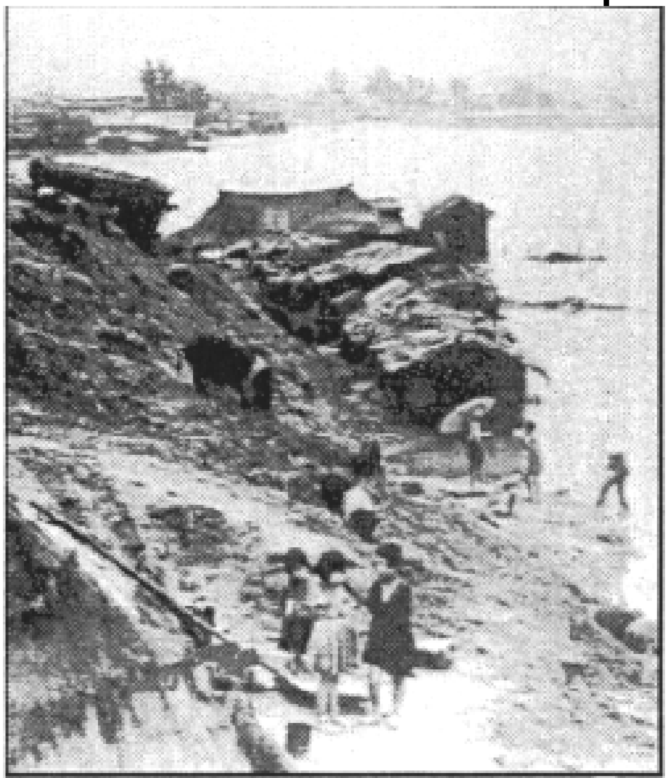
2nd Edition

Vulnerability and Risk Assessment



Disaster Management Training Programme

Vulnerability and Risk Assessment

2nd Edition

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DHA

Disaster Management Training Programme **1994**

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The draft for this text was reviewed by Mary B. Anderson, Harvard University; Yasemin Aysan and Ian Davis, Oxford Polytechnic Disaster Management Centre; Stephen Bender, Organization of American States; Jose Luis Zeballos, Pan American Health Organization; and Ron Ockwell.

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Cover photo: from "Shelter After Disaster" by Ian Davis, fishermen's houses on the banks of a river in Seoul Korea

■ CONTENTS

United Nations reorganization and the Disaster Management Training Programme

Since this module was written, there have been reorganizations within the United Nations system. This section describes these organizational changes and explains the expanded role of the United Nations in Disaster Management.

In December 1991 the General Assembly of the United Nations adopted resolution 46/182* establishing the Department of Humanitarian Affairs (DHA) in order to strengthen **"the coordination of humanitarian emergency assistance of the United Nations"** and ensure **"better preparation for, as well as rapid and well-coordinated response to complex humanitarian emergencies as well as sudden and natural disasters"**. The Department incorporates the former UNDRO as well as former UN emergency units for Africa, Iraq and South-East Asia. The Secretariat for the International Decade for Natural Disaster Reduction (IDNDR) also forms part of the Department.

With regard to complex emergencies, DHA often operates in the grey zone where security, political and humanitarian concerns converge. Policy planning and policy coordination are performed in New York, where DHA works closely with the deliberative organs of the United Nations and with the political, financial and economic departments of the Secretariat.

The Geneva Office (DHA-Geneva) concentrates its activities on the provision of emergency operational support to governments and UN operational entities. It is also responsible for the coordination of international relief activities related to disaster mitigation. It continues to handle the UN system's response to all natural disasters.

An Inter-Agency Standing Committee (IASC) chaired by the Under-Secretary-General for Humanitarian Affairs has been established pursuant to General Assembly resolution 46/182. It associates non-governmental organizations, UN organizations, as well as the International Committee of the Red Cross (ICRC) and the International Federation of Red Cross and Red Crescent Societies (IFRC). The Executive heads of these agencies meet regularly to discuss issues relating to humanitarian emergencies. An inter-agency secretariat for the IASC has also been established within DHA.

Several Special Emergency Programmes (SEP) have been organized within the Department, including the Special Emergency Programme for the Horn of Africa (SEPHA), the Drought Emergency in Southern Africa Programme (DESA), the Special Emergency Programme for the New Independent States (SEP-NIS), as well as the United Nations Office for the Coordination of Humanitarian Assistance to Afghanistan (UNOCHA).

DHA promotes and participates in the establishment of rapid emergency response systems which include networks of operators of relief resources, such as the International Search and Rescue Advisory Group (INSARAG). Special attention is given to activities undertaken to reduce the negative impact of sudden disasters within the context of the International Decade for Natural Disaster Reduction (IDNDR).

The Disaster Management Training Programme (DMTP), which was launched in the early 1990s, is jointly managed by DHA and UNDP, with support from the Disaster Management Center of the University of Wisconsin, on behalf of an Inter-Agency Task Force. It provides a framework within which countries and institutions (international, regional and national) acquire the means to increase their capacity-building in emergency management in a development context.

** Copy is included in The Overview of Disaster Management Module.*

■ INTRODUCTION

Purpose and scope

This training module, *Vulnerability and Risk Assessment,* is designed to introduce this aspect of disaster management to an audience of UN organization professionals who form disaster management teams, as well as to government counterpart agencies, NGOs and donors. This training is designed to increase the audience's awareness of the nature and management of disasters, leading to better performance in disaster preparedness and response.

The content has been written by experts in the field of disaster management and in general follows the *UNDP/UNDRO Disaster Management Manua*l and its principles, procedures, and terminology. However, terminology in this field is not standardized and authors from different institutions may use the same terms in slightly different ways. Therefore, there is a glossary of terms used in this module at the end of this text. Definitions found in the glossary are those of the *UNDP/UNDRO Disaster Management Manual.* Definitions in the text also include technical definitions proposed by DHA expert groups.

Overview of this module

The evidence shows that losses from natural and human-made disasters are increasing, causing death and injury to many millions, leading to the destruction of property, and continually setting back the efforts of the poorest countries to develop their economies.

Enough is now known about the causes and frequencies of disasters and their likely effects for us to begin to estimate future losses, and plan to reduce them as a part of an overall development strategy.

This module examines the scope for measuring the risk of future losses and for using this knowledge to assist in the selection of an appropriate disaster mitigation strategy.

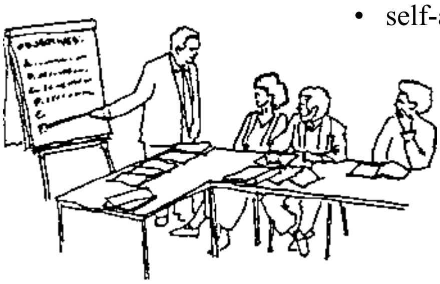
It considers the nature of risk, and the difference between actual and perceived risk; it discusses the techniques by which natural hazards and the accompanying risk of future losses can be estimated; and it discusses the ways in which future risk estimates can be used to assist the choice of the optimum disaster mitigation strategy.

Training methods

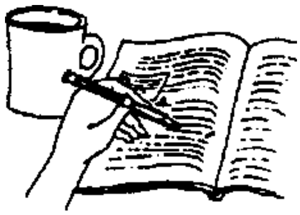
This module is intended for two audiences, the self-study learner and the participant in a training workshop. The following training methods are planned for use in workshops and are simulated in the accompanying "training guide". For the self-study learner the text is as close to a tutor as can be managed in print.

Workshop training methods include:

- group discussions
- simulations/role plays
- supplementary handouts
- videos
- review sessions
- self-assessment exercises



The self-study learner is invited to use this text as a workbook. In addition to note-taking in the margins, you will be given the opportunity to stop and examine your learning along the way through questions included in the text. Write down your answers to these questions before proceeding to ensure that you have captured key points in the text.



PART **1**

UNDERSTANDING RISK

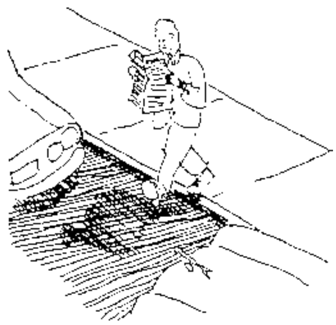
This part of the module is designed to enhance your understanding of:

- *the concept of risk*
- *the various ways of quantifying risk*
- *the comparative nature of risk*
- *how information and perception affects the acceptability of risk*
- *the role of the community in risk management.*

Nothing in life is safe…

When crossing the road there is a risk of being injured by a car. At home there is an everyday risk of accident or fire. We take actions to minimize risk. When we cross the road, we carry out rituals of looking out for vehicles. When we leave home we turn of heat sources and electrical appliances to minimize the risk of fires. *Low levels* of risk we accept. *High levels* of risk we try to do something about.

The risk of natural disasters is something we all face. For some of us that risk is higher than others. Where we live, what we live in, and what we do determines our risk. How important the risk of natural disasters is compared with other risks in our lives will determine whether we do anything about it and how much we do. Awareness of the risk by the public in general and perception of how it compares to other risks will determine society's attitudes about reducing it. Understanding risks and their causes is important in dealing with disasters. Our knowledge of what makes a person or a community more vulnerable than another determines the steps we can take to reduce their risk.



Society takes collective action to protect itself against risks and has been successful in doing so. Reducing the risk of disease has been one of the greatest social achievements of the last century and a half. Average life expectancy for someone born in Europe in 1841 was 35 yeas. Now in most high income countries it is over 70 years, and over 50 years even in the 40 poorest countries.[1] Most of this is due to the virtual disappearance over this time of mortality due to infectious disease. Societies appear to become generally safer and less tolerant of risks as they become more technologically advanced. And yet some technological advances bring with them increased risks: the automobile has cost many lives. Energy supplies and industries introduce new hazards, and so on. The benefits of new technologies appear to outweigh the risks they bring and we as a society seem to tolerate different risks for different reasons. The demand for increased safety in the home and safety in the workplace continue. As the risks diminish from common events like disease, the risks posed by extraordinary events, like natural hazards assume a greater significance. The level of safety that is being pursued is not specific. How safe is safe enough? What risk are we really facing from disasters and how does it compare with other, more familiar risks?

In many cases it is far more cost-effective to prevent disasters from occurring beforehand than to recover from them afterwards. In developing countries, the United Nations Development Program is promoting the goal of sustainable development, and it is argued that disaster awareness considerations should be incorporated into all development programming and planning, both to protect the development process and to reduce the risk of wasting scarce development resources. The UNDP and DHA also have a growing involvement in projects specifically orientated towards disaster mitigation. These projects are prompted by growing awareness of the risks faced and increasing realization that some level of protection is possible. How can the risks be assessed? And how can decisions be made on the appropriate level of protection?

This module deals with risk as a concept and examines risk from natural hazards in the context of other risks. It discusses risk assessment techniques and their use in defining mitigation strategies. Fundamental to reducing risk is the assessment of vulnerability. How much we know about vulnerability and methods of assessing vulnerability are discussed in the following sections.

Definition of risk

RISK

The official definition of terms for risk assessment in natural disasters was established in an international convention agreed by an expert meeting organized by the Office of United Nations Disaster Relief Co-ordinator (UNDRO) in 1979.[2]

The term *risk* refers to the expected losses from a given hazard to a given *element at risk,* over a specified future time period. According to the way in which the element at risk is defined, the risk may be measured in terms of expected economic loss, or in terms of numbers of lives lost or the extent of physical damage to property.[3]

Risk may be expressed in terms of average expected losses, such as:

"25,000 lives lost over a 30 year period"

or

"75,000 houses experiencing heavy damage or destruction within 25 years"

or alternatively on a probabilistic basis:

"a 75% probability of economic losses to property exceeding 50 million dollars in the town of Puerto Nuevo within the next 10 years"

The term *specific risk* is used to refer to risks or loss estimations of either type which are expressed as a proportion of the total; the first two examples might also be expressed as:

"10% of the population (of the given settlement) killed by natural hazards within 30 years"

or

"50% of houses (in a given region) heavily damaged or destroyed in the next 25 years"

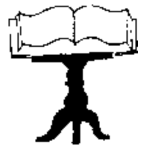
Specific risk is also used for financial losses to property, where it usually refers to the ratio of the cost of repair or reinstatement of the property to the cost of total replacement. Frequently the shorter term 'risk' is used to refer to what are strictly 'specific risks'.

Risk assessment and evaluation

The overall task of risk management must include both an estimation of the magnitude of a particular risk and an evaluation of how important to us the risk is. The process of risk management therefore has two parts:[4]

RISK ASSESSMENT

RISK EVALUATION



a) ***Risk Assessment.*** The scientific quantification of risk from data and understanding of the processes involved.

b) ***Risk Evaluation.*** The social and political judgement of the importance of various risks by the individuals and communities that face them. This involves trading off perceived risks against potential benefits and also includes balancing scientific judgements against other factors and beliefs.

In order to understand a risk and to compare different risks, scientists and economists usually try to quantify it. This is done by gathering data on the effects of various hazards that cause the risk and on the basis of statistical analysis, predicting the probability of future events. The identification of causes, effects and the understanding of the processes of disaster occurrence are critical to the assessment of future risks.

The accuracy of risk quantification depends to a considerable extent on the amount of data available. The number of events on which information is available has to be large enough to be statistically significant. In addition the quality or reliability of the data has to be adequate. These factors all pose problems for the risk assessor who has to identify 'confidence limits' or range of doubt over any future risk estimations offered. Some risks are easier to quantify than others. The risks of the effects of minor floods and small earthquakes are easier to predict than catastrophic ones because they have happened more often and there is more data on their occurrence. Likewise the recurrence of droughts may be predicted on the basis of historical experience. On the other hand, risks of events that have not yet happened, such as the melt-down of a nuclear reactor for instance, have no past statistics and so have to be estimated from probabilities and forecasts.

Data collection

In disasters, like war, information is an early casualty.

Collecting data on disasters is not straightforward and the systematic study of disasters is a relatively young science, so the quality of data available for risk estimation is considerably lower than that available for assessing other types of risks, like medical risks or engineering failures.

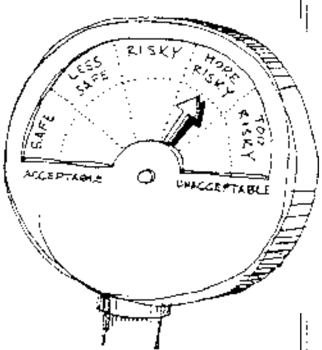
In disasters, like war, information is an early casualty. There are many large disasters that have happened this century in which, after all the confusion, it is still not known with any certainty how many people were killed let alone accurate estimations of financial losses, physical damage or disruption to the economy.

The detailed investigation of individual disasters that occur is now seen to make a major contribution to disaster mitigation efforts in a large number of countries. Flood prevention planners in Brazil, for example can learn a lot from a detailed analysis of a major flood in Bangladesh. The analysis of flood statistics world wide can help define risk levels and characteristics of return periods of floods in individual locations where specific data is scanty. The United Nations has been at the forefront of investigating and reporting disasters to the international community, through its various agencies like DHA, FAO, UNCHS, UNESCO and others.

Detailed surveys of disaster effects can identify risk factors and establish relationships between hazard and vulnerability. For example the systematic survey of earthquake damage can establish that one type of building was more badly damaged than other types : i.e. the *vulnerability* of one building type is greater than another. People who live in the more vulnerable building type are more at risk from a future earthquake than the others. The importance of studying the effects of hazards in order to understand risk and to make effective decisions on risk mitigation should be clearly understood. To understand risk it is necessary not just to study the casualties, but also to study those people who were not affected. Risk needs to be defined in terms of the probability of the effects and the proportion of the total population affected.

How risky is it? the measurement of risk.

Risk can be described and expressed in a number of ways. One standard method is to count all the people exposed to a particular risk and divide this number by the number of people who have actually experienced the hazard over a defined time span. If the number of people who travel by train in any one year is ten million and ten people are killed on average each year, then the annual risk of being killed in train travel is one in one million. These simplified quantifications of risk raise more questions than they solve. Is the risk spread equally over the ten million people or are some people more at risk than others? Did some special type of failure cause all 10 deaths? Are longer trips more hazardous than shorter trips?



Not all risks define the people exposed to them as clearly as train travel. When trying to quantify risks to the population from, for example, chemical release from an industrial plant, the risk is obviously highest for those who live nearest, and less for those who live further away. If 20 people required hospital attention from a particular chemical release, then to quantify the risk from a similar event in the future, that 20 should be divided by the total population exposed – but where should the line be drawn to define the population exposed? Five kilometers from the plant? A hundred? The whole country? Similarly with risk

Probability of an individual dying in any one year[5]	
Smoking 10 cigarettes a day	One in 200
All natural causes, age 40	One in 850
Any kind of violence or poisoning	One in 3,300
Influenza	One in 5,000
Accident on the road (driving in Europe)	One in 8,000
Leukemia	One in 12,500
Earthquake, living in Iran	**One in 23,000**
Playing field sports	One in 25,000
Accident at home	One in 26,000
Accident at work	One in 43,500
Floods, living in Bangladesh	**One in 50,000**
Radiation working in radiation industry	One in 57,000
Homicide living in Europe	One in 100,000
Floods, living in Northern China	One in 100,000
Accident on railway (travelling in Europe)	One in 500,000
Earthquake, living in California	**One in 2,000,000**
Hit by lightning	One in 10,000,000
Wind storm, Northern Europe	**One in 10,000,000**

Figure 1

Probability of an individual dying in any one year

assessment from natural hazards, the definition of the population exposed affects the assessment of that risk. There is no one standard way of defining the population exposed to a risk, so statistical expressions of risk need to be carefully defined and explained for them to be useful.

Gross levels of risk, taking the number of deaths from hat cause, divided by some estimate of the population exposed can give the type of approximate ranking of probability of death to an individual by different causes, as shown in figure 1. This gives some idea of how disaster risk to an individual compares with other risks, and how disaster risk may vary from place to place. The probability of being killed in an earthquake in Iran during any one year for example, is obtained from the total number killed by earthquakes in Iran this century (120,000), divided by 90 years. This gives an average of 1,300 people killed annually. The population of Iran (currently 55 million) averaged over the past ninety years is less than 30 million, so the average probability of being killed in an earthquake is given as one in 23,000.[6] Of course not everyone in Iran is equally at risk. Some parts of Iran are more seismic than others, so those living in the seismic zones are more at risk. Those living in poorer quality houses are more at risk than people who live in strong seismically-resistant houses. But to define the exact seismic zones and the exact number of people in houses of different seismic resistance requires much more detailed analysis. Some of these types of analysis are described in examples given later in this module.

Risk and priorities: comparative risk

Disaster risks are unlikely to be considered important in a community that faces much greater everyday threats of disease and food shortages — even if disaster risk is quite significant it is unlikely to compare with the risk of child mortality in a society with minimal primary health care. Villages in the hazardous mountain valleys of Northern Pakistan, regularly afflicted by floods, earthquakes and landslides, do not perceive disaster mitigation to be one of their priorities.[7] Their priorities are protection against the greater risks of disease and irrigation failures.

By contrast, communities in much less hazardous environments, living in much less vulnerable houses, in California for example, initiate disaster mitigation programs, because relative to diseases and other risks which are very low, disasters are perceived as important. The level of disaster risk relative to other comparable risks is important in determining whether a community or an individual takes action to reduce it. The amount of resources available to invest in disaster mitigation and the value of infrastructure to be protected also determines how readily a community will carry out disaster mitigation.

The level of disaster risk relative to other comparable risks is important in determining whether a community or an individual takes action to reduce it.

As societies develop economically, disaster mitigation is likely to assume greater importance to them. Development itself can increase the likelihood of disasters. Industrial development can bring new hazards; improved health care and economic growth can cause demographic changes, migration and concentrations of population. The amount which could be lost in a disaster grows, as resources are accumulated. Better public health and improvements in other sectors are likely to reduce comparative risk levels in everyday threats, so that the risks posed by extraordinary events assume a greater significance. As societies become richer more resources can be made available to invest in some degree of protection. Protection of the development process itself becomes a disaster mitigation issue.

Protection of the development process itself becomes a disaster mitigation issue.

Development programs and developing countries are the most important arenas for disaster mitigation. Societies in transition from an agrarian to an industrialized economy will be developing an awareness of some of the new environmental risks they face, and an understanding of some of the possible means of protecting themselves from them. But at the same time, the development process has the potential to damage or destroy protection provided by traditional ways of doing things — through siting and land-use, building practice, community defenses or agricultural practices. Replacing these with modern techniques may be a very costly option. Thus an appropriate risk reduction strategy for a developing country has to include an understanding of traditional risk mitigation techniques and should build on them rather than replace them.

Perception of risk

The key to a successful program to reduce risk is to understand the importance that society attaches to the hazards that confront it, that is to say on its own *perception of risk.*

Decisions have to be made about risks, even if that decision is to do nothing about it. In most societies, several groups are involved in these decisions; in particular:

- The general public
- Their political representatives
- The experts, communicators and managers

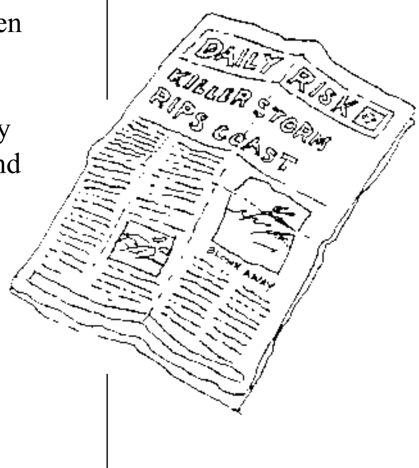
In principle, experts gather the scientific and socio-economic evidence and give technical advice to the politicians, who then legislate and regulate for the benefit and with the implicit agreement of the general public. In practice, of course, things do not very often work out that way. Assessing risk from the available data is not always as helpful as the experts would like. Politicians can have interests and objectives in decisions other than the simple consideration of risk mitigation, and the general public may not see things the same way as either the experts or the politicians.

Decisions are made and actions are taken according to the way that risks are perceived. Perception of risk can differ from one group to another. Experts like to use statistics. But most other people are less comfortable with statistical concepts and prefer to base perceptions of risk on a range of other values, philosophies, concepts and calculations.

Perception of risk has been an important area of psychological research. The mental process of evaluating risk—making sense out of a complex collection of different types of information—tends to differ significantly between individuals and groups. Rules of judgement may be evolved within one group which can lead to valid and consistent decisions, but which may be significantly different from those of another group or individual that has used different patterns of thought to evaluate the same set of facts. Similar differences exist between the individuals within any group.

Risk and the media

An important element in the psychology of risk perception is the 'availability' of information. The mental strategy for decision-making is to match a situation under review with the information that is most readily available and easily recalled. The more 'available' the information on a given event, the more likely it is judged that the event will occur. Things that happen often are easy to remember. The frequency of reporting the occurrence of an event like a natural hazard will increase its perception. But many other factors also influence recall—mental 'availability' of information—and thus perception of risk. Attributes of drama, context and experience influence recall. Dramatic information rich in death and disaster tends to be highly memorable.



For most people, personal contact with hazards is fairly rare and so knowledge of them is acquired more through the news media than from first-hand experience. The way the media report hazards is extremely influential in risk perception. The media tend to concentrate on the more unusual and dramatic happenings in its reporting, and so these events are often perceived to be more frequent than they actually are.

Research has been carried out in the USA and a number of other industrialized countries into risk perception. Experiments asking various groups of people to judge the frequency of various causes of death, like diseases, accidents and natural hazards, show that judgements are moderately accurate with a number of distinct biases. People tend to know in general which are the most common and least frequent lethal events but there is a general tendency in these fairly well-informed subject groups to over-estimate the incidence of rare causes of death and underestimate the frequency of the more common ones. A summary of one of the tests in Oregon, USA is given in figure 2.[8]

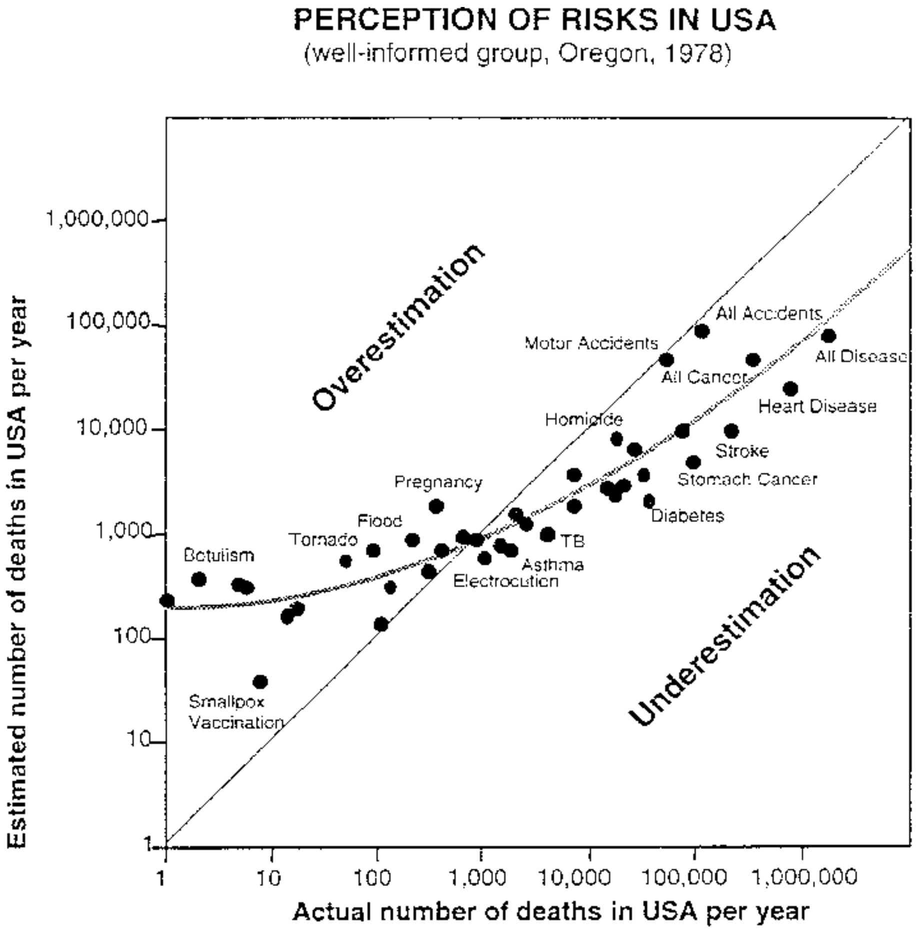


Figure 2

Perception of risks in USA

It has been suggested that these over and under-estimation biases correspond to coverage in the United States media. In the Oregon example accidents are perceived to cause as many deaths as disease, but in reality diseases cause 15 times as many deaths; murder is wrongly attributed to cause more deaths than diabetes, and disaster risks such as floods and tornados are distinctly overestimated. The overestimated risks correspond with favorite newspaper and media topics and it appears that in a society with strong media exposure perception of risk is highly influenced by media treatment.

Research has also shown that frequent reiteration of the fact that certain events (like an aircraft crashing) are rare may have the opposite effect on an audience who may perceive only the fact of the event (the concept of air crashes) and not the message (that they are rare) thus reinforcing the psychological 'availability' of information on air travel risk.

Risk perception with less information

By contrast with the above example of a well-informed group in an affluent society, populations without regular exposure to news media may underestimate the environmental risks they face. There is evidence that risk perception is considerably influenced by availability of information. Some societies without access to information on hazards appear to have lower perceptions of the risk of natural hazards that might strike them. Research with a range of different subject groups has shown that an individual's background and experience—variables like technological familiarity and social grouping—can affect risk perception considerably and quite selectively. There have been no psychological studies of perception of risk among groups much less exposed to media coverage or groups with much higher actual risks of natural disasters comparable with that described above, but a number of social studies of less-informed communities facing high risks have concluded that the individuals are probably more at risk from hazards than they realize.[9] Rural communities or societies with little formal education may have less information available to them on which to make risk decisions. Their perception of risk is likely to be shaped more by personal experience, local and recent events and verbal folklore than by media presentation of risks. Information horizons—the distance from which they are brought news and the length of history they have available to them—may not encompass the rarer events that pose their major threat. Their familiarity with hazards—particularly with return periods longer than their lifetimes—may be minimal and causes of hazards and recognition of danger signs may be beyond their experience.

A common ingredient of disaster mitigation programs is a public education program to increase disaster awareness. This is not only to increase perception of risk where is judged too low, it is also to educate the public that disasters are preventable and to encourage them to participate in protecting themselves.

There is evidence that risk perception is considerably influenced by availability of information.

Q. Some risks are dealt with on a day to day basis and are considered "acceptable". We consider other risks "unacceptable" and alter our plans significantly in order to avoid them. What factors associated with risks make them seem more "acceptable" to us? Compare your answer with the discussion of qualitative aspects of risk perception on the next page.

A.

"It'll never happen to me."

It is also clear that increased access to factual information can increase perception of risk and thereby also reduce acceptable of risk and affect what is considered 'safe'.

ANSWER (from page 17)

Whether or not a particular risk is "acceptable" is largely a question of perception. Factors affecting the perception of hazard risk include:

- presentation of the hazard through the media *(exposure)*
- availability of other information including personal experience (familiarity)
- the degree that we feel that we can control the hazard *(preventability)*
- the horror associated with the hazard *(dread)*

Qualitative aspects of risk perception

An important finding of the research in risk perception is that the abstraction of risk is more easily accepted than the personalization of risk. "It'll never happen to me", is a common attitude in both richer and poorer societies. Complex issues relating to risk and to the possibility of personal injury are handled psychologically by rejecting them. The risk of death or injury to a group of people, even a group that includes the individual is more readily accepted than the risk to the individual personally. Familiar risks confronted many times like driving a car on mountain roads or crossing a dormant volcano may well make this risk discountable, or of lower perception. Inescapable risks may be completely rejected and virtually ignored.

In general, the research into perception shows that people evaluate risks through a number of subjective concepts and beliefs in a multi-dimensional way. The quantitative aspects of risk are less important than some of the qualitative attributes of the risk – the image of a particular risk and the conjecture associated with it. Four factors appear to be important in perception of risk:

Exposure – Actual quantitative risk level

Familiarity – Personal experience of the hazardous events

Preventability – The degree to which the hazard is perceived as controllable or its effects preventable

Dread – The concept of the hazard that some researchers term 'dread' is the horror of the hazard, it's scale and consequences.

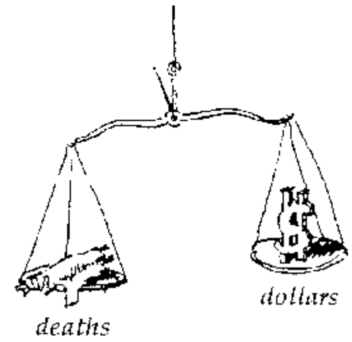
It is clear that disasters have a high dread factor, and are widely perceived as unpreventable. Images of disasters maiming, burning and spilling blood evoke higher dread factors than those of suffocation or drowning. Disasters that cause large numbers of deaths are more dreadful than low-fatality catastrophes. Perception of risk appears closely related to the dread factor, and only generally related to exposure levels or to personal familiarity.

High levels of perceived risk are usually associated with desires or actions to reduce risk and with support to the community and its representatives to reduce risks on their behalf. It is also clear that increased access to factual information can increase perception of risk and thereby also reduce acceptance of risk and what is considered 'safe'.

Acceptable levels of risks

Very high levels of perceived risk are associated with actions to reduce risk—when people think the risk of the volcano erupting is too high, they move. At some level the risk becomes unacceptable. What level constitutes an acceptable risk is always a complex issue. It is a matter of political discussion and public comfort. The concept of risk tolerance and the thresholds of unacceptability are what determine, ultimately, whether public money is voted through for a flood dike project or whether people comply with building regulations to make their houses earthquake resistant.

Many risks are also associated with benefits. Living close to a volcano may bringbenefit of fertile igneous soils for good agriculture. The risks associated with chest X-rays and driving to work are generally considered acceptable because the benefits are immediately obvious. Generally, the exposure to natural and environmental hazards does not have any specific benefit associated with it: the exposure is a simple consequence of living or working in a particular location. This can have the effect of making such risks less acceptable than those from which some benefit is obtained. Generally the acceptable levels of risk appear to increase according to the benefits derived from being exposed to it.



Some risks are entered into voluntarily and a distinction is sometimes made between *voluntary* and *involuntary* risk. Many recreational activities and sports, involve considerable levels of personal risk entered into voluntarily. Indeed the thrill of the risk is part of the enjoyment of the recreation. The benefits of the risk outweigh the costs and so the perception of the risk is reduced; i.e. the level that is deemed acceptable is much higher than a risk that is imposed from outside or involuntary.

Studies of what people actually do about risks – accepted levels of risk in society – have been carried out to try to derive an understanding about the acceptability of risk.[10] An example from the U.S. is shown in figure 3.

The figure suggests three things. First it indicates that the level of risk accepted increases with the benefit involved. Secondly that tolerance of so-called voluntary risks may be as much as 1,000 times higher than that of involuntary risks. Thirdly it suggests that the background risk of death from disease in society as a whole may provide a yardstick from which acceptability of involuntary risks may be judged. Subsequent research has shown that this notion is rather simplistic and that acceptable levels of risk are rather more complex to determine, but the research does identify some important factors involved.

STUDIES OF ACCEPTED RISK LEVELS

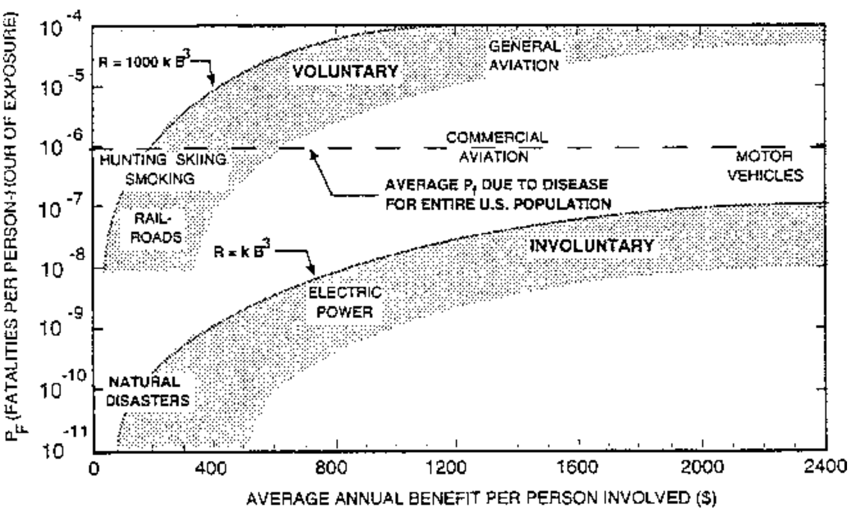


Figure 3

Studies of accepted risk levels

Another concept derived from research studies is that of the comparability of risks: the notion is that classes of similar risks may have approximately the same level of acceptability. Thus the acceptable level of risk from wind hazards would be expected to be similar to the acceptable level of risk from floods, but need not necessarily be comparable with transportation risks, for which other value systems would operate.

The judgement that a risk is acceptable is not something that depends on actual risk level so much as subjective determination using value judgements.

The important point to emphasize from this discussion is that the judgement that a risk is acceptable is not something that depends on actual risk level so much as subjective determination using value judgements. Factual information about risk, if it is believed, can affect the acceptability of a risk.

Management of community risk

The level of risk from a natural hazard to an individual is far less than the risk posed to a whole community. The risk to an individual of being killed in a natural disaster in Turkey is about one in 100,000 each year—perhaps to this individual this is a minor risk. Yet the Turkish nation suffers an average of 1,000 people a year killed in earthquakes, landslides and floods—a high level of attrition. The chance of an individual being caught in an area randomly hit by a natural hazard, for example, is relatively small, but if the area of jurisdiction of an authority – a district, a province, or a whole country, is larger, the chances of being affected by a disaster are proportionately higher. For this reason it is commonly argued that management of risk is more important to the community than to the individual. Many risks are managed at a community level rather than at an individual level. Not only are the community's resources greater, there is also more motivation to tackle the risk. Legislation, large-scale engineering structures and installations for hazard reduction, and establishment of safety organizations are all community-level initiatives for reducing risks.

Institutions which can influence the safety and protection of the community include the legislature, government departments and administrative bodies, industrial organizations and many others. Non-governmental organizations may also act on behalf of the community and may be involved in assisting risk reduction activities, being voluntarily answerable to the community.

Different countries and social groups have different attitudes towards safety and community protection. The greatest difference is likely to be in the degree of public participation envisaged, either formally, through public enquires and protection drills or informally, through pressures of public opinion expressed in the media. Actual techniques of risk mitigation are described in more detail in the Disaster Mitigation module of this series.

Q. Why are communities often more active in taking measures to reduce risk than individuals?

A.

Risks of natural and technological hazards

Historically, the perception of risk, and thus society's motivation for reducing it, is dependent to some extent on exposure to the risk—i.e. its probability of occurrence. Generally, however, the 'dread factor' which is related to the scale of the potential catastrophe has a greater impact. There is little doubt that disasters are formidable and newsworthy events because of the number of deaths that can occur even though higher levels of risk may be represented by losses on a smaller scale. For example, leukemia or diabetes may be the greater killers in aggregate, but the fact that they kill individually and without drama makes them less "newsworthy" and less alarming.

Disasters kill numbers of people at once—an airplane crash causes more horror than an equivalent number of the more frequent car crashes because larger numbers of passengers are killed in a single event. The size of a disaster then, represented by its number of fatalities, is almost as important for its perception as its frequency of occurrence.

Data on the size and frequency of disaster occurrences for a particular country can be described as f:N curves plotting the frequency of events causing greater than a certain Number of fatalities. The f:N curves for several types of disaster for the world as a whole are presented in figure 4.[11]

It is clear from these that natural disasters greatly exceed technological disasters caused by industry or transportation in their capability to cause massive loss of life. Indeed the scale of energy release that is possible in nature—in a cyclone, flood, volcano or large earthquake (which may be equivalent to hundreds of atomic bombs)—still far outstrips any human-made source of energy. Drought and famine have been the greatest killers this century, though precise numbers killed are difficult to estimate. Among the so-called rapid onset disasters, floods and earthquakes are the world's severest hazards, both in frequency and lethality. Storms, including cyclones and tornados are only slightly less severe.

The largest single life losses from a rapid-onset disaster to have occurred this century were from floods in China; an estimated 2 million people were killed in Northern China in flooding in 1956 and 1.4 million people were reportedly killed in a flood in 1931 on the Yangtze-Kiang river in China. The worst casualty rate from an earthquake this century was also in China, in Tangshan in 1976, when a quarter of a million people died.

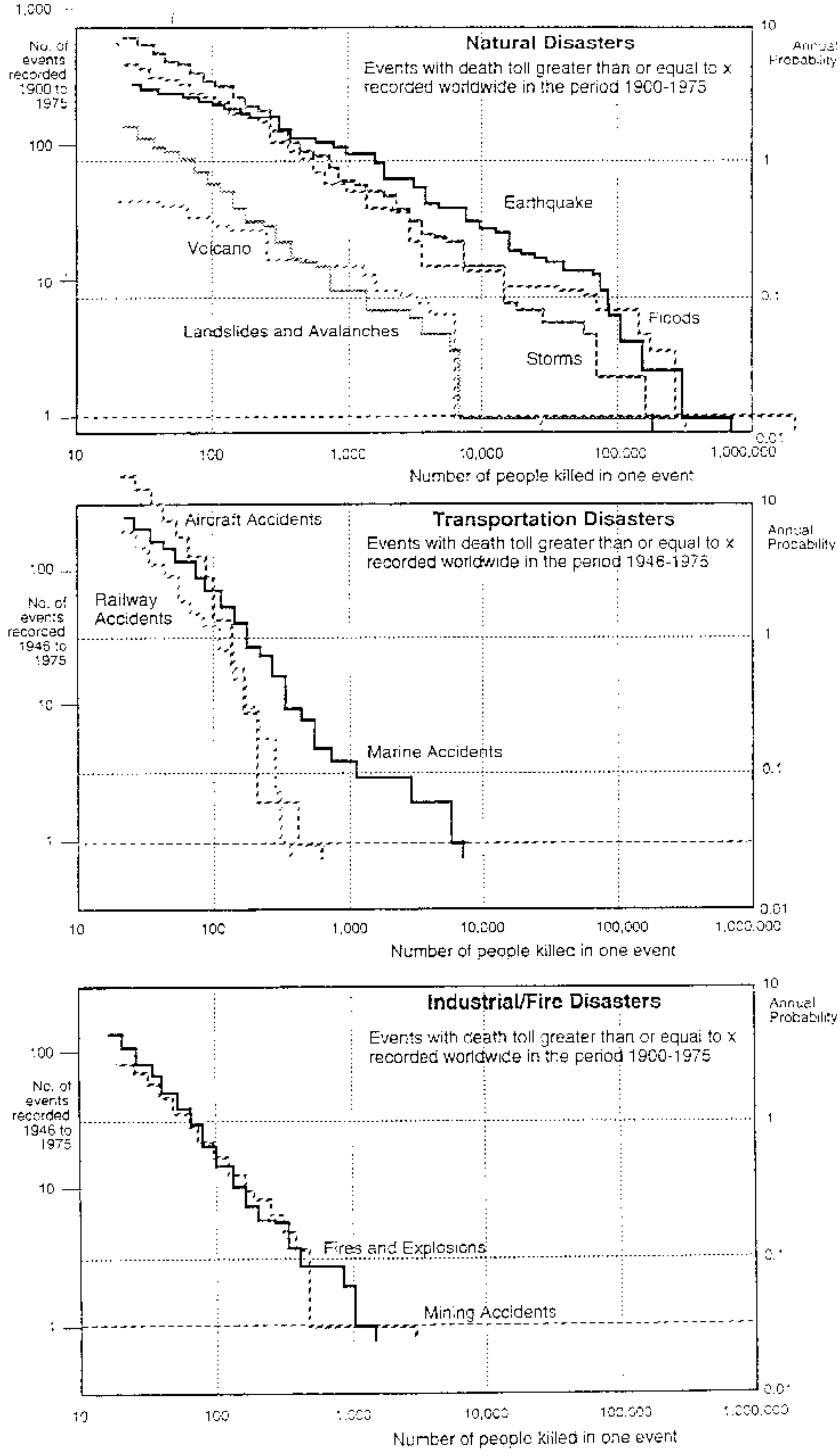
These individual events represent extreme causes of severe hazards, dense populations and vulnerable communities: risks which may be extremely rare. Less severe situations resulting in lower death tolls happen more commonly. The f:N curves in figures 4 show the risk per year of disasters of this less severe type happening. Judging by the record of disasters this century, an earthquake killing at least 100,000 people can be expected on average every 15 years. These diagrams tell us something about the levels and scale of risk of disasters faced but ***risk analysis*** and ***vulnerability assessment*** can also help to structure effective disaster mitigation to reduce risk levels.

Figure 4

f:N curves for various disaster types (worldwie)

It is clear that natural disasters greatly exceed technological disasters caused by industry or transportation in their capability to cause massive loss of life

f:N CURVES FOR VARIOUS DISASTER TYPES



ANSWER (from page 20)

The communities' resources and exposure to the risk are greater than that of the individual. Therefore both motivation and resources for mitigation activities are higher for the community.

■ *SUMMARY*

UNDERSTANDING RISK

- Effective risk management requires information about both the magnitude of the risk faced (risk assessment) and on how much importance society places on the reduction of that risk (risk evaluation).
- Risks are often quantified in aggregated ways (e.g. a probability of 1 in 23,000 per year of an individual dying in an earthquake in Iran). Such gross risk estimates can be useful for comparative purposes, but usually conceal large variations in the risk to individuals or different regions.
- The importance a community places on the risk of a natural disaster is likely to be influenced by the type and level of other everyday risks it faces.
- The process of economic development needs to incorporate a risk mitigation strategy because traditional ways of coping with environmental risks are otherwise likely to be lost.
- Risk is perceived differently by different individuals and different groups. Those with regular access to news media are likely to be more aware of the environmental risks they face than others, but they may also as a result overestimate the likelihood of uncommon risks such as natural disasters.
- Risk perception is also influenced by the degree to which a hazard is considered controllable or its effects preventable and by the extent of the ‘dread’ an individual feels towards it.
- The acceptability of a level of risk to individuals and societies appears to increase with the benefits which are obtained from exposure to it, and to be much greater where exposure to the risk is voluntary (as in sports) than where it is involuntary (like natural disasters). The acceptable level of risk also appears to decrease over time as more people become exposed to a particular type of risk.
- For many risks, mitigation can best be handled at the level of the community because the exposure of the community is greater than that of the individual, and because protection often requires collective, sometimes large-scale action.
- In the 20th century the scale of natural disasters (including famine) has been much greater than that of technological disasters (apart from wars), both in terms of the total number of casualties and the numbers of high-casualty events.

NOTES

PART **2**

ASSESSING RISK AND VULNERABILITY

This part of the module explains

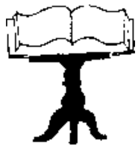
- *the importance of "loss parameters" in risk analysis*
- *the various ways of presenting risk*
- *the importance of hazard evaluation and mapping*
- *how to evaluate and quantify vulnerability*
- *the root causes of vulnerability in societies*

Using risk in decision-making

The estimation of probable future losses is a matter of increasing interest to those concerned with development planning or with the management of facilities or public administration in hazard-prone regions. Future loss estimates are of interest to those responsible for development and physical planning on an urban or regional scale, particularly where planning decisions can have an effect on future losses; for the same reason they are of interest to economic planners on a national or international scale. Loss estimates are also of interest to those who own or manage large numbers of buildings or other vulnerable facilities and to the insurance and reinsurance companies which insure those facilities. Equally, loss estimates are of importance to those responsible for civil protection, relief, and emergency services to enable adequate contingency plans to be prepared; and they concern also those who draft building regulations or codes of practice for construction, whose task is to ensure that adequate protection is provided by those codes at minimum cost. The type of loss estimates required depends on the user: for some purposes estimates of physical losses – of buildings, infrastructure and equipment may be the primary need, while in other cases the numbers of human casualties, and numbers of homeless may be equally important. For long-term development planning, aspects such as economic loss and social disruption also need to be estimated.

Taking measures to reduce the effects of future hazards is becoming increasingly common in planning the future development of cities or regions which have a history of disasters. *Preparedness Planning* involves contingency measures to cope with the emergency when it occurs and *Mitigation Planning* involves the long-term control of land use, building stock quality and other measures to reduce the impact of a hazard when it eventually strikes. Fundamental to these planning processes is an understanding of what to expect. This needs to be quantified, if only in a crude and approximate way, in terms of the degree of risk faced, the size of event that is likely, and the consequences of an event if it occurs.

PREPAREDNESS PLANNING



Also see glossary entry: "DISASTER PREPAREDNESS"

Q. The preceding paragraph dealt with the concept of future loss. What are some specific losses which might be predicted in the event of a major disaster resulting from a natural or human made hazard?

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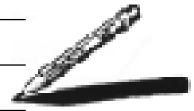

Types of losses to be considered

The most common parameter of loss, and the one most easily dealt with, is economic cost.

Risk is quantified in most of the examples given so far in terms of loss of life. It is generally accepted that saving life is the highest priority of disaster mitigation and preparedness. Furthermore, deaths are absolute and can be counted more easily than injuries. It is therefore relatively straightforward to compare smoking and flood risks in terms of number of people killed. However, many other parameters of disaster consequences may be of equal or more practical value to us. For the medical profession, for example, prediction of injuries are more useful than fatality estimates because injury risk relates to resources needed for treatment. Whatever the ultimate purpose of the analysis, the calculation of risk generally needs to consider several types of loss. The most common parameter of loss, and the one most easily dealt with, is economic cost. Cost is widely used because many types of loss can be converted into economic cost. It is a currency for considering a wide range of effects. Effects which are considered in terms of economic costs are known as ***tangible*** losses. But there are a range of oter effects resulting from disasters which are important but which cannot be converted into a monetary equivalent, and these are referred to as ***intangible*** losses.

A full consideration of risk would include a complete range of effects, both tangible and intangible, and of several qualitatively different types. The range of undesirable consequences of natural hazards that we might consider as loss parameters are listed in table 1. Their qualitative differences make it impossible to aggregate them into any single indicator of disaster impact. Environmental degradation, for example, is almost impossible to compare with social disruption. Indeed, the intangibles may in some cases be equally or more important than the tangibles. Nevertheless, because of the difficulty of quantifying the intangibles, most risk analysis procedures use only one or two loss parameters—such as deaths and the tangible costs of physical damage—as their main concerns.

Loss Parameters for Risk Analysis

Consequences	Measure	Losses: Tangible	Losses: Intangible
Deaths	Number of people	Loss of economically active individuals	Social and psychological effects on remaining community
Injuries	Number and injury severity	Medical treatment needs, temporary loss of economic activity by productive individuals	Social and psychological. Pain and recovery
Physical damage	Inventory of damaged elements, by number and damage level	Replacement and repair cost	Cultural losses
Emergency operations	Volume of manpower, man-days employed, equipment and resources expended for relief	Mobilization costs, investment in preparedness capability	Stress and overwork in relief participants
Disruption to economy	Number of working days lost, volume of production lost	Value of lost production	Opportunities, competitiveness, reputation
Social disruption	Number of displaced persons, homeless	Temporary housing, relief, economic production	Psychological, Social contacts, cohesion, community morale
Environmental impact	Scale and severity	Clean-up costs, repair cost	Consequences of poorer environment, health risks, risk of future disaster

Table 1

Loss parameters for risk analysis

How is risk determined?

There are three essential components in the determination of risk, each of which should be separately quantified:

a) the *hazard occurrence probability:* the likelihood of experiencing any natural or technological hazard at a location or in a region

b) the *elements at risk:* identifying and making an inventory of people or buildings or other elements which would be affected by the hazard if it occurred, and where required estimating their economic value

c) the *vulnerability* of the elements at risk: how damaged the buildings or people or other elements would be if they experienced some level of hazard

Each of these is not a single parameter to be evaluated, but several. Quantifying hazard probability involves assessing not only the probability of, for example, a wind storm occurring, but also the probability of occurrence of wind storms of a range of strengths. A strong windstorm will be rarer than a mild wind storm. A very strong windstorm will be rarer still.

The elements at risk consist of a wide range of things that make up our society – people's lives and their health are elements at risk; so are their economic activities, their jobs, equipment, crops and livestock. Their houses are clearly elements at risk and so are the roads and services they depend on. The community services—schools, hospitals, religious institutions—are further elements at risk. So, in many cases, is the natural environment. These elements are not easily aggregated and have to be treated as a number of separate categories—and the tangible and intangible aspects of each considered.

Vulnerability is similarly multi-dimensional. Each element – a building, a person, an activity – will be affected differently by hazards of different severity. The more severe the hazard is, the more damage will be inflicted on the element. This relationship between the severity of hazard and the degree of damage caused is the vulnerability relationship. Both hazard and vulnerability are described in more detail in subsequent sections.

Presentation of risk

According to the definitions previously given, risk or specific risk is defined as the average rate of loss or 'attrition rate'. While this is useful for estimating losses over a long period of time, it can give a misleading idea of the nature of the risk from natural hazards. Most of the losses from these events actually occur through infrequent large single events, rather than in the form of a slow continuous process of destruction. A variety of different methods have been developed for the presentation of risk to help overcome this difficulty.

One method is the use of f:N curves, such as those shown on page 20 (figure 4) which present the frequency of events with different numbers of casualties (or magnitude of losses expressed in some other way). Presenting risk in this way is thought to be closer to the way people actually perceive it. However, such relationships always show aggregated losses for a large region and period of time. They do not help to identify the geographical distribution of damage, for which *risk mapping* is needed.

Risk maps attempt to show the spatial or geographical distribution of expected losses from one or more natural hazards. Because of the way natural hazards occur, the presentation of annual risk, as defined above, is not necessarily the most useful, and several different ways of presenting losses are commonly used including:

a. *Scenario Mapping:* The presentation of the impact of a single hazard occurrence. Scenario mapping is often used to estimate the resources likely to be needed to handle an emergency. The number of people killed and injured, and the losses arising in other elements is estimated. From these can be estimated the resources needed for medical attention, to reduce disruption, accommodate homeless, and minimize the recovery period. See Example 1 (A scenario event).

b. *Potential Loss Studies:* Mapping the effect of expected hazard occurrence probability across a region or country shows the location of communities likely to suffer heavy losses. The effect of the hazard of each area is calculated for each of the communities within those areas to identify the 'Communities Most At Risk'. This shows, for example, which towns or villages are likely to suffer highest losses, which should be priorities for loss-reduction programs, and which are likely to need most aid or rescue assistance in the event of a major disaster. See Example 2 (Potential loss study).

c. *Annualized Risk Mapping:* Calculation of the probable levels of losses occurring from all levels of hazards over a period of time. The probability of each level of hazard occurring within that unit time period is combined with the consequences of that level of hazard to generate the expected loss within that time. Summing up the losses over all levels of hazard gives the total losses expected with time.

ANSWER (from page 26)

Buildings, infrastructure (such as roads and bridges) crops, other means of livelihood, and human lives may all be lost in the event of a major disaster.

The map indicates expected losses over both time and space. With sufficient detail in the calculation, the likely effect of mitigation policies on reducing earthquake losses can be estimated, and costed. The relative effects of different policies to reduce losses can be compared or the change in risk over time can be examined. See Example 3 (Annualized risk).

Q. What is the main advantage of risk mapping over the plotting of risk curves (f:N curves) as previously discussed?

A. ______________________________

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Example 1: Scenario mapping

The map in figure 5 shows the expected consequences of an earthquake of a particular magnitude (Surface-wave magnitude, Ms = 7.2) occurring with its epicenter at a particular location in Bursa Province, Western Turkey. The magnitude and location are within the range of possible occurrences, i.e. they are consistent with seismological knowledge of the faulting and earthquake history of the region. The earthquake is thus a possible event, and not the largest or the most damaging which could occur. The probability of its occurrence has not been calculated. The damage distribution resulting from this event has been estimated from:

a) statistics on damage distributions caused by other earthquakes in this region for a range of building types, and
b) a knowledge of the actual composition of the present building stock in this area

Each settlement in the affected area is represented by a circle, the area of which represents the population of the settlement. The proportion of the circle which has been shaded indicates the expected extent of damage to the settlement (more precisely the proportion of the residential buildings which can be expected to suffer heavy or irreparable damage).

Table 2 accompanies the map and gives totals on the amount of damage to houses and numbers of people killed, injured or made homeless. It also gives a breakdown between the villages, towns, and the provincial capital city of Bursa.

	VILLAGES	TOWNS	BURSA CITY	TOTAL
HOUSES LIGHTLY DAMAGED	34,000	21,000	50,000	105,000
HOUSES HEAVILY DAMAGED	15,000	9,000	30,000	54,000
HOUSES COLLAPSED	4,000	2,000	6,000	12,000
PEOPLE KILLED	2,000	800	1,500	4,300
PEOPLE INJURED	6,000	2,500	4,500	13,000
PEOPLE HOMELESS	73,000	36,000	130,000	239,000

Table 2

Summary of expected damage and losses caused by hypothetical 7.2 magnitude earthquake in Bursa Province, Turkey[12]

Even though the map shown in figure 5 is an illustration of possible effects and not a prediction, it is able to play an important part in warning local officials, fire departments and the public at large of possible consequences of this particular hazard as an aid to mitigation planning.

Q. What information is best presented in the scenario map? What basic information is not provided in this type of map?

A. ____________________

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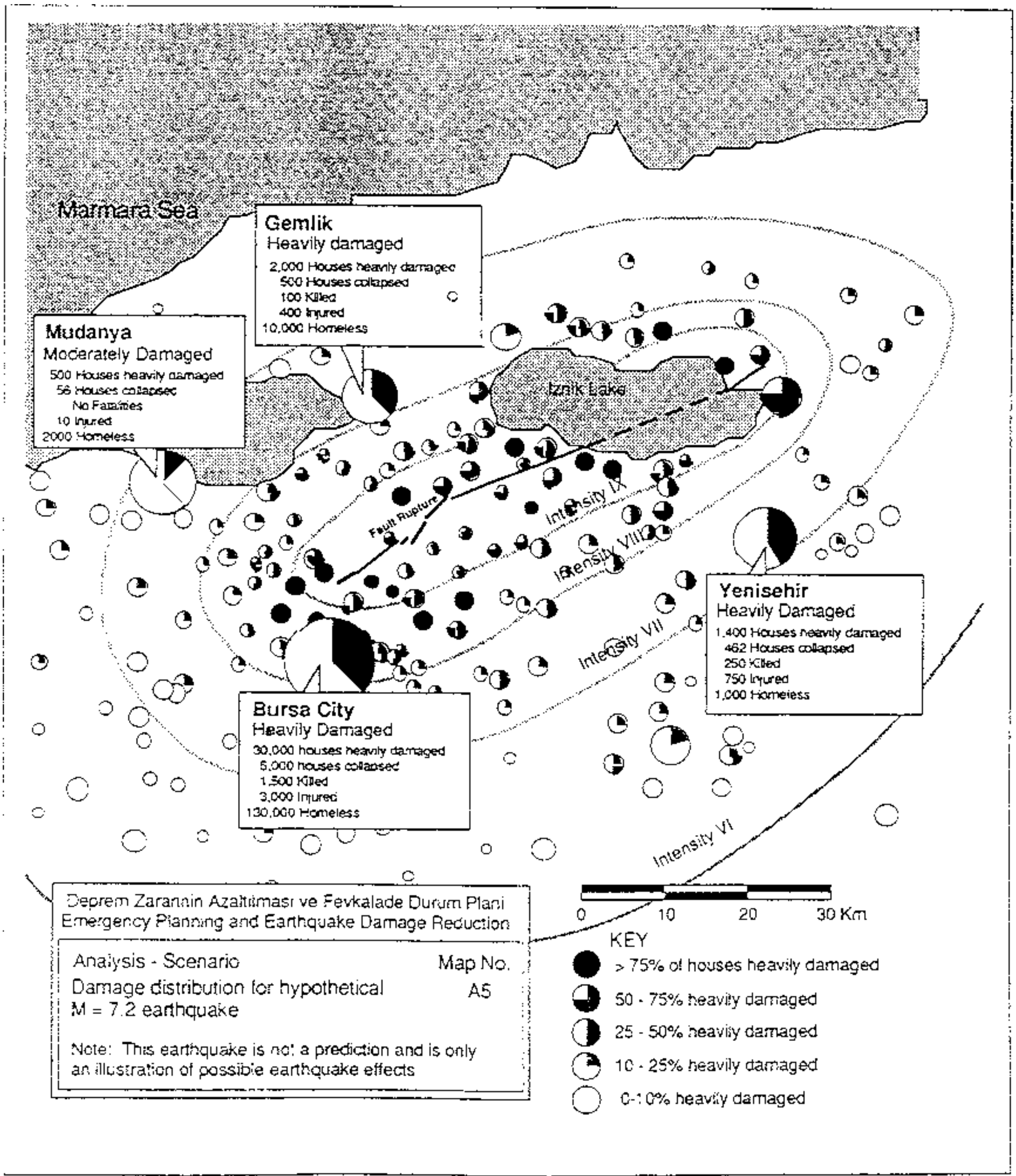
Figure 5

Example 1 —

A scenario event



ANSWER
(from page 29)

Risk mapping presents risk in a geographical way that shows the risk trends over an area and allows comparison of risk levels in different geographic areas. The f:N curves, on the other hand, show aggregated losses for a large region over a given time period.

Example 2: Potential loss mapping

The ***potential loss*** map presents risk as the levels of losses that would occur if a certain level of hazard were to occur at all the locations simultaneously (see figure 6). In this case the type of loss plotted (Map 4) is urban earthquake casualties in Turkey. Casualties are defined as those people whose houses are liable to be totally destroyed by the largest expected earthquake—a measure used because it has been found in Turkey to correlate closely with the numbers of killed and injured. The potential loss plotted in each location is derived from three other types of geographically varying data, which are shown in Maps 1, 2 and 3 (see figure 6).

Map 1 shows the earthquake *hazard* in terms of the maximum intensity of earthquake which might possibly occur there—based largely on reinterpretation of historical records. This map is published by the Earthquake Research Institute of Turkey and is also used to define the level of earthquake which new buildings should be designed to resist.

Map 2 shows the *elements at risk*—in this case the total size of the urban population. Larger towns and cities (over 25,000 population) are plotted individually, and are identified by circles whose area represents the population —apart from the four largest cities whose population is specified. The population in the smaller towns of 2,000 to 25,000 population is shown in the form of a population density. This information is derived from national census data. Other elements at risk – bridges, schools or roads could be mapped in a similar way.

Map 3 shows one aspect of the *vulnerability* of those elements at risk. The casualties are caused by the collapse of buildings. The vulnerability of a building depends primarily on the type of construction. A useful approximate classification of the building types in Turkey divides them into just three types. For each of these building types damage statistics from past earthquakes have been used to derive vulnerability functions, showing expected proportions of the buildings of each type which may collapse at different intensities:

> **Type A:** Rubble and adobe walls (1% collapse at intensity VII, 5% at VIII, 50% at IX)
>
> **Type B:** Brick and timber walls (1% collapse at intensity VIII, 5% at intensity IX)
>
> **Type C:** Reinforced concrete frame (5% collapse at intensity IX)

To assess total damage the distribution of the urban residential buildings between these three classes is needed. Such information is available from Turkish census data. Map 3 plots this data for the province center and other towns for each province of Turkey. The way in which the proportion of reinforced concrete buildings increases towards the richer, more affluent west is immediately apparent, as is the predominance of weaker rubble and adobe buildings in the south east.

Map 4 shows the analysis of the three preceding maps for each location. This is derived by estimating the numbers of people living in each building type (from Maps 2 and 3), and then estimating the potential proportion of collapsed buildings of each type if the largest earthquake were to occur there. The total potential casualties are obtained by adding those from all three building types.

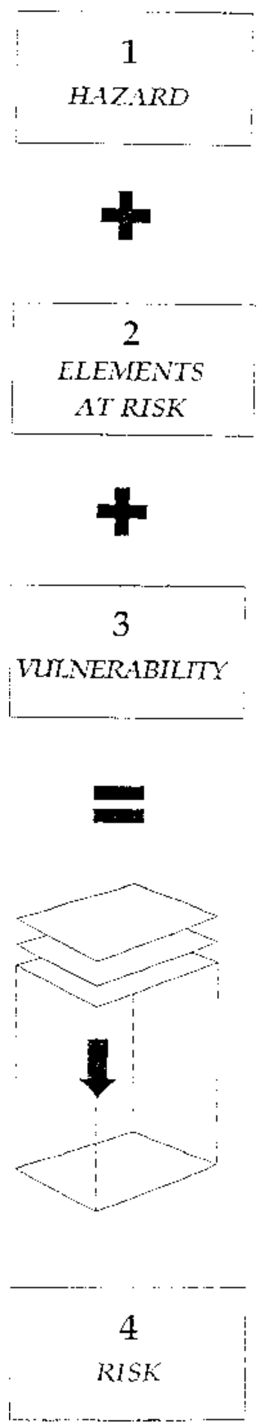
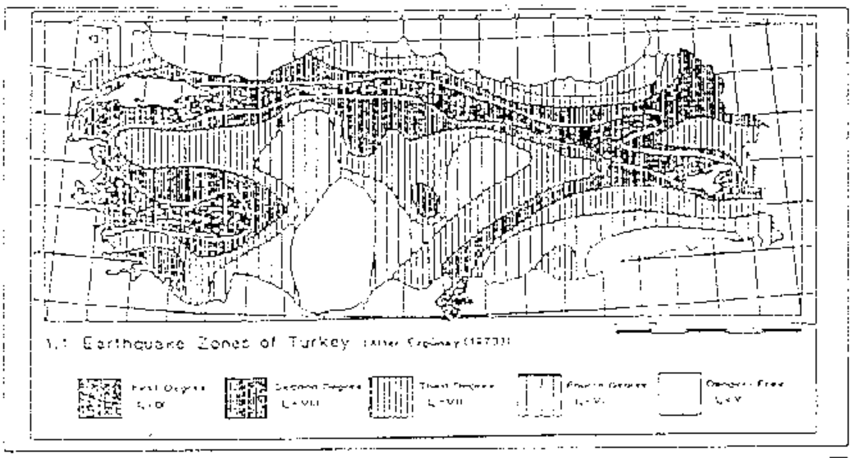


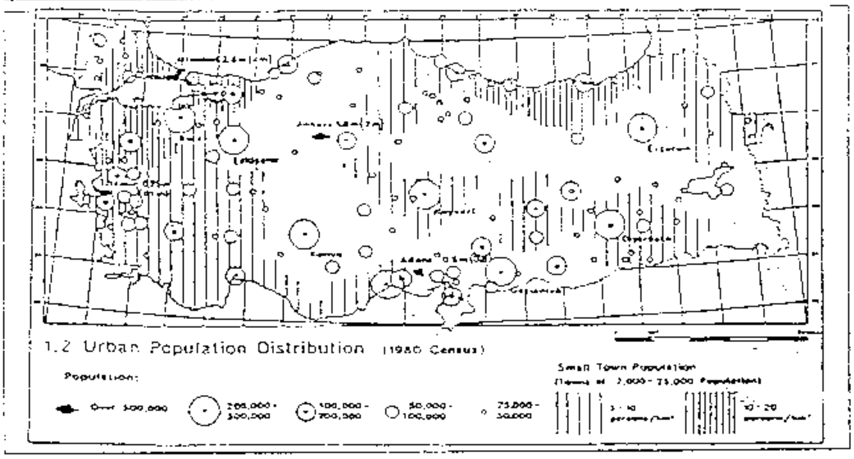
Figure 6

Example 2— Potential loss study

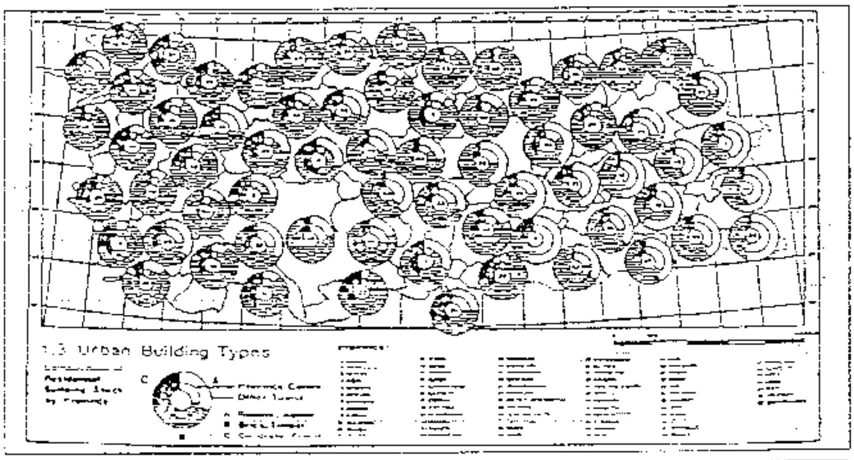
1 – HAZARD



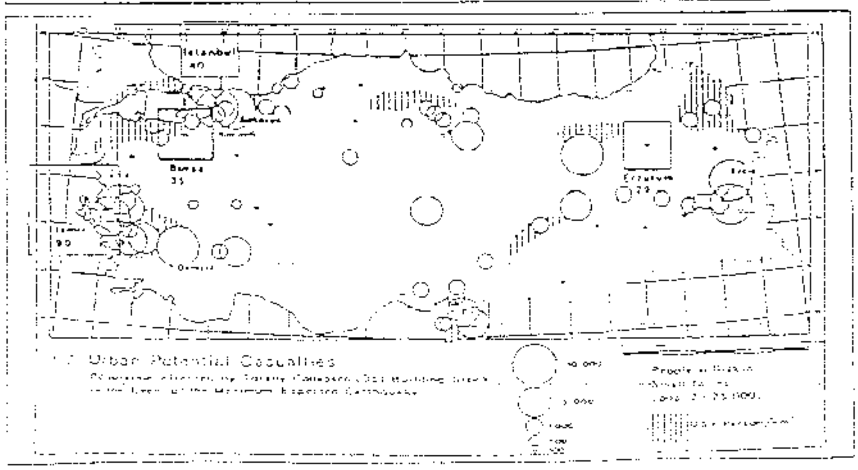
2 – ELEMENTS AT RISK
(population)



3 – VULNERABILITY



4 – CASUALTY RISK
(potential loss of life)



The total potential loss plotted in this way helps to suggest priorities for what national planning should be. In this case the large cities in the west have the greater potential loss (because of larger population), though the potential loss in the larger eastern cities is also significant (because of weaker buildings). Few countries have census data giving as precise data on building types as Turkey, and the distribution of building types may have to be estimated in some other way.

Q. The potential loss map in figure 6 combines three types of maps (hazard, population, and vulnerability). What are some of the assumptions that have been made to produce the final map?

A. ______________________________

Example 3: Annualized risk mapping

The annualized specific risk from any hazard at any location is the average expected total losses from all events over an extended time period divided by the number of years involved. It is expressed as a proportion of the total value (or number) of the total population of that element at risk. The annualized risk can be shown in the form of a contour map (see figure 7). This map plots the annual risk contours for village housing in a particularly high-risk part of Eastern Turkey. Loss is defined as heavy damage or collapse, measured by the proportion of all houses suffering this level of damage. The risk increases towards Karliova in the top right hand corner of the map and then begins to decline. At Karliova, with an annual risk of 2%, about 50% of houses would be expected to be lost within 25 years, whereas at Palu (bottom left) losses would be only half this. Such calculations make the perhaps unrealistic assumption that destroyed houses are replaced by new houses built in the same way.

One feature of all damage distributions is considerable variation between villages, and some indication of this variation can be obtained by plotting, instead of the average expected loss, the loss which can be expected to be exceeded by a given proportion of the locations. The specific risk exceeded by 75% of all villages is shown as a second set of contours.

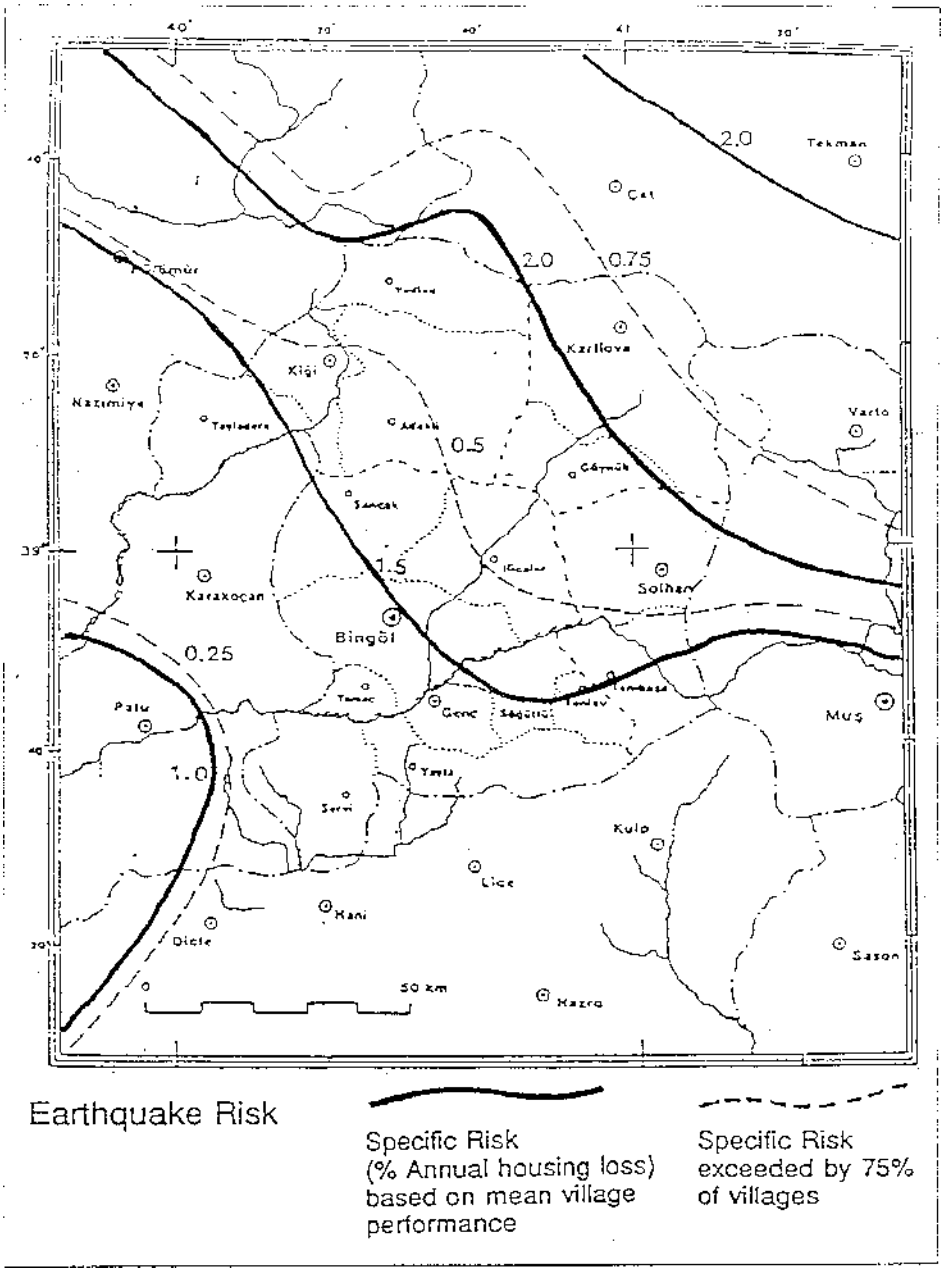
Either of these plots can be used to measure the reduction in risk resulting from some change in the elements at risk such as strengthening the building stock or changing the settlement pattern. Such plots can therefore be very useful in mitigation planning.

ANSWER (from page 30)

Probable property damage to the cities and towns shown due to a hypothetical M = 7.2 earthquake is clearly indicated. The probability of the occurrence of such an earthquake is not presented.

Figure 7

Example 3—
Annualized risk —
% housing loss per year
Bingöl Province,
Turkey



ANSWER (from page 33)

1. It must be assumed that the present population estimates will still be valid at the future unspecified date of the hazard occurrence.
2. It is assumed that the building materials of the houses are the main factor contributing to vulnerability in this area (as opposed to siting and configuration of the structures, for example).

Remember…

In reading risk or loss maps of any of these types it is important to realize that they do not offer predictions. Because of the uncertainty of the knowledge available about hazards, their recurrence patterns and their effects, all loss estimates are merely extrapolations into the future of the observed statistical distribution of occurrences of hazards and their effects in the past. Quite large-scale shifts in the pattern of occurrence of both geological and climatological hazards can and do occur, and development planning must consider this possibility.

Q. The annualized risk map presents most clearly:
(check the appropriate answer)

A.

- ☐ *the number of people exposed to the hazard*
- ☐ *the degree of severity of the hazard expected*
- ☐ *the comparative probable losses between different sites*
- ☐ *the probability of the specific hazard occurring*

Hazard evaluation

To perform risk calculations we need to know the probability of the occurrence of a hazard of a certain level of severity, within a specific period of time, in a given area. The level of severity of natural hazards can be quantified in terms of the magnitude of the occurrence as a whole (event parameter) or in terms of the effect the occurrence would have at a particular location (site parameter). Some of the ways in which the severity of different types of hazard are quantified, using both event and site parameters, are shown in table 3.

HAZARD EVALUATION

Also see glossary entry:
"HAZARD ASSESSMENT"

Natural hazard	Event parameters	Site parameters
Flood	Area flooded (km^2) Volume of water (m^3)	Depth of floodwater (metres)
Earthquake	Energy release (magnitude)	Intensity of ground shaking (modified mercalli/MSK intensity) Peak ground acceleration (%)
Volcano	Eruption size and duration	Potentail to be affected by: ash coverage (m); lava; dust fallout; debris flow
Strong Winds	Windspeed velocity (km/h) Area	Windspeed velocity (km/h)
Landslide	Volume of material dislodged	Potential for ground failure; ground displacement (metres)
Tsunami	Height of wave crest	Depth of floodwater (metres)
Drought	Area affected (km^2)	Rainfall deficit (mm)

Table 3

Hazard evaluation

Like risk, hazard occurrence may be expressed in terms of average expected rate of occurrence of the specified type of event, or on a probabilistic basis. In either case annual recurrence rates are usually used. The inverse of an annual recurrence rate is a *return period*. Examples of hazard defined in terms of the their occurrence parameters are:

"There is an annual probability of 0.08 of an earthquake with a Magnitude exceeding 7.0 in Eastern Turkey"

This is effectively the same thing as saying

"The average return period for an earthquake of $M \geq 7.0$ in Eastern Turkey is 12.5 years"

or

"There is a probability of 25% that an earthquake with a Richter magnitude exceeding 7.0 will occur in Eastern Turkey within the next 25 years"

Examples of earthquake hazard expressed in terms of its site characteristics are:

"an annual probability of 0.04 (or 4% of an earthquake of Intensity VI in the town of Noto"[13] (or expected return period of 25 years for the same event – an equivalent definition)"

or

"an annual probability of 0.20 (or 20%) of a Peak Ground Acceleration exceeding 0.15%g in the Centre of Mexico City."[14]

The hazard expressed in this way is of course only a partial definition of the hazard, related to events of a particular size range. The definition of the hazard for all possible size ranges cannot be done by a single statement of the type given above, but can be presented graphically, as a relationship between the annual probability and the size of the event, as shown in the examples of hazard maps in figures 8 and 9.

Estimating the occurrence of rare events

Natural hazards are extreme cases of normal events; a hurricane is an extreme wind, a destructive earthquake is a large version of the energy released by geological processes that are occurring everyday, a flood is the result of extreme precipitation or storm, or tidal conditions. Extreme meteorological, hydrological or geophysical events pose threats to the human-made environment and to individuals. By definition, extreme events are rare. The more extreme and severe an event is, the rarer it is.

The more extreme and severe an event is, the rarer it is.

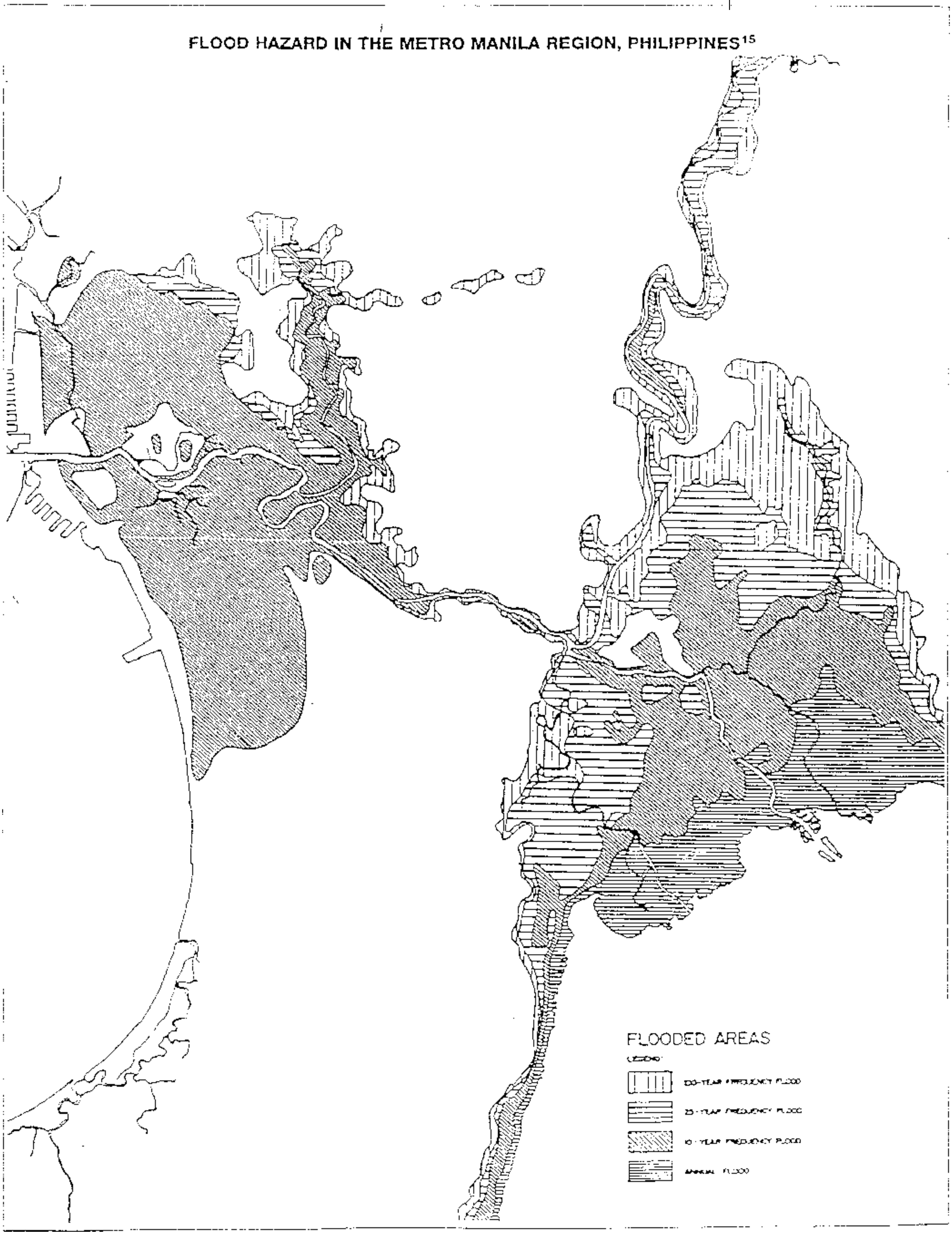
Extreme occurrences of natural hazards are difficult to predict. They occur irregularly – there are very few clearly identifiable patterns of occurrence of natural hazards (although studies are beginning to show that some longer term patterns may be discernible) – and in the short term they appear almost random. Because they happen rarely, there is not a large number of extreme cases in the databases, and statistical forecasting based on past occurrences is unreliable. A volcano that has erupted only once in the past century may erupt once every thousand years or it may have an average eruption rate of once every twenty years and its recent quiescence just happens to be an unusually long gap in its eruption frequency. Estimating the likelihood of another eruption in the near future would need much more than a hundred years statistics on its eruptions. It may be possible to build

ANSWER (from page 35)

- ☐ the number of people exposed to the hazard
- ☐ the degree of severity of the hazard expected
- ☒ the comparative probable losses between different sites
- ☐ the probability of the specific hazard occurring

Figure 8

Hazard Map 1



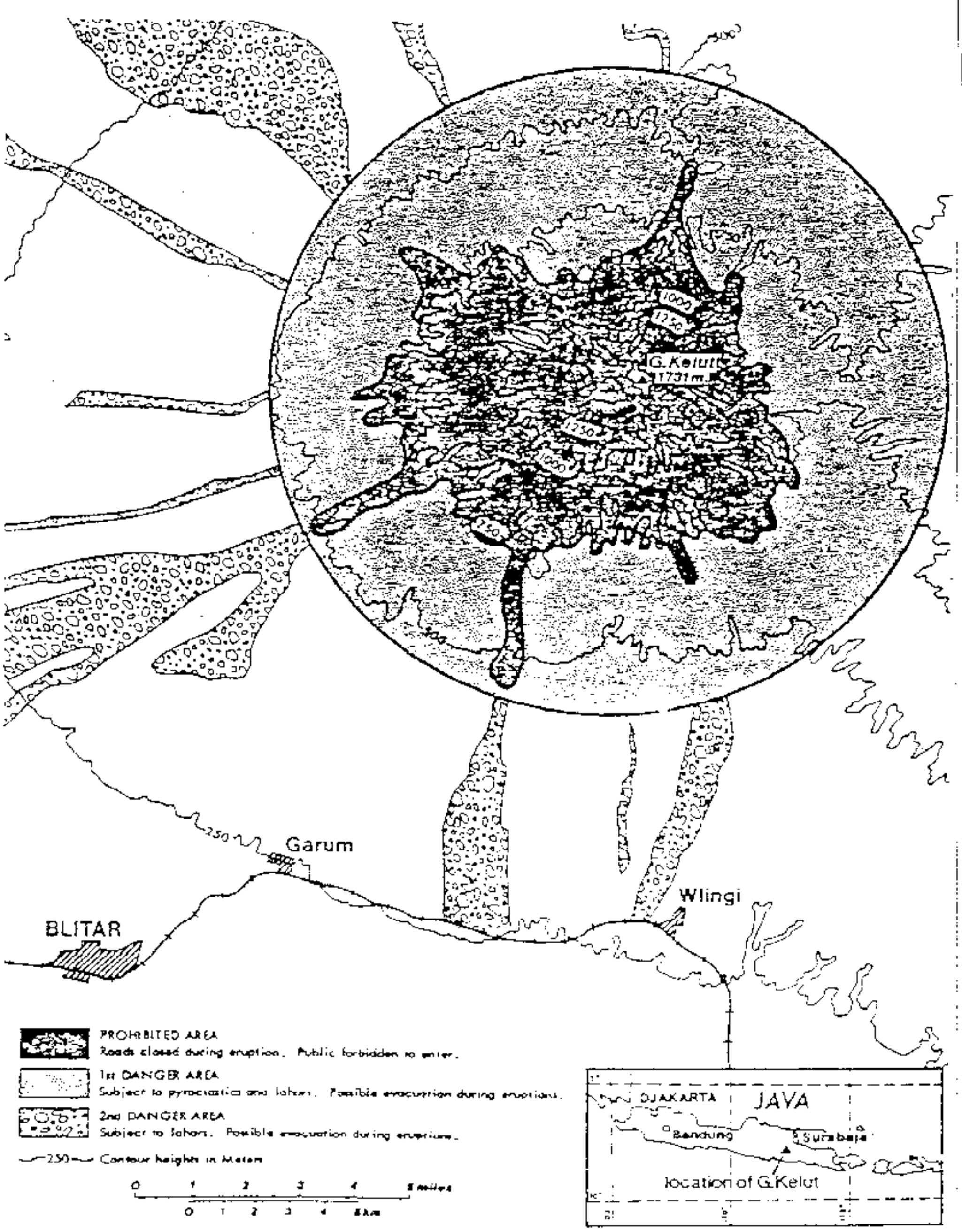
up a much longer record of how often the volcano has erupted by carefully searching historical records back through previous centuries. It may also be possible for geologists to analyze old lava flows and try to date the eruption frequency from that.

Similar corroborative evidence on hazard occurrence can sometimes be found for floods (siltation, deposits and high-water marks) and earthquakes (geological evidence of past fault movements) but for most areas where hazards are likely, the main evidence for hazard probability has to come from human records of their occurrence.

Figure 9

Hazard Map 2

VOLCANIC HAZARDS AT GUNUNG KELUT IN JAVA [16]



Research studies have examined how likely extreme cases of natural phenomena are to occur. It has been found that the number of large events of a flood or an earthquake or extreme cases of other natural hazards has some relation to the number of smaller events that occur and thus that the number of small events that occur much more frequently can be used to predict the likelihood of the rarer, more severe ones. Statistical theories on the distribution of extreme values of things, derived from long-term observations indicate that the severity of the event (or logarithm of this severity) may be assumed to be inversely proportional to the logarithm of its frequency of occurrence. The f:N curves of the number of fatalities in different events shown in figure 4 on page 22 illustrate this principle.

Standard methods of plotting the data from smaller, more frequent events can be used to estimate the probability of occurrence of extreme ones. The hazard map in figure 8 shows the distribution of annual flood flows in a particular river plotted in such a way as to offer an estimate of the expected 100 year flood. Usually some corroborative evidence from other geological and historical sources can further justify such projections.

Hazard mapping

Hazard recurrence probability varies from place to place, and one of the most important ways of understanding the risk faced by any community or region is to use the available data to plot hazard maps. According to the type of hazard, various types of hazard maps may be useful. A map of expected maximum site parameter over a specified time period, as shown for an earthquake hazard in map 1 of figure 6, may be useful for some purposes. For other purposes the probability of the occurrence of an event exceeding a certain magnitude may be more useful, as in the following examples.

Flood hazard is often mapped so that the maximum extent of floods with different return periods are superimposed on each other. The hazard map in figure 8 shows the flood hazard for Manila plotted to show the areas inundated by the expected annual flood and the larger areas expected to be inundated by floods with average return periods of 10 years, 20 years and 100 years.

Volcanic hazards are less easily quantified, but areas at greatest risk can easily be identified. The hazard map in figure 9 identifies three areas of Gunung Kelat in Java with increased hazard severity. The area closest to the summit is permanently prohibited; a larger first danger area of about 20 km diameter is identified as being subject to pyroclastic (air-borne volcanic debris) and lahars (lava flows) and liable to be evacuated during eruptions, while parts of the lower slopes which are the presumed paths for lava and mudflows, are identified as a second danger area.

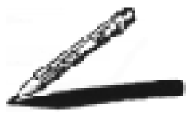
The scale of mapping appropriate for hazard maps depends both on the use and the amount of data available. Knowledge of the spatial distribution of some hazards, such as earthquakes, landslides and floods has reached the level at which variations in risk within a small community can be mapped. Such micro-zoning maps have an important role in land-use planning. Micro-zoning maps can be based on a single event of a single hazard, multiple events of a single hazard, or they can attempt to combine the impact of several different hazards.


The areas of probable occurrence of other hazards, particularly meteorological hazards such as drought and high winds, can only be indicated on maps of much larger areas – for example areas of the world most prone to drought and desertification or tropical storm paths. These maps although not very detailed, nevertheless have an important role in warning development planners of large scale trends and may be useful to UNDP Resident Representatives to identify the hazards to expect and prepare for.

Q. The discussion above points out that there are some hazards which may be mapped in rather fine detail (micro-zoning maps) while others can only be mapped as general trends over much greater areas. In the list given below, identify those hazards which might be presented in the micro-zoning format and those that would be better presented covering a greater area with less detail. (Note: some of the hazards listed are presentable in both formats.)

A.

Hazard type	**Micro-zoning map**	**General trend map**
Earthquake	________	________
Tsunami	________	________
Volcanic eruption	________	________
Landslide	________	________
Tropical storms	________	________
Floods	________	________
Drought	________	________
Population displacements (caused by war or other hazards)	________	________



Vulnerability evaluation

Vulnerability is the propensity of things to be damaged by a hazard. People's lives and health are at risk directly from the destructive effects of the hazard. Their incomes and livelihood are at risk because of the destruction of the buildings, crops, livestock or equipment which these depend on. Each type of hazard puts a somewhat different set of elements at risk. Most of disaster mitigation work is focused on reducing vulnerability, and in order to act to reduce vulnerability, development planners need an understanding of which elements are most at risk from the principal hazards which have been identified. These are discussed in more detail in the module on Disaster Mitigation and are summarized in table 4.

The 'intangible' aspects of vulner-ability will often be as important as the quantifiable aspects and must not be neglected.

It is important for development planners to make some effort to quantify the tangible aspects of vulnerability and loss to assist mitigation and preparedness planning. Some methods for doing this are discussed below. But, as explained earlier, the 'intangible' aspects of vulnerability will often be as important as the quantifiable aspects and must not be neglected. Local experience is a good guide to what is vulnerable in a society, and the list of potentially vulnerable elements should be supplemented by a study of written reports and the knowledge (often never recorded) of those who lived through previous disasters.

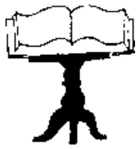
	Principal vulnerable elements	
	Tangibles	Intangibles
Floods	Everything located in flood plains or tsunami areas. Crops, livestock, machinery, equipment, infrastructure. Weak buildings	Social cohesion, community structures, cohesion, cultural artifacts
Earthquakes	Weak buildings and their occupants. Machinery and equipment, infrastructure. Livestock. Contents of weak buildings	Social cohesion, community structures, cohesion, cultural artifacts
Volcanic eruption	Anything close to volcano. Crops, livestock, people, combustible roofs, water supply.	Social cohesion, community structures, cohesion, cultural artifacts
Land instability	Anything located on or at base of steep slopes or cliff tops, roads and infrastructure, buildings on shallow foundations	Social cohesion, community structures, cohesion, cultural artifacts
Strong winds	Lightweight buildings and roofs. Fences, trees, signs; boats fishing and coastal industries	Social cohesion, community structures, cohesion, cultural artifacts
Drought/ desertification	Crops and livestock. Agricultural livelihoods. Peoples' health	Disruption of populations. Destruction of the environment. Cultural losses
Technological disasters	Lives and health of those involved or in the vicinity. Buildings, equipment, infrastructure, crops and livestock	Destruction of the environment. Cultural losses. Possible population disruption.

Table 4

Principal elements vulnerable to specific hazards

Quantifying vulnerability

VULNERABILITY



Vulnerability is defined as the degree of loss to a given element at risk (or set of elements) resulting from a given hazard at a given severity level. (The distinction between this definition and that of risk is important to note. Risk combines the expected losses from all levels of hazard severity, taking account also of their occurrence probability). The vulnerability of an element is usually expressed as a percentage loss (or as a value between 0 to 1) for a given hazard severity level. The measure of loss used depends on the element at risk, and accordingly may be measured as a ratio of the numbers of killed or injured to the total population, as a repair cost or as the degree of physical damage defined on an appropriate scale. In a large number of elements, like building stock, it may be defined in terms of the proportion of buildings experiencing some particular level of damage.

The *vulnerability* of a set of buildings to a hurricane of 130 km/hr may be defined as:

"20% of buildings suffering heavy damage or worse, experiencing 130 km/hr winds"

or

"average repair cost ratio of 5%, experiencing 130 km/hr winds"

Vulnerability of human populations may be expressed in terms of mortality or morbidity:

"5% killed and 20% injured in an earthquake of intensity VIII"

Q. What is the difference between risk and vulnerability?

A. ____

____

____

____

____

____

____

Table 5

This is an example of a damage probability matrix for landslides

	Probability of slope failure in earthquake ground shaking intensity				
Slope failure state	**VI**	**VII**	**VIII**	**IX**	**X**
Light	40	25	15	10	5
Moderate	30	30	35	30	20
Heavy	25	35	40	40	35
Severe	5	10	10	15	30
Catastrophic	0	0	0	5	10

Failure probability for slope of low stability, summer conditions, earthquake shaking of various intensities.[17]

As the severity of the hazard increases, the level of damage that the element is likely to suffer will increase. The 20% of buildings suffering heavy damage in a 130 km/hr winds is likely to increase to 50% in a 160 km/hr wind.

For a full definition of vulnerability, the expected damage level at every level of severity of hazard would need to be defined. Vulnerability for a range of events of different severities, can be given by means of a damage probability matrix.

Where data permits, a continuous vulnerability function mapping values of damage to values of hazard severity can be defined graphically or mathematically as an equation.

An example of this is the vulnerability relationship for a class of buildings against increasing severities of ground shaking in an earthquake, compiled from a collection of damage statistics (see figure 10). In figure 11, five different vulnerability functions are plotted for unreinforced masonry buildings, one for each of the 5 damage levels ranging from D1 (slight damage) to D5 (total collapse). The D1 curve shows the percentage of buildings in a large sample which would be expected to experience damage level D1 or above at any level of ground shaking indicated on the horizontal scale.

ANSWER *(from page 40)*

Hazard	Micro-zoning	General trend
earthquake	x	x
tsunami	x	
volcanic eruption	x	x
landslide	x	
tropical storms		
floods	x	
drought		x
population displacements (caused by war or other hazards)	?	?

■ CASE STUDY

Reducing disaster risk in Mexico City "vecindades"

Part A

Physical vulnerability assessment: identifying buildings most at risk

Background

After a major earthquake in 1985 caused over 7,000 deaths and caused extensive damage to the center of Mexico City, the Mexican authorities instigated a major program of risk reduction measures to protect the city against a recurrence of future disasters. A project funded by United Nations Development Program and executed by United Nations Centre for Human Settlements (Habitat) ran for three years, concentrating on measures for the revitalization and protection of the historic city center.[18] The project attracted bilateral and multi-lateral technical assistance from USA, Japan, UK, Yugoslavia and Italy, providing consultants, equipment and material assistance.

Mitigation measures

The Mexican government (Department of the Federal District) instigated a number of disaster protection measures, which have been quite widely reported.[19] These included re-zoning, proposals for decentralization and reductions in allowable densities; a revision of building codes to enforce higher standards of design against earthquake forces; a program of renovation, strengthening and reuse of historical buildings; a large-scale program of reinforcement of several hundred important buildings; and a major housing program to upgrade poor-quality and vulnerable housing in the city center.

Hazard analysis

Mexico City has suffered from flooding, due to poor drainage and seasonal rains, and a number of industrial accidents, such as gas explosions in the city center, but the major risk to the city comes from earthquakes. An earthquake the size of the one that damaged the city in 1985 could be expected roughly every eleven years. The worst threat comes from a seismic fault system on the coast (The Guerrero Gap) where seismologists fear a major earthquake is imminent.

Identifying buildings most at risk

The program instigated by the city to upgrade public housing was particularly important because of the characteristics of the damage in the 1985 earthquake. The earthquake selectively damaged taller buildings (due to the characteristics of the vibration), and the collapse of weaker structures with large numbers of occupants was responsible for the high death toll. Low-income, rented housing in the center of Mexico City – the vecindades – were thought to be particularly vulnerable to another earthquake in the future. Part of the mitigation project was to establish policies for reducing risk in the vecindades.[20] The first part of the project involved identifying the vecindades most at risk – i.e. those most likely to contribute to the losses in a future earthquake. Buildings were surveyed to find the characteristics of the building in the historic center and their occupancy rates – summarized in the urban maps on the next page.

Vulnerability assessment

The buildings most badly damaged in the earthquake were high-rise (buildings of 5 to 15 stories were worst affected), designed as a simple reinforced concrete frame, and built in the 1960s or early 1970s before the seismic building code was upgraded. The statistics of damage from the earthquake identified the vulnerability of a range of building type characteristics to earthquakes of different strength likely to occur in the future. By identifying buildings with high vulnerability factors (for example finding high-rise reinforced concrete framed buildings built before 1975) the buildings most likely to be damaged in a future earthquake are identified. Where these buildings also have large numbers of residents, they will contribute both to casualties if they collapse, and to homelessness if they become uninhabitable. The buildings with highest projected future earthquake losses are graded into primary and secondary priority for attention.

The assessment of the human vulnerability of the occupants of these buildings and the opportunities for reducing risk are discussed in Part B of this case study.

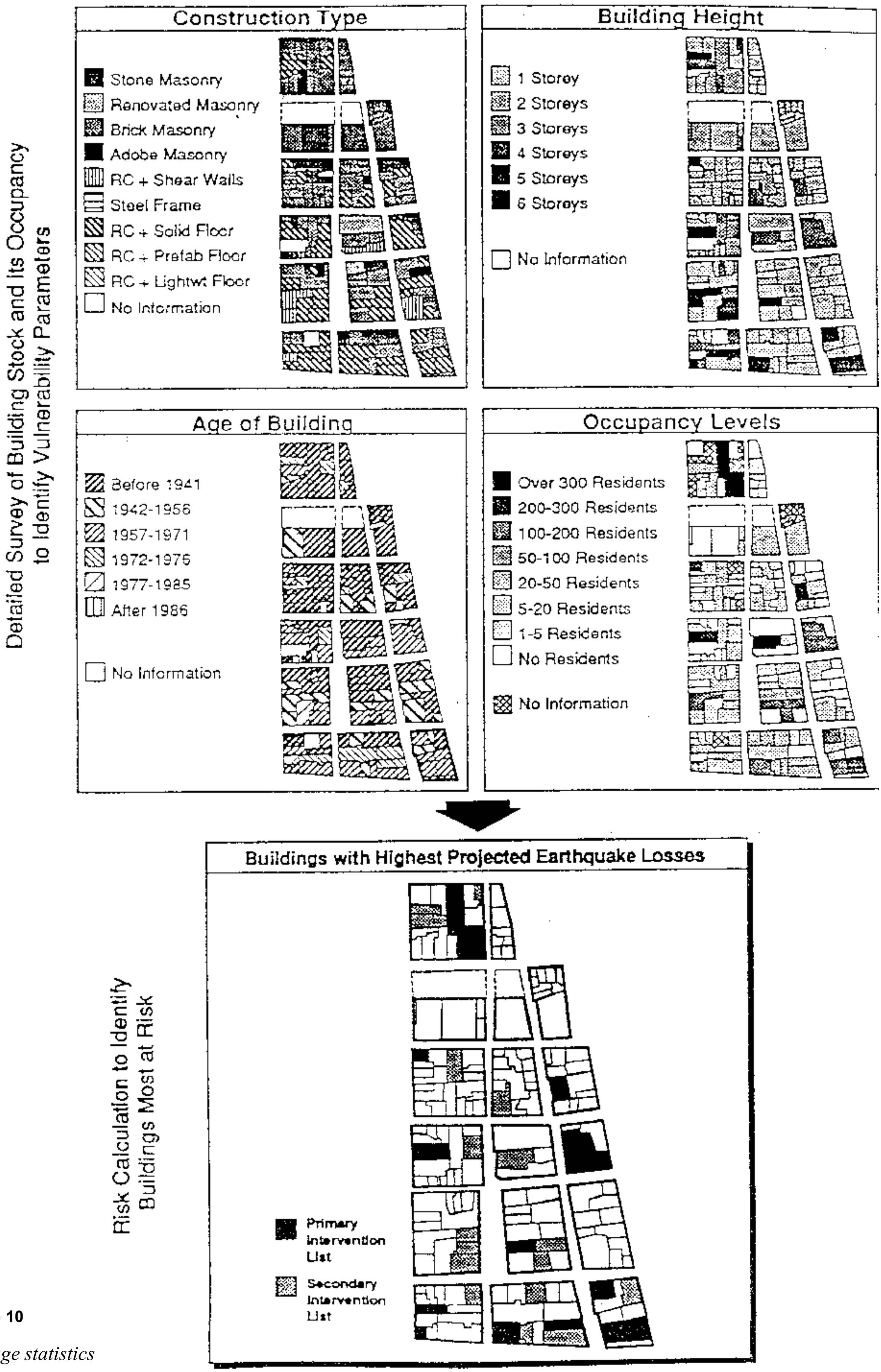


Figure 10

Damage statistics

EARTHQUAKE VULNERABILITY FUNCTIONS FOR BRICK MASONRY BUILDINGS[21]

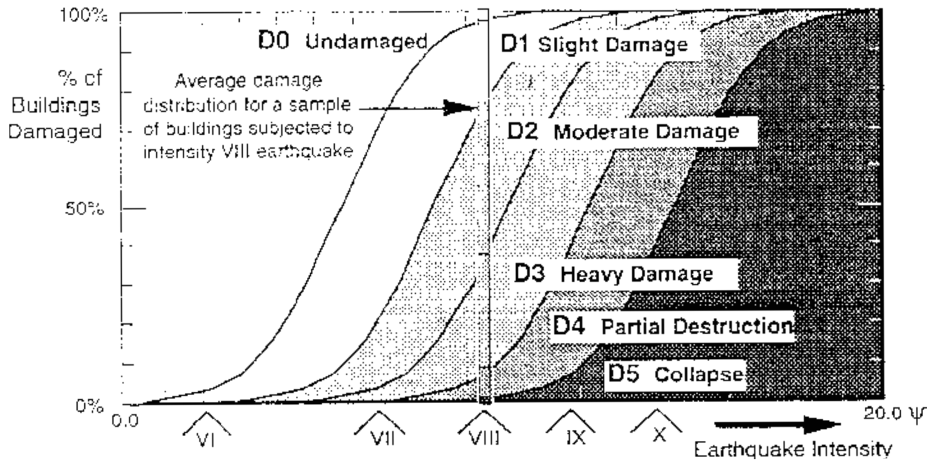


Figure 11

Earthquake vulnerability functions for brick masonry buildings

Damage is almost zero below intensity V, but reaches 100% by intensity IX, at which intensity no buildings would remain undamaged. The D5 curve has a similar shape but shows that the proportion of collapsed buildings is nearly zero up to intensity VIII, but will reach about 50% at intensity X. The value of plotting in this way is that by drawing a vertical line at any level of ground shaking, the intersections with the 5 curves show the expected distribution of a sample of buildings among the 5 levels of damage. The vertical loss scale can also be interpreted as the probability of a given damage level for a single unreinforced masonry building at any particular level of ground shaking.

VULNERABILITY FUNCTION FOR BUILDINGS AFFECTED BY FLOODS[22]

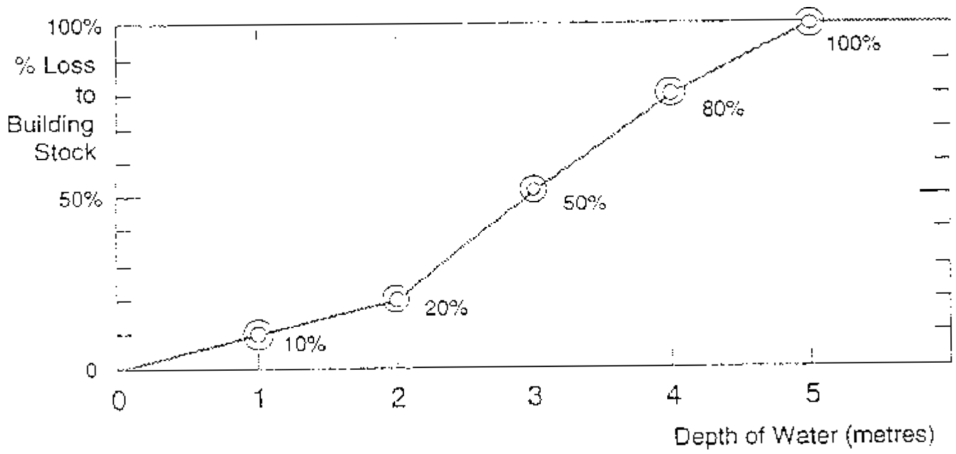


Figure 12

Vulnerability function for buildings affected by floods

Losses inflicted on building stock by increasing depths of high-velocity water (e.g. tsunami)

For many purposes it is not necessary (or possible with the available data) to determine the damage distribution at each level of hazard, and only the total proportional loss is needed. The example of the vulnerability function in figure 12 for floods shows the expected losses to buildings caused by inundation by high velocity water, expressed as a proportion of the total replacement cost of the buildings. Such loss curves are useful for economic planning, but less valuable for assessing probable numbers of casualties or homeless people.

ANSWER *(from page 42)*

Risk combines the expected losses from all levels of hazard severity, taking into account their probability of occurrence while vulnerability is usually expressed as a percentage loss (or given a value between 0 and 1) for a given hazard of specified intensity.

Reducing vulnerability: robust societies

It is sometimes argued that using risk concepts in disaster mitigation is too hazard-specific. In a classic risk analysis, the hazard is first identified, then the probability of that hazard occurring is estimated, the vulnerability that relates to that hazard is then identified, and finally action is taken to reduce vulnerability. In this way of doing things, if a hazard happens that has not been foreseen, the disaster mitigation program may not protect against it. It is clearly impossible to predict every disaster hazard. Any society faces a wide range of potential hazards – one thing that characterizes disasters is that however carefully they are planned for, they are always surprising. Yet many of the elements of the vulnerability for different hazards are similar.

A strong economy is the best defense against disaster.

The soundest defense against disasters is a society that is generally less vulnerable. Although each hazard works in ways that may selectively damage elements with different characteristics – a flood threatens people in the valleys more than on the high ground, hurricanes blow down lightweight houses but not solid ones – in general the defenses of a community are roughly the same. A strong economy is the best defense against disaster. The objective of programs to reduce vulnerability should be to create a robust society, resistant to hazardous influences in general, rather than one rather narrowly protected against one type of event – an earthquake or a flood. The underlying reasons that make communities vulnerable are the same for any type of disaster, and if it is possible to tackle some of the root causes of vulnerability, the robustness of that society will be improved.

Vulnerability is largely a developmental issue, and vulnerability reduction needs to be carried out within a developmental context.

The linkage between disasters and economic development is strong. It is the subject of the *Disasters and Development* module in this training course. The most vulnerable societies are those weakest economically. Similarly the most vulnerable members of each society are those that are economically marginalised. The worst locations to live, the steep landslide-prone hillsides, the riverside flood plains, are the places that the poorest find to live. Houses built for minimal cash cost are most vulnerable to wind storms or earthquakes. The underlying mechanisms that cause vulnerability have to be well understood in order to reduce it. Vulnerability is largely a developmental issue, and vulnerability reduction needs to be carried out within a developmental context. Protection of their resources and improvements in the economic potential of a community or group may be as critical as reducing their vulnerability.

■ CASE STUDY

Reducing disaster risk in Mexico City "vecindades"

Part B
Human vulnerability assessment

Context

From the analysis of damage after the earthquake that affected Mexico City in 1985 and after detailed geotechnical studies it was established that patterns of future earthquake hazard were likely to be concentrated in and around the historic center of Mexico City. The very high occupancy rates of many of the more vulnerable buildings in the town center by low-income households was a matter of concern. The assessment of buildings most at risk (Case Study Part A, pages 46 and 47) identifies a number of very high occupancy, highly vulnerable buildings. Understanding the social and economic context of the risk is essential to the design of a suitable risk mitigation program.

Social survey

A systematic survey, interviewing a sample of the residents of the area, enabled a social and economic profile to be built up of the community at risk.[23] This was carried out through neighborhood surveys, building use surveys and household interview questionnaires. Consultations were held with many of the occupants of the buildings identified as being at risk.

Economic profile of community at risk

A summary of some of the key characteristics of the community at risk is shown on the next page. This community is a low-income community with 60% of the households on an income less than the legislated minimum wage. Most of the community are street traders – the city center is a focus of street markets for the suburban population who travel in to the center to buy. This is a very flexible and insecure form of employment, dependent on a variable market. Many incomes are supplemented by cottage industry – simple manufacturing, sewing etc., carried out in the home. These incomes would be severely affected by damage to homes and to any damage to the city center which would dissuade the market customers from visiting.

Socio-demographic profile of community at risk

The families are large for an urban area – 60% of the households have 5 or more members. Accommodation in the vecindades is extremely cramped – most families have one or two-roomed apartments, occasionally split-level with makeshift mezzanine for extra sleeping space. Single parent families (mainly mothers) are common, about a third of all households. Many families have young children. In earthquakes young children and women are more vulnerable as they spend more time inside the home.

Accommodation

The low-income families are mainly concentrated in very high occupancy tenement buildings. The occupancy profile shows that a small percentage of the buildings have very high numbers of residents – in the hundreds. These concentrations of the population make them extremely vulnerable to earthquakes – the collapse of any one of these very densely occupied buildings would cause a disaster on its own. Conversely, it means that a mitigation program to protect a large number of people can focus on a relatively small number of buildings (identified in Part A of the case study). Nearly all the households most at risk live in rented accommodation. Rent-freeze laws mean that landlords receive very little rental revenue and maintenance of the buildings is minimal, as is the provision of basic services.

Actions to reduce vulnerability

A trust fund to facilitate housing upgrading in the city center has been established by special legislation and will be financed through property development taxation in other parts of the city. The fund will be used largely to encourage private sector finance in housing upgrading. Some of the worst vecindades could be expropriated under compulsory purchase powers established in the earthquake reconstruction. Expropriated vecindades would be refurbished and managed by a tenants cooperative. The budget available for the upgrading is small and it is important that spending is used to maximize the effect it would have in reducing future earthquake risk. How many buildings should have such intervention and what would be the effect?

The assessment of the benefits of possible building upgrading strategies are discussed in Part C of this case study.

CASE STUDY: Reducing disaster risk in Mexico City "vecindades"

Part B – Human vulnerability assessment

Socio-Demographic Factors

Families with Young Children

Families with Children under 6 years old:	60%
Families with more than one child under 6:	10%

Single-Parent Families

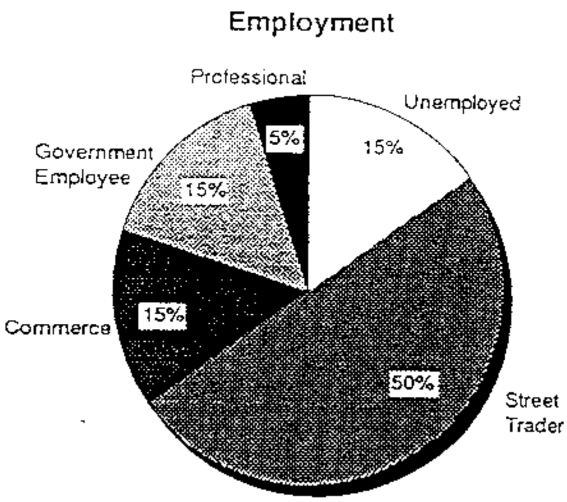
% of Sample Households that are Single-Parent Families:	30%
Single-Parent Families with income< 1x Minimum Salary:	99%

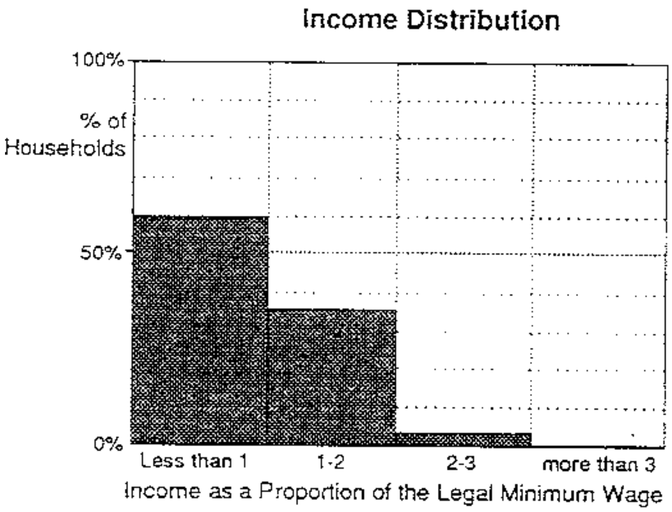
Large Families

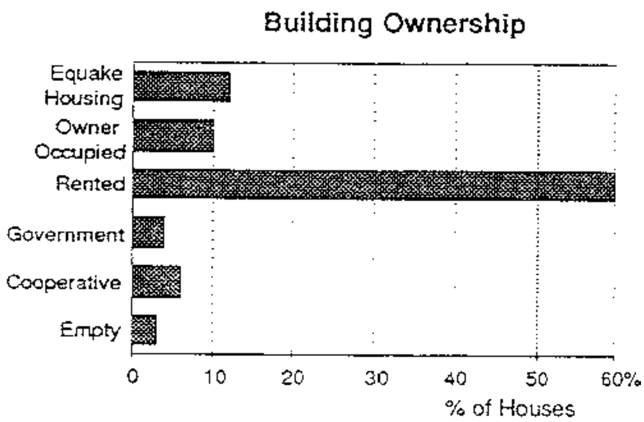
Number of Families with 5 or more Members:	60%
% of Survey Classified as Extended Families:	30%

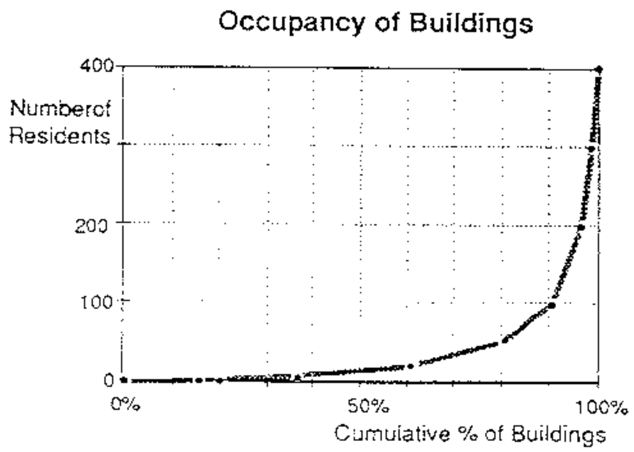
Long-Term Residents of City Centre

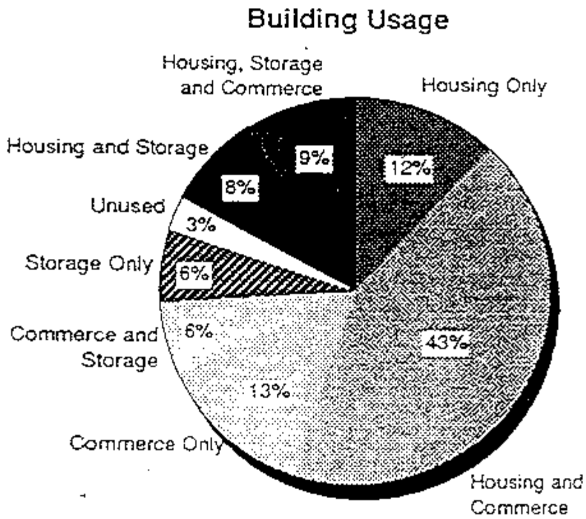
% of Sample that are First Generation Immigrants to DF:	10%











■ SUMMARY

ASSESSING RISK AND VULNERABILITY

- Quantification of the level of risk is an essential aspect of both preparedness planning and mitigation planning
- By UN definition, the term risk refers to the expected losses from a particular hazard to a specified element at risk in a particular future time period. Loss may be estimated in terms of human lives, or buildings destroyed or in financial terms.
- There are 3 essential components to the quantification of risk:

  Hazard occurrence probability, defined as the probability of occurrence of a specified natural hazard at a specified severity level in a specified future time period

  Elements at risk, an inventory of those people of artifacts which are exposed to the hazard and

  Vulnerability, the degree of loss to each element should a hazard of a given severity occur.
- The probability of occurrence of the extreme levels of natural hazards which may cause a disaster maybe estimated by statistical extrapolation from data on the normal levels of occurrence. The accuracy of such estimates depends on the amount and completeness of data and the period of time over which it has been collected. Historical records can be an invaluable source of information.
- Recurrence frequency and intensity of most natural hazards varies from place to place – hazard mapping may be used to show this variation. For some, notably geological hazards, detailed local mapping (micro-zoning) can be used to establish local variations and assist land-use planning decisions. For others only coarse mapping of geographical areas at risk is possible.
- Vulnerability assessment involves first identifying all the elements which may be at risk from a particular hazard. Local knowledge may be used to complete the inventory, and census data to enumerate the elements at risk
- Loss functions in the form of vulnerability curves or damage probability matrices may be obtained for some elements at risk (buildings, people) based on past experience elsewhere.
- Many aspects of vulnerability are unquantifiable, and these should not be overlooked.
- Because hazards tend to be uncontrollable, much mitigation work is centered on reducing vulnerability. Improved economic conditions reduce many aspects of vulnerability and a sound economy may in many cases be the best defense against disaster.
- Risk is compiled from hazard and vulnerability data and from the inventory of elements at risk. A variety of ways of presenting risk are available such as f:N curves, scenario mapping, potential loss mapping and annualized risk.

NOTES

PART 3

APPRAISING DISASTER MITIGATION OPTIONS

This part of the module deals with the advantages and disadvantages of:

- *Cost benefit analysis in program design*
- *Assigning cost to human lives saved or lost*
- *Alternatives to cost benefit analysis*

It also touches on the importance of the political context of mitigation planning.

The higher the level of protection, the higher the cost of protection will be.

Disaster mitigation measures take a variety of different forms, discussed in more detail in the Disaster Mitigation module in this training course. These include engineering measures to build more hazard-resistant structures, physical planning to locate important facilities away from hazards, economic measures to protect earnings, management structures to ensure protection measures are carried through and societal measures to encourage the public to support mitigation measures.

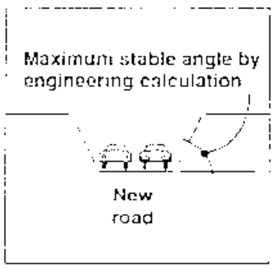
Measures like establishing building codes for new construction, strengthening existing buildings, land-use controls, and improving preparedness planning are generally costly to apply, whether it is individuals, private companies or the general tax-payer who will ultimately be responsible. Equally, it can be costly to fail to apply any mitigation measures in an area of known hazard, both in financial and in human terms. As a general rule, it can be expected that the higher the level of protection, the higher the cost of protection will be; but against this can be set the lower cost of future losses.

Clearly it is important to have some means of deciding on the right level of protection, and of choosing between alternative ways in which limited resources might be spent to improve protection. Questions to which answers are needed include: what is the appropriate level of hazard for which mitigation measures should be designed? Which facilities should be strengthened, and to what level? Should certain types of building development be prohibited in certain areas? How much should be invested in disaster mitigation or emergency planning measures?

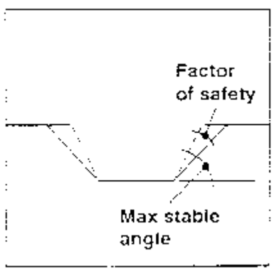
Answers to these questions will depend on many social and political considerations to which no formal decision-making process can be applied. Nevertheless it has been argued earlier that access to more information can be an effective means of stimulating action to reduce risks. Even though the uncertainties in any estimate will be large, the quantification of costs and the estimation of corresponding benefits of disaster mitigation measures can at the very least illuminate the choices to be made and, in many instances, can greatly assist in the decision-making process, whether private or public.

Development projects and disaster risk

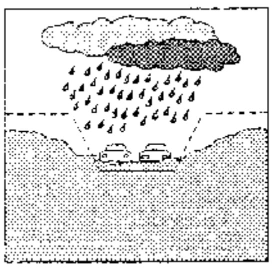
When development projects, like any other projects, are undertaken without regard for the risks of future hazards, the investment level considered adequate for the program may be insufficient to protect it during its lifetime.[24] When making a cutting for a road, for example, a steeper angle for the cutting is cheaper than a shallow one, so an efficient engineer will choose the steepest angle that the soil will bear to minimize the cost. If however, the possibility of an extremely heavy rainfall or strong ground tremor is not considered, the cutting will collapse and the road may be buried or washed away. The investment in the road may be wasted for the lack of the extra cost to widen the cutting angle a few extra degrees to give a safety margin against natural hazards. Of course a good engineer would always include some level of safety margin, but what safety level is adequate? How safe is safe? What levels of extra cost are justified to protect the investment during it's lifetime?

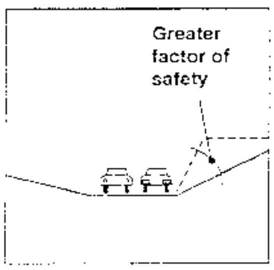


Cheapest design



Safer, but more expensive


Possible scenario



Very safe, very expensive

It is not just the engineering content of development programs that need to build in safety factors and protections, the entire project needs to be designed with a level of risk awareness.

It is not just the engineering content of development programs that need to build in safety factors and protection, the entire project needs to be designed with a level of risk awareness. Investments in development projects have been lost repeatedly in hazard-prone areas wiped out by a cyclone or an earthquake or a flood – often hazards that should have been foreseen. Perhaps more common is the occurrence of a disaster interrupting an ongoing project and diverting resources from their original intended use.

One important procedure that has been proposed is to include disaster potential in the economic analysis of a project design.[25] The extra costs of protection, it is counter-argued, would make some projects not economically viable. However, the basic argument for integrating disaster awareness into development planning is that it is wasteful not to do so.

Cost benefit analysis

The most widely-used method for choosing between alternative investments designed to achieve some socially desirable outcome is cost-benefit analysis. This method has been widely used for assessing hazard mitigation projects in floods and other hazards, particularly major engineering projects.[26] At its simplest, the idea is that all the benefits of the project are computed in financial terms, the costs are then deducted, and the difference is the value of the project. All projects with a positive value are worthwhile, but in a situation with a number of possible alternative projects and with limited resources available for investment, the project or projects with the highest value, or alternatively the highest rate of return on initial investment, are chosen.

In most cases this simple idea is complicated by the fact that the investments are made some time in advance of the benefits being felt, so that some rate of trade-off between present cost and future benefit has to be introduced. This is generally dealt with by introducing a ***social discount rate,*** which is considered to reflect society's preference for present benefits over future benefits, and for which a consistent value is used in all project evaluations. All future costs and benefits are discounted by the use of this rate.

This method can be used in comparing alternative strategies to protect against hazards if, for example the cost is taken as the additional project cost solely related to providing hazard resistance, while the benefits are the reduction in future losses, in terms of building damage, loss of life and other incidental losses, which result from the improved resistance.

This simple theoretical formulation of the approach, does, however present considerable difficulties in application. The most important of these are the very large uncertainties about the probable levels of future losses, the fact that those who benefit and those who pay are often not the same people, and, even more serious, the theoretical and moral problems associated with putting a financial valuation to the loss or saving of human life.

This simple theoretical formulation of the approach does however present considerable difficulties in application… the theoretical and moral problems associated with putting a financial valuation to the loss or saving of human life.

Estimation of protection costs and future benefits

The calculation of the additional cost of a particular protection strategy is generally straightforward. If the alternative strategies being considered are alternative sets of strength requirements for facilities for example, it is a simple matter to cary out designs according to alternative sets of requirements, and calculate the cost difference based on current construction costs. The costs of other types of mitigation projects can similarly be evaluated through standard project costing techniques.

Benefits from the protection strategies accrue from savings in losses that would otherwise have occurred, i.e. the difference between the damage that would occur if the strategy was not implemented and the damage that would occur if it was implemented. Estimation of future losses for the range of hazard occurrences likely during the project lifetime may be made by the risk assessment method outlined above. Since neither the severity nor the occurrence time of future hazards can be predicted, these future loss calculations need to be done on a probabilistic basis. The range of possible severities is divided into discrete intervals; the annual probability of occurrence of a hazard within each interval is determined; and the probable damage distribution for each element at risk as a result of the hazard at each level of severity is assessed. Only those losses associated with the particular elements to be affected by the alternative strategies need to be computed, as any other losses will be unaffected. The cost of the tangible losses are summed up without the protection strategy, then the calculation is repeated to assess the lower levels of losses resulting from implementing the protection strategy. The savings in losses are the benefits.

PROJECTED LOSSES DUE TO NATURAL HAZARDS (GEOLOGICAL) 1700–2000 AND COSTS OF MITIGATION, CALIFORNIA USA[27]

Table 6

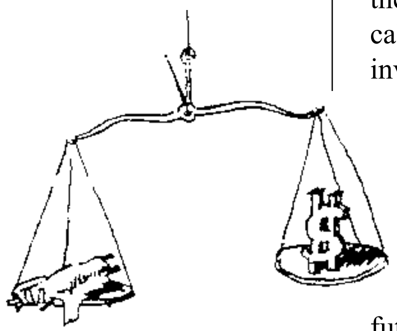
Hazard (1)	Projected total losses (2) $ x 10^9	Possible loss reduction (a) (3) $ x 10^9	Total cost of reduction (b) (4) $ x10^9	Benefit/cost ratio (3)/(4)
Earthquake shaking	21.0	10.5	2.1	5.0
Loss of mineral resources	17.0	15.0	0.09	167.0
Landslide	9.85	8.86	1.02	8.7
Flood	6.53	3.43	2.70	1.3
Erosion	0.57	0.38	0.25	1.5
Expansive soils	0.150	0.148	0.075	20.0
Fault displacement	0.076	0.013	0.075	1.7
Volcanic Hazards	0.049	0.008	0.0017	4.9
Tsunami Hazards	0.041	0.037	0.026	1.5
Subsidence	0.026	0.013	0.0088	1.5

a) applying all feasible methods b) applying all feasible methods at current state of the art

Table 6 shows for example, the expected losses from a range of geological hazards in the state of California during a particular 30-year period. The reduction in losses from the application of 'all feasible measures' has also been calculated, and so has the cost of applying these measures. From such a table (though difficult to compile), the costs and the benefits of different mitigation schemes can be easily seen.

Costing saved lives

The most important aspect of many disaster mitigation strategies is likely to be that they will save lives. Evaluating which programs will save most lives is therefore an important output for risk assessment. Some analysts extend the technique of cost-benefit analysis to include the saving of life in its calculation. This is difficult for most people to come to terms with as it involves equating a human life with a financial value, which appears both illogical and morally questionable.



Where life-saving is to be evaluated in financial terms, the most widely used method of evaluating human life loss is the human capital approach, in which a life is valued in accordance with its potential for future productivity. At its simplest, the monetary value of an individual's life is the discounted sum of all of his or her expected future earnings. The advantage of this approach is that it is relatively simple to calculate. The method has been used in quantifying the benefits of life-saving programs, for instance the mandatory use of seat belts in automobiles. But distinguishing between the value of different individuals lives on the basis of their earning power is liable to lead to quite unacceptable decisions; for example, it could be computed that there was a zero or even negative loss in the collapse of an old people's home.[28] Similarly the lives of people living on low incomes would be given a lower value. Thus alternative means of appraising options are preferred.

Alternatives to cost-benefit analysis

Q. Performing a cost-benefit analysis may seem like a straight forward mathematical exercise; however, there are large uncertainties factored into the equation which may drastically influence the result of the calculation. What are some of these factors?

A.

Cost-benefit analysis was originally developed as a tool for evaluating development projects – and work best when the costs and the benefits are calculated in the same terms. But disaster mitigation projects are not solely about economic benefits. The risk parameters being considered are multi-dimensional, as listed earlier. Their benefits are measured not only financially, but in other terms as well, such as lives saved, injuries prevented, social disruption avoided, and environmental impact reduced. The difficulties of cost-benefit analysis in dealing with saving life shows the problems with a unidimensional approach to risk analysis. Risk analysis that presents risk to life in one equation, economic losses in other and even further dimensions of the problem including environmental impact and the rest separately is still useful.

Procedures which prescribe decisions appear far less useful than those that provide information to assist decisions to be made.

It allows us to make informed decisions. Procedures which prescribe decisions appear far less useful than those that provide information to assist decisions to be made.

Goal-orientated risk reduction

Cost-benefit analysis chooses the appropriate level of protection according to a minimum cost criterion; in other words it is assumed that the best level of protection to choose is that which minimises overall cost. It has been shown above that acceptable levels of risk are decided by societies on the basis of perceived risk, and that perceived risk is only partly determined by the actual exposure level. Priorities are assigned and preferences made on the basis of a wide range of cultural influences.

Where a community is capable of agreeing what levels of consequences it would find acceptable (or in fact defining the consequences it would find unacceptable) these criteria can be used to define the appropriate level of protection. The community is effectively defining its goals or the target levels of risk it would like to achieve at some future date – the exact level of risk may be unimportant.

This goal-orientated approach is the one which is implicitly adopted in the formulation of many building codes for example. The seismic building codes in California state explicitly that the level of resistance to be designed for is based on the concept of an acceptable risk, and what is taken to be acceptable is that buildings designed according to the code should.[29]

1. resist minor earthquakes without damage
2. resist moderate earthquakes without significant structural damage, but with some non-structural damage, and
3. resist major or severe earthquakes without major failure of the structural framework of the building or its equipment, and maintain life safety.

Once the meaning of ‘minor’, ‘moderate’ and ‘major’ earthquakes has been more precisely established in terms of earthquake severity or intensity levels, the above criteria can become the basis for defining suitable levels of protection. Many other countries have now adopted the same philosophy for their building codes, or used the same rules without explicitly acknowledging the philosophy.

But the procedure implies that the acceptable level of risk has already been defined. How is it possible to decide whether this level of risk is right, too high, or too low? One method proposed is to use the concept of balanced risk, using as a decision criterion the level of risk which is acceptable in other similar risks activities. Another is to try to determine an acceptable rate of trade of between life-safety and capital cost, again with reference to other areas of human activity in which money is spent to protect life. These procedures will be further discussed below.

Balanced risk criterion

The approach to risk reduction using the ***balanced risk criterion*** attempts to equalise the levels of risk which are accepted in society in a range of comparable activities. As in the studies of risk described in the first section of this module, risks of death to an individual can be grouped into two general categories – those associated with voluntary activities, and those associated with involuntary activities, and into further sub-groups of similar risks, like natural disasters, transportation, technological and so on. It has been suggested for instance that the acceptable risk from technological systems from which considerable benefits are obtained approaches that due to disease in society as a whole, while that from uncontrollable (and totally non-beneficial) natural disasters may be 1,000 to 10,000 times lower.[30]

Cost-effectiveness criterion

An alternative decision-making criterion is available which incorporates both economic costs and life-safety, but without making an explicit valuation of human life. For a range of possible strategies, the financial costs and benefits are assembled, but without including a valuation of human life. The expected benefits in terms of saved human lives, and saved injuries, are calculated separately. The financial cost per saved life is also calculated, or the marginal cost in comparing one level of protection with an alternative adjacent one.[31] Decision-makers are then faced with choosing between the projects on the basis of these separate attributes, and may use the cost per saved life as an indicator of the cost effectiveness of a particular policy in terms of life saving.

Table 7

Estimated costs and benefits of alternative rural housing improvement strategies in eastern Turkey to reduce earthquake losses

IMPROVEMENT STRATEGIES TO REDUCE EARTHQUAKE LOSSES[32]

	Project costs and benefits of housing improvement program for 1 million houses over 25 years				
Upgrading strategy *(Level of strengthening for government grant)*	Strengthening cost per house	Saved losses— No. of buildings	Saved lives	Cost per saved life (million TL)	Cost per saved building (million TL)
A. Low-cost Modified Traditional	50,000	18,000	2,050	24.4	(b) 2.7
B. Medium-cost Traditional	125,000	49,000	6,400	19.3	(b) 2.6
C. High-cost Traditional	270,000	58,000	7,800	34.6	4.6
D. Turkish Building Code	350,000	65,000	8,000	43.8	5.4
E. Fully Reinforced Masonry	500,000	70,000	8,000	62.5	7.2

(a) Costs in Turkish Lire, 1983. (250 TL to US$ in 1983). (b) Reconstruction costs are estimated at 3.5×10^5 TL per house, so the least cost strategies will actually save more over the 25 year period than they cost.

ANSWER (from page 54)

1. The assigning of a monetary value for human life
2. The ***"social discount rate"*** which reflects the preference for present over future benefits.
3. The probabilistic nature of the occurrence of the hazard itself

■ CASE STUDY

Reducing disaster risk in Mexico City "vecindades"

Part C
Calculating the benefits of risk reduction programs

Context

Parts A and B of the Case Study (pages 43–44 and 47–48) described the analysis of physical building stock and the social and economic characteristics of the people that inhabit the high risk neighborhoods of the center of Mexico City. A number of buildings were identified which are highly vulnerable to a future earthquake and which also have large numbers of residents.

Likely severity of hazard

The 1985 earthquake that killed over 7,000 people in central Mexico City, made 30,000 people homeless, and cased over US$ 12 billion worth of damage had a ground motion severity of 15–20%g (peak ground acceleration with an unusual 2 second frequency). A future earthquake that is considerably larger, perhaps 25%g, is a distinct possibility, particularly from a larger magnitude earthquake occurring in the predicted Guerrero Gap. A more remote possibility is a major earthquake occurring close to the city that could cause ground motions as high as 30%g. Smaller earthquakes of 10–15%g can be expected every few years.

Loss prediction

Using this range of hazard levels, a risk analysis program was run, assessing the likely levels of damage, casualties and costs to the small sample neighborhood of 200 buildings. For each building, probabilistic calculations of damage were carried out based on its vulnerability factors from the 1985 earthquake damage statistics. Fatality levels and repair costs from the 1985 earthquake were also applied. The results can be seen on the next page. It can be seen that for stronger level earthquakes, the effects of damage and human losses increase exponentially.

Mitigation programs

In Case Study Part A (pages 43–44), it was shown how two groups of buildings were identified as primary and secondary intervention priorities. The first list consists of the worst 8% of the building stock. The strengthening of these worst buildings is taken as Program I. Program II envisages strengthening both primary and secondary intervention priorities – about 18% of the sample building stock. Strengthening the buildings to bring them up to the 1986 seismic building code would involve adding shear walls or external bracing to the simple reinforced concrete frame structures and would cost 15–30% of the cost of the structure. Refurbishment of the buildings would also improve services and other quality of accommodation. Program I would cost around Mex$600 million (US$300,000) and Program II would cost nearly three times as much at Mex$1,500 million (US$50,000).

Reductions in losses

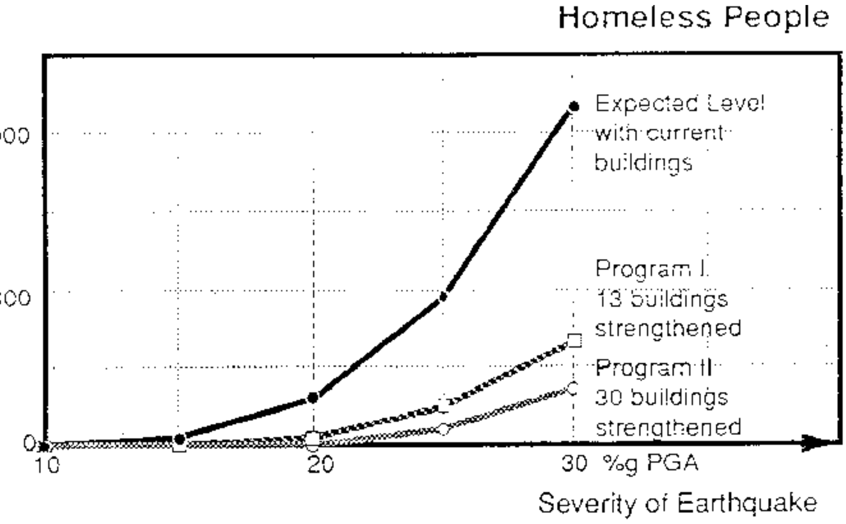
The calculations of risk show very significant reductions in earthquake losses can be achieved by strengthening a limited number of buildings, if they are well targeted. Program I reduces expected casualties and homeless in the event of the larger earthquakes by up to 50%. Program II reduces expected casualties and homeless by up to 80%. Savings are larger with the more severe (and less probable) earthquakes but significant for the smaller and more common events. Very large reductions are achievable in homelessness – damage levels rendering the highly occupied buildings uninhabitable would be prevented. Repair costs are not so much affected – many buildings other than the small percentage strengthened still experience some damage cost.

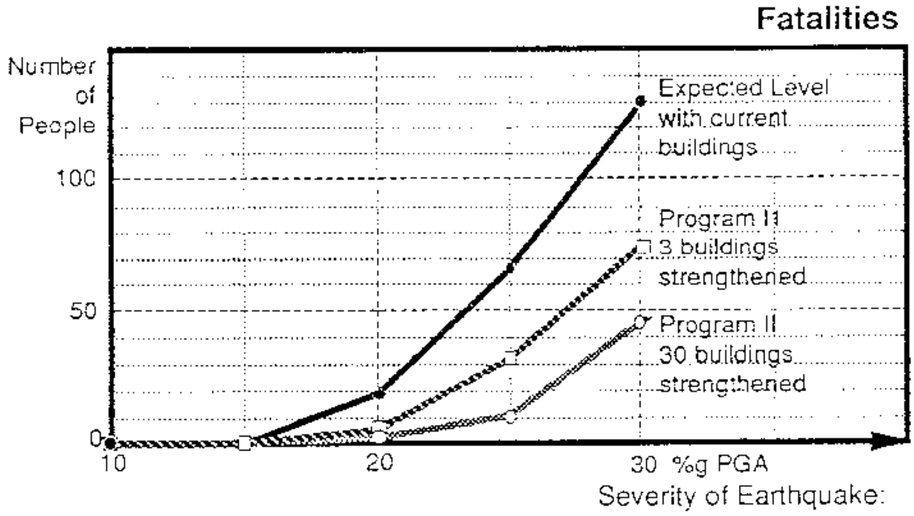
Which program?

The decision on what level of risk is acceptable, it has been argued here, is not a question of mathematical optimization – rather the calculations are used to provide information for the community and its representatives to make informed decisions within their own priorities. Their perception of how important the risk is compared with other risks, the budget available and the political process of deciding public sector programs will all decide the applicability of risk information. If it is important to save the maximum numbers of lives for a minimum budget, then Program I identifies the key targeting of those resources. If safety for larger numbers of people are important – perhaps a notion of equal risk across the community – then other, broader programs would be more appropriate.

CASE STUDY: Reducing disaster risk in Mexico City "vecindades"

Part C – Calculating the benefits of risk reduction programs





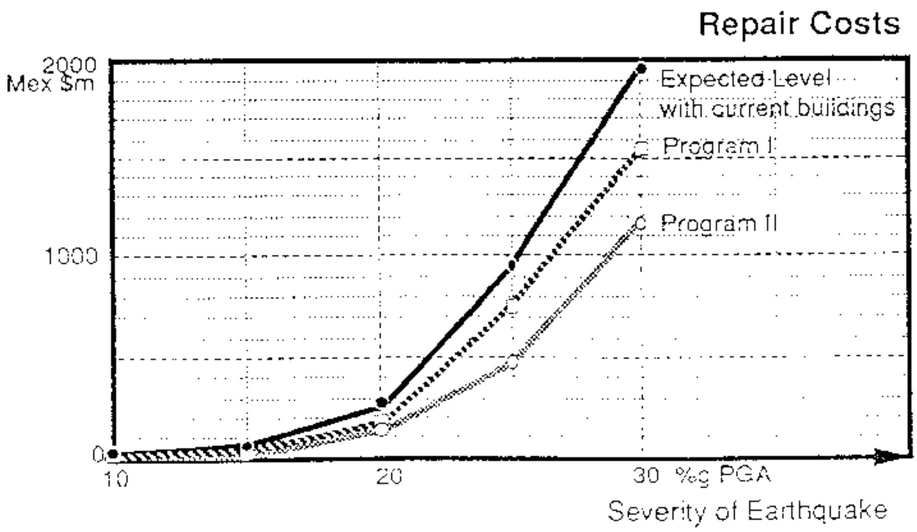


Table 7 shows, for example, the expected costs and benefits of alternative strategies of upgrading rural dwellings in Turkey for protection against future earthquakes. It well be seen that the lower cost upgrading strategies have the best returns in terms of both saving lives and property. The two least cost strategies in fact cost less over the 25-year period than accepting the continuation of future losses which would occur if no action were taken. Successively more expensive strategies save more, but at a higher initial cost, so they offer a lower return in terms of both saved lives and property. The appropriate choice will depend on whether the decision-makers are concerned more with absolute numbers of lives saved, or with cost effectiveness, in terms of saved lives or property. It will also depend on how they perceive the relative importance of these different risks and others. They may choose some strategy which gives a compromise between the different possible goals. Or they may do nothing and accept continuing very high losses. But public knowledge of the costs and benefits of the alternatives should increasingly make such a policy of inaction on the part of decision-makers unacceptable and unjustifiable.

Conclusion: social and political context

It is clear from the discussion above hat the quantification of risks, future losses, and the costs and benefits of mitigation programs, though offering valuable information, does not lead to any clear-cut guidance for the development planner on which is the optimum risk-reduction strategy to choose. The costs and the cost-effectiveness of alternative strategies are a necessary part of the set of factors which need to be considered. But the intangibles, by their nature, cannot be quantified, yet they must be given proper consideration. Further, the actual degree of risk and benefit must be judged against the perceived risk, as indicated by the importance which the community attaches to any proposed expenditure on mitigation. The distribution of costs and benefits among different sections of society has also to be taken into account. Those who will pay and those who will benefit are not always the same people. Some people, such as land-owners or property owners may appear to lose more than they gain from mitigation strategies designed to protect the lives and incomes of the poorest and must vulnerable. It is possible to modify cost-benefit analysis so as to identify costs and benefits to different groups, but this exercise can lead to such a mass of data as to be unintelligible.

Ultimately, decision-making on risk reduction strategies is a political matter, on which all sections of the community must be consulted, and to which the normal political processes of social decision-making must be harnessed.

Ultimately, decision-making on risk reduction strategies is a political matter, on which all sections of the community must be consulted, and to which the normal political processes of social decision-making must be harnessed. To be adopted, any strategy must be not only affordable, but also both publically acceptable and institutionally manageable. A discussion of this important topic is beyond the scope of this module. Other modules deal in more detail with the implementation of disaster mitigation programs (see the module on Disaster Mitigation) and the interrelationship with development (see the module on Disasters and Development).

In conclusion it should be emphasised that vulnerability and risk assessment can make two principal contributions to the process of decision-making in disaster mitigation:

1. By considering risk as a framework for decision-making and quantifying costs ad benefits, the decision-makers (both development planners and political representatives) can obtain a clearer indication of the potential benefits of alternative risk-reduction strategies, to complement other considerations in making a sound decision.
2. The same information can be used to increase the awareness of the general public, as an input to community meetings, education or public awareness programs; and thus it can help lower the threshold of acceptable risk, and make expenditure on risk reduction easier for decision-makers to justify.

■ *SUMMARY*

APPRAISING DISASTER MITIGATION OPTIONS

- One of the main uses of risk analysis is to assist in choosing between different mitigation options, all of which may be costly to apply, though beneficial in the longer term.
- Cost benefit analysis may be used to compare different strategies if the costs are the extra costs of introducing mitigation measures while the benefits are the reductions in expected losses expressed financially. Either a minimum cost or a maximum benefit/cost ratio criterion may be used as a criterion of choice. One difficulty is the evaluation of the benefit from saving a human life in financial terms
- Alternatively an acceptable risk may be defined in relation to other risks to individuals or society, the balanced risk criterion. This method ignores the cost element.
- A more sophisticated approach is to quantify the costs and different types of benefits separately (economic, human), and also calculate the cost effectiveness of each strategy in relation to different objectives of mitigation. The approach is more in keeping with the social and economic realities of decision-making.
- In any mitigation strategy the costs and the benefits will be unevenly distributed within society. There may be some losers. It can help to quantify the costs and benefits to different individuals, but ultimately choosing an appropriate strategy is a political rather than a technical matter.

END NOTES

1 Life expectancy is one of the indicators of development gathered on individual countries in *World Development Report,* 1989, published for The World Bank by Oxford University Press.

2 UNDRO, 1979, *Natural Disasters and Vulnerability Analysis,* Report of Expert Group Meeting 9–12 July 1979, Office of the United Nations Disaster Relief Coordinator, Geneva.

3 The general equation for the calculation of risk is: $[R_{ij}] = [H_j] \times [V_{ij}]$
where, for an Element at Risk (e.g. an individual building) i, in a given unit of time:
$[R_{ij}]$ is the specific Risk; the probable loss to element i due to a hazard of severity *j.*
$[H_j]$ is the Hazard; the probability of experiencing a hazardous event of severity *j.*
$[V_{ij}]$ is the Vulnerability; the level of loss that would be caused to element i as a result of experiencing a hazard of severity *j.*

By summing the risk from all levels of hazard, (min ≤ j ≤ max), the total specific risk to any individual element can be derived. The Risk is then the product of the Specific Risk and the value of the element at risk.

4 Risk assessment and evaluation is differentiated in *Living with Risk,* 1987, The British Medical Association Guide, John Wiley & Sons

5 Probability of an individual dying in any year from various causes is published in *Living with Risk,* 1987, The British Medical Association Guide, John Wiley & Sons and the statistics in bold type for probability of deaths from natural hazards are added from The Cambridge University Human Casualty database and other sources.

6 Making sense of risk levels is difficult and the format of 'one in …' is probably the easiest to comprehend quickly. With small probabilities, the number of noughts may be difficult to deal with and some probabilities are expressed in a logarithmic scale, called Safety Degree Units or SDUs (the Urquhart and Heilmann scale). In this scale the order of magnitude of the risk is defined a risk of one in 100 and is expressed as 2 – the logarithm of 100, and one in 1,000 is expressed as 3 (a simple guide is the number of noughts). Thus the risk of being killed by an earthquake in Iran is around 4 SDUs, but the risk of a Californian being killed by an earthquake is lower; around 6 SDUs – i.e. one hundred times lower or two orders of magnitude less. In comparing low probability events, the SDU scale may sometimes be more useful.

7 Studies of mountain communities, their risks and their development priorities formed part of the work of the International Karakoram Project: Housing and Hazareds Group, 1980, reported in the proceedings of Royal Geographic Society, 1983.

8 S. Lichtenstein et al., 1978, 'Judged Frequency of Lethal Events', *Journal of Experimental Psychology: Human Learning and Memory,* Vol 4., No. 6.; American Psychological Association.

9 Villagers living in areas of high seismic risk were interviewed by social scientists in Eastern Anatolia, Turkey. as part of a study of risk reduction programs, reported in *Bingol Province Field Study, 2–24 August 1982,* Turkish National Committee for Earthquake Engineering and The Martin Centre for Architectural and Urban Studies, University of Cambridge.

10 C. Starr, 1969, 'Social Benefit versus Technological Risk: What is Our Society Willing to pay for Safety?', *Science,* Vol. 165, p. 1232–1236.

11 L.S. Fryer; R.F. Griffiths, 1986, *Worldwide Data on the Incidence of Multiple-Fatality Accidents,* United Kingdom Atomic Energy Authority.

12 Presentation of Risk Example 1 is taken from *Emergency Planning and Earthquake Damage Reduction for Bursa Province,* eds A.W. Coburn and U. Kuran, Project on Regional Planning for Disasters, 1985.

13 Earthquake intensity is a measure of the degree of shaking of the ground at a particular point, expressed as a degree in Roman numerals I to XII. Common intensity scales include the Modified Mercalli (MM) and the Medvedev, Sponheuer, Karnik (MSK) scales.

END NOTES CONTINUED

14 Peak ground acceleration is one of the best measures of the potential damage of earthquake ground motion. Its normal units are meters per second per second, but it is often, for ease of interpretation, expressed in a non-unit form as a percentage of the acceleration due to gravity (g) which equals approximately 9.81 m/sec2.

15 Hazard Map Example 1 is taken from UNDRO, (1977) *Composite Vulnerability Analysis: A Metholodogy and Case Study of the Metro Manila Area,* Technical Advisory Mission to the Government of the Philippines, Human Settlements Commission (HSC).

16 Hazard Map Example 2 is taken from a study of Gunung Kelat by Volcanology Division, Geological Survey of Indonesia.

17 Damage Probability Matrix for Landslides taken from ATC–13.

18 The case study of *Reducing Disaster Risk in Mexico City Vecindades* is a summary of some of the work carried out in Project MEX-86-009, Mitigation of Seismic Risk in Urban Areas, United Nations Development Program, United Nations Centre for Human Settlements (Habitat); Secretaria General de Obras, Departamento del Distrito Federal.

19 Reconstruction after the Mexico earthquake in 1985 is documented in DDF-DGRUPE, 'Programa de Revitalizacion del Centro Historico de la Ciuadad de Mexico'. Direccion General de Reordenacion Urbana y Proteccion Ecologica, September 1986.

20 Y. Aysan, A.W. Coburn, I. Davis, R.J.S. Spence, *Mitigation of Urban Seismic Risk: Actions to Reduce the Impact of Earthquakes on Highly Vulnerable Areas of Mexico City,* First Year Report of Bilateral Technical Cooperation Agreement between the Governments of Mexico and United Kingdom, April 1989.

21 Human Vulnerability Survey in Mexico City was directed by Oxford Polytechnic Disaster Management Centre, reported in Aysan et al., ibid.

22 Flood vulnerability functions taken from ATC-13, p. 251.

23 Human Vulnerability Survey in Mexico City was directed by Oxford Polytechnic Disaster Management Centre reported in Aysan et al., ibid.

24 M.B. Anderson, 1990, *Analyzing the Costs and Benefits of Natural Disaster Responses in the Context of Development,* Environment Working Paper No. 29, Policy Planning and Research Staff, The World Bank.

25 M.B. Anderson, ibid.

26 E.C. Penning-Rowsell, J.B. Chatterton, 1980, 'Assessing the Benefits of Flood Alleviation and Land Drainage Schemes', *Proc. Instn Civ. Engnrs,* Part 2, 69, June, 295–315.

27 The expected losses from a range of geological hazards in the state of California is taken from California Division of Mines and Geology, 1975.

28 Grandori (1982).

29 ATC3-06 Tentative Provisions for Seismic Regulations in California

30 For further discussion of acceptable risk see H.D. Foster, *Disaster Planning: The Preservation of Life and Property,* Springer-Verlag, 1980.

31 Grandori and Benedetti (1973).

32 Example of costs and benefits of rural upgrading programs for earthquake protection is taken from R.J.S. Spence and A.W. Coburn, *Reducing Earthquake Losses in Rural Areas,* Overseas Development Administration, United Kingdom, 1987.

■ ANNEX 1

ACRONYMS

DHA	Department of Humanitarian Affairs
FAO	Food and Agriculture Organization
NGO	Non-Governmental Organization
UNCHS	United Nations Center for Human Settlements
UNDP	United Nations Development Programme
UNDRO	United Nations Disaster Relief Organization (now DHA-Geneva)
UNESCO	United Nations Educational, Scientific and Cultural Organization

■ ANNEX 2

ADDITIONAL READING

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GLOSSARY

This glossary lists the disaster management terms as used in the *UNDP/UNDRO Disaster Management Manual.*

Assessment

(Post-disaster) (sometimes Damage and Needs Assessment)

The process of determining the impact of a disaster or events on a society, the needs for immediate, emergency measures to save and sustain the lives of survivors, and the possibilities for expediting recovery and development.

Assessment is an interdisciplinary process undertaken in phases and involving on-the-spot surveys and the collation, evaluation and interpretation of information from various sources concerning both direct and indirect losses, short- and long-term effects. It involves determining not only what has happened and what assistance might be needed, but also defining objectives and how relevant assistance can actually be provided to the victims. It requires attention to both short-term needs and long-term implications.

Disaster

The occurrence of a sudden or major misfortune which disrupts the basic fabric and normal functioning of a society (or community). An event or series of events which gives rise to casualties and/or damage or loss of property, infrastructure, essential services or means of livelihood on a scale which is beyond the normal capacity of the affected communities to cope with unaided.

Disaster is sometimes also used to describe a catastrophic situation in which the normal patterns of life (or eco-systems) have been disrupted and extraordinary, emergency interventions are required to save and preserve human lives and/or the environment. Disasters are frequently categorized according to their perceived causes and speed of impact. [See: Sudden natural disasters; Slow-onset disasters; Technological disasters; Human-made disasters].

Disaster management

A collective term encompassing all aspects of planning for and responding to disasters, including both pre- and post-disaster activities. It refers to the management of both the risks and the consequences of disasters.

Disaster mitigation

A collective term used to encompass all activities undertaken in anticipation of the occurrence of a potentially disastrous event, including preparedness and long-term risk reduction measures.

The process of planning and implementing measures to reduce the risks associated with known natural and man-made hazards and to deal with disasters which do occur. Strategies and specific measures are designed on the basis of risk assessments and political decisions concerning the levels of risk which are considered to be acceptable and the resources to be allocated (by the national and sub-national authorities and external donors).

Mitigation has been used by some institutions/ authors in a narrower sense, excluding preparedness. It has occasionally been defined to include post-disaster response, then being equivalent to disaster management, as defined in this glossary.

Disaster preparedness

Measures that ensure the readiness and ability of a society to (a) forecast and take precautionary measures in advance of an imminent threat (in cases where advance warnings are possible), and (b) respond to and cope with the effects of a disaster by organizing and delivering timely and effective rescue, relief and other appropriate post-disaster assistance.

Preparedness involves the development and regular testing of warning systems (linked to forecasting systems) and plans for evacuation or other measures to be taken during a disaster alert period to minimize potential loss of life and physical damage; the education and training of officials and the population at risk; the establishment of policies, standards, organizational arrangements and operational plans to be applied following a disaster impact; the securing of resources (possibly including the stockpiling of supplies and the earmarking of funds); and the training of intervention teams. It must be supported by enabling legislation.

Expected losses/effects

The expected number of lives lost, persons injured, damage to property and disruption of essential services and economic activity due to the impact of a particular natural or man-made hazard. It includes physical, social/functional and economic effects.

Hazard
(or hazardous phenomenon or event)

A rare or extreme event in the natural or man-made environment that adversely affects human life, property or activity to the extent of causing disaster.

A hazard is a natural or man-made phenomenon which may cause physical damage, economic losses, or threaten human life and well-being if it occurs in an area of human settlement, agricultural, or industrial activity.

Note, however, that in engineering, the term is used in a more specific, mathematical sense to mean the probability of the occurrence, within a specified period of time and a given area, of a particular, potentially damaging phenomenon of a given severity/intensity.

Hazard assessment
(Sometimes Hazard Analysis/Evaluation)

The process of estimating, for defined areas, the probabilities of the occurrence of potentially-damaging phenomenon of given magnitudes within a specified period of time.

Hazard assessment involves analysis of formal and informal historical records, and skilled interpretation of existing topographical, geological, geomorphological, hydrological, and land-use maps.

Hazard mapping

The process of establishing geographically where and to what extent particular phenomena are likely to pose a threat to people, property, infrastructure, and economic activities.

Hazard mapping represents the result of hazard assessment on a map, showing the frequency/probability of occurrences of various magnitudes or durations.

Human-made disasters

Disasters or emergency situations of which the principal, direct causes are identifiable human actions, deliberate or otherwise. Apart from “technological disasters”, this mainly involves situations in which civilian populations suffer casualties, losses of property, basic services, and means of livelihood as a result of war, civil strife, or other conflict.

In many cases, people are forced to leave their homes, giving rise to congregations of refugees or externally or internally displaced persons.

Human-made hazard

A condition which may have disastrous consequences for a society. It derives from technological processes, human interactions with the environment, or relationships within and between communities.

Man-made disasters

See Human-made Disasters

Mitigation

See Disaster Mitigation

Natural hazard

Natural phenomena which occur in proximity and pose a threat to people, structures or economic assets and may cause disaster. They are caused by biological, geological, seismic, hydrological, or meteorological conditions or processes in the natural environment.

Preparedness

See Disaster Preparedess

Risk

For engineering purposes, risk is defined as the expected losses (lives lost, persons injured, damage to property, and disruption of economic activity) caused by a particular phenomenon. Risk is a function of the probability of particular occurrences and the losses each would cause. Other analysts use the term to mean the probability of a disaster occurring and resulting in a particular level of loss.

A societal element is said to be “at risk”, or “vulnerable”, when it is exposed to known disaster hazards and is likely to be adversely affected by the impact of those hazards if an when they occur. The communities, structures, services, or activities concerned are described as “elements at risk”.

Risk assessment (sometimes risk analysis)

The process of determining the nature and scale of the losses (due to disasters) which can be anticipated in particular areas during a specified time period.

Risk assessment involves an analysis and combination of both theoretical and empirical data concerning: the probabilities of known disaster hazards of particular force or intensities occurring in each area (“hazard mapping”); and the losses (both physical and functional) expected to result to each element at risk in each area from the impact of each potential disaster hazard (“vulnerability analysis” and “expected loss estimation”).

Risk mapping

The presentation of the results of risk assessment on a map, showing the levels of expected losses which can be anticipated in specific areas, during a particular time period, as a result of particular disaster hazards.

Risk reduction (long-term)

Long-term measures to reduce the scale and/or the duration eventual adverse effects of unavoidable or unpreventable disaster hazards on a society which is at risk, by reducing the vulnerability of its people, structures, services, and economic activities to the impact of known disaster hazards.

Typical risk reduction measures include improved building standards, flood plain zoning and land-use planning, crop diversification, and planting windbreaks. The measures are frequently subdivided into “structural” and “non-structural”, “active” and “passive” measures.

N.B. A number of sources have used “disaster mitigation” in this context, while others have used “disaster prevention”.

Technological disasters

Situations in which large numbers of people, property, infrastructure, or economic activity are directly and adversely affected by major industrial accidents, severe pollution incidents, nuclear accidents, air crashes (in populated areas), major fires, or explosions.

Vulnerability

The extent to which a community, structure, service, or geographic area is likely to be damaged or disrupted by the impact of a particular disaster hazard, on account of their nature, construction, and proximity to hazardous terrain or a disaster-prone area.

For engineering purposes, vulnerability is a mathematical function defined as the degree of loss to a given element at risk, or set of such elements, expected to result from the impact of a disaster hazard of a given magnitude. It is specific to a particular type of structure, and expressed on a scale of 0 (no damage) to 1 (total damage).

For more general socio-economic purposes and macro-level analyses, vulnerability is a less-strictly-defined concept. It incorporates considerations of both the intrinsic value of the elements concerned and their functional value in contributing to communal well-being in general and to emergency response and post-disaster recovery in particular. In many cases, it is necessary (and sufficient) to settle for a qualitative classification in terms of “high”, “medium”, and “low”; or explicit statements concerning the disruption likely to be suffered.

Vulnerability analysis

The process of estimating the vulnerability to potential disaster hazards of specified elements at risk.

For engineering purposes, vulnerability analysis involves the analysis of theoretical and empirical data concerning the effects of particular phenomena on particular types of structures.

For more general socio-economic purposes, it involves consideration of all significant elements in society, including physical, social and economic considerations (both short- and long-term), and the extent to which essential services (and traditional and local coping mechanisms) are able to continue functioning.