CHAPTER: II
REVIEW OF LITERATURE

A well-known proverb is that “All disasters are local”

(Erramilli, 2009)

The literature within this chapter has been reviewed at different levels to fulfill the objectives of the research undertaken. The first level of literature review has been dealt with understanding disaster management and its related concepts, components and programmes. The second stage of literature study is based on earthquake management, specifically in regards to earthquake mitigation. The third level aims to review earthquake disaster management and mitigation process specifically in relation to India. However, the fourth level of literature review undertaken is to comprehend the tools and techniques being used for mitigation of earthquakes around the globe with main consideration on the strategies, scenario and model building processes. The last level of the literature review shall attempt an appraisal of the study area of Shimla city, with special reference to earthquake mitigation management to fill the gaps under the research work.

2.1. Understanding Disasters and Related Concepts

2.1.1. Conceptual shift From Hazard to Disaster

The disastrous display of natural hazards is rooted in the human-environment relationship which forms the main part of the geographical research (Singh, 2011). As per Darwin’s theory of ‘Survival of the Fittest’, natural hazards also test humans’ survival capacity against disasters. Humans face some degree of personal risk every day, as “it is impossible to live in a totally risk-free environment” (Tewari, 2000). Human interaction with nature, through different ways of activities and land-use patterns, have converted natural hazards into natural disasters (ZumBrunnen, 2012). Till the early 20th Century, studies related to natural hazards were considered part of Natural Sciences. Gilbert F. White, who later came to be known as the “Father” of “Natural Hazard Research and Management”, had put Geography in the forefront of hazard studies, as a student at Chicago University, USA, in the early 20th Century. He upheld the view that ‘natural hazards’ are a result of interaction between natural and social forces, and that hazards along with their impacts can be reduced through individual and social adjustments (Mileti, 1999; Singh, 2011; ZumBrunnen, 2012). However, the dissertational work on
technological disasters of Prince in 1920, started the approach on Disasters which followed investigations into natural disasters and review of its nature and panic conditions. Then, around the mid-century natural hazards became part of geophysical events, mainly seen in engineering work and got separated from the society. The Cold War lead to inseminating of the disaster research in the 1950’s.

Over time various school of thoughts evolved in various disciplines regards to hazards and by 1970, the terms ‘Natural Hazard’ and ‘Disaster’ had been inserted into disciplines of geography and sociology. These two approaches were brought together by Geographer Gilbert F. White and Sociologist Eugene Haas, at the beginning of 1972, which led to the first research assessment on natural hazards, for suggesting directions for national policy and for inventory of future research needs of the nation (Mileti, 1999). Their work focused on identifying and distribution of hazards, individual and societies’ adjustment to these hazards, human perception to hazards and emergency - response preparedness to disasters. Thus, the merger of scientific investigation, engineering solutions, non-structural measures and better land –use planning emerged as the safety key against disasters (Singh, 2011). Hazards in the initial study got the lion's share of attention, which was in step with the control of physical over social sciences at that time (Hewitt, 1983).

2.1.2. **Paradigm shift in the Concepts of Disaster**

With the passing of time various school of thoughts that emerged, created a paradigm shift in the concept of Disaster, with policymakers and scholars initially giving attention to hazards by entrenching on the attempt to control nature but undermined the social, political and economic determinants of disasters. The 1970s and 1980s saw structural influence on research under the study of Natural Hazards due to the occurrence of climatic events on one hand and the rise in technological and industrial disasters on the other (Singh, 2011). With this, social scientists started to put pressure on the role of the physical environment which lead to a lot of dissatisfaction among scholars initially. Later, the physical character was considered as one part of research in disaster, and humans as the other, capable to adjust with nature but at the same time their actions could aggravate disasters.

Comprehensive Emergency Management (CEM) or Integrated Emergency Management, as was called, later stressed on ‘three-step process’ for understanding disasters: assessing risks; assessing capabilities; and working to close the gap between the two (McEntire,
2005). However, decision-making model along with adjustment concept established a ‘five-step strategy’ for coping with hazards. It included assessing hazard vulnerability; studying of possible adjustments; hazard estimation and human perception; analysis of decision-making process; and identifying the best adjustments (Burton et al. in Mili, 1999). This paradigm shift leads to the development of a management strategy model with the aim to reduce hazard–related losses through the ‘four stages of the cyclic process’ (Fig. 1.5) of preparedness, response, recovery and mitigation (Mili, 1999).

James Lee Witt of FEMA introduced ‘Project Impact- the disaster resistant community’ in the 1990s, with the goal to encourage mitigation for improved engineering, better land-use planning, and other risk-reduction measures (McEntire, 2005). Another paradigm shift occurred in the late 1990’s when the interest in resistance got diverted to the concept of resilience to capture social, economic, political and psychological variables related to disasters. At the same time when the debate of resistance and resilience (Mili, 1999; McEntire, 2005), was going on, another concept, emerged within disaster studies and gained prominence called as sustainable development or sustainable hazard mitigation. With the increase in number of disasters over the years, risk management gained prominence as proactive and justifiability, for reducing the exponential rise in disaster losses (McEntire, 2005).

However, one thing that went unnoticed during the process of paradigm shifts was a holistic, integrated and balanced approach towards disasters. Seeing the increase in frequency and intensity of disasters over the years, it led to a shift towards the ‘concept of vulnerability’. This brought the concept of disaster to the centre stage because hazards are natural in nature but disasters are not and was considered occurring as a result of human interaction. The “radical critique,” produced by researchers amid 1979-83, argued that vulnerability carried more weight than hazard during disasters (Hewitt, 1983). Hazards are regarded as a cause for the social processes leading to vulnerability, which is the key determinant of disaster potential (Alexander, 2012). For, reduction of disasters as was suggested by ‘The School of Social Vulnerability’, one needed to modify the power structures and political /economic ideologies. The greatest strength of this school of thought was emphasised on the important variables that had gone neglected in disaster research and policy application. The advantage of this ‘concept of vulnerability’, was that it had a direct relation to practically all hazards, phases, actors and variables within disasters (McEntire, 2005). Disasters with their strategies, underwent a
change, over the last one decade and assumed a new pro-active dimension as shown in table 2.1.

### Table 2.1: Paradigm Shift in Thinking about Disaster Planning

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hazard</strong></td>
<td><strong>Vulnerability</strong></td>
</tr>
<tr>
<td>(an incoming disaster as a peril)</td>
<td>(possibility of damage to community)</td>
</tr>
<tr>
<td><strong>Reactive</strong></td>
<td><strong>Proactive</strong></td>
</tr>
<tr>
<td>(making plan effective after disaster)</td>
<td>(making plan effective before disaster)</td>
</tr>
<tr>
<td><strong>Single Agencies</strong></td>
<td><strong>Partnership</strong></td>
</tr>
<tr>
<td>(each agency working separately)</td>
<td>(agencies working together)</td>
</tr>
<tr>
<td><strong>Science Driven</strong></td>
<td><strong>Multi-disciplinary</strong></td>
</tr>
<tr>
<td>(dependence on fundamental research)</td>
<td>(innovation through dialogue between different professions)</td>
</tr>
<tr>
<td><strong>Responsive Management</strong></td>
<td><strong>Risk Management</strong></td>
</tr>
<tr>
<td>(managing tasks as a response to disaster)</td>
<td>(managing to minimise risk before disaster)</td>
</tr>
<tr>
<td><strong>Planning for Community</strong></td>
<td><strong>Planning with Community</strong></td>
</tr>
<tr>
<td>(designing an action plan with authority and not necessarily involving community)</td>
<td>(designing an action plan with the consent and involvement of community)</td>
</tr>
</tbody>
</table>

(Source: Deshmukh, 2009)

### 2.2. Disasters and their Impact

Disasters are said to set back development (Alexander, 2012) with enormous losses leading to severe consequences for the survival, livelihood (particularly of the poor) and development (ISDR, 2007). Disasters are not totally discrete events, their probability of occurrence, time, place and severity to strike can be reasonably, and in some cases accurately, predicted by technological and scientific advances (Sundar and Sezhiyan, 2007). But some disasters like earthquake, usually have underlying features like unpredictability, uncertainty, unfamiliarity and speed (Tripathi, 2010; Erramilli, 2009, Sibil, 2010). Disasters have been stated to be inevitable and multi-dimensional in nature disrupting various administrative, social, economic, ecological aspects, thus, creating a negative impact on the environment, humans and their infrastructure (Satendra, 2003; Erramilli, 2009). Disasters are also considered
as nature’s monumental system of checks and balances, designed to control the world’s population (Lee, 2010).

Analysts state that substantial growth in population, both natural and migrated, and their assets, due to the expansion of cities within high-risk areas having inappropriate standards of living, including degradation of the environment, is the main cause for the speedy rise in disasters. The process of urbanisation has made the societies weak in coping with the inherent capacity and local mechanism available, with the likelihood that secondary effects could occur due to disasters. It is, thus, suggested that disasters are not a function of violent natures of environmental hazards but of people being in the wrong place, at the wrong time, with limited capacity to prevent impacts (Ghosh, 2008; Collins, 2012; EM-DAT Database). Hence, the wrath of disasters is mostly experienced by people of local level requiring sustainable development (Ramgirwar, 2011).

2.2.1. Cost of disasters

According to the World Bank Report 2012, during the second half of the Twentieth Century, more than 200 natural disasters occurred around the world, with more than 2.5 million people died between 1980 and 2011, amounting to about US$ 3.5 trillion of economic loss across the world (worldbank.org). The year 2011 was declared the costliest year for natural disasters with a loss of US$380 billion. From 1960 to 1990, there has been three times increase in disasters and nine-time increase in their costs (Moin, 2012, Goodyear, 2001). Kobe Earthquake of Japan in 1995, was considered the world’s costliest natural disaster with US$ 100 billion, killing 5300 people, 120,000 buildings being collapsed, lifeline facilities (electricity, water, gas supply, etc.) having been destroyed, along with paralysing of transportation network and leading to immediate evacuation of about 230,000 residents. However, 1999 Taiwan earthquake, the cost was at US$ 57 billion, where 2400 people were killed (Pricovic, 2002).

According to United Nations, the incidence of death due to disasters is four times higher in low- income countries as compared to countries with high income per person, as people within low- income countries cannot invest in assets and insurance. Proximity to extreme natural event combined with low economic or social status results in deadly consequences (Goodyear, 2001). World Development Report 2000/2001 has stated that loss due to disasters with regards to costs, is both direct and indirect. Direct costs involve physical damage to
infrastructure and buildings, while indirect cost involves unemployment, illness, loss of earnings, etc. (World Bank, 2001; Basbug, 2009).

2.2.2. Effects of Disasters

The principal cause of 75% deaths around the world, in most large-scale disasters, is the result of total or partial collapse of buildings (Rafeeqi, 2005). The unsound urban growth and development, aggravated by the unsafe buildings, low-quality infrastructures, economic conditions, low levels of education and awareness, inadequate investment increases the vulnerabilities, leading to destruction by catastrophic disasters that have both short and long-term effects. This rapid unmanaged growth is a critical challenge being faced by development, for it puts strain on national and local government capacities for providing the basic services of food, shelter, health, education and employment, thus, further increasing vulnerability to disasters (Goodyear, 2001; Shaw and Fernandez, 2010; Moin, 2012; Sampath, 2012). Cataclysmic disasters disrupt the road to development and lead to loss of momentum for developing countries, with 90% natural disasters and 95% disaster-related deaths worldwide (Moin, 2012).

Household income and wealth has also been seen to negatively relate to disasters in many ways. As, observed in the East Japan earthquake of 2011, where wealthy persons were prepared to face disastrous situations like earthquake due to wealth and self-insurance than low-income households that concentrated in high-risk zones (Naoi, Seko, and Ishino, 2012). World Development Report 2000/2001 also mentioned disasters as a dimension of poverty. It slows down the pace of human development that has an effect on Gross Domestic Profit (GDP) of the countries especially of the developing countries (World Bank, 2001). Hence, developing countries need to undertake planning without waiting for a major disaster and without the constraint of lack of resources, with local self-government entrusted with the larger role in governance for Disaster Management (Mansourian, Rajabifard, ValadanZoie, Williamson, 2006). Loss reduction strategy for disasters can only take place when the vulnerability assessment will be incorporated into developmental processes with a shift from reaction to anticipation (Fernando, 2012). Thus, sustainable development encompasses three dimensions of economic efficiency, social equity and environmental protection, all of which contribute to and are also affected by natural disasters (Sharma, 2009).
2.2.3. Vulnerable groups in Disaster Management

One important component that arose from UNISDR and found no answer in clear monetary terms was, recognising the most vulnerable groups in case of disasters. It is not necessary, that all people living in the same area would face the same level of disaster risk and be affected by disasters at the same level. Largely, the underprivileged or marginalised groups of communities are the hardest hit by the disasters, as they have the least resources and capacities to recover from the repercussion of disasters (Medury, 2012). People with weak positions in the society or those having limited access to resources due to gender, race, status or religion, in particular, are the socially vulnerable groups which are largely affected by disasters (Sampath, 2012). It includes the vulnerable groups within society like women, children, elderly citizens, physically and mentally challenged, poor people, refugees and livestock (Paton & Johnston, 2001; Kumar, 2012; Sampath, 2012; Flanagan, Gregory, et al., 2011). Japan earthquake of March 11, 2011, saw 54% women population and 65% of 60 plus aged group population as casualties during the quake (Naoi, Seko, and Ishino, 2012). Life expectancy, literacy rate, nutritional status, mobility, access to information, control over available resources, all generally favour the men in most of the cultures and societies across the globe. The households headed by females are affected much greater than male-headed households in the aftermath of a disaster, as women have less physical protection and fewer resources for recovery due to uneven distribution and control over the tangible and intangible resources. Women and especially children are the ones that suffer an unbreakable social crisis and suffering beyond one's imagination after a disaster strikes (Kumar, 2012). Poor communities and population are usually the prime victims of natural disasters.

According to the Human Poverty Index Measure, poverty is a deprivation of basic human development. This results in death, illiteracy, no or poor access to health services, drinking water, settlements, undernourished children as some indicators, making the poor more vulnerable (Kumar, 2012). However, it is understood that poverty is not always linked to vulnerability but the latter is often related to capacity (Sampath, 2012). Vulnerability is, hence, linked with net assets rather than income, greater the assets lesser the vulnerability. The other factors like geographical location, social and ethnic groups and communal conflicts can also make the community vulnerable (Singh, 2009). Thus, the vulnerable groups need to be provided special attention by involving them in various mitigation and preparedness activities of disaster management. Employing of the Participatory Vulnerability Analysis (PVA) process
can help involve the community and other stakeholders in carrying out an in-depth study of their respective vulnerabilities (Singh, 2009).

2.3. United Nation Global Programmes on Disaster Management and Risk Reduction

Till late 1980s disaster programmes, policies and planning were looked upon as merely subject for distribution of relief and rehabilitation to the affected population within an area. In 1989, the United Nations (UN) General Assembly Resolution 236, declared 1990-1999 as the International Decade of Natural Disaster Reduction (IDNDR) with the objective to reduce loss of life and property and restricting socio-economic damage through concerted international action (Kaul, Ayaz & Lohitkumar, 2011; Sharma, 2012, Modh, 2010). IDNDR, thus, shifted the focus from hazards and disasters to risk and vulnerability. Firstly, through the people-centric approach and secondly, through integrating science and technology with political, economic and social science (Bhatt, 2012). IDNDR consisted of 10 high-level councils of internationally prominent people, 24 scientists in scientific and technical committee from around the world, about 120 national committees, to promote IDNDR and for forming disaster preparedness programmes. “13 October” was declared as the “International Day for Natural Disaster Reduction” for raising awareness for mitigation and preparedness measures for disasters.

The midterm review of International Decade of Natural Disaster Reduction (IDNDR) was held by the General Assembly with its UN members and related State members of the world, in partnership with the non-government organisation during the Conference held in Yokohama, Japan, on May 1994. The Conference on Natural Disaster Reduction, Yokohama Strategy and Habitat Plan of Action for a Safer World, spoke of the basic un-naturalness of urban disasters and addressed the strong need to decentralise decision making in order to reduce risks (Shaw and Krishnamurthy, 2009; Lee, 2010). The following important message was imparted to the disaster-prone countries for consideration and action:

“Disaster prevention, mitigation and preparedness are better than disaster response in achieving the goals and objectives of the decade. Disaster response alone is not sufficient, as it yields only temporary results at a very high cost. We have followed this limited approach for too long. Prevention contributes to lasting improvement in safety and is essential to integrate disaster management.” (Arya, 2000).
Thus, members were asked to review the accomplishments of IDNDR at all national, regional and international levels along with the exchange of information related to programmes and policies implemented, to chart out future actions and increase further awareness in regard to disaster reduction.

Fig. 2.1: Global Programmes of United Nation on Disaster Management

The IDNDR (Fig. 2.1) experience was built upon by International Strategy for Disaster Reduction (ISDR). For the implementation of ISDR, the UN General Assembly on January 2000 through its resolution 54/219, which was reconfirmed in December 2001 under resolution 56/195, establishing two mechanisms- Interagency Secretariat and Interagency Task Force. It is, thus, the secretariat of International Strategy with focus on the shift from stress on traditional disaster response to disaster reduction through “Building a Culture of Prevention” (UNISDR; Shaw and Krishnamurthy, 2009). The mission of International Strategy for Disaster Reduction (ISDR) in 2002, was to build disaster resilient communities by promoting increased awareness of the importance of disaster reduction as an integral constituent of sustainable development, with the goal of reducing human, social, economic and environmental losses, caused due to natural hazards and related technological and environmental disasters (Chamlagain, 2009). ISDR had four objectives for disaster reduction:

1. Worldwide increase in public awareness with regards to the understanding of terms risk, vulnerability and disaster reduction.

2. Obtaining commitment from the public authorities for implementation of disaster-related reduction policies and actions.

3. To encourage inter-disciplinary, intersectoral partnership for expansion of risk reduction network.
4. Develop scientific knowledge related to disaster reduction (Shaw and Krishnamurthy, 2009).

Further, on January 2005 at Kobe, Japan under ‘The Hyogo Framework for Action (HFA) 2005-2015: Building the Resilience of Nations and Communities to Disasters’ managed by United Nations International Strategy for Disaster Reduction (UNISDR), brought all international stakeholders together around a common coordinate system. HFA, an international voluntary framework to mobilise action and track progress (Sendai Report, 2012) during the Global Conference on Disaster Risk Reduction with the participation of 168 countries, laid down three strategic goals –

1. Integration of DRR into sustainable development policies, planning and programming at all levels emphasising on disaster prevention, mitigation, preparedness and vulnerability reduction.

2. Development and strengthening of institutions, mechanism and capabilities at all levels particularly at the community level to build resilience to hazards, and

3. Systematic incorporation of risk reduction approaches into the design and implementation of emergency preparedness, response and recovery programmes in the reconstruction of the affected communities.

Hyogo Framework had attempted to cover risks related to all disasters, specifically risks of earthquakes, due to lack of forecasting which included the collapse of structures, loss of transportation and other infrastructure. The goal was to substantially reduce the loss of lives with social, economic, and environmental assets by 2015 (ISDR, 2007).

United Nations Development Programme (UNDP) initiated a regional programme for Earthquake Risk Reduction and Recovery Preparedness (ERRP), for South Asia with support from the Japan Government, for the fulfillment of the Hyogo Framework for Action (HFA). It aimed to strengthen the institutional and community capacity, through planning and implementing earthquake risk reduction strategies in five high-risk countries of Bhutan, Bangladesh, India, Nepal and Pakistan. The programme seeks to support regional cooperation for disaster risk reduction, integrating disaster preparedness, mitigation and post-disaster recovery preparedness in the context of SAARC Framework for Disaster Management, which was aligned with the implementation of the Hyogo Framework for Action (Khan, 2009).
The present successor of HFA, ‘The Sendai Framework: 2015-2030’ has been adopted by the UN Member States on 18 March 2015 during the Third UN World Conference on Disaster Risk Reduction in Sendai City, Miyagi Prefecture, Japan, with the aim of:

“The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries” (Sendai Report, 2012).

The Sendai framework consists of four priorities to be achieved by 2030, namely Understanding Disaster Risk; Strengthening disaster risk governance to manage disaster risk; Investing in Disaster Risk Reduction for resilience; and Enhancing disaster preparedness for effective response and “Build Back Better” in recovery, rehabilitation and reconstruction (Sendai Report, 2012).

2.4. Components of Disaster Management

2.4.1. Vulnerability and its types

Increase in population has mounted lots of pressure on the land-use pattern and the environment, hence decreasing the man-land ratio for the population to be housed in such kind of structures that are primarily prone to disasters. The environment is divided into two parts: physical environment (composed of natural systems as well as built environmental and technological structures) and social environment (composed of individuals and groups of individuals as well as cultural, economic, and political systems) (McEntire, 2001; Singh RB, 2008; Alexander, 2012). These two environments are termed as physical and social vulnerabilities under disaster management. Physical vulnerability focuses on physical assets related to buildings, infrastructure and agriculture. While social vulnerability concept which were introduced in the 1970s, was partially the product of social inequalities and social factors that influence or shape the susceptibility of various groups to harm and govern their ability to respond (Cutter, Boruff, Shirley, 2003).

These two elements of vulnerabilities have been pronounced as a product of four components - Risk, Susceptible, Resistance and Resilience (McEntire, 2001& 2005). Risk and Resistance are part of physical vulnerability, while Susceptibility and Resilience, are part of social vulnerability. Physical environment’s proximity or its exposure to hazards is associated with ‘risk’ that increases the probability of a disaster and its potential for loss (Buckle, Marsh,
and Smale, 2000; McEntire, 2001). However, the physical environment’s ability to resist the damage imposed by hazards is referred as ‘resistance’ (Norton and Chantry cited in McEntire, 2001 & 2005). While social environment is considered ‘susceptible’ to disasters due to social, cultural, economic and political forces and the activities which determine individual’s and group’s ability towards the adverse effects of a disaster (McEntire, 2001). However, the capacity of the society to cope with or its ability to react or recover effectively from a hazard that becomes disastrous is referred to as ‘resilience’ of the social environment (Mileti, 1999; Buckle, Marsh, and Smale, 2000; Lettieri, Masella and Radaelli, 2009). “Resilience Capacity” is considered as a social vulnerability indicator in earthquakes while “Losses” are considered as a hazard indicator (Armas, Damian and Sandric, 2006). With the acceptance that communities are capable of drawing upon internal resources and competencies to manage the demands, challenges and changes that they encounter, a paradigm shift has been seen in the concept of vulnerability (Paton and Johnston, 2001).

The third vulnerability recognised by experts is ‘Economic Vulnerability’, which analysis the hazard that causes losses to economic assets and processes through two forms- Direct and Indirect. Direct losses are considered to be caused by destruction or damage to physical and social infrastructure, their repair or replacement cost, including crop damage. While the indirect loss is related to production, employment, important public services, income disparities, etc. (McEntire, 2001; Kumar, 2012; Sampath, 2012). Vulnerability has also been recognised as cultural, political and technological (Fig. 2.2) (McEntire, 2001; Aysan, 1993 cited in Medury, 2012; Palliyaguru, Amaratunga and Baldry, 2014; Municipal Corporation Shimla, 2012) as well as individual vulnerability, (Weichselgartner in McEntire, 2001), organisational vulnerability (lack of strong national and local institutional structures), educational vulnerability (lack of access to information and knowledge), attitudinal and motivational vulnerability (lack of public awareness) (Aysan, 1993 cited in Jigyasu, 2002 & Medury 2012), locational vulnerability (related to site) and occupational vulnerability (Bhatt, 2012) by researchers. David Alexander (2012) has also recognised ‘six-point typology’ of hazard vulnerability which consists of economic, technological, residual, newly-generated, anti-social and total vulnerabilities. Vulnerability is, thus, considered not voluntary but forced or involuntary in nature (Kumar, 2012; Sampath, 2012).
At least 80 countries around the world are considered vulnerable to natural disasters (Ranghieri and Ishiwatari, 2014). Vulnerability Reduction measures had been seen as relief and charity measures over years rather than investment measures to maintain stability and productivity of the urban economies (Bhatt, 2012). The elements of vulnerability considered in planning process are the critical facilities of water, energy, communication, sanitation, emergency medical services, fire, police station, disaster institutes, transportation, economic production facilities which are major sources of livelihood, public assembly sites like schools, markets, public and private office buildings and cultural patrimony (Singh, 2009). These elements at risk can be measured along a continuum, from ‘total resilience at one end to total susceptibility at the other end’, suggesting analysis of vulnerability as complex, which is dependent upon a large set of data and qualitative analysis. Thus, five components: initial well-being, self-protection, social protection, livelihood resilience and social capital are considered under Participatory Vulnerability Analysis (PVA) involving community and stakeholders together, for in-depth examination, with the aim of linking disaster preparedness with response to long-term development (Singh, 2009).


The vulnerability reduction and increase of capacity are directly related to the degree of decentralisation. Looking into the scale of threats in urban areas it is perceived as 'too big to handle', while decentralisation is paid 'lip service' by the government (Lee, 2010). Vulnerability
and Capacity are closely related as two sides of the same coin, where vulnerability may increase or decrease at the cost of capacities (Jigyasu, 2002). According to research, three main areas where vulnerability reduction matters are: new trends and emerging lessons, designing and developing tools and influencing public policies (Bhatt, 2012). Thus, preparedness and vulnerability are said to be inversely related, higher the level of preparation, lower the intensity of vulnerability and vice-versa (Fernando, 2012).

2.4.2. **Risk and Disaster Risk Reduction**

Disaster risk is increasingly being regarded as a global concern and its impact and actions within one region are considered to have an impact on risks of another region, and vice versa (ISDR, 2007). The factor of risk defines balance - which is the gap between the balance of ends, means and way (Kazmi, 2008; Prasad, 2008). The urban risk from hazards has been ignored on a large scale by local, national and international authorities due to lack of political feasibility, insufficient knowledge, capacity, experience and unplanned urbanisation (Bendimerad, 2010). Studies have indicated that humans do have risk awareness for hazards, but they misjudge the dangers either due to denial and ignorance of the danger or overestimating the chances of protection (Sampath, 2012). People’s perception of risk is, thus, heavily influenced by the process in which they balance the degree of danger they face, in relation to the benefits they receive by staying where they are (Stephens, C. cited in Sampath, 2012). Risk perception can either increase or decrease vulnerability depending on the level of salience and precision. It has been evaluated in terms of relative risk (RR), risk probability (RP), immediate benefit (IB) and person-year (PY) factor, which is a number of people inhabiting the affected region within a period. Thus,

\[
\text{Hazard planning } \alpha \text{ RR.PR. IB. PY (Valdiya, 1987)}
\]

The Risk level which is calculated as the product of ‘Probability x Consequences’ can be managed by two basic strategies. Firstly, by trying to lower the likelihood of the event happening and secondly, by reducing the damage or severity by employing suitable provisions for ameliorating the worst effects that can lead to life loss and financial damage (Talwar and Juneja, 2009). Under the UN Framework Convention on Climate Change, local governments are considered as one of the pillars for risk reduction at the local level. Thus, they should have a strong policy and action plan for disaster risk reduction, with dedicated personnel and
assigned budget. One age-old challenge which many local governments still face is changing their ‘mind-set’ from disaster response to disaster reduction and preparedness (UNISDR).

The term ‘Vulnerability Reduction’ and ‘Disaster Risk Reduction’ are interchangeably used for overcoming and minimising disaster losses (Palliyaguru, Amaratunga, Baldry, 2014). To reduce vulnerability and risks on a long-term and permanent basis it requires preparedness along with prevention/mitigation measures like inculcating awareness, overcoming poverty, developing infrastructure and spreading literacy along with development programmes aimed towards sustainability (Singh RB, 2008). Governance is considered as the core of vulnerability reduction, disaster preparedness and development (Ammann, 2006 cited in Alexander 2012; Lee, 2010; Bendimerad, 2010). Disaster Risk Reduction needs to be; thus, seen as a political, economic, and social issue integrating disaster management into sustainable development (Tekeli, et al., 2010; Alexander, 2012).

The concept of Disaster Risk Reduction (DRR) not only refers to structural or technically advanced strategies but also to ‘soft methods’ such as policy, planning and knowledge management, including Hazard or Risk Mapping (Mileti, 1999; Ranghieri and Ishiwatari, 2014). Risk mapping is fundamental to Disaster Management and considered as an effective mitigation tool (Coppola, 2011; Ranghieri, and Ishiwatari, 2014). DRR decisions, actions and results all depend upon a complex interaction between perception and culture (Alexander, 2012; Bendimerad, 2010). Thus, various actors of Disaster Management should consider it as a culture (Deolankar Vivek, 2010; Dheri, 2012). The aim of DRR is to manage and reduce the effects of hazardous events on human and physical assets of a community for the supply of essential services to the population (Bendimerad, 2010). Its policies and strategies are said to evolve from both top-down and bottom-up perspective, properly linking up to the grassroots level (Mercer, 2010). Risk Management is, thus, classified into four types: “avoid”, “reduce”, “transfer” and “retain” and into five main strategies of Total Disaster Risk Management (TDRM) of Coordination Mechanism; Information; Investment for Disaster Reduction; Public Awareness and Collaboration among Stakeholders. (Deolankar Vinayak, 2010).

Disaster Risk Management (DRM) is a pro-active, i.e., ex-ante concept in contrast to disaster response and rehabilitation/reconstruction, which is a post-event concept, i.e., post-ante (Bendimerad, 2010; Ghesquiere and Mahul 2010). DRM was an initiative of the Board of the Swiss Federal Institutes of Technology and Virginia Polytechnic Institute and State
University in conjunction with The Pro-Vention Consortium of the World Bank. The objective of DRM was enabling people to anticipate disasters and take action to protect life and property, in order to ensure sustainable social and economic development, through DRR, risk sharing mechanism and management of residual risks in face of limited resources (Tripathi, 2010). Self-efficacy is considered to determine the amount of effort and persistence that is invested in risk reduction behaviours to sustain if social and structural environmental support is provided (Paton and Johnston, 2001). The community becomes resilient to external damaging hazardous events when better measures are taken towards the built environment and resource management along with delivery of services. Thus, ‘DRM and Development’ are directly correlated in accomplishing DRR (Bendimerad, 2010). Schematic 2.3 shows the five pillars of DRM framework as per Sendai report 2012.

![Schematic 2.3: A Disaster Risk Management Framework](Source: Ghesquiere and Mahul, 2010)

**Fig. 2.3: A Disaster Risk Management Framework**

### 2.5. Mitigation

The absence of a disaster does not essentially indicate that a robust level of safety exists, but it may be an indication that appropriate information has not been analysed which may precipitate the development of illusions of certainty (Masys, 2012). The maximum loss of life takes place immediately during or after a disaster strikes. The first few hours after a disaster has occurred and before any help arrives from elsewhere is considered as the “Golden Hour” (Gupta, Sinvhal, Shankar, 2006; SAARC, 2009). Damage caused during a disaster should be
repairable and not a threat to life (Sharma, 2012) but it is observed that usually the “Golden Hour” is lost by the time a clear picture about the actual damage pattern emerges for action to take place (SAARC, 2009).

Prevention or risk reduction is often related to mitigation (Coppola, 2011). Mitigation consists of efforts intended to reduce the degree of risk, in order to prevent disasters and reduce the vulnerability of both the ecosystem and social system, i.e., the community (Lettieri, Masella and Radaelli, 2009). Mitigation mechanism is the most compatible process to help reduce the actual or probable effects of disasters on people, economic, social and structural system including the environment (Erramilli, 2009; Fernando, 2012). The new approach of disaster management suggests that, for sustainable development, disaster mitigation needs to be built into developmental processes, policy formulation and implementation. Second, the “Cornerstone of Disaster Management” is considered as mitigation, which is multi-disciplinary and traverses across various sectors of development, to reduce the short and long term vulnerability of the communities from natural hazards (McEntire, 2001; Singh RB, 2008; Deolankar Vinayak, 2010; Coppola, 2011) The main elements of mitigation strategy are considered as Risk Assessment and Vulnerability Analysis; Applied Research and Technology; Public awareness and training; Institutional mechanisms; Incentives and resources for mitigation; land-use planning and regulation; Hazard resistant design and construction; Structural and Constructional Reinforcement of existing buildings (Fernando, 2012; Singh, 2009). This is a gradual shift from the reactive mechanism which was considered to prove temporary results but at a high cost, to proactive mitigation approach leading to the concept of sustainable development (Singh RB, 2008).

2.5.1. Types of Mitigation Measures

Mitigation measures are considered both as Active and Passive. ‘Active’ mitigation measures rely on providing incentives to the public for disaster risk reduction like government grants, subsidies, lessening of the insurance premium for safe construction, government technical advice to reduce disasters; ‘Passive’ measures are based on respective laws and controls. Active measures are more effective than Passive measures (Dheri, 2012; Sampath, 2012). The mitigation strategies fundamental principle involves an investment of money for reducing future investment in emergency recovery, repair and reconstruction after a disaster. It also provides a degree of socio-economic continuity of the community, which can be affected due to disruption in transportation and communication systems, dislocation of people, job loss
and disrupting social life (Fernando, 2012). Mitigation or Hazard reduction measures tend to be costly, disruptive, time-consuming, and in some cases socially unpalatable. However, they help in the faster recovery of the community from the cultural and socio-economic impacts of the society, based on partnership encompassing government, private sector and the community (Coppola, 2011; Medury, 2012).

Table 2.2: Types of Mitigation Measures

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Structural Mitigation</th>
<th>Non Structural Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Resistant construction</td>
<td>Regulatory measures,</td>
</tr>
<tr>
<td>2.</td>
<td>Building codes</td>
<td>Community awareness and education programmes</td>
</tr>
<tr>
<td>3.</td>
<td>Relocation of people</td>
<td>Non-structural physical modifications</td>
</tr>
<tr>
<td>4.</td>
<td>Structural modifications</td>
<td>Environmental control</td>
</tr>
<tr>
<td>5.</td>
<td>Construction of community shelters, barriers, helipads, etc.</td>
<td>Behavioural modification</td>
</tr>
<tr>
<td>6.</td>
<td>Physical modification</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Treatment systems</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Redundancy in life safety infrastructure</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Coppola, 2011; Hayward, 2011; Dheri, 2012; Fernando 2012)

Mitigation is, thus, an integral component of sustainable development which can be carried out through Structural and Non-Structural measures (Ranghieri and Ishiwatari, 2014) as shown in Table 2.2. Among the structural measures, choosing a safe site is the most important factor to determine how strong a hazard can be experienced in an area but is a secondary factor to how well the building is built as per building codes (Fernando, 2012). While Non-Structural Mitigation is considered as a mechanism where “man adapts to nature” and tends to be less costly and fairly easy for communities with few financial or technological resources to implement (Coppola, 2011).

2.5.2. Paradigm Shift and Mitigation goals

A Paradigm Shift from post to pre-disaster management started taking place around the 1980s and 1990s when institutes began shifting their developmental thinking away from externally imposed blueprint solutions. The shift from response centric attitude to mitigation and preparedness indicated, acknowledgment and understanding of the ways through which
people at risk should manage and change their lives (Goodyear, 2001). It is seen that the vital primary focus in disaster management is on community-level mitigation linked to their daily lives. Otherwise, mitigation measures will be seen in the light of luxury, rather than as a basic requirement for safe living. This process is most effective when the local community assesses its own risks (Sampath, 2012). Schematic 2.4 shows the process of mitigation and preparedness.

![Intervening factors]

Risk of hazard \[\rightarrow\] Risk awareness \[\rightarrow\] Evaluation of costs and benefits \[\rightarrow\] Attitude and intention \[\rightarrow\] Action

Evaluation

(Source: Tekeli-et al., 2010)

**Fig. 2.4:** Conceptual framework for the process of taking action regarding Disaster mitigation and preparedness

![Goals of Mitigation]

Risk Likelihood Reduction \[\rightarrow\] Risk Consequences Reduction

Risk Transfer, Sharing or Spreading \[\rightarrow\] Risk Acceptance

Risk Avoidance

(Formed on the concept of Coppola, 2011)

**Fig. 2.5:** Goals of Disaster Mitigation
Disaster Mitigation Managers need to employ certain goals along with measures for making the society resilient to disasters (Coppola, 2011) as presented in figure 2.5. The two goals of mitigation, Risk Likelihood Reduction and Risk Consequences Reduction are grouped into primary categories of structural and non-structural mitigation (Coppola, 2011). Through proper planning mitigation efforts can be integrated with normal development activities at very small or sometimes no additional cost (Sanderson, 2000).

2.5.3. Mitigation and planning

The planning of Disaster Management demands a more methodical and orderly approach (Ramgirwar, 2011). Appropriate mitigation planning and measures can substantially, if not wholly, reduce the heavy toll on lives, property, dissipation of developmental, industrial and infrastructural gains and the hard-earned socio-economic infrastructure (Ministry of Home Affairs, 2011). Natural hazard mitigation planning is a multi-criteria task, which is dynamic and complex process, involving the public, different agencies and levels of government involving both management and engineering level. Multi-criteria decision making procedure consists of generating alternatives through scenarios including ‘worst-case scenarios’ (Ranghieri and Ishiwatari, 2014) for sustainable hazard mitigation effects, generated in the form of comprehensive land-use plans. These plans should be evaluated according to criteria representing - natural environment, social environment, economy, culture, politics, public safety and reliability (Pricovic, 2002).

Proper mitigation planning efforts, with up-to-date spatial data, can help reduce the economic loss and its effects on an economical aspect of sustainable development (Erramilli, 2009). Spatial Data Infrastructures (SDI) can be used for facilitating disaster management and assist disaster management agencies to improve the quality of their decision-making, efficiency and effectiveness in all levels of disaster management. This developed system was tested successfully as a pilot project in the earthquake-prone area of Tehran (Mansourian, et al. 2006; Guven & Ergen, 2011). Mitigation mechanism is, thus, the most compatible process of cost-effectiveness in regard to prevention of life and property from consequent hazards. After hazard have been recognised with its consequences and likelihood, the two risk components must be precisely perceived with the belief that hazard risk can be reduced, or else inaccuracies in any of the 3 areas can disrupt mitigation efforts (Coppola, 2011; Singh, 2009).
Organisation of American States guidelines on Regional Development Planning (OAS, 1984; Singh, 2009) developed certain steps and stages that a disaster manager should perform to make an Integrated Development Plan successful and operative as shown in figure 2.6 below:

![Fig. 2.6: Stages of Integrated Development Plan](Source: Formed on a concept of Organisation of American States guidelines on Regional Development Planning)

Mitigation processes are seen as expensive projects by the governments, as they usually maintain limited funds to support hazard related development and some even consider hazard as the matter of chance events that might not occur. Similarly, if mitigation is to occur in periods when no imminent threat exists in an area, politicians tend to have low ‘buy-in’ for mitigation planning and programmes. To maintain their high public standing, they tend to prefer projects that increase their stature over risky endeavours that may not offer a return in the short run. These obstacles along with socio-cultural issues and risk perception of the people make mitigation planned measures difficult to be implemented and achieved (Coppola, 2011).

### 2.5.4. Community Awareness and Mitigation Preparedness

No community is 100 percent self- sufficient. For, humans have evolved beyond subsistence living having more dependence upon each other and on societal infrastructure. Failure in any one of the life safety systems-like electricity, public health infrastructure,
emergency management infrastructure, water storage, treatment, conveyance, and delivery systems, transportation infrastructure, irrigation systems and food delivery- can lead to greater catastrophe. Thus, requiring redundancy of lifeline infrastructures for community resilience is necessary (Coppola, 2011; Dheri, 2012). Similarly, Non–Structured Mitigation, activities like development of land–use plans, zoning ordinance, sub-division regulations and tax incentives, insurance and disincentives to discourage development in certain high hazard areas need to be looked into through educational programmes like 'Community Vulnerability Reduction Programmes –CVRP' (Davis, 2000). Increasing awareness levels would succeed in freeing the community from unrealistic situations, thoughts and myths related to disasters.

Awareness prevents rising of “a panic situation” that often results in needless deaths and injuries. Once everyone knows ‘what to do’ and ‘when to do it’, it can help make decisions in a calm and rational manner, thereby, reducing losses (Sampath, 2012). Awareness based on success stories and lessons learned from particular disasters, like earthquakes and indigenous knowledge for various mitigation measures within respective regions, can be of immense value in any disaster mitigation strategy (SAARC, 2009). Based on experiences, the community should be made aware of strengthening its immovable assets in order to withstand disasters by helping in guiding mitigation efforts and policies to protect natural and cultural resources of the community, through a partnership involving government, NGO’s, private and public sectors (Davis, 2000; Rafeeqi, 2005; Fernando 2012; Medury, 2012).

A well aware community will always be physically and mentally prepared to face the realities of any disaster and can contribute towards mitigation efforts to a considerable degree. In many instances, people are either not aware of the preparedness/ mitigation measures to be taken, or they do not take these measures seriously, believing “this will not happen to me” (Sanderson, 2000). United Nations Conference on Environment and Development at Rio in 1992, stressed upon the need for enhancing capacity building of indigenous communities, based on the adaption and exchange of traditional experiences, knowledge and resource management practices, to ensure communities sustainable development at national and local levels in resource management (who.org; Medury, 2012).

“As the community is a dynamic entity, no plan can be a static document” and for quick mobilisation, training should be accompanied by periodic mock-drills for testing and updating the plans (Dheri, 2012). Awareness, thus, can be launched by educating people and the community about the disastrous effects of disasters, especially earthquakes through education,
training, mock drills, making them resilient to future disasters (Tiwari, 2000; Singh, 2009). Regulation of disaster mitigation norms has a greater potential impact than any other single management tool (Fernando, 2012). Thus, problem-focused coping strategies facilitate resilience of the community, rather than emotionally focused coping strategies which tend to increase the vulnerability level (Paton and Johnston, 2001). To make disaster management a community movement, efforts for an extremely active process are being made by linking local cultural events, with the culture of preparedness and raising awareness through greater participation of the communities (Kaul, Ayaz, & Lohitkumar, 2011; Davis, 2000). Recent studies are indicating towards the concept of public participation in disaster management as one of the holistic approaches towards Disaster Risk Reduction (Lettieri, Masella and Radaelli, 2009).

DRM practices are considered more sustainable and efficient for long-term only if they are explicitly integrated with formal development processes and implemented at local levels through “mainstreaming” (Bendimerad, 2010). Local governments are responsible for community development and sustainable disaster risk reduction as ‘first-responders’ (UNISDR. Org). Therefore, training of the people at grassroots level is important for long-term benefits (Erramilli, 2009). DRM activities will empower the communities to deal with disasters, as maximum lives are saved by relatives and neighbours within the first 24 hours, or during the Golden Hour, before professional help arrives. This has been evident from the data of 1995 Hanshin- Awaji (Kobe) earthquake, where 80 percent of the people were rescued by their neighbours (Ranghieri and Ishiwatari, 2014), indicating the need for trained and equipped community teams at the local level, especially for disasters like earthquakes (SAARC, 2009).

The World Health Organisation started a networking programme between Inter-Community Groups or linkages between community groups referred to as ‘TWINNING’ (Medury, 2012) in the 1980 earthquake of Italy, which that took 3000 lives and it was seen to work successfully. Few hours after the earthquake took place each of the local communities struck by the disaster was twinned with an Italian town for immediate assistance. Exercises like Incident Response System (NIDM), Training Needs Assessment (TNA) and Rapid Visual Screening (RVS) help to identify the gaps that are needed to be taken care of and train people, accordingly, in the areas of disaster management (Fernando, 2012). Another measure of Vocational Training of the youth through using locally available skills for manufacturing and
supplying of specific low-cost essential relief material can be useful in disasters and it can also increase employment opportunities for the community (Sampath, 2012).

2.6. Urbanisation and Disasters

The world population by 2050 is expected to reach 9 billion (Shaw and Fernandez, 2010) leading to increase in size and number of settlements across the globe, of which 80% population will reside in developing countries. 60% of it will be highly vulnerable, due to maximum population concentration in megacities on fragile land, due to migration leading to densification of urban areas along with the mushroom growth of unlawful settlements, especially, within the developing third world (Rafeeqi, 2005; Erramilli, 2009; Bendimerad, 2010). Cities undergoing urbanisation are at risk not only from hazards like earthquakes and floods, but from development that is changing the tangible and intangible values of the cities’ rich heritage. The increasing frequency and intensity of urban disasters are becoming more associated with human actions involving multi-storied buildings that crumble like a pack of cards within seconds of an earthquake (Paul, 2009; Jigyasu, 2010). However, urban risk due to urban development bypasses urban disaster reduction efforts, as can be seen in South Asian urban cities of Allahabad, Dhaka, Lahore and Colombo where the social, physical, and economic vulnerability of poor is ever on the increase. The factor of time-lapse or ‘Golden Hour’ equally affects the poor communities that reside in crowded and unstable locations within the cities (Gupta, Sinvalal, Shankar, 2006).

“Poverty is the core dimension of vulnerability but poverty is not the only factor that leads to vulnerability” (Singh, 2009).

Disaster risks must be properly understood and managed in urban planning, starting with recognition of hazard types, urban risk assessment, vulnerability assessment, loss assessment, hazard-mapping and resource identification. This should be carried out alongside on-the-job training, mentor training, workshops, and advanced academic master's degrees and programmes, including 'hands-on' approach using disaster simulation exercises based on scenarios of what transpires into a major event (Lee, 2010).

UN organisations have launched number of Urban Risk Reduction programmes like Global Risk Identification Programme (GRIP), Global Facility for Disaster Risk Reduction (GFDRR), Regional Strengthening and Disaster Risk Reduction in Major Cities in the Andean Communities. UN-ISDR has established two regional task forces for Urban Risk Reduction -
One in Latin American and the Caribbean and the other one in Asia-Pacific (Bendimerad, 2010). IDNDR legacy on series of international initiatives for Urban Risk Reduction is as shown in table 2.3 below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Initiative</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-1995</td>
<td>Megacities Project submitted to the 1994 Yokohama IDNDR Conference</td>
<td>The Institute of Civil Engineers supported by the UK IDNDR committee</td>
</tr>
<tr>
<td>1994-2001</td>
<td>Mumbai City</td>
<td>The state government of Maharashtra, with the support of the World Bank, the Department for International Development (DFID), and the UNDP</td>
</tr>
<tr>
<td>1996</td>
<td>The 'Habitat Agenda, Goals and Principles, Commitments and Global Plan of Action'</td>
<td>Developed at the Istanbul City Summit Conference.</td>
</tr>
<tr>
<td>1996</td>
<td>The 'Healthy Cities Project'</td>
<td>Initiated to bring together international groups with specific attention on urban health problems.</td>
</tr>
<tr>
<td>1996</td>
<td>The 'Radius Project’ administered by the IDNDR Secretariat and to be reported at the closing conference</td>
<td>Aim was of identifying key cities at risk from earthquakes throughout Asia, and supporting seismic risk reduction programmes.</td>
</tr>
<tr>
<td>1996</td>
<td>Research project in Ahmedabad and Delhi - The Engineering Division of the DFID</td>
<td>Focus on multi-hazard risk reduction at the community level</td>
</tr>
<tr>
<td>1997</td>
<td>The 'Asian Urban Disaster Mitigation Programme' (AUDMP) by The Asian Disaster Preparedness Centre (ADPC)</td>
<td>Multi hazard pilot projects in Asian countries. In India, the focus has been on technological and industrial hazards with projects in Baroda and in Metropolitan Calcutta.</td>
</tr>
<tr>
<td>1998-2000</td>
<td>The 'Disaster Resistant Communities Programme' promoted by the Federal Emergency Management Agency (FEMA)</td>
<td>Seeking to create safe communities. This was a constructive partnership by central and local governments together with the private sector, local institutions, and through the mobilisation of the local community</td>
</tr>
</tbody>
</table>

(Source: Davis, 2000)

2.7. Earthquakes Hazard

Study of hazards types have considered earthquakes as one of the worst enemies of mankind (Rafeeqi, 2005). Studies undertaken in urban cities regarding the existing environment to natural hazards has also indicated high structural vulnerability towards earthquakes (Bendimerad, 2010). The maximum human loss that took place around the world, as a result of natural hazards, is mainly attributed to earthquakes, in order of Asia, South and
Central America and Africa among the worst hit. Earthquakes are, thus, considered as the worst killer, affecting especially the developing countries and the poor (Arya, 2000).

2.7.1. Earthquake Prediction

World over, lack of understanding of the earthquake events coupled with vast and frightening devastation, without any visible cause and random distribution, earned them the position of divine judgment. Earthquakes, according to the Greek God Poseidon were the instruments of displeasure. In Japanese mythology, the earthquake was caused due to spiteful wriggling of the subterranean catfish Namazu. In Hindu mythology, movement of Sheshnaga, who held the earth on its hood, caused it. They were considered as punishment for sinners in Christian belief (Rautela, 2005; Singh, 2011). Thus, earthquakes have carried a number of myths with them.

The human quest for knowledge of earthquakes and its disastrous consequences since the earliest times has been considered instrumental in shaping human history and in predicting or preventing earthquake disaster (Sinha, Brzev and Kharel, 2004). The scientific truth is that “Earthquakes cannot be predicted”, there is no complete way to predict an earthquake even today in respect to time and space (Talwar and Juneja, 2009; Hayward, 2011; Devi, 2012). However, efforts are being continued by seismologists in the hope of a major breakthrough in prediction technology for the near future. Scientific data is being, thus, used to calculate the probabilities of potential future earthquakes (Talwar and Juneja, 2009). Seismologists have found that earthquakes are sometimes steered by some signals like that of ground shaking, foreshocks, change in groundwater level, variation in the discharge of springs, anomalous oil flow from the producing wells and unusual animal behaviour. They, however, are in a position to indicate the possibility of earthquakes recurrence, particularly in large areas based on Palaeo-seismicity, Micro-seismic activities, Precursors (Tewari, 2000; Upreti & Yoshida, 2009) as in cases of USA where place and magnitude of earthquake has been successfully predicted but not the time (Valdiya, 1987). It is believed that Chinese have mastered the art of earthquake forecast by closely monitoring and analysing animal behaviour. Their first successful earthquake prediction in the world is that of Haicheng event of Lioning Province, which took place on February 4, 1975, with the magnitude of 7.3 on the Richter scale. It was based on micro-seismicity activity, ground tilting and unusual animal behaviour (Valdiya, 1987; Tewari, 2000; Singh, RP. 2008; Shukla & Maru, 2013). Similarly, in 2001 prediction was announced for the Great East Japan Earthquake of March 11, 2011, using a combined earthquake
prediction algorithm called M8-MSc based on premonitory seismicity patterns and prior to prediction was also validated but with a missed possibility for considerable damage reduction.

In order to reduce a seismic build-up to dangerous levels of the explosion, some suggestions have also been given, like artificially causing ruptures in rocks through detonation that induce creeps in fault zones, or injecting fluids in walls and holes; for example Denver, Colorado USA. Other suggestions provided are, pumping out water from deep levels through drill holes of active zones which can delay the occurrence of earthquakes and by inducing a load of water as in reservoirs creating pressure for the release of seismicity (Valdiya, 1987). An earthquake prediction is, thus, statements which include a range of magnitude, geographical area, time interval and the probability of a future event.

Currently, there are no identified reliable methods that can precisely predict the location of a damaging earthquake within an immediate timeframe, that is, a few hours to days (Davis, et al. 2012). Knowledge about earthquakes should be put into developing effective programs that help individuals to gain critical earthquake awareness and focus on changing attitudes of individuals, largely with the belief in the effectiveness of measures and probability to cope with earthquakes (Tekeli et al., 2010). Even, if the earthquakes are predicted correctly or not, the damage caused to life and property on such a large scale can be controlled only through careful Earthquake Disaster Mitigation Management both at Structural and Non- Structural levels to make the society resilient through use of mitigation aspects (Rafeeqi, 2005; Dheri, 2012).

2.7.2. Causes of Earthquakes and their effects

Earthquake waves are caused due to faults, volcanic activities, and mainly due to plate tectonic activities around the world. The large masses of rocks on the earth’s surface called as plates when move past each other become locked, due to friction. This leads to accumulation of stress along the locked land masses and creates enough force to cause a sudden slippage of the rock masses. The magnitude of shock waves released into the surrounding rocks depends upon the quantity of stress built up because of the friction along the faults, tectonic plate boundaries or along mid-oceanic ridges (Tikka, 1991; Ahmad, 1992, Upreti & Yoshida, 2009). ‘Foreshocks’ may precede after a larger earthquake in the same location, or ‘Aftershocks’ can occur due to continued release of frictional stress after the ‘Mainshock’ which can continue for days to years together (Talwar and Juneja, 2009). Most of the aftershocks are smaller in magnitude than the main one but they can still cause considerable damage to the already
weakened natural and human features (Devi, 2012). More than 150,000 strong tremors are felt by humans every year (Talwar and Juneja, 2009).

It has been mentioned that the amount of damage or loss to life and property caused by earthquakes depends upon a number of factors:

- Time of the day
- Magnitude of the quake and duration of the event
- Distance from the earthquake focus
- Geology of the area affected and soil type
- Type of building construction, material and design used
- Population density and availability of facilities.
- Vulnerability of Public supply systems (water, electricity, communication, transportation)
- Policies - short and long-term (Pricovic, 2002; Talwar and Juneja, 2009).

Seismicity results in different seismic effects, on the structures and facilities getting damaged, which have been classified below as direct and indirect. (Talwar and Juneja, 2009).

Direct effects relate to two types:

1. Instabilities caused owing to ground failures consisting of ground cracking; surface faulting or fault rupture; liquefaction; ground lurching; vibration of soil; differential settlement and landslide.

2. Spreading of vibrations from the shaking ground to the neighbouring structures and vulnerable lifelines.

However, Indirect effects result in events like tsunamis, landslides, floods and fires (Talwar and Juneja, 2009; Thakur, 2008).

Earthquake effect on the ground, buildings, infrastructures and services vary greatly within the impacted area, with a non-uniform damage pattern. Distance from the causative fault determines the damage scale and pattern. Greater the distance, lesser the damage, except when the soil of local area may amplify the ground motion and bring about changes. Softer the soil,
more will be the damage within the earthquake impacted area. Similarly, the vulnerability scale of the structure can lead to earthquake impact, that is, stronger the building, lesser the impact; weaker the building, more of the damaging impact (Valdiya, 1987; Arya, 2000). Another important thing in seismic hazard assessment (SHA) is the creation of seismic source models primarily based on seismo-tectonics, past earthquake events and damage pattern (Kumar and Bhatia, 1999; SAARC, 2009; Singh, 2009). It is the quantitative estimation of strong ground shaking called as peak ground acceleration (PGA) done through algorithmic computations (Kumar and Bhatia, 1999) based on four independent parameters of magnitude, distance, fault types like normal, slip or thrust and tectonic environment. To avoid or minimise earthquake risk, three areas are involved: seismic prediction, seismic risk assessment and reduction mitigation measures (Singh, 2009).

Seismic risk is a direct function of the state of built environment or vulnerability of the building stock. Vulnerability assessment is an important aspect and the first step towards earthquake protection and seismic risk reduction (Gupta, Shankar & Sinval, 2007; Rautela, Chandra and Bhaisora, 2011). Earthquake risk is the product of the hazard intensity and the vulnerability of the buildings. The output of a seismic risk analysis could give the probability of damage and loss from a nearby earthquake. However, quantification of risk would require socio-economic and housing statistics (Arya, 2000). Seismic risk can be reduced by reduction in three elements – seismic hazard, seismic vulnerability and its expected consequences (Kumar and Bhatia, 1999; Talwar and Juneja, 2009). Seismic hazard can only be removed by the relocation of dwellings and population, while seismic vulnerability can be calculated through correlating consequences with damage (Fig. 2.7).

![Seismic Risk expressed graphically with occurrence of the damage and consequence](source: Talwar and Juneja, 2009)
There are seven key indicators as given in figure 2.8 for evaluating the vulnerability ratio for earthquakes in any place by disaster managers.

(Source: Hashemi, Mahmoudzadeh & Yousefi, 2014)

Fig. 2.8: Vulnerability indicators of earthquake

2.7.3. Earthquake Mitigation

Damage caused by an earthquake, around the continents, appears almost the same. As, the saying goes “earthquakes don’t kill people, buildings do” (Gupta 2000; Surjan & Shaw, 2009), 90% of the deaths, injuries and damages caused during earthquakes take place due to collapsing of structures like houses, schools, hospitals, roads, dams, bridges and other infrastructures (SAARC, 2009). In the past decades, millions of people have died as a result of earthquakes, mainly due to the collapse of buildings, which is attributed to the use of faulty materials like mud, weak cement, brittle steel, heavy roofing materials, shortage of wood etc. However, the real culprit of loss and damage is people being ignorant, having non-caring attitude, lack of strategic risk reduction mechanism, management and communication system (Bilham, 2009; Joshi & Khan, 2009).

Another often neglected observation found through earthquake studies is people’s attitude, that the next earthquake will not strike the region that has been once destroyed by the quake but would strike elsewhere (Bilham 2009, SAARC, 2009). National differences in
culture between countries like USA and Japan have also shown concern about the way people wonder about earthquake mitigation and response (Palm, 1998). Earthquake vulnerability assessment mainly depends on major geological/geophysical components that include mapping and characterising active faults; seismic micro-zonation; assessment of seismicity induced landslides and reconsidering the seismic history of the area (Joshi & Khan, 2009). It is; thus, essential to prioritise activities for earthquake mitigation to be carried out, based on a survey of the most critical facilities like housing of the first responders from where response and recovery is to be conducted, to the lifeline facilities within community, such as electricity, water, food, transportation, commercial and industrial buildings which could be severely affected in case of an earthquake. Priority also needs to be given to the residential structures by incorporating all the priorities into capital improvement plans (FEMA).

Safety of the non-engineered buildings, from the fury of earthquakes, is also a subject of the highest priority in moderate to severe seismic zones of the developing world. More than 90 percent of the population still lives and works in such buildings. Policies of the governments also do not address the issue of preventive actions of building codes and retrofitting toward seismic risk reduction (Arya, 2000:33). Under, non-engineered Type ‘A’ traditional buildings, which mainly comprise of field stone or clay walled structures, are predominantly liable to heavy damage, destruction and total collapse during moderate MSK Intensities of VII and VIII, which may occur in epicentral areas of 6.0 to 6.5 Magnitude shallow earthquakes. Similarly, during higher MSK Intensity of IX having 6.6 to 7.2 Magnitudes earthquake, Type ‘A’ buildings will hardly ever survive; similarly, Type ‘B’ buildings consisting of unreinforced ordinary brick walls, concrete block constructions, and better quality stone structures will be destroyed on a large scale. Only buildings of Type ‘C’ consisting of reinforced buildings and well-built wooden buildings will have a chance to survive under such high-intensity earthquakes (Arya, 2000; Gupta, Shankar, Sinvhal, 2007) (Appendix V).

In such massive earthquakes, the dominance of uninsured victims or vulnerable houses has been subjected to large recovery costs in form of government grants or low-interest loans which are funded by taxpayers (Naoi, Seko, and Ishino, 2012). Seismic mitigation is said to be processed in a number of forms from public information, adopting building codes or modifying existing critical structures and drawing up of family disaster plan (FEMA; Shaluf, 2007; Tekeli et al. 2010). Earthquake Protection Measures have been divided into three parts: (i) Architectural design, (ii) Structural counter measures, and (iii) Construction and maintenance
quality (Valdiya, 1987; Arya, 2000). The techno-legal regime has been suggested as means for amending the acts and by-laws for including safety aspects from a viewpoint of natural hazards, along with a review of relief manuals, preparation of calamity preparedness guidelines to suit local needs and geo-climatic conditions (Arya, 2000; Devi, 2012). Creating public awareness is suggested as the most important and crucial step towards mitigation of seismic risk at all levels by government and public (Upreti & Yoshida, 2009). Similarly, setting up of task teams of trained and equipped local people for earthquakes can help in SAR before state machinery and specialised search and rescue teams arrive at the site of the incident (SAARC, 2009).

The absence of strong earthquake in the recent past has left the present generation unaware of the possibility of a major earthquake (Kumar and Bhatia, 1999) which can lead to full economic development, investments and progress of decades, being wiped out within a flick of a moment. The 1995 Kobe earthquake in Japan is one such example where about US$100 billion worth economic loss took place within seconds of seismic activity (Joshi & Khan, 2009). Thus, the rapid expansion of built environment in moderate or high –risk cities around the world, makes it imperative to incorporate seismic risk reduction strategies in various aspects of urban planning and construction of new structures (Shah, 2012). Sustainability of Earthquake Risk Reduction and Recovery Preparedness approach significantly depends on the proper vulnerability assessment (Joshi & Khan, 2009). These disastrous consequences of earthquakes are overcome by humans on three levels: firstly spiritual - through prayers and appeasement of God; secondly - through scientific efforts by identifying earthquake-prone areas and their prediction; and lastly - through the development of engineering efforts for earthquake-resistant construction technologies (Sinha, Brzev and Kharel, 2004). Six Basic Recommendations for Earthquake Risk Reduction suggested are:

1. Form a consortium of governments to collaborate in earthquake risk reduction as well as relief efforts, since risk is distributed across national boundaries.
2. Identify and share information about hazards based on systematic seismic studies.
3. Assess individual and community vulnerabilities and capacities.
4. Educate communities in risk reduction, practices, and methods.
5. Involve all stakeholders to ensure risk avoidance, self-rescue, mutual aid, synergy and resilience in the risk reduction system.
6. Seek external grants to fund upfront costs of research and implementation of collaboration (SAARC, 2009).

Earthquake Risk Management measures (EQRMs) have been suggested as a function of numerous parameters of pre and post-earthquake risk management measures. Pre-Earthquake Risk Management measures (Pre-EQRMs) include Preparedness (pr), Human Measures (hm), Non-structural Measures (ns), Risk Analysis (ra) and Structural Measures (sm) and the Post-Earthquake Risk Management measures (Post-EQRMs) include Efficacy (ef), Human Resource Response factor (hr), Planning (pl), Risk factor (rf) and Built Environment (be). Thus,

\[
\text{EQRM performance} = f (\text{pr, hm, ns, ra, sm}) + f (\text{ef, hr, pl, rf, be})
\]

Or

\[
f (\text{pre-disaster variables}) + f (\text{post-disaster variables}) \quad (\text{Deshmukh, 2009}).
\]

Earthquakes are, therefore, considered as a measure of stability of human structures and earth’s surface (Singh RP, 2008).

**2.8. Approach of Disaster Management in India**

For highly populated and developing country like India, lack of awareness and improper planning in earthquake disaster management can lead to a large number of lives being lost. The expanding scale of urban pressures, problems, and risks in India is a daunting challenge which has been ignored largely by local authorities and national governments. India has been ‘reactive’ in its approach towards disasters – with precious resources being spent on relief, rehabilitation and reconstruction. Recently, there has been a paradigm shift towards a balanced approach which includes pre-disaster aspects of disaster prevention, mitigation and preparedness (Ministry of Home Affairs, 2011). The government of India, along with United Nations Development Programme (GOI-UNDP) has been carrying out various programmes within India for Disaster Management. One such joint programme for disaster risk mitigation was taken up in 2002, with the assistance of United States Agency for International Development (USAID) and European Union (EU), aimed at building capacity in seventeen of the most disaster-prone states within India (Erramilli, 2009, Khan, 2009). To accelerate the pace of disaster mitigation within India, it laid emphasis on linking disaster mitigation with developmental plans; effective communication system; use of the latest information technology; insurance in all relevant sectors; extensive public awareness and education.
campaigns, particularly in the rural areas; legal and legislative support; and greater involvement of NGOs/private sector (Arya, 2000).

The memorandum signed between the Government of India, Ministry of Home Affairs and United Nations Development Programme (UNDP) on August 2002, for implementing “Disaster Risk Management Programme” for reducing the vulnerability of the communities to natural disasters, in multi-hazard disaster-prone areas, had the following objectives:

1. Ministry of Home Affairs to undertake National Capacity Building,
2. Environmental building, awareness, education, capacity strengthening at all levels and Sustainable recovery,
3. Multi-Hazard preparedness, mitigation and response plans at State, District, Block and Village levels within the selected programme states, and
4. Networking knowledge on effective approaches, methods and tools for natural disaster risk management, developing and promoting policy frameworks (Jain, 2012).

2.8.1. Legislative framework of Disaster Management in India

Disaster Management in India dates back to 1878 under the Ministry of Agriculture. However, in 2002, Division of Disaster Management got shifted to the Ministry of Home Affairs, headed by Joint Secretary Disaster Management after a high powered committee was formed to draw a systematic, holistic and broad approach to disasters after the 2001 Bhuj Earthquake (Ministry Of Home Affairs, 2011; NDMA, 2007). India being a Federal Government, has specific roles for the Central and the State Governments. It included integrating administered machinery for management of disasters at National, State, District Sub-District levels and Panchayats, involving various ministries, departments and administrative bodies, through a multi-sector and multi-disciplinary approach (Fig. 2.9) in Disaster Management strategy and planning (Jaiswal, 2006; NDMA, 2007). Disaster Management Act was constituted in 2005 within India, ensuring the various wings of the government, work for mitigation and prevention of disasters along with the response.

Under the 2005 Act, National Disaster Management Authority (NDMA) was established as the Nodal Authority, with Honourable Prime Minister of India as its Chairperson. Under it was framed the National Executive Committee (NEC), National Disaster Response Force (NDRF), National Institute of Disaster Management (NIDM) - as its statutory body.
responsible for training, research, and documentation of disasters with capacity building. However, National Policy on Disaster Management (NPDM) was formed in 2009, with the aim of bringing about a transparency and accountability in all aspects of Disaster Management by including the communities, Community Based Organizations (CBOs), Panchayati Raj Institutions (PRIs), local bodies and civil society (Sunder and Sezhiyan, 2007). For the National level, strategic policies and guidelines were laid down by NDMA which was the national authority for Disaster Risk Reduction. However, for the states, State Disaster Management Authorities (SDMA) were given the responsibility of laying down state policies and plans in accordance with NDMA. The policy also envisages the specific roles to be played by the local bodies both at rural and urban levels. National Disaster Mitigation Fund and National Disaster Response Fund were also formed under the DM Act 2005 for the nation.

Fig. 2.9: National Disaster Management Structure - India
Under the Ministry of Finance, 13th Finance Commission had been operative with the aim to strengthen the institutions of Disaster Management, capacity building and response mechanisms within India and which cannot be sustainable unless disaster management is put into action (NDMA, 2007; Deolankar Vivek, 2010). This holistic and multi-disciplinary approach is the key to effective mitigation (Singh, 2009). Presently, the 14th Finance Commission is operative within the country.

2.8.2. *Causes of Seismicity in India and its impact*

Analyses done through different scenarios indicate that more than 100 million people in India are at seismic risk of varying intensities, ranging between VII and above, on the Richter Scale (Talwar and Juneja, 2009). The built environment of India is very fragile and the ability to prepare and respond to earthquakes is inadequate (Shah, 2012). Review of disasters within India indicated that 64% deaths are caused as a result of earthquakes (Fig. 2.10), based on the analysis of mortality data from 1980-2010 (EM-DAT: The OFDA / CRED International Disaster Database).

![Chart showing the distribution of disasters in India](chart.png)

(Source: EM-DAT: The OFDA / CRED International Disaster Database - *includes Tsunami)

**Fig. 2.10: National Disasters Mortality Rate in India (1980 -2010)**

2.8.3. *Cause of Earthquakes*

Seismic evaluation and vulnerability assessment indicated that the main reason for earthquakes in India is the plate tectonic movement (Tikka, 1991; Valdiya, 1987; Gupta 2000; Arya, 1992; Satender, 2003; Ghosh, 2008; Chamlagain, 2009; Joshi & Khan, 2009). Indian plate broke away from the Gondwanaland of Pangea landmass and moved northwards over the
centuries to where it lies presently, colliding with the Angaraland (Tikka, 1991). This collision of the Indo–Australian Plate with the Eurasian Plate (Map 2.1) led to compression of the land mass lying between the two, called the Tethys Sea, and led to the formation of the youngest fold mountains of the world, called the Himalayas. The active faults, in and around this belt, are direct indicators of recent crustal movement due to the collision between the Indian and Eurasian plates (Valdiya, 1987; Arya, 1992; Gupta 2000; Chamlagain, 2009; Joshi & Khan, 2009). These mountain ranges were formed in three different stages beginning with the gentle evolution in the Cretaceous era (130 million years ago), with eminent compressive movement in the Tertiary era (70 million years ago). But the major part of the movement of the Himalayas took place between the Pliocene (12 million years ago) to Pleistocene epoch (1 million years ago) (Tikka, 1991; Ahmad, 1992). The Indian plate is still penetrating deeper under the Eurasian Plate, at an estimated rate of about 50mm/year (5 to 6 cm), triggering intense seismic activity around the entire region (Satendra, 2003; Ghosh, 2008, Thakur, 2008).

Subduction/collision earthquakes within India, thus, mainly occur along the Himalayan Frontal Fault/ thrusts (Map 1.5). This ongoing convergence is responsible for both neotectonism and seismicity within the Himalayas, Tibet and the adjoining areas of the Indian Sub-Continent (Rautela, Chandra, Bhaisora, 2011). The Himalaya is one of the most active and the youngest mountain belts in the world, which is still isostatically imbalanced and geodynamically active due to northward push of the Indian Plate towards the Eurasian plate (Joshi & Khan, 2009).

The sections that have not ruptured in the past several decades, along these plate boundaries, are called as seismic gaps. These are mainly traversed structures of the submerging Indian Shield and the underthrusting rocks which are considered as the areas of next earthquake gap filling. These areas are considered as major rupture zones, within the plates, that have not ruptured into great earthquakes for more than 160 years and are undoubtedly accumulating strain. This main displacement zone with morpho-tectonic units is popularly known as "Reentrants" example the Kangra Reentrant and the Dehra Dun Reentrant (Valdiya, 1987, Satendra, 2003; Tewari, 2000, SAARC, 2009; Joshi & Khan, 2009). One such example of the rupture within the Northern Himalaya Zone was that of the 1905 Kangra earthquake called the "seismic gap". Its estimated rupture was about 280 km long, extending from Kangra in Himachal Pradesh to Dehra Dun in Uttarakhand. It is even today considered as the potential location for the next large earthquake to occur within the Himalayas (Chamlagain, 2009,
Rautela & Chandra, 2009). This longtime interval for the release of next strain from within the earth into another earthquake has been called as ‘time-predictable model’ of earthquakes (Khattri, 1993).

Another scenario based on ‘Fault modeling’ for Nepal Himalayas showed that there is ‘accumulation of elastic strain’ within the area that can reactivate old geological faults and generate earthquakes of different magnitude. These models, thus, indicate one or more mega-earthquakes overdue for the Himalayas (Chamlagain, 2009; Kumar, Kumar, Sinvhal, 2011). This has been proved by the recent incident of the great Nepal earthquake of May 2015. Proximity to faults, on the other hand, does not indicate the occurrence of big hazards in relation to those that are further placed because damage from an earthquake depends on a number of other factors like subsurface geology, adherence to building codes, population density, etc. (Municipal Corporation Shimla, 2012). View of the last 1000 years of earthquakes in the Himalaya’s has been indicated by seismologist that the recent earthquakes are much stronger and more destructive than those occurring during the ancient and medieval times (Bilham, 2009; Chandel & Brar, 2010).

(Source: Valdiya, 1987; Satendra, 2003)

Map 2.1: Tectonic Plates and their Movement
2.8.4. **Earthquake Timeline of India**

Earthquake history of India showed that the first recorded earthquake took place in Kutch of Gujarat in 1819 with magnitude of 8 on the Richter scale. Over the last three decades, India has witnessed several earthquakes like Bihar – Nepal Border (1988), Uttarkashi (1991), Latur (1993), Jabalpur (1997), Chamoli (1999), Bhuj (2001), Kashmir (2005) all being ground shaking seismic activities and one being Tsunami (2004) (Singh, RP., 2008; Purohit & Suthar, 2012). Thus, since 1990 -2013, India has experienced some major earthquakes that resulted in a large number of deaths. Looking into 25 major earthquakes that have occurred between 1819 -2013 in India (Appendix IV) and its surrounding area as per EMDAT and IMD, the number of earthquakes of various magnitude that have occurred are shown in graphic 2.11 below:

![Number of Earthquakes 1819 -2013](chart.png)

(Source: EMDAT and IMD)

**Fig. 2.11: Magnitude of Major Earthquakes between 1819 -2013 within India**

Besides, Tsunami of 2004 that had a magnitude of 9.3 on the Richter scale, the largest earthquake has been of 1897 of Shillong Plateau with 8.7 magnitude. This is followed by 1950 earthquake of Sadiya Region along Arunachal Pradesh-China Border, with 8.6 magnitude (EM-DAT and IMD), where it has been cited that rivers changed their course and ground elevations changed permanently with stones having been thrown upwards with an acceleration exceeding 1g (Arya, 2000).
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There has been a huge loss of life and property in the olden times in spite of low population density; and if the earthquake of matching magnitude would presently visit the region, the devastation would be many folds. Increase in the loss of life and property, over the years, is not due to increase in number and strength of earthquake frequency. But due to rapidly increasing vulnerability level of human civilization, to the hazards along with an increase in population concentration and rapidly developing infrastructure within the fragile regions (Tewari, 2000; Joshi & Khan, 2009; Shukla & Maru, 2013). Past earthquakes have caused enormous damage to life, property, assets and public infrastructure, indicating the extremely fragile nature of India and its inadequacy in preparation and effective response towards earthquakes (Shah, 2012). Timing of the event and epicentre also matters a lot in the impact of earthquakes, as was seen in the Killari earthquake of 1993 which occurred at 03:00 hours, during the winter morning when people were sleeping, causing a high rate of casualties (Shukla & Maru, 2013). One of the reasons for the lack of progress in saving lives from earthquakes is that we have begun to understand earthquake mechanism only in the last quarter of the twentieth century (Rautela and Chandra, 2009).

2.8.5. Earthquake Prediction in India

In India, efforts are going on for prediction based on statistical analysis of past events and their recurrence intervals, swarms activity and seismic gaps (Ahmad, 1992). The mega-earthquake was predicted in North East India based on the theory of cyclical earthquakes and the return of earthquakes was calculated at an average of 55 years (Sarmah, 1999). The earthquake return period in the Himalayas has been calculated by some scientists through spatio-temporal distribution of seismicity. It has been estimated that the entire Himalayan arc would rupture in a time period of about 180 to 240 years, while repeat time for 8 magnitude earthquakes with rupture length of 3300 km would be 200 to 270 years. Secondly, paleo-liquefaction evidence has also been reported as evidence for a pre-historic earthquakes of Shillong Plateau. Another method of prediction recognised was swarm and quiescence before the occurrence of the main shock, as was done in 1988 earthquake of NE that proved medium-term forecast true. It could be used elsewhere within the Himalayan arc as well (Gupta, 2000; Tewari, 2000). In India, efforts are hampered as instrumental data is available only for last 100 years from 1898 onwards.
2.9. Seismological Mitigation Measures of India

The prevention of an earthquake is impossible but the loss caused by it can be controlled through careful disaster mitigation management (Dheri, 2012). Seismic Hazard Mitigation programme within India is a coveted effort of R. D. Oldham, Director, of Geological Survey of India, who carried out detailed study after the Great Assam Earthquake of 1867 with a magnitude of 7.5 on the Richter scale and who published ‘Oldham’s Monograph’ thereafter (Oldham, 1973).

2.9.1. Indian Seismological Structure

Review of Indian Seismological Structure showed that the first seismological observatory within India was established at Alipur, Kolkata in 1898 after 8.7 magnitude earthquake struck Shillong in 1897. Later two more observatories were established at Colaba (Mumbai) and Madras (now Chennai) in 1899 but were later shifted to Kodaikanal (Arya, 2000; Gupta 2000; Singh RP, 2008; Verma and Bansal, 2013). However, Instrumental Earthquake monitoring in India initially began in the 20th Century and was carried out by Indian Meteorological Department, IMD, New Delhi (Ministry of Home Affairs, 2011) and even today is monitored by the same department. In 1967, at National Geophysical Research Institute (NGRI) Hyderabad, another observatory was established (Singh RP, 2008). Some of the Seismological Institutes that monitor earthquakes and carry out surveillance within India (Ministry of Home Affairs, 2011) are shown in the schematic 2.12 below:

(Source: NDMA)

Fig. 2.12: Earthquake Management Departments within India
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The Indian Tsunami Early Warning Centre is located at Indian National Centre for Oceanic Information Services (INCOIS), Hyderabad which provides advance warnings on tsunamis that may affect the coastal areas of the country. It was set up after the aftermath of the Great Sumatra earthquake of 26th December 2004 by the Ministry of Earth Sciences (MoES). The Centre for Excellence for Earthquake Management at Guwahati conducts research, develops resources and network with related institutions at national, regional and international levels (Ministry of Home Affairs, 2011). All India Disaster Mitigation Institute (AIDMI) an NGO based in Ahmedabad, Gujarat, was established in 1987 and works in six different fields of disaster including earthquakes. IMD also maintains a nationwide National Seismological Network (NSN), consisting of 82 seismological stations which are divided into three types:

1. 16-stations of V-SAT, based on Digital Seismic Telemetry System (DSTS) located around National Capital Territory (NCT), Delhi;

2. 20-stations also of V-SAT, based on Real Time Seismic Monitoring Network located in North-Eastern region of the country, and

3. 17-stations consisting of Real-Time Seismic Monitoring Network (RTSMN) which are meant to monitor and report the large magnitude of under-sea earthquakes capable of generating tsunamis on the Indian coastal regions.

The remaining 29 stations are of individual/ analog type.

National Seismological Data Base Centre (NSDC) compiles, processes, analyses and archives all available seismological data received from all the network stations including those operated by other agencies, on a regular basis. A Control Room is operational, on a 24X7 basis, at IMD Headquarters (Seismology) New Delhi, having state-of-the-art facilities for data collection, processing and broadcasting information to the concerned agencies. The information related to earthquakes is also transmitted to various agencies including public information channels, press, media etc. through different modes of communication, like SMS, fax, email and posted on IMD’s website www.imd.gov.

The Ministry of Earth Sciences (MoES), is the nodal ministry in India which prepares the Earthquake Management Plan covering all aspects of earthquake preparedness, mitigation, public awareness, capacity building, training, education, Research and Development (R&D),
documentation, earthquake response, rehabilitation and recovery. However, the Indian Meteorological Department (IMD) is the nodal agency for monitoring seismic activity within India and the Bureau of Indian Standards (BIS) is the nodal agency for preparing earthquake-resistant designs and building codes, with other safety structural codes.

Geological Survey of India compiled the first national seismic hazard map for India in 1935. The second seismic hazard map was published in 1965 based primarily on an earthquake epicentral and isoseismal maps, which were later revised in 1966 and 1970 (SAARC, 2009; Joshi & Khan, 2009; Kumar & Bhatia, 1999). Another significant change in the revision of maps was the abolition of zone ‘zero’ of an earthquake after acknowledgment of the fact that no region within India has the probability of an earthquake equal to zero (Joshi & Khan, 2009). However, the work of seismic zoning was carried out in 1956 when seismic zoning map was formed based on the broad concept of earthquake distribution and geotectonics into 3 zones – severe, moderate and minor (Kumar and Bhatia, 1999). The Indian Standard Institute (now Bureau of Indian Standard) in the year 1960 included the first map within the code IS: 1893-1962 (Appendix VI). Recent versions of seismic zoning map of India are given in earthquake-resistant design codes of India [IS 1893(Part 1) 2002] and has assigned four zones for entire India - zone II, III, IV, and V (Singh, RP. 2008).

The National Building Code (NBC) (Appendix VI) brought out the first Indian Standard Code IS 1893 : Criteria for Earthquake- Resistant Design of Structures in 1962 and IS: 4326, Earthquake-Resistant Design and Construction of Buildings – General Code of Practice in 1967, while the first manual was published in 1970 by Planning Commission and later revised in 1975 and 1983. After this, it has undergone three amendments -two in 1987 and a third in 1997. The revised NBC (2005) for development in building construction includes the lessons learnt in the aftermath of the devastating earthquake and super cyclones of 2001 and 2005. The latest revision of IS code 1893 by NBC has been done in 2016. A Monograph was prepared to cover “Basic Concepts of Seismic Codes”. It was divided into three parts dealing with (i) Seismic Zoning, (ii) Non-Engineered Construction, and (iii) Engineered Construction. The first two parts were published as per International Association for Earthquake Engineering (IAEE) in 1980 and part three in 1982 (Arya, 2000; Surjan and Shaw, 2009; bmtpc.org). A national Core Group for Earthquake Mitigation has also been formed comprising engineers and architects to draw plans and strategies for mitigating the impacts of earthquakes within India (NDMA, 2007; Singh, 2009). The Vulnerability Atlas of India was prepared during 1994–
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1997, by Ministry of Urban Development which included earthquake, cyclone and flood hazard maps for every state and union territory of India, prepared at the scale of 1: 2.5 million (Arya, 2000).

2.9.2. Earthquake Mitigation measures and Guidelines in India

Initially, earthquake disaster prevention and mitigation were not addressed as such by government bodies within India. The earthquake of magnitude 6.3 (1993) at Killari in Maharashtra highlighted the need for upgrading the seismological instrumentation in peninsular India to state-of-the-art level (Arya, 2000). Similarly, after the 2001 Bhuj Earthquake of Gujarat, it came to the forefront that the non-compliance of structural regulations within Ahmedabad city was the main cause of its vulnerability that lead to destruction (Thiruppugazh, 2008). Keeping in view the large-scale destruction due to earthquakes, the Tenth Five-Year Plan added a detailed chapter on Disaster Management. The plan emphasized on the fact that development cannot be sustainable without mitigation. Being part of developmental processes, each State needs to prepare a plan for disaster mitigation in accordance with the approach outlined (Kaul, Ayaz, & Lohitkumar, 2011).

Subsequent to the Bhuj earthquake of 2001, Government of India initiated a number of significant measures for earthquake hazard mitigation. The developed measures included (Kaul, Ayaz, & Lohitkumar, 2011; SAARC, 2009):

- National Disaster Management Earthquake Guidelines.
- Formation of National Core Group for Earthquake Risk Mitigation.
- Urban earthquake vulnerability reduction project was initiated in 38 cities of seismic zones 3, 4 and 5 within the country.
- Earthquake safe construction guidelines for masonry buildings in different zones.
- Review of building bye-laws and their adoption was initiated and model amendment in town and country planning legislations, regulation for land use Zoning and building bye-laws for structural safety were suggested.
- Retrofitting including earthquake safety analysis for lifeline buildings
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- Various national level training and education programmes for capacity building of engineers, architects and masons for seismic-resistant construction have been initiated at different levels.

- National Earthquake Risk Mitigation Project.

- A National School Safety Programme was also initiated.

NDMA has also laid down Earthquake Disaster Management guidelines for reducing seismic effects that consist of three broad sections: (a) the context and approach to the management of earthquakes in India; (b) an outline of the specific Guidelines; and (c) a broad overview of the DM plan. The specific Guidelines referred to as ‘The 6 Effective Pillars or Guidelines’ for earthquake mitigation especially for Zones III, IV and V (Shah, 2012; NDMA 2007) are shown in the graphic 2.13 represented below:

![Six Major Guidelines of Earthquake Management System within India](source: NDMA, 2007)

**Fig. 2.13:** Six Major Guidelines of Earthquake Management System within India

Based on these guidelines certain projects and programmes (NDMA, 2007) have also been carried out in India as follows:

1. National Earthquake Risk Mitigation Project (NERMP)
2. National Building Code (NBC)
3. Building Materials and Technology Promotion Council (BMTPC)
4. National Disaster Mitigation Fund (NDMF) formed under the DM Act
Government of India is, thus, trying to integrate mainstream Disaster Risk Reduction (DRR) into the Developmental Strategies and Planning (Sharma, 2009). It has also talked about the role of Urban Local Bodies in disaster-related concerns which were paved by the Constitution’s 73rd and 74th Amendments. Local governance institutions having grassroots level contacts can make a substantial contribution to spreading awareness and ensuring people’s participation in disaster mitigation (Sharma, 2012).

2.9.3. Earthquake mitigation and case studies of India

Even after India has formed guidelines and building codes for construction practice of seismic resistant construction, the destruction seen as a result of various earthquakes over the past, indicates that buildings constructed with modern materials and technology mainly belong to the socially and economically more affluent classes. While economically weaker sections of the society, even today, use traditional construction materials, due to their low cost (Sinha, Brzev and Kharel, 2004) and the bulk of the households constructed within rural areas are non-engineered in structure (Singh, 2009). Thus, lack of knowledge of the Bureau of Indian Standards (BIS) codes (Appendix VI) of seismically safe construction among architects and engineers, and lack in awareness regarding construction vulnerability among the public, has led to housing construction without BIS Standards within urban/suburban and rural areas. Studies have shown that the cost of construction for making earthquake-safe buildings is not more than 5-10% of the normal construction cost (Bendermaid, 2010). Communities affected by earthquakes have understood the essential principle of structural safety as the key, to avoid loss of human lives in a seismogenic event and thus have led to the development of innovative practices for minimising human losses originating from structural collapse (Rautela and Chandra, 2009).

Similarly, the effectiveness of traditional technologies obviously become apparent during the various earthquake studies within India, which suggested that local traditional construction practices have been lost due to the introduction of today’s modern materials and construction techniques, without addressing the seismic safety of modern constructions (Sinha, Brzev and Kharel, 2004). Measures of retrofitting infrastructure under mitigation can considerably reduce vulnerability and misery of earthquake disasters, as appeared, in the study undertaken in Mussoorie town (Rautela, Chandra, Bhaisora, 2011). Study of indigenous construction styles, like Dhajji-dewari and Taq in Kashmir or 880 years old Wood-frame construction of Koti Banal Architecture style buildings in Uttarakhand, suggested that even
today local traditional construction practices can help in seismic safe construction especially for those who cannot afford the high cost of seismic resistant construction (Rautela and Chandra, 2009). The indigenous earthquake-resistant construction technologies used after the earthquakes of Killari (1993) and Bhuj (2001) have also shown that even though they are relatively low cost but their use provides a chance to build safer housing for the economically weaker sections of the society, who otherwise are forced to live in non-engineered houses (Sinha, Brzev and Kharel, 2004).

Seeing today’s building material and construction of the houses in Kangra, a Scenario-based study was undertaken for the same area, on the likelihood of the same intensity earthquake of 1905 with VIII to X, MMI scale. This exercise led to even more shocking results, showcasing even severe damage and destruction than the 1905 Kangra earthquake, which till date is considered as one of the worst hit within India. The study emphasised the importance of retrofitting of important buildings for risk reduction (Arya, 1992). However, a mixed review regarding use of earthquake structural measures have also been seen among the communities, like the one in Narendranagar Block in Uttarakhand, where study conducted on hypothetical earthquake scenario for assessment of vulnerability of houses rejected traditional construction measures of houses and suggested modern construction methods and practices (Gupta, Shankar & Sinvhal, 2007). Other methods stressed upon under literature review, for Earthquake Disaster Mitigation within India were the preparation of action plans at grassroot level (Pande & Sharpe, 2004), awareness of local government, citizens, especially school children (Sharma, 2009).

Under earthquake infrastructural mitigation world over, importance to lifeline structures and their related departments have been stressed upon for structural mitigation and retrofitting. During Turkey Earthquake, a fire broke out after the earthquake. Due to collapsing of electric poles and closely packed houses with narrow streets it led to about 10,000 deaths (Erramilli, 2009). Similar lifeline failure conditions were also seen in Kobe earthquake of 1995, where over 120,000 buildings collapsed with about 230,000 residents having to evacuate immediately after the earthquake. The lifeline facilities like electricity, water, gas supply, etc. had been destroyed, along with transportation network which was completely paralysed (Pricovic, 2002). Nepal, especially Kathmandu Valley is considered as one of the most vulnerable cities in the world from earthquake disaster viewpoint due to its continued unplanned and haphazard urbanisation. There is un-engineered or poorly engineered construction, along with intertwined wires and cables, shortage of water supply and narrow
winding roads and lanes, causing inaccessibility to the ambulance and firefighting equipment. Thus, improving the quality of most public and government buildings is highly questionable to even moderate magnitude earthquake if it ever strikes (Upreti & Yoshida, 2009). The May 2015, 7.8 magnitude earthquake of Nepal proved the researchers correct which led to the large-scale destruction of both life and property.

2.10. Tools and techniques used in Earthquake Mitigation

Preparing for disasters like earthquakes one needs to ensure that the plans are realistic and achievable in practice (Paton & Johnston, 2001; McEntire & Myers, 2004). One suggested way to cope with vulnerability at the social level is through “Social Vulnerability Maps” that help in accessing appropriate needs of the people. Social maps help in identifying remote and vulnerable areas that usually get neglected by planners and relief workers. Such maps once made, especially by the community itself, will not lead to the absence of chances for development, distribution or misuse of relief goods (Khan, 2006). SWOT Analysis/ Model is another suggested technique for earthquake study. It identifies and inspects the threats and opportunities of the external environment along with scrutinising and recognising the strengths and weaknesses of the community/ organisation for future planning and development. It also helps in developing a strategy to conduct and control the crisis by identifying factors and selecting the strategy which matches the best. Thus, the appropriate strategy not only helps to maximise the strengths and opportunities of an area with regards to disasters like earthquakes, but also helps to minimise the threats and weaknesses by building the capacities of the community and making the society resilient towards earthquakes (Satendra, 2003; Hashemi, Mahmoudzadeh & Yousefi, 2014).

Revolution in information technology has also brought about global change in understanding disasters from parameters of theory to new methods and models capable of unravelling complexity of the rapidly changing milieu (Alexander, 2012). A necessary precondition for realistic planning and effective mitigation for assessment of seismic vulnerability is Rapid Visual Screening (RVS) and Detailed Vulnerability Assessment (DVA) of buildings (SAARC, 2009) accompanied with present day tools of Geographic Information System (GIS) and remote sensing. In some cases, EZ-FRISK88M software is being used to estimate PGA for probabilistic hazard assessment (Kumar & Bhatia, 1999). Use of such techniques within the Himalayan belt has been seen in the study of the seismic vulnerability of the built environment in Mussoorie which falls in Zone IV as per Earthquake Zoning Map of
India (Rautela, Chandra, Bhaisora, 2011). GIS and Remote Sensing not only helps to establish the varying degree of vulnerability within areas prone to disasters but also help to update previously made maps for making plans and policy implementation easy (Arya, 2000; Singh RB, 2008; SAARC, 2009; Dheri, 2012). Space technologies are, thus, being widely used to monitor the occurrence of various disasters and to evaluate the loss and their impact on developmental processes (Fernando, 2012).

Other tools and models being used for earthquake mitigation are the ‘Simulation Models’ like the ‘HAZUS’ developed by The Federal Emergency Management Agency (FEMA) and ‘RADIUS’ - Risk Assessment Tool for Diagnosis of Urban Areas against Seismic Disasters. They help in risk assessment of seismic hazards based on computer programmes associated with GIS and help to estimate location, amount of damage and human loss, using multidisciplinary databases with different quality (Momani, 2012). It has been effectively used in Southern San-Andreas Fault, in the USA, where, HAZUS supplemented with local data was used to characterize overall damage to the building stock and some lifeline structures (FEMA; Porter, et al., 2011). It can be used to integrate data and understanding scope of emergency to manage an incident, to recommend preventive and mitigating solutions as well as prioritising for SAR tasks with long and short-term recovery operations (Tak, 2008). Another Simulation Model used by FEMA is ‘CATS’ or Consequences Assessment Tool Set, which combines damage prediction models and databases with GIS to display and analyse hazard predictions, perform consequences assessment, facilitate resource management and create pictorial and textual reports, to ensure adequate contingency planning and post-disaster assistance (Swiatek and Kaul, 1999). However, recent research undertaken by the National Aeronautics and Space Administration, USA, has indicated that Global Positioning System (GPS) may be able to rapidly determine the magnitude and location of earthquakes and tsunami warnings (American Society of Civil Engineers, 2012). GPS, on the other hand, is considered to detect tectonic movements to some extent that can be useful in issuing warnings in case of earthquake prediction, through observation of ground deformation (Singh RB, 2008; SAARC, 2009; Dheri, 2012).

Urban cities have distinct characteristics like topographic feature, economic structure, buildings and infrastructure system, population density, etc., that experience different impact of an earthquake. Urban Local Earthquake Disaster Index (ULEDRI) expresses the earthquake risk of a city by paying attention to the features of the city that will be affected by an earthquake.
ULEDRI has been derived from Earthquake Disaster Risk Index (EDRI) formed in 1997 by Dr. Rachel Davidson who integrated knowledge and techniques from earth science, engineering, socioeconomics, culture and politics. ULEDRI (Fig. 2.14) has the same key features as EDRI but becomes more localised within cities (Yang, Xiao & Zhu, 2000). The conceptual framework of combining all indicators into factors and combining all factors into ULEDRI, is the linear combination, as defined for Shanghai city in figure 2.14.

Fig. 2.14: Conceptual Framework of ULEDRI

2.11. Prominence of Strategies and Scenarios in Earthquake Disaster Mitigation

2.11.1. Concept of Strategic Planning in Disaster Management

Faulkner, in 2001, suggested that good management means having strategies for coping with unexpected events over which organisations have no control (Asghar, Nejati and Mollaee, 2010). Strategies and scenarios in disaster management refocus thinking and lead to developmental models which challenge assumptions concerning linearity and effective planning which supports uncertainty and foresight for tackling issues of black swans and
increase resilience. Strategic Planning for Disaster Management is carried out at various levels - national, state, district, city and village levels (NDMA), while implementation of disaster management policy is carried out at policy level, strategic level, administrative level and functional level (Phule, 2010). Strategic Decision making is largely the responsibility of the senior administrators and is mainly a process of selecting a course of action from among many alternatives (Kazmi, 2008; Prasad, 2008). Strategic Management consists of four phases:

- Environmental Scanning involving monitoring, evaluating and disseminating information from both internal and external environments.
- Strategy formulation carried out through scanning the hazard-prone area along with risk, vulnerability of that area and administrator’s appraisal with regards to resources, finance, technology, etc.
- Strategy Implementation to be done through series of administrative and managerial actions.
- Evaluation and Control is the final phase involving assessment of how appropriately the strategies have been formulated and how effectively they have been implemented (College of Defence Management, 2004).

Strategies, thus, address long-term goals and outputs (Lettieri, Masella and Radaelli, 2009, Deolankar Vivek, 2010). Some basic aspects are considered while designing strategy for disaster management like avoid disastrous situations, take preventive actions prior to occurrence, arresting of further damage, managing the situation for faster recovery and stability, recover through implementation of plan as early as possible and learn from the disaster making WHY-WHY- analysis or cause-effect analysis (Phule, 2010). In Disaster Management a collective efficacy through collaborations and coordination has been thought of to be more pragmatic than segregated effort for the success of mitigation strategies (Paton and Johnston, 2001). Some researchers have suggested greater participation of vulnerable groups in the decision-making process of the developmental and risk-reduction programmes, especially for communication strategies (Goodyear, 2001). While some have stressed on decentralised delivery system for decision making and providing aid to strengthen organisations for disaster preparedness and mitigation, keeping in view the need of rapid and local response at the time of catastrophe (Ministry Of Home Affairs, 2011; Moin, 2012; UNISDR.Org; Coppola, 2011). Strategies are of three types - core strategies, hedging strategies
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and contingency strategies, which are as a result of issues identified during scenario building exercise and which become objectives for future planning by decision makers (College of Defence Management, 2004; Prasad, 2008).

2.11.2. Scenario Building and Earthquake Disaster Mitigation

Scenario planning is that part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future (Ringland & Schwartz, 1998). They are employed to study present strategies, adding meaning to new strategies that are being created and doing mid-term corrections of the same (Prasad, 2008). Scenario Building process is neither a prediction nor projection of the past into the future but investigation that produces a number of possible futures (Alexander, 2012). They are reliable and yet indefinite (Keough & Shanahan, 2008), supporting “thinking the unthinkable” thought process involved in exploring uncertainty and challenging mental models (Phule, 2010; Masys, 2012) to develop sound strategies, that can prepare organisations for an uncertain future in a better manner within the space of possibilities.

Michael Porter defined scenarios in 1985 (Porter, et al. 2011) as: "an internally consistent view of what the future might turn out to be - not a forecast, but one possible future outcome."

Scenario planning as a method for public policy decisions started in the US, around the 1950s for war game analysis. Rand Corporation within the US became the centre for scenario thinking to help the US Department of Defence. Herman Kahn of Rand Corporation pioneered the technique of ‘future-now’ thinking, ‘aiming through the use of detailed analysis plus imagination, to be able to write a report in the present as if it was being written at some date in the future’. Kahn used the Hollywood terminology of scenario, given by Leo Rosten, a Hollywood writer to his stories, to avoid his future reports from being seen as a series of forecasts but rather as stories. However, Pierre Wack of Shell and Peter Schwartz of SRI International (Stanford Research Institute at Stanford University) during the 1970s and 1980s were the ones who really introduced scenario planning to management as a strategy tool; and ever since scenarios have been accepted and embedded in all forms of planning cycles (Ringland & Schwartz,1998; Verity, 2003). Scenarios have the characteristics of being multi-dimensional and graphical (Wilkinson and Eidinow, 2008; Masys, 2012) with three-step scenario planning: building scenarios, brainstorming and decisions with action planning
(Ringland & Schwartz, 1998). There are numerous styles of scenario planning existing in literature such as Schwartz’s 8-Step Scenario Building Model, Schoemaker’s 10-Step Scenario Building Model and Avin’s 12-Step Scenario Building Model (Keough & Shanahan, 2008). They make use of different approaches to build scenarios as ‘problem-focused’, ‘actor-focused’, and ‘reflexive interventionist or multi-agent based’ (Wilkinson and Eidinow, 2008). Scenario techniques are, thus, very flexible and may be applied to almost any issue that involves a degree of uncertainty (Verity, 2003). Scenarios after discussion are considered to develop core issues, hedging issues, peripheral or contingency issues which become objectives for future strategic planning by the decision makers (College of Defence Management, 2004). They are, thus, a complex combination of data, model and solver (Ahmed & Sundaram, 2009) as in case of the Southern San Andreas Fault Shake out scenario of 7.8 M (Porter, et al. 2011)

The NDMA Guidelines have also suggested Scenario analysis and simulation modelling as extremely useful for undertaking long-term Disaster Management programmes and for strengthening earthquake preparedness, mitigation and response efforts. Scenarios for alternative land use plans consider parameters like location (epicentre), magnitude, probability, number of relocated settlements, land use types, development regulations, fiscal policies and construction techniques (Pricovic, 2002). Thus, risk assessment and scenario projections require data on the existing built environment, infrastructure, and economic activities. The non-availability of such data leads to assumption based scenarios, especially for abnormal situations. Scenarios are mainly developed by ‘Net Assessment Teams’ or ‘Strategists’ for drawing possible alternatives for the future (College of Defence Management, 2004).

2.12. Modelling Technique in Earthquake Disaster Mitigation

For effective management of disasters in near future, Modelling technique is considered appropriate by some, for it would help in improving the performance of implementing agencies, private, public or government. Models accommodate contingent relationships between hazard effects and community, culture, geography, and temporal factors, especially in resilience models. Disaster managers, thus, need to recognise heterogeneity within community characteristics (Paton and Johnston, 2001). Modelling for hazards and vulnerability require collection and analysis of data both in a quantitative and qualitative manner with surveys like households, institutional analysis, livelihood, physical structures and infrastructures, etc., (Singh, 2009). The ultimate aim of a model is two dimensional – to increase the performance of the disaster management functionaries by identifying gaps and shortcomings; and secondly,
to decrease the vulnerability of the region and the society to disasters that are controlled by different variables. Performance improvement is measured basically in terms of timelines, quality of service and reducing the cost of providing such services. Modelling technique basically have 4 steps-

- Recognition and analysis of the problem - one way is the SWOT analysis of policies, their implementation and other secondary data,
- Identification of the variables affecting the problem – outcome, controllable and uncontrollable variables,
- Collection of data – based on the variables from various sources, and
- Model building. (Satender, 2003).

Model Building is a reiterative process and used to bridge the gap by scientists between description and explanation. It “is an idealized representation of a part of reality, which is constructed so as to demonstrate certain of its properties”. Types of models used are:

1. Experimental- in which properties being investigated are translated into some tangible structure.
2. Graphical- simplest kind and widely used in form of maps, graphs, diagrams.
3. Mathematical- which are abstract and symbolic (Demeritt and Wainright, 2005).

The earliest human ecological models on disaster were linear in conception, while the 1979-83 “radical critique,” (Fig. 2.15) concept weighted vulnerability over hazards (Hewitt, 1983). At the beginning of the 21st century, a new model was formulated where the vulnerability of human socio-economic system acted upon physical hazards, including cultural and historical factors. In the context and consequences of these associations, the model determined the form, entity and size of any resulting disaster (Alexander, 2012).

After the Bam Earthquake of Iran, Data Flow diagram (DFD) based model system for urban disasters like earthquakes was developed which could be used in combination with other diagramming methods for modelling information system. It helped to handle and manage disaster operations by government and public managers in a better manner for controlling the consequences of earthquake impact. DFD aimed to capture the links between the different factors starting from data collection, transformation of data to information, and then, to
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decision making (Asghar, Nejati, and Mollaee, 2010). In order to simulate as many thinkable scenarios with different earthquake source parameters, numerous models can also be formed using GIS (Tak, 2008).

![Linear Model](image1)

**"LINEAR" MODEL:**

| Physical Event | Human Vulnerability | Human Consequences of Disaster |

![Radical Critique Model](image2)

**"RADICAL CRITIQUE" (K. HEWITT et al.):**

| Human Vulnerability | Physical Event | Human Consequences of Disaster |

![Proposal for a New Model](image3)

**PROPOSAL FOR A NEW MODEL:**

- **Culture**
- **Human Vulnerability**
- **History**
- **Physical Event**
- **Context & Consequences**

![Disaster Management Model](image4)

**Fig. 2.15: Possible Evolution of Models of Disaster**

A Successful Disaster Management Strategical Model consists of 3 Step Cycle:

1. Understanding the disaster for which strategy is to be prepared.

2. Evaluating the risk involved, Understanding the vulnerability of the place, Hazard, Community, Time, Structure, Damage, Level of Awareness etc., to prepare a measured response.

3. Evaluating the success of the response to evolve a future strategy (Sibil, 2010).

Today simulation and optimisation models are being used by man within an exploratory approach in system analysis. Western government agencies involved in crisis management are using the four-stage model of mitigation, preparation, response and recovery or prevention, preparation, response and recovery for various disasters (Asghar, Nejati, Mollaee, 2010). Local government authorities and communities have a large number of tools, guidelines and resources that need to be adapted and updated for use of Disaster Risk Reduction. Public and Government
preparedness plays a major role in reducing human and monetary losses from earthquakes, if authorities are aware of their roles and responsibilities as per Standard Operating Procedures, (SOPs) and are ahead of time through scenario building, rather than considering them as “Act of God” (Shaluf, 2007; Surjan & Shaw, 2009). It is important to deal with risk and vulnerability rather than overlooking them (Momani, 2012). Whichever models may be used they must aim at managing the controllable variables to minimise the impact of disasters, as chances to control, the uncontrollable variables are trivial (Satender, 2003). Multi-criteria modelling can; thus, provide measures for improving global safety within the area where potential natural hazards exit (Pricovic, 2002).

2.13. Appraisal of Shimla City and Earthquake Disaster Mitigation Management

The State of Himachal Pradesh which is part of western Himalayas, in which lies the study area of its Capital city, Shimla, has been jolted by some major earthquakes over the past decades as shown in table 2.4.

<table>
<thead>
<tr>
<th>Place of Earthquake</th>
<th>Year</th>
<th>Magnitude (Richter Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kangra</td>
<td>1905</td>
<td>7.8</td>
</tr>
<tr>
<td>Chamba</td>
<td>1945</td>
<td>6.5</td>
</tr>
<tr>
<td>(Place not specific)</td>
<td>1968</td>
<td>4.9</td>
</tr>
<tr>
<td>Dharamshala</td>
<td>1986</td>
<td>5.5</td>
</tr>
<tr>
<td>Chamba</td>
<td>1995</td>
<td>4.9</td>
</tr>
</tbody>
</table>

(Source: Joshi & Khan, 2009)

The 1905 Kangra earthquake was India’s one of the worst earthquakes, which took place in the early hours of 4th April, causing about 20,000 human deaths, killing 53,000 domestic animals and destroying about 1,00,000 houses with total economic loss of estimated 2.9 million rupees (Arya, 1992; Bilham, 2009; Municipal Corporation Shimla, 2012). However, 1995 earthquake of Chamba area having had the epicentral intensity of VII and magnitude of 4.9 on Richter scale had also caused damage to a large number of buildings. More than 70% buildings had developed cracks. The magnitude of the earthquakes depended on the
amount of stress that accumulated within the fault zones of the Neo-tectonic active fault that stretched along the course of river Ravi around the Chamba town (Joshi & Khan, 2009).

Shimla city which lies in the Main Boundary Thrust (MBT) and is surrounded by the Main Central Thrust (MCT) (Map 5) has number of other thrusts near its location, as the Jwalamukhi and Drang Thrust which have led to number of fractured and faulted blocks and active faults around the study area (Arya, 1992; Satender, 2003). Researchers indicate that the frequent mild tremors that keep occurring on and off around Shimla City, can lead to maximum expected peak ground acceleration (PGA) of 4.0 meters per Second Square with seismic intensity of VIII on the Modified Mercalli Intensity Scale (MMI) (Municipal Corporation Shimla, 2012; Gupta, Sharma, Kaushik, 2006; Sharma, 2009). City reports of departments indicated that around 25% older town of Shimla today lies in the sinking zone which comprises the commercial area with residences namely Krishna Nagar area, Lakkar Bazar to Grand Hotel, including Ridge which houses the water reservoir beneath it. Of the overall structures built within the city, 90% of them are categorised to fall in “poor built” classification of building codes (Town and Country Planning Organisation, 2011; Municipal Corporation Shimla, 2012).

The population congestion within Shimla is an indicator of the vulnerability aspect of the city. The actual population within the city, on a maximum number of days, is double of the native population residing within it. This is mainly due to a large number of tourists visiting the city, which sometimes equals or even become more than the residents. Most of the city is located on slopes without adhering to seismic building codes and earthquake resistance measures (Gupta, Sharma, Kaushik, 2006). The mountainous terrain further increases the vulnerability of the city due to earthquake triggering subsidiary effects of rock falls, soil and rock slides along steep slopes. Landslides are a common and frequent problem within Shimla even on normal days. Deputy Director – General PN Razdan of Geological Survey of India has stated that:

“The problem of landslides in Shimla town is aggravating and we feel that the town needs urgent treatment for this” (Municipal Corporation Shimla, 2012).

75% of the total built-up area of Shimla is residential, with few and small open spaces, or parks of hardly 0.41% (Municipal Corporation Shimla, 2012; Town and Country Planning Organisation, 2011). Which when seen from earthquake viewpoint, leaves no space for people to evacuate and administrators to respond. The haphazard growth and lack in the land –use
pattern have led to construction along steep and unstable slopes of over 45° angle with improper construction practices (Municipal Corporation Shimla, 2012; SEEDS, 2010). The high priority lifeline structures have mostly been constructed during the British Era like the hospitals, power stations, telecommunications, and water supply systems, which today are outdated and vulnerable. Schools and prime buildings have also been constructed during the British time, like the Town Hall, Municipal Corporation Office, Fire Stations, Deputy Commissioners Office which are the strategic points of disaster management. But today, these structures stand worn out with poor connectivity. 72% buildings are not accessible by trafficable roads and of this 38% are accessible only by pedestrian paths and stairways having less than one-metre width. All these indicate blockage within buildings and localities during an earthquake, due to a building collapse or landslides leaving no route open for search and rescue (Municipal Corporation Shimla, 2012).

Town and Country Planning Department has designated 1.52% buildings as safe and earthquake resistant, while 72.70% of the buildings have been classified as ‘very poor’ especially within 6 wards of the city, which is higher than the city's average of 36%. Seismic codes were first time introduced by Public Works Department within the city in 1971 and there are 27% buildings which were constructed prior to it (Town and Country Planning Organisation, 2011). More than 50% buildings within Shimla are above two stories high and a few buildings rising upto 8 or 10 stories, adding to the risk factor from the seismic viewpoint. Another factor of buildings that came forth during the review was that 15% of the buildings within the city were constructed prior to 1925, with another 25% of them being 20-50 years old (Town and Country Planning Organisation, 2011; Municipal Corporation Shimla, 2012). Rapid Visual Screening of the city indicated that 50% of the buildings are poorly maintained and liable to collapse even if a minor earthquake strikes the area. Moreover, the wood construction of the houses makes them susceptible to fire hazard as well. There are only 3 fire stations within the city. Recently, 5 stories with parking area have been regulated leaving the green belt, heritage and core areas highly congested and vulnerable within the city (Municipal Corporation Shimla, 2012).

Literature review highlighted traffic congestion as another big problem within the city. The road infrastructure existing today was constructed during the British period to cater 18,000 people in 1880 (Buck, 1904, 1989). Little progress has been made till date with regard to the same. Prominent educational institutes within the city were established by the British regime
and today lie in the most crowded bottlenecked traffic areas (SEEDS, 2010). Around 200 vehicles are registered every day within Shimla and this number increases during the tourist season when about 3000 vehicles increase on the narrow winding roads of the city (Municipal Corporation Shimla, 2012). The utility services and lifeline structures of Shimla city like water and sewerage are more than 100 years old and still continue to serve the city. Only 30 Milliliter (MLD) water daily is available against the demand of 39 MLD and is, thus, considered inadequate due to the rapid growth of the population. The supply is tapped from six main source areas around the city, having a capacity of 47.50 MLD with only 2 reservoirs at Ridge and Sanjauli areas (Buck, 1904 & 1989, Municipal Corporation Shimla, 2012).

Recently, seeing the manifold increase in population, a proper sewerage system has been designed with 6 treatment plants at strategic locations, amounting to only 40% of the city being properly covered. Electricity consumption within the city is higher due to being an administrative and service city with a high influx of migrant and tourist population. There is one Grid and 6 sub-stations within the city (Municipal Corporation Shimla, 2012). Disruption in electricity can affect search and rescue operations, health and water supply during an earthquake. There is no centralised communication system which can address the different aspect of emergency management in order to avoid creation of chaos after an earthquake.

The above scenario of the study area of Shimla city has also been supported by leading national and state level newspapers (Appendix XIII). Based on United Nations Development Programme survey, Indian Express dated July 2011, stated that “most of the buildings in Shimla have been constructed in recent years are structurally unsafe and pose risks to the local population as they are not earthquake resistant”. Anand Bodh, writer, Times of India on August 2012 during the proceedings of the multi-state preparedness workshop ‘Disaster Scenario for Disaster Risk Management-NDMA’ held in Shimla, presented the accounts of Himachal Pradesh Chief Secretary Sudript Roy who “stressed the need for creating an awareness about earthquake resistant construction and mentioned sensitization towards it as the need of the hour to mitigate disasters”. Pratibha Chauhan wrote in The Tribune, September 2012, of a much-awaited move made by the government that will help owners of structures built in violation of building codes be approved and get the structures legalized. According to her, over 15,000 structures (Appendix XIII) were to be regulated within the Municipal limits of Shimla. Similarly, a seminar on earthquake construction methods and measures was held in Himachal Pradesh Institute of Public Administration (HIPA, 2011) Shimla in 2011 and was presided over
by Dr Hemant Kumar Vinayak, Professor, National Institute of Technology, Hamirpur, Himachal Pradesh, along with Dr Pradeep Kumar and Dr Umesh Kumar Pandey (Kumar, Vinayak, & Pandey, 2011). It housed a training session for officials of Municipal Corporation, Shimla, the main body authorised for Disaster Management to providing knowledge, awareness, need and type of building construction required for Earthquake Safe Construction within in seismically active Shimla city.

2.14. Conclusion

The growing body of knowledge on the relationship between disasters and development indicated that disasters do have a serious impact on long-term economic development. Disasters especially earthquakes can set back developmental programmes by destroying years of initiatives. Disaster mitigation should, therefore, become a part of the development programmes at all levels of administration. The risk related to structural and non-structural measures of earthquake need to be mitigated through plans, implementation of building codes and bye-laws, risk transfer, emergency preparations, training etc. Lack of awareness of seismic impacts and effects leads the community to reside in the most vulnerable locations along with the weak institutional capacity to address the earthquake disaster. Thus, planning and preparation need to look further into things that can be done to avert events (by preventing them altogether), to shape them so that their consequences are not so severe if they do occur (through efforts of mitigation), or to permit more rapid recovery from disastrous consequences that still occur in spite of these efforts. Hence, the application of strategies and scenario planning becomes an enabler for foresight (Coppola, 2011; Collins, 2012; Masys, 2012). It may never be possible for the mankind to live in "Zero Risk Situation" even after full implementation of mitigation measures, as there may be some unpredictable situations that may cause hazards. Hence, ‘Build back Better’ should be the main aim for authorities, especially for cities like Shimla lying in the high seismic zone, to make the society resilient and sustainable from earthquakes that cause the maximum loss to life and property even in the 21st Century.

2.15. Gaps in Literature

Review of Literature on Disaster Management and especially Earthquake Disaster Mitigation Management highlighted certain important gaps:
Ineffective implementation of Disaster Management Programmes among communities lying at the lower levels of the society.

Lack in addressing the ways of equitable participation of departments/stakeholders in Disaster Mitigation Management.

Strategies formed for disasters especially with regard to earthquakes overlooked the capacities of the local communities.

More stress on technocratic solutions rather than on the social dimensions and actions to increase awareness and capacity.

Inadequate stress on the safe and serviceable operation of ‘lifeline systems’ that are equally important to structural building mitigation measures.

There is a large literature on terminology, concepts, and case studies related to earthquake disaster management but Scenario Building Exercises for urban and rural centres not widely researched upon.

Limitation in the use of Software’s especially within the developing countries like India, due to cost and time involved in the collection of data for its implementation.

Little work found related to public awareness, especially for earthquake mitigation measures.

Most of the literature with regards to earthquakes, in India, has been based on case studies of earthquake-hit areas and measures taken therein.

In India, most field work related to earthquake studies have been post-disaster rather than pre-disaster.

Maximum case studies of earthquake mitigation management in India has been on structural designs and concepts.

Among the studies undertaken no disaster studies have been undertaken in combination with management concept of mitigation.

As no major earthquake events have taken place for more than past 100 years, literature related to the study area of Shimla City, lying within the Western Himalayas, was equal to negligible:
Most of the earthquake literature of western Himalayas is that of the earthquakes that have struck the neighbouring areas, of the study area, of Uttarakhand in the east and Jammu and Kashmir in the North.

Within the state of Himachal Pradesh earthquake studies found were mainly related to the one and only major earthquake of 1905 Kangra region, which lies to the north of the study area.

Literature related to the city was also next to negligible, with some countable articles, and mainly the Disaster Management Plan of Municipal Corporation, Shimla, as a Draft and Town and Country Plan for Shimla planning area.

No specific research related to earthquakes has been undertaken for Shimla City, which lies in the seismic zone IV, liable to Modified Mercalli Intensity (MMI) scale of VIII, surrounded by zone V and MMI of IX and X.

Hazard Risk Vulnerability Analysis and Mapping of the city with a view to Earthquake mitigation has not been found.

Rapid Visual Assessment reports for structural mitigation also not found.

Training Needs Assessment was not found at the ground level to increase the awareness and capacity of the citizens and stakeholders of Shimla City.

Earthquake mitigation based on Scenario Exercise has not been carried out for Shimla city.

No Earthquake Mitigation Programme and Policies formed for Shimla City.

Awareness programmes related to seismic events and their effects on the general public has not been found.

Inter-Departmental Mitigation Model for Stakeholders is non-existent.

Thus, the main gap on which this research has been based is relationship between Earthquake Disaster Mitigation Measures, Vulnerability and local people’s knowledge, awareness and capacity to cope with future earthquakes, in order to build better seismic resilient society for the ‘Queen of Hills’ lying in Zone IV of seismicity within the Himalayan belt.