1.1 Earthquakes and Their Impact on Society

The mankind has been facing and struggling with the natural disasters since the evolution of life on the planet Earth. These natural disasters include earthquakes, tsunamis, landslides, avalanches, forest fire, volcanoes, hurricanes, and floods. These disasters seriously disturb the normal functioning of the society and pose considerable and widespread threats to life, property and environment. Among these disasters, earthquakes affect and disrupt the society suddenly and without warning.

An earthquake is the result of a sudden release of energy in the earth’s crust. At the earth surface earthquakes manifest themselves by shaking and sometimes displacing the ground. The maximum loss during the earthquake is caused because of the collapse of the physical systems (houses, buildings, industries, dams etc.) which in turn causes great loss of economy, life and property. Historically, there is no other natural phenomenon that has produced loss of life as great as the 8 lakhs people killed in the Chinese earthquake of 1556 (Yeats et al., 1997). A recent example of such damage was Japan earthquake (M 8.6) which hit the East coast of Honshu, Japan on March 11, 2011. A ferocious tsunami spawned by one of the largest earthquakes ever recorded slammed Japan's eastern coast, killing hundreds of people as it swept away boats, cars and homes while widespread fires burned out of control. At least 15,703 people killed, 4,647 missing, 5,314 injured, 130,927 displaced and at least 332,395 buildings, 2,126 roads, 56 bridges and 26 railways destroyed or damaged by the earthquake and tsunami along the entire east coast of Honshu from Chiba to Aomori. The total economic loss in Japan was estimated at 309 billion US dollar (www.earthquake.usgs.gov). Japan's worst previous quake was in 1923 in Kanto, an 8.3-magnitude temblor that killed 143,000 people, according to USGS. The Bhuj (Gujarat) earthquake occurred on January 26, 2001 killed about 20,000 people, injured another 167,000, and destroyed nearly 400,000 homes and 600,000 people left homeless (www.gujarat-info.co.in). Due to this earthquake not only the region near to source is affected but the region at far distances is also affected. There is not only the loss of life but the economy losses are also very heavy. The shock waves spread 700 km and the total
property damage was estimated at $5.5 billion (www.gujarat-info.co.in). The financial losses from the Kobe, Japan earthquake of 1995 are estimated to have exceeded 200 billion dollars (Yeats et al., 1997). More recently, the world has witnessed the widespread damage of life and property during earthquake of magnitude 7.8 occurred near Kathmandu, Nepal on April 26, 2015. On the average, 10,000 people die each year from earthquakes (Bolt et al., 1975). Sometimes earthquake triggered phenomenon like landslides cause far greater loss of life and property than the ground shaking. For example, more than one lakh people were killed by massive landslides in loess triggered by the great 1920 earthquake in northern China (Close and McCormic, 1922).

Thus earthquakes are the major source of natural hazard to the society. It is important to understand and study the earthquakes in order to understand the impact of the earthquakes on society. One of the most important objectives for studying earthquakes is to evaluate and mitigate the earthquake hazard to the society. The science which deals with the study of earthquakes and its related phenomena is known as Seismology (Richter, 1958). The Seismology, relatively young science, involves the investigation of the phenomena that are unpredictable and random. The causes, occurrence, properties and scientific use of the earthquakes are studied by the seismologists. The seismic waves spread from the earthquake source, propagate through the interior of the Earth and recorded at the surface (seismogram) carry information about the internal structure of the Earth. The seismic waves can also be used to detect the secret nuclear explosions.

1.2 Seismicity: Global and Indian Context

With the advancement of the science and technology it is now possible to locate the Earthquake precisely both in space and time. The seismological understanding has been improved with time. But earlier the occurrence of the earthquakes was assumed to be a curse on the society. People believed that they were punished by the God due to some of their sins. In the ancient mythologies, the earthquakes were considered to be due to movement of giant animals such as catfish (Japan), elephants (India) or a tortoise (Algonquin Indians) (Reiter, 1990). It was also considered that they were uniformly distributed all over the surface of the earth. It was only after the Portugal earthquake of 1775, they were studied more as natural phenomena and knowledge of them grew gradually (Howell, B.F. Jr., 1990). Later in nineteenth century, it was believed that faulting is related
to or caused by earthquakes due to the repeated observation of fault scraps associated with earthquakes in places such as India and California (Reiter, 1990). As the time passes, the earthquakes were located in a routine manner and it was found that they tend to occur along well defined narrow active belts rather than distributed uniformly or randomly all over the earth’s surface. Figure 1.1 shows the distribution of the earthquakes around the globe. This reveals that the seismic activity separates the oceanic and continental regions. Most of the earthquakes occur in the margins of Pacific Ocean known as Pacific Ring of Fire and then extending in the west through Indonesia, China and Central Asia (Figure 1.1). The seismicity maps are useful for the mitigation of earthquake hazard during the construction of physical systems of the society.

Figure 1.1: Distribution of the earthquakes along the major belts in the world. (www.earthquake.usgs.gov)

The global patterns of earthquake occurrence have contributed in our knowledge to understand the evolution of mountain ranges, continents and oceans. The occurrence of the earthquakes can be explained with the help of the Plate Tectonics (from the Late Latin tectonicus, from the Greek: τεκτονικός "pertaining to building") theory. According to this theory, the Earth’s outermost part (Lithosphere) consists of several large slabs of solid and hard rock called plates. The major plates are shown in Figure 1.2. The lithosphere is underlain by the asthenosphere, the weaker, hotter, and deeper part of the upper mantle. The
boundary between the lithosphere and the underlying asthenosphere is defined by a difference in response to stress: the lithosphere remains rigid for very long periods of geologic time in which it deforms elastically and through brittle failure, while the asthenosphere deforms viscously and accommodates strain through plastic deformation. These lithospheric tectonic plates ride on the asthenosphere. These plates move in relation to one another at one of three types of plate boundaries (i) Convergent, or collisional boundaries, where the plates are approaching each other, the convergence rate varies from 20 to more than 110mm/year; (ii) Divergent boundaries, also called spreading centers, where the plates are moving away from each other, the spreading rate varies from 12 to 160mm/year (DeMets et al., 1990); (iii) Conservative transform boundaries, where the plates are moving slide past to each other. The strain accumulation along these tectonic plate boundaries causes the occurrence of the earthquakes, volcanic activity, mountain-building and oceanic trench formation.

The tectonic earthquakes occurred along the plate boundaries are known as interplate earthquakes. There are earthquakes which occur far away from these plate boundaries, known as intraplate earthquakes. These are due to stresses within the plates themselves and show a diffused geographical distribution (Kulhanek, 1990). The earthquakes occurring at intracontinental zones are source of major hazards to the society as these earthquakes can occur very close to human establishments in comparison to the interplate earthquakes.

Figure 1.2: Major tectonic plates in the world. (www.pubs.usgs.gov)
Indian context:

The Indian subcontinent has a history of devastating earthquakes. Figure 1.3 shows the seismicity of the Indian region. It shows that the seismicity of the Indian region is concentrated in Himalaya which is a result of collision of the Indian and Asian plates. The rate of convergence varies from about 20mm/year in the eastern Himalaya to about 10mm/year in the western Himalaya (Molnar & Deng, 1984; Lyon-Caen & Molnar, 1985; Avouac & Tapponnier, 1993; Peltzer & Saucier, 1996 and Gahalaut & Chander, 1997a & b). The Himalayan mountain chain forms a great arc extending for 2500 km from Kashmir in West to Arunachal Pradesh in the East. The persistent convergence of the northward-drifting India with Asia caused successive breaking up of the northern front of the Indian plate by deep faults and uplift of the deformed rock-piles (Valdiya, 1993). This has resulted in the development of two northerly dipping interplate convergent zones: the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT) (Valdiya, 1981). The MBT separates lesser Himalaya from the sub-Himalaya belt while MCT separates the high Himalaya from the lesser Himalaya. At the present time, the principal tectonic displacement zone is the Himalayan Frontal Fault system (Nakata, 1989; Yeats et al., 1992) which includes the Himalayan Front fault at the edge of the Indo-Gangetic plains (Yeats et al., 1997).

Figure 1.3: Seismotectonic map of the Indian Subcontinent. (modified from GSI, 2000; Nath et al., 2011c)
The seismicity of the Himalayan zone appears to be non-uniform as a function of time as well as space (Khattri, 1987). The Himalayan region has been shocked by four great earthquakes of magnitude > 8 in the past 100 years. These are the Assam earthquake of 1897, the Kangra earthquake of 1905, the Bihar-Nepal earthquake of 1934, the Assam earthquake of 1950 which caused great losses of life and property. The great earthquakes occur at sections of the plate boundaries which are still under stress and yet to rupture (Mogi, 1985). These unruptured sections are termed as seismic gaps. Khattri and Tyagi (1983), Khattri (1987) established the existence of three seismic gaps in the Himalaya plate boundary from the analysis of the space-time patterns of seismicity of the region. These are (i) the Kashmir gap to the west of 1905 Kangra earthquake (ii) the Central Seismic Gap (CSG) between 1905 Kangra and 1934 Bihar-Nepal earthquakes and (iii) the Assam gap between the two Assam earthquakes of 1897 and 1950.

The Indian Peninsular region is seismically less active in comparison to the Himalayan region or considered to be a seismically stable region. However, the recent occurrences of the several hazardous events within the Peninsular India, such as the 1967 Koyna earthquake, 1993 Latur earthquake, 1997 Jabalpur earthquake and 2001 Bhuj earthquake instigate the administrators and scientists to reconsider the seismic hazard assessment and risk of the region. Chandra (1977) studied the seismicity of the peninsular India and prepared a list of all recorded events (intensity V and above) since historical times to 1975. Khattri (1990) suggested that the peninsular India is subjected to block tectonics, with the strain field being caused mainly by the Indian plate’s motion and its collision along Himalaya. In the subsequent paper, Khattri (1994) developed the hypothesis further for the origin of peninsular seismicity and defined the blocks on the basis of the zones of seismicity. The 1993 Latur earthquake occurred at the boundary of two such blocks defined by the earlier seismicity (Khattri, 1994). The Bhuj Earthquake (M_w 7.6) of January 26, 2001, one of the most deadly earthquakes to strike India in its recorded history, occurred on the Kutch peninsula, within failed rift systems that are currently in a state of active compression from India to Asia collision processes. The epicentral region, more than 250 km from the Indian plate boundary, lies well within the Indian Stable Continent (ISC).
1.3 Seismic Hazard

Seismic Hazard is defined as the vulnerability of region to the effects of earthquakes and its related phenomenon such as ground shaking, land slides or soil liquefaction etc. The vulnerability is expressed on a scale from 0(no damage) to 1 (full damage). Seismic Risk is the probability of human and property loss caused by the earthquakes. Risk can be generally quantified by three terms: probability, hazard (loss or other measurements), time exposure.

Seismic Risk = Hazard * Vulnerability

If no lives or property are exposed to earthquakes the seismic risk is nil no matter how great be the hazard. For Example, the 1989 Macquarie Ridge earthquake produce no losses despite its magnitude of 8.3, whereas the 1960 Agadir, Morocco earthquake of magnitude 5.5 killed more than 12000 people (Yeats et. al., 1997). Although the term seismic risk is occasionally used in a general sense to mean the potential for both the occurrence of natural phenomenon and the economic and life loss associated with earthquakes.

The short term prediction of the earthquake in terms of its location, time of occurrence and its size is not possible till now. It is now established that the human and economic losses due to earthquakes can be minimized to a considerable extent if the physical systems of a region are designed to cope up with them and resist to strong shaking. This requires a proper seismic hazard mitigation plan. The first step to mitigate the seismic hazard from a region is to evaluate the seismic hazard itself.

The Seismic hazard can be evaluated deterministically by assuming a particular earthquake scenario, or probabilistically, in which uncertainties in earthquake size, location, and time of occurrence are explicitly considered (Kramer, 1996). The main purpose of seismic hazard analysis is to provide parameter for estimating seismic risk. The earthquake hazard assessment of a region is not less important than predicting the earthquake itself as it is an effort to foresee the likelihood and effects of the future earthquakes. The assessment of earthquake hazard is also necessary to solve the long term problems of seismic design and construction even if the short term prediction of the earthquake becomes possible. There are two basic approaches to seismic hazard analysis. These are (i) the deterministic methods and (ii) the probabilistic methods. Both use the same basic body of information to determine what the “Design Earthquake” should be.
1.3.1 Deterministic Seismic Hazard Analysis (DSHA):

An earthquake hazard assessment is said to be deterministic when it specifies a particular earthquake or level of ground shaking that is to be considered in terms of single valued parameters such as magnitude, location or peak ground acceleration (Yeats et al., 1997). The steps involved in the deterministic assessment of the earthquake hazard are as follows:

(i) To define the potential earthquake source: This may be a point source, a line source or area source. It involves the identification of the earthquake generating faults on the basis of past seismicity of the region.

(ii) Determination of the maximum earthquake that is capable of occurring in a given area or on a given source defined above. This ‘controlling earthquake’ is also known as the Maximum Credible Earthquake (MCE). The magnitude of the maximum credible earthquake is determined on the basis of past seismicity data of region under consideration as well as from the dimensions of the faults in that region. The historical data of the region plays an important role in the process of estimating maximum credible earthquake magnitude. The length of the fault is probably the most commonly used parameter in estimating the maximum earthquake magnitude (Yeats et al., 1997).

(iii) To determine the effect, such as the peak ground acceleration, of the earthquake at a site using the regression between peak ground acceleration, magnitude and distance.

(iv) To define and determine the hazard at the site.

Figure (1.4) shows the various steps of deterministic earthquake hazard assessment (Kramer, 1996). This approach has the advantage that it does not require the presence of data bearing on time dependent processes such as rate of earthquake occurrence or fault slip rate (Yeats et al., 1997). Anderson (1997) described the deterministic maps as "scenario" ground motion maps and discussed the benefits of such maps.
1.3.2 Probabilistic Seismic Hazard Analysis (PSHA):

In the probabilistic assessment of earthquake hazard, numerical probabilities are assigned to earthquake occurrences and their effects during a particular period. This approach is not limited to the ‘worst case’, like deterministic approach, but takes into account the effects of all the possible earthquakes of different sizes capable of affecting the region. The probabilistic hazard analysis is widely regarded as the most general way to combine and present the large quantities and diverse types of information (Anderson, 1991). Riznichenko (1966) first formulated the statistical method of calculation to determine the probability of occurrence of earthquake effects at a site from the knowledge of the cumulative distribution of the known effects during a given observation time. Cornell (1968) defined an approach that has become the standard methodology of the probabilistic assessment of earthquake hazard. The basic steps are as follows:

(i) To delineate the earthquake source regions and determination of their seismic regime.

(ii) To obtain the recurrence relationship for each source zone. This can be obtained using Gutenberg and Richter (1954) recurrence relationship. Instead of taking one maximum earthquake for each source zone, like in deterministic assessment, a
maximum earthquake is chosen that defines the upper limit of earthquakes of all sizes that are required in the hazard assessment.

(iii) To estimate the effects of earthquakes in a probabilistic manner. A number of attenuation curves are required for the different sizes of earthquakes to relate to a ground motion parameter (e.g. peak ground acceleration) with distance.

(iv) To define a curve, by incorporating the effects of all the earthquakes of different sizes occurring at different locations, that indicates the probability of exceeding different levels of ground motion parameters at a site during the particular period of time.

Figure (1.5) shows the various steps of probabilistic earthquake hazard assessment (Kramer, 1996). A number of researchers have developed different numerical algorithms, but the basic steps for determining the earthquake hazard remain the same (McGuire, 1976; Mayer-Rosa, 1976; Algermissen and Perkins, 1976; Anderson and Trifunac, 1977; Anderson, 1978; Schenkova et al., 1981 and Algermissen et al., 1982). Schenk et al. (1981) has compared the seismic hazard values determined by some of these programs. The earthquake hazard maps for the different parts of the world have been prepared by the different authors (e.g. Schenkova et al., 1981; Khattri et al., 1984; Wesnousky et al., 1984; Ihnen and Hadley, 1987; Fernandez et al., 1989; Tsapanos and Burton, 1991).

Figure 1.5: Steps involved in Probabilistic Seismic Hazard Analysis. (Kramer, 1996)
A precise and useful seismic hazard assessment of a region requires the multidisciplinary approach including the results from neotectonics, paleoseismology and geodesy. For this purpose, the Global Seismic Hazard Assessment Program (GSHAP) was launched in 1992 by the International Lithosphere Program (ILP) with the support of the International Council of Scientific Unions (ICSU). This program promotes a homogeneous approach to evaluate the seismic hazard. As the historical data of the earthquakes for many regions of the world is not available, the GSHAP is based on non-homogeneous data.

The extreme events, which are most disastrous, may occur any time for any design life. The mitigation policy based on likelihood has serious problems as it ignores catastrophic events as too rare, and yet they are most dangerous to the society (Mualchin, 2011). The DSHA, as pointed out by Mualchin (2011), used the occurrence likelihood of an earthquake qualitatively by using faults that are presumed to be seismogenic. The MCE is the largest potential earthquake that supersedes and automatically considered all other possible earthquakes on that fault (Mualchin, 2011). However the output of DSHA and PSHA may be considered as complementary to each other. A deterministic approach has been used in the present thesis to evaluate the seismic hazard.

1.4 Seismic Hazard Maps of Indian Region

The first national seismic hazard map of India was prepared by Geological survey of India (GSI) in 1935 (Krishna, 1992). In 1962, second national seismic hazard map was published by Indian Standard Institutions (ISI) which divided India into seven zones from zone 0 (no damage) to zone VI (extensive damage). Later on it was again revised in 1966 and then in 1970. In 1970 revision the zone 0 was abolished as it was thought that there is no such area where probability of occurrence of earthquakes is zero (Krishna, 1992) or in other words no area is earthquake free. The number of zones is now reduced from seven to five as zone V and zone VI are merged. The map was again revised in 1984 and 2002 with certain modifications. The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version which consisted of five or six zones for the country. Figure 1.6 shows the seismic zones of Indian region. According to the
present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity.

The seismic zoning maps of Indian region were prepared by other researchers also. The seismic zoning maps prepared by Tandon (1956) and Krishna (1959) identified the areas of high, moderate and light damages while the maps prepared by Guha (1962) and Gubin (1968) are based on Modified Mercalli Intensity (MMI) as the main parameter for zoning the different regions. Kaila et al. (1972) prepared three seismicity maps of India namely A-value, b-value and the return period maps for earthquakes with magnitude greater than or equal to 6. Kaila and Rao (1979) prepared the seismic zoning maps of India showing the average seismic risk, expected maximum earthquake magnitude, MMI, and peak horizontal acceleration by taking the different grid size.

![Figure 1.6: Seismic Zonation and Intensity map of India. (www.nidm.gov.in)](image)

In order to prepare a seismic hazard map more useful to civil engineers the estimation of the probability with which the ground motion parameters like intensity, peak ground acceleration, velocity or displacement etc. will be exceeded in a given exposure time window is required. The probabilistic maps of the Indian region have been prepared by incorporating the statistical models (Cornell, 1968; and Algermissen and Perkins, 1976) of the earthquake process (Sinvhal et al., 1976; Basu and Nigam, 1977, 1978; Khattri et al.,
The hazard map prepared by Khattri et al. (1984) shows the 10% probability of exceedance of peak ground accelerations in 50 years. The map shows the accelerations values of the order of 0.7g for the Himalaya and less than 0.05g for most of the Indian shield. While the probabilistic hazard map prepared by Ravi Kumar and Bhatia (1999) under GSHAP shows the lower values of the hazard level. Das et al. (2006) have done probabilistic hazard analysis of Northeast India and a probabilistic seismic hazard map for Peninsular India has been prepared by Jaiswal and Sinha (2007). Mahajan et al. (2010) have prepared probabilistic seismic hazard map of NW Himalaya and adjoining area. Nath and Thingbaijam (2012) have presented probabilistic seismic hazard assessment of India by incorporating new data and concepts in seismogenic source considerations and ground motion predictions.

An evaluation of the seismic hazard in Garhwal Himalaya and the adjacent Ganga plains due to a future great earthquake has been done by Khattri (1999) based on synthesizing the strong ground motion time histories at a number of sites. Parvez et al. (2003) have prepared a deterministic seismic hazard map of India in terms of maximum displacement, maximum velocity and design ground acceleration.

1.5 Seismic Hazard to National Capital (Delhi) Region:

The National Capital Region (NCR) between latitude 26°N to 31°N and longitude 75°E to 81°E lies in the geological realm of Peninsular India. It is about 200 Km from the Indian plate boundary (Himalaya) and falls in seismic zone IV of India as per BIS 2002. Figure 1.7 shows the position of NCR with respect to Himalaya as well as Indian Peninsula. The Indian Peninsula, considered as seismically stable region, has witnessed a number of hazardous earthquakes in the recent past such as 1967 Koyna, 1993 Killari and 2001 Bhuj earthquakes. It has been suggested by Bendick et al. (2001) that the 1819 Allah Band earthquake, occurred in Kachchh region of Gujarat, has induced dilatational perturbations in the ambient strain field to cause moderate size events as well as 2001 Bhuj earthquake in the region. This region of dilatational loading was currently moving towards East and NCR is located east of this strain contraction zone. The NCR is also affected by the ongoing India-Asia collision process in the Himalaya.
A number of damaging earthquakes have occurred in NCR in past. The region has been rocked by the strong events (MMI ≤ IX) in 1742, 1803 and 1842 (Oldham, 1883; Narula et al., 2000). It has been suggested that the Kutab Minar was severely damaged by the 1803 earthquake (Ambraseys and Jackson, 2003). An earthquake occurred in 893 or 894 in the Delhi region has claimed several lives (Srivastava and Roy, 1982). The moderate size earthquakes occurred in recent past in and around the region like October 10, 1956 (M 6.7), August 27, 1960 (M 6.0) and August 15, 1966 (M 5.8) have caused significant damage to lives and property (Srivastava and Somayajulu, 1966). The 1999 Chamoli earthquake (Mw 6.4) occurred in Garhwal Himalaya caused non-structural damage to several buildings. The more recent 2005 Muzaffarabad (Pakistan) earthquake (Mw 7.6) with mild intensity III at Delhi enhanced the consciousness about the increasing vulnerability that the growing population in the region is facing (Mahajan et al., 2006, 2009). All this information implies, as pointed out by Kumar et al. (2012), that presently the large population of NCR is exposed to severe seismic hazard and risk, not only in terms of human lives and property, but also in terms of internal and external security and national economy from earthquake-induced disruptions in regional transport and communication facilities.

![Figure 1.7](image-url)  
*Figure 1.7: The position of NCR (Delhi) with respect to Himalaya as well as Indian Peninsula along with the epicenter of major earthquakes in the Indian shield.*
A number of studies have been done to address the issue of seismic hazard in the NCR. Khattri et al. (1984) using PSHA have estimated the expected Peak Ground Acceleration (PGA) of the order of 0.1-0.2 g with 10% probability of exceedance in the time window of 50 years. A PGA of the order of 0.15g has been estimated by Ravi and Bhatia (1999) with the same probability and time window. Sharma et al. (2003) obtained a maximum pga value of 0.34g at bedrock level by considering six seismogenic sources in Delhi region. A seismic hazard microzonation map of Delhi has been prepared by Iyengar and Ghosh (2004) which suggested a pga of 0.15g in a 100 year time window. Joshi and Sharma (2011) have estimated the uncertainties in strong ground motion estimation for Delhi region by mapping Coefficient of Variation (COV) maps. Nath and Thingbaijam (2012) have estimated a PGA value of 0.24g with 10% probability of exceedance in time window of 50 years. Parvez et al. (2002) obtained a value of 0.15g using the synthetic seismograms generated by a mode summation procedure. Kumar et al. (2012) have presented the seismic exposure of the population of the Delhi due to moderate size earthquakes within NCR.

The studies have been done to evaluate the seismic hazard in the NCR due to great earthquake in the central seismic gap of Himalaya. For this case, Khattri(1999) estimated a PGA value of the order of 0.22g using composite source model. Using a semi-empirical hybrid technique, Kumar (2001) obtained a PGA value of the order of 0.3g. For the similar magnitude earthquake in the CSG, Singh et al. (2002) obtained the similar results based on simulation of the earthquake strong ground motion using a stochastic method and random vibration theory.

These studies show a high seismic hazard to the NCR due to (i) occurrence of great earthquake(s) in the CSG of Himalaya and/or (ii) moderate size earthquakes within the NCR. There is deficit in released seismic strain energy capable of generating a moderate size earthquake in NCR (Verma et al., 1995). With the presence of old and weak structures as well as growth of population density and infrastructure, the NCR is exposed to high seismic risk even due to moderate size earthquake(s) within NCR. The moderate size earthquakes are expected to have return periods of the order of a few decades only and therefore higher probability of occurrence in near future.
The present thesis is devoted to the evaluation of seismic hazard in NCR using a deterministic approach.

1.6 Objectives of Thesis

The objectives of the thesis are as follows:

(i) To estimate the earthquake strong ground motions at bedrock level for the NCR.
(ii) To estimate empirical transfer functions/site characteristics at the different sites on the varied geology of the NCR.
(iii) To estimate earthquake strong motions at surface level by incorporating the estimated site characteristic.
(iv) To prepare the Scenario Hazard maps for the evaluation of seismic hazard in the NCR.

1.7 Plan of the Thesis

The thesis consists of 6 chapters. Chapter 1 (this chapter) gives the introduction about the earthquakes, their impacts on the society, brief description of techniques to evaluate seismic hazard, seismic hazard scenario of NCR. Chapter 2 describes the geology and the seismotectonics of the NCR. The estimation of the empirical transfer functions/site amplification at the various sites the NCR has been presented in Chapter 3. Chapter 4 is devoted to the estimation of earthquake strong ground motions at bedrock level as well at the surface level. Chapter 5 presents the scenario hazard maps and evaluation of seismic hazard for the NCR. The discussion, conclusions and future scope of the work have been described in the Chapter 6.