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Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Disaster management**
Module Name/Title	**Hazard, Vulnerability and Risk Assessment**
Module Id	04
Pre-requisites	
Objectives	1. To develop the capability of performing hazard identification and profiling 2. To develop the ability of carrying out vulnerability assessment and understand the associated complexities 3. To explore the concept of risk assessment and elaborate on the approaches to conduct risk assessment
Keywords	

Module 4. Hazard, Vulnerability and Risk Assessment

Rationale

The module is a continuation of the previous chapter and aims introducing the concepts of hazard, vulnerability, capacity and risk assessment (HRVA). HRVA is particularly important in context of disaster management as it helps the institutional organizations and community to make risk based choices to prepare for and mitigate hazards, address vulnerabilities and build capacities, thereby minimising disaster risk. The module will introduce the technicalities of hazard and vulnerability assessment and then assimilate the two concepts to elaborate on risk assessment.

Disaster Risk Reduction (DRR) refers to the key set of activities aimed at reducing the impact of disasters and promoting a disaster resilient society.DRR efforts cannot be pursued without an understanding of the disaster risks facing the region or community. Hazard, Vulnerability and Risk Assessment is an important tool for developing the contextual understanding of disaster risks. It is based on the assessment of three factors-

- **Hazard**:Hazard is a natural or man-made event that has the possibility to cause adverse effects. It's the chance/ likelihood/ probability of the occurrence of the potential adverse natural or man-made event.A hazard becomes a disaster only when it interacts with vulnerabilities and exposure.
- **Exposure**: The resources, assets, and infrastructure that might be lost/ damaged if the hazard materializes.
- **Vulnerability**: Likelihood that the exposed assets would be damaged during the occurrence of the hazard event. It accounts for the susceptibility of the exposed assets. Vulnerability functions give an estimate of the extent of damage and the consequent losses (including social costs) due to the occurrence of the hazard event.

Hazard vulnerability and Risk analysis falls into two general categories: *quantitative analysis* and *qualitative analysis*. The former utilizes mathematical and/ or statistical data to arrive at a numerical description of disaster risk and the later also relies on mathematical and/or statistical data, but instead uses defined terms (words) to describe and categorize the hazard risk likelihood and consequence value outcomes. While quantitative analyses provide specific data points (e.g. - dollars, probability, frequency or number of injuries/fatalities), qualitative analyses consider ranges of possible values for which each qualifier is assigned. It is often cost and time prohibitive and often not necessary, to determine the exact quantitative measures for the likelihood and consequence factors of a hazard's risk. Qualitative measures are much easier to determine and typically require less time, money, and, most important, expertise, to conduct. For this reason, it is the most commonly encountered method of assessment in practice.

Unit 1 – Hazard Assessment

The process of Hazard assessment involves the identification and systematic ranking of all hazards that might affect a location. It involves a two-step process,

1. Developing an exhaustive list of all hazards that might affect the location.
    a. Hazard history and hazard risk assessment data is utilised to develop the list.
2. Ranking the hazards in order of their likelihood of occurrence.
    a. Likelihood is a probabilistic assessment of whether a hazard will occur, and in case of a hazard occurring, what might be the expected frequency (the number of times the event is expected to occur in a given time period).
    b. This is done through the assessment of hazard frequency and comparing it with hazard probability assessments published by different technical agencies.

Hazard Frequency data indicates the frequency or the number of times a particular hazard event occurs in a specified period of time. For instance, the frequency of auto accident deaths in the United States is roughly one death per 81 million miles driven (Dubner and Levitt 2006). Sources of Hazard frequency data include historical data including governmental reports, statistical or archival records including media archives, Focus Group Discussions with elderly in the communtiy, existing disaster management plans, sector wise records like that of transportation, public workds, local police, fire departments etc. and all other sources of hazard data that could include detailed information about date of occurrence, magnitudes, corresponding damages, and further evidence of past disasters in the community or state. The hazard frequency data is sometimes depicted in maps by few agencies like the Centre for Research on the Epidemiology of Disasters (CRED).

Probability data - Probability refers to single-event scenario.where the value is expressed between zero and one. Zero signifies a zero percent chance of occurrence while one signifyies a certain occurrence. Examples of probability data include Earthquake Zonation mapping, flood zone mapping etc. which indicates the likelihood of occurrence of events but might not have happened yet. In disaster management, hazards are expressed as probabilities. For example, if an area has experienced four flood events in the past 200 years where floodwaters reached 20 feet above the base flood elevation, then this severity of flooding has a one-in-fifty chance of occurring in any given year, or a probability of 2 percent, or 0.02, each year(Etkin, 2016).

The likelihood of a particular event giving rise to an emergency or disaster event could be expressed using a qualitative system of likelihood:

- **Certain**: having greater than 99 percent chance of occurring in a given year (one or more occurrences per year)
- **Likely**: having a 50–99 % chance of occurring in a given year (one occurrence every one to two years)
- **Possible**: 5–49 % chance of occurring in a given year (one occurrence every two to twenty years)
- **Unlikely**: 2–5 percent chance of occurring in a given year (one occurrence every twenty to fifty years)
- **Rare**: 1–2 percent chance of occurring in a given year (one occurrence every fifty to one hundred years)

Event Tree

One important component of hazard analysis is the identification of subsequent hazards that might arise as a result of the hazard occurring in a particular community/ location. These kind of hazards are often termed as secondary or tertiary hazards depending on its time of initiation; while the hazard which led to the occurrence of secondary/tertiary hazard is termed as the primary hazard. The secondary or tertiary hazard need not be physical geo-morphological processes but could also be social reactions to the adverse event. For example, Earthquake is a hazard that could give rise to landslides. It could also damage electricity connectivity that could impact patients in intensive care in hospitals (which themselves have not been affected by the earthquake). Earthquakes could also lead to fire incidences as secondary hazard. Another example is the rise in epidemics like cholera or gastro-intestinal illnesses post floods.

These secondary hazards when occurring by themsleves shall be primary hazards, but when it follows the occurrence of primary hazards, are termed as secondary hazards. Imagination of such secondary and tertiary cascading hazards is an important component of Hazard Assessment.

An Event Tree is an effective method to identify secondary and tertiary hazards that might arise from a primary hazard and prepare accordingly.Event trees explore multiple outcomes that might result from a particular primary hazard as the instigating event.

Figure 1 Secondary Hazards due to Earthquake

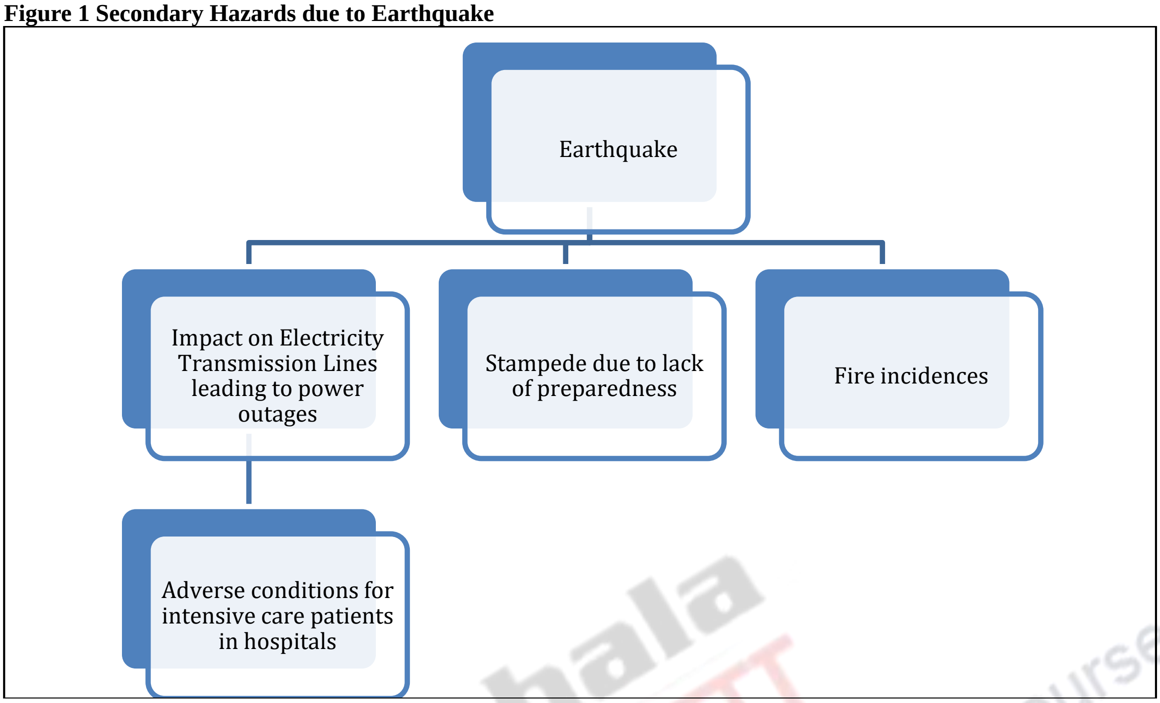
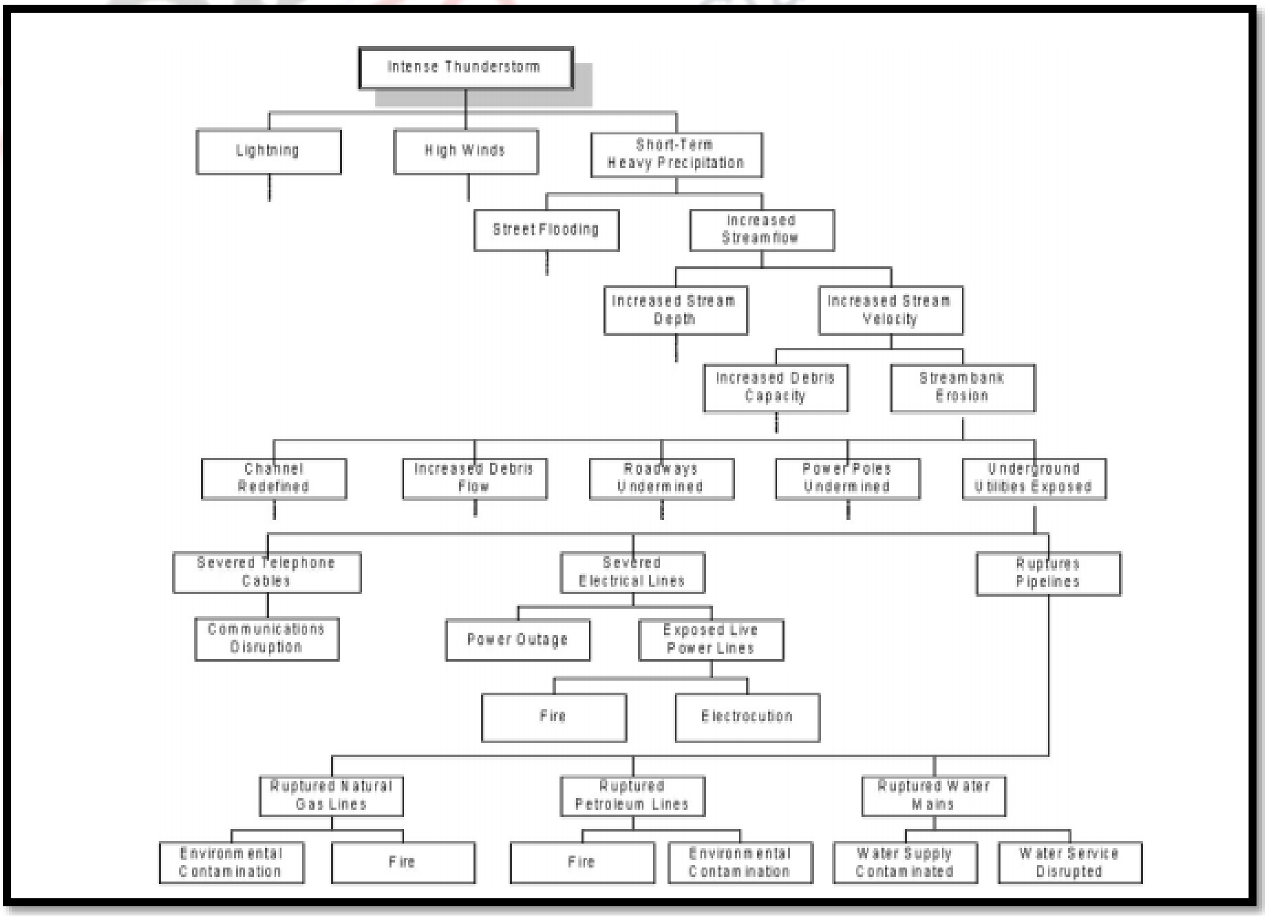


Figure 1 represents a simple Event Tree. In disaster risk assessment, event trees are detailed and arrived at post intense brainstorming with various multi-disciplinary experts and members of the community. The event-trees could cross 7 or 8 levels also (Fig.2).

Figure 2 Event Tree for Disaster Risk Assessment

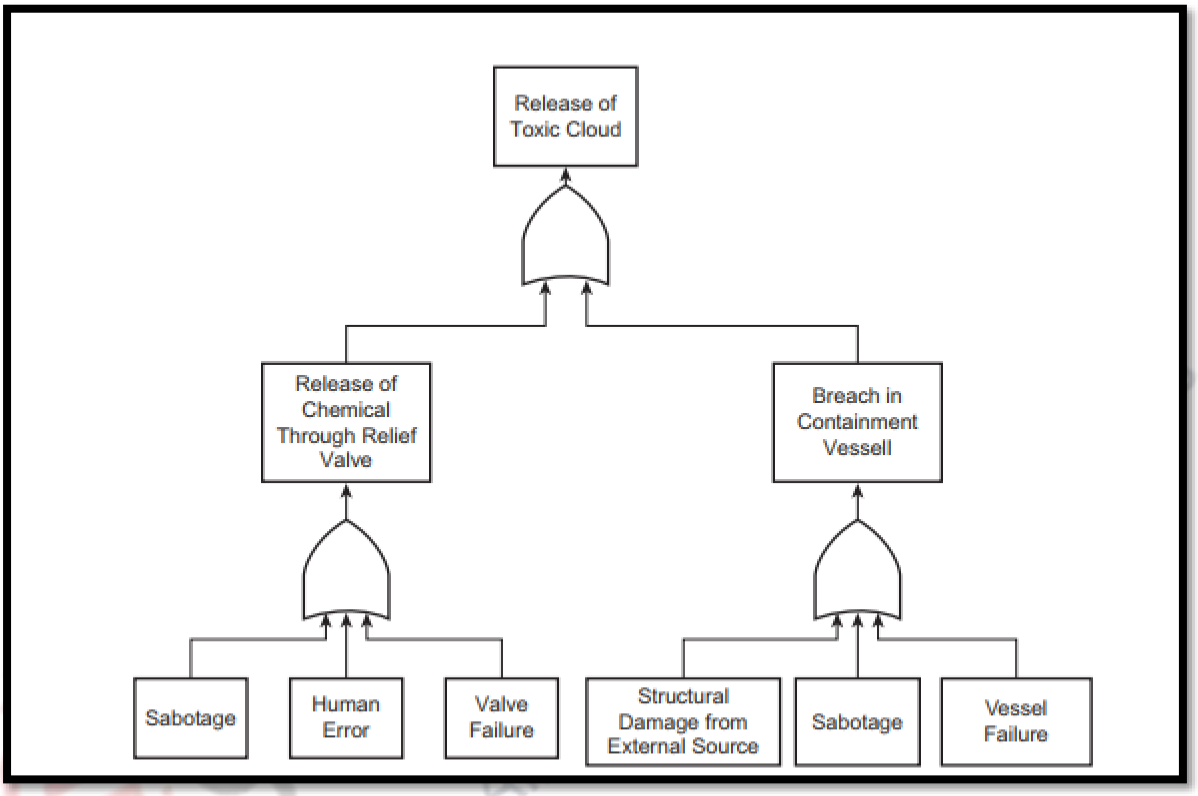


Source – NRC, 1991

Fault tree

Fault Tree and Event Trees are in principle similar. In event tree as we begin with the primary hazard and imagine the consequences, Fault Trees are usually made as an analysis of an adverse event that has already happened. Fault Trees begin with the impacts or consequences and trace back to the possile initiating event (hazard) that could have triggered the impacts.

Figure 3 Fault Tree Analysis



Source - Slovic et al., 1979

With the listing of the frequency and probability of hazards and the event tree analysis to list the possible secondary and tertiary hazards, a composite map could be prepared based on these findings under various themes like the Season of occurrence etc. . These composite maps are the outcome of hazard assessment.

Unit 2 - Vulnerability assessment and approaches

Vulnerability is highly complex and contextual. The contextual nature of vulnerability and community being the central theme for vulnerability makes the concept extremely dynamic as the community characteristics might change over time. There are mainly four types of vulnerabilities:

(1) **Physical Vulnerability**- depending on the location/ geographic proximity of the community or spatial distribution of community from the source/ origin of the hazard. It also includes the difficulty in access to resources or the lack of planning that leads to settlement in floodplains or zones with high liquefaction potential of the soil.

(2) **Social Vulnerability** depends on the family structures, decision-making, organization potential of the community to collect, discuss and react to changes collectively. Weak structures and a segregated community on caste, religioun, language, race, ethnic lines

could lead to increased vulnerability of communities.

(3) **Economic Vulnerability** depends on the varied, sustainable source of livelihood, control and access to means of production, presence/ absence of savings or buffer in times of distress etc.

(4) **Environmental Vulnerability** depends on the natural resource management. Excess degradation/ depletion could increase the vulnerabiltiy of system to disasters

(5) **Institutional vulnerability** depends on the institutional capacity and weakness.

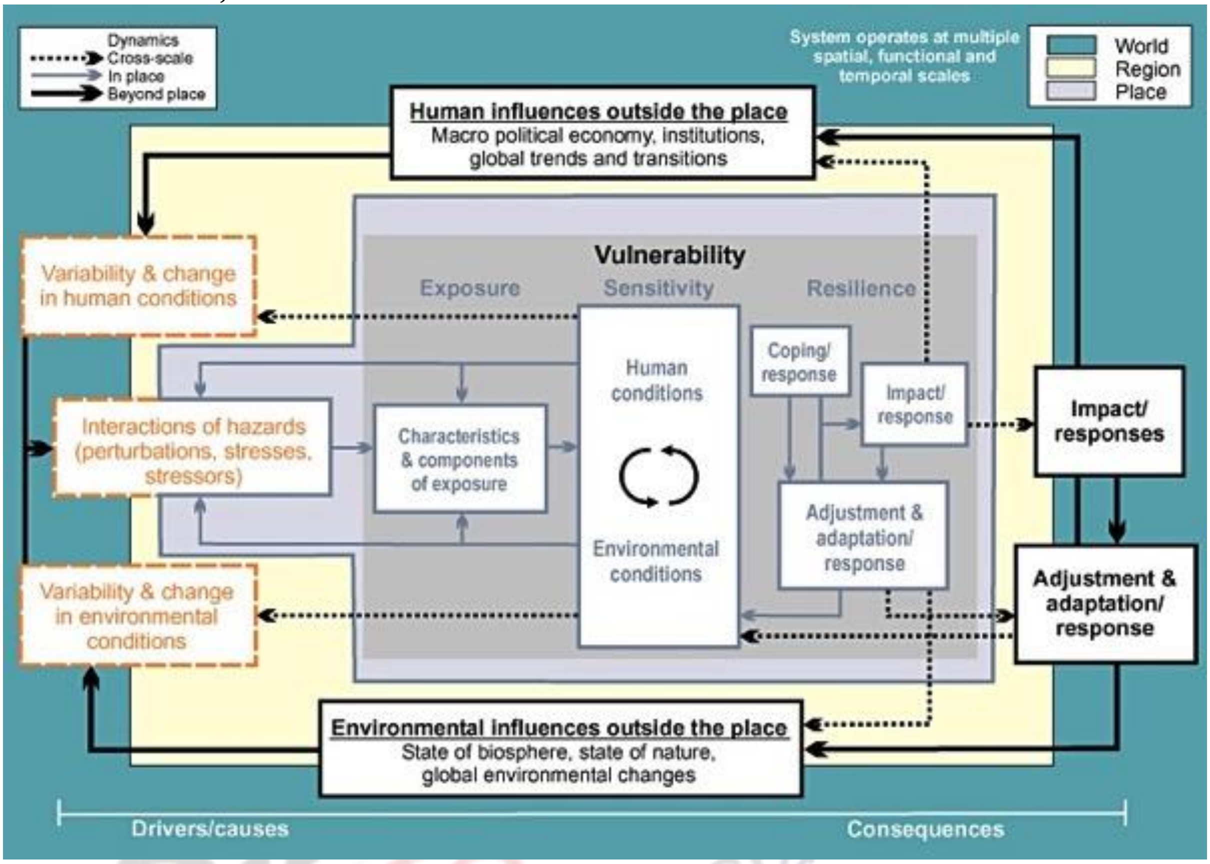
Vulnerability Assessment

There are four main clusters of assessing vulnerabilities:

1) **Laundry List approach**- which tries to list the elements at risk. This includes the structural fragility of infrastructure, the vulnerability of people etc.
2) **The Taxonomy Approach**- that forms taxonomies of vulnerable population (like A-B-C Classification of buildings depending on their structural strength, classification of population in gender, social status, access to power, physical abilities etc.)
3) **Situational Approach-** is to look at vulnerability to certain specific situations like in case of eathquake or in case of a policy change like change in currency denomination)
4) **Community Based Approach**- When communities determine their own vulnerability and their capability which could utilize any of the above three approaches nested into this approach. Often the pre-existing inequalities within a community, get reinforced when community based or community led vulnerability analysis is done.

Holistic analysis of vulnerability may be very complex due to the variety of interactions that act between individuals and communities. The drivers of vulnerability are the intrinsic human and environmental conditions depending on the resilience of the system that are sensitive to exposure to the stress induced by the hazard.

Figure 4 Vulnerability Framework
Source: Turner et al. , 2003



Essential elements of vulnerability analysis includes:

(a) **Assessment Purpose and Scope** including assessment purpose, expected outcomes, existing targets/ goals, the time frame and geographical scope, key stakeholders and resource availability and requirement
(b) **Assessment of the sensitivity and exposure** (the potential impact on the socio-economic and ecology of systems) due to the magnitude of the stress/ hazard, the existing local stresses (including routine risks) and the differences in how individuals or insitutions might be affected by the hazards under assessment.
(c) **The Adaptive Capacity** that assess the ability of communities to cope with and respond to the hazards (along with the routine risks faced). These inlcude the effectiveness of social networks and their access, the local knowledge/ customs/ practices that helps to cope with the stress/ hazard, community awareness towards the hazards, their ability to mobilize, plan, respond to and learn from the hazard, access to material resources and financial resources, along with access to information etc.

Assessment is mainly qualitative but could be converted to a quantitative scale. For instane the vulnerability assessment carried out by Australian Emergency Management Society suggests a logarithmic table quantifying the qualitative assessment into four levels of susceptibility and four levels of resilience (Very Low, Low, Medium, and High). Vulnerability results due to the combination of susceptibility and resileince. The scale is as follows:

Susceptibility	**Resilience**	**Vulnerability** (Resilience * Susceptibility)

Scale	*Score*	*Scale*	*Score*	*Score*
Very Low	1	High	1	1
Low	2	Medium	2	4
Medium	3	Low	3	9
High	4	Very Low	4	16

Susceptibility is the exposure to danger and *Resilience* is the capacity to recover, while vulnerability is the predisposition of system to suffer damage.

Further, the factors that needs to be assessed for each hazard is also specified.

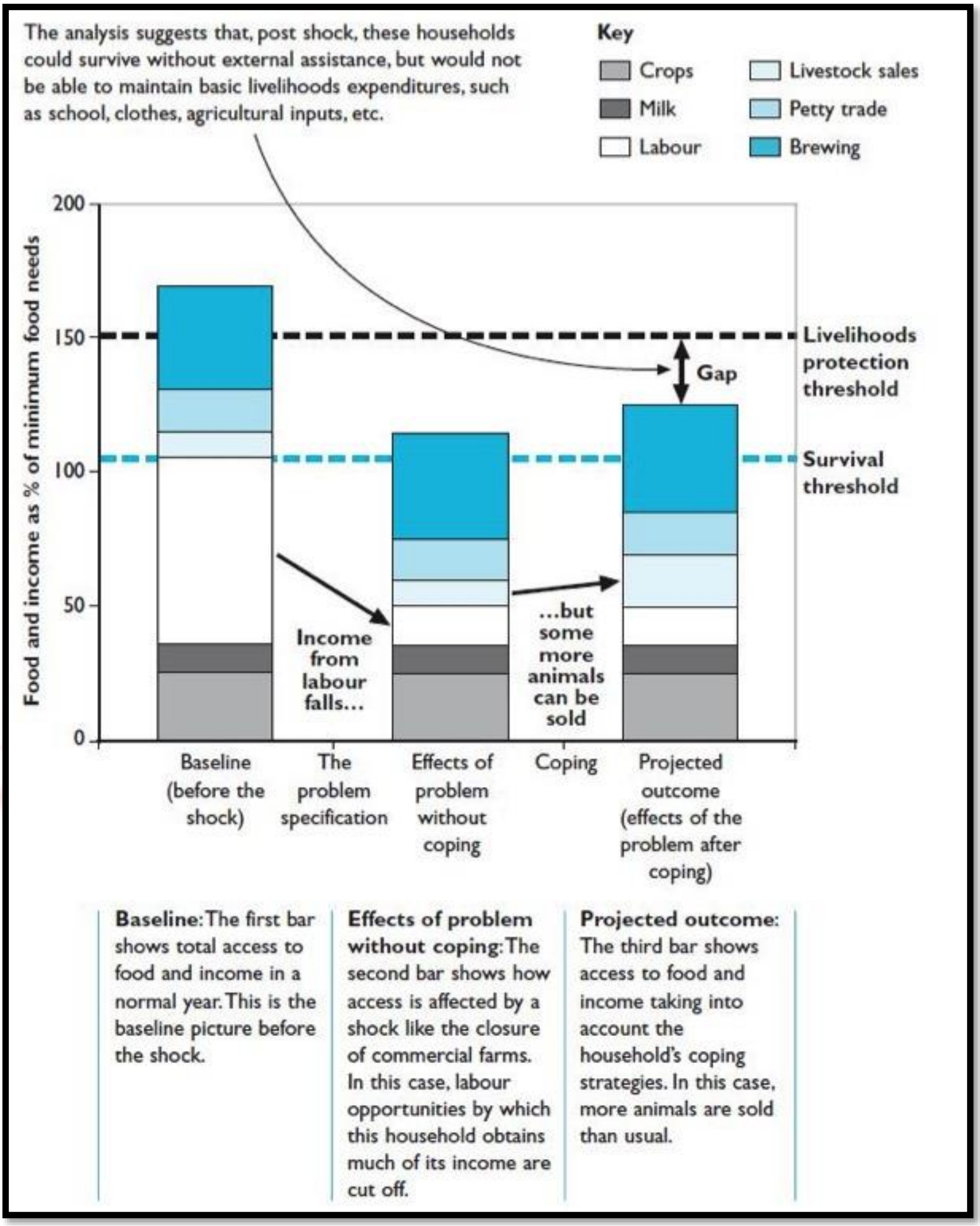
Figure 5 Principle Elements of Vulnerability
Source: (WHO/EHA, 1999)

	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 artefacts
Earthquakes	Weak buildings and their occupants. Machinery and equipment, infrastructure. Livestock. Contents of weak buildings	Social cohesion, community structures, cohesion, cultural artefacts
Volcanic eruption	Anything close to volcano. Crops, livestock, people, combustible roots, water supply.	Social cohesion, community structures, cohesion, cultural artefacts
Land instability	Anything located on or at the base of steep slopes or cliff tops, roads and infrastructure, buildings on shallow foundations	Social cohesion, community structures, cohesion, cultural artefacts
Strong winds	Lightweight buildings and roots. Fences, trees, signs: boats fishing and coastal industries.	Social cohesion, community structures, cohesion, cultural artefacts
Drought/ desertification	Crops and livestock. Agricultural livelihoods	Destruction of the environment. Cultural losses. Possible population disruption.
Technological disasters	Lives of those involved or in the vicinity. Buildings, equipment, infrastructure, crops and livestock	Destruction of the environment. Cultural losses. Possible population disruption.

Socio economic vulnerability assessment

There are few useful models available to carry out the socio-economic vulnerability assessment viz. Household economy approach (HEA), Individual household model (IHM), Household livelihood security analysis (HLSA).
The Household Economy Model for instance could help in performing an outcome anaylsis by investigating how baseline access to food and income could be affected by particular hazard.

Figure 6 The HEA Framework
Source: (HEA)



Using such analysis for operationalization of DRR Efforts is challenging and has lot of difficulties that includes the lack of a common understanding and difficulties in finding metrices to represent.

Physical Vulnerabilities are amongst the most easily identified and assessed. These could be done through Vulnerability scales, building codes, fragility functions etc. on the basis of arriving at typology of buildings and utilizing maximum credible hazard parameters and response functions when damage states have been identified. But significant resources would be required for a multi-hazard physical exposure profiling at different geographical scales.

Unit 3 - Risk Assessment and Approaches

The scientific quantification of risk based on hazard, vulnerability and capacity analysis is called *Risk Assessment*. It involves gathering data of various hazards and on the basis of statistical analysis, predicting the probability of their occurrence and impact in future. The understanding of the causes of disasters and their probable impacts is very important for conducting proper risk assessment.

Once hazard and vulnerability assessment are completed , risk assessment for disasters may be evaluated.

Risk Assessments must be-

(1) **Multi-hazard**: as the same geographical area might be threatened by multiple hazards. It is necessary to identify the range of hazards and impacts on the current infrastructure and planned infrastructure, on different groups of people, and their coping caapcity to bounce back from various hazards
(2) **Multi-sectoral**: Different hazards will impact to different sectors differently. Consequences of drought and that of earthquake to the building stocks would be different. Likewise consequences of drought and earthquakes on agriculture would also be completely different.
(3) **Multi-level**: The risk assessment could be carried out at the ward level, that is integrated to the district level and later the state finally leading to the country's disaster risk assessment
(4) **Multi-stakeholder**: involving relevant stakeholders
(5) **Multi-phase**: considering actions for response, recovery, mitigation, and prevention.

Types of Risk Assessment

(1) **Qualitative Assessment**- describing risks into categories as high, medium and low based on expert judgment
(2) **Semi-Quantitative**- expressing risks in terms of indices based on relative rankings or weights assigned by means of certain criteria
(3) **Quantitative**: expressing risk in quantitative terms as probabilities or as expected losses. Quantitative assessment of risk could be:
    a. **Probabilistic**: expressed as probabilities (0-1) for having predefined loss
    b. **Economic** (as a quantification of expected losses in monetary terms) and the following calculated:
        i. Probable Maximum Loss- the largest loss possible for a particular time period
        ii. Average Annual Loss- The loss when average of losses per year is calculated
        iii. Loss Exceedance Curve- a risk curve plotting the losses against probability for many events
    c. **Population risk** (as a quantification of the risk to population)
        i. Individual risk- risk of fatality/ injury to identified individuals in the

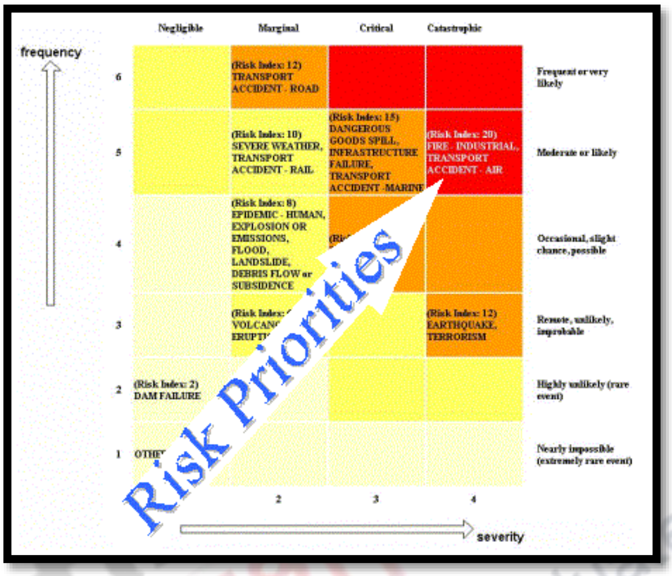
impact area

ii. Societal risk- individual risk extrapolated to a society

An example of quantitatve assessment of risk is the HRVA (Hazard Risk Vulnerability Analysis) Toolkit, which is a comprehensive method utilized for such evaluation. Based on the vulnerability and frequency of occurrence, a matrix of risk for the hazards is developed.

Figure 7 HRVA

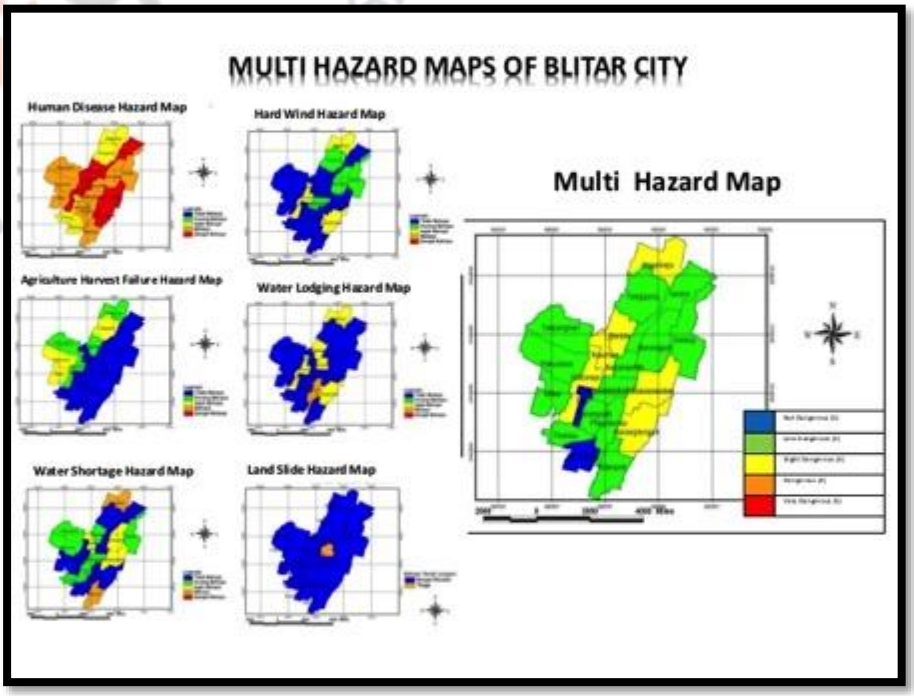
Source (Emergency Management British Columbia, 2004)



An example of semi-quantitative assessment is utilizing GIS (Geospatial Information System), where multi-criteria techniques are utilized. The risk identified qualitatively when represented in spatial method utilizing risk indices by combining vulnerability index and hazard index is such a technique.

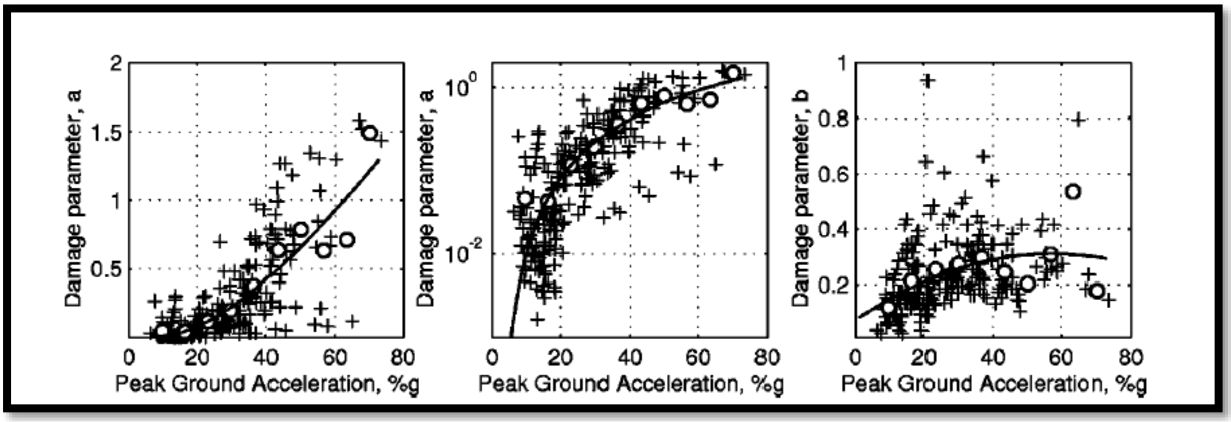
Figure 8 Multi criteria analysis for Risk Assessment

Source: (Ratni, 2014)



Plotting of Vulnerability curves and Fragility curves by utilizing damage functions for earthquake hazard is an instance of quantitative assessment of risk.

Figure 9 Regreession analysis of damage to woodframe buildings in 1994 Northridge Earthquake
Source: (Porter, 2016)



The RADIUS (Risk Assessment Tool for Diagnosis of Urban Areas against Seismic Disasters) tool is a popular tool to analyze earthquake risk. It allows its users to perform a loss estimation using gridded mesh with its accuracy depending on the accuracy of information provided in the modeling.

Necessity of risk assessment

Risk Assessment provides tremendous scope for interventions towards Disaster Risk Reduction. The Sendai Framework for Disaster Risk Reduction (SFDRR) has Understanding Risk as its first priority. The other priorities are strengthening disaster risk governance to manage disaster risk followed by investment in disaster risk reduction for resilience and enhancing disaster preparedness for effective response and "build back better" in recovery, rehabilitation and reconstruction. Three of the 4 priorities require a thorough understanding of risk (risk assessment) which would enable fruitful measures towards disaster risk governance and investment in disaster risk reduction. SFDRR also states that no new risk must be created by any new development project, thereby making risk assessment an important parameter in the design and implementation of development programmes. Investments in development projects have repeatedly been negated by losses due to natural disasters especially in hazard prone areas including the recent Fukushima nuclear tragedy due to the strong earthquake that rocked Japan. A cost benefit analysis could be utilized as a trustworthy tool post a proper risk assessment.

Cost benefit analysis consists of the following steps:

- Estimation of protection costs, and the corresponding future benefits (calculating the current costs for different designs)
- Costing saved lives- which could be difficult as it would try to equate human lives with financial equivalent. Generally, the accepted rule of thumb is that the economic value of a single individual is the discounted sum of her or his expected earnings in her/ his future.

With these in mind and with proper risk assessment goal oriented risk reduction techniques could be designed with the concept of acceptable risk.

The current understanding of vulnerability, coping capacity and resilience of communties play an important role in any development or disaster risk reduction programme. Risk assessment information could be used in the insurance sector for better policies, in the construction sector for the design and modification of building codes, in land-use, land-planning sector for driving investments towards greater resiliency of projects and outcomes, at communtiy level for influencing decision making, preparedness and capacity building. Utilizing risk assessment techniques, we could strategize to reduce the impact of hazards and to prevent their turning into disasters. This could be achieved through better prevention, mitigation, preparedness or risk transfer mechanisms.

Summary

Hazard may be a natural or a man-made event that has the possibility to cause adverse effects. The occurrence of the hazard is not the disaster, but all disasters result due to the exposure of vulnerabilities by hazards.The scientific quantification of risk based on hazard, vulnerability and capacity analysis is called risk assessment.The components of assessing Risk:**Hazard**: The chance/ liklihood/ probability of the occurrence of the potential adverse natural or man-made event; **Exposure**: The location, values and attributes of the assets that are important to the community. It could be the stock of property or infrastructure and **Vulnerability**: Likelihood that the exposed assets would be damaged during the occurrsence of the hazard event. It accounts for the susceptibilitiy of the exposed assets.
Hazard assessment process involves the identification and systematic ranking of all hazards that might affect a location. An Event Tree is an effective method to identify secondary and tertiary hazards that might arise from a primary hazard and prepare accordingly.Event trees explore multiple outcomes that might result from a particular primary hazard as the instigating event. Fault Trees begin from the impacts or consequences and trace back to the possile initiating event (hazard) that could have triggered the impacts.

The concept of Vulnerability is multi-layered. Vulnerability is highly complex and contextual. The drivers of vulnerability are the intinsic human and environmental conditions depending on the resilience of the system, that are sensitive to exposure to the stress induced by the hazard. Useful models are available to arrrive at the socio-economic vulnerability assessment including models like Household economy approach (HEA), Individual household model (IHM), Household livelihood security analysis (HLSA).
An example of quantitatve assessment of risk is The HRVA (Hazard Risk Vulnerability Analysis Toolkit) which is a comprehensive method utilized for such evaluation.
An example of semi-quantitative assessment is utilizing GIS (Geospatial Information System) where multi-criteria techniques are utilized. The RADIUS (Risk Assessment Tool for Diagnosis of Urban Areas against Seismic Disasters) tool is a popular tool to analyze earthquake risk. The Sendai Framework for Disaster Risk Reduction has Understanding Risk as its first priority. Risk assessment information could be used in the insurance sector for better policies, in the construction sector for the design and modifcaiton of building codes, in land-use, land-planning sector for driving investments towards greater resiliency of projects and outcomes, at communtiy level for influencing decision making, preparedness and capacity building.

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