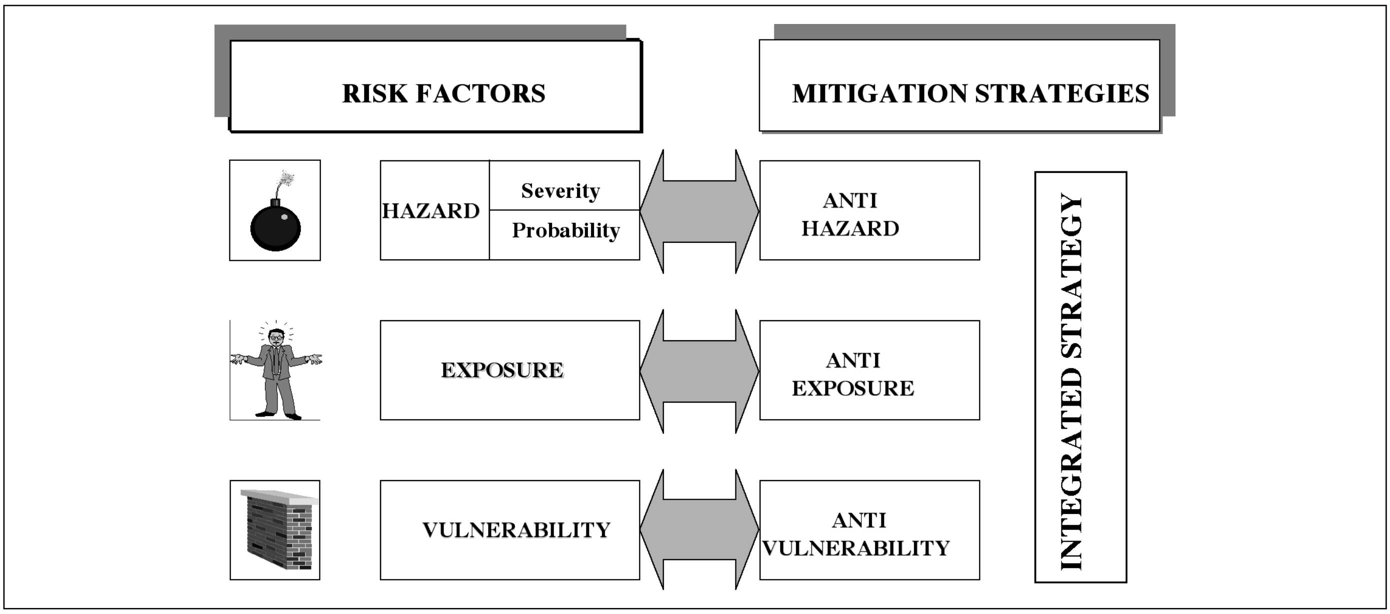

Fig. 22. Mitigation Strategies are classified according to the Risk Factor mitigated (Ayala-Carcedo, 1993)
Fig. 22. Las Estrategias de Mitigación, se clasifican de acuerdo con el Factor de Riesgo mitigado (Ayala-Carcedo, 1993)

canic lahars (ashes mud-flow), earthquake amplification (when there are microzonation maps, see Marcellini, 1991), mass movements, floods and coastal risks (tsunamis, storm surges, etc.). Insurance, with premiums established according to risk, must take into account spatial forecasting of hazard, which is then related to land-use, as will be shown below for the National Flood Insurance Program of the USA, managed by the FEMA (Federal Emergency Management Agency).

Many structural measures are provided by governments, and governments also have, at different geographic scales, the power to establish land-use measures as well as codes for the construction of private dwellings. Governments are mainly concerned in avoiding human disasters, sometimes because, as in the Spain´s case, the Constitution requires government to protect the life of citizens; then, Societal Risk Acceptability criteria, as indicated before, might be the first choice among mitigation measures. In this approach, land-use planning measures take precedent over structural ones because, many times they can guarantee zero risk for population from flash-floods, coastal dynamics and mass movements; an alternative and more expensive measure is the "maximum hazard approach" increasingly used in dam design. This is not possible for consolidated settlements; in these cases, structural measures are often necessary.

Two objections may be raised against structural measures. The first problem is the limited risk coverage. Most structural measures have been designed with a hazard approach for a return period; then the risk coverage is limited. The problem is that most people believes that there is a total risk coverage and uses the land freely, many times with much more higher societal risk levels than is acceptable. The second problem is related with the cost of many structural measures. Must the government pay for expensive structural measures when it is possible to avoid human risk with land-use planning? This is a key question in the authorisation of new settlements. Government or city town halls may provide risk maps where the risk for people and properties is shown; with this base, land-use measures to avoid human disasters will save a lot of money for taxpayers... and will guarantee total protection for people in the cases discussed before. Land-use planning may involve other expenses, such as higher transport costs and so on; in these cases, an optimised solution may include antivulnerability measures for dwellings. The main opposition against land-use planning comes from flood plain private landowners.

Flood insurance, when premium costs for the insured are tied to the exposure to risk, may be a complementary way to avoid disasters. There are different systems around the world to insure against natural risks (Nájera, 1999). They all shift between systems based on premiums linked to the type of good insured, independent of risk exposure, and systems based only on risk with prices fixed by the free market, that is, the value of exposed goods, vulnerability and exposure to hazard. The first systems, called solidarity systems, are single and convenient to manage, don't need, in general, government grants, have the obligation to insure, but are unjust, force consumers to insure for non-existent risks and don't contribute to risk mitigation; an example is the Spain´s system. Other intermediate systems, with a part of prices financed by government grants like the French, linked to a Preparedness Risk Program and land-use rules or the National Federal Insurance Program(NFIP) in the USA, linked to land-use limitations in flood plains, managed by flood plain managers, combine solidarity (through government grants) and risk mitigation, and are more selective. The efficiency in mitigating human risk is linked to private owners aversion to pay for economic losses.

For floods, the NFIP has an annual average premium of 0.33 %; that means, for a lifetime of 50 years in the case of dwellings, a total cost equivalent to almost 17 % of the dwelling and contents (http://www.fema.gov/nfip/pstat.htm). The infrequent use of insurance in undeveloped countries, limits the use of this non-structural tool in these countries; there, the role of land-use planning, associated with most vulnerable settlements and the difficulty of financing expensive structural measures, are clearly more important than in developed countries. Risk maps may play a key role in undeveloped countries as a necessary tool for Sustainable Development. Opposite to the central role of government in avoiding human disasters, its role in avoiding economic ones might be only secondary and government investments to avoid economic risk are more controversial than those for human risk. As may be seen in Figure 19, in Zone I investment for private owners is individually profitable and they must invest to avoid economic losses. From a point of view of global economic concern, only investment in Zone II are justified, to pair cost and benefit at a global level (Ayala-Carcedo, 1999 a).

Towards a technical-administrative procedure for population risk assessment

All the actions related to disaster preparedness must be put in the context of government action, mainly oriented to avoid human disasters, and indirectly to avoid great economic losses. The tool, for natural and technological risk, might be a technical-administrative procedure for Population Risk Assessment (PRA).

There are several antecedents. Wildlife and natural heritage are protected in many countries against human impacts with a technical-administrative procedure for Environmental Impact Assessment. Is human life less important than wildlife?

Human life expectancy is one of four components of the Human Development Index introduced by the

SOME PROJECTS TO BE INCLUDED IN A TECHNICAL-ADMINISTRATIVE PROCEDURE FOR POPULATION RISK ASSESSMENT (PRA)	
FACTOR	EXAMPLES
Hazard level of site or facility	Flood plains, alluvial fans, torrential riversides, volcanic environments, seismic areas, active faults, snow avalanche tracks, unstable areas, shores, nuclear, chemical, military or biohazard facilities
Vulnerability	Campsites, single one floor dwellings, wooden housing
Exposure	Public facilities as schools, stadiums, churches, movies or theatres, squares
Esential Services to Community	Hospitals, police, institutions, radio & TV, press, energy & water facilities, bridges

Fig. 23. The selection of projects to be included in a Technical-Administrative Procedure for Population Risk Assessment must be performed according to factors increasing risk for population

Fig. 23. La selección de proyectos a incluir en un Procedimiento Técnico-Administrativo de Evaluación de Riesgos para la Población debe tener en cuenta aquellos factores que pueden aumentar el riesgo para la población

first "Human Development Report"; the other three are adult literacy, amount of education and per capita GDP (United Nations, 2001). All of the components are influenced, especially in undeveloped countries, by natural disasters and associated problems such as postdisaster famines, epidemics, homelessness, lost jobs and so on.

If human life has at least the same importance as wildlife and the main disasters have been natural ones, why have not governments, seriously concerned with disaster mitigation, set up a general procedure for PRA?. There are several factors explaining this situation. From the scientific side, the development of Risk Analysis started in the1960s, and risk acceptability criteria date to the 1980s. In fact, rules for engineering design in many countries are still "hazard approaches" to risk mitigation, based mainly on the return period of design hazards; awareness of the serious limits of this approach has produced a shift to the "maximum hazard approach" in fields such as dam design when downstream exposure is high (Interagency Committee on Dam Safety, USA; Berga, 1998). And, obviously, another explaining factor is the knowledge development rate of natural hazards complexity.

From the social point of view, risk perception is difficult because of the long return periods of many natural hazards such as earthquakes and population´s unawareness of possible hazards.

Another problem is the low scientific and technical level of many Civil Defence agencies around the world, which are supposed to set up these PRAs and are in fact mainly focused on responding to emergencies.

The political problems for mitigation programs design have been analysed by O´Riordan (1990). Many governments, which are ready to reject disaster responsibilities by calling upon the anti-scientific traditions of "acts of God " or the "unforeseeable nature" of hazards, are also partly responsible for the delay in setting up these procedures. A key indicator of government attitude towards disaster preparedness is the political will to set up Multidisciplinary Investigation Commissions when a disaster has happened, which is necessary to learn from our own errors to avoid repeating them in the future.

Today it is possible to design this PRA to avoid natural or technological disasters (Ayala-Carcedo, 2001).

Disaster risk is determined by hazard, exposure and vulnerability levels. A campsite is highly vulnerable to floods, and disaster risk will be higher with higher sizes of population exposed and higher hazard levels in probability or severity. It is possible, for different risks, to make a catalogue of project conditions subject to the PRA according with hazard, exposure or vulnerability. For floods, for instance, there might be: a) Exposure conditions: Any facility or urbanised zone with 100 or more people subject in the first floor to maximum exposure; b)Vulnerability conditions: campsites; wood dwellings; first floors windows without shutters; c) Hazard conditions: dwellings or facilities on alluvial deposits.

Risk Acceptability Analysis may be performed in a quantitative way (see Figure 21) or qualitatively by defining lists of unacceptable risk conditions or by combining scales of hazards, exposure and vulnerability with ad-hoc tables. Another useful approach may be that of "maximum hazard" for moderately and highly vulnerable exposures.

The procedural steps, conducted by the Civil Defence agency, in a similar way to those of Environmental Impact Assessment, might be (Ayala-Carcedo, 1999):

*Presentation by the promoter of the project to the Civil Defence agency of a Project Risk Analysis showing that risk level is acceptable.

*The Civil Defence agency sends the study to the Land-Use Planning agency, scientific and technical bodies, consumer organisations, ecology organisations and concerned local administrations.

*Opening of a public information period to receive comments from people and other organisations concerned.

*With the information collected and the findings of its own technical services, Civil Defence issues and publishes the Risk Statement with a) Approval with enforced conditions to make the risk acceptable, or b) Denial if risk, despite mitigation measures, is unacceptable. Risk Statement is sent to Administrations concerned with authorisation of project and the Land-Use Planning agency.

This procedure, which is possible today, may be the key to transform available expert knowledge into real disaster mitigation and may be the tool to raise the Human Development Index. The PRA proposed also has special interest for consumers and insurers.

Conclusions and Suggestions

From the above exposition, some conclusions may be made:

- Natural risks, epidemics and drought excluded, around the world cause about 50,000 deaths each year on average, with high variability. They also produce twice as many injured and more than 100 times as many victims, many homeless.
- Natural risk, epidemics and drought excluded,

produce each year on average losses about 0.35 % of Gross World Product, about 55,000 USD million, with variability about a half of societal one, with a world insurance rate around 20 % of total losses. Insured losses show a steeply rising trend in the last 15 years.

- Economic and specially human vulnerability to natural risk are much higher in undeveloped countries.
- Reliability of data is reasonable for societal losses and clearly lower for economic losses, often overestimated. Insured losses are much more reliable than any other measure of economic loss.
- Mortal casualties from natural risk have a very limited importance when compared with other causes of accidental death, for instance traffic casualties, especially in developed countries. The reasons for the importance of natural risk at a world level are: a) They produce most of the fatalities in events with 10 or more deaths, which have a greater capacity to impact societal conscience; b) They are the primary cause of accidental events with great losses, producing problems for governments and insurance companies. At a world level, natural disasters are the main disasters. For most developed countries technological disasters are probably more important in terms of quantity, but great disasters are usually natural ones.
- Welfare and societal cohesion at a world and national levels are basic conditions for Sustainable Development. Reduction of natural disasters is a basic condition for Sustainable Globalisation, understood as a solidarity choice with undeveloped countries, the most damaged nations at the world level, and with the lower-income social sectors, the most adversely affected groups at the national level. A comparison of impacts on developed and undeveloped countries that shows the problem of natural disasters in the world is largely a problem of development.
- The key concept to mitigate natural risk (the expected losses, human and economic) is preparedness to reduce risk, supported by Risk Analysis, a scientific and technological multidisciplinary approach with three stages: Risk factors analysis, Risk assessment and Risk reduction analysis. The main objective in Natural Risk Analysis, taking into account the reasons for its importance showed above, must be disaster reduction after the identification of potential disaster situations.
- The set of all economic risk reduction measures is subjected to decreasing yields´ rules dividing into three zones, the first with individually profitable measures that might be undertaken by individuals, the second with profitable measures only in a global strategy that might be undertaken by public agencies, and the third without economic justification. Insurance systems might play the main role in economic risk reduction.
- The main justification of government intervention is to avoid human disasters; government action in economic risk reduction might play only a supporting role.
- There is a clear trend in technological projects to mitigate risk by shifting from the traditional "hazard approach"(mainly return period) to a "risk approach" associated with risk acceptability criteria or to "maximum hazard approaches".
- There is a need to improve severity-vulnerability scales for some hazards like floods and mass movements.
- Probably hazard and risk maps are the best investment in disaster preparedness for risks with spatial prediction likelihood. Rational planning of this sort might start with identification in settlements and zones of possible types of risk and its potential severity, followed by assessment of possible disasters locations and then by mapping at suitable scales. This measure may be especially useful for undeveloped countries.
- Post-Disaster ad-hoc Multidisciplinary Investigation Commissions are necessary to mitigate future disasters and are a clear indicator of Sustainable Development.
- Greater emphasis might be placed on land-use planning for human-disaster risk mitigation for floods, mass movements, volcanoes and, to a lesser extent, earthquakes (liquefaction zones, faults).
- Today, it is possible to set up a technical-administrative procedure for Population Risk Assessment, based on Risk Analysis, according to the above exposition. This procedure might be the best tool for countries to achieve a better UN Human Development Index.

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References

ANCOLD (Australian National Committee on Large Dams) 1994. *Guidelines on Risk Assessment,* Australia

ANCOLD (Australian National Committee on Large Dams). 1994. *Guidelines on Design Floods for Dams,* Australia

Ayala-Carcedo, F. J. 2001. La Ordenación del Territorio en la prevención de catástrofes naturales y tecnológicas. Bases para un procedimiento técnico-administrativo de evaluación de riesgos para la población. *Boletín de la Asociación de Geógrafos Españoles,* 30, 37-50

Ayala-Carcedo, F.J. & Sanz, Mª. J. 2000 a. Plagas y epidemias entomológicas. En Ayala-Carcedo & Olcina Cantos (eds.), *Riesgos Naturales. Una perspectiva global,* Ariel, Barcelona, in press

Ayala-Carcedo, F.J. & Piserra, M. 2000 b. Impacto potencial del Cambio Climático en los seguros en Europa, *Revista MAPFRE Estudios,* Madrid, 69, 15-20

Ayala-Carcedo, F.J. 2000 c. La inundación torrencial catastrófica del camping Las Nieves (Biescas, Pirineo Aragonés) del 7 de agosto de 1996. En Ayala-Carcedo & Olcina Cantos (eds.), *Riesgos Naturales. Una perspectiva global,* Ariel, Barcelona, in press

Ayala-Carcedo, F.J. 1999 a. Selección racional de estrategias estructurales y no estructurales y de actuaciones públicas y privadas en la mitigación del riesgo de inundaciones en España. Un análisis comparativo, *Revista de la Real Academia de Ciencias,* Vol. 93,1, 99-114

Ayala-Carcedo F.J. & Silva, J. 1999 b. *Desastres Naturales y Tecnológicos en España (1950-1999),* Escuela Técnica Superior de Ingenieros de Minas, Madrid, unpublished report

Ayala-Carcedo, F.J. 1994. Socioeconomic impacts and vulnerability resulting from slope movements. In Corominas & Georgakatos (eds.), *US-Spain Workshop on Natural Hazards,* Iowa Institute of Hydraulic Research, Iowa University, USA, 235-254

Ayala-Carcedo, F.J. (ed.).1990-95. *Los Peligros Naturales en España. Informes Anuales,* ITGE, Madrid

Ayala-Carcedo, F.J. (ed.).1990-95. *Natural Disasters in the World. Annual reports,* ITGE, Madrid

Ayala-Carcedo, F.J. 1991. Concepts and problems dealing with Optimum Design Strategies for Natural Risks Mitigation. *International Congress on Alleviation of Natural Disasters,* World Federation of Engineering Organizations, Arusha, Tanzania, 6.1.5, FE-1 to FE-20

Ayala-Carcedo, F.J. 1993. Estrategias para la reducción de desastres naturales, *Investigación y Ciencia,* Mayo, 6-13

Ayala-Carcedo, F.J.1990. Análisis de los conceptos fundamentales de riesgos y aplicación a la definición de tipos de mapas de riesgos geológicos, *Boletín Geológico y Minero,* ITGE, Madrid, (101), 3, 456-467

Berga, L. 1998. New trends in hydrological safety. In Berga (ed.), *Dam Safety,* Vol. 2, 1099-1106

Bolt, B. A. 1987. *Terremotos*. Orbis, Barcelona, 266 pp.

Braunner, C. & Cochrane, S. 1995. *The Great Hanshin Earthquake. Trial, Error, Success.* Swiss Re, Zurich, 28 pp.

Chicken, J. C. 1975. *Hazard Control Policy in Britain,* Pergamon Press, New York

Cunny, F.C.1994.Cities under siege: problems, priorities and programs. *Disasters,* 18 (2), 152-159

Dubreuil, H., 2000, *Acceptability of Risk: Individual Choice and Social Construction,* http://trustnet.cepn.asso.fr/DOC2.html, 11 pp.

Foster, H.D.1994. Disease as disaster. *Interdisciplinary Science Reviews,* 19 (3), 237-254

Fujita, T.T. 1970. *A Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity,* SMRP Research Paper No. 91, Department of Geophysical Sciences, University of Chicago, Chicago

German IDNDR-Committee. 1994. *Projects for the Understanding and Mitigation of Natural Disasters,* Bonn, 307 pp.

Gil Olcina, A. & Olcina Cantos, J. 1999. *Climatología Básica.* Ariel, Barcelona,387 pp.

Grigg, N. S. And Helweg, O.J. 1975. State-of-the-Art of Estimating Flood Damage in Urban Areas, *AWRA Water Resources Bulletin,* 370-390

Hart, G.C. 1976. *Natural Hazards: Tornado, Hurricane, Severe Wind Loss Models,* prepared for the National Science Foundation (NTIS No. PB 294594/AS), J.H. Wiggins Co., Redondo Beach, California

Hewitt, K. 1997. *Regions of Risk. A Geographical Introduction to Disasters,* Longman, England, 389 pp.

Higson, D.J. 1990. Nuclear Safety Assessment Criteria. Nuclear Safety, 31 (2), 173-186

IDNDR. 1994. *Disasters around the World. A global and regional view,* World Conference on Natural Disaster Reduction, Yokohama, Japan,87 pp.

IDNDR. 1994. The Yokohama Declaration. In Munashinge, M. and Clarke, C., *Disaster prevention for sustainable development.* IDNDR/The World Bank, Washington, 1995

Instituto Nacional de Estadística. 1999. *Anuario Estadístico*
Interagency Committee on Dam Safety, USA, 2000, http://www.fema.gov/mit/

Kauf, E. 1978. *La Maîtrisse des Risques.* Ed. Securitas, 188 pp. (spanish edition in Mapfre)

Lachman, R., Tatsouka, M. & Bonk, W.J. 1961, Human behaviours during the tsunami of May, 1960. *Science,* 133, 1405-1409

Lee, L.T. & Eguchi,, R. 1977. *Capital Investment Program for Mitigation of Risk from Natural Hazards,* prepared for the U.S. Naval Facilities Command, J. H. Wiggins Co., Redondo Beach, California

Lee, L.T.; Chrostowski, J. & Eguchi, R. (1978), *Natural Hazards: Riverine Flooding, Storm Surge, Tsunami Loss Models,* prepared for the National Science Foundation (NTIS No. PB 294682/AS), J.H. Wiggins Co., Redondo Beach, California

Marcellini, A. 1991. Methodology for Microzonation Assessment. In Fantechi & Almeida-Texeira (eds.), *Earthquake hazard assessment,* Commission of the European Comunities, Louxembourg, 119-132

Mark Tweeddale, H. 1995. "Acceptable risk in petrochemical and hazardous chemical plants". Heinrich & Fell (eds), *Acceptable Risks for Major Infrastructure,* Balkema, Rotterdam, 79-86

McNeill, W.H.1984. *Plagas y pueblos.* Siglo XXI, Madrid, 313 pp.

Miller, J. B. 1997. *Floods. People at Risk, Strategies of Prevention.* DHA (Department of Humanitarian Affairs), United Nations, 93 pp.

Munich Re. 1990-99. *Annual reports on natural disasters in the world*

Nájera, A. 1999. *Las catástrofes naturales y su cobertura aseguradora. Un estudio comparativo.* Consorcio de Compensación de Seguros, Madrid, 263 pp.

National Floods Insurance Program. 2000, USA, http://www.fema.gov/nfip/pstat.htm

National Research Council. 1994. *Facing the Challenge.* National Academy Press, Washington D.C.,78 pp.

O´Riordan, T. 1990. Hazard and risk in the modern world: political problems for programme design. En Hammer & Penning-Roswell eds. *Hazards and the communication of risk,* Gower Technical, Brookfield, Vt., 293-302

Parry, M; Parry, C. & Livermore, M., edit. 2000. *Valoración de los efectos Potenciales del Cambio Climático en Europa.* Universidad de Castilla-La Mancha, 29 pp.

Petak, W.J. & Atkisson, A.A.1984. *Natural Hazard Risk Assessment and Public Policy. Anticipating the Unexpected.* Springer Verlag, 489 pp.

Swiss Re. 1990. *Natural Disasters in the World* 1970-89, Zurich

Swiss Re. 1990-99. *Natural Disasters in the World. Annual Reports,* Zurich

The Great Hanshin (Kobe) Earthquake, Japan, 1999, http://www.kanados.com/kobe-quake/

Tiedemann, H. 1992. *Earthquake and Volcanic Eruptions. A Handbook on Risk Assessment.* Swiss Re, Zurich, 951 pp.

U.S. Bureau of Reclamation. 1989. *Policy and Procedures for Dam Safety Modification Decision Making,* Denver, Colorado

UNDRO. 1984. *Disaster Prevention and Mitigation. Vol. 11: Preparedness Aspects,* United Nations, New York, 217 pp.

United Nations. 2001. Analytical Tools for Human Development, http://www.undp.org/hdro/anatools.thm

Varnes, D.J. 1978. Slope movements types and processes. *Landslides and Engineering Practice.* National Research Board Special Report 176, 11-33

Withman, R. V. 1984. Evaluating calculated risk in Geotechnical Engineering. ASCE *Journal of Geotechnical Engineering,* 110(2), 145-188

Wrigley, J. & Tromp, F. 1995. Risk management of major hazards in Hong Kong In Melcher & Stewart (eds.), *Integrated Risk Assessment.* Balkema, Rotterdam, 37-41.

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