Risk management and assessment for natural hazards

by

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Abstract

Risk management is a methodology, which provides a framework for a logical approach to disaster management. It is presented as a chain of action, each of which is well defined and based on traditional engineering and management practices. The links of the chain are described verbally, as well as through the concepts of risk analysis. They are illustrated by references to flood and wind hazards.

Risk assessment is the first step in a risk management scheme, where the hazards are identified, such as, for example, floods and their recurrence intervals, as the basis for decisions on flood protection schemes. However, hazard identification is not enough; a flood occurring in a natural wilderness will have only limited consequences, whereas a flood in a heavily populated area may lead to extreme disasters. Human involvement is a necessary prerequisite for a disaster. This is quantified by means of risk analysis, in which the hazards as well as the consequences of the occurrence of an extreme natural event are considered.

The combination of hazard and consequences is the risk, which for natural hazards is ideally represented by risk maps. Very often, such maps suffice as a decision aid for risk mitigation measures, but what decision is made depends also on the second step in the risk analysis chain: the evaluation of the risk. In order to be able to assess the consequences in monetary terms, or in terms of potential loss of lives, one must consider the options that are available for disaster mitigation. Options range from comprehensive (and costly) structural solutions to complete absence of structural solutions, where mitigation is effected only by individual actions, such as reactions to more or less organized forewarnings, or individual protection against financial losses through insurance. The risk posed by a natural hazard is not an absolute criterium for deciding on the actions to be taken; its reduction is one among many social goals, and the available financial and other resources must be suitably allocated for many different purposes. In the end, the final decisions on large scale risk mitigation measures are made only if other needs are considered less pressing - an attitude that applies to nations as well as to individuals. Whatever the decisions that are made, it can be stated that an additional protection against the threat from natural hazards is obtained by preparedness against disasters: structural strengthening of threatened buildings, preparation of emergency supplies, provision of medical services, and last but not least, training of people who are to be active in disaster mitigation, are measures which complete the chain of risk management. We conclude that decisions on risk management for protection against large natural disasters are made according to criteria which are rooted in human factors depending on the social and political decision environment, as well as on financial constraints.

Much effort is given by the scientific community to the development of an analytical theory of risk assessment. We think that the process of analytical risk analysis is an important step in the procedure of determining objective decision criteria for disaster management. It is outlined why the method, in spite of its rational foundation, is not used as much as it should be. It is a method which should work well in situations where probabilities can be obtained from relative frequencies. It is of little value in cases of rare events. Yet, it has been applied mostly to rare events, and because of its lack of credibility there, it is not believed as useful for cases where it should work well as a valuable decision tool

Introduction

The foremost task of political decision makers in all countries is to assure the safety and health of the population, and to create and maintain a climate for stable and sustainable development. This implies the necessity to provide protection against natural disasters - a task which has to be integrated into development planning and whose management requires resources that have to be allocated in competition to other necessary tasks. The activity by which this is accomplished is risk management. In order to assess the role which disaster management should have in the general development of a country, decision makers need to appreciate its function. They need to know costs and benefits both in monetary and in social terms. Risk management therefore begins with planning for disaster mitigation. A rational basis for obtaining planning criteria for disaster management strategies is risk analysis.

Risk management is, however, a much broader activity than risk analysis. It is a methodology for a rational response to the threat of natural disasters, which orders, evaluates and executes, in conformity with other social sectors, all aspects of disaster management, from the identification of hazards to the planning of relief and rehabilitation. It yields analytical as well as "soft" criteria, some of which allow quantification of the effects of disaster management strategies and balancing of expenditures for disaster mitigation measures against other measures, for example for highway safety. An excellent summary of risk management activities as they relate to natural disaster reduction has been given in a manual by the United Nations Disaster Relief Organization (UNDRO), and much of what will be said is presented in more detail in that report (UNDRO, 1991), to which one should turn also for many valuable references

The risk management chain

The process of risk management can be conceptualized as a chain, as is shown in Fig. 1 (adapted from Yadigaroglu and Chakraborty, 1985). It forms a logical sequence of actions that have to be taken for disaster mitigation. Roots of the method are found in traditional engineering approaches; its full development into a consistent tool is a result of safety studies for technical installations, such as nuclear power plants, or some large chemical plants, whose failure could cause large scale disasters. The large threat to populations posed by failure of these installations has led to high level scientific councils in many countries (for example in Britain; Royal Society, 1983), that were charged with evaluating all aspects of risk, and who found classical risk analysis, as used for example in the well-known Rasmussen report (US Atomic Energy Commission, 1974), to be a starting point for the discussion of the broader issues of risk management. The method of risk analysis has also been applied to assess the safety of existing structures, such as old buildings that might be exposed to earthquakes, or to the safety of dams.

Risk management

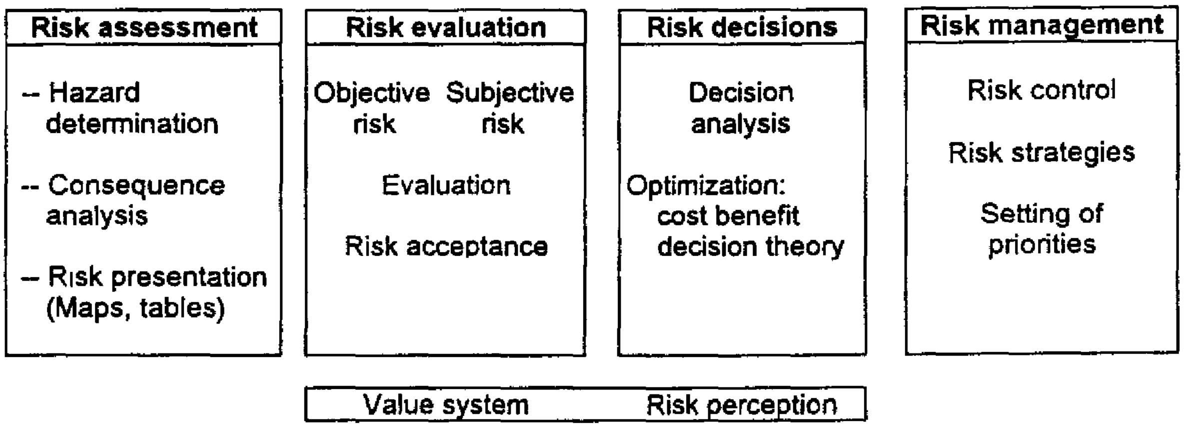

Figure 1: The risk management process

Risk assessment

The first link in the risk management chain is risk assessment, a procedure of first identifying the events that may cause a natural disaster, for example, extreme winds or floods; second of determining the hazards for the event, which is the probability of the event to occur within any one year; third of evaluating the consequences that are caused by the event. A fourth part of risk assessment is the presentation of the results in a useful form, for example in maps. The events are characterized through their strength, such as an extreme wind speed, or a flood discharge. We shall indicate the strength of an event by a variable u. The magnitude u of the event is a variable with the property that the extreme event is rare. Engineers express the rare event by the time T_U that elapses on the average between occurrences of events with strength u above a certain threshold U. This time is called the recurrence interval, and the quantity $1/T_U$ is called the exceedance frequency. Closely related to this frequency is the hazard, expressed through the probability P_E, which is defined as the probability that the event U will be exceeded in any one year, and it is calculated by using for T_U the number of years. In this way, engineers use for example the term "100 year flood" to mean a flood which is exceeded once every 100 years on the average.

In practical applications, the result of hazard determination consists of hazard maps. A hazard map shows the exceedance probability for a particular extreme event U as a function of location, or alternatively, it shows that value of U, for which the hazard is a given constant. Codes, for example for earthquake or wind loads on structures, usually include such maps. Wind codes show the extreme wind thresholds, independent of direction, for different regions of validity for the codes. The hazard map for floods is the map showing the area under water if a flood of magnitude U occurs, sometimes with water depth as a third variable, to better assess the vulnerability. In a more refined analysis, a series of maps is provided, each corresponding to a constant hazard associated with a natural event. Such maps leave a choice to designers or users to judge the severity of the potential disaster. It enables him to base his design decision on the expected recurrence interval for the event. The utility of such maps is undisputed, and the Scientific and Technical Committee (STC) for the IDNDR therefore rightly gives the development of hazard maps a very high priority. In fact, one of the main targets set by the STC for the IDNDR is that all countries should, by the end of the decade, have identified all hazards existing in the country, and have available maps for them.

Modern thinking is that the hazard maps developed today need to be revised continuously, for a number of reasons. Evidently, the longer we observe natural events with modern measurement technology, the better will be the statistical basis for the maps, and the more accurate the maps will be. Furthermore, hazard maps should reflect the changes in the processes which cause the extreme events A much discussed example is the effect of climate change. This is not the place to discuss the connection between climate and hazard, although it is likely that climate change may increase the disaster hazard of many locations. This effect is well researched for the case of a change in climate that leads to a sea level rise, which apart from its gradual flooding of low lying countries directly increases the danger of high storm surges Low lying countries like the Netherlands or Bangladesh are especially vulnerable, and responsible politicians evaluate the potential effects at an early date, in order to plan ahead for the large investments required for protection against higher storm surges (Wind, 1987). Less obvious is the effect on storms and extreme rainfalls: increased incidence in Europe of extreme cyclonic winds have been reported and are associated with an increase in frequency of storm producing weather patterns, as well as with more frequent storm surges in the North Sea.

Consequence analysis is the second part of a risk assessment. A 100 year flood in a small creek is not the same as a 100 year flood of a large river, yet we find that the damage done by a 100 year flood may be quite unrelated to the size of the river. Rather, it depends on its effects on property and health of the people affected by the flood. Fig. 2 illustrates this by showing a cross section through two rivers in populated cities: the city of Paris, France, and Nagoya, Japan (from Iwasa and Inouye, 1984). One does not need much imagination to see that the area in Nagoya to be inundated by a flood that exceeds the design height of the dikes will be much larger than that flooded by overtopping of the river banks of Paris! It is thus seen that the consequences of exceeding a critical event have to be considered in the decision process for disaster mitigation. This is where the concept of a risk, used in the technical sense, comes into the picture. Risk involves both the recurrence interval and the consequences if the event should occur. A refined risk analysis of a situation therefore considers explicitly all adverse and positive consequences, and gives proper weight to the severity of negative effects, or the value obtained from the design.

Consequence analysis implies that for each point in an endangered region, the consequences of the event occurring have to be determined. This includes determination of the number of people that live in the area, and the assessment of what might happen to them if the event occurs. Or one looks at the potential damage to structures, agricultural fields or others. The persons or material exposed to a hazard are called the elements at risk, and the degree of their exposure to the event is their vulnerability, which is usually defined on a scale from zero (no damage) to one (complete damage). The number of elements at risk determine the consequences. In some cases, it is possible to quantify the consequences through a consequence function $K(u)$, where the argument u is indicating that the consequences might well depend on the magnitude of the disaster causing event.

K(u) can be expressed in monetary terms, for example if the cost of repairing the damage from a disaster is estimated, as insurance companies are likely to do. However, quantification through costs is only one possible way of describing the function K(u). It might also express the fraction of the number of persons in an area affected by the event which have their health impaired, or lose their lives. A formal procedure for calculating the local risk is available (for example, Plate, 1993), in which it is shown that the simplest expression for the risk is given by the product of P_E and K, where the assumption is made that the consequences are independent of the magnitude of u, as long as u exceeds a critical threshold U_{crit}. The consequence function depends on the measures that are taken to reduce the risk, such as structural strengthening, or on the effect of the warning systems.

An evaluation of the regional risk requires that the hazard maps are overlaid by the land use and population information for the area at risk. In the past, such overlays had to be prepared by hand, with careful drawings being superimposed. Nowadays, the use of computer based Geographic Information Systems (GIS) is well suited for the purpose, as they not only allow the superposition of different maps of the kind required by the analysis, but in conjunction with appropriate data banks they make possible the analytical evaluation of data from different maps. In this way, maps can be prepared that show directly the risk, as for example quantified through the product of P_E and K.

Experience has shown that an assessment of the risk in numerical terms is fraught with uncertainties. it is very difficult to estimate damages that have not occurred, and to evaluate impairments for developments that are to take place in the future. In fact, a risk analysis depends on many assumptions, of which some are based on predicting the future development of the region. The assessment of future land development, for example the effect of increasing urbanization, is a major cause of uncertainty. Naturally, winds are only weakly dependent on urban or rural developments, but in urban areas obviously more people per unit area are exposed to extreme events, such as hurricanes crossing the city, than in sparsely populated rural areas. Thus, if a rural area is anticipated to become a part of a large city,the number of elements at risk greatly increases. The assessment of the development that takes place if a flood proofing scheme has been initiated is even more difficult. The higher protection of the diked area attracts people and industry to settle in it, and when an extreme event occurs that overtops the dikes, then the disaster might be larger than if the unprotected but less utilized area had been flooded. In comparison to these uncertainties of human actions it appears that the possible effects of natural variability, such as anticipated climate changes, in most regions are minor - perhaps with the exception of the effect of sea level rise on low lying countries.

Examples such as these are the reason why a risk analysis is never exact but is subject to large uncertainties. There exist mathematical tools based on statistics which permit the expression of these uncertainties in numerical terms by establishing error bounds for the risk, but the question of the significance of such error bounds often has to remain unanswered. The uncertainty is another reason why engineers work on the basis of exceedance probabilities and/or safety factors.

The design according to codes avoids the necessity to evaluate the consequences of the occurrence of an extreme event. Design loads for codes are usually based on exceedance probabilities that are thought to be acceptable to the society in which the codes are used. For example, German engineers use for structure design extreme winds of 30 second duration, which are exceeded once every 30 years, or they design flood storage dams or other hydraulic structures on the basis of the 100-year flood. These numbers reflect a high disaster potential, whereas lower return intervals are chosen for less critical designs. For example, we select a 1 to 2 year flood when designing a sewer system of a city, where the consequences of flooding are minor, whereas the design of the spillway for a large dam may be based on the 1,000 year flood.

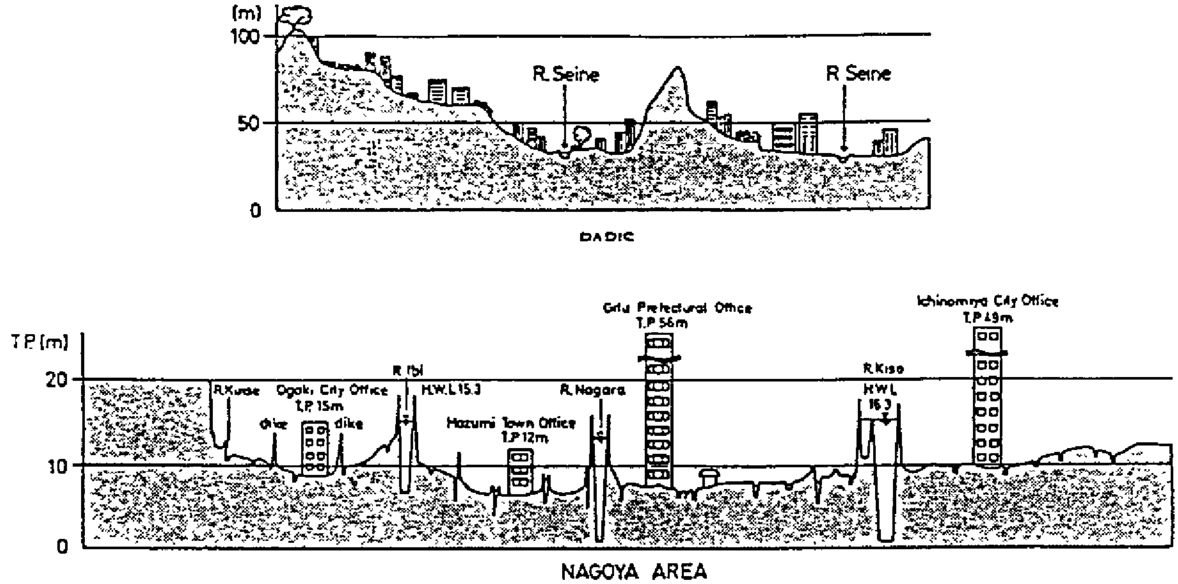

Figure 2: Cross section through the cities of Paris, France, and Nagoya, Japan

Risk evaluation

The next step in the risk management chain is risk evaluation, in which it is attempted to determine the acceptable risk and to develop alternatives for possible disaster mitigation measures, and thus to give a basis for the decision process of what to do in managing the risk. In contrast to hazards imposed by human activities, natural hazards cannot be managed. People that live in a disaster prone area have no choice but to live with the hazard, but they do not have to accept disasters as an act of fate and hope that it will not strike. However, they must know which hazards exist, and how to cope with them, if possible. Therefore, risk evaluation is based on three parts: risk assessment, risk perception, and development of concepts for risk mitigation. Hazards and the risks associated with them must be known so that the options which are available for reducing the impact of a disaster can be assessed. Risk perception as used here is the process of comparing the risk posed by the natural hazard with an acceptable risk.

An acceptable risk in the engineering sense is a number which is of the same dimension as the risk calculated for the hazard under investigation. It can serve as a standard against which all measures for disaster mitigation are compared For example, if the risk calculated is an expression of the expected monetary losses (expressed, for example, in terms of dollars) caused by the disaster, then the acceptable risk also is a numerical value expressed in dollars. The difficulty of the engineering approach based on risk comparison is the problem of finding an appropriate standard: what is a permissible risk? If this is not given a priori - and it practically never is - then its value has to be determined during the decision process, which is the next link in the risk management chain However, because of the difficulties of defining an acceptable risk, structural engineers prefer design risks specified in terms of failure probability P_F, whereas hydraulic engineers tend to use exceedance probabilities. These figures of merit do not express any real natural conditions, but if they are determined "according to the rules of practice", by an accepted design process, they provide safety standards which are based on experience and which yield a compromise between safety and economics. The advantage of this approach is that by using the same figure of merit for all alternative solutions, it permits to compare them on a common ground.

What may appear to be an acceptable risk in engineering may not be an acceptable risk in the public's perception. For most people, the acceptable risk is not necessarily a numerical quantity, just as the risk from the risk assessment process does not have to be a number. Rather, it is the weight that they give to the impact of a natural hazard. It is a well known fact that risk perception for natural disasters is time dependent. The threat of a disaster is felt most strongly directly after the occurrence of a disaster, or a near disaster. With re-establishment of the way of life before the disaster, the memory of the impact fades, and thus the will to take action to be protected. Hydraulic engineers involved in flood protection works have suffered a good deal from the shortness of collective memories of disasters. After an extreme flood event had occurred, people demand extensive protection. The political process is set in motion, and after some time, engineers are authorized to go to work and draw up plans for preventing future disasters of the kind experienced. When finally after more time the plans are finished and all protective measures planned and ready for execution, the willingness to pay has diminished and other needs are felt more strongly and draw away the resources.

Risk perception is also involved in estimating the long term effects of risk reduction measures. History has shown that people in flood prone areas learn to live with the floods: being frequently exposed to smaller floods they learn how to cope; they stay out of the region of floods, or they build on high ground only. When the large flood comes, they are prepared, having been trained on the frequent smaller floods. This experience fades when flood protection measures provide a high degree of flood protection, say, protection against the 100 year flood, but when this flood strikes, then people are unprepared. In Germany, we have experienced this during the high floods of December 1993 on the Moselle and Rhine rivers: no people were harmed, but the damage of these floods was extensive, in part because people in the picturesque villages below the vineyards along the Moselle river are now protected against low floods, and had given up making their basements flood proof, or protecting their wine barrels from being washed down the river. Erroneous risk perception also is the cause of many recent disasters involving landslides in urban areas. In some countries, farmers from impoverished lands move to cities. Because they do not know the hazards, they settle on sloping land that is subject to landslides during heavy rains.

The modern concept of risk management for industrial plants distinguishes among objective and subjective risk. An objective risk is one that is quantified in the process of risk assessment, whereas a subjective risk is that risk that people involved perceive to exist. Usually, a risk that a person accepts voluntarily by his own choice, such as the risk of death from cancer caused by smoking, or the risk of accidental death from driving a motor car, is perceived as much smaller than it actually is, whereas risks imposed from the outside are usually perceived subjectively to be larger than they objectively are. In the discussion of risk acceptance it is pointed out that people are more likely to accept high risks if they decide the risk themselves, whereas they do not tolerate imposed risks of smaller magnitude, such as imposed by a high dam, or by a chemical plant. These issues play a minor part in natural disaster management, but they do come into the picture when the interaction of natural hazards and large engineering structures are made public for new projects.

The acceptance of a risk depends on the value system and the financial resources of a country. The individual person may use his personal value system in deciding on the risk that he accepts, if for example he decides to stay in the earthquake prone area of San Francisco, USA, or likes to live in one of the villages along the Moselle river. Or he may want to reduce his personal risk by considering the options for taking individual risk mitigation actions, or by demanding actions from political decision makers. However, in many countries such actions are not among the options for disaster preparedness.

The last step in risk evaluation is the establishment of the different alternatives for possible mitigation. Approaches to disaster mitigation can be of many different forms, and usually a number of options are available to reach the same effect on risk reduction. A systematic summary of the options is shown, for the case of flood protection, in Fig. 3 (from UNDRO, 1991). However, as the example of flood protection shows, it is usually not possible to separate disaster mitigation activities from other plans. Flood protection and thus flood disaster mitigation is usually one aspect only of a multi-objective project. The use of different alternatives, of which each might be equally useful for the single purpose of flood protection, is usually heavily constrained by one or more of the requirements of other users. This shall be illustrated by a discussion of the development of flood protection along the Rhine river. The approach used for alleviating flood hazards during the age of industrial development has been the straightening of rivers and the construciton of dikes. In this manner, the velocity of the river flow was increased, and as a result the flood wave had lower peaks and moved downstream more rapidly, while at the same time the floods were contained by the dikes. These methods dramatically reduced the flooding risk and proved to be extremely beneficial, because they permitted an extensive agricultural use of land that formerly was flooded too often for a profitable agriculture. Since this type of river training was also useful for making rivers navigable for large ships, the advantages of this method were considered to outweigh the disadvantages, such as the increase in erosion of the river bed, and the resulting lowering of the water level in the river and of the groundwater table in the adjacent lands. In later days, these disadvantages were compensated by technical means, i.e. by introducing river training works such as groynes and barrages - which again had disadvantages by effectively cutting the river off from its surroundings.

From the standpoint of flood control, the greatest disadvantage of this type of training is that the formerly flooded areas now are no longer available for storing flood waters, which formerly had flowed into the flood plain and were retained there instead of causing damage downstream. In the process of making land adjacent to the straightened Rhine river between Basel and Mannheim safe for modern agriculture, dikes were built along the river to contain the 200 year flood - and consequently, the masses of water of large floods was transported downriver and caused increasingly high flood levels in cities like Bonn and Cologne, and further downstream in Holland. Recently, water resources planners in Baden-Württemberg have been trying to reverse this effect: the so-called "Integrated Rhine Program" was set up with the purpose of, among other objectives determined by ecological and landscaping aspects as well as by water resources development, restoring some of the formerly flooded lands to the flood plain through the method of polders - areas set aside parallel to the river, which can be flooded in extreme flood conditions and thus reduce the flood volume.

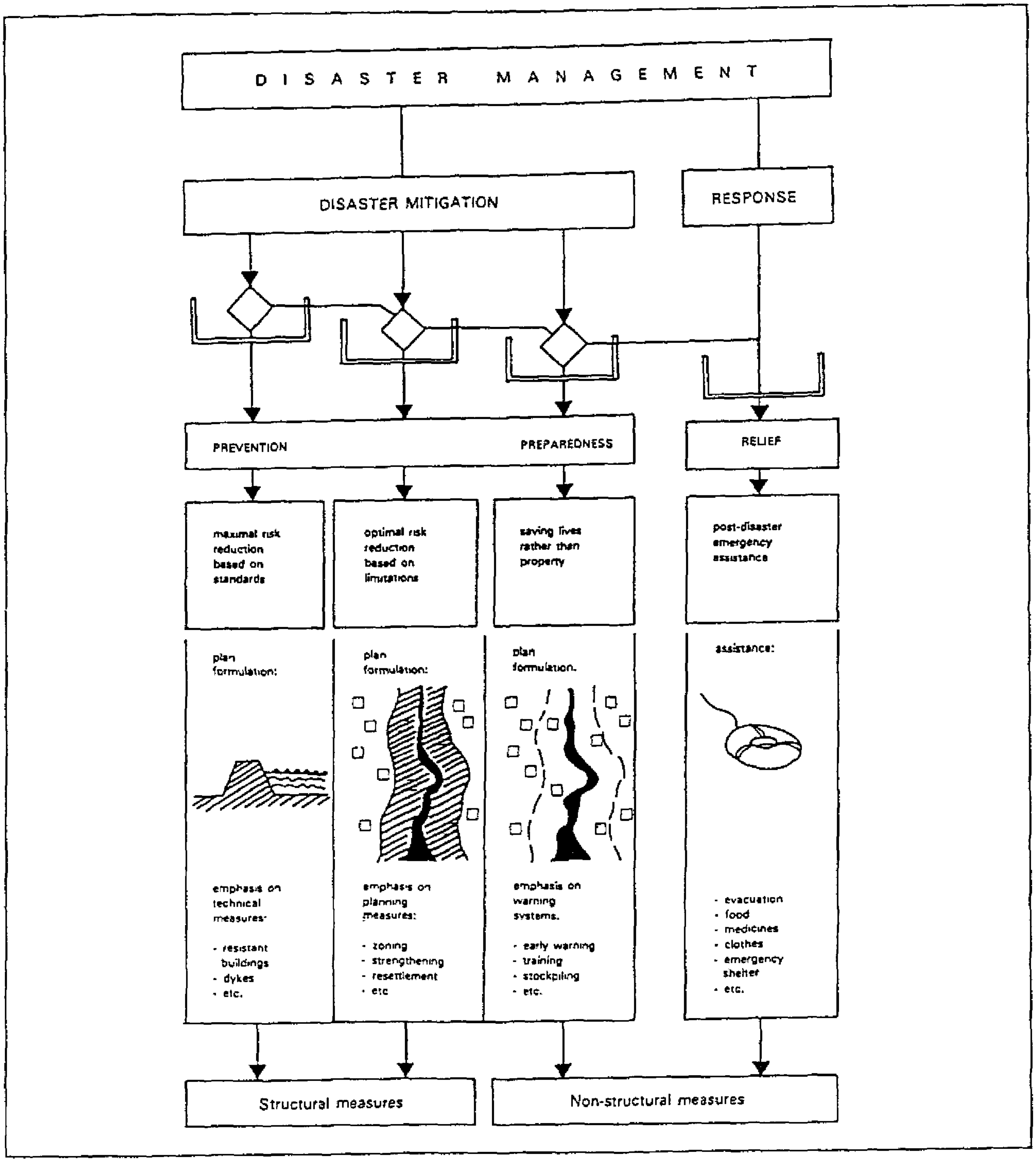

Fig. 3: Risk reduction measures: from UNDRO, 1991

A big problem of all flood protection concepts is that the flood against which protection is provided can be exceeded, and when it is and the river overflows its bed, the damage is perhaps much greater than what would have happened if there had not been any dikes. This points to a philosophical issue that is always associated with flood control. Obviously, the simplest solution to the flood problem is to identify the flooded areas for the biggest conceivable flood and to declare this area off limits for all human activities. This solution, declared as optimal risk reduction based on limitations in Fig. 3, has recently been rediscovered, in particular by many nature minded scientists. However, flood plains, as the old Egyptians and the peoples of Mesopotamia as well as the ancient Chinese already had found out, have the best arable lands and are flat and thus comparatively easy to use for agriculture. And later generations found that cities located on big rivers had the advantage of the river as transport system, or that the water supply for large populations or industries could best be served by direct withdrawal of water from the river. Consequently, people everywhere in the world decided to rather live with and fight the floods than to stay protected outside of the flood plain. As long as the arguments in favour of settling on the flood plains are stronger than the arguments against it, people will live with the floods. Disaster mitigation must therefore apply technical solutions of the kinds listed, which are usually expensive, or to increase preparedness against disasters, with the purpose of saving lives rather than property.

Options available for preparedness are emergency plans and relief preparations based on warning systems. Emergency plans include the identification of escape routes, the provision of food and medical supplies, the provision of emergency shelters, and the like. Forewarning is of special importance for all hazards. If it is possible to forewarn people of an impending disastrous natural event, they can save their lives by moving out of the endangered area. The longer in advance a forewarning can be given, the more effective it will be. As an example, Fig. 4 shows the effect of forewarning on people against major floods (in this case caused by dam breaks and flash floods in Europe and the United States (von Thun, 1984). A warning system that permits warning an hour or more ahead of the arrival of the disaster had been sufficient to save most of the people in most of the cases, but this depends on the communication system and on the forecasting methods available.

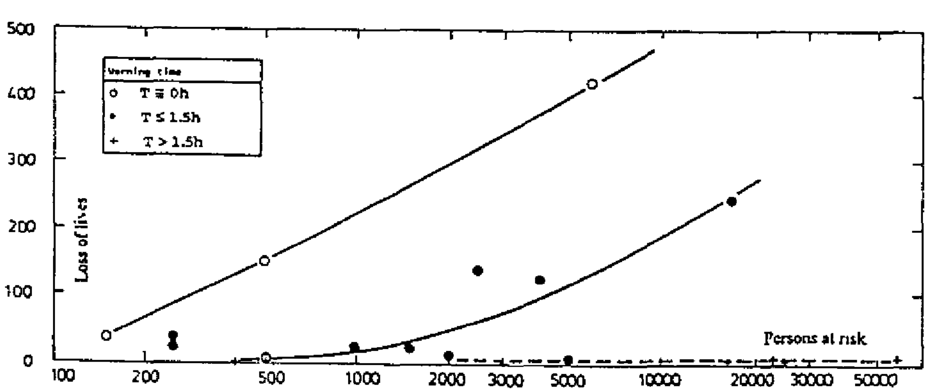

Fig. 4: Loss of lives from 24 dam break and flash flood disasters in Europe and the USA (von Thun, 1984).

Risk reduction decision

The third part of the risk management chain is the decision on the measures that are to be taken. The problem is one of optimization: to find, among the available alternatives, the one that satisfies the criteria of safety with a minimum of costs, or the one that yields the most protection for the available resources. Because other uses are often in conflict with or support disaster management actions, the problem to be solved analytically would be one of risk reduction optimization for multi-purpose projects, with decisions to be made under uncertainties.

Some analytical methods exist for solving such problems, provided that the data and information basis is available. It has been lamented by the scientific community fond of optimization techniques that these methods are seldom used. The reason for this is that decision makers prefer to make decisions taking into account many criteria, among which the analytical optimum risk solution is but one. Decisions for disaster management are usually not based only on technical criteria, but on intuition and political priorities. Criteria may be rooted in the traditions of a society. Undoubtedly, the importance assigned to disaster reduction is a matter of the value perception of a society, and decision makers first of all use criteria from the locally accepted value system - ranging from a fatalistic acceptance of disasters as expression of the will of fate, to the determination to be fully prepared for any, even the most remotely possible, disaster potential. And why not? As Bondi (1985) has pointed out: for large projects such as the storm barrier on the Thames river, the concept of a risk expressed as product of a very small probability P_E and extremely large consequences K is rather meaningless: a mathematical risk based on a failure probability of the order of, say 10^{-5} or 10^{-7} has no meaning, because it can never be verified and defies intuition. Therefore, if money is available for it, why not use it to get the best protection that can be had for the available funds? Indeed, if one looks at large disaster mitigation projects, it is found that the major constraint for disaster management is imposed by the available resources for meeting the social obligations of a country.

In many developing countries funds are limited by low incomes, or because of the prioritizing of industrial development, or else all available funds are needed to reduce the impact of the most recent disaster. The best cost benefit analysis does not help in cases where the resources are not available at this time to invest for obtaining benefits at some more or less distant future. The poorer a country and the higher the incidence of disasters, the larger is the fraction of the national income that has to go into disaster relief and reconstruction. This is also at present reflected in the priorities of development aid. The breaking of the emphasis on relief was among the key motivations for establishing the IDNDR It has been a major concern of the IDNDR organisers to make clear - and to provide the evidence - that the often quoted ounce of prevention in development assistance saves pounds in relief aid in later years.

But financial constraints are not the only reason why a risk obtained from an analytical risk analysis is at most a secondary decision criterium. Politicians are humans, and their field of vision is limited by the perception of the priorities. It is shaped by the influence of the forces of society. In some countries, political pressure of persons affected by potential disasters, and in particular by persons who have been subjected to previous natural disasters, are a major moving force in disaster reduction activities, which are pushed to the exclusion of other priorities. In other cases, projects urgently needed are abandoned because of other pressures. This has been the experience in particular with flood control projects. Engineers as well as enlightened decision makers know that every flood protection measure has some side effects, and that a decision of implementing a disaster reduction scheme may in later days be condemned because of secondary effects that originally were either overlooked or considered to be unimportant or easily manageable. Modern tendency in many countries is to exaggerate possible side effects - such as the impact of flood proection reservoirs on the local climate - until they put into question the usefulness of actions that are very much needed and that objectively and on the basis of risk analyses are well justified - and in the course of this process the opponents of the action may destroy the credibility of the proponents. Hydraulic engineers in countries like Germany who have to design flood control measures can attest to this.

Risk management and conclusions

Risk management combines all the aspects discussed in the previous section into a chain of planning and implementation, and it provides for the continuous preparedness for disasters. Risk management is a process, in which engineers, managers, politicians and the people involved. It has parts which are to be decided strictly on the level of experts: engineers, financiers, city planners. The experts can handle the more analytical aspects of their trade and, for these persons, analytical methods of risk analysis are useful. But from the previous discussions of the detriments to an analytical formulation of risk, it can be concluded that designs using analytical risks are useful mainly if the frequency of the disasters is rather high, and if many structures of the same type are considered. For large risks, the engineering approach based on safety factors and worst case scenarios is the more accepted approach.

Other parts are decided by the political process, whatever that may be in a given country, and by the availability of funds and the priority given to risk reduction. Risk management provides the framework for the decision process leading to disaster reduction measures; it has to be filled out by dedicated persons who not only work on disaster mitigation during the planning stage of a project but continuously on all aspects of disaster mitigation. This is a task that is not solved by good will alone: it requires trained persons and the necessary infrastructure. It may be said that in Europe the incidence of disasters is comparatively small; not because of the absence of large events, as we have witnessed again during the floods of December 1993, but because of a tradition of mitigating actions extending over many decades, and of preparedness through a well trained staff and extensive precautionary measures. This includes the development and adjustment of building codes which translate local hazard assessment into instructions for designers and engineers, and it includes safety inspections and quality controls for the structures to ensure that they are actually built as designed. And they include training of well qualified managers and technicians - and last but not least the willingness of the political decision makers to give risk management the priority in the national goals that it deserves.

The International Decade for Natural Disaster Reduction was established to increase, at all levels of all countries, an awareness for the contribution that disaster reduction activities can make in the development of a country, and to urge the community of nations to exchange information that can help to reach this goal. The concept of risk management can supply the conceptual framework for these activities.

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