MCN 301
Disaster Management

Module II

Hazards, Vulnerability and Risk

Module II

Hazard types and hazard mapping; Vulnerability types and their assessment- physical, social, economic and environmental vulnerability. Disaster risk assessment –approaches, procedures

Hazard Mapping

- Hazard mapping involves a graphical representation of the location, magnitude and temporal characteristics of hazards on 2 or 3 dimensional surfaces.
- The objective of this it to represent the spatial and temporal characteristics of the hazard as well as its magnitude using graphical symbols.

Different Categories of Hazard

- Hazard can be categorized based on their origin,
  - **Natural:** Phenomena experienced in the physical environment which are harmful to humans and caused by forces for which there is no control.
  - **Human-induced:** Changes of natural processes within the earth's system caused by human activities which accelerate or aggravate damaging events.
  - **Technological:** Dangers caused by technological or industrial accidents, infrastructure failures or certain human activities.

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- Hazards can be single (such as volcanoes and earthquakes), sequential (such as flood) or combined (such as earthquake accompanied by tsunami) and, as a result, causing a flood or torrential rains leading to landslides in their origin.
- Each hazard is categorized by its location, intensity, occurrence, probability, duration, distance, speed of onset, spatial dispersion and temporal spacing.

Data Requirements of Hazard Mapping

- Spatial characteristics such as location, distribution and dimension; temporal (duration and speed of onset) and magnitude are the major data requirements for hazard mapping.
- Sources are;

Base maps

- Base maps represent topographic layers of data such as elevation, roads, water bodies, cultural features and utilities.
- It must be plan metric, ie a representation of information on a plane in true geographic relationship and with measurable horizontal distances.
- It must orient the user to the location of the hazard.

Remotely sensed images

- Satellite images are sources of readily available information of locations on the earth's surface compared to conventional ground survey methods of mapping that are labour intensive and time consuming.
- Depending on the sensor type or capabilities (spatial resolution, spectral resolution, radiometric resolution and temporal resolution), different images may be obtained from different service providers to feed into the information extraction process.

Field data

- Ground surveying methods using electronic survey systems like Total Station, the global positioning systems (GPS) and Laser Scanners, have all greatly increased opportunities for data capture in the field.

Cartographic Representation of Hazard

- Maps are the most operative way to convey actual and relative location.
- Hazard maps not to just convey the existence of natural hazards, but also to note their location, severity, and likelihood of occurrence in an accurate, clear, and convenient way.

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- The application of cartography in hazard mapping will eventually lead to the creation of:
  - ***Base map:*** which contains sufficient geographic reference information to orient the user to the location of the hazard.
  - ***Scale and coverage:*** which draw the relationship between linear measurement on the map and the actual dimension on the ground.
    - Small-scale maps show less detail for a large area and are applicable for regional development planning.
    - Large-scale maps reveal more detail for a small area and are more suitable for local or community level development planning.

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- The choice of scale for a hazard map may consider the following issues:
  - Number of hazards to be displayed at a go;
  - The hazard elements necessary to be displayed;
  - Range of relative severity of hazards to be shown;
  - The area of interest to cover;
  - The use of the map with other planning documents;
  - Function of the map

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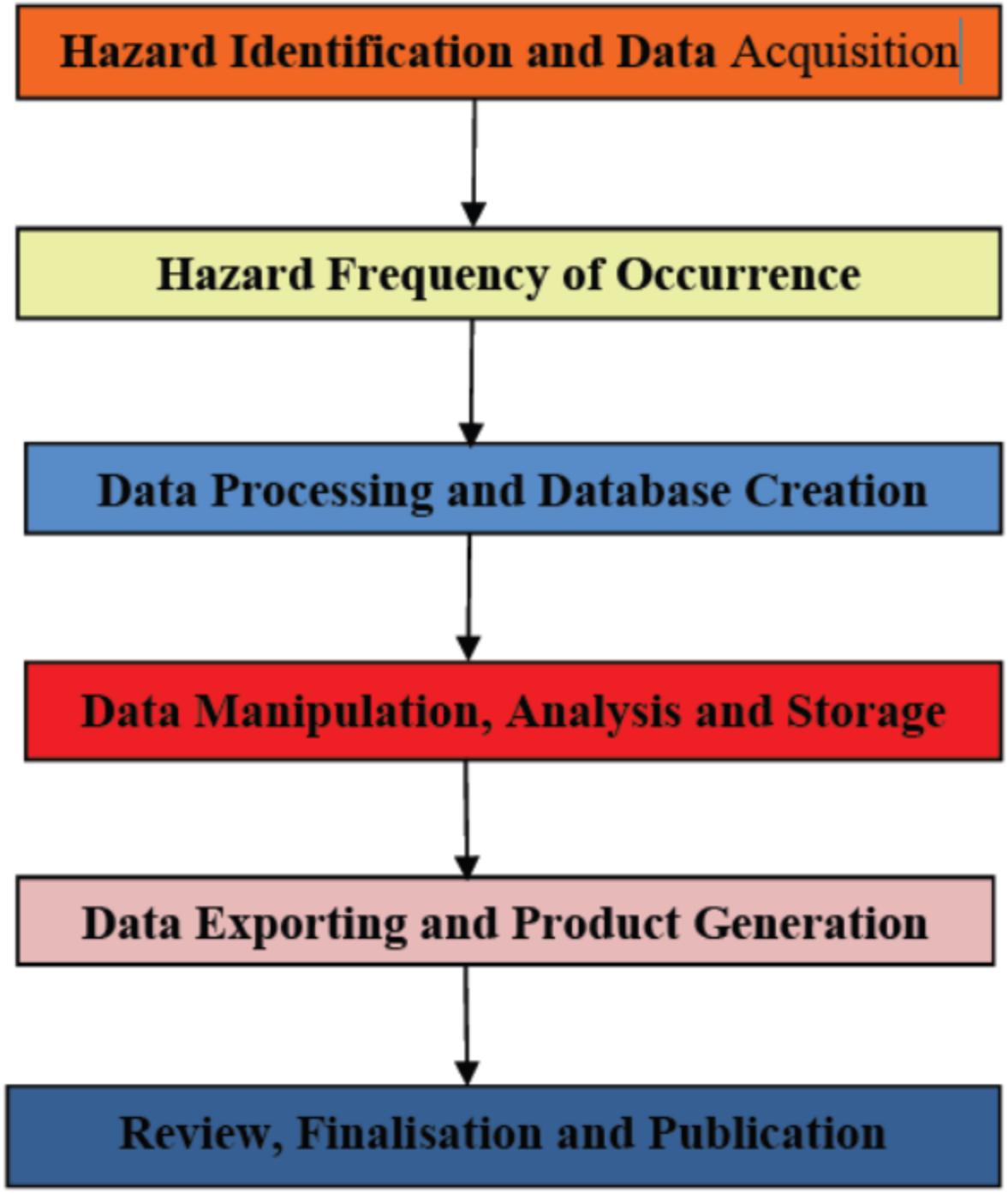
- ***Types of symbols***
  - Symbols are used to represent reality
  - Symbols are selected for their legibility and clarity and/or map production characteristics.
  - Location can be depicted using one of these basic geometric symbols –point, line or an area.
  - Points are more preferred for displaying volcanoes, while areas have been used for showing flooding.

Approaches to Hazard Mapping

- The key factors of consideration in the spatial analysis is appreciating that:
  - All components of a hazard assessment vary in space and time;
  - As the consequences of hazards are usually large, it is prudent to include vulnerability and risk reduction strategies in the process.
- Geographic Information System (GIS) mapping
- Participatory mapping

Hazard mapping using GIS

- GIS provides an excellent basis for processing and presenting hazard information in the form of maps.
- GIS is very useful in arranging a high volume of data necessary to produce a hazard map.
- The three-dimensional representation available in modern GIS offers opportunity to model hazard.


Hazard Identification and Data Acquisition
Hazard Frequency of Occurrence
Data Processing and Database Creation
Data Manipulation, Analysis and Storage
Data Exporting and Product Generation
Review, Finalisation and Publication

Participatory mapping

- Participatory mapping is a technique that allows for the integration of local level participation and knowledge in the map production and decision taken process.
- It is an interactive process that draws on local people's knowledge and allows them to create visual and non-visual data to explore social problems, opportunities and questions.

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- The main objectives are to:
  - Collect evidence assets of the study area and issues during the mapping process;
  - Interpret the study area mapping experience and related experience to answer questions that have been developed about the study area;
  - Develop a presentation that synthesises the participatory mapping experience and presents the conclusion and possible questions for further investigation.

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- **Steps**
  - Outlines the nature and essence of activities to be done.
  - Organize the activities of participatory mapping in two blocks –preparation and implementation.
  - The preparation involves 'scouting' and 'designing survey instrument, materials and directions'.
  - The implementation may be organised into sessions-preparation of participants; undertake participatory mapping field trip; make presentations and carry out debriefing exercises.

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- **Utilisation of Participatory Mapping**
  - To create maps that represent resources, hazards, community values, usage, perceptions, or alternative scenarios
  - To gather traditional knowledge and practices and to collect information for assessments or monitoring
  - To identify data gaps.
  - To inform other data collection methods
  - To evaluate existing programmes, plans and activities
  - To facilitate the decision-making process
  - To assist with data gathering for research
  - To empower stakeholders
  - To conduct trend analysis
  - To educate stakeholders about issues and interrelationships of resources outside their immediate areas of concern

Applications of Hazard Maps

- Spatial planning
  - Provide a basis for communal and district spatial planning processes (e.g. definition of hazard zones in development plans and formulation of building regulations).
- Risk reduction measures
  - Assist in the localisation and dimensioning of hazard protection measures (e.g. flood protection structures, avalanche barriers, etc.)
- Instruments used in emergency planning
  - Indicate where the biggest risks arise and the events most likely to occur.
  - This information can be used as a source of orientation in emergency planning.
- Raising awareness among the population.
  - Help to demonstrate potential risks to the population and to increase awareness of eventual protective measures.

Vulnerability

Vulnerability

- Vulnerability was defined as the degree to which a system is exposed and susceptible to the adverse effects of a given hazard.

Vulnerability = (Exposure) + (Resistance) + Resilience

Where

- Exposure: Property and Population at risk
- Resistance: Measures taken to prevent, avoid or reduce loss
- Resilience: Ability to recover prior state or achieve desired post-disaster state.

Types of Vulnerability

- **Physical vulnerability**
  - This refers to the potential losses to physical infrastructure such as roads, bridges, railways, radio and telecommunication mast and other features in the built environment.
  - Also includes impacts on the human population in terms of injuries or deaths.
- **Social vulnerability**
  - Social vulnerability refers to losses as experienced by people and their social, economic, and political systems
    - Vulnerability refers to the extent to which elements of society such as children, the aged, pregnant and lactating women, single parents, physically and mentally challenged, the poor and destitute, social class, caste, ethnicity, gender, family systems, political systems, economic systems and cultural values degrade after being exposed to a hazardous condition.

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- **Economic vulnerability**
  - This refers to the potential impacts of hazards on economic assets and processes and includes vulnerability of different economic sectors.
- **Ecological/environmental vulnerability**
  - This refers to the degree of loss that an ecosystem will sustain to its structure, function and composition as a result of exposure to a hazardous condition.

Vulnerability Assessment

- This refers to the quantification of the degree of loss or susceptibility to an element at risk.
- Variations exist in the method of quantification of vulnerability based on the following:
  - Type of vulnerability being measured
  - The scale at which vulnerability is being measured
  - The type of hazard.

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- ***Data needed for vulnerability assessment and their usefulness***
  - Historical data on the magnitude of a hazard and the level of damage it caused
  - Socio-economic data such as level of education, social networks, sanitation, income level, access to land, access to technology etc
  - Level of exposure to hazardous conditions
  - Data on policies, institutions and processes which influence capacity of individuals, households and communities

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- **Approaches to Physical Vulnerability Assessment**
  - There are a wide variety of ways to measure physical vulnerability.
  - Two main methods are the empirical and analytical methods.
    - The empirical methods can be applied to groups of related structures.
    - The analytical methods rely on the use of geotechnical engineering software and are often limited to individual structures

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- Analysis of observed damage
- Empirical methods
  - Expert opinion
  - Score Assignment
- Analytical models
  - Simple Analytical models
  - Detailed Analytical methods

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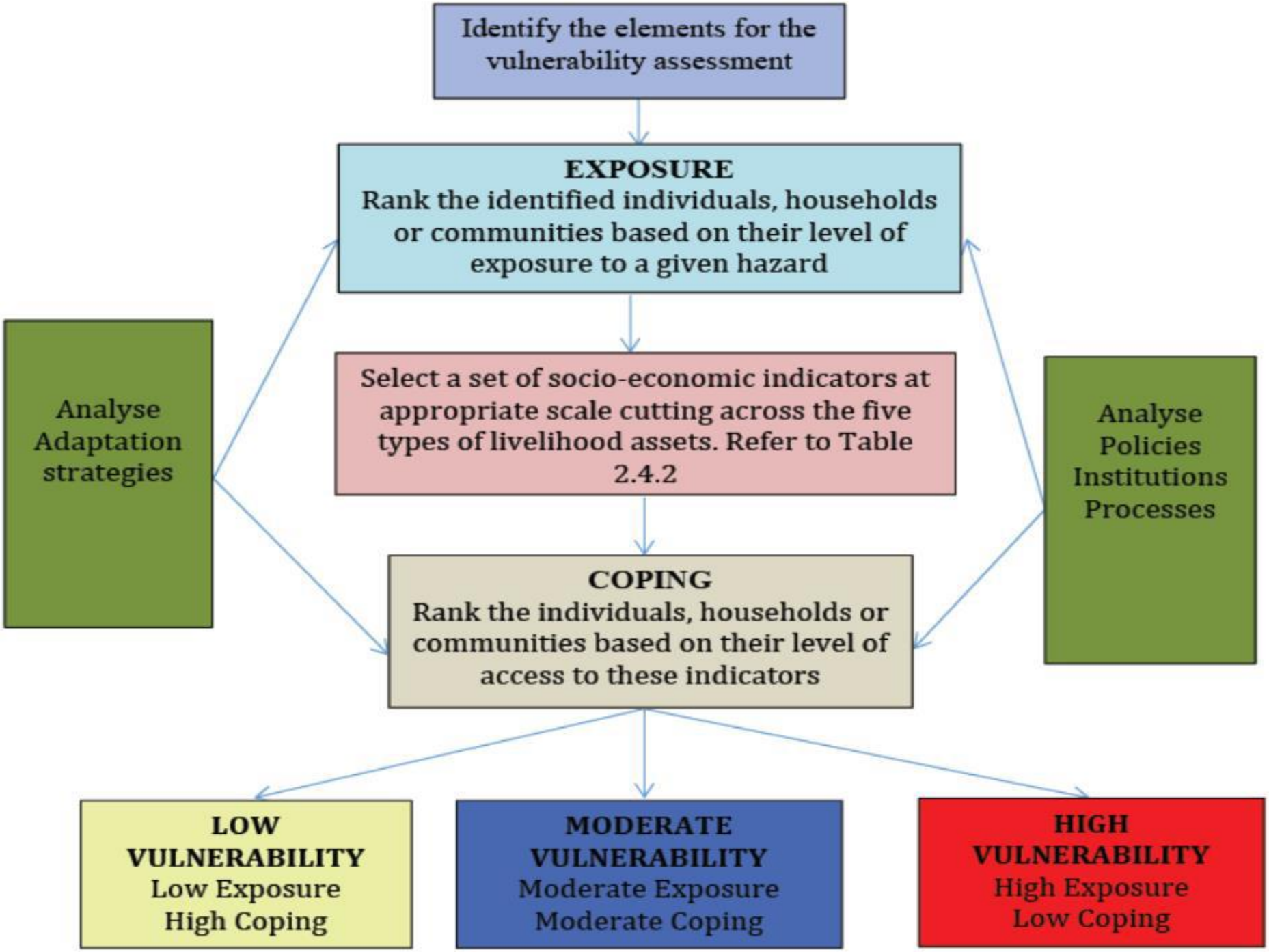
- **Methods of Measuring Socio-economic Vulnerability**
  - Socio-economic vulnerability is indicator-based and can be assessed by analysing the level of exposure and coping mechanisms of individuals, households and communities.


Identify the elements for the vulnerability assessment
EXPOSURE
Rank the identified individuals, households or communities based on their level of exposure to a given hazard
Select a set of socio-economic indicators at appropriate scale cutting across the five types of livelihood assets. Refer to Table 2.4.2
Analyse Adaptation strategies
Analyse Policies Institutions Processes
COPING
Rank the individuals, households or communities based on their level of access to these indicators
LOW VULNERABILITY
Low Exposure
High Coping
MODERATE VULNERABILITY
Moderate Exposure
Moderate Coping
HIGH VULNERABILITY
High Exposure
Low Coping

Human Capital	Natural Capital	Social Capital	Physical Capital	Financial Capital
Health	Land and produce	Networks and connections	Infrastructure • Transport - roads, vehicles, etc. • Secure shelter & buildings water supply & sanitation	Savings
			• Energy communications	
Nutrition	Water & aquatic resources	Patronage	Tools and technology • Tools and equipment for production • Seed, fertiliser, pesticides • Traditional technology	Credit/debt - formal, informal, NGOs
Education	Forest products	Neighbourhoods		Remittances
Knowledge and skills	Wildlife	Kinship		Pensions
Capacity to work	Wild foods & fibres	Relations of trust and mutual support		Wages
Capacity to adapt	Biodiversity	Formal and informal groups		Dividends
	Environmental services	Common rules and sanctions		Return on Investments

Methods of Representing Vulnerability

- **Vulnerability indices**: Based on indicators of vulnerability
- **Vulnerability table**: The relation between hazard intensity and degree of damage can also be given in a table.
- **Vulnerability curves**: These are constructed on the basis of the relation between hazard intensities and damage data
  - Relative curves: They show the percentage of property value as the damaged share of the total value to hazard intensity.
  - Absolute curves: Show the absolute amount of damage depending on the hazard intensity
  - Fragility curves: Provide the probability for a particular group of
  - elements at risk to be in or exceeding a certain damage state under a given hazard intensity.

Disaster Risk Assessment

Disaster Risk

- The probability of serious damage, deaths and injuries occurring as a result of a potentially damaging hazard interacting with vulnerable elements such as people and properties.

Disaster Risk Assessment

- It is a methodology to determine the likelihood and magnitude of damage or other consequences by analysing potential hazards and evaluating existing conditions of vulnerability that jointly could likely harm exposed people, properties, services, livelihoods and the environment they depend on.

Components of Risk Assessment

- Risk analysis: The use of available information to estimate the risk caused by hazards to individuals or populations, property or the environment.
- It contains the following steps:
  - Hazard identification,
  - Hazard assessment,
  - Elements at risk/exposure,
  - Vulnerability assessment and
  - Risk estimation.
- Risk evaluation: This is the stage at which values and judgement enter the decision process by including the importance of the risk and associated social, environmental, in order to identify a range of alternatives for managing the risk.

Contemporary Approaches to Risk Assessments

- Multi-hazard:
  - The same area may be threatened by different types of hazards.
  - Each of these hazard types has different areas that might be impacted by hazard scenarios.
  - Each of the hazard scenarios also might have different magnitudes.
- Multi-sectoral:
  - Hazards will impact different types of elements at risk.

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- Multi-level:
  - Risk assessment can be carried out at different levels.
  - Depending on the objectives of the risk study, it is possible to differentiate between national, regional, district and local policies, plans and activities to see how they have contributed to increased or reduced risk, their strengths and weaknesses in dealing with risks, and what resources are available at the different levels to reduce risks.
- Multi-stakeholder:
  - Risk assessment should involve the relevant stakeholders, which can be individuals, businesses, organisations and authorities.
- Multi-phase:
- Risk assessment should consider actions for response, recovery, mitigation and preparedness.

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- Qualitative methods:
  - This involves qualitative descriptions or characterization of risk in terms of high, moderate and low.
  - These are used when the hazard information does not allow us to express the probability of occurrence, or it is not possible to estimate the magnitude.
  - Risk matrices can be constructed to show qualitative risk.
  - A risk matrix shows on its y-axis probability of an event occurring, while on the x-axis potential loss.

A risk matrix

Loss

Based on the potential by taking into account elements at risk

- Fatalities
- Injuries
- Impact on facilities, critical services and infrastructure
- Property damage
- Business interruption
- Environmental/ Economic impact

Risk levels

A: Very high. Frequent events causing very high losses, or moderate frequent events causing very high losses

B: High. Frequent events with moderate losses/ moderate & low frequent events causing (very) high losses

C: Moderate. Frequent events with low losses or very low frequent events causing (very) high losses

D: Low. Low frequency events with low losses

Probability

High	Events that occur more frequently than once in 10 years
Moderate	Events that occur from once in 10 years to once in 100 years
Low	Events that occur from once in 100 years to once in 1000 years
Very Low	Events that occur less frequently than once in 1000 years

Potential Hazards

Earthquake	Lightening	Debris Flow	Civil unrest
Flood	Heat Wave	Hazardous materials release	Terrorism
Fire	Drought	Transportation accident	Market fires
Storms	Pandemic (e.g., HIV/AIDS, flu)		
Fire		Water shortage	
Food poisoning	Landslide	Power shortage	

Risk Assessment Matrix

A. Hazards	B. Hazard Likelihood **0 low – 5 is high**	C. Impact Severity **(Vulnerabilities/ Resources) 0 is low – 5 is high**	D. Risk Score **B x C** E. Priority	E. Priority

In Column A, enter all of those hazards that may affect your community.

In Column B, the likelihood of occurrence of this event (between 0 low to 5 high)

HAZARDS	1	2	3	4	5
B. Likelihood	Very low	Low	Medium	High	Very high

In Column C, enter the severity of the impact you expect. This would be based on your understanding of the various vulnerabilities and the measures your community has already taken to reduce them.

Vulnerability	1	2	3	4	5
C. Impact severity	Minor	Controllable	Critical	Devastating	Terminal

In Column D, Multiply your likelihood by impact rating. Column B x C. This would give you your risk score

Risk score	1-3	4-8	9-14	15-19	20-25
Description	Very low	Low	Medium	High	Very high

In Column E, convert your risk scores into simple priority scores. 3-Low, 2-medium, 1-high

Risk score	1-3	4-8	9-14	15-19	20-25
Priority level	3	3	2	1	1
Description	Low		Medium	High	

Semi-quantitative Methods

- These techniques express risk in terms of risk indices.
- These are numerical values, often ranging between 0 and 1.
- The main difference between qualitative and semi-quantitative approaches is the assignment of weights under certain criteria which provide numbers as outcome instead of qualitative classes.

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- The semi quantitative estimation for risk assessment is found useful in the following situations:
  - As an initial screening process to identify hazards and risks
  - When the level of risk does not justify the time and effort
  - Where the possibility of obtaining numerical data is limited
- This approach could be adapted to cover larger areas.
- Semi-quantitative risk can also be conceptualised as:

  Risk = Hazard * Vulnerability / Capacity

- It allows incorporating the multi-dimensional aspects of vulnerability, and capacity.

Quantitative Methods

- This aims at estimating the spatial and temporal probability of risk and its magnitude.
- Risk is perceived as follows:

$$\text{Risk} = \text{Hazard} * \text{Vulnerability} * \text{Amount of elements-at- risk}$$

- The amount of elements-at-risk are characterized the way in which the risk is presented.
- The hazard component in the equation actually refers to the probability of occurrence of a hazardous phenomenon with a given intensity within a specified period of time.
- Vulnerability is limited to physical vulnerability of the elements-at-risk considered,
- determined by the intensity of the hazard event and the characteristics of the elements at-risk

Different ways of Expressing Risk

- Qualitative
  - Qualitative
  - Semi-Quantitative
- Quantitative
  - Probability
  - Economic risk
  - Population risk

General	Type	Principle	
Qualitative	**Qualitative**	Based on relative risk classes categorised by expert judgment. Risk classes: High, Moderate and Low	
	Semi-Quantitative	Based on relative ranking and weights assignments by a given criteria. Risk index: Ranked values (0-1, 0-10 or 0-100). (dimensionless)	
Quantitative	**Probability**	Probabilistic values (0-1) for having a predefined loss over a particular time period	
	Economic risk	Quantification of the expected losses in monetary values over a specific period of time	
		Probable Maximum Loss (PML)	Probable Maximum Loss (PML) The largest loss believed to be possible in a defined return period, such as 1 in 100 years, or 1 in 250 years
		Average Annual Loss (AAL)	Expected loss per year when averaged over a very long period (e.g., 1,000 years). Computationally, AAL is the summation of products of event losses and event occurrence probabilities for all stochastic events in a loss model.
		Loss Exceedance Curve (LEC)	Risk curve plotting the consequences (losses) against the probability for many different events with different return periods.
	Population risk	Quantification of the risk to population	
		Individual risk	The risk of fatality or injury to any identifiable (named) individual who live within the zone impacted by a hazard; or follows a particular pattern of life that might subject him or her to the consequences of a hazard.
		Societal risk	The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a hazard causing a number of deaths, injury, financial, environmental, and other losses.