UNIT 4 RISK ANALYSIS TECHNIQUES

Structure

4.0 LEARNING OUTCOME

After reading this Unit, you should be able to:

- Understand risk assessment;
- Examine the process of risk assessment; and
- Know about hazard and risk maps

4.1 INTRODUCTION

Disasters have struck mankind with increasing severity of late. According to Munich Re (2003), over the last decade, around 7,000 natural disasters, including earthquakes, volcanic eruptions, tropical cyclones, floods and droughts have taken place the world over, killing more than 300,000 people and causing over US$800 billion in economic losses. Many of the Asia and Pacific developing countries are situated in the world's hazard belts and are subject to floods, droughts, cyclones, earthquakes, windstorms, tidal waves and land slides, besides man made, technological, biological, hazards, etc., with the added threat now of terrorism.

Since disaster management is a technical area of expertise, science and technology has a vital role to play in the research and dissemination of knowledge about disasters. It has both an *educative* and a *deliberative* role to perform for the purpose of creating awareness in society, articulating policy inputs, and upgrading response mechanisms. Public administrators have the task of organising and synergising (co-operative action involved in public administration) activities, coordinating personnel involved, that are both generalists and specialists, placing them in organisations as per specialisations and requirements, for achievement of organisational goal, institute coordination and communication between wings/agencies *inter se* and utilise organisations' optimum potential. Thus public administration as theory and practice has a more substantive role to play in disaster management in general and disaster risk reduction in particular.

Risk is defined as follows in the Disaster Management Training Programme, (1994).

"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 certain occurrences and the losses each would cause. Other analysts use the term to mean the probability of disaster occurring and resulting in a particular level of loss."

Accordingly, *"risk assessment, (sometimes risk analysis) is the process of determining the nature and scale of losses (due to disasters) which can be anticipated in particular areas during the specified time period. Risk analysis involves an analysis of both theoretical and empirical data concerning: the probability 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 from each potential disaster hazard ("vulnerability analysis" and "expected loss estimation").*

With this understanding, risk assessment of a natural hazard involves the collection of relevant information regarding the following:

a) Identification of the natural hazard and the probability of its occurrence

b) The chain of events, processes and pathways that connect the cause to the effects

c) The relationship between the characteristics of the natural hazard and the types and magnitude of its effects.

With the above outline, risk assessment comes across mainly as a scientific and *quantitative* activity undertaken/attempted for the purpose of objectivity and rationality of policy for disaster mitigation and response processes. It is imperative that policy be objective and fact based, to the extent possible, in order to avoid *a prior* judgements in policy 'choices'. The exploration of historical, scientifically relevant data, its analysis for understanding of factors underlying disaster phenomenon, and incorporation of facts derived thus, into disaster planning initiatives makes for objective policy. Success of the exercise will depend on objective risk evaluation, the 'awareness' or 'perception' of risk in the society, chiefly among policy makers, co-ordination in policy formulation and implementation processes, prioritising of disaster mitigation over other concerns, though not implying preference of any one concern to the exclusion of other equally important ones, but rather, providing for in–built disaster mitigation mechanisms/provisions in each sector policy, as also on a macro scale, in the national socio economic development policy as a whole. Reference is mainly to resource allocation decisions.

4.2 UNDERSTANDING RISK ASSESSMENT

The process of risk management had been elucidated in the previous Units. Risk management, as per Coburn, Sspence and Pomonis (1994), has two components: *Risk Assessment and Risk Evaluation*.

Risk assessment is the scientific process of data collection and accumulation over time and its analysis to foretell disasters and aid preparedness planning in accordance with articulated requirements. Hazards (s) are examined closely to understand the chain of causation leading up to the undesirable event, estimate the losses incurred/ probable in possible repeat of the event and human lives lost with a view to framing suitable strategy for future risk reduction. It also involves estimating the probability of repeat of an event, question being if yes, with what frequency, and what magnitude? Such an exercise has to be undertaken on *a continuous basis* since risk factors undergo changes over time, to ensure continued relevance of preparedness strategies.

As a natural corollary, an important component/aspect of risk assessment is hazard assessment, understood as the process of studying the nature and characteristics of a hazard, that is, whether one dimensional or complex, the nature of hazard; whether natural or human-induced, if man made, ascertaining the factors, the likelihood of the hazard striking, the probable frequency of its occurrence, level of severity and expected losses. The regions likely to be affected are mapped through satellite imagery. Specifically, hazard assessment is defined as follows in the Disaster Management Training Programme (1994):

"*Hazard assessments, also called hazard evaluation and analysis is the process of estimating for defined areas the probability of occurrence of potentially damaging phenomenon of given magnitude within specified period of time.*

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

Hazard assessment estimates the consequences arising out of an identified hazardous situation. To reiterate, it depends on two factors; the probability of occurrence of such an incident and the potential damage it can cause, (if it occurs).

Correspondingly, an inquiry into the factors making regions (s) vulnerable to a hazard (s) is necessary. These factors could be physical, i.e. relating to topography, hazard proneness or proximity to water body etc., or socio economic, i.e. arising out of backward/ disadvantageous positioning of a community in society or lack of resources to sustain life, especially during catastrophes. Hence vulnerability analysis/assessment is the third important component of risk assessment.

Each of the three steps/processes outlined above, as part of risk assessment, are indispensable components of the exercise, since each complements/ supplements the other. Hence for a total/comprehensive perception/understanding of the situations involving vulnerabilities and consequent risks, technical analyses involving hazard assessment has to include vulnerability analysis as an imperative condition. Hence risk assessment is an inclusive and multi -dimensional process. It would now be in order to discuss each component aforesaid separately and in detail.

4.3 PROCESS OF RISK ASSESSMENT

4.3.1 Mseasurement of Risks

Quantitative risk assessment involves estimation of disaster potential and the probability of event occurrence using simple arithmetic. Though estimations arrived at are gross/ crude, they help increase awareness of risk or risk perception among the general public and in the political circles, particularly. It also helps articulate the level of 'acceptable risk' for the purpose of policy. As explained in the Disaster Management Training Programme (1994), one standard method of 'measuring risks, is to count all the people' exposed' to a particular risk; divide the number by the number of people who have actually experienced the hazard over a definite time span. For example, if the number of people who travel by train in any one year is ten million and ten people are killed on an average each year, then the annual risk of being killed by train travel is one in one million. However such estimations do not give the *spread of risk* that is they do not say to what degree a community is at risk. To clarify further, people living near a chemical facility will be at varying degrees of risk depending on the physical proximity to the facility. Such considerations are not brought to light in such crude estimates. Some of the commonly used estimations as referred in the Disaster Management Training Programme (1994) are as follows:

Probability of an individual dying in a year	
Smoking 10 cigarettes a day	One
Any kind of violence or poisoning	One
Influenza	One
Leukemia	One

4.3.2 Risk Assessment using Statistical Models

The purpose of statistical analysis is to arrive at a peculiar statistical model that relates risk posed by a natural disaster to socio economic parameters. UNDP carried out an exercise to relate the risk posed by natural disasters such as earthquakes, tropical cyclones, floods and drought etc. to specific socio economic factors like HDI, rate of urban growth etc. that create losses. The study was carried out under the aegis of the United Nations (UNDP) using data for more than 90 countries over a period of 20 years.

Statistical analyses is based on two major assumptions; *one,* that risk can be measured in terms of the number of victims of past hazardous events, and second, that the equation of risk follows a 'multiplicative model,' in that following risk identification in each case (taking into account) the number of people killed is arrived at by taking into account the relevant 'factor' values in each case, for example, rate of urban growth was taken as the factor that would determine loss of life from earthquakes, and access to water supply in case of droughts, etc.

Methodology

The exercise has two key assumptions.

- The number of people killed by a natural disaster is a measure of Risk (physical exposure or PhExp)
- The equation of risk follows a multiplicative model where the number of people killed is related to socio economic factors and number of people exposed to the risk by the following equation

  $K = C. (PhExp)^{\alpha}. \ V_1^{\alpha 1} \ .V_2^{\alpha 2}\ldots.V_N^{\alpha N}$

  Where,

  K is the number of people killed by the disaster

  C is a multiplicative constant

  $V_{1\text{-}N}$ is socio economic parameters

  $\alpha_{1\text{-}N}$ is the exponent of $V_{1\text{-}N}$

{Note: Taking logarithm of both sides transforms this into a linear equation. Empirical data of natural disasters is taken and relevant socio economic parameters and their exponents are estimated using linear regression (difference between actual and desired states)}

For example in case of earthquakes, the socio economic parameter is urban growth, in case of cyclones, percentage of arable land and human development index; in case of floods, local population density and gross domestic product; in case of droughts, percentage of population with access to improved water supply *{read at,* http://www.undp.org/bcpr/disred/documents/publications/rdr/english/ta/t5.pdf.}

4.3.3 Hazard Assessment

As explained above, to perform risk calculations, we need to know the probability of the occurrence of a hazard, within a specified time period, in a given area. Information regarding probability of hazard actually occurring along with related information like the level of severity or intensity of impact is necessary to derive proper risk assessment data. As explained in the Disaster Management Training Programme (1994), like risk, hazard occurrence is expressed in terms of average expected rate of occurrence of the (specified type of) event or on a probabilistic basis regarding occurrence probability/possibility. Hazard maps present graphically, the annual probability and magnitude of the event following intensive geological analysis of the area, along with a study of past records, sometimes dating a century back or more, as in case of dormant volcanoes. Other corroborative evidence such as soil composition analysis to predict landslides or the NDVI (normalised drought vegetation index) to predict droughts may be used in case of inadequacy of temporal data to predict the recurrence of an event. Information gathered is collated and depicted on a hazard map for necessary correlations tracing causes and effects for the purpose of objective derivations of variables (independent and dependant) involved in the phenomena and their analysis (statistical methods discussed above). Information collation is relatively easier for events with relatively regular periodicity. Corroborative evidence can be gathered from geological ‘hints’ such as silt deposit, high water marks, deposits in case of floods, and past fault lines in case of earthquakes, and, human records as the main source evidence regarding hazard probability in all cases. The latter are considered more important and are being stressed more as compared to geological records by scientists.

The level of severity of natural hazards can be quantified in terms of the magnitude of occurrence as a whole (event parameter) or in terms of the effect the occurrence would have at a particular location site (site parameter).

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, the annual occurrence rates are usually used. The inverse of an annual recurrence rate is a return period. Examples of hazards as defined by Coburn, Sspence and Pomonis (1994) in terms of their occurrence parameters are:

There is an annual probability of .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 of an earthquake of M=7.0 in eastern Turkey is 12.5 years."

Rare events like volcanoes are hard to predict since adequate historical data is not available. It may be possible for geologists to analyse old lava flows and try to date the eruption frequency from that.

Smaller more frequent events can also be studied for indications of severity of future large-scale events.

Knowledge of the consequences of events will be helpful in planning for control of hazards during the design and operation of the facility by taking proper action to reduce hazard rate or minimise the consequences, as the case may be, or else the assessed risk may just be ignored. By evaluating the risk of various hazards to which the country is liable or potentially liable, it becomes practicable to formulate strategies to mitigate the impact of hazards in a cost-effective way. If a community is especially vulnerable to a particular type of disaster, severe risk treatment measures may be required to reduce the disaster risk to 'acceptable levels'.

The other important function of risk analysis is to develop a comprehensive disaster preparedness plan by providing a clear understanding as to what hazards exist and what risk(s) they pose vulnerable neighboring communities.

Risk Assessments are conducted on several parameters with regard to both natural and man made hazards. Studying risk assessment as a management activity with regard to single unit can have complete understanding of Risk Assessments.

Taking the example of a chemical processing unit, the hazard potential of the unit depends on:

1) Chemical identities
2) Locations of facilities that use, produce, process or store hazardous materials
3) The type and design of chemical container or storage
4) Quantity of material that could be involved in an air borne release and,
5) Nature of the hazard (for example, air borne toxic vapors or mists, fire, explosion, large quantities stored or processed, handling conditions, etc.) most likely to accompany hazardous material spills or release.

Conditions, under which the chemicals are processed, handled or stored including the temperature, pressure and other unique features in manufacturing, storage or handling if any are also to be understood. Information may also be obtained on transportation routes used for movement of chemicals, quantities involved in transportation, frequency of such movements and form of transportation such as tankers, tank cars, drums, wagons, pipelines, etc.

4.4 ANALYTICAL SYSTEMS FOR RISK ASSESSMENT

The task of disaster management and of preparedness and protection can be thought of as making up a 'cycle' of events. It is the objective of a National Disaster Plan or Service to complete and command the 'whole' cycle from the central to the local level, both in the planning and operational senses. This command would seek man-environment equilibrium, leading to reduction of risks from natural hazards in a sustainable way.

There are many excellent analytical systems in use for the identification of potential and actual hardware errors, such as 'fault tree analysis'. Some such analytical models are discussed as under:

A) **Effect Models**

A disproportionate amount of time and resources is spent on crisis and emergency plans, which are not pre-evaluated from sustenance or workability point of view. The operation of a plan frequently fails due to the omissions and oversights that occurred during the plan formation stage. In order to estimate the disaster potential, calculations are done based on the basis of *Effect Models*. These mathematical models are those relating to idealised situations that can be approximated in actual operating conditions of the plant or installation. Mathematical models are used to study processes like:

1) Discharge of liquid, gases and vapors: The release of liquid, gas or a mixture of gas and liquid from containment through a hole or pipeline rupture and the spreading characteristic immediately after the release.
2) Evaporation of liquids on land: Nature of the evaporation process depending on the surface characteristics and heat drawn from the ground for boil off.
3) Evaporation of liquids on water: Extent of release into air once the liquid spills over water.
4) Gaussian dispersion models: For dispersion of neutrally buoyant plumes and for heavy gases at sufficiently high wind velocities and at sufficient distance from down wind.
5) Heavy gas dispersion models: These incorporate terrain effects, complex geometries and wind effects.
6) Heat radiation due to pool fire, flash fire, and Boiling Liquid Expanding Vapor Explosion (BLEVE): Pool fire can be from a pool of fuel spread over ground, water or a tank fire. Flash fire involves delayed ignition of a dispersed vapor cloud, which does not cause blast damage. BLEVE result from the overheating of a pressurised vessel by primary fire.
7) Unconfined Vapor Cloud Explosions (UVCE) or explosive deflagration of a dispersed flammable vapor.
8) Lethality due to toxic gas release: These include acute toxic effects arising out of short-term exposure at high concentrations and chronic effects from long term exposure at low concentrations.

These models will quantify the effect of the disastrous situation in terms of the damage criteria. In most cases the damages occur mainly due to thermal radiation effects, pressure wave effects and toxic gas release that imply digression from the idealised state. Effect models conjure up a perfect state and analyse real life situations heuristically, which involves examining processes to observe the degree of divergence from the perfect process and making attempts at approximating the perfect state to the extent possible.

B) **Quotient Method**

For industrial and chemical Units, currently for pesticides, the quotient method (QM) of ecological risk assessment is used. This method compares the predicted, expected or measured environmental concentration with a measurement test end-point or in many cases the LOC:

$$\frac{\text{Environmental Concentration}}{\text{LOC}} = \text{Quotient}$$

Or

$$\frac{\text{Predicted Environmental Concentration}}{\text{Quotient}} = \text{Predicted No-e}$$

If the quotient is equal to 1 or more, a risk of equaling or exceeding the LOC or PNEC[2] is inferred. If the quotient is less than there is less risk of reaching the concern level. This method is very simple and contributes with the exposure and ecological effects characterisation carried out by the USEPA.

The quotient method can identify risks that exceed measurement end-point (for example, mortality, growth and reproductive effects), but it cannot relate these risks to assessment end-point. There are limitations to the quotient method. It does not address taxonomic or life-stage sensitivities to an industrial chemical or pesticides, and it cannot address risks objectively at intermediate levels where the quotient is ‘almost’ 1 or approaches it.

LOC - Level of Concern

PNEC - Predicted No-Effect Concentration

As discussed by Keong Hiap Tang in “Risk Assessment Methodologies”, a number of qualitative and quantities risk assessment techniques are being used by industries which are equally relevant to disaster management. Some of those techniques are discussed below:

C) **Preliminary Risk Analysis**

This is a qualitative risk analysis technique that traces the cause and effect sequence of a hazard turning to disaster. Each undesirable event in the chain of causation is analysed separately for remedial treatment. Hazards are ranked in the order of importance, as per damage potential, and, resources allocated accordingly to minimise the collective threat posed by hazards. Information is graphically depicted with the help of diagrams, called the *Frequency Consequence Diagrams* (Keong).

D) **Hazard and Operability Studies (HAS)**

Imperial Chemical Industries Ltd developed the Hazard Operability Studies Technique or the HAZOP technique in the early 1970s. This technique emphasises process improvement in that the process is studied in relation to design specifications to detect whatever, if any, deviations might have occurred. Analysis brings to light the structural improvements that might be needed in design specifications to prevent possible hazards that could result. This technique had gained wide acceptance in the process industries as an effective tool for plant safety and operability improvements (*ibid*).

E) **Failure Mode and Effects Analysis (FMEA/FMECA)**

This technique was developed in the 1950s by reliability engineers to detect potential micro system failures and their impact on the functioning of the total system. Hence each potential failure mode in a system is analysed to determine its effect on the system and to classify it according to its severity Failure mode and effects analysis has gained wide acceptance in the aerospace and the military industries. All the above-discussed techniques are hardware specific and widely employed today, especially in nuclear power plants and chemical processing industries (*ibid*).

F) **Tree Based Techniques**

Tree based techniques include, fault-tree analysis (FTA), event-tree analysis (ETA), cause-consequence analysis (CCA), along with other techniques such as the management oversight risk tree (MORT) and safety management organisation review technique (SMORT), which may not particularly be relevant here.

I) **The Fault Tree Analysis**

The concept of fault tree analysis (FTA) was originated by the Bell Telephone Laboratories in 1962, as a technique to perform safety evaluations of the Intercontinental Ballistic Missile Launch Control System. This is an analytical technique to identify a particular (unusual) effect in the system and to trace it back to its causes. Fault tree is a graphical display of how faulty situations in a system can lead to a predefined failure. It gives a quantitative evaluation of the probability of the occurrence of the “top event” which can be broken down into sub events and studied deductively. Fault tree analysis (FTA) is widely used, especially where extremely tight process controls are needed to attain the required standards of safety.

Understanding of the systems’ functioning is necessary to construct a fault tree. System function diagram is used to show the pathways by which signal or materials are transmitted between components comprising the system. A logic diagram is also required to depict the logical relationships of the components.

A fault tree is a logical diagram, which shows the relation between a specific undesirable event in the system and the failures of the components of the system. The system failure events to be studied are called the ‘top event’. Successive subordinate (for example, subsystem) failure events that may contribute to the occurrence of the ‘top event’ are then identified and linked by logical connective functions. The subordinate events are then broken down into their logical contributors, and in this manner, a failure event structure is created. Progress in the synthesis of the tree is recorded graphically by arranging the events into a tree structure using connecting symbol called gates (see diagram below). Once the tree structure has been established, subsequent analysis is deductive and takes two forms: -

a) Qualitative Analysis: To inquire into the causes of digressions with a view to qualitatively upgrading the system by analysing specific combinations of basic events sufficient to cause the undesired top event to occur.

b) Quantitative Analysis: Numerically calculating the probability of occurrence of the top event from the probabilities of occurrence of the basic.

In case of qualitative analysis, the fault tree is comparatively loosely structured, since the analysis in this case is not as rigorously specific as in case of a quantitative analysis; being more judgemental and valuation based, compared to the former which is more 'fact based' and 'objective.'

In multi-component systems as complicated as nuclear reactors, it is important to analyse the possible mechanisms for failure and to perform probabilistic analysis for the many events that interact to produce other probably undesirable events. Reference may be made to the Bhopal gas tragedy and the Uphaar cinema fire, which could use fault tree, both as a diagnostic and a preventive tool to avoid future losses. These events can be related using simple logical relationships and these relationships permit a methodical building of a structure that represents the system.

A complete safety analysis on an extensive system such as a nuclear power plant normally requires three levels of fault tree development. The top level includes the top undesired event and the key sub-events that are modeled from the point of view of how the system functions. As the events are statistically independent, actual construction of fault trees is an art as well as a science and comes only through experience. For trees containing several tens of events, computer applications are needed. Several computer codes have been developed for this purpose. Environmental risk assessment is likely to become increasingly important in development planning in the coming years, considering the level of environmental degradation that has taken place. As managing and utilisation of increasingly scarce natural resources involving water and soil sustainability becomes more and more complex, the need increases for improving our understanding of environmental risk and the relationship of ecology to economic development and social welfare.

To date, risk assessment techniques have been applied mostly to potential industrial hazards and to the assessment of environmental health risk. The assessment of ecological risk is still not as common, although methods are increasingly being tested and applied, often in conjunction with environmental cost-benefit analyses (for example, in forestry project involving a combination of production and conservation activities, or in the assessment of impacts on natural habitats of water diversions). The main reason for this 'lag' when it comes to ecological risk assessment is that the relationship between different human activities and ecological 'chain reactions' in different environmental settings is still subject to great *uncertainty.* Consequently, there is some resistance towards applying the methodology on a *systematic basis*. The World Bank will continue to encourage and expand the use of environmental risk assessment and seek to contribute to the development and refinement of risk assessment techniques and their application to new areas.

ii) The Event Tree Analysis (ETA)

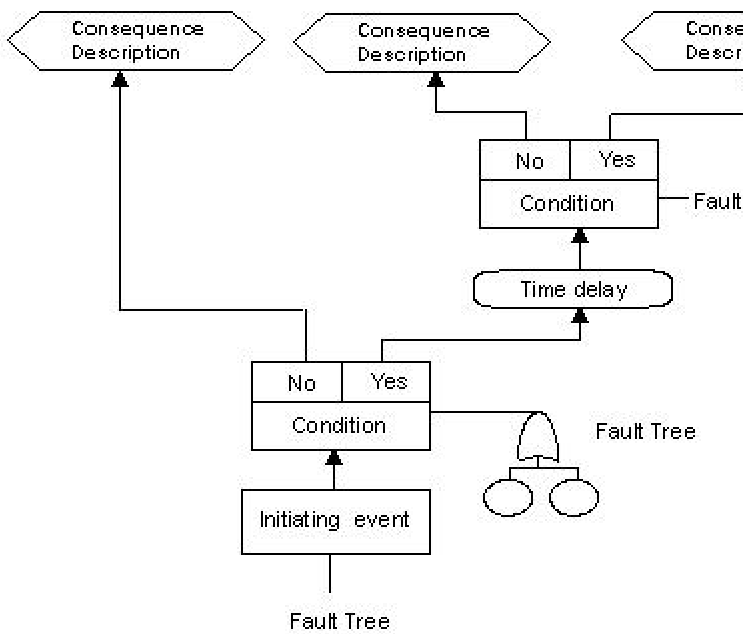
An event tree is similar to a fault tree but differs in exploring the consequences of an undesirable event as against causes in fault tree. This is a bottom up approach, suggesting how one wrong initiating event can lead to a potential disaster. The event tree follows *inductive logic* in that consequences following an identified event are studied as against deductive logic of fault tree, which studies events and subsequent causes. Event tree analysis is a *forward reasoning technique*, which identifies the ultimate consequences arising out of a basic cause or initiating event. It gives the probability of occurrence of the ultimate consequence. Event tree analysis (ETA) records the accident sequences and defines the relationship between the initiating events and the subsequent events that combine to result in an accident. The procedure involves identifying the initiating event, listing all events that could arise as a result, constructing the event tree and evaluating the resultant failure. If the failure frequency level is intolerable, special efforts should be made towards containing the same. The fault-tree method allows one to proceed back in time from possible catastrophic accidents to examining components of the sequence. The event-tree method allows the observer to proceed forward in time from potential component failures to their accident implications. These methods can make the study of such accidents more systematic. They establish a classification of some potential accident sequence and permit identification of procedures for estimating the risk(s) associated with these sequences. A database must exist on the risk of the failure of critical component elements. The methods however cannot be totally comprehensive. The important thing is the attempt at completeness and the ability to provide assurance that only minor contributors to accidents might have been left out (Keong).

iii) The Cause Consequence Analysis (CCA)

This technique was invented by RISO Laboratories in Denmark to be used in risk analysis of nuclear power stations. However, it can also be adapted by the other industries for estimation of safety.

The purpose of CCA is to identify the chain of events that can result in undesirable consequences. With the probabilities of the various events in the CCA diagram, the probabilities of the various consequences can be calculated, thus establishing the risk level of the system. The cause-consequence diagram can be considered as a combination of fault and event tree analyses. It presents the sequence of events in the form of a logic diagram and makes possible quantification of the risks from the system. It is easier to identify by this method, the sequence of events that finally culminated in the disaster. The CCA therefore combines the benefits of fault tree and event tree in that both causes and consequences of undesirable events are studied using both inductive and deductive logic. With the probabilities of the various events in the CCA diagram, the probabilities of the various consequences can be calculated, thus establishing the risk level of the system. The diagram below from Tang's is illustrative of it (*ibid*).

Figure 2 below shows a typical CCA



The above methods display logical relationships, identify combination of failures that lead to undesired events and can be used as the basis for hazard assessment. One of the major distinctions between man-made and natural hazards is the notion that the former is possibly preventable. The natural hazard, the earthquake or typhoon is not preventable. One can act so as to mitigate its impacts but not forestall the occurrence of the natural phenomena. Of course, a continuum may be said to exist between hazards, which are totally man-made, and those, which are exclusively natural, presuming that man's activities interfere with natural processes and lead to hazards. Man-made or institutional hazards are typically subject to the development of a logic structure, which can be used to analyse the preventability of the rare event. The Ramussen Report on nuclear accidents, for example, used the methods of the Fault-tree/ Event-tree analysis.

Evaluation of Tree Techniques

Risk-benefit analysis based upon methods such as fault-tree and event-tree have proceeded a long way in the last several years for examining hazards from nuclear plants, food additives and pharmaceuticals. Fault-tree studies of reactor accidents have established that between one-third and two-third of hypothesised accidents are caused by human error. What is human error? Is it frailty, vulnerability, and incompetence in the assigned task? When one superimposes the maps of seismic risk and population density over the maps showing the location of nuclear reactor sites, along with their management and operation safety rating which varies considerably, the aggregate distribution of catastrophe potential is probably high but still to an unknown degree. When one adds to this distribution the potential danger from sites now under construction and those planned to begin construction soon, that composite picture of the distribution of hazard is gained which adds to rationality of policy choices involving location and scale of activities of projects.

Largely, the area of fault tree application is the prediction of institutional, legislative and judicial impacts of measures taken and proposed improvements for better compliance with risk reduction guidelines. The private sector and pubic sector projects and programmes can be studied with reference to their impact on the economy to point out possible shortfalls. Natural disasters like earthquakes, landslides, floods and cyclones strike nations most unexpectedly, inflicting massive damage to life and property. Man-made installations such as chemical storages, chemical processing industries add yet another dimension to the devastating impacts of natural calamities. A number of tools are available for identifying the potential hazards from a plant. These are based on previous experience, discussions involving people with more specialised knowledge and other creative and analytical methods.

4.5 NATURAL HAZARD/ RISK ASSESSMENT

A) **Earthquake Risk Assessment**

According to a recent study by Khattri (1999), an important factor that controls the ground motion severity is site characteristic. Sites covered by loose soft soil are liable to *amplify ground* motion in the event of an earthquake. Various studies are used for site investigation (i.e. dominant period and amplification level). Techniques such as *noise studies, shallow refraction* and *swell boring* are used for studying site characteristics. Using this information, a detailed map of expected ground motion in different areas can be prepared which can be a suitable basis for vulnerability mapping.

The RADIUS Tool

Risk Assessment Tool for Diagnosis of Urban areas against Seismic disasters (RADIUS) tool was developed for IDNDR (International Decade for Natural Disaster Reduction) by OYO Corporation, Japan and RMSI to enable the city administrator to do quick assessment of earthquake risk to a city. The tool was showcased at IDNDR (International Decade for Natural Disaster Reduction) seminar, Mexico in 1999 to many city planners and administrators.

The goal of this tool is to aid users in understanding the seismic hazard and vulnerability of their cities and to guide them in preparedness programs for future risk management. The tool provides risk-mapping of the area of a city and probable loss estimates involving infrastructure and life, which is displayed as a mesh of rectangular cells which allows the user to get a graphical view. The outputs are seismic intensity, building damage, lifeline damage, and causality estimates which are presented in tabular forms as well as in map forms.

Epicentral Maps

Epicentral maps are used for preparing seismic hazard maps. These maps are prepared after collecting data over a period of time, possibly for the past hundred years and its analyses by computer programs. Apart from earthquake data, geological factors, structural design, soil data etc., are used for preparing building codes. These codes are used for designing earthquake resistant structures in the region. Upgrading of this code is a continuous exercise since changes take place in geological factors such as soil composition over time. The building code is accordingly reviewed from time to time. The different zones indicate vulnerability from seismic disturbances and help assess actual disaster potential of the hazard.

However, in order to assess the exact nature of risk, several data regarding important factors such as gravity, magnetic, geodetic and, electrical data are necessary. These data are then used to prepare micro-zonation maps, which are used for urban and rural planning.

Example from China

From a public administration perspective, the administrative set up is significant in the way it applies principles of organisation theory to maximum effect in implementation of policy. Reference is to unity of command; specialisation, work division and coordination etc. which determine the efficacy of policy implementation and evaluation processes. A policy unsuccessfully implemented is a waste.

Recent initiatives taken by China would be worthy of consideration here. In response to the United Nations current emphasis on disaster management, through the International Secretariat for Disaster Reduction, (ISDR), China has set up special Earthquake Management Agencies in every major city and large state enterprises. As related by Tao Xiapin, some cities located in high earthquake risk area ensure regular rehearsals of rescue squads, and rush-repairing procedure every year. The anti-seismic awareness of the public is upgraded by training and awareness programmes. Such initiatives are necessary because of the specific geological situation where the famous Circum-pacific active structure zone intersects the Himalayas-Mediterranean active structure zone. China faces high earthquake disaster risk and hazard.

The Chinese administrative arrangement resembles a pyramid, in that primary responsibility is with the General Emergency Directing Center, led by the Chinese State Department and Chinese Seismological Bureau. Provincial government and related Ministries is the second layer, the Local Government is the third layer, and other organisations or enterprises form the lowest rung. In the event of a catastrophe, the machinery swings into action, with the emergency-directing center at the helm of affairs. The system is functional in that there is there is *unity of command* as well *unity of direction* in public administration parlance, since agencies report to the top authority which issues guidelines and supervise the work of provincial authorities. In order to keep the information moving smoothly and fluently into the networks of earthquake preparedness and rescue effort, the Chinese government had started a series of programs to set up digital networks since 1990, based on GIS, GPS and RS, take in a lot of new achievements in earthquake engineering and information science. Other organisations in the middle and lower rungs have clear-cut responsibilities relating to implementation of plans and no jurisdictional disputes have been known to jeopardise or in any way affect the collective effort.

This endorses the significance of collaboration between the twin fields of specialist scientific expertise and generalist mainstream public administration public administration to articulate meaningful policy and ensure quick and efficient implementation.

B) **Landslide Risk Assessment**

According to A. I. Kelarestaghi, geological, topographic and climatic condition of the area and human factors such as land use changing and road construction are the important factors that have caused landslides.

Landslide zonation map is a map demarcating the stretches or areas of varying degrees of anticipated *slope stability* or *instability*. The map has an in-built element of forecasting and is hence of a probabilistic nature. Depending upon the methodology adopted and the comprehensiveness of the input data used, a landslide hazard zonation map provides help concerning some or all the following aspects:

- Location of proposed project
- Extent of the slope area likely to be affected, and
- Rate of mass movement of the slope mass.

The use of aerial photographs and adoption of remote sensing techniques helps in the collection of data. For storage, retrieval and analysis, adoption of computerised techniques speeds up information processing.

Hazard zonation maps have multifarious uses, some of which are listed below:

- In the preparation of development plans for townships, dams, roads, and other development
- General purpose Master Plans and Land use Plans.
- Discouraging new development in hazard prone areas.
- Choice of optimum activity pattern based on risk zones.
- Quick decision making in rescue and relief operations.

C) Drought Risk Assessment

As explained by Fatima Rabab, the Normalised Difference Vegetation Index (NDVI) index helps forewarn of droughts. NDVI is a satellite data processed index, which can be used to indicate deficiencies in rainfall and portray meteorological and /or agricultural drought patterns and measure of the amount of radiation being absorbed by plants. Amount of radiation absorbed is directly related to 'evapo-transpiration,' since the plant must cool primarily by evaporating water. The evapo-transpiration is constrained by the amount of water in the soil, which in turn is constrained by low rainfall. (Rowland et al, 1996), Onset of drought conditions over a large area can be predicted by comparative analysis of the trend of derived NDVI of that year, relative to the trend in the normal year. Other factors along with vegetation cover that need monitoring; include climate, soil type, hydrology, and socio economic condition of people. Hence multidisciplinary spatial analysis with the help of GIS can lead to a decision support system for concerned government departments, NGOs and others to help drought vulnerable people and others living in potential drought prone areas.

Application of NDVI will aid decision-making allowing better integration and more timely planning of methods to promote food security. Droughts affect the poor more than the resourceful (access to labour capital and wealth). Unlike rapid onset events like earthquakes, drought has slow onset, which can be observed and curbed with timely preventive action. Accordingly, *Drought Indices* have been developed to monitor and forecast drought. Such indices incorporate data collected over time regarding multifarious factors like rainfall, snow pack stream flow, and other water supply indicators, which together give the comprehensive 'big' picture. Drought indices for areas with undulating topography need to take account of additional factors like surface water supply index etc.

According to Verstappen (1995), Satellite Remote Sensing (SRS) and the Geographic Information System (GIS) should be integrated for identification of drought vulnerable conditions in a particular geographic area for research purposes. There are two principal advantages of such integration. First, the technology allows long-term series studies and storage of the information; second, information accessibility is improved. Remote sensing can provide large amounts of data quickly and inexpensively, relative to other means of collection and GIS can bring together vast amounts of information from a wide variety of sources and make the information quickly visible and applicable in emergency situations.

New scientific techniques such as remote sensing, satellite imaging, geographical information system and geographical positioning position (GPS), can be put to effective use in forecasting and monitoring droughts.

D) Volcano Hazard Assessment

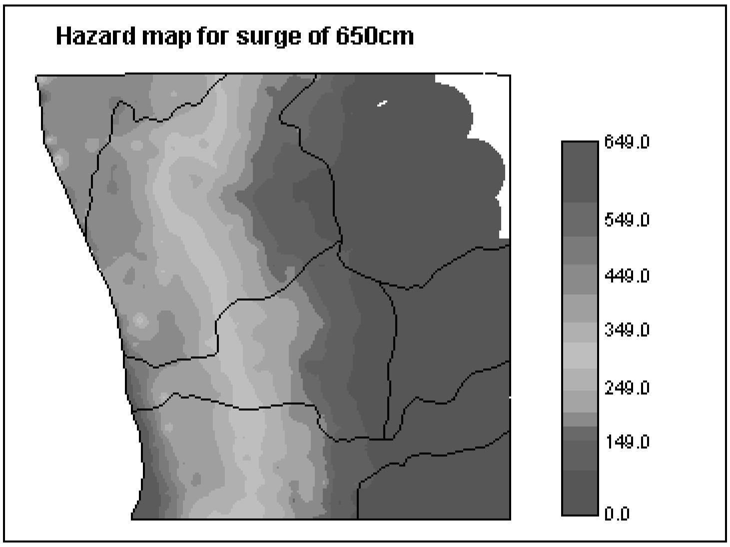
GIS is being used to map areas of intense *mudflow paths* from water filled craters in adjoining residential areas. GIS contributes in identifying areas at risk, monitoring and forecasting hazards to warning the possibly affected people or responsible teams to take precautions.

E) Flood Risk Analysis

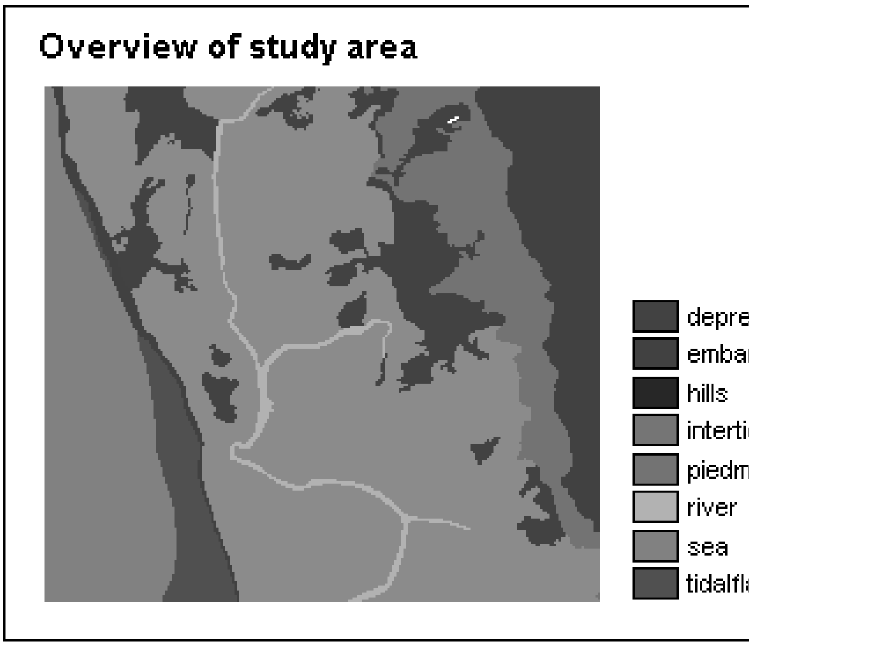
Flood Risk Analysis is done using GIS and RS tools. Land use maps are prepared which show residential areas and main commercial complexes in hazard prone areas. Lack of land use planning is also exposed in a flood hazard map. Critical facilities' map is prepared separately to depict hospitals, schools, and colleges in hazard prone areas.

The map below gives an overview of the Banskhali study area situated in the East of Bangladesh, South of the city of Chittagong. Area maps and attribute tables of the geomorphology, village population, the Union-districts, roads, embankments, cyclone shelters, and the elevation of the terrain with cm accuracy are provided (Demon and Westen, 2002).

MAP-1



MAP-2



F) **Cyclone flood modeling**

Surge heights are modeled as follows:

- the surge height remains constant for a certain distance from the coast line
- then, the surge height decreases according to a constant factor, the so-called Surge Decay Coefficient (SDC); this is the influence of resistance caused by surface forms and land cover, at a certain distance from the coast the surge height will be zero.

The SDC is calculated as:

$$\frac{\text{Surge height} - \text{Average elevation at end of surge}}{\text{Total inundation width} - \text{Width of constant surge}}$$

For a surge height of 650cm at the coast, a flood hazard map can be calculated which depicts the water height (in cm) in the area (all required parameters are given):

- first a distance calculation from the coast line is performed,
- The map is obtained with the water height (in cm) in a particular area after the surge of 650cm. (decreasing water height showed in colours, descending towards left- see Map 2)

Taking into account population densities in different hazard zones and other factors such as infrastructure etc. vulnerability and risk assessments are done. Satellite imagery enables superimposition of maps providing information on different counts such as the infrastructure in the area, the tribes inhabiting the area, the occupational pattern of people, livelihood options, communication network etc. Different information can be put together on map "The highest loss of people (factor 1.0) will occur at places where high flood depths occur while there will be no loss of people (factor 0.0) at places where the flood depth is zero. (In this exercise, vulnerability is regarded as a kind of 'killing factor'" (Demon and Weston, 2002). Population densities are calculated separately for each village in terms of the elderly, women and children among vulnerable sections.

Risk calculations are done separately for different surge heights, over the next 15, 20 or 25 year periods and for different categories of people, women, children, elderly, young. It has been observed that small surge height cyclones are more frequent creating more risk especially to children.

4.6 UNDERSTANDING CLIMATE RISK

The United Nations has called for factoring 'risk' from climate change in every developing decision taken with regard to any project, especially in the third world. Climate change in part has been a natural process, which has been misdirected and mismanaged by human intervention through the course of development; to the extent, that natural 'resources' like water and sunlight have today turned to hazards. As per Hazard Assessment of the Intergovernmental Panel on Climate Change (2001), human activities which have disturbed the ecological balance are; industrial processes leading to emission of green house gases lack of alternate energy sources, everyday activities involving burning of charcoal and fossil fuels, deforestation, migration of rural folk to urban metropolises creating problems of urban congestion etc.

Some of the natural and man-made factors highlighted in the IPCC report are discussed below:

A) **Natural factors**

a) **Continental Drift**

Based on geological evidence, such as similarity of plants and animal fossils etc., scientists contend that continents of the world were once part of a huge landmass. The continents have since then drifted apart, causing changes in the physical features of the landmass, their position and the position of water bodies. The separation of the landmasses changed the flow of ocean currents and winds, which affected the climate. This drift of the continents continues even today with the Himalayan range rising by about 1 mm (millimeter) every year because the Indian land mass is moving towards the Asian land mass, slowly but steadily.

b) **Volcanoes**

When a volcano erupts, volcanic ash, composed of SO_2 and dust particles, can reach up to the stratosphere, trap sunlight cooling the troposphere, which alters weather patterns in the region and around the globe. Gases and dust particles lead to cooling of the earth surface by trapping much of the energy. SO_2 combines with water vapour (H_2O) to form sulphuric acid ($H_2 SO_4$) which floats for long periods and travels long distances in the form of tiny droplets resulting in climate changes in different parts of the globe. (H_2SO_4 reflects sunlight.) The extent to which it happens is still under study. There was a famous year without a summer when significant weather-related disruptions occurred in New England and in Western Europe with killing summer frosts in the United States and Canada. These strange phenomena were attributed to a major eruption of the Tambora volcano in Indonesia in 1815.

c) **The Earth's Tilt**

The earth is tilted at 23.5^0 to the perpendicular plane of its orbital path. The more the tilt, more acute the angle, more the severity of seasons experienced since the distance between the sun and earth gets different. The earth's axis is not fixed as is generally assumed. It is moving at the rate of a little more than a half-degree each century. When the pyramids were built, around 2500 BC, the pole was near the star Thuban (Alpha Draconis). This gradual change in the direction of the earth's axis, called *precession* is responsible for changes in the climate (IPCC, 2001)

d) **Ocean Currents**

Ocean Currents affect the climate of adjoining regions. For example the warm Gulf Stream current affects the temperature of South West America and the cold Labrador Current affects the temperature in Northern Europe. Winds change the direction or the speed of an ocean current, which leads to phenomena such as the El Nino. Ocean currents absorb large amounts of heat from the atmosphere that gets released in the form of water vapour. Water vapor is the most abundant green house gas on Earth. But water vapour also leads to cloud formation and contributes to cooling of the atmosphere.

B) **Human Factors**

Human made causes, are emission of green house gases from electrical appliances, (Use coal) automobiles (petrol and diesel) which run on fossil fuels (Oil, coal, natural gas, large scale deforestation for various purposes such as buildings, paper, timber etc, plastic waste that cannot be recycled. All such activities have contributed to rise in greenhouse gases in the atmosphere. The energy sector is responsible for about ¾ of the carbon dioxide emissions, 1/5 of the methane emissions and a large quantity of nitrous oxide. It also produces nitrogen oxides and carbon monoxide, which is not greenhouse, gases but do have an influence on the chemical cycles in the atmosphere that produce or destroy greenhouse gases (IPCC, 2001).

4.7 MAPPING FOR RISK ASSESSMENT

Methods developed for near accurate estimations include f: N curves, scenario mapping, potential loss studies as explained by Coburn, Sspence and Pomonis (1994) in the Disaster Management Training Programme.

a) **f:N Curves:** Data on the size and frequency of disaster occurrences for a particular country can be plotted as f:N curves. These involve plotting the frequency of events causing greater than a certain number of fatalities. Different numbers of casualties (or magnitude of losses expressed in some other way) are plotted for different frequency of occurrence on *x* and *y-axis* on a graph respectively. However such relationships always show aggregated losses for a large region over a period of time. They do not help identify the geographical distribution of damage, for which risk mapping is needed.

b) **Scenario Mapping:** In scenario mapping the presentation of the impact of a single hazard is attempted. Scenario mapping is used to estimate the resources likely to be needed to handle an emergency. The number of people killed and injured and the losses likely with respect to other 'elements' are estimated. From these can be assessed the resources needed for medical attention, accommodating the homeless and other measures to minimise the recovery period. For example assessing the state of the present infrastructure can aid damage assessment in the event of an earthquake. Circles and shaded regions on a map are used to depict settlements and building types, low density and high-density areas etc. to assess damage likely in particular locations, based on past experience and development since the last event for proper assessment in the changed scenario. Hence a scenario map can identify 'communities at risk' and regions at risk. Hot spots thus located are the foci of restorative and regenerative activities post disaster.

c) **Potential Loss Studies:** Mapping the impact of expected hazard occurrence probability across a region or country shows the location of communities like 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 likely to suffer heaviest losses, which should be priorities for loss reduction programs, and which are likely to suffer heaviest losses, which should be priorities for loss reduction programme and which are likely to need most aid or rescue assistance in the event of disaster of differing magnitudes.

d) **Annualised Risk Mapping:** The annualised specific risk from any hazard at any location is the average expected total losses from all events over an extended time period. The probability of each level of hazard occurring within unit time period is combined with the consequence of that level of hazard to generate the expected losses within that time. Summing up losses of all levels of hazards gives the total losses likely over a time period. Hence an annualised risk map gives the total losses over both time and space. With high level of precision in calculations, the desired focus of disaster mitigation policy as also the effects of disaster mitigation measures if attempted can also be assessed. Areas of concentration of damage over a year in a given area are depicted on the map. It is expressed as a proportion of the total value (or number) of the total population at risk. Calculation of the probable levels of losses occurring within a unit time period is combined with the consequences of that level of hazard to generate the expected loss within that time. (Coburn, Sspence and Pomonis, 1994)

4.8 DECISION MAKING FOR RISK REDUCTION

4.8.1 Risk Evaluation

Decision-making regarding risk depends on the perception of risk or risk evaluation carried out in the social and political circles. Risk evaluation entails 'comparative evaluation of risks' faced by a society and the relative ordering of risks as per resource availability and the significance attached by the society to the risks it faces. In developing countries, development policy for risk reduction has not been evident on a satisfactory scale, since there are other pressing concerns such as poverty reduction, employment generation, public health etc., which are ordered higher than disaster risk reduction. Not being a core public policy issue, disaster management remains a 'contingency' measure, dependent mainly on international assistance, in case such an eventuality occurs. As part of daily governance, risk largely remains un- accounted in decision-making. This is a fundamental error since risk reduction and development are inextricably linked. There has been a realisation by the international community that disasters set back development, negating years of effort. There has been an extended understanding of poverty in academic circles of late in that poverty assessment is not limited to the income criterion alone, but to myriad issues concerning quality of human life, such as better education, access to public health facilities, gender equity, child care and a better overall sense of well being. Accordingly, poverty reduction is increasingly being looked upon as an integral aspect of development planning relating to other sectors, such as environment management, gender development and public health. Such integration with disaster management however, is still not evident on a satisfactory scale (DMTP, 1994).

According to Suvit Yodmani, definitions of poverty reduction and disaster management have evolved over the years, almost concomitantly, in that a similar pattern can be discerned in shifting paradigms. Disaster management over the past few decades was seen as a technical issue, which only trained scientists, could handle. The approach was consequently techno centric or concerning only engineering expertise. With the change in the understanding of poverty, has come about a corresponding, though not necessarily related, change in the perception of disasters as issues in development. For example, provision of livelihood options is an important development issue and also an important risk reduction measure. The change in perception was brought about, as technical know-how or even better contingency planning could not curb disaster losses. It was evident that there was some other factor at work, apart from the natural causes of hazards or the deficiency in contingency planning. The other factor was diagnosed subsequently as 'vulnerability'. Frederick Cuny in his much-acclaimed book *Disasters and Development* cites an example to illustrate the point. Earthquakes of almost similar magnitudes struck

California in 1971 and Managua in Nicaragua, two years later. While only 58 deaths were reported in California, which has a total of seven thousand people, Managua were reduced to rubble with six thousand reported dead.

The context of disaster management only makes development policies empirical in that they are based on scientific vulnerability analyses, involving a number of agencies, which ensures better effectiveness of policies and also cost effective implementation. It also ensures 'sustainability' of policies in the long run, in terms of compatibility with environmental concerns (protecting environmental degradation, pollution, modifying cultural practices that harm the environment, etc.). It also makes policies 'relevant' from the public administration perspective in that they are need based and hence ensure benefit over the long run.

4.8.2 Vulnerability Assessment

Vulnerability is not a uniform phenomenon. It differs across regions and communities. Specific vulnerabilities relating to a specific community or a region have to be identified through empirical study and area/people specific strategies devised accordingly, to tackle vulnerabilities. The exercise to identify what creates risk is termed *vulnerability assessment*. The Disaster Management Training Programmed, 1994, defines vulnerability assessment in the following words:

Vulnerability Analysis is:

"*The process of estimating the vulnerability of specified elements at risk. For engineering purposes vulnerability analysis involves the analysis of theoretical and empirical data concerning the effects of particular phenomenon 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 term and long term) and the extent to which essential services and traditional local coping mechanisms) are able to continue functioning.*"

Vulnerability thus can be physical, economic, social or cultural. *Physical vulnerability* refers to the resilience of the infrastructure in the face of disasters. If quality of infrastructure is poor, buildings collapse easily; communication gets disrupted, creating hurdles in relief effort, causing loss of capital infrastructure and more loss of life. In the aftermath of an earthquake, buildings are analysed for damage resistance, and categorised as per differing levels of susceptibility. 'Retrofitting' measures are accordingly applied to provide for more hazard resistant construction. As a preventive measure, building codes and regulations are drafted to force hazard resistant construction in hazard prone areas.

Social vulnerability refers to a state of weakness, which creates a predisposition to harm. Social and economic vulnerability are found to go together in that in that weak and the marginalised do not have access to power centers wherein the means of production are concentrated. Statistically, the poor and the marginalised have been seen to suffer more in the event of a disaster than the relatively better off, on account of iniquitous access to power and resources. Vulnerable position depends significantly on differential access to 'power', which is an intangible resource, though a prime determinant of 'survival quotient' or resilience in the event of difficulty. Power situation determines largely, the access to relief resources in the aftermath of a disaster. This explains the particularly weak position of women and children and backward sections of society in securing aid relief. Therefore, in the current paradigm of risk management approaches, there is more room than ever before for addressing the issues of risk reduction for the poor. This is also in consonance with the paradigm shift in the mainstream development practice, which is now characterised by emphasis on good governance, accountability and greater focus on people friendly bottom-up approaches.

Warning systems detect impending disasters. Warning systems are complex systems because they link many specialties and organisations, science (government and/or private, engineering technology, government news media, and the public. Disaster preparedness involves integrating the subsystems of management of hazard information and public response. Preparedness components are, planning, exercise, and training of officials concerned along with local volunteers. Thus warning system must be considered having scientific, managerial, technological and social components that are linked by a variety of communication processes. One pertinent finding has been that a single warning concept will not equally serve the requirements for all hazards (Mileti and Sorensen, 1990). For example, a system designed for a hurricane will not be good for a flash flood. Likewise a general alert or warning may not be adequate when a very specific warning is needed. There have been cases where a warning system failed because the wrong system design was used. This is often found in areas, where a lesser-known hazard strikes, for example, tornadoes occurring in areas of frequent hurricane activity. Over the past years, significant progress has been achieved in the United States, in predicting forecasting and graphically presenting scientific information and warnings hurricanes and nuclear hazards. In case of other hazards, such significant improvement is still not discernible.

4.8.3 Instituting Disaster Response

Traditionally, due to lack of technology and scientific approach, it was difficult to carry out the search, rescue and evacuation operations. Today there are techniques available, like remote sensing through satellite imagery and GIS, which help to identify areas that are disaster prone, zoning them according to risk magnitudes, inventory populations and assets at risk, and simulating damage scenarios. The information communication revolution has greatly facilitated matters in search and rescue. Specific areas of use include warning and forecasting, creating awareness among people, establishing contact between relief teams, instituting coordination mechanisms through control rooms set up for the purpose.

4.9 PROBLEMS IN RISK ASSESSMENT

Risk assessment is largely ignored in policy making. Where it does figure, it tends to be confined to hazard mapping and the assessment of physical vulnerability; consideration of the political and social dimensions being conspicuously absent. There is also the need to appreciate the concept holistically, in the sense of integrating hazard and vulnerability assessment with development planning. For disaster management planning to be effective, certain minimum standards based on acceptable risk should serve as guidelines. Below, is a summary of the necessary activities, which can be taken up to advance and improve the process?

- hazard mapping of all key hazards to various scales; frequency, location, severity and duration
- vulnerability assessment; social, economic, physical, institutional
- risk evaluation where absolute requirements for mitigation and preparedness are decided.

Resource constraint is a major problem. Disaster prevention, however, has been found to be far costlier than preventive strategies. The emphasis of Risk Assessment has consequently to be on devising innovative approaches to prevent disasters as part of development planning.

4.10 CONCLUSION

Risk assessment is a scientific approach to understanding disaster phenomena with a view to preempting/preventing them by means of innovative and proactive policy. Risk analysis is an important element in the wider function of policy analysis especially with respect to development administration. Researchers and academics have to consider risk assessments in wider context of 'policy analysis' from the point of view of public interest. By the public choice perspective, policies are democratic to the extent they are based on the imperatives of public interest. Since disaster management is now imminent, it should form an important perspective in analyses of development policies. Such broad conception of policy analyses or the widening of this scope of policy analyses will contribute to its success at the implementation stage. Policy analyses also lead to the development of 'policy science' that is a ready body of knowledge for reference in similar circumstances would be presented. Therefore, provision for risk assessment has to be built into regular policy design to arrive at a proper cost benefit analysis regarding disaster related development planning. Right estimate of expenditure for e.g., could lead to better economic policies in the country such as a better, more just taxation policy.

4.11 KEY CONCEPTS

Vulnerability : The degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).

Elements at Risk : The population, building and civil engineering works, economic activities, public services, utilities and infrastructure etc. at risk in a given area.

Specific Risk : The expected degree of loss due to a particular natural phenomenon and as a function of both natural hazard and vulnerability.

Risk : The expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements of risk.

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4.13 ACTIVITIES

1) Risk analysis involves an analysis of both theoretical and empirical data. Discuss.
2) Discuss the process of risk assessment with suitable example from India.
3) Write a note on risk evaluation.