Overview

1. Concept of Disaster

A **disaster** is a serious disruption of the functioning of a community or society involving widespread human, material, economic, or environmental losses and impacts. It exceeds the ability of the affected community to cope using its own resources. Disasters result from the combination of hazards, exposure, and vulnerability.

Definitions:

- **UNDRR (United Nations Office for Disaster Risk Reduction):** *A disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.*

Key Characteristics:

- **Sudden or progressive onset** (e.g., earthquake vs. drought)
- **Overwhelms local capacity**
- **Causes significant damage or loss**
- **Requires emergency response or external assistance**

Disaster vs. Hazard:

- A **hazard** becomes a **disaster** when it impacts a vulnerable population or system and causes significant disruption or loss.

2. Different Approaches to Understanding Disasters

Disasters are complex phenomena and require a multidisciplinary approach to understand and manage effectively.

a. Natural Science Approach:

Focuses on understanding natural phenomena like earthquakes, floods, cyclones, and volcanic eruptions through geophysical, meteorological, and hydrological processes. It emphasizes predicting hazards and understanding their magnitude and patterns.

b. Engineering Approach:

Deals with designing infrastructure and systems to withstand disasters. Includes structural engineering, seismic design, resilient infrastructure, and safe construction practices.

c. Social Science Approach:

Studies the social, cultural, economic, and political factors that influence vulnerability and resilience. Emphasizes poverty, education, governance, social networks, and inequality in disaster impacts.

d. Developmental Approach:

Links disasters with development failures. Poor planning, urbanization without infrastructure, and unregulated land use increase disaster risk. Promotes sustainable and inclusive development to reduce disaster vulnerability.

e. Environmental Approach:

Emphasizes the role of environmental degradation in amplifying disasters. Deforestation, loss of wetlands, and climate change increase the frequency and intensity of disasters like floods and droughts.

f. Integrated/Holistic Approach:

Combines all the above. Advocates for comprehensive disaster risk reduction strategies that address hazards, reduce vulnerability, increase resilience, and improve early warning, preparedness, and recovery.

3. Concept of Risk

Disaster risk is the potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society, or community in a specific period of time, determined probabilistically.

Risk Equation:

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \times \text{Exposure}$$

- **Hazard**: Potentially damaging event.
- **Vulnerability**: Conditions increasing susceptibility to damage.
- **Exposure**: People, property, systems, or other elements present in hazard zones.

Types of Risks:

- **Physical risk** (e.g., infrastructure collapse)
- **Social risk** (e.g., community isolation)
- **Economic risk** (e.g., loss of livelihood)
- **Environmental risk** (e.g., deforestation, contamination)

4. Levels of Disasters

Disasters vary in scale and required response. In India, the classification is:

a. Level 1 Disaster

- Localized events manageable by district administration.
- Example: small floods, localized fire.

b. Level 2 Disaster

- Require state-level intervention and coordination.
- Example: large flood, moderate earthquake.

c. Level 3 Disaster

- Major disaster needing central/national level intervention.
- Example: Gujarat Earthquake (2001), Kerala Floods (2018).

d. Level 4 Disaster (International Level)

- Require international assistance or coordination.
- Example: Indian Ocean Tsunami (2004), COVID-19 pandemic.

5. Disaster Phenomena and Events

a. Global Events

- **Indian Ocean Tsunami (2004)** – Affected 14 countries, over 230,000 deaths.
- **Hurricane Katrina (2005, USA)** – Devastating cyclone causing widespread damage in New Orleans.
- **COVID-19 Pandemic (2019–)** – Global health disaster with long-term socio-economic impacts.

b. National Events (India)

- **Gujarat Earthquake (2001)** – Over 20,000 deaths, widespread destruction.
- **Uttarakhand Flash Floods (2013)** – Triggered by cloudburst and glacial lake outburst.
- **Bhopal Gas Tragedy (1984)** – World's worst industrial disaster.

c. Regional Events

- **Assam and Bihar Annual Floods** – Affect millions yearly.

- **Landslides in Himachal and Uttarakhand** – Frequent due to fragile geology and monsoon.
- **Urban Floods in Mumbai (2005) and Chennai (2015)** – Caused by poor urban planning and extreme rainfall.

6. Hazards and Vulnerabilities

A. Hazards

Natural Hazards:

- **Hydrological:** Floods, flash floods
- **Meteorological:** Cyclones, storms
- **Geological:** Earthquakes, tsunamis, landslides
- **Biological:** Epidemics, pandemics
- **Climatological:** Droughts, heatwaves

Man-Made Hazards:

- **Industrial accidents:** Chemical leaks (e.g., Bhopal)
- **Technological hazards:** Power grid failure, nuclear disasters
- **Human-induced:** Terrorism, arson, war

B. Vulnerabilities

Factors Influencing Vulnerability:

1. **Physical Vulnerability:** Poor construction, location in hazard zones
2. **Social Vulnerability:** Lack of education, health care, and community support
3. **Economic Vulnerability:** Poverty, loss of livelihood
4. **Environmental Vulnerability:** Deforestation, poor land use
5. **Institutional Vulnerability:** Poor governance, lack of early warning systems

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Summary Table: Hazard Characteristics

Hazard Type	Forewarning	Frequency	Response Time	Damage Potential
Earthquake	Very low	Moderate	Seconds	Very high
Flood	Moderate	High	Hours to days	High
Cyclone	High	Seasonal	Days	High
Landslide	Low	Localized	Minutes	Medium to high
Industrial Accident	Low	Rare	Minutes	Very high

Natural and Man-Made Hazards: Response Time, Frequency, and Forewarning Levels

1. Introduction to Hazards

A **hazard** is a potentially damaging physical event, phenomenon, or human activity that may cause loss of life, injury, property damage, social and economic disruption, or environmental degradation. Hazards are typically classified into **natural** and **man-made** types.

2. Natural Hazards

Natural hazards arise from natural processes in the environment. They can be **geophysical**, **hydrological**, **meteorological**, **climatological**, or **biological**.

Types of Natural Hazards:

Hazard Type	Description
Earthquake	Sudden shaking of the ground due to tectonic movements.
Flood	Overflow of water onto normally dry land, often caused by heavy rains.
Cyclone	Large storm systems characterized by strong winds and heavy rain.
Drought	Long-term deficiency of rainfall leading to water scarcity.
Landslide	Sudden movement of rock/soil down a slope.
Tsunami	Large sea waves caused by underwater earthquakes or volcanic activity.
Volcanic Eruption	Discharge of lava, ash, and gases from a volcano.
Heatwave/Coldwave	Prolonged period of excessive heat or cold temperatures.
Pandemics	Widespread outbreaks of infectious diseases (e.g., COVID-19).

3. Man-Made (Anthropogenic) Hazards

Man-made hazards result from human activities, technological failures, or negligence. These may be sudden or slow in onset.

Types of Man-Made Hazards:

Hazard Type	Description
Industrial Accidents	Chemical spills, gas leaks, explosions (e.g., Bhopal gas tragedy).
Fires	Urban or forest fires caused by human actions or negligence.
Nuclear Accidents	Release of radioactive materials (e.g., Chernobyl, Fukushima).
Transport Accidents	Rail, air, or road traffic accidents.
Structural Failures	Building or dam collapses due to design or maintenance issues.
War and Terrorism	Armed conflicts, bombings, and attacks disrupting civilian life.
Environmental Degradation	Pollution, deforestation, and climate change effects.

4. Response Time, Frequency, and Forewarning Levels

These three characteristics are critical in understanding the impact and management strategy for each hazard.

Key Terms:

- **Response Time**: Time available between the onset of the hazard and the impact.
- **Frequency**: How often the hazard occurs (high, moderate, or low).
- **Forewarning Level**: The extent to which advance warning is possible (high, moderate, or low).

5. Implications for Disaster Management

- **High Forewarning + Long Response Time** → Focus on evacuation and preparation (e.g., cyclones, droughts).
- **Low Forewarning + Short Response Time** → Emphasis on resilient infrastructure and emergency response (e.g., earthquakes, industrial accidents).
- **Frequent Hazards** → Require long-term mitigation strategies and community preparedness (e.g., floods, urban fires).
- **Rare Hazards** → May cause complacency; require drills, monitoring, and robust design (e.g., tsunamis, dam failures).

Comparative Table: Natural and Man-Made Hazards

Hazard	Type	Response Time	Frequency	Forewarning Level	Remarks
Earthquake	Natural	Seconds	Moderate	Very Low	No reliable short-term prediction available.
Flood	Natural	Hours to Days	High	Moderate to High	Forecasts possible via weather and river data.
Cyclone	Natural	Days	Seasonal	High	Accurate tracking by meteorological satellites.
Drought	Natural	Months	Low to Moderate	High	Long-term monitoring needed.
Landslide	Natural	Minutes to Hours	Moderate (local)	Low	Triggered by rain, earthquakes, or deforestation.
Tsunami	Natural	Minutes to Hours	Rare	Low to Moderate	Early warning possible after seismic event.
Volcanic Eruption	Natural	Minutes to Days	Rare	Moderate	Monitoring systems can predict increased risk.
Heatwave	Natural	Days	Seasonal	High	Predictable during weather extremes.
Pandemic	Natural	Weeks to Months	Rare	Low initially	Surveillance and early detection can help.
Industrial Accident	Man-Made	Minutes	Rare to Moderate	Low	Depends on safety standards and regulation.
Fire (Urban)	Man-Made	Minutes	High	Low	High in densely populated areas.
Nuclear Accident	Man-Made	Minutes to Hours	Very Rare	Low	Needs robust safety protocols.
Transport Accident	Man-Made	Instantaneous	High	Very Low	Most are unpredictable.
Terrorist Attack	Man-Made	Minutes	Rare	Very Low	Requires intelligence-based preparedness.
Dam Failure	Man-Made	Minutes to Hours	Very Rare	Low	Often caused by poor maintenance or extreme load.

Characteristics and Damage Potential of Natural Hazards; Hazard Assessment

1. Introduction

Natural hazards are extreme natural events that have the potential to cause harm to life, property, infrastructure, and the environment. Understanding their **characteristics** and **damage potential** is vital for planning, designing resilient infrastructure, and managing disasters effectively.

2. Characteristics of Natural Hazards

Each type of natural hazard exhibits unique physical and behavioral features. The **key characteristics** common to most natural hazards include:

A. Origin and Cause

- Result from natural processes such as tectonic movements (earthquakes), meteorological phenomena (cyclones), hydrological events (floods), or climatic imbalances (droughts).

B. Speed of Onset

- **Sudden-onset hazards** (e.g., earthquakes, flash floods): minimal or no warning.
- **Slow-onset hazards** (e.g., droughts, pandemics): develop over days, weeks, or months.

C. Duration

- Varies widely depending on the type of hazard:
  - Earthquake: seconds to a few minutes
  - Floods: days to weeks
  - Drought: months to years

D. Frequency and Recurrence

- Hazards may be seasonal (cyclones), rare (tsunamis), or frequent (floods in certain regions).

E. Forewarning and Predictability

- Some hazards are easier to forecast (e.g., cyclones, floods) due to advancements in technology.
- Others are difficult to predict (e.g., earthquakes, landslides).

F. Spatial Extent (Areal Coverage)

- Localized (e.g., landslides) or widespread (e.g., drought, cyclones).

G. Intensity and Magnitude

- Measured using specific scales:
    - Earthquakes: Richter/Moment Magnitude Scale (Mw)
    - Cyclones: Saffir–Simpson Scale
    - Floods: Water discharge and inundation depth

H. Interaction with Human Systems

- The severity of impact depends on population density, infrastructure vulnerability, preparedness, and environmental condition.

3. Damage Potential of Natural Hazards

Natural hazards cause different types of **direct**, **indirect**, and **secondary** damages:

A. Earthquakes

- **Characteristics:** Sudden ground shaking due to fault rupture.
- **Damage Potential:**
    - Collapse of buildings and bridges
    - Landslides and liquefaction
    - Fires and utility failure
    - Casualties and trauma
- **Affected Areas:** Himalayan belt, Indo-Gangetic plains, NE India

B. Floods

- **Characteristics:** Overflow of water submerging land.
- **Damage Potential:**
    - Destruction of homes and crops
    - Waterborne diseases
    - Infrastructure damage
    - Displacement and livelihood loss
- **Affected Areas:** Ganga-Brahmaputra basin, coastal areas

C. Cyclones (Hurricanes/Typhoons)

- **Characteristics:** Rotating storm systems with strong winds and heavy rain.
- **Damage Potential:**
    - Wind damage to buildings

    - Coastal flooding (storm surge)
    - Communication and power disruption
    - Agriculture and fishery damage
- **Affected Areas:** East coast of India (Odisha, AP, Tamil Nadu)

D. Droughts

- **Characteristics:** Prolonged period of rainfall deficiency.
- **Damage Potential:**
    - Crop failure and food insecurity
    - Water scarcity
    - Economic slowdown in agriculture-dependent regions
- **Affected Areas:** Rajasthan, Maharashtra, interior Karnataka

E. Landslides

- **Characteristics:** Mass movement of soil or rock downslope.
- **Damage Potential:**
    - Blockage of roads and rivers
    - Burial of structures
    - Disruption in transportation and communication
- **Affected Areas:** Western Ghats, Himalayan regions

F. Tsunamis

- **Characteristics:** Sea waves triggered by undersea earthquakes.
- **Damage Potential:**
    - Inundation of coastal areas
    - High mortality and property loss
    - Salinization of soil and water
- **Affected Areas:** Andaman-Nicobar Islands, eastern coastal belt

G. Volcanic Eruptions *(less relevant in India)*

- **Characteristics:** Eruption of lava, ash, gases.
- **Damage Potential:**
    - Lava flow destruction
    - Air quality deterioration
    - Global climate effects

4. Hazard Assessment

Hazard Assessment refers to the process of identifying and evaluating the probability and potential severity of a hazardous event in a particular geographic area.

A. Objectives:

- Identify the **nature**, **location**, **intensity**, and **frequency** of hazard events.
- Understand potential consequences on people, property, and ecosystems.
- Guide planning, zoning, building design, and preparedness.

B. Steps in Hazard Assessment:

1. **Hazard Identification**
    - What hazards can occur in the area? (e.g., floods, earthquakes)
    - Use historical data, geological surveys, and local knowledge.
2. **Frequency Analysis**
    - How often do these hazards occur?
    - Use statistical tools and historical event records (e.g., return period analysis).
3. **Intensity and Severity Analysis**
    - Measure hazard strength using scientific tools:
        - Earthquake: seismic zoning, ground acceleration
        - Flood: floodplain mapping, discharge volume
        - Cyclone: wind speed, pressure systems
4. **Spatial Mapping**
    - Use GIS and remote sensing to create hazard maps
    - Identify high-risk zones (e.g., flood-prone areas, seismic zones)
5. **Temporal Analysis**
    - Determine when hazards are likely to occur (e.g., seasonal floods)
    - Understand peak periods and potential for cascading effects
6. **Modeling and Simulation**
    - Use hydrological or seismic simulation models
    - Predict impacts under different scenarios

C. Tools and Techniques

- **Remote Sensing (RS)**
- **Geographic Information Systems (GIS)**
- **Global Positioning System (GPS)**
- **Hydrological and Climatological Models**
- **Historical Disaster Databases**

D. Outcome of Hazard Assessment

- Hazard maps and zoning regulations
- Risk-informed infrastructure design
- Early warning systems and response planning
- Improved land use and environmental planning

5. Case Example: Earthquake Hazard Assessment in India

- **Seismic Zonation Map of India** classifies regions into Zones II to V:
  - **Zone V:** Very high risk (e.g., NE India, parts of Kashmir, Kutch)
  - **Zone IV:** High risk (e.g., Delhi, Chandigarh)
  - **Zone III:** Moderate risk (e.g., Mumbai, Chennai)
  - **Zone II:** Low risk
- Parameters considered:
  - Peak Ground Acceleration (PGA)
  - Soil amplification
  - Building typology

Dimensions of Vulnerability Factors and Vulnerability Assessment

1. Introduction

Vulnerability refers to the degree to which a system, community, or individual is likely to experience harm due to exposure to a hazard. It is a **key component** of disaster risk, along with hazard and exposure.

Definition (UNDRR):

Vulnerability is the conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

2. Dimensions of Vulnerability Factors

Vulnerability is **multi-dimensional**, influenced by a wide range of factors that shape how individuals or communities experience and recover from disasters.

A. Physical Vulnerability

- Refers to the susceptibility of physical structures and infrastructure.
- **Factors:**
  - Building quality and materials
  - Proximity to hazard zones (floodplains, fault lines)
  - Inadequate infrastructure (e.g., poor drainage in flood-prone areas)
- **Example:** Kutcha houses in seismic zones are more vulnerable to earthquakes.

B. Social Vulnerability

- Relates to the social characteristics that affect the capacity to respond and recover.
- **Factors:**
    - Age, gender, disability, caste
    - Education and awareness
    - Population density and migration
    - Access to social support networks
- **Example:** Elderly people living alone may not evacuate quickly during a cyclone.

C. Economic Vulnerability

- Indicates the level of economic resilience and dependence on affected sectors.
- **Factors:**
    - Income levels and employment type
    - Access to financial services (insurance, credit)
    - Asset ownership and savings
    - Informal economy reliance
- **Example:** Daily wage laborers lose livelihoods instantly during disasters.

D. Environmental Vulnerability

- Results from environmental degradation or poor resource management.
- **Factors:**
    - Deforestation and soil erosion
    - Poor land-use planning
    - Depletion of natural buffers (mangroves, wetlands)
- **Example:** Deforested hills are more prone to landslides during heavy rain.

E. Institutional/Political Vulnerability

- Reflects the strength and functionality of governance systems.
- **Factors:**
    - Disaster governance and policy enforcement
    - Corruption and lack of accountability
    - Early warning dissemination
    - Emergency response capability
- **Example:** Delayed relief due to bureaucratic inefficiency increases losses.

F. Technological Vulnerability

- Arises from dependence on complex technologies that may fail during disasters.
- **Factors:**
    - Poor infrastructure backup systems
    - Lack of data and communication tools
    - Inadequate monitoring systems

- **Example:** Power outages during floods disabling communication.

G. Cultural Vulnerability

- Includes traditions or beliefs that may hinder disaster response.
- **Factors:**
    - Fatalistic beliefs
    - Traditional construction not aligned with safety
    - Resistance to evacuation due to cultural ties
- **Example:** People refusing to relocate from ancestral land in flood zones.

3. Vulnerability Assessment

Definition:

Vulnerability assessment is the process of **identifying, quantifying, and prioritizing vulnerabilities** in a system, community, or infrastructure to determine their susceptibility to hazards.

A. Objectives of Vulnerability Assessment

- Identify who and what is at risk.
- Understand the root causes of vulnerability.
- Prioritize actions for disaster risk reduction.
- Strengthen resilience and preparedness.

B. Steps in Vulnerability Assessment

1. **Identify the Target Area and Population**
    - Define the geographic boundaries (village, city, region).
    - Identify sectors (housing, health, education, etc.)
2. **Hazard Identification**
    - Determine the relevant hazards (floods, earthquakes, drought, etc.)
3. **Select Vulnerability Indicators**
    - Choose measurable indicators across physical, social, economic, and institutional dimensions.
    - Examples:
        - % of houses with non-engineered construction
        - % of people below poverty line
        - Access to healthcare or education
        - Distance from emergency shelters
4. **Data Collection**
    - Use surveys, interviews, field visits, GIS/remote sensing, and census data.
5. **Scoring and Mapping Vulnerability**
    - Assign scores or ranks to different indicators.

    - Use GIS tools to prepare vulnerability maps for visual analysis.
6. **Analysis and Interpretation**
    - Aggregate scores to assess composite vulnerability.
    - Identify high-risk zones and vulnerable groups.

C. Tools and Techniques for Vulnerability Assessment

- **GIS and Remote Sensing** for spatial vulnerability mapping.
- **Participatory Rural Appraisal (PRA)** for local knowledge gathering.
- **Risk Index Models** like:
    - **Social Vulnerability Index (SoVI)**
    - **Livelihood Vulnerability Index (LVI)**
    - **Community-based Vulnerability Assessment Toolkits**

D. Example: Vulnerability to Flood in Bihar

- **Physical:** Non-elevated houses near embankments
- **Social:** High population density and illiteracy
- **Economic:** Predominantly agriculture-based livelihoods
- **Institutional:** Weak flood forecasting and delayed relief

4. Output of Vulnerability Assessment

- **Vulnerability Profiles** for different population groups or sectors
- **Thematic Maps** showing vulnerable areas
- **Policy Inputs** for targeted interventions
- **Early Warning Dissemination Plans**
- **Disaster-Resilient Development Planning**

Vulnerability and Disaster Risk – Vulnerabilities to Flood and Earthquake Hazards

1. Introduction

Disasters occur when **hazards interact with vulnerable systems or populations**. Vulnerability is thus a **key determinant** of the level of disaster risk faced by a community or region. Even if hazards cannot be fully prevented, reducing vulnerability can drastically reduce the **impact and losses** caused by disasters.

2. Vulnerability and Disaster Risk

A. What is Vulnerability?

- Vulnerability refers to the **susceptibility of a system or community** to the adverse effects of hazards.
- It is shaped by **physical, social, economic, and environmental factors**.
- Vulnerability is **not static**; it changes with time, development patterns, and environmental conditions.

B. What is Disaster Risk?

- **Disaster risk** is the potential loss (lives, property, livelihoods, etc.) that can occur due to the combination of:
  - **Hazard:** Probability and intensity of a damaging event.
  - **Exposure:** People and assets in harm’s way.
  - **Vulnerability:** Weaknesses that make them susceptible.

- **Example:**
  A powerful earthquake in a sparsely populated desert (low exposure) may cause less disaster than a moderate earthquake in a densely populated urban area (high vulnerability).

3. Relationship between Vulnerability and Disaster Risk

- High vulnerability **amplifies** disaster risk, even when hazard intensity is low.
- Reducing vulnerability (e.g., through safer construction, preparedness) is the **most effective way** to reduce disaster risk.
- Risk reduction focuses on:
  - Strengthening resilience
  - Improving early warning systems
  - Ensuring safe land use and construction standards

4. Vulnerabilities to Flood Hazards

Floods are among the most common natural hazards globally. Vulnerabilities to floods depend on geography, social factors, and infrastructure.

A. Factors Contributing to Flood Vulnerability:

1. **Physical Vulnerability**
   - Settlement on floodplains, riverbanks, or low-lying areas.
   - Poor drainage infrastructure in urban areas.
   - Non-elevated houses and unprotected critical facilities.

2. **Social Vulnerability**
    - High population density in flood-prone zones.
    - Lack of awareness and preparedness for evacuation.
    - Vulnerable groups like children, elderly, or disabled individuals.
3. **Economic Vulnerability**
    - Heavy dependence on agriculture (loss of crops/livestock).
    - Lack of insurance coverage.
    - High concentration of economic activities in flood zones.
4. **Environmental Vulnerability**
    - Deforestation and loss of wetlands reducing natural water absorption.
    - Encroachment of natural flood channels and drainage lines.
5. **Institutional Vulnerability**
    - Inadequate flood warning systems.
    - Delayed or inefficient response by authorities.

B. Flood Hazard Impacts:

- **Direct impacts:** Submergence of houses, road and bridge damage, loss of crops and livestock.
- **Indirect impacts:** Spread of waterborne diseases, loss of livelihoods, displacement.
- **Long-term impacts:** Soil erosion, contamination of groundwater, economic slowdown.

C. Case Example – Bihar Floods

- Annual floods affect millions due to:
    - High rainfall in upstream Nepal.
    - Encroachment on riverbeds.
    - Poor embankment maintenance.
    - Heavy dependence on floodplain agriculture.

5. Vulnerabilities to Earthquake Hazards

Earthquakes are sudden-onset hazards caused by seismic activity. The **destruction level** depends largely on the vulnerability of the built environment and preparedness.

A. Factors Contributing to Earthquake Vulnerability:

1. **Physical Vulnerability**
    - Non-engineered construction (e.g., unreinforced masonry).
    - Buildings not designed for seismic loads.
    - Dense urban settlements with narrow streets obstructing rescue efforts.
2. **Social Vulnerability**
    - Lack of earthquake awareness or preparedness.
    - High population density in seismic zones.
    - Inadequate emergency evacuation planning.

3. **Economic Vulnerability**
    - Loss of industrial or commercial hubs due to structural damage.
    - Lack of financial capacity to retrofit older buildings.
    - Disruption of economic activities.
4. **Environmental Vulnerability**
    - Soil liquefaction in river basins or coastal areas.
    - Landslides in hilly terrains triggered by seismic shaking.
5. **Institutional Vulnerability**
    - Poor enforcement of building codes.
    - Lack of disaster-resilient urban planning.
    - Weak emergency response systems.

B. Earthquake Hazard Impacts:

- **Immediate impacts:** Structural collapse, casualties, fires, and utility failures (electricity, water).
- **Secondary hazards:** Landslides, tsunamis (in coastal areas), dam failures.
- **Long-term impacts:** Economic recession, psychological trauma, migration.

C. Case Example – 2001 Gujarat Earthquake

- Magnitude 7.7 quake devastated Bhuj and nearby towns.
- Over **20,000 deaths** due to:
    - Poor construction quality (non-reinforced masonry).
    - Lack of seismic design compliance.
    - High population density in affected towns.

6. Strategies to Reduce Vulnerability

For Flood Hazards:

- Construct embankments, levees, and proper drainage systems.
- Promote flood-resistant housing (elevated plinths).
- Implement zoning regulations to avoid construction in flood-prone areas.
- Enhance early warning systems and evacuation drills.

For Earthquake Hazards:

- Enforce seismic building codes (IS 1893, IS 13920 in India).
- Retrofit critical infrastructure (hospitals, schools).
- Use earthquake-resistant construction materials and designs.
- Conduct public awareness campaigns and earthquake drills.