TIGRA

THE INTEGRATED GEOLOGICAL RISK ASSESSMENT

ITGE (SPAIN) CONTRIBUTION

This work has been performed by Francisco Javier Ayala-Carcedo

INDEX

1.- INTRODUCTION

The TIGRA Project is included in the European Commission Research Programm ENVIRONMENT.

The research has been coordinated by ENEA (Italy), and the partners are:

*Consorzio Civita (Italy)

*ITGE (Spain)

*Dipartimento Scienze della Terra, Università di Genova (Italy)

*Aristotle University of Thessaloniki (Geece)

*Université de Liège (Belgium)

*Université de Nice Sophia Antipolis (France)

*FINISITEL (Italy)

*ENEA (Italy)

*CNR IRPI, Torino (Italy)

*ISMES S. P. A. (Italy)

*Instituto di Elettronica Università di Cagliari (Italy)

*Norwegian Geotechnical Institute

The work presented here is the one performed by ITGE for this Project.

2.-OBJECTIVES

The objectives of the project TIGRA are:

*Criteria for the identification of territorial units of reference and land zoning

*Multi-hazard assessment in the light of meteorological and climate change

*Development of a socioeconomic analysis to be integrated in multi-hazard assessment and focusd to the risk definition

*Development of methodologies and criteria for the identification and evaluation of integrated risk in european areas

*Suggestion and principles for multihazard and multi-risk assessment

The hazards and risk analysed are the next:

-Fluvial dynamics and floods

-Coastal dynamics

-Slope behaviour

-Avalanches and glaciers

-Sea level rising

-Earthquakes

-Volcanic eruptions

-Fires

Short term trends of the territory and analysis of impact of climate change on natural hazards are considered.

Severity/Vulnerability relationship have been investigated as well as the factors of socioeconomic vulnerability.

In the risk assessment, social and economic risks must be considered: Dead, injured, homeless, unemployed, buildings and contents, agricultural and cattle, public infrastructures, environment and benefit losses.

An other objective is the elaboration of criteria for "land vulnerability indexes".

3.-SOCIOECONOMIC IMPACTS, LEGISLATION AND VULNERABILITY: A RISK ASSESMENT GLOBAL APPROACH

3.1.-INTRODUCTION

Natural disasters represent a widespread problem in the world. It is also an increasing problem for a sustainable world in absolute terms, social and economic, as will be shown below. This is the reason why the United Nations have 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 emphasise the *preventive* measures because efficiency of emergency measures, in general, is very limited 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 human expected losses, we have the so-called societal risk, with several types according with the expected dead, injured, homeless and unemployed; if we consider economic expected losses, we have the economic risk, with several kinds according with structural damage, contents 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 a vulnerability of this exposure, a degree of loss from 0(no damage) to 1(destruction or dead). Only when all the risk factors exist there is risk, a conceptual reality (Figure 2). In a simplified quantitative way, Risk may be expressed as:

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

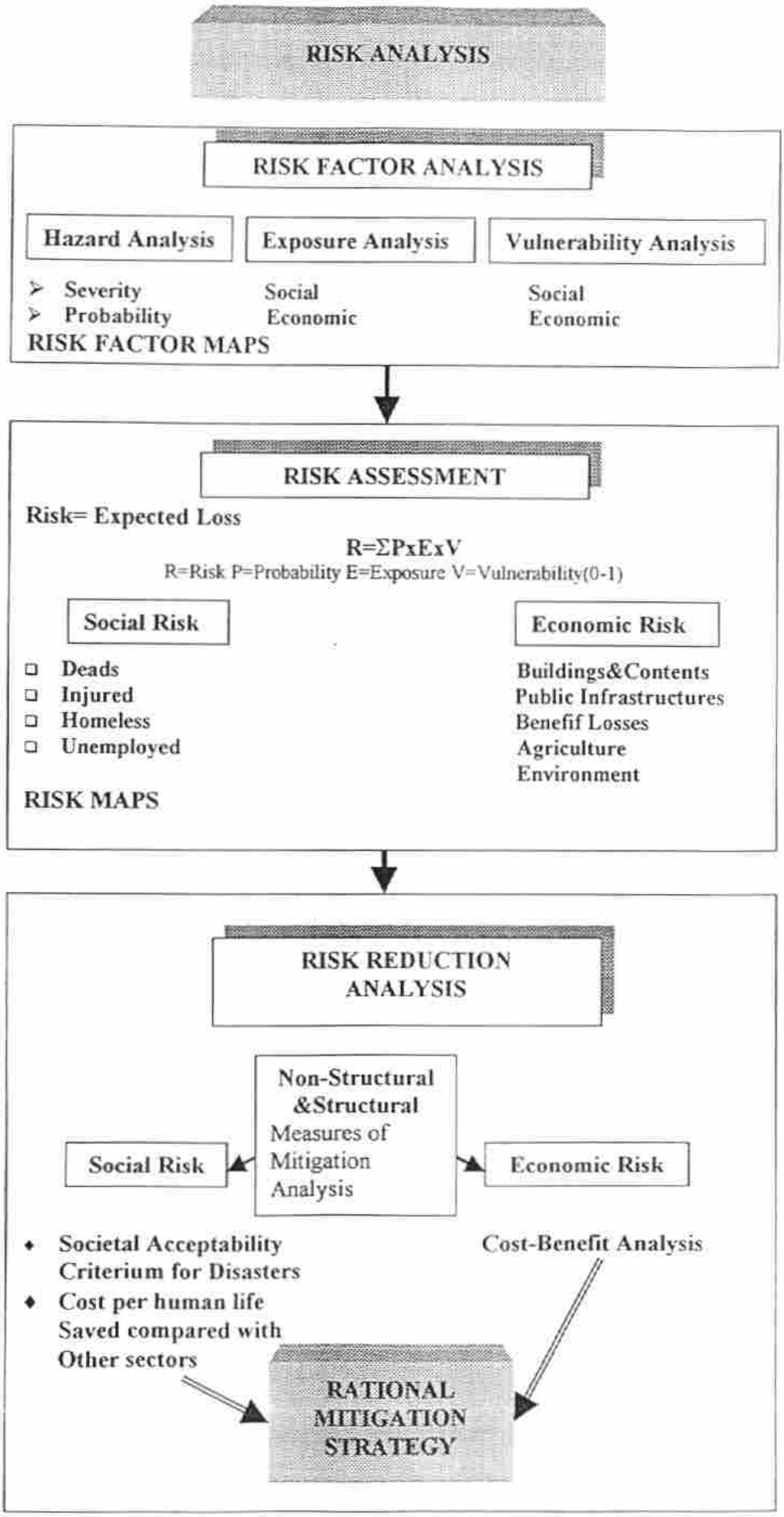
R: Risk (Expected Annual Losses) ; P: Annual Probability of occurrence; V: Vulnerability (0-1); E: Exposure

Obviously, preventive measures pretend risk mitigation, the preventive way to avoid disasters.

The exploitation 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 made from Natural Sciences and Engineering to the problem are hazard approaches, studying both Severity and Probability. Risk Analysis is a global approach , including Social Sciences. This approach is more convenient from the point of view of decision-makers because people is 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 .

The main disasters in the history of Mankind from natural causes were those produced by great epidemics like those in the XIV Century from bubonic pest, ("Black Dead"). killing around one fourth of the European population(McNeill, 1984).


RISK ANALYSIS
RISK FACTOR ANALYSIS
Hazard Analysis
Exposure Analysis
Vulnerability Analysis
Severity
Probability
Social
Economic
Social
Economic
RISK FACTOR MAPS
RISK ASSESSMENT
Risk= Expected Loss
R=ΣPxExV
R=Risk P=Probability E=Exposure V=Vulnerability(0-1)
Social Risk
Economic Risk
Deads
Injured
Homeless
Unemployed
Buildings&Contents
Public Infrastructures
Benefif Losses
Agriculture
Environment
RISK MAPS
RISK REDUCTION ANALYSIS
Non-Structural &Structural Measures of Mitigation Analysis
Social Risk
Economic Risk
Societal Acceptability Criterium for Disasters
Cost per human life Saved compared with Other sectors
Cost-Benefit Analysis
RATIONAL MITIGATION STRATEGY

The impact of these natural biohazards has been, and is, several thousands times greater than the impact of violent physical natural hazards, meteorological and geological (Ayala-Carcedo, 2000), analysed in this paper. Famines produced by drought, often coincident with war, are other source of dead 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).

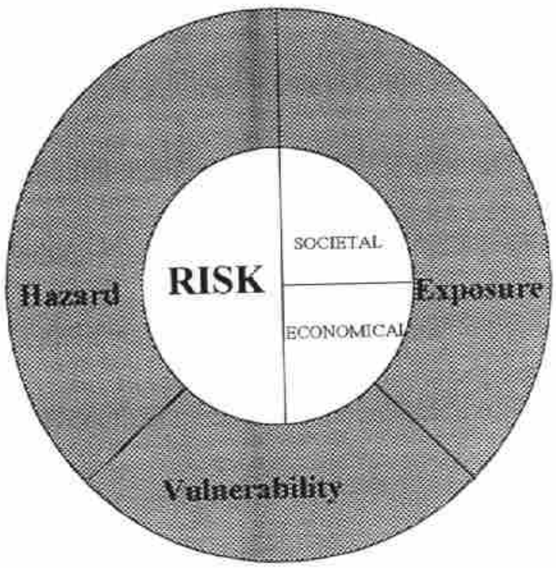


Figure 2.-Factors of Risk and Risk kinds

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 community; a disaster always produce damages over a threshold. By operational reasons the criterion used here is that a societal disaster is the event producing at least 10 dead; this is the threshold to be recorded at national, and sometimes, global media, an index of potential interest of people in these events. It is very difficult to find a single criteria to define economic disasters, because the importance is different at local, regional and global level or at the level of insurance or industrial companies.

There is a problem in 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 cyclone phenomena of different sizes with severe winds like hurricanes, typhoons and including also tornadoes , of floods triggered by other meteorological phenomena like frontal rainfalls or monsoons.

3.2.-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 suffer serious disorders.

Data *reliability* of societal impacts is in general good for developed countries and less good for undeveloped ones; reliability decreases with the size of the disaster. This means that great catastrophes casualties assessment in undeveloped countries may have serious errors, perhaps around 50 to 100 %, sometimes encouraged by governments trying to minimise the figures, sometimes resulting from the difficulties to arrive to the catastrophic zones and realise the true dimensions of the catastrophe.

Main data sources are the database of the Centre pour la Recherche de l'Epidemiologie des Disastres (CRED) in the University of Louvaine in Belgium, reports of reinsurance companies like Swiss Re or Munich Re, databases of the U.S. Geological Survey or NOOA, specialised papers on different hazards or national reports.

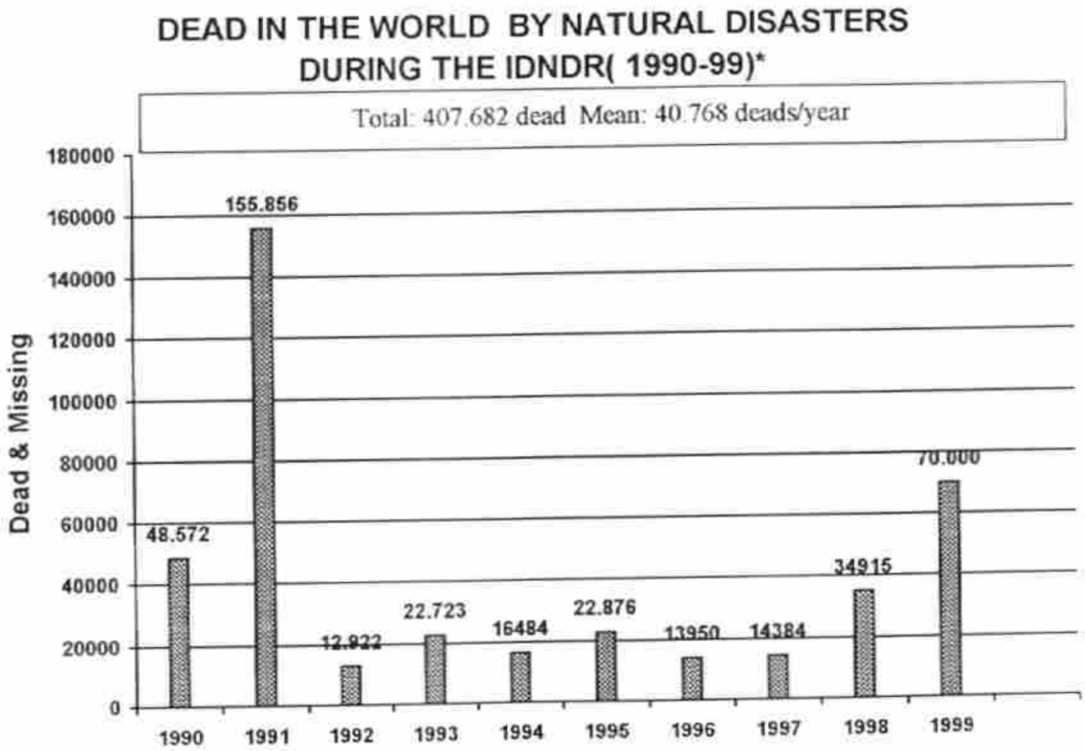


Figure 3.-Dead during The International Decade for Natural Disaster Reduction 1990-2000 (With data of Swiss Re, Munich Re(1996-99) and Ayala-Carcedo(1990-95))

After ten years of IDNDR, most countries, even some 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 estimations up to 650.000). During the IDNDR 1990-1999, there was a total of 407.682 mortal casualties (Figure 3) according with data of Swiss Re, Munich Re and own data (Ayala-Carcedo, edit., 1990-1995). This means an average of 40.768 casualties/year versus 57.000 during the whole period 1965-1999, perhaps a sign of an improved prevention.

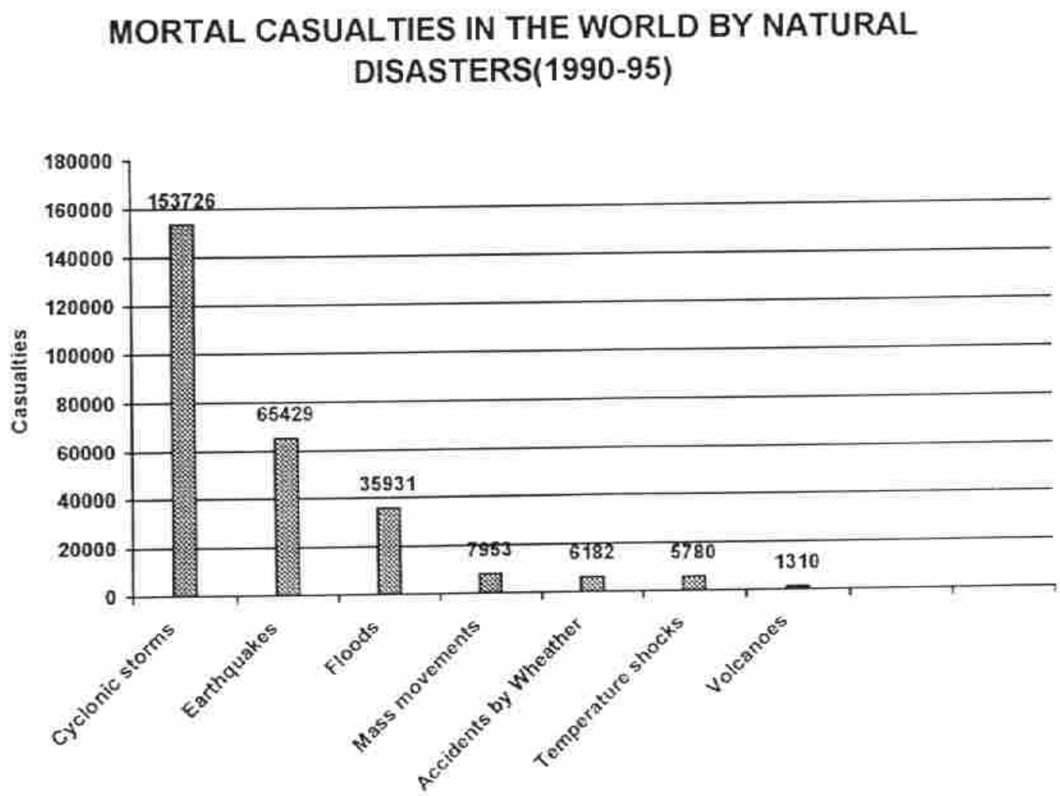


Figure 4.-Dead produced by Natural Violent Hazards, 1990-95 (Ayala-Carcedo, 1990-95)

A distribution by hazard for the period 1990-95 is shown in the Figure 4 , which points cyclone storms followed by earthquakes and floods as 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 lesser catastrophic year was of 11,2 . In terms of hazard, for the period 1990-95, as Figure 5 shows, the higher inter-annual variability were those from cyclone 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.

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 higher 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 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 edit., 1994). Main hazards for sufferers are meteorological, floods and earthquakes.

the world (Ayala-Carcedo edit., 1994). 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-year (Petak & Atkisson , 1984).

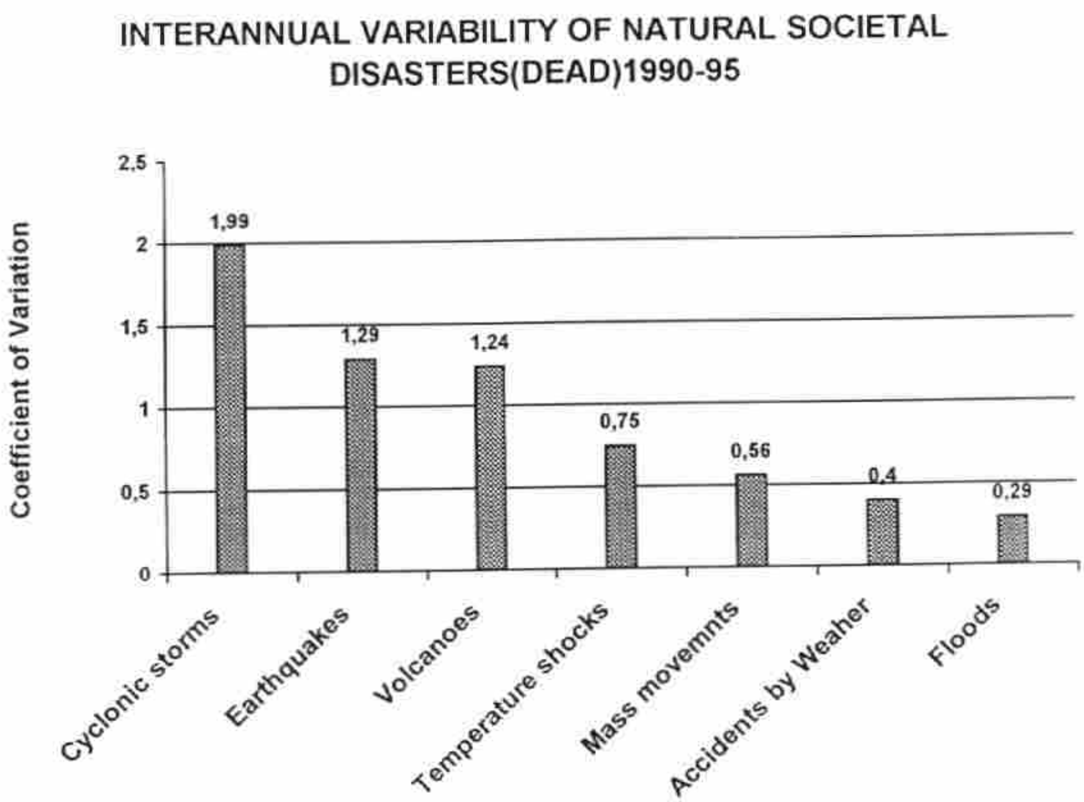


Figure 5.-Variability of annual dead toll of Natural Violent Disasters 1990-95 (Ayala-Carcedo, 1990-95)

The geographical distribution of disasters during the period 1900-1987 may be seen in Figure 8 . A causal research about this distribution may be conducted through Risk

Analysis. Asia, with the 85 % of dead , have all kinds of hazard with the higher severity and greater geographical areas, the highest population exposed and also the highest vulnerability; this means the higher risk factors, and higher risk produce higher casualties. On the other side, Africa has limited violent hazards in geographical area and severity, with medium exposure and high vulnerability; this means much lower risk than Asia, and, according with data, much lower casualties (in droughts, due to semiarid or arid climate, 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 shows the Kobe earthquake of 1995 with 5.426 dead (Braunner & Cochrane, 1995).

Disaster distribution in time was increasing in the period 1963-1992: the number of disasters with 100 or more dead increased from 89 in 1963-67 to 205 in 1988-92 (IDNDR, 1994); but this trend is broken during the period 1992-1998.

3.3.-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 to work in a devastated region and the individual, societal and governmental prevention against 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 in 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 lesser than the one of casualties, and the only reliable data are those from insured losses.

Losses may be classified in *direct* (mainly structural loss of dwelling and public infrastructures, building contents , agricultural and emergency costs) and *indirect* (injured attention, loss of benefit, 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 with actual, residual value of good not with the replacement value.

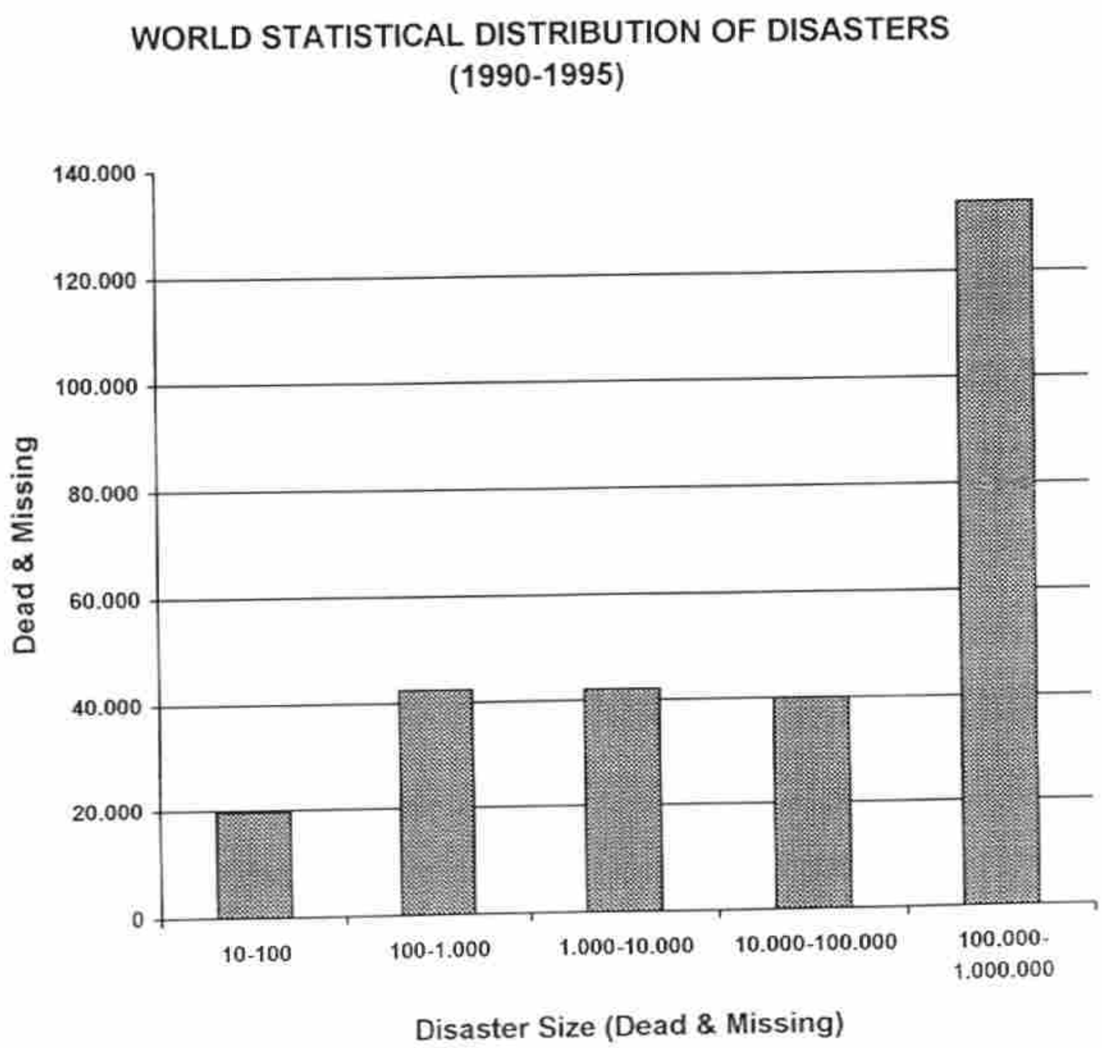


Figure 6.-Accumulated dead in Natural Disasters 1990-95 by disaster size

The main and most reliable *sources* of economic losses are the reports of insurance companies like Swiss Re or Munich Re. The conversion from insured losses to total losses has a doubtful reliability; an objective and reproducible way may be 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 $, *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, edit., 1990-95).

According to Munich Re data , during the period 1986-1995, floods caused 31% of world total losses, wind storm 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.

In a developed country like 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, corresponding 58 % to meteorological damages in agriculture (Ayala-Carcedo, edit., 1995).

The *worst* economic disasters were the mentioned Kobe earthquake with total losses ranging from 82.400 US $ million to 100.000 (Kobe web page) ; 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) and 52 % in the Andrew hurricane (

German IDNDR, 1994). For the period 1990-95, total insured losses were in the world 81.373 US $ million, 20,8 % of total losses. Trend in total losses for a single risk as floods in USA is increasing (Figure 9), probably as a result of increased economic value of exposure. There is a high rising trend from 1987 in insurance losses according with data of Swiss Re and Munich Re. Probably, Climate Change, introducing more energy through temperature increase in the atmospheric and oceanic systems, will change in a progressive way the frequency and severity of all climate related risks as

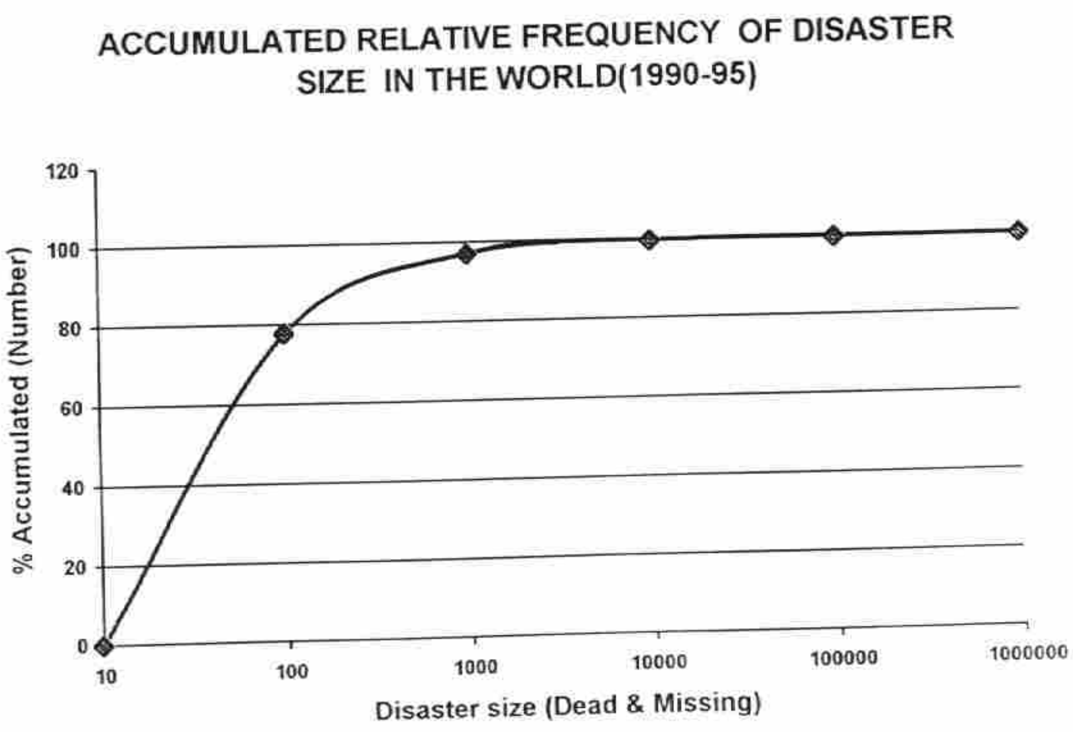


Figure 7.-Accumulated % of Natural Disasters 1990-95 according with Disaster size, shows a much more higher frequency of small and medium disasters

has been suggested for several authors (Ayala-Carcedo, 1999; Ayala-Carcedo & Piserra, 2000) and shown for Europe by the ACACIA project of the European Union (Parry, Parry & Livermore edits., 2000).

WORLD GEOGRAPHICAL DISTRIBUTION OF DEADS IN NATURAL DISASTERS (1900-1987)

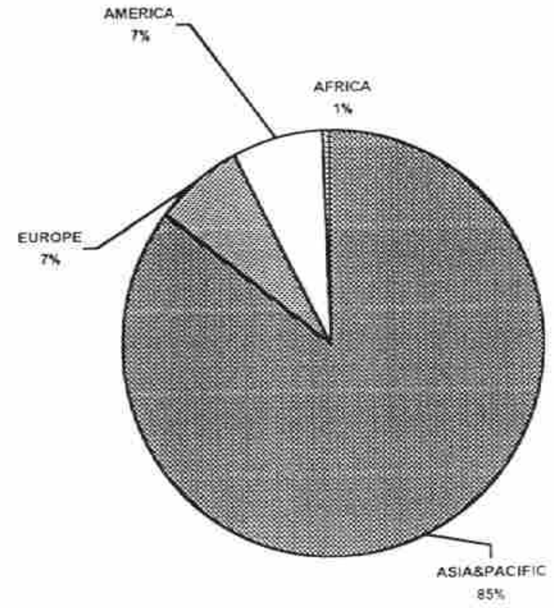


Figure 8.-World geographical distribution of fatalities shows Asia is the continent most hit by Natural Disasters (with data of Japan IDNDR)

The geographical distribution of %GNP losses shows clearly a greater impact for undeveloped countries (Figure 10). The main reason may probably be a higher

necessary a quantitative comparison concerning societal and economic aspects.

From the point of view of societal aspects the weight of mortal casualties by natural structural vulnerability and also a greater weight in economy of agriculture, strongly affected by meteorological risks. Most of total losses are in developed countries due to higher exposure values in despite the lower economic vulnerability; this is specially true for insured losses. This trend to more intense damage for lesser development is also true inside each nation: *social impact of economic losses* is higher for low income groups.

The awareness of the fact that lower income levels per capita at national and world level are the most hit by natural disasters at human and economic level is the key to understand the contribution of natural disaster reduction to Sustainable Development in the way from the Yokohama Declaration (IDNDR, 1994). *Safety and increase in societal cohesion at national and global level are the contributions to Global Sustainability* of the mitigation strategies.

3.4.-WHY NATURAL DISASTER ARE IMPORTANT?

To understand the relative importance of natural risk with regard to other risks, is necessary a quantitative comparison concerning societal and economic aspects.

From the point of view of societal aspects the weight of mortal casualties by natural hazards as regards of other hazards like traffic and general morbidity is very low, as may be seen in Figures 11 and 12 . In Spain, for instance, industrial accidents affecting workers accounted during the period 1996-99 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 in an active life of 35 years of $4x10^{-3}$, and an annual probability of dead of $1x10^{-4}$. Nevertheless, natural hazards, with a probability in Spain of dead during life of $1,7x10^{-4}$ and an annual probability of dead of $2x10^{-6}$, 50 times lesser than industrial accidents, have a greater societal impact for disasters with regard to other risks like industrial or traffic accidents.

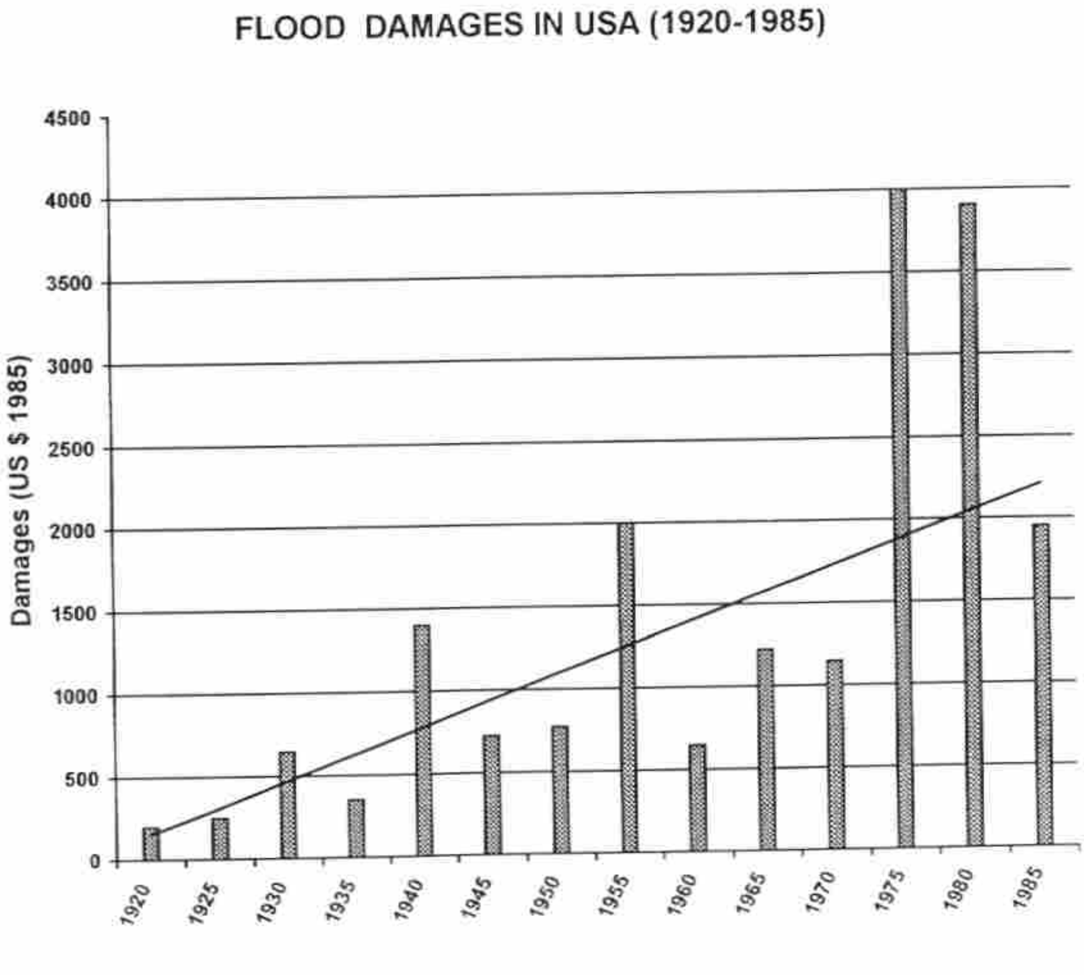


Figure 9.-Rising trend of floods losses in USA, probably related with rising economic exposure (with data of NOOA)

If we perform a deeper analysis of casualties presentation in time , a new insight spurts in relationship with the difference between events and disasters showed before. Traffic or industrial accidents with 10 or more dead are very rare; events with 10 or more dead produced by natural hazards, natural disasters, are much more common. This reality is much more enhanced when the dead toll of events is 100 or higher.

If we review among all the events with a dead result, only those with 20 or more dead at a world level, the conclusion is very clear: *natural disasters are at a world level the main source of disasters* , that is, events with a high production of dead (Figure 13). And this fact is enhanced when we see historical disasters (Figure 14).

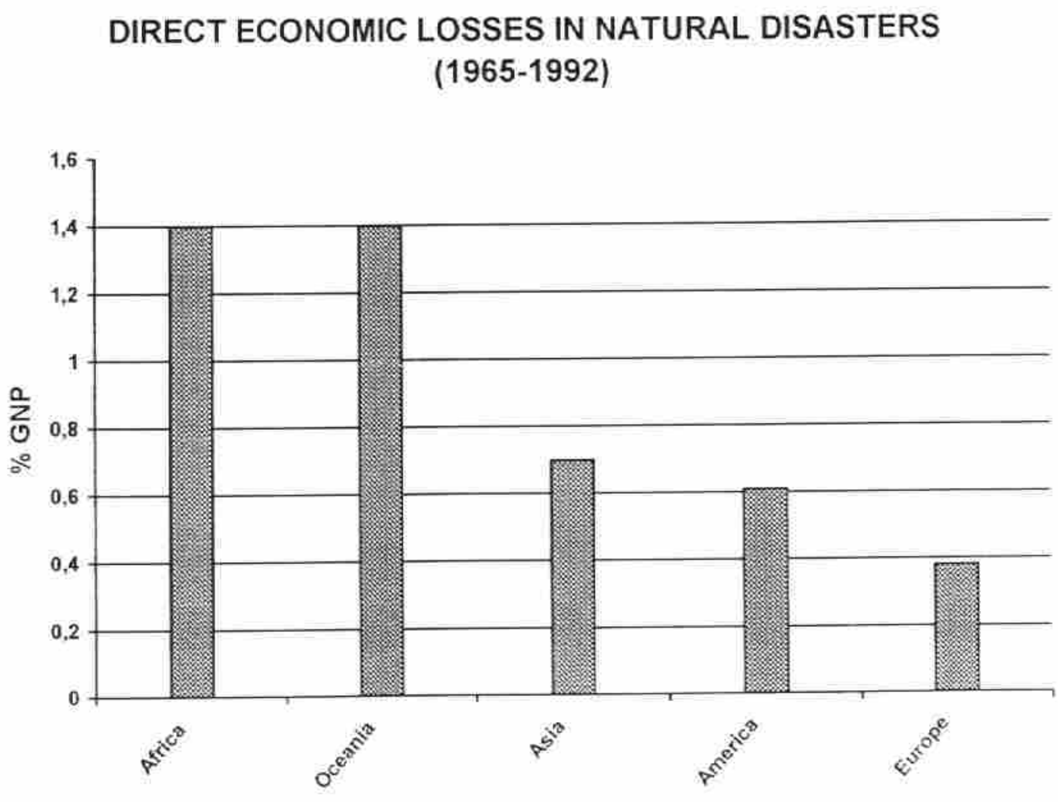


Figure 10.-Economic vulnerability to Natural Disasters is clearly higher in undeveloped continents (with data of CRED, partly modified by IDNDR of Japan)

companies.

countries present the higher impacts in GNP terms.

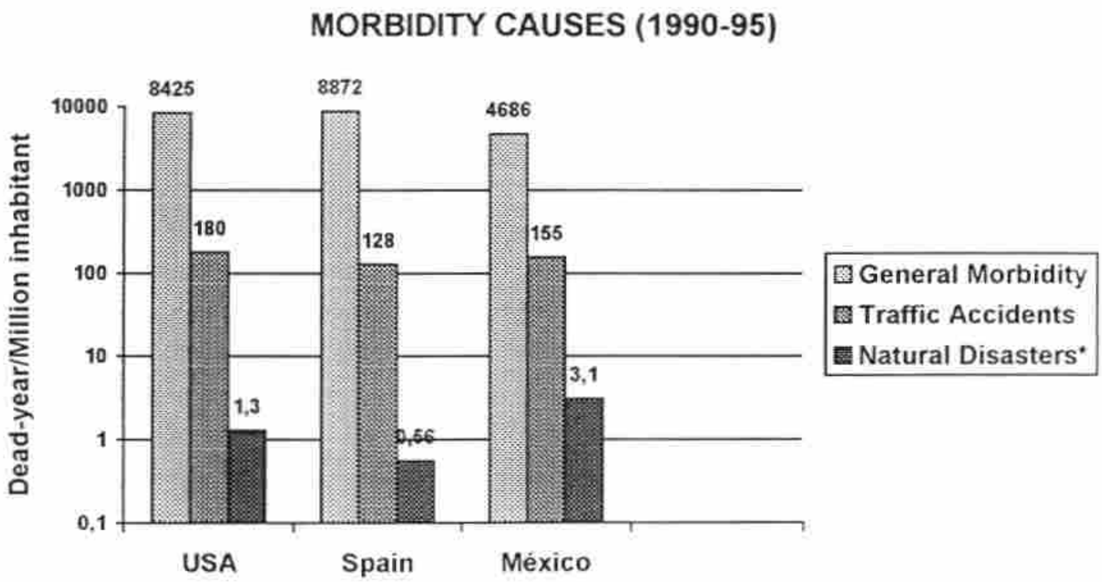
Disasters, opposite to common accidental events, have an increased capacity to hit *simultaneously* the conscience of a great quantity of people. A good test of this assertion is the volume of news in media when there is a disaster, and we have in mind recent cases such as the Mitch hurricane in Central America of 1998, and the Turkey earthquake and Venezuela floods of 1999, with a total dead toll of some 80.000, all filling newspapers headlines during two weeks. 45.000 mortal casualties in traffic accidents each year in USA do not have such a comparative concentrated impact. People almost assumes traffic risk and everyday traffic dead but , without a clear awareness of natural risk, with relatively high recurrence periods, don't assume natural disasters and claims government responsibilities.

In developed countries such as Spain, this is not the pattern because technological disasters with ten or more casualties have produced during the last 50 years higher human losses than natural disasters (Ayala-Carcedo and Silva, 1999), being also the worst single disasters by dead toll. Despite this fact, developed countries may be hit by great societal disasters with low recurrence periods like the Kobe earthquake in 1995, with 5.426 dead(Braunner & Cochrane, 1995).

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

As it has been shown, undeveloped countries present the higher impacts in GNP terms, and some great disasters, have impact on economies for several years. Developed countries have, due to higher economic exposures, higher total economic impacts, but lesser impacts on GNP. Besides, insurance cover of damages is about ten times higher in developed countries, being much more lesser the societal side associated to economic losses and also the economic claims to governments.

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



*More than 9 dead

Figure 11.- Comparison of *total* dead toll of Natural Disasters with other dead causes don´t give an adequate idea of real importance of Natural disasters, an importance coming only of a comparison of dead toll in events with 10 or more dead, the disasters (With data of Hewitt(1997) and own data)

From these facts, the answer to the question posed 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.*

3.5.-PHILOSOPHY AND KEYS FOR MITIGATION STRATEGIES

The design of an *optimum* mitigation strategy according 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(Beaufort Scale for wind at the beginning of XIXth Century, Gil Olcina & Olcina Cantos, 1999) and also Severity-Vulnerability Scales(the Rossi-Forel Scale for earthquakes in 1880 and the Mercalli one in 1902; Bolt, 1981), important fields like mass movements (despite works like those of Varnes , 1978) and floods(there are some works on curves of standardised floods to the mean annual one –return period, DHA,1997), have not adequate scales, necessaries for Risk Analysis. Volcanoes have an Explosivity Index Scale (see Tiedemann, 1992).

Science and Technology have also investigated structural vulnerability, specially for earthquakes(MSK scale, 1964). 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 USBR (1989), showing the great importance of warning time: when warning time is lower than 1,5 hours, vulnerability increases in a exponential way. Human and economic vulnerability in mass movements has been investigated by the author (Ayala-Carcedo, 1994). Use of MDR (Mean Dead Rate or Mean Damage Rate) may be a good option in disaster analysis (Tiedemann, 1992). Exposure is also an insufficiently studied risk factor, being often the key factor. For example, from the study of Lee et al. (1978), it is clear that flood risk, due to higher percentage of exposures in floodplains , 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 antropogenic changing factors. Thus, the evolution of fatalities due to lightning in Spain, is well explained by changes in farmers population , the most exposed group as they work outdoors (Figure 16).

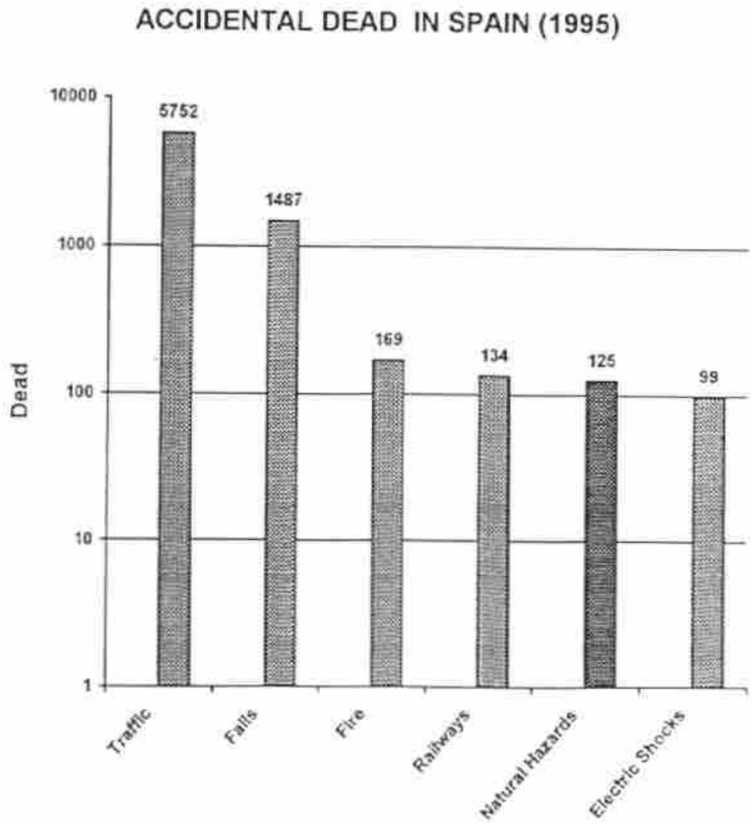


Figure 12.-Total dead toll of Natural Hazards in Spain compared with other accidental dead (With data of National Institute of Statistics, 1999)

Much more work must yet be done in these fields to have reliable risk assessments.

Disaster Analysis is the main way to new knowledge, and, in this way, *Post-Disaster Analysis by interdisciplinary ad-hoc Investigation Commissions is a key criterion of Sustainable Development.*

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

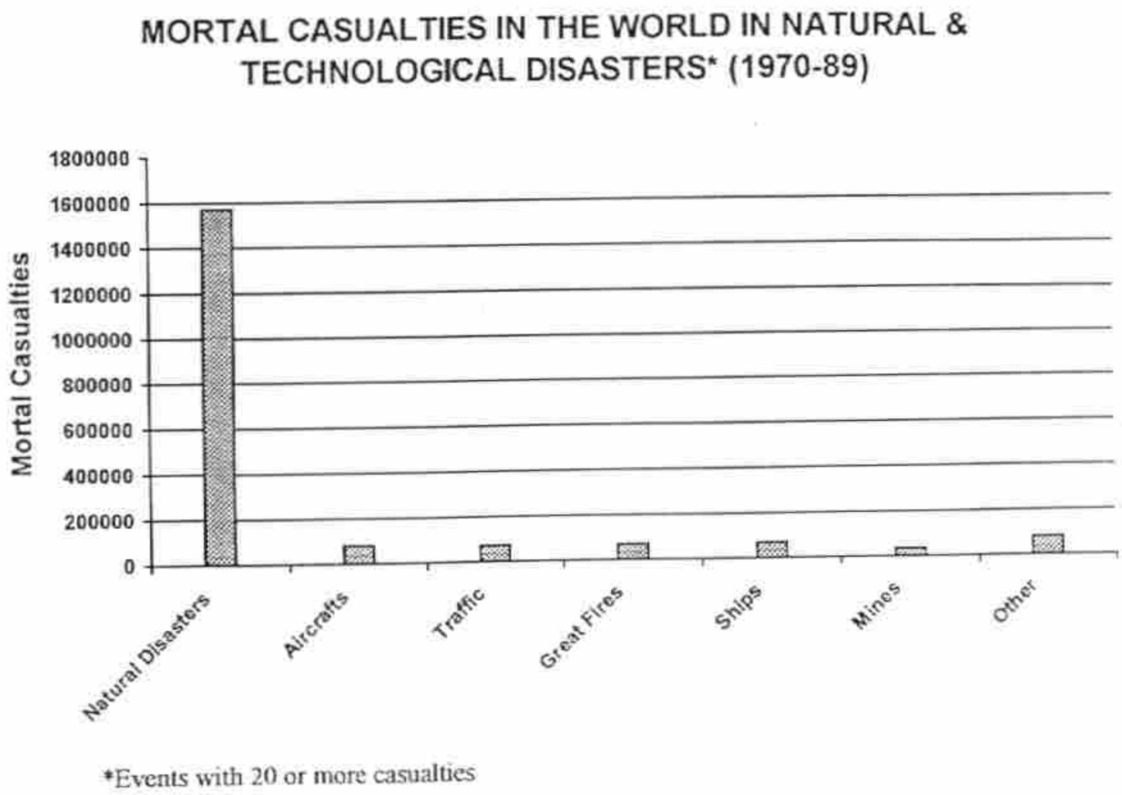


Figure 13.-Analysis at a world level of dead toll in disastrous events, shows that Natural Disasters are the main source of dead in disasters in the World, and this is the main reason of its importance (Swiss Re, 1990)

Preparedness needs to know *the 3W, what, where, when*. The what, the where and the when, are closely related as shown below.

What is related with the *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 earthquake-triggered liquefaction and flash-flooding due to 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 means to define the *spatial forecasting* of hazard and risk with all kinds of *risk maps* (Ayala-Carcedo, 1990).

When means *temporal forecasting* of hazard happening, with two intervals: short term and long term. Long-term forecasting is in general possible and is directly related with hazard probability for risk assessment, needing records of events, specially the 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 of landslides, snow-avalanches and most of extraterrestrial impacts. Opposite, short-term forecasting is possible for far triggered tsunamis, most of storms with lightning, medium and great river basins floods, about a half of volcanic eruptions and most of epidemics and plagues. A subject to investigate related with temporal forecasting is the 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, clearly related with summer monsoon (Ayala-Carcedo & Llorente, 1991).

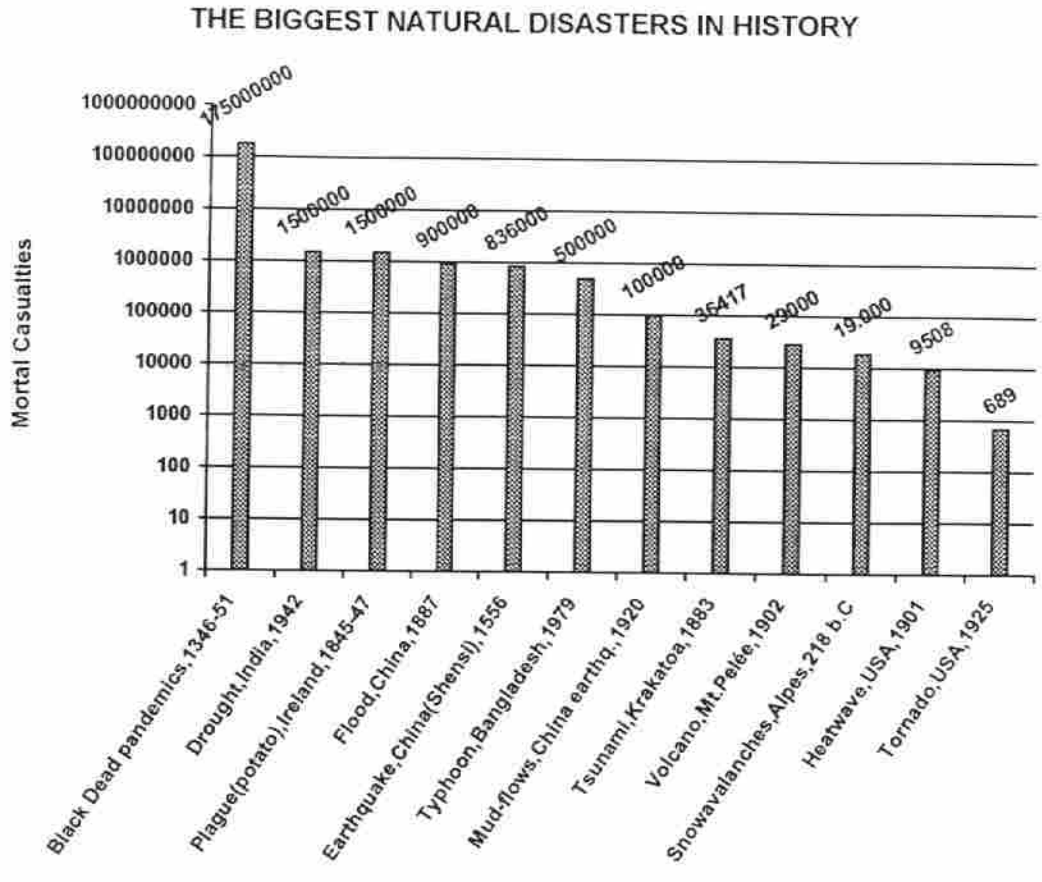


Figure 14.-Epidemics and droughts have been the biggest Natural Disasters

The fact that there are severe problems with short-term forecasting, enhances the need of preparedness from a long term point of view.

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

How to choose between different strategies to mitigate *economic risk*? There are two criterions for: efficiency and economy. Efficiency means better capacity to diminish risk . Economy means higher 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 have three zones: a) Zone I: all the actions have benefit (risk reduction) greater than cost thus they are economically interesting for private owners ; the cut point is placed when the tangent to the curve equals 1; b) Zone II: actions are not economically advantageous but may benefit from the positive balance of actions in Zone I through governmental action; c)Zone III: all the actions are not profitable from both private or public point of view in an economic sense (but may be necessary from the societal point of view).For *societal risk* strategy choice, there are three criterions. We saw that natural hazard importance from a societal point of view must be economic : the minimum cost by avoided dead. From this point of view, Petak & Atkisson (1984) showed in a crossed analysis the differences among natural hazards in terms of dead by million US $ loss in USA (Figure 20). Risks with lower ratio dead/economic loss are in general more affordable to mitigation.

In this sense may be oriented the general government strategy against morbidity. 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 opportunity cost associated with natural risk mitigation investments. Despite this assertion being substantially true, this point of view might take into account the increased importance for public opinion of this disaster generation capacity of natural hazards.

The third criterion is *societal risk acceptability*, sometimes called "group risk acceptability" (Mark, 1995). Society loathe disasters and there is a non-linear relationship with disaster size but an amplified one; people only accepts greater disasters when probability is lower with a log-log, a potential relationship. Besides, it is known the probability of individual dead for many kinds of events and also the probabilities associated to different actual events with different number of fatalities; so, present day mean annual probability of immediate individual dead 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 delayed, lifetime individual probabilities are the former times life expectancy.

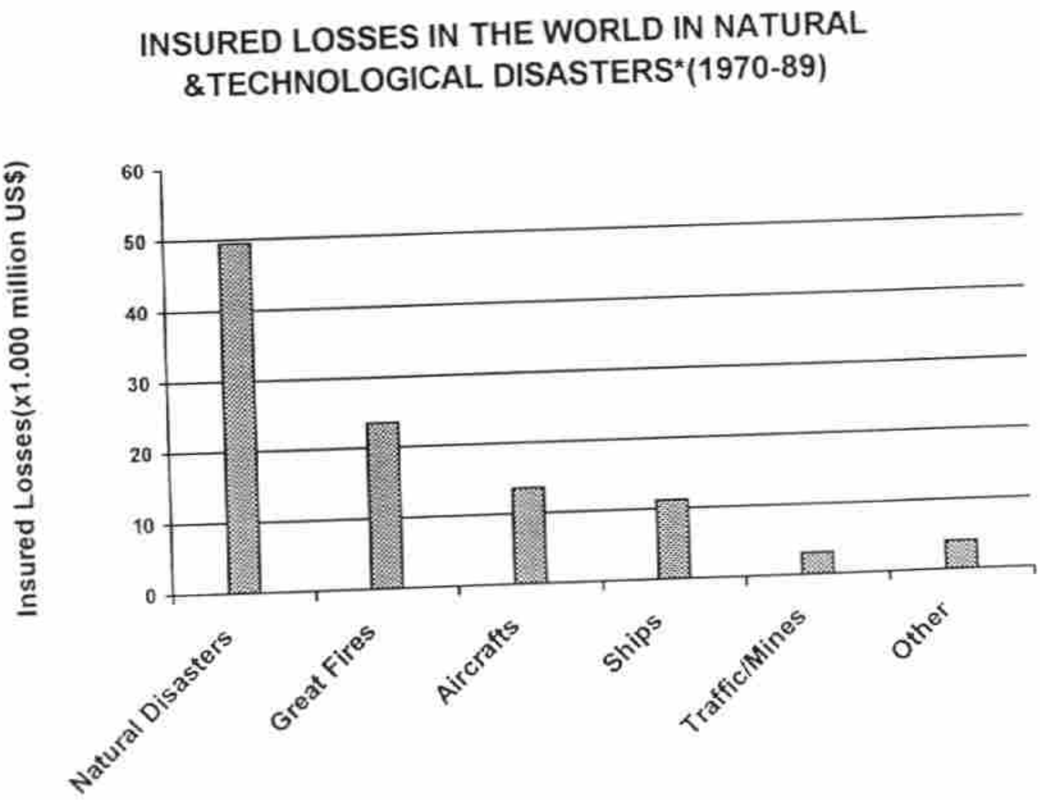


Figure 15.-Natural Disasters at world level are the bigger economic disasters (Swiss Re, 1990)

These studies about individual immediate dead risk (Chicken, 1975) are the base for individual risk acceptability risk criteria like the VRJ, being 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).

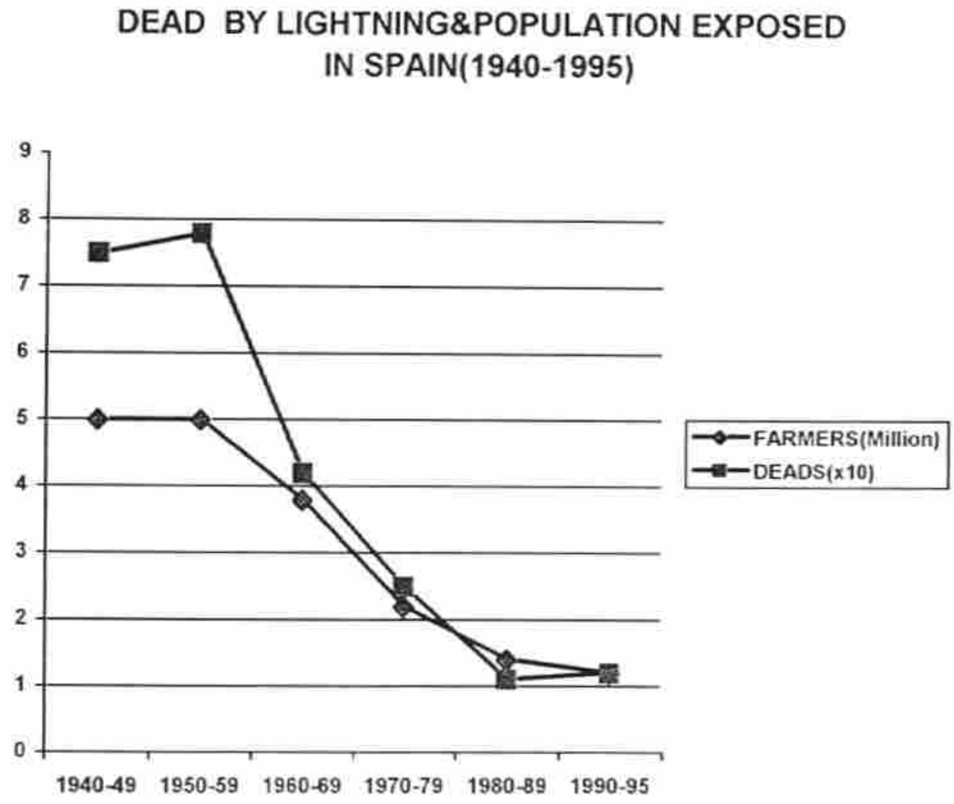


Figure 16.-Farmers population decrease in Spain is the key to understand the fall of dead by lightning

For groups exposed to risk, a societal approach is needed due to probability of a catastrophe. The criteria are called F-N , with F being frequency of one event with N or more fatalities, and the relationship a log-log or potential one. Figure 21 , shows the criterion of Hong Kong Government (Wrigley & Tromp, 1995), a criterion where catastrophes with 1.000 or more fatalities are not accepted. 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 potential scenarios of disasters for risks as earthquakes or cyclone storms, where all population is exposed, are megacities in undeveloped countries, vulnerable settlements with a clearly increasing trend. Then it is probable that earthquake risk be increasing.

Aversion to economic risk has the same rules, a log-log relationship between annual probability of failure and economic potential losses (Withman, 1984), the foundation for insurability criteria .

3.6.-STRUCTURAL AND NON-STRUCTURAL MITIGATION MEASURES : A RATIONAL APPROACH

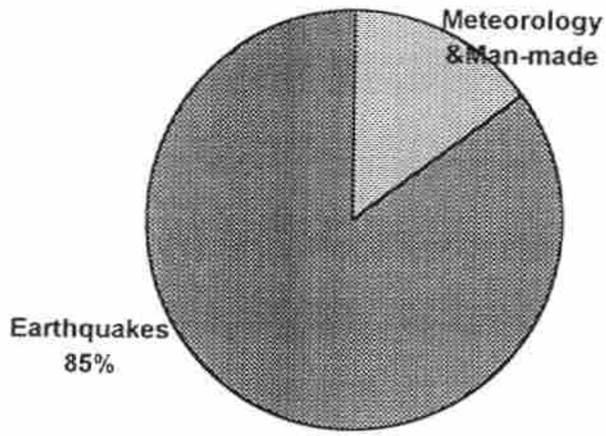
Mitigation strategies may be classified according with the risk factor mitigated as may be seen in Figure 22 (Ayala-Carcedo, 1993).

Antihazard and antivulnerability(structural) measures are usually called structural measures, and may be classified in active measures (antihazard) and passive ones (antivulnerability); antiexposure measures are called 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 freato-magmatic eruptions.

MORTAL CASUALTIES BY TRIGGERING CAUSE IN EARTH SLOPE DISASTERS* (From 1000 A.D.)



*Events with more than 100 Dead&Missing

Figure 17.-Dead analysis in landslides shows earthquake triggering accounts the most of them (Ayala-Carcedo, 1994)

*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 non-structural measures, and engineers to structural ones. Before we have provided the main criteria for a rational choice, but it seems that a deeper insight is needed in a comparative way. Feasibility of insurance and population exposed to risk training is a fact, and are always necessary measures; Brauner & Cochrane (1995), showed the importance of population training in the Kobe earthquake of 1995 for first-aid due to accessibility problems for

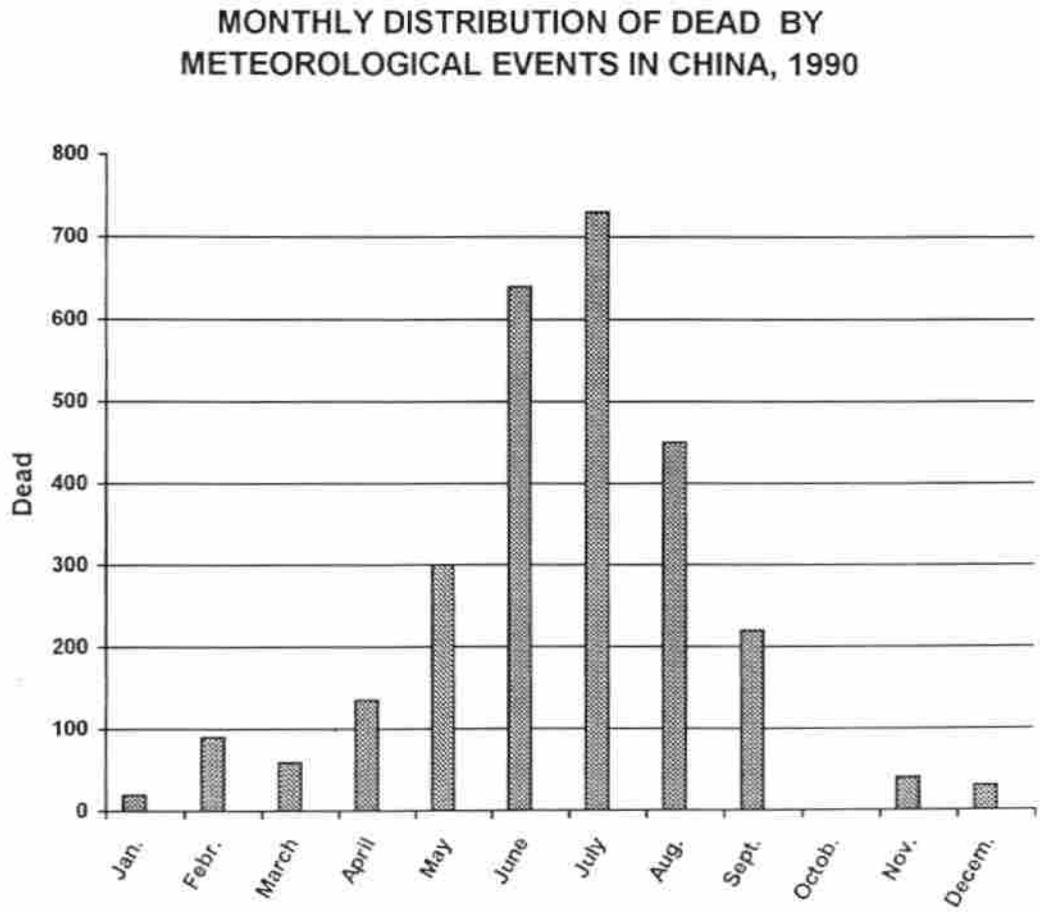


Figure 18.-Analysis of dead distribution in time , necessary for emergency organization, shows in this case of China, a control by summer monsoon (Ayala-Carcedo & Llorente, 1991)

The feasibility of enough warning to produce practical effects is a fact only in some cases as has been shown before.

Land-use planning is feasible and useful for : volcanic lahars (ashes mud-flow), earthquake amplification (when are microzonation maps, see f. i. Marcellini, 1991), mass movements, floods and coastal risks (tsunamis, storm surges etc.). Insurance with premiums established according with risk, must take into account spatial forecasting of hazard, and are then related with land-use, as will be shown below for the National Flood Insurance Program of USA, managed by the FEMA.

Many structural measures are paid by governments, and governments have also, at different geographic scales, the power to establish land-use measures and also codes for construction of private dwellings. *Governments are mainly concerned in avoiding human disasters*, some times because, like in the Spanish case, the Constitution entitles government to protect the life of citizens; then , Societal Risk Acceptability criteria, as indicated before, might be the first choice of mitigation measures. In this approach, land-use planning measures take advantage with respect to structural ones because, many times, and in a single way, may guarantee zero risk for population as regards floods, coastal dynamics or mass movements; an alternative and expensive measure is the "maximum hazard approach" used to dam design. This is not possible for consolidated settlements; in these cases, structural measures are often necessary.

Structural measures have two objections. 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 there is a total risk coverage and uses the land in a free way, many times with much more higher societal risk levels than acceptable. The second problem is related with the cost of many structural measures. *Must the government pay expensive structural measures* *when there is the possibility to avoid human risk with land-use planning?* This is a key question in new settlements authorisation. Government may provide risk maps where 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 a total protection for people in the cases shown before. Land-use planning may induce other costs, such as higher transport costs or so on; in these cases, an optimised solution may

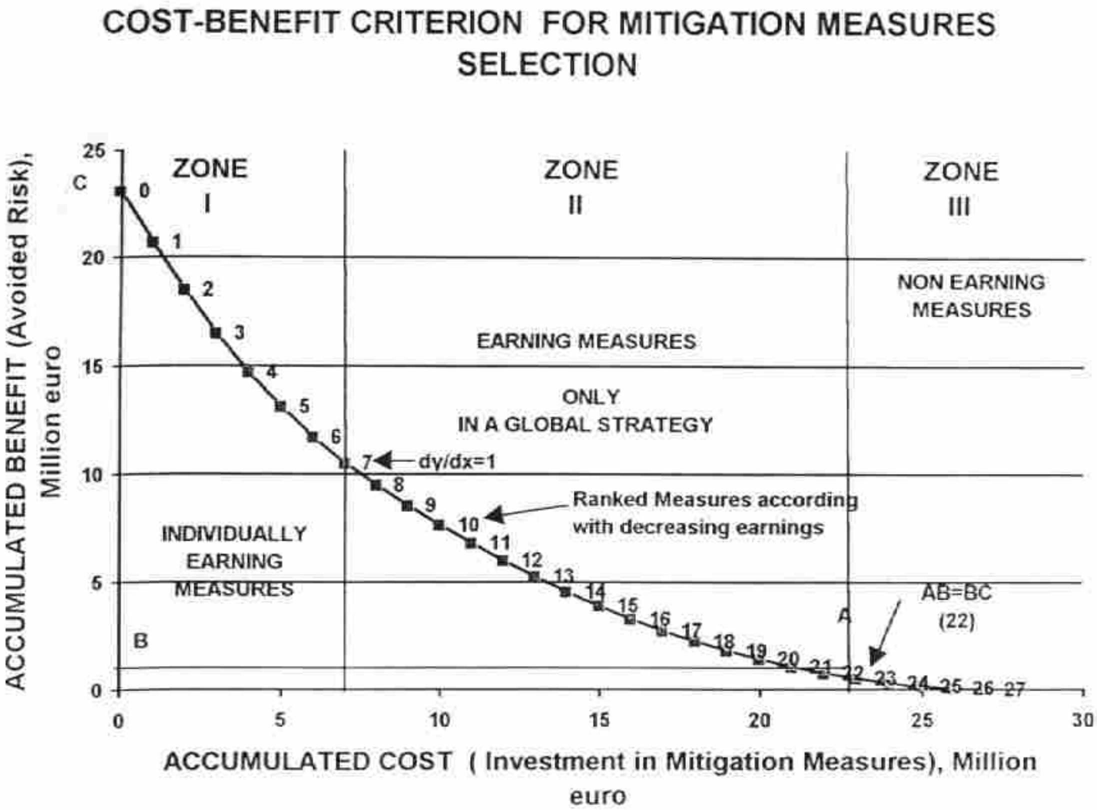


Figure 19.-Ranking of mitigation measures according with cost and benefit, shows a decreasing yields curve that may be used to do a rational choice (Ayala-Carcedo, 1993)

include antivulnerability measures on dwellings. The main opposition against land-use planning comes from flood-plain soil private owners.

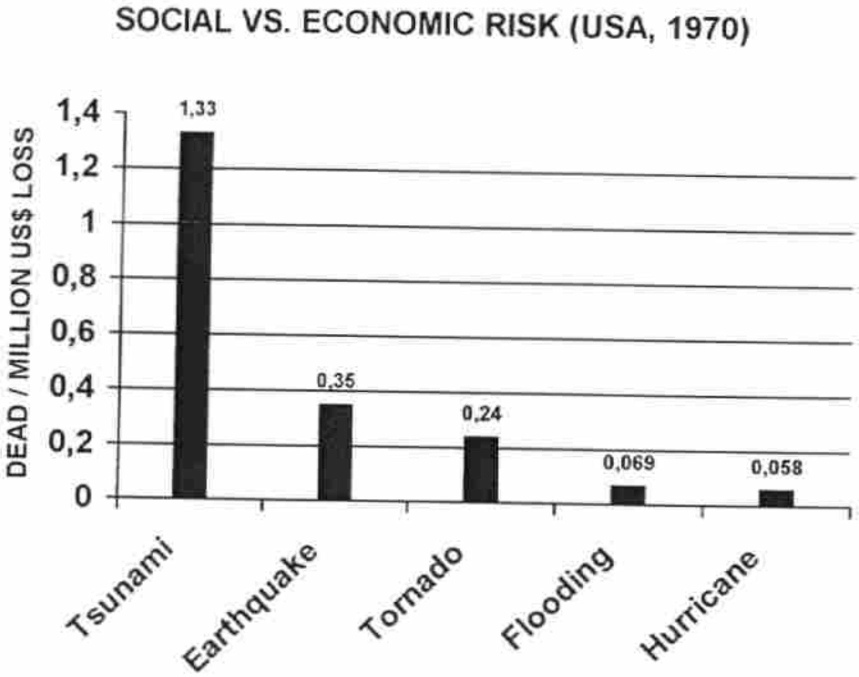


Figure 20.-Rate dead/economic loss is very different for different hazards, and sometimes, people dead and economic losses don´t coincide in space (Petak & Atkisson, 1984)

Flood insurance, when premium cost for insured is associated with 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). All they shift between systems based on premiums linked with type of good insured, independent of risk exposure, and systems based only on risk with prices fixed by free market, that is, value of exposed goods, vulnerability and exposure to hazard. The first systems, called solidarity systems, are single and comfortable to manage, don't need, in general, government grants, have the obligation to insure , but are unjust, forces to consumers to insure for non existent risks and don't contribute to risk mitigation ; an example is the Spanish system. Other intermediate systems, with a part of prices financed by government grants like the French, linked with a Preparedness Risk Program and land-use rules or the National Federal Insurance Program(NFIP) in the USA, linked with flood-plains land-use limitations, managed by the flood-plain managers, put together solidarity(through government grants) and risk mitigation and are more selective. Efficiency to mitigate human risk is linked with private owners aversion to pay for economic losses. For floods, the NFIP have 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 (NFIP web site). The scarce diffusion of insurance in *undeveloped countries*, limits the use of this non-structural tool in these countries; then, the role of *land-use planning* in this case, associated with most vulnerable settlements and financial problems for expensive structural measures, is clearly more important than in developed countries. Then, *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 subsidiary and, in this case, government investments to avoid economic risk are more controversial than 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).

3.7.-SURPASSING LEGISLATION INEFFICIENCIES: TOWARDS A TECHNICAL- ADMINISTRATIVE PROCEDURE FOR POPULATION DISASTER RISK ASSESSMENT

All the actions related with disaster preparedness must have a general frame in the 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 Disaster Risk Assessment (PDRA). 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 is protected in most countries against earthquakes with Seismic Codes for construction, and some countries like Australia (ANCOLD, 1994)and USA (USBR, 1989) have developed procedures to protect population downstream of dams with risk acceptability criteria .

Also, it is protected against some major technological accidents like explosion, fire or toxic gas release, and workers life inside industries is also protected with many early developed safety rules, due to conscience of risk exposure through industrial accidents and the pressure capacity of organised workers. Human life is also protected from pollutants exposure by risk assessment procedures developed by many government environmental agencies like EPA in USA; protection against radioactive agents were also early developed .

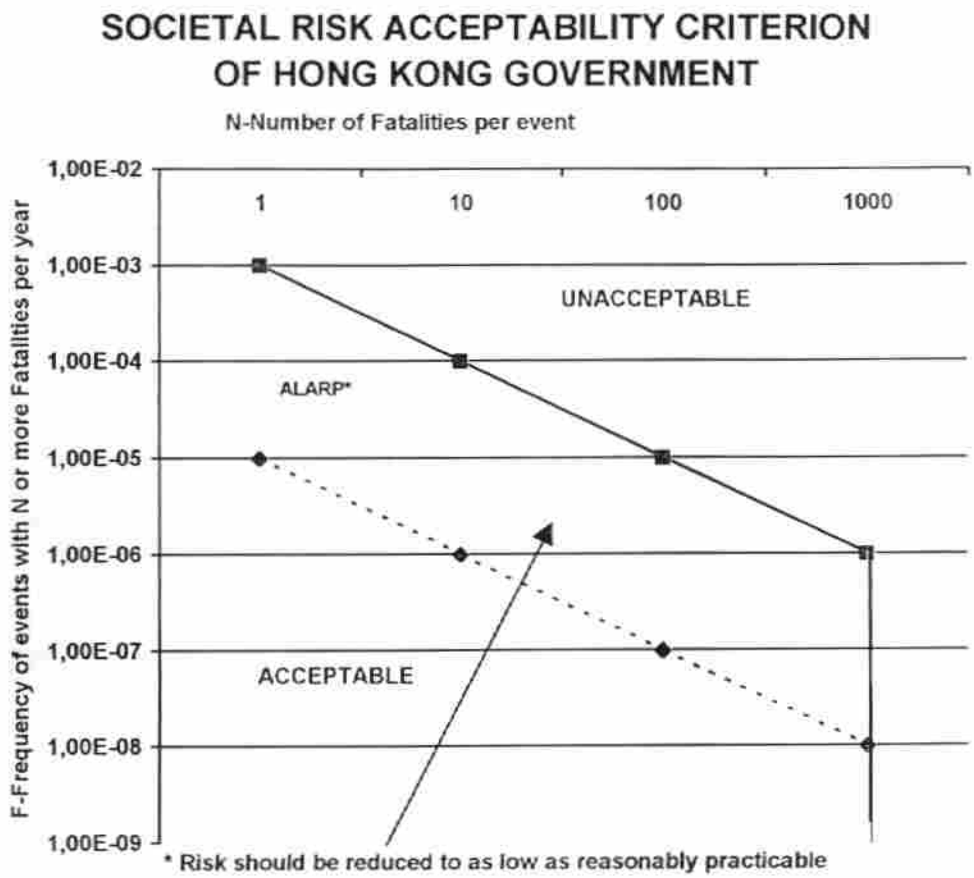
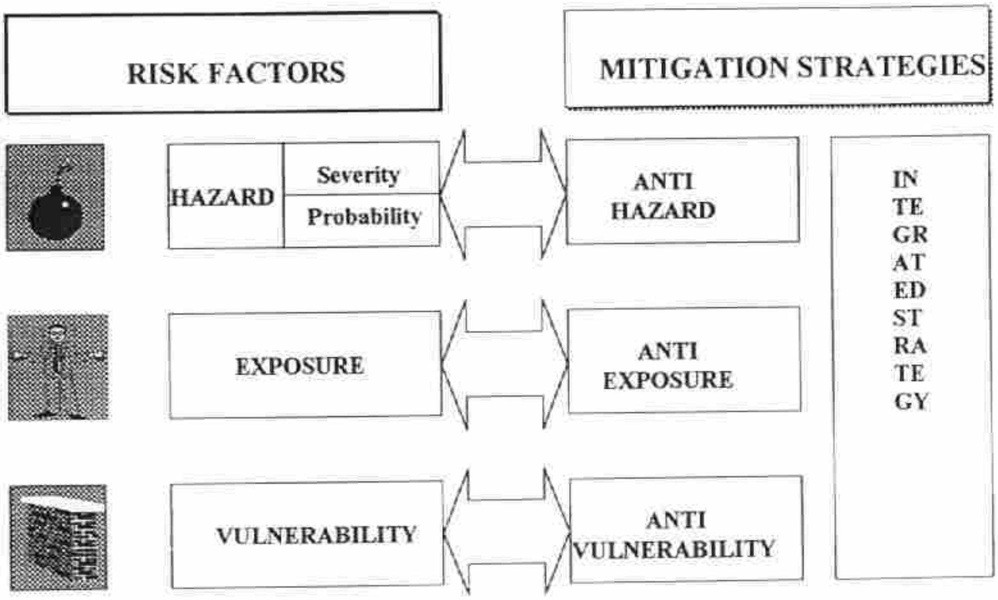


Figure 21.- Hong Kong Government Risk Acceptability Criterion , type F-N (Frequency-Fatalities Number)

If human life has at least the same importance than wildlife and the main disasters have beenthe natural ones, *why governments, strongly concerned with disaster mitigation, have not set up a general procedure for PDRA?*.There are several factors explaining this situation. From the scientific side, the development of Risk Analysis comes from the1960´s, and risk acceptability criteria comes from the 1980´s. In fact, rules for engineering design are yet in many countries "hazard approaches" to risk mitigation.

based mainly in return period of design hazards; awareness of the serious limits of this approach has produced a shift to the "maximum hazard approach" in fields like dam design when downstream exposure is high (Interagency Committee on Dam Safety, USA; Berga, 1998) . And, obviously, is the knowledge development rate of natural hazards complexity .



Source:Ayala-Carcedo, 1993

Figure 22.-Mitigation Strategies are classified according with Risk Factor mitigated

From the social point of view, risk perception is difficult by long return periods of many natural hazards like earthquake and population 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 PDRA and are in fact mainly focused to emergencies.

The political concerns of many governments, ready to reject disaster responsibilities calling upon the anti-scientific traditions of "God acts" or the "unforeseeable nature" of hazards, are also facts related with the delay to set up these procedures. A key indicator of government attitude towards disaster preparedness and development level is the political will to set up Investigation Multidisciplinary Commissions when a disaster has happened, the necessary way to learn from our own errors to avoid them in the future.

Today it is possible to design this procedure to avoid natural or technological disasters. Disaster risk is determined by hazard, exposure and vulnerability levels. A campsite is highly vulnerable against floods, and disaster risk will be higher with higher sizes of population exposed and higher hazard level in probability or severity. It is possible, for different risks, to perform a *catalogue of project conditions subject to the PDRA* according with hazard, exposure or vulnerability. For floods, for instance, might be: a)Exposure conditions: Any facility or urbanised zone with 100 or more people exposed in the first floor in 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 in a qualitative one defining lists of unacceptable risk conditions or combined scales conditions of hazard, exposure and vulnerability with tables; another useful approach may be the one of "maximum hazard" for medium and high vulnerable exposures.

The steps of the procedure, conducted by the Civil Defence agency, in a similar way to the one 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, consumers organisations, ecologist organisations and concerned local administrations.

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

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

This procedure which is today possible, may be the key tool to transform available expert knowledge into real disaster mitigation. The PDRA proposed have special interest for consumers and insurers.

3.8.-CONCLUSIONS AND SUGGESTIONS

From the above exposition, some conclusions may be made:

- Natural risks, epidemics and drought excluded, produce around the world about 50.000 dead each year in average, with high variability. They also produce twice as many injured and more than 100 times victims, many homeless.

- Natural risk, epidemics and drought excluded, produce each year in 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 high rising trend in the last 15 years.
- Economic, and special human vulnerability to natural risk are much more 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 .
- Mortal casualties from natural risk have a very limited importance when compared with other accidental dead causes, for instance traffic casualties, specially 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 dead, which have the higher capacity to impact societal conscience and hit a lot of victims at the same time; b)They are the first cause of accidental events with great losses, producing problems to governments and insurance companies. At a world level, natural disasters are the main disasters. For most of developed countries , technological disasters are probably more important in terms of quantity, but great disasters, are often natural ones.
- Welfare and societal cohesion are at a world and national level basic conditions for Sustainable Development; then reduction of natural disasters is a basic condition for a Sustainable Globalisation, understood as a solidarity choice with undeveloped countries, the most damaged , at the world level, and with the lower income social sectors, also the most hit, at national levels. A comparison of impacts on developed and undeveloped countries, shows the problem of natural disasters in the world is a problem of development.

- The key concept to mitigate natural risk (the expected losses, human and economic) is a preparedness way to reduce risk, supported on 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 of its importance above showed, must be disaster reduction after identification of potential disaster situations.
- All economic risk reduction set of measures is subjected to decreasing yields rules dividing the set in three zones, the first with individually profitable measures that must be accomplished by individuals, the second with profitable measures only in a global strategy that may be accomplished by public agencies, and the third without economic justification. Insurance systems might play the main role in economic risk reduction .
- Main justification of government intervention is to avoid human disasters; government action in economic risk reduction might be done only from a subsidiary philosophy.
- There is a clear trend in technological projects to mitigate risk to shift 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 hazard severity-vulnerability scales for some hazards like floods and mass movements.
- Probably, the best investment in disaster preparedness for risks with space prediction likelihood are the hazard and risk maps. A rational planning of this action may start with identification in settlements and zones to develop of possible types of risk and its possible severity, followed by assessment of possible places of disasters and then by mapping at suitable scales. This measure may be specially useful for undeveloped countries.

- Post-Disaster ad-hoc multidisciplinary Investigation Commissions are a necessary way to mitigate future disasters and are a clear indicator of a Sustainable Development.
- A greater emphasis might be on land-use planning for human disaster risk mitigation of floods, mass movements, volcanoes and to a lesser extent for earthquakes (liquefaction zones, faults).
- Today, it is possible to set up a technical-administrative procedure for Population Disaster Risk Assessment, based on Risk Analysis, according with the above exposition.

4.-SLOPE MOVEMENTS HAZARD ASSESSMENT AT A GLOBAL SCALE

4.1.-INTRODUCTION

As is well known, there are two main geological cyles: the internal geodynamic cycle and the external one.

The internal cycle comes from the energy supplied by the internal heat of the Earth ; this energy moves the convection currents in the mantle, causes the volcanic phenomena and also generates the thermal flow of the Earth. In this global process, new metamorphic and igneous rocks are produced, and new mountains are the result of orogenic processes in the edges of convergent tectonic plates. This internal process supplies materials and potential gravitacional energy for the other great cycle: the external one.

The external geodynamic cycle takes further energy from the sun: sun energy is the responsible of the hydrological cycle , necessary for the activation of water erosion & transport and also is responsible for global atmospheric circulation , wich is necessary for eolian erosion & transport. Then, the external cycle is the result of : materials with gravitational potential energy supplied by the internal geodynamic cycle; the existence of an atmosphere and the energy supplied by the sun activating the hydrological cycle and the global atmospheric circulation.

Two minor cycles inside the main two are the geochemical cycle of chemical elements and the petrogenetic or rock cycle.

The two major geological cycles are not independent in space and time; continental erosion & transport supplies materials for the oceanic basins, where tectonic processes are going on in a quantity of about 9 km ^{3}/ year (Milliman & Meade, 1983). The subduction process consums about 4 km^3/year of continental crust in the so called "deep erosion" (Lallemand & Malavielle, 1993). Then we may speak of a single geological macrocycle with two parts, the external and the internal one.The duration of this geological cycle may be assessed as about 500-1000 million years, the time for all continents to join as one : the Pangea; the last was formed by the tectonic plates movement at the end of the Paleozoic Era about 250 million year ago.

The geological cycle is the cycle of matter in the Earth, dependent on energy and the internal and external cycles.

Mass movements, also called mass wasting processes, are part of the external geodynamic cycle and supply material for other processes such as water and eolian ones in the continents and are also the last transport process before sedimentation , when sediments are transported by gravity currents.

Mass movements are the largest in size of the erosion-transport processes . These processes range from ions or molecules in dissolution (chemical erosion) to olistostromes, submarine giant slides of hundreds of km^3 produced during orogenic periods(Flores, 1955), perhaps according with a fractal distribution where the number of discrete units transported is geometrically less with greater sizes.

Mass movements are a form of mechanical erosionas well as water, coastal and eolian erosion. The rate of chemical versus mechanical erosion was analized by Garrel &

Mckenzie (1977) who concluded that is greater than 1 in Europe (1.6) and Africa (1.4) and that mechanical erosion is greater in South America (0.5), North America (0.4), Asia (0.1) and Australia (0.1). Maybeck (1976) computed the ratio of solid to dissolved load in several great rivers of the World and found ratios of 46 for the Colorado River, 1.7 for the Amazon, 6.9 for the Ganges and 1.1 for the Congo; these figures show that chemical erosion is much more important in ecuatorial areas, linked with incresed moisture and temperature and edaphogenetic processes, and that mechanical erosion prevails in semiarid areas. Chemical erosion is also the main process in limestones, dolomites and gypsums and has been studied by Smith & Atkinson (1976).

In general, solid transport dominates in mass movements, specially in lanslides or falls, but water content may be important in viscous flows and specially in gravity currents in submarine canyons, where it may be dominant. Costa(1988) has analized the continuous water floods-hyperconcentrated flows-debris flows. An operational criteriom to differenciate mass movements(including viscous flows) may be to have a ratio solid matter/water equal to 1 or more in weight; it is important be in weigh not in volume, because the transport efficiency must be measured in terms of energy. Displacement capacity, the run-out, increases with a lesser cohesion of materials, and a greater water content and increasing slope. Travelling distance in mass movements is highly variable with typology, from a few centimeters per year in creeps to one hundred kilometer in lahars, a viscous flow of ashes and pyroclasts from volcanoes; movements that extend more than one kilometer are uncommon, in marked difference with fluvial transport that may reach several thousands of kilometers. Sometimes the fluid is viscous ice, as in rock glaciers. Ice is the most important agent of movement in glacial heighs and frequently in periglacial ones as well (Arnáez-Vadillo, 1990).

The typical water erosion acts through raindrop splash and removal by rainfall runoff on edaphic soil, generally to a millimetric depth; mass movements occur in the initial failure process and later movement acts on depths several orders of magnitude greater, up to several hundreds of meter. Water erosion is an edaphic erosion; mass movements are geologic erosion, deep erosion affecting a massif in a similar way to karstic processes.

In most continental zones, including semiarid ones, fluvial processes are the main ones (Derruau, 1965 ; Pedraza, 1996) ; mass wasting breaks the terrain and performs an initial transport downwards until creeks or rivers. The reason for the key role of fluvial transport and edaphic erosion associated is the almost universal extension of rains versus the limited extension of mass movements. Under the sea, the equivalent to continental river network are the gravity currents carrying soft cohesionless sediments from the external shelf through the continental slope to abyssal plains.Then the role of mass movements in transport is much more important under the seas than on the continents.

4.2.-SLOPE MOVEMENTS CLASSIFICATION: A CRITICAL APPROACH FROM HAZARD ASSESMENT

In a general way, mass movement is any massive movement on the Earth. With this definition subsidence and earthquakes are mass movements. A restricted and probably more acceptable definition valid only for hillslope movements , amore familiar concept, may be: mass movement is all movement in the Earth's crust in a massive form, with a water content less than 50% in weighand with a downslope direction.

The following factors may be used to classify mass movements:

-Lithology

-Geologic structure (macro, meso and micro levels)

-Failure conditions: agent and mechanics (see Fig. 23)

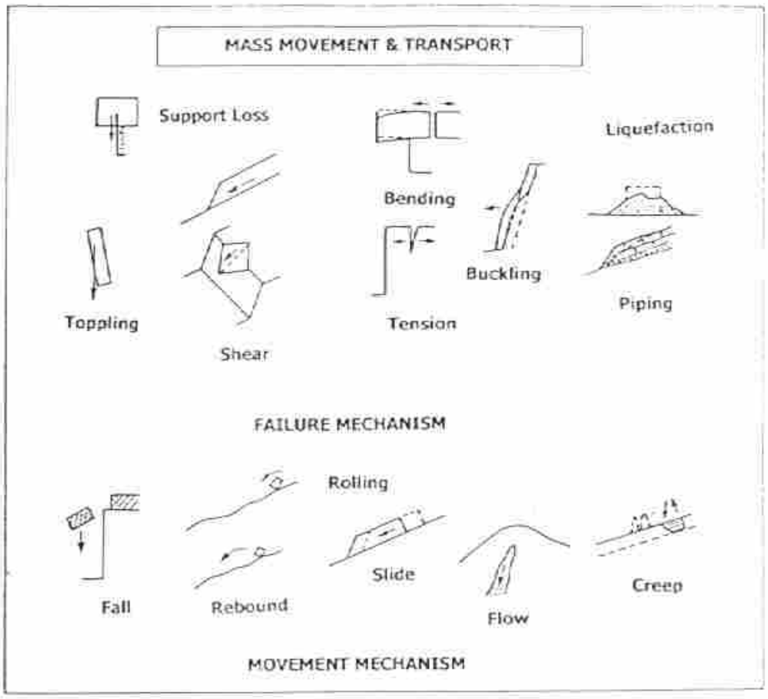


Figure 23.- The main types of single mass movements in accordance with failure and movement conditions.

-Kinematical conditions: velocity, run-out

-Movement mechanism: fall, slide, flow, complex (see Fig. 23)

-Activity state(active, dormant, fosil) and frequency of movement (continuous, cyclic etc.)

-Environmental conditions: continental/submarine, relief, climate

-Geometric conditions: volume, area, shape, depth

The combination possibilities are very high if a global characterization is sought.

Many authors have performed such classifications ; among them may be cited Heim (1882), Howe (1909), Almagià (1910), Terzaghi (1950), Varnes (1958, 1978), Hutchison (1968), Záruba & Mencl (1969), Carson (1976) , Cruden & Varnes (1996), Corominas & García-Yagüe (1997) etc.The criterion used is simplification to a few main factors. The main factors usually considered have been lithology, linked with strength, and movement type, linked with geologic structure and relief.

A useful classification must take into account the factors important for the objectives of the search. If the purpose of the study of mass movements is to avoid human casualties, then identification of well known typologies such as catastrophe agents, rock avalanches, debris flows or planar translational movements must be the main objective; if the purpose is stabilization of movements, then factors affecting the mechanical equilibrium are most important; if the purpose is an assessment of the role in global cycle erosion-sedimentation, geometrical factors such as volume, the relationship between different environments and the loss of potential energy in the process, weigh times heigh, a quantitative way to understanding its comparative role with other processes (see Fig. 24) are the key factors. An important problem to assess the relative weigh of mass movements in the global erosion-sedimentation cycle is that age of most movements, many times in landslides with a long activity, is generally unknown .

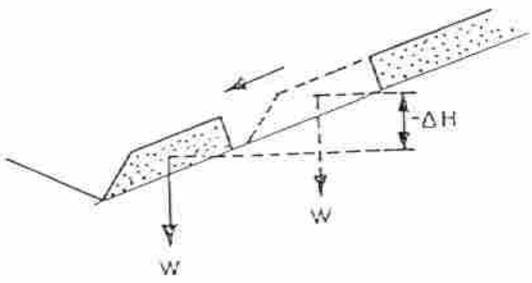


Figure 24.-Loss of Potential Energy is the main physical base to assess and compare the contribution of mass movements to global cycle erosion-sedimentation.

In Fig. 25 are listed with the names most widely accepted the main types of movements from high mountains to the continental slope. In accordance with the above definition black and rock glaciers, movements where ice plays an equivalent role to water, are mass movements and so are most of hyperconcentrated flows as defined by Costa (1988), sediment concentration in weigh 40-70 %.

Mass movements are very common in the cliffs of shoreline. Silva da Fonseca (1997) measured rates of shoreline retreat in the Alentejo coast (Portugal) of 0.26 m/year in miocene sands and up to 0.02 m/year in mesozoic cliffs (Fig. 25).

Today, probably the most widely used classification is the one proposed by Varnes, that the main mass movements are falls, slides, flows, topples and lateral spreads.

In Fig. 23 may be seen a method to classify simple mass movements in accordance with two factors: failure way and movement way; complex movements as rock avalanches or slides-flows, have in general several types of movement. In Fig. 27 may be seen an slide-earthflow reproducing at small scale the entire process of erosion-sedimentation; this reproduction of the global process at different scales is common in mountain creeks with alluvial fans. Hiura & Fukuoka (1996) have showed that shallow slides in japanese granitic weathered zones follow a fractal law $N(r)=Cxr^{-D}$ where $N(r)$ is the number of slides with a characteristic linear dimension greater than r and D, the fractal dimension is 1.44-1.70.

In practice, the use of terms such as circular slide or debris-flow are relatively well understood, but the increased need for more accurate terms probably will lead to new improved classification systems.

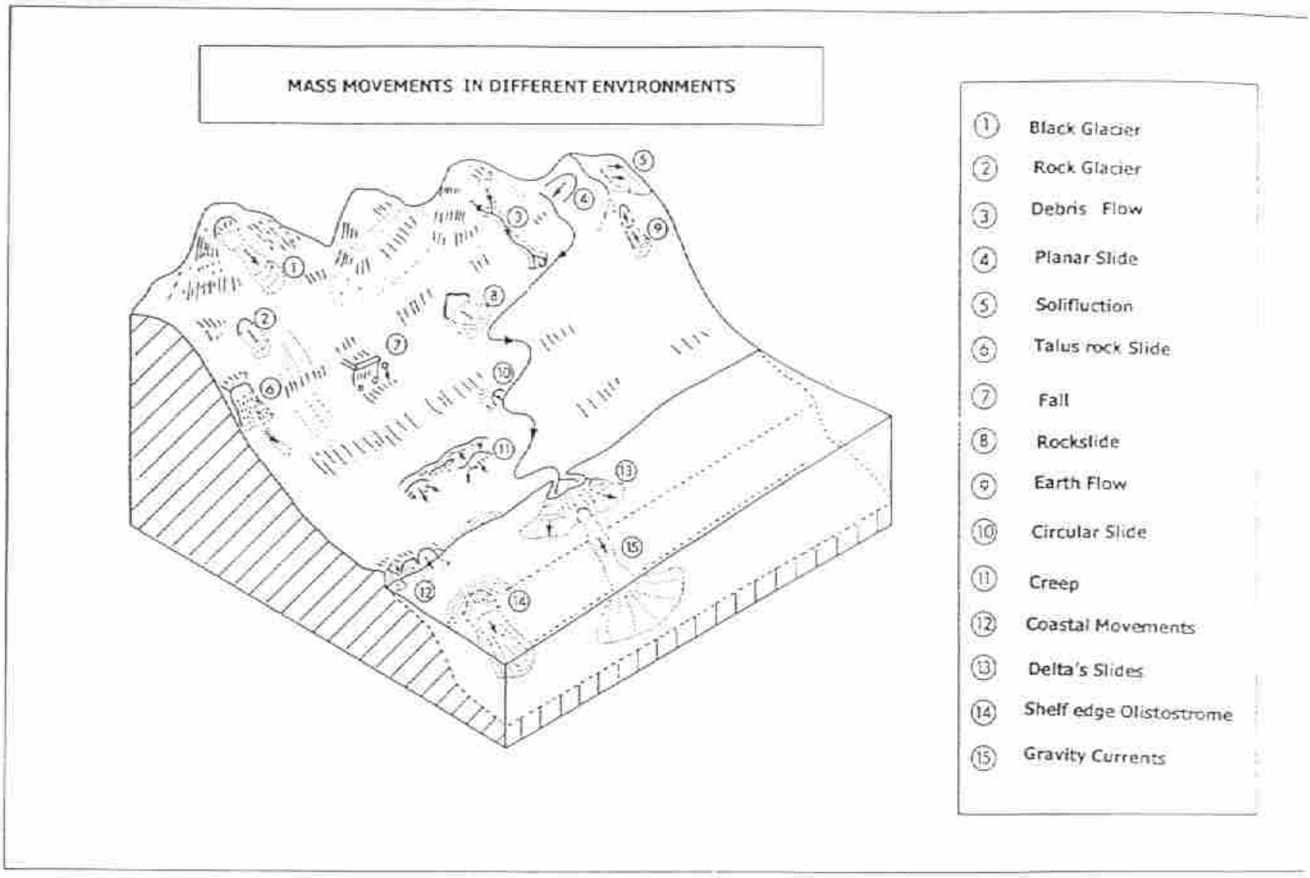


Figure 25.- The main types of mass movements in continental and oceanic environments.

4.3.- STABILITY: CONDITIONING AND TRIGGERING FACTORS FROM HAZARD ASSESSMENT

Landslides, flows and many complex movements depend on the strength of geologic materials being overcomed. This situation occurs when one of the two conditions of mechanical equilibrium, forces or momentum equilibrium, is overcome. Then, the material slides or flows. Often the initial failure starts at the toe of the hillslope, where stresses are higher; lateral and downcutting by rivers and creeks or coastal storms affects primarily this zone.

In the case of falls or topples, when weight force is out of the supporting surface , the mass falls.

There are two kinds of factors affecting the stability: those varying slowly, called conditioning factors, and those varying in a comparative quicker way, called triggering factors.

The main *conditioning factors*, are :

-Lithology

-Tectonic structure

-Relief

The principal *triggering factors*, are :

-Earthquakes

-Rains

-Freezing and thawing

-Antropogenic actions : deforestation, cutting, reservoirs

Comparative analysis of conditioning factors is the base of mass movements susceptibility maps (Brabb, Pampeyan and Bonilla,1972 ; Irigaray, Chacón & Fernández, 1996). Susceptibility is a first approach to forecasing the stability of geographic zones through an analisys of factors, mainly conditioning, and must not be confused with the probability of instability in these zones because it only represents an extrapolation of conditions met in instabilities, often in a qualitative way.

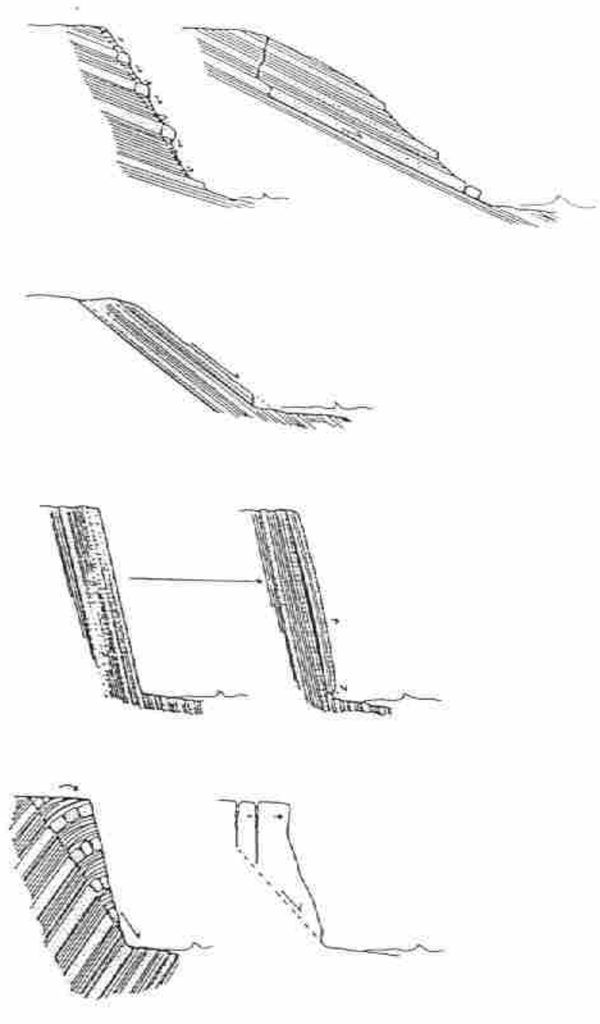


Figure 26.- Main types of coastal mass movements in the Alentejo (Portugal);see the structural controls. Silva da Fonseca, 1997.

For small-scale maps wich cover big regions often with climatic differences, climate is a conditioning factor in two ways: a) it affects the water balance through differences in rainfall , temperature and then evapotranspiration b) rainfall regime . Ferrer & Ayala-

Carcedo(1996) , on a basis of morphoclimatic zonation have performed a climatic susceptibility map of Spain.

Conditioning factors are linked ; relief with lithology and structure, climate with relief and relief with climate as willbe discussed.

Triggering factors of mass movements only have the capacity to lower the factor of safety to 1 for the set of slopes placed by the conditioning factors in a value relatively near of the equilibrium. In fact, many or most of the movements after a severe period of rain are dormant slides with factors of safety 1.1 or less.

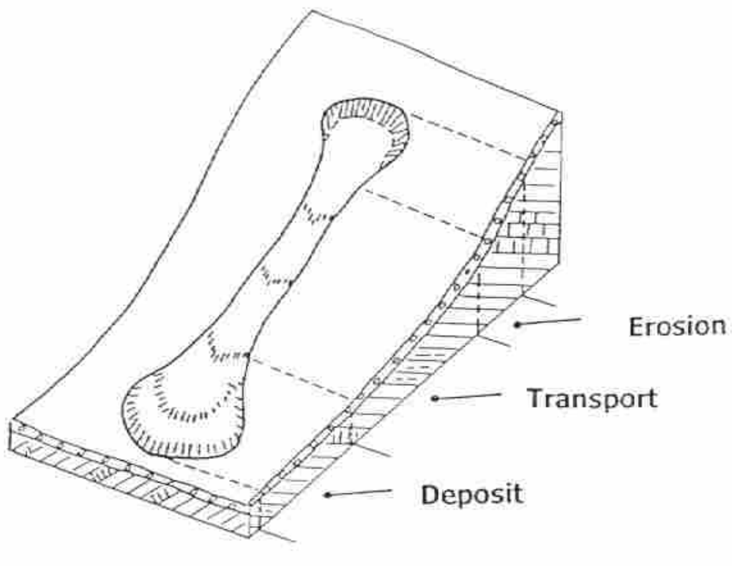


Figure 27.- Complex movement: an slide changes downwards to an earthflow. The movement has the three processes: erosion, transport and sedimentation.

Lithology affects, with microtectonic structure (mainly joints) , the strentgh parameters cohesion c' and, friction angle ϕ'. Many slides are associated with clays, with low ϕ'. The residual friction angle ϕ'_r , reached after failure is a characteristic of each lithology

(Horn & Deere, 1963 ; Skempton, 1964). Cohesion c' plays a key role in stability for slopes with low or middle height; ϕ' has a role more important than c' for higher slopes because the frictional component of shear resistance is proportional to weight. Progessive failure is a process correlated with an earlier failure, specially in series with heterogeneous materials. The reason is the difference in shear strength of different materials for a common shear strain ; then , after confined failure of weaker lithology, the strength decreases to the residual one and stress in harder lithologies increases causing an earlier failure of mass (Terzaghi & Peck, 1967). This process helped by a rise of groundwater level is the main way that strength is lowered in rock masses,.

Structure plays a key role in typology as may be seen in Fig. 4 .

Relief affects two parameters: height and angle of slope, playing a clear role in the factor of safety (see Hoek & Bray, 1977) . Greater angles of slope are, with greater rainfall and increased downcutting of creeks and rivers (may reach an annual rate more than 500 times greater in mountains than in rivers like Volga, according with Kukal, 1990) are the main reasons for the increased frequency of mass movements in mountains. Relief is the conditioning factor more affected by antropogenic actions. Relief is continously renewed by isostasy after removal of materials by erosive processes; outcrops of plutonic rocks, generally formed into the continental crust at s of about 25 km are a good proof.

Relief and lithology (shear or tensile stress) vary with time; structure is almost a constant factor.

Rain is the most widely spread triggering factor. It acts in two ways: the first and main way is by entering the terrain and raising the groundwater level, and the second is by increasing the weight of the terrain with moisture. All sensibility analysis show a clear decrease of the factor of safety with higher groundwater level due to decreases of

normal stress and , then, frictional resistance (effective normal stress σ' times *tan* ϕ').
Obviously the relative rise of grounwater height to the slope height for a single storm is greater for small slopes or surficial formations such as colluvial debris. Then, under these conditions, slides may be triggered by single storms or rains of a few days. In permeable sediments such as debris, the critical aspect is the hourly intensity, and this fact allows criterion to forecast probability(Záruba & Mencl, 1969 ;Onodera et al. 1974; Campbell, 1975 ; Nielsen & Turner, 1975) .

In less permeable materials or thicker formations until shear surface, higher periods of rain are needed and general criteria forecsting probability are not possible (Ayala-Carcedo, 1995). As a qualitative guide, mudflows need periods of rain of some weeks and earthflows of several months. Deep slides require periods of several decades (Jans, 1978). Sheko (1988) showed a relationship for Odessa mudflows between the integral curves of sunspots Wolf number and the number of flows for periods of hundred years.

Reactivations are the more frequent event in periods of intense rains. In this case, the factor of safety is near 1 and often the permeability of mass is relatively high due to cracks. Shallow movements may be reactivated by single intense storms; medium and deep slides need for reactivation humid periods of months to years.

These facts in relationship with climate, vegetation and weathering are the basis for differentiating climatic zones; wich will be discussed below.

The second important triggering factor, concentrated only in prone zones, is *earthquakes*. These sudden events act mainly by liquefaction of loose, saturated fine sands or coarse silts, often ocurring as thin layers in other thicker beds (Bolton, 1975). The physical process is related with the progressive increase of water pressure in the pores of soil and decrease of effective stress σ' to zero (Seed & Lee, 1966).

Triggering of debrisflows by earthquakes is an impressive phenomenom; Yen & Trotter (1978) identified more than one thousand after the San Fernando earthquake in California in 1971.

In general, the Magnitude must be higher than 5.5 on the scale of Richter. Ambraseys (1991) has developed thefollowing regression equation:

$$M_w=-0.31+2.65\cdot 10^{-8}R_e+0.99\log R_e$$

M_w= Magnitude of momentum

R_e=Epicentral distance (cm)

Earhquakes were the triggering factor in the high number of mudflows in loess in 1920 in the Kansu (China) earthquake killing 180.000 people. Often the most impressive mass movements in volcanic environments as debris-avalanches or rockslides are triggered by volcanic tremors in early stages of erupcions, associated with underground movements of magma.

Freezing is a factor clearly related with falls in canyons (Peckover, 1975) ; *thawing* is also related with a greater number of falls in Norway (Bjerrum & Jorstad, 1968) and Sweden (Rapp, 1960). Thawing in periglacial areas is, after the ice swelling in winter, the time for solifluxions.

Deforestation has a complex effect. Trees have a higher rain interception capacity via the leaves than do herbaceous plants , but have less biologic transpiration . In arid areas with rainfall below 350 mm/year , suction, with a positive effect on cohesion of soils, is clearly higher under trees than in naked soils (Gray, 1996).

Excavations , specially in the toes of slopes, has a clear negative effect on stability and are the most important triggering factor along roads and cities.

Reservoirs reactivate many landslides and also produce new slides. A catastrophic case was the Vaiont reservoir (Italy) in 1963, where a new rockslide , along bedding , of about 250 million m^3 at a speed of about 25 m/s killed 1900 people, through a giant wave overtopping the dam (Kiersch, 1964).

4.4.-THE ROLE IN EVOLUTIVE MODELS OF RELIEF: A GLOBAL APPROACH

Davis in 1899 presented a *general model of the erosive cycle*, called "the geographical cycle", distinguising three main stages in the evolution of a region : youth, maturity and old age. This model has been modified, among others, by A. Penck (1919) with his theory of summit level and W. Penck (1924) with his theory of piedmont platforms, but is a general reference still widely used. Obviously, the youth stage, with a more energetic relief, would be the most important for mass movements.

The three main *Lithologic Relief Models* are the volcanic, plutonic and karstic ones.

Mass movements play a significant role in the evolution of *volcanic* zones. There are two main types of mass movements in these zones that may be seen in Fig. 28 .

The lahars are surficial flows made possible by the presence of cohesionless pyroclastic materials with high slopes and triggered by snow melting after a volcano's reactivation. Deep landslides are, in general, related with the increase in height of volcano, specially in marine volcanoes with the bottom part under the sea; the El Hierro Island in the Canary islands has an old giant slide of several km^3 , La Herradura (Horseshoe) beach . Another origin of deep slides in volcanoes are lateral explosions, like the one produced in 1980 in the Saint Helens volcano (Lipman & Mullineaux, 1981).

The evolution of relief in *plutonic massifs*, i.e. granite due to mass movements, is strongly conditioned by structure, as may be seen in Fig. 29 . In accordance with structure, the relief may be infuenced by wheathering along joints, with a final morphology of boulders or tors, toppling or slides.

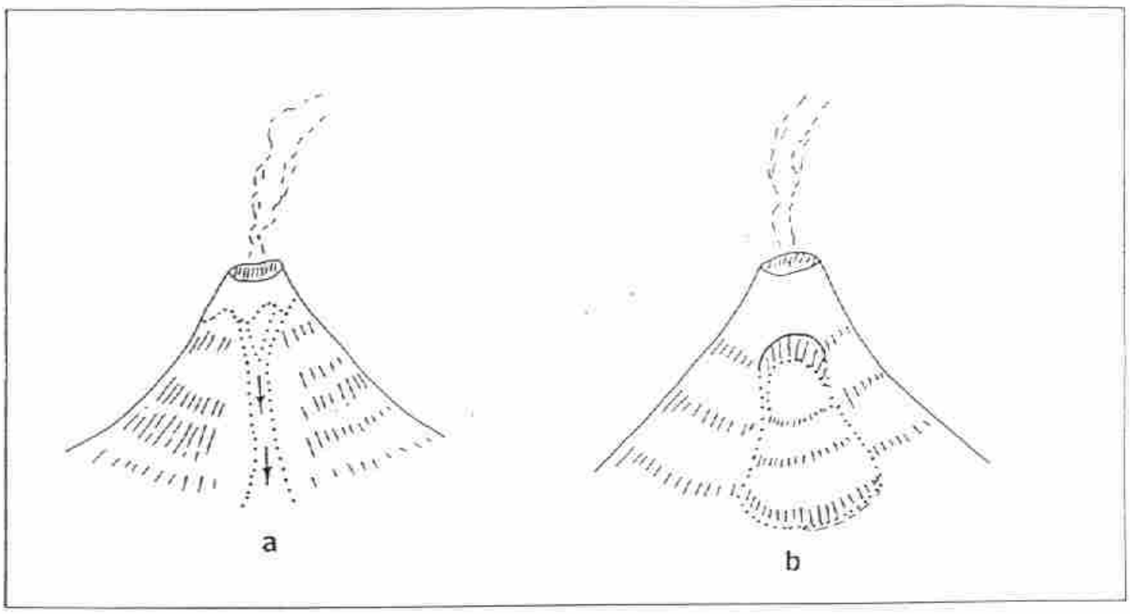


Fig. 8.- Main mass movements in volcanic reliefs: a)Lahars b)Deep landslides conditioned by height or triggered by lateral explosions.

The evolution of *karstic regions* is a combination of chemical and mechanical processes such as those that occur in sinkholes.

The role in *structural reliefs* is mainly related with typologies of movements according to bedding dip. A cuesta relief, typical in monoclinal formations, is clearly prone to planar translational slides; an example in a cretaceous series with an slope of 25° in the Torrelaguna Sierra, near Madrid, triggered by collapse of karstic caves, may be seen in Ayala-Carcedo, 1996. Slumps in clays underlying limestone mesas are relatively common. Landslides in faulted reliefs in horst and graben scarps , are also common. Mass movements in folded reliefs are also closely related to different structural morphologies defined by Archambault et al. (1970) i.e. planar translational slides to" monts" or " vals".

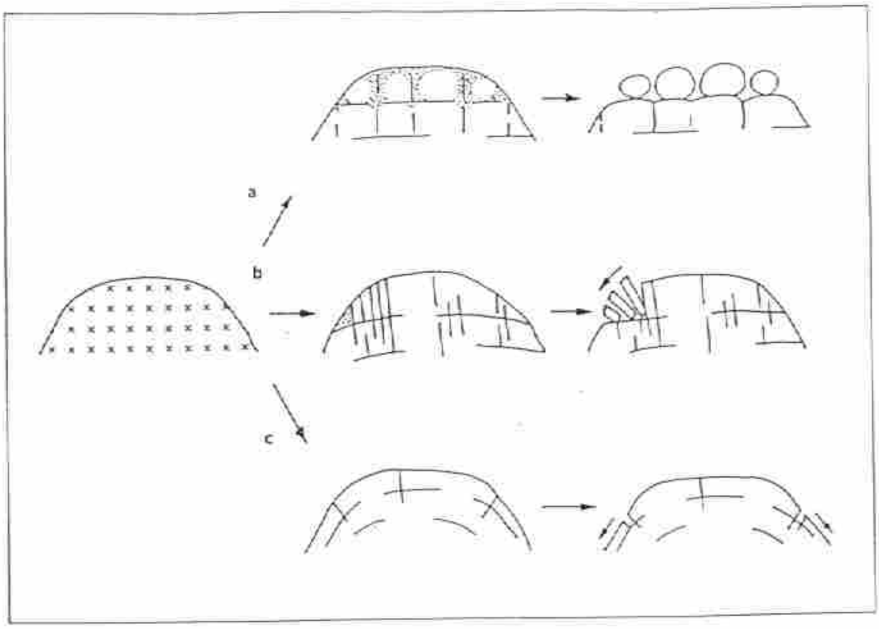


Figure 29.-The structure conditions the evolution of relief in granitic zones : a) Weathering b) Toppling c) Slides.

We speak of *climatic reliefs* or morphoclimatic zones (Sauer, 1925), or erosive bioclimatic models (Derruau, 1965) when climate causes a homogenization of relief in a zone despite the original geologic heterogeneity. Sometimes the relief we see is a relict one inherited from previous climates, specially from the last glacial period. The relationship between climatic zones and mass movements have been analyzed at global scale by Peltier (1950), Wilson (1968) and Carson (1976). For Peltier, mass movements are more important in the morphogenetic regions maritime and wet forest, have a moderate influence in temperate regions and have little in arid zones. For Wilson, mass movements are among the dominant processes in periglacial, semiarid (savanna, steppe), temperate humid and tropical humid climates. Carson has shown that rock-fall and talus production are specially prolific in cold areas but have been observed in desert, temperate and humid tropical areas ; rapid type flows are more common in alpine and mountainous semiarid areas; slides and avalanches are more related to slope than to climate ; slow mass-wasting in cold areas (combined gelifluction and frost-creep) with rates of 10-100 mm/year seems to be of an order of magnitude higher than debris-creep in other areas. According to Young (1960) and Kirby (1967) grass covered slopes in humid climates such as those in England have more creep than soil wash, but in other humid climates suchas the tropical savanna and temperate forest in Australia soil-wash was 5-7 times greater than creep (Williams, 1973, in Carson, 1976). As basin area increases, the average slope decreases, and susceptibility to movements likely decreases.

Olistostromes are submarine megaslides produced during orogenic processes (Flores, 1955). In the Guadalquivir river valley (Spain) there is an olistostrome of oligocene age with more than 100 km of foreface and 15 km width, having a volume probably greater than 200 km^3. This is a clear example of the role of tectonics in erosive processes.

4.5.-CONCLUSIONS FOR HAZARD ASSESSMENT AT GLOBAL SCALE

- Mass movements are the main way of deep, geological erosion versus surficial, edaphic erosion and have a high variety of typologies that may be classified according with failure, movement, lithology, etc.

- Mass movement probability is a function of conditioning factors such as lithology, structure, relief, climate, vegetation and also of triggering factors as seismicity and antropogenic actions .
- Mass movements are the most important erosion-transport processes in the shoreline, deltas and the continental slope .
- Also important are processes in periglacial, humid temperate and tropical humid environments, specially in mountain ranges. Relative weight of mass wasting decreases with basin size. Several typologies are common to different environments and others belong to specific ones.
- A comparative assessment of mass wasting versus water or eolian processes on a quantitative basis is very difficult due to the lack of geomorphological cartographies and landslides inventories.The comparison must be establshed in volume but specially in potential energy loss contribution, an approach likely to emphasize the role of mass movements due to their higher frequency in mountain environments. The lack of knowledge about age of movements is a major problem to establish rates.
- A general opinion is that fluvial processes and edaphic erosion are in general the most important processes in the continents due to the almost total universality of rain on any place on Earth. Mass movements help the transport work of rivers supplying masses of rock and soil, specially in the above cited environments.

ACKNOWLEDGEMENTS

The author wish to acknowledge to José L. Barrera his information about the movements triggered in volcanic environments by tremors ; to Steven L. Driever, of

University of Missouri by his general revision of this chapter and to Cecilio Quesada, of ITGE, by his valuable information about olistostroms.

5.-CRITERIA FOR THE ACHIEVEMENT OF RISK MAPS

5.1.- INTRODUCTIÓN

Each hazard has a different relationship between social impact (deads) and economic impact (losses), and very different effects (Petak & Atkinsson, 1984).

Then, for analysis and mapping, is necessary to separate social Risk and social Vulnerability of economic Risk and economic Vulnerability for each hazard. Then must be added, separatedly, for computing total social and economic Risk.

5.2.- CONCEPTS

* **Hazard:** Natural phenomenon with potential of damage for society.

  Has two components:

  a) **Severity or Intensity (Hazard Level):** Defined in general from a set of carachteristics in a qualitative or semicuantitative way as several classes. Example: Scales of Seismic Intensity, from effects and Vulnerability observed. For a flood, the set would be: heigh, velocity, solid load, concentration time.

  Poorly developed concept for landslides.

  b) **Probability:** 0-n (times/year)=1/Tr.

  Tr= Return period

Severity and Probability are linked according with Extreme Values Statistics.

*** Exposure (Elements at Risk)**:

. *Social*: people exposed.

. *Economical*: Goods and Services exposed.

Exposure has an structure relevant for Vulnerability. A population exposed has higher Social Vulnerability with higher proportion of children and old people. One-floor dwellings are more vulnerable than two-floor ones.

*** Vulnerability:** 0-1 (Degree of damage, always related at a defined Severity)

. *Economical*

0: No damage

1: Destruction

. *Social*

. To death

. To wound

. To loss of home

Social and Economical Vulnerability are related. When dwellings collapses, people die.

Due to differences in types of elements at risk (Exposure) in cartographic units, Mean Damage Ratio (MDR) may be preferable to be used.

*** Risk:** Potential losses (annual or for a period or event)

. *Social*: Number of deads, injured, homeless

. *Economical*: Money (loss of goods and services + loss of benefits)

. *Computation*: cost of repair on reposition.

$R = P \times V \times E$

R= Total Risk (social or economical)

P= Probability in a year

V= Vulnerability

E= Exposure (Value in economic risk)

Example: Earthquake with P=0,01

$V_{social} = 0{,}01$ $V_{economical} = 0{,}3$

$E_{social} = 100.000$ inhabitants $E_{economical} = 5.000.000.000$ Ecu

R(social)= 0,01 x 0,01 deads/inh.x100.000 inh.= 10 deads/year

R(economical)= 0,01 x 0,3 x 5.000.000.000 Ecu = 15.000.000 Ecu/year

These figures are used for insurance premiums rate.

Losses for the event: P=1:

R event (social) = 0.01 x 100.000 = 1.000 deads

R event (economic) = 0,3 x 5.000.000.000= 1.500.000.000 Ecu.

The way showed, is a single one. In fact, for a zone, and a type of hazard like i.e. floodings, may have several events, them, we must add the potential losses for each event. Then, the correct formula is:

$R = \sum P_i \times V_i \times E_i$

i = event

When we add the potential losses for the different kind of hazards, we have the general formula:

It shows the annual degree of expected loss (social or economical) for a severity and a Kind of exposed good or people. Is a good tool to comparate zones in a map or study

$$R = \sum \sum P_{ij} \times V_{ij} \times E_{ij}$$

j= kind of hazard

Another concept, specially useful for Regional scales in zones without present-day Exposure, is *Specific Risk*

$$r = P \times V$$

It shows the annual degree of expected loss (social or economical) for a Severity and a Kind of exposed good or people. Is a good tool to comparate zones in a map or study from the point of vue of Risk (not Hazard). The map produced is an open map, allowing computation of future risk according with changes in Exposure.

5.3.- VALUES

5.3.1.- Landslides

a) Probability: Not well solved problem. Only orientative proposals.

Actives: 1

a-1) Meteoclimatic triggering

- Debris-flow: from return period of dayly rainfall 100 mm (wet climate), 150 mm (dry climate) for debris, and weekly for mud-flows. Only in zones with slope higher than 30-35°. Movements may be activated with 40 mm/day if hourly intensity is higher than 10 mm/h during 4 hours. (Zaruba & Mencl, 1968).

- Mud-flows: Same daily values, spread during 3-7 days. Slope > 10°.

- Earth-flows: Values of about 200mm during 1-3 months. Slope > 15°.
- Reactivation of slides until 3m depth: the same criteria of debris-flow. Until 7m, the same of mud-flow.
- River bank or shoreline slides: according with return period of extreme events: floods and sea storms.
- Slides reactivation with 10-20m depth: seasonal rainfall.
- New slides:
  a) Depth lower than 5m: sesasonal rainfall for fine formations; like debris-flow or mud-flow for small rockfalls.
  b) Depth 5-15 m, circular: pluriannual humid cycles and strength decrease.
  c) Others: generally needs long-term processes of strenght decrease.

Indicated values are only a first guide; observation of evolution in a region is the best way, combining analysis from susceptibility and meteorology.

a-2) Earthquake triggering

Assessment of T_r must come from analysis of ground acceleration from expected earthquake, and, in most cases, liquefaction potential (needs a minimum M=5,5 and may affect at more than 100 km far from epicenter).

When are present earthquake and meteoclimatic triggering, both probabilities must be added.

In general, only in moved or highly susceptible areas are probability of slides. A probability of 0,001 (10^{-3}) needs a Safety Factor 1.5 to 2, due to natural variability of strenght.

b) Vulnerability

b-1) Social

Landslides are the hazards with a lowest relationship deaths/economic losses. At a world level, debris and mud-flows produced from 1000 A.D. 87,7% of deaths and rockavalanches and traslational slides almost all the rest. Main triggering cause of death (86,1%) were earthquakes due to impossibility of warning.

These data shows hourly velocity of movement and warning, controls Severity and Vulnerability. A well know classification by velocity, may be seen in Varnes (1984).

A first approach may be V from 0,25 for types cited above; earthquake triggering and snow avalanche may rise until 0,5. For slower landslides V is practically negligible due to very probable warning.

b-2) Economical

For building and life-lines & infrastructure, V is from 0,5 to 1, like in a high severity earthquake. Contents may be saved in most of medium to low velocity slides.

c) Exposure

Comprises all goods (and all people when no warning).

5.3.2.- Floods

a) Severity

Due to the great importance of warning in social and economical vulnerability, must be represented always the concentration time (T_c time to arrival of peak flow) for exposed zones. Critical T_c, for saving lifes may be assessed when warning is guaranteed from upstream, according with population size (ASCE, 1988)

Population	Minimum Warning Time
50	2h
100	4h
500	8h
1000	12h

b) Probability

Must come from Flood Frequency Analysis (FFA). FFA in USA is performed according with recommendations of an special team-work of 1968, with a Log-Pearson Type III statistical distribution.

Basic data comes, preferably, from gauge stations, or from hydrometeorological analysis.

From this FFA, and chanel hydraulics, flow, water level and velocity, may be derivated for T_r=100 year, chosed for the test area.

c) Vulnerability

c-1) Social

Dead for water level in flooded zone higher than 1m or product heigh (m) x velocity (m/s) greater than 0,7 (ASCE, 1988). Exposed people according with warning, only in general in the first floor, the ground level.

Vulnerability for people in houses is not well studied. People may move up on tables, chairs etc. in one-floor dwellings. Two cases from Spain shows respectively Vulnerability of about 0.3 for a camping on an alluvial fan (Biescas, 1996), and only 0.0004 for a single-floor zone during a flashflood at the begining of night (Badajoz, 1997). In this last case, practically all corpses were found outdoor, suggesting death in streets. The camping case suggest Vulnerability of tents and caravanas as the causal factor of death. Exposure were about 300 in camping, and 6,000 in Badajoz.

c-2) Economical vulnerability

Often operates specially on contents of building in the first 1.5m from ground, and secondarily on building fabric. The usual way to present date area stage-damage curves or tables. An updated approach for U.K. may be the next by middle class home (Penning-Rowsell & Chatterton, 1977).

a) Building fabric:

Depth 0 m	Damage: 0
Depth 0.6 m	Damage: 960 _
Depth 1.5 m	Damage: 2.400 _
Depth >1.5 m	Damage: 2.400 _

b) Contents:

Depth 0 m	Damage: 0
Depth 0.6 m	Damage: 2.800 _
Depth 1.5 m	Damage: 6.300 _
Depth >1.5 m	Damage: 6.300 _

According with relative rate of Gross National Product by person vs. U.K. in 1977, is possible to know total damage for floodings (losser are closely proportional to mean individual income with a trend for increasing contents damage).

Failure of buildings and structures may come with water depths greater than 3.60 m o product depth x velocity greater than 6. (ASCE 1988).

Vunerability increases with solid load.

c) Exposure

Comprises all goods when no warning, and only a part of contents when apropiated warning.

For people, according with warning, generally not existing in flash-flooding (concentration time lower than 6 hours).

5.3.3.- Earthquakes

a) Probability

Severity (measured by Intensity or Magnitude Scales), is logaritmically linked with Probability according with Gutenberg-Richter Law or similars.

The standard return period for seismic hazard maps is 500 years. These maps show only "basic" intensity or acceleration, then it is strictly necessary to assess local amplification due to ground nature, morphology, groundwater level or other causes.

b) Vulnerability

b-1) Social

Social Vulnerability depends of Structural Vulnerability, specially of building collapses percentage. Then, is a function of construction quality and, obviously, hazard.

Also, depends of civil defence capacity to help quickly to people. The first 6 hours are critical to avoid deads. Training for risk, is another factor.

b-2) Economical

Vulnerability or MDR are well studied, then it is easy to determine. (Tiedemann, 1992).

c) Exposure

Comprises all goods (dwellings & life-lines) and people in home (exposure is higher during night).

5.3.4.- Other Risks

a) Coastal dynamics

Risk may be assessed from long term erosion or sedimentation rate and goods exposed (including beaches, facilities, etc.). Most of damage is caused by severe storms, specially in seasonal high tides.

b) Soil Erosion

Rates of erosion-sedimentation may be derivated from different approaches performed. Empirical equations as USLE, may over estimate several times actual rate in mediterranean climates. Most of erosion takes place during storms.

Vulnerability may be estimated by loss of agronomical or ecological productivity, probably increasing with erosion stage. Selection of a reference crop is generally needed.

c) Fires

Have specific approaches performed. Risk is strongly dependend of warning and resources for fight against fire. Statistical data about size and

Vulnerability, generally available, are needed. Damage to wood must be diferentiated of ecological damage, of difficult assessment.

5.4.- RISK MAPS ZONING

From the point of view of risk, three zones must be distinguished with colors in the final map (added, total risk) for *societal risk*:

Aceptable societal risk: No color

Acceptable societal risk with conditions (ALARP): Blue

Unacceptable societal risk: Red

The *economical risk map* may have also three zones:

No economical risk: No color

Acceptable economical risk: Blue

Unacceptable economical risk: Red

In the case of *economical risk* acceptability depends of map use. When map is for insurers use, criteria for no acceptability are premium rates. In this case a map of Specific Risk is the best way probably. Building and contents annual insurance costs for industry are in average, 0,1% by year in Spain and 0,06% by year in USA and Canada (MAPFRE, 1991).

These values are in contrast to official premiums in Spain (Compensation Consortium of Insurances, 1987):

Activity	Annual Premium*
Dwellings & offices	0.084
Commarce	0.168
Industries	0.252

Roads	0.35
Bridges	1.26
Dams	0.93
Tunnels	1.54

* % Total Value

If, for instance, we have for a road subjected to landsliding, seismic risk and floodings, an specific Risk.

$r_T = \Sigma p_i \times V_i = 0.65 > 0.35$

, then economical risk must be qualified as unacceptable for insurers (but acceptable for owners!).

From the *social* point of view, two approaches may be performed.

The first is from an individual standpoint, and is refered to annual probability of dead. The second one is the societal, with a limited capability to accept disasters (simultaneous death for several persons) with a lesser probability for greater disasters.

This second aproach has originated the concept of "societal acceptable risk". This approach is the approach for zoning.

In general, assessment of societal risk needs elaboration of scenarios in the most unfavourable condition. For earthquakes, floodings and landsliding, in general is during the night, with people sleeping in their houses.

Application of acceptable risk criterium need an assessment of social vulnerability.

The final zoning for Map of Social Risk is:

-Acceptable: No color

-As low as reasonably practicable (ALARP), Acceptable with conditions:

Blue

-Unacceptable: Red

BIBLIOGRAPHY

- Almagià, R. (1910) *Studi geografici sulle frane in Italia*. Soc. Geogra. Italiana, Roma, 342 pp.
- Ambraseys, N. N. (1988) Liquefaction-Induced ground failures, in *Earthquake hazard assessment*, Fantechi, R. & Almeida-Texeira, M.E. ed. , Comm. of the European Communities, Brussels.
- ANCOLD (Australian National Committee on Large Dams) (1994), *Guidelines on Risk Assessment*, Australia
- ANCOLD (Australian National Committee on Large Dams), *Guidelines on Design Floods for Dams*, Australia
- Archambault, M. ; Lhénaff, R. & Vanney, J. R.(1970)*Les reliefs structuraux*, Masson, Paris, 166 pp.
- Arnáez-Vadillo, J.(1990)Dinámica y organización espacial de los procesos de evolución de vertientes de montaña, in *Geoecología de las áreas de montaña*, García-Ruiz, J. M. edit., Geoforma ediciones, Logroño, 33-47.
- Ayala-Carcedo F.J. and Silva, J. (1999),*Desastres Naturales y Tecnológicos en España (1950-1999)*, unpublished report
- Ayala-Carcedo, F. J. (1996) The traslational landslide of Torrelaguna Range (Madrid), in *Field Trip Guide*, VIII International Conference on Landslides, Chacón, J. , convenor, Granada, Spain
- Ayala-Carcedo, F. J. (1995) Probabilidad y vulnerabilidad en movimientos de ladera, in *Reducción de Riesgos Geológicos en España*, Ayala-Carcedo, F. J. Edit., ITGE, Madrid, 95-113
- Ayala-Carcedo, F.J. (1990-95), *Natural Disasters in the World. Annual reports*, ITGE, Madrid

- Ayala-Carcedo, F.J. (1990-95),*Los Peligros Naturales en España. Informes Anuales*, ITGE, Madrid
- Ayala-Carcedo, F.J. (1993), Estrategias para la reducción de desastres naturales, *Investigación y Ciencia*, May, 6-13
- Ayala-Carcedo, F.J. (1994), Socioeconomic impacts and vulnerability resulting from slope movements, in *US-Spain Workshop on Natural Hazards*, Corominas & Georgakatos Edit., Iowa Institute of Hydraulic Research, Iowa University, USA, 235-254
- Ayala-Carcedo, F.J. (1999), 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. (2000), Plagas y epidemias entomológicas, in *Riesgos Naturales. Una perspectiva global*, Ayala-Carcedo & Olcina Cantos, edit., Ariel, Barcelona, in press
- Ayala-Carcedo, F.J. and Llorente, E. (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. and Piserra, M. (2000),Impacto potencial del Cambio Climático en los seguros en Europa, *Revista MAPFRE Estudios*, Madrid, in press
- 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, Vol. 101-3, 456-467

- Berga, L. (1998), New trends in hydrological safety, in *Dam Safety*, Berga(ed.), Vol. 2, 1099-1106
- Bjerrum, L. & Jorstad, F. A. (1968) *Stability of Rockslopes in Norway*, Norv. Geotechn. Institute, Oslo.
- Bolt, B. A. (1987),*Terremotos*, Orbis, Barcelona, 266 pp.
- Bolton, H. (1975) Earthquake effects on soil-foundations systems, in *Foundation Engineering Handbook*, Winterkorn, H. F. & Fang, H-Y., edit., Van nostrand Reinhold Co., USA.
- Brabb, E. ; Pampeyan,E. H.&Bonilla, M.G.(1972)*Landslide susceptibility in San Mateo County* , U.S.Geological Survey Miscel. Field Studies Map, MF-360(Repr. 1978).
- Braunner, C. & Cochrane, S. (1995), *The Great Hanshin Earthquake.Trial, Error, Success.* Swiss Re, Zurich, 28 pp.
- Campbell, R. H.(1975)*Soil slips, debris flows and rainstorms in the Santa Mónica Mountains*, U.S. Geological Survey Prof. Paper 851.
- Carson, M.A.(1976)Mass wasting, slope development and climate, in *Geomorphology and Climate*, Derbyshire, E. Edit.,Wiley&Sons,U.K.,101-128.
- Chicken, J. C. (1975), *Hazard Control Policy in Britain*, Pergamon Press, New York
- Corominas,J.&García-Yagüe,A.(1997)Terminologia de los movimientos de ladera,in *IV Simpos. Nac. sobre taludes y laderas inestables*, Corominas, J. Edit.,Granada, Spain,1051-1072.
- Costa, J.E.(1988)Rheologic, geomorphic and sedimentologic differentiation of water floods, hyperconcentrated flows and debris flows, in *Flood Geomorphology*, Baker, V.E.; Craig, R. &Patton, P.E., edit., Wiley and Sons, USA, 113-123.

- Cruden, D.M.& Varnes, D.J. (1996)Landslide types and processes, in *Landslides.Investigation and mitigation*, Turner, A.K.& Schuster, R.L. edit., Transport. Research Board Spec Rep. 247, Nat. Academy Press, Washington D.C., 36-75.
- Derruau, M.(1965) *Précis de Geomorphologie*, 5th edit., Masson et Cie., Paris.
- Dubreuil, H. (2000), *Acceptability of Risk: Individual Choice and social Construction*, http://trustnet.cepn.asso.fr/DOC2.html, 11 pp.
- Ferrer, M.& Ayala-Carcedo, F.J.(1996) Landslides climatic susceptibility map of Spain, in *Landslides*, Chacón , J.; Irigaray, C. & Fernández, T.,edit.,A.A. Balkema, Rotterdam,323-335.
- Flores,G.(1955) Discussion on Les resultates des études pour la recherche petrolifère en Sicile, *Proceed. of the 4th World Petroleum Confer.*, sec.1/A,121-122.
- 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
- Garrels , R.M. & Mackenzie, F.T.(1971)*Evolution of sedimentary rocks*, W.W. Norton, NY,421 pp.
- German IDNDR-Committee (1994), *Projects for the Understanding and Mitigation of Natural Disasters*, Bonn, 307 pp.
- Gil Olcina, A. y Olcina, J. (1999),*Climatologia Básica*, Ariel, Barcelona,387 pp.
- Gray,D.H. & Sotir, R.B.(1996)*Biotechnical and Soil Bioengineering: Slope Stabilization.A practical guide for erosion control*, Wiley and Sons, NY.
- 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
- Heim, A.(1882) Der Bergsturz von Elm, in *Zeitschr. der Deutsch. Geol. Ges., 34*,74-110.
- 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* Vol. 31, No. 2, 173-186
- Hiura, H. & Fukuoka, H.(1996)An analysis of the transition of the distribution of the shallow slides in use of a fractal dimension and the Weibull distribution function, in *Landslides* , Chacón, J.; Irigaray, C. & Fernández, T., edit.,A.A. Balkema, Rotterdam,363-373.
- Hoek, E. & Bray, J.(1977)*Rock slope engineering* , The Inst. of Mining&Metallurgy, London.
- Horn, H.M. & Deere, D.U. (1963) Frictional characteristics of minerals, *Géotech.* ,12, 319-335.
- Howe, E. (1909) *Landslides in the San Juan Mountains, Colorado*,U.S. Geological Survey,67, 58 pp.
- Hutchinson, J.N. (1968) Mass movements, in *The Encyclopedia of Geomorphology*, Fairbridge, R. W. Edit., Reinhold, 688-695.
- 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 *Disaster prevention for sustainable development*, Munashinge, M. and Clarke, C., IDNDR/The World Bank, Washington, 1995
- Interagency Committee on Dam Safety (2000), http://www.fema.gov/mit/, USA
- *Internet: The Great Hanshin (Kobe) Earthquake:* http://www.kanados.com/kobe-quake/
- Irigaray, C.; Chacón, J. & Fernández, T.(1996) Comparative analysis of methods for landslide susceptibility mapping, in *Landslides* , Chacón. J. ; Irigaray, C. & Fernández,T., edit.,A.A. Balkema, Rotterdam,373-385.
- Jahns, R.H.(1978), Landslides, in *Geophysical Predictions*, National Acad. Of Sciences, Washington,D.C., 58-65.
- Kauf, E. (1978), *La Maîtrisse des Risques*, Ed. Securitas, 188 pp. (spanish edition in Mapfre)
- Kiersch, G.A.(1964) Vaiont Reservoir disaster, *A.S.C.E., Civil Engineering* ,March 1964,32-37.
- Kirby, M.J.(1967) Measurement and Theory of soil creep, *Jour. of Geology* ,75, 359-378.
- Kukal, Z.(1990) *The Rate of Geological Processes* , Academia, Praha, 284 pp.
- Lallemand, S. & Malavielle, J.(1993) La erosión profunda de los continentes, *Mundo Científico* , 132, vol. 13, Edit. Fontalba, Barcelona, 136-148.
- Lee, L.T. and 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. and 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

- Lipman, P.W. & Mullineaux, D.R.(1981) *The 1980 eruptions of Mount Saint Helens*, U.S. Geol. Survey Prof. Paper 1250, 844 pp.
- Marcellini, A. (1991), Methodology for Microzonation Assessment, in *Earthquake hazard assessment*, Fantechi & Almeida-Texeira(eds.), Commission of the European Comunities, Louxembourg, 119-132
- Mark Tweeddale, H. (1995), "Acceptable risk" in petrochemical and hazardous chemical plants, *Acceptable Risks for Major Infrastructure*, Heinrich & Fell (eds), Balkema, Rotterdam
- McNeill, W.H.n(1984), *Plagas y pueblos*, Siglo XXI, 313 pp.
- Miller, J. B. (1997), *Floods. People at Risk, Strategies of Prevention*, DHA (Department of Humanitarian Affairs), United Nations, 93 pp.
- Milliman,J. & Meade, R.(1983) *Journ. of Geology*, 91,1 (in Lallemand & Malavielle).
- 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), http://www.fema.gov/nfip/pstat.htm, USA
- National Research Council (1994), *Facing the challenge*, National Academy Press, Washington D.C.,78 pp.
- Nielsen, T.H. & Turner, B.L.(1975) *Influence of Rainfall and Ancient Landslide Deposits on Recent Landslides(1950-1971): An Estimate of Economic Losses and Correlation with Slope, Rainfall and Ancient Landslide Deposits* , U.S. Geolog. Survey Bull. 1398, 21 pp.

- Onodera, T.; Yoshinaka, R. & Kazama, H. (1974) Slope failures by heavy rainfall in Japan, *Proc. Of 2th Intern. Congress on Engineering Geology*, IAEG, Sao Paolo,V-11, 1-10.
- Parry, M; Parry, C. And Livermore, M., edit. (2000), *Valoración de los efectos Potenciales del Cambio Climático en Europa*, Universidad de Castilla-La Mancha, 29 pp.
- Peckover, F.L.(1975) *Teatment of Rock Falls on Railway Lines*, Amer. Railway Engin. Assoc., Chicago, Bull, 653.
- Pedraza, J. Edit.(1996) *Geomorfología. Principios, Métodos y Aplicaciones,* Ed. Rueda, Madrid, 414 pp.
- Peltier, L.C. (1950) The Geographic Cycle in perglacial regions as it is related to Climatic Geomorphology, *ann. Assoc. Of Amer. Geographers,*40.
- Penck, A.(1919) Die Gipfelflur der Alpen, *Sitz. Pr. Ak. Der Wissen.* , Berlin, 256-258.
- Penck, W.(1924) *Die Geomorphologische Analyse*, Geogr. Abh., Stuttgart.
- Penning-Rowsell, E.C. & Chatterton, J.B. (1977). The benefits of flood alleviation: a manual of assessment techniques. Gower. Aldershot. U.K.
- Petak, W.J. and Atkisson, A.A.(1984), *Natural Hazard Risk Assessment and Public Policy. Anticipating the Unexpected*, Springer Verlag, 489 pp.
- Rapp, A. (1960) Recent developments of mountain slopes in Karkenagge and surrounding, *Geograp. Annals.*
- Sauer, C.O. (1925) The morphology of landscape, *Univer. of California Publ. Geograp.*, 2(2), 19-53.
- Seed, H.B. & Lee, K.L.(1966) Liquefaction of saturated sands during cyclic loading,*ASCE J. of Soil Mechan.*,92,, Nº SM6,105-134.

- Sheko, A.I. (1988) Mudflows, in *Landslides and mudflows* , UNEP/UNESCO, Moscow,54-74.
- Silva da Fonseca, F.M. (1997) *As arribas do litoral do Algarve* , Thesis Doct.,Faculdade de Ciências da Universidade de Lisboa, 556 pp.
- Skempton, A.W. (1964) Long-term stability of clay slopes, *Géotechn.*,14, Nº 2, 77-101.
- Smith, D.I. & Atkinson, T.C. (1976) Processes, landforms and climate in limestone regions, in *Geomorphology and Climate* , Derbyshire, J. edit. , Wiley & Sons, U.K., 367-409.
- Swiss Re (1990), *Natural disasters in the World 1970-89*, Zurich
- Swiss Re (1990-99), *Natural Disasters in the World. Annual Reports*, Zurich
- Terzaghi , K. & Peck, R.B. (1967) *Soil Mechanics in Engineering Practice*, 2th edit., Wiley & Sons, NY
- Terzaghi, K. (1950) Mechanics of landslides, in *Geolog. Soc. of America, Berkey volume*, NY, 83-124.
- Tiedemann, H. (1992), *Earthquake and Volcanic Eruptions. A Handbook on Risk Assessment*, Swiss Re, Zurich, 951 pp.
- U.S. Bureau or 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.
- Varnes, D. (1958) Landslide types and processes, in *Landslides and Engineering Practice* , NRC Public. 544, 20-47.
- Varnes, D.J. (1978), Slope movements types and processes, in *Landslides and Engineering practice*, National Research Board special report 176, 11-33

- Williams, M.A.J. (1973) The efficacy of creep and slopewash in tropical and temperate Australia, *Australian Geograp. Studies,* 11, 62-78.
- Wilson, L. (1968) Morphogenetic classification, in *The Encyclopaedia of Geomorphology,*Fairbridge, R. W. Edit., Reinhold, NY,717-729.
- Withman, R. V. (1984), Evaluating calculated risk in Geotechnical Engineering, *ASCE Journal of Geotechnical Engineering*, 110(2), 145-188
- Wrigley, J. and Tromp, F. (1995), Risk management of major hazards in Hong Kong, *Integrated Risk Assessment*, Melcher & Stewart (eds.), Balkema, Rotterdam, 37-41
- Yen, B.C. & Trotter, J.R. (1978) Shallow slides due to 1971 San Fernando Earthquake, *Conf. on Earthquake Engin. and Soil Dynamics, ASCE* ,1076-1097.
- Young, A. (1960) Soil movement by denudational processes on slopes,*Nature,* 188, 120-122.
- Záruba, Q. & Mencl, V. (1969) *Landslides and their control*, Elsevier-Academia, Praha, 205 pp.