CHAPTER I
INTRODUCTION

1.1 Introduction

Human being has always faced different types of hazard and some of phenomena have left many serious and disruptive footprints. Despite the efforts to reduce the likelihood of harmful of hazards, the frequencies and magnitude of major hazard have been increasing (Khanal, 1996). Among different natural hazard like landslide, flood, storm, drought, etc. the losses and damage by earthquake hazard is extremely high both in terms of life and property damage.

"Infrastructure" is the basic physical and organizational structures needed for the operation of a society, the services and facilities necessary for an economy to function. It is also the term denoting those types of facilities which are necessary for the effective functioning and wellbeing of any society. It is a vital structure for human life and urban function. Infrastructure basically convey food, water fuel, energy, information and other materials necessary for human existence from the production areas to consuming urban areas. Due to modernization and urbanization infrastructure facilities such as Transportation, water supply, telecommunication, electricity etc are increasing day by day. The term typically refers to the technical structures that support a society, such as road, water supply, sewers, power grids, telecommunications, and so forth. Viewed functionally, infrastructure *facilitates* the production of goods and services; for example, roads enable the transport of raw materials to a factory, and also for the distribution of finished products to markets. In some contexts, the term may also include basic social services such as schools and hospital *(http;//en.wikipedia.org/wiki/infrastructure).*

Nepal is a disaster prone country in the world which is exposed to several types of disasters. A wide variety of physiographic, geological, ecological and metrological factors contribute to the high level of hazards in the country. In addition, low level of awareness and demographic factors such as rapid population growth, unplanned settlement and improper land use contribute to increase the vulnerability of the communities. Flood, landslide, earthquake, fire, epidemic, drought and hailstorm are major types of hazard in Nepal. Out of them flood, landslide, and fire are common that occur almost every year with heavy loss of lives and property (DPNET Nepal 2005). Earthquake is one of the most destructive natural hazards, which may occur at any time anywhere without warning that destroys buildings and infrastructure killing or injuring the inhabitants. In every earthquake most of the loss of life and property is caused by the damage of weakest buildings and infrastructure located in a seismically active area.

Simply, earthquake is a trembling, shaking or vibration of the ground surface caused by the passage of energy, in the form of waves, through the rocks of earth's outer shell. The most common cause of the release of this energy and thus, of the vibrations is the breaking and shifting of rocks in earth's outer zones. This breaking and movement of rocks is a process known as faulting. Thus, the immediate cause of most earthquakes is faulting (Conte, Thompson & Moses, 1997 cited in Rai, 2009).

Earthquakes do not kill people but structures that collapse by earthquake do kill the people, as we well know that earthquakes are natural phenomenon that can't be avoided or even accurately predicted. In brief, earthquake is known to humans directly as a trembling or shaking of the ground. Commonly, earthquakes are bare perceptible to the senses, but sometimes so violent as to crack or collapse strong buildings, break water and gas mines, causes gaping cracks in the ground, and bring great loss of life and property (Nevi, 1977).

Earthquake throughout the history have rank high among natural hazard. Earthquake is shocks due to sudden movement of crystal rocks. They are generated along the weak planes such as long crake inside the earth. Earthquake is mainly cause by two factors i.e. anthropological and natural. Nuclear tests, construction of large reservoir came under anthropological activity and volcano, landslide, tectonic movement are the natural causes of earthquake. Earthquake below 2.5 Richter scale could not generally felt by man. Earthquake with 5 or more magnitudes are considered to be destructive. Collapse of building, bridges, dam and structure and loss of life are the primary effect of earthquakes. The short term nature consist of fire, landslide, in the ground water hydrology are the long range secondary effect of the earthquakes (Tolba, 1992 cited in Khanal et.al, 1996).

Earthquake usually originates some miles beneath the surface, and from the origin or seismic focus the vibrations spread in all directions. They reach the surface first at the point immediately above the origin and this point is called the epicenter. It is at the epicenter that the shock of the earthquake is first experienced, and on the ground it seems to spread outwards on wave spread form a stone thrown into a pool of water (Lake, 2006).

Every day and every time, there is earthquake in the earth. From the year 1990 and till 2006, there were 12 perceptible earthquakes that were of have than magnitude 8, 226 earthquakes which were measured between mignitude7 to 7.9 and 12558 earthquakes measured between mignitude6 to 6.9. 5, 51,500 people have also died in these earthquakes. 74,698 people in total died earthquake in the Pakistan in 2005 in which 30,000 people died at Bam in Iran in 2003, and 2,84,000 died in the tsunami in South-east Asia in the year 2004 (Kantipur, 2009). In the Sichuan region of China, a great earthquake with 7.9 richter scale occurred in 12 May 2008. It has 19 kilometer depth from the earth surface. About 69,176 people were killed, 374,142 people were injured and 17,415 people have been missing. The earthquake left about 4.8 million people homeless. On May 25 2008, a major earthquake of 6 richter scale hit northeast of the Qingchuan of China causing eight deaths, 1000 injuries, and destroying thousands of buildings (http://www.earthquake.usgs.gov)

The leastest news in earthquake on 11March 2011 at 2:46pm JST a massive 9.0-magnitude earthquake occurred near the northeastern coast of Japan, creating extremely destructive tsunami waves which hit Japan just minutes after the earthquake, and triggering evacuations and warnings across the Pacific Ocean. This earthquake marks as the largest to hit in Japan's history. The earthquake and tsunami have caused extensive and severe damage in Northeastern Japan, leaving thousands of people confirmed dead, injured or missing, and millions more affected by lack of electricity, water and transportation (http;//www.goole.com/crisisresponse/japan).

Nepal is known as one of the most seismic prone countries of the world. Nepal lies two ancient plate boundaries i.e. Angora land and Gondwanaland. After breaking of Pangaea, Teethes sea opening and several orogenetic movements has taken place different tectonic plates. Devastating earthquakes have repeatedly hit on the country in 1833 and 1934. High seismicity of the country is related to the presence of active faults between tectonic plates along the Himalayas, such as the Main Boundary Fault (MBF) and Main Central Thrust (MCT). In the global seismicity distribution map, Nepal occupies the intercontinental seismic belt elongating from the Mediterranean sea in the west via Turkey, Iran, Afghanistan, Pakistan, India, Burma, Philippines of the Pacific ocean. Since Nepal is located on the northern edge of Indian sub-continent and occupies major part of central Himalaya, the seismicity of the country could be related with the northern drift of the Indian sub continent.

Nepal has experienced a large number of devastating earthquakes in the past, where 22 earthquakes has gone within the last 33 years (1971-2003), with magnitudes ranging from 4.5 to 6.5 Richter scale. During this period about 34000 buildings were destroyed, 56000 damaged and property of more than 126 million US$ were lost mainly because of earthquakes. Out of the total losses was recorded during the 1988 earthquake (NSET, 2004).

Historical records shows that the earthquakes occurred in 1225, 1408, 1861, 1934, 1980 and 1988 were more notable for large number of loss of life and property in different part of the country. In the 1934(1990 B.S.) earthquake, about 19000 buildings were heavily damaged, about 3800 people were killed and about 1000 people were seriously injured only in the Kathmandu valley (JICA, 2002).

1.2 Statement of the Problem

Among different natural hazards like landslide, flood, storm, drought, etc. the losses and damage by earthquake is extremely high both in terms of life and property. In Nepal more than 16 big earthquakes of magnitude 6 or larger rector scale have been reported since 1255 (Khanal et.al, 1996) Earthquake are short lived but the most fearful natural hazard because of their sudden impact and devastating within a few second affecting immense losses of life and property. Throughout the history, Nepal suffered from many major and minor earthquakes like the Bihar-Nepal earthquake of 1934, Bihar-Nepal Earthquake of August 21, 1988 with epicenter at Udayapur. If in future this scale of earthquake occurs in the Nepal again, the losses of life and properties could be tremendous especially in the urban area of Nepal

Infrastructure has a direct impact on our personal and economic health, and the infrastructure crisis is endangering our national future propriety. For the safety and security of our families, we can no longer afford to ignore the congested roads, aging dams, broken water main and deficient bridges, we can face every day. As a society, we most become batter stewards of the environment through the use of the sustainable infrastructure practices. The quality of life for this and future generation depends on our willingness to rise to the challenge.

Therefore it is very necessary to study infrastructure vulnerability mapping for earthquake hazard carefully and also necessary to estimate the losses during the earthquake. The vulnerability of buildings and infrastructure systems depend on the type of risk involved, in combination with the physical (structural) characteristics of the buildings and infrastructure involved and factors associated with the environment. In every earthquake, vulnerability is heavily concentrated in the areas where the structures are of poor quality. In the context, vulnerability asset of lifeline infrastructure like road transportation, water supply, telecommunication, electricity etc. In our county usually vulnerability is poorly understood so, it is necessary to carry out most useful type of earthquake vulnerability reduction measure, like infrastructure system, public awareness campaign, and preparedness. Some of the research questions have been raised.

- What is the level of vulnerability to services infrastructure in Dhankuta municipality?
- What is level of vulnerability exposure to earthquake hazards- Road, Electricity, Water supply system, Telecommunication and Petrol pump?
- What is the level of Hazard which exposed to public services such as school, hospital etc?

1.3 Objectives of the Study

The main objective of this research is to find-out infrastructure vulnerability assessment of earthquake. The specific objectives of the present research are as follows:

- To prepare infrastructure service mapping in Dhankuta municipality
- To find out level of vulnerability of infrastructure services.
- To develop damage/ scenario the infrastructure services.

1.4 Significance of the Study

Nepal is among the countries with the highest seismicity in the world, due to the presence of active faults between tectonic plates along the Himalayas, mainly in the main boundary fault and main central thrust. Nepal is facing a serious situation in reducing natural disasters. Disaster reduction strategy involves every human community, and almost every human endeavor. It also involves almost every physical phenomenon of the earth's surface. The main theme of strategy is to find a way to live with this phenomenon's, rather than die from them. The study somehow tries to fill the critical gap, which is useful to increase the ability of cities to reduce disaster risk.

Although, there are different agencies to pursue researches on flood, landslide, fire, draught which occurs in particular areas where as due to the uncertain occurrence there are a limited researches in the field of seismic hazards. It is very rare but takes heavy tools of life and property so it is important for research to minimize the risk as well as human lives and property. Therefore, the study on seismic vulnerability assessment of buildings is important for forecast the expected losses and minimize the vulnerability of infrastructure, population as well as property. Such types of study also could important to identify the factors responsible for increasing vulnerability and risk. Such information may help government and other NGO/INGOs working in the area to make disaster management plans and conduct necessary programmes and further researcher on this field.

Especially, this study has been based on a need to better understand the impact of disruption of infrastructure from earthquakes and to assist in the identification and prioritization of hazard mitigation measures and policies. In addition, this thesis is intended to improve national awareness of the important of protecting infrastructure systems from earthquakes, and of assuring lifeline infrastructure reliability and continued serviceability.

1.5 Limitation of the Study

In this research, has been based on infrastructure services which has confined in Dhankuta municipality. So the findings were not necessarily representing the situation of other remaining municipality in the country. Infrastructure services such as road transportation, electricity, telephone line, drinking water, bridge and petrol pump have been included in this research. Infrastructure of critical importance have been analyzed to estimate seismic vulnerability and to identify those infrastructure having the greatest economic impact. The examined lifelines include road, electricity, bridge, telephone, petrol pump, water supply system and emergency services (Hospital, School). The estimated vulnerability is presented in terms of direct damage according to methodology utilized.

During the development of this research and its supporting data, several problems were encountered that could not resolved because of technical difficulties, the major limitation of the study is the limitation of time and resources for carrying out the field data collection.

Infrastructure damage resulting from secondary effects such as landslides was also considered in developing this research. It has been emphasized that this research is macroscopic investigation at the local level. Field survey has been carried out to collect information about condition and location of different type of infrastructure services.

CHAPTER II
LITERATURE REVIEW

Basically, literature review establishes the relationship of proposed research to previous and or ongoing research. Literature review also helps to find-out methodological gap as well as in the substantive aspect of existing research. More importantly, the review of literature in any study must be able to establish the relation of relevant knowledge and information. Some related theoretical and empirical literatures are reviewed as bellows:

2.1 Concept of terminology used in hazard

A number of natural events, such as earthquakes, floods, fires are capable of causing death, injuries, and property damage. These natural hazards cause tremendous damage around the world each year. Hazards associated with earthquakes are commonly referred to as seismic hazards; some related terms frequently used in the study are given below.

Emergency: An emergency is a situation that poses an immediate risk to health, life, property or environment. Most emergencies require urgent intervention to prevent a worsening of the situation, although in some situations, mitigation may not be possible and agencies may only be able to offer palliative care for the aftermath.

While some emergencies are self evident (such as a natural disaster that threatens many lives), many smaller incidents require the subjective opinion of an observer (or affected party) in order to decide whether it qualifies as an emergency. (http://en.wikipedia .org/wiki/emergency)

Disaster: A disaster is a natural or man-made hazard that has come to fruition, resulting in an event of substantial extent causing significant physical damage or destruction, loss of life, or drastic change to the environment. A disaster can be ostensively defined as any tragic event with great loss stemming from events such as earthquakes, floods, catastrophic accidents, fires, or explosions (http://en.wikipedia.org/wiki/disaster). Disasters can be characterized by the scope of an emergency. An emergency becomes a disaster when it exceeds the capability of the local resources to manage it.

Hazard: Hazards can include latent conditions that may represent future threats and can have different origins-geological, hydro-metrological, biological, human and technological process (UNDP, 2004). Hazards can be combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability. Earthquake hazard is usually expressed in probabilities of occurrence of certain earthquake (ground shaking) in a time. Hazard generally refers to physical characteristics that may cause an emergency or potentially damaging physical event, phenomenon, or human activity which may cause loss of life and property damage (Smith, 2001). For example, earthquake faults, active volcanoes, flood zones, landslide prone areas and highly flammable brush fields are all hazards.

Earthquake Hazard: An earthquake is a sudden shift or movement of the earth’s crust caused by the release of stress accumulated along geologic faults or volcanic activity (Pandey, 1999). On the surface, this is manifested by a moving and shaking of the ground, and can be massively damaging to poorly built structures. The most powerful earthquakes can destroy even the best built of structures. Most earthquakes occur at fault zones where tectonic plates collide against each other. They are capable of killing hundreds of thousands of people. Earthquakes, also called temblors (OALD, 2007), can be so tremendously destructive; it’s hard to imagine. They occur by the thousands every day around the world, usually in the form of small tremors.

Magnitude and intensity are two measurements to identify physical strength of earthquake.

Vulnerability: Vulnerability is a set of conditions and process resulting from physical, social, economical and environmental factors which increase the susceptibility of a community to the impact of hazards, (UNDP, 2004). In relation to hazards and disasters, vulnerability is a concept that links the relationship that people have with their environment to social forces and institutions and the cultural values that sustain and contest them. “The concept of vulnerability expresses the multidimensionality of disasters by focusing attention on the totality of relationships in a given social situation which constitute a condition that, in combination with environmental forces, produces a disaster”.

It's also the extent to which changes could harm a system, or to which a community can be affected by the impact of a hazard. In global warming, vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (http://en.wikipedia.org/wiki/vulner-ability).

Risk: Risk is the probability of harmful consequences or expected loss (Khanal, Shrestha & Ghimire, 2007). Another definition of Risk is the potential or likelihood of an emergency to occur. Risk results from the interaction between natural/ human induced and vulnerable conditions. For which can be calculated by the equation.

Risk Assessment/ Analysis: A process to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability/ capacity that could pose a potential threat or harm to people, property, livelihood and the environment on which they depend.

The process of conducting a risk assessment is based on review of both technical features of hazards such as their location, intensity, frequency and probability and also the analysis of physical, social condition while taking particular account of the coping capabilities portrait to the risk scenarios.

Earthquake Magnitude: The magnitude of earthquake measures the total seismically released energy, so it is related to ground acceleration of the area from where the energy is released.

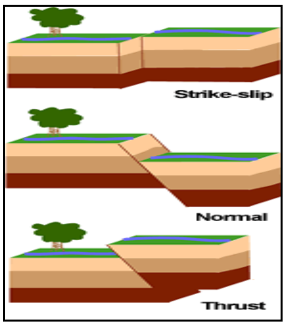
Earthquake Intensity: The effect of earthquake is assessed in terms of intensity. Intensity refers to the severity of ground shaking experienced at site. It is subjective measurement; however it includes all the earthquake variables which are magnitude, hypo-central distance, attenuation media and local enhancing factor. It is generally greatest near the epicenter and decreases outwards from it. Intensity is usually expressed on the Modified Mercalli Intensity (MMI)**.**

Infrastructure service: The infrastructure services include road, electricity, bridge, telephone, petrol pump, water supply system

Public Service: Essential facilities include hospitals, police stations, fire stations and schools are like a public service.

2.2 Explanations of Earthquakes in Relation to Faults and Plate Boundaries:

It is observed that the occurrence of earthquake have relationship with the fault boundaries that reveals along the plate boundaries of the earth surface. Below figure shows the three main types of fault that may cause an earthquake: normal, reverse (thrust) and strike-slip. Normal and reverse faulting are examples of dip-slip, where the displacement along the fault is in the direction of dip and movement on them involves a vertical component. Normal faults occur mainly in areas where the crust is being extended such as a divergent boundary. Reverse faults occur in areas where the crust is being shortened such as at a convergent boundary. Strike-slip faults are steep structures where the two sides of the fault slip horizontally past each other; transform boundaries are a particular type of strike-slip fault. Many earthquakes are caused by movement on faults that have components of both dip-slip and strike-slip; this is known as oblique slip (Rai, 2009)



2.3 Earthquake in Nepal:

Nepal is vulnerable to earthquakes because of its location in a tectonically active zone. The presence of three main fault lines: the Main Central Thrust (MCT) at the foot of the Greater Himalaya joining the midland mountains, the Main Boundary Fault (MBF) at the junction of the Lesser Himalaya and the Siwaliks and the Himalayan Frontal Fault (HFF) south of the Siwaliks, Each running east to west, are the main causes of earthquakes of small and great magnitude in Nepal. These fault lines are a result of the movement of the Indian plate under the Eurasian plate. Earthquakes of major consequence were reported in 1255 AD, 1810 AD, 1866 AD, 1934 AD, 1980 AD and 1988 AD in Nepal. The earthquake in 1934, which also hit Kathmandu Valley, was in the order of 8.4 on the Richter scale. It did great damage to Kathmandu Valley with the loss of more than 8,500 lives and partial collapse or complete destruction of 38,000 buildings (NSET, 2006). There had been many other devastating earthquakes in Nepal resulting in great economic loss and social disruption.

2.4: Japan Earthquake of March 11, 2011

The 2011 Tōhoku earthquake and tsunami (*Higashi Nihon Daishinsai*, literally "Eastern Japan Great Earthquake Disaster") was caused by a 9.0-magnitude undersea megathrust earthquake off the coast of Japan that occurred at 14:46 JST (05:46 UTC) on Friday, 11 March 2011.The epicenter was approximately 72 km (45 mi) east of the Oshika Peninsula of Tōhoku, with the hypocenter at an underwater depth of approximately 32 km (19.9 mi). On 1 April 2011, the Japanese government named the disaster resulting from the earthquake and tsunami the "Great Eastern Japan Earthquake" (*Higashi Nihon Daishinsai*).

The earthquake triggered extremely destructive tsunami waves of up to 37.9 meters (124 ft) that struck Japan minutes after the quake, in some cases traveling up to 10 km (6 mi) inland, with smaller waves reaching many other countries after several hours. Tsunami warnings were issued and evacuations ordered along Japan's Pacific coast and at least 20 other countries, including the entire Pacific coast of the Americas.

The Japanese National Police Agency has confirmed 13,219 deaths, 4,742 injured and 14,274 people missing across eighteen prefectures, as well as over 125,000 buildings damaged or destroyed. The earthquake and tsunami caused extensive and severe structural damage in Japan, including heavy damage to roads and railways as well as fires in many areas, and a dam collapse. Around 4.4 million households in northeastern Japan were left without electricity and 1.5 million without water. Many electrical generators were taken down, and at least three nuclear reactors suffered explosions due to hydrogen gas that had built up within their outer containment buildings after cooling system failure. On 18 March, Yukiya Amano—the head of the International Atomic Energy Agency—described the crisis as "extremely serious." Residents within a 20 km (12 mi) radius of the Fukushima I Nuclear Power Plant and a 10 km (6 mi) radius of the Fukushima II Nuclear Power Plant were evacuated. In addition, the U.S. recommended that its citizens evacuate up to 80 km (50 mi) of the plant.

Estimates of the Tōhoku earthquake's magnitude make it the most powerful known earthquake to have hit Japan, and one of the five most powerful earthquakes in the world overall since modern record keeping began in 1900. Japanese Prime Minister Naoto Kan said, "In the 65 years after the end of World War II, this is the toughest and the most difficult crisis for Japan. The earthquake moved Honshu 2.4 m (7.9 ft) east and shifted the Earth on its axis by almost 10 cm (3.9 in). Early estimates placed insured losses from the earthquake alone at US$14.5 to $34.6 billion. The Bank of Japan offered 15 trillion (US$183 billion) to the banking system on 14 March in an effort to normalize market conditions. On 21 March, the World Bank estimated damage between US$122 billion and $235 billion. Japan's government said the cost of the earthquake and tsunami that devastated the northeast could reach $309 billion, making it the world's most expensive natural disaster on record (http://.en.wikipsdia.org/wiki/earthquake/japan).

2.5: Review of Theoretical Models

Several methods have been developed by different institutions to identify vulnerable conditions of the structures. The methods range from very simple to very complex and data demanding. Some of the methods are given below.

- A method developed by JICA (2001)
- A method developed by RADIUS (1996)
- A method of ATC-25 developed by FEMA

2.5.1: The Method Developed by JICA (2001)

This method was based on a Study on Earthquake Disaster Mitigation (SEDM) for Kathmandu. Road and bridge inventory maps were produced for whole Kathmandu valley and put into GIS database. This database includes four earthquake scenarios with MMI maps. PGA maps and liquefaction maps, roads and bridges are classified into different categories. Where road cross slopes are more than 50mm or high were taken as hazardous points (JICA, 2001). It is considered that a road segment likely to block/damage at slope failures. But to find out the bridge vulnerability, condition of bridge has been scored by the field reconnaissance and defined score 26 and above are more collapsed, score below 26 and above are taken as stable.

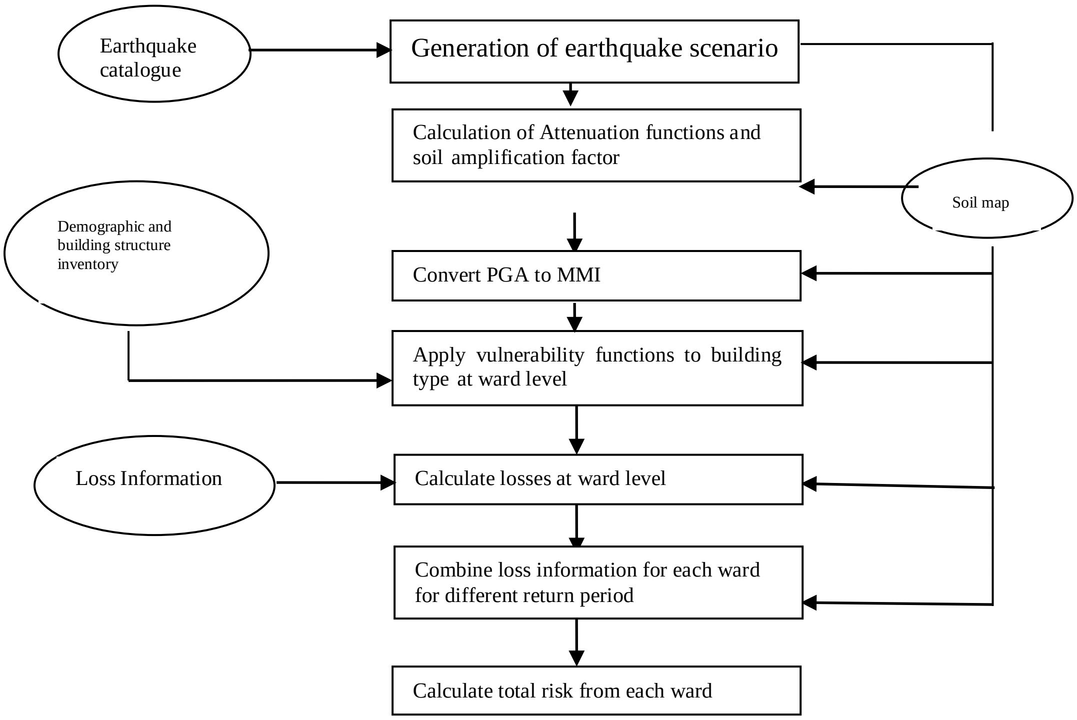
This method has been developed for city oriented study. It is very simple to calculate vulnerability condition based on road classification. The classification is based on function of roads, and the importance of road in an earthquake scenario is also considered.The vulnerability is evaluated based on probability of unstable slope failure not on structure of road and other factors such as landslide/ liquefaction of soil etc. If they are affected by the landslide, the road will be certainly high damaged than the slope.

Since the hazardous points are only, one has high slopes than 50mm. If the method is applied in a gentle slope area, there are not any hazardous points. Therefore, the methods need to be modified to make it applicable to individual city.

2.5.2: The Method of RADIUS

The method was developed by the IDNDR secretariat, UN Geneva in 1996 with financial and technical assistance from the government of Japan for reduction of seismic disasters in urban areas of developing countries. The main objectives of the project were to develop practical tools for urban risk management. This methodology has been developed and applied by GHI through actual projects in such cities such as Quito, Equador, and Kathmandu, Nepal. The estimation of the potential damage of an adopted hypothetical earthquake is carried out in two steps: theoretical and non-theoretical. The theoretical estimation is performed by combining the seismic intensity distribution that is estimated for the adopted earthquake with the inventory of the structures and infrastructure of the city. This combination is performed using vulnerability functions (See figure 2.1) that are developed to reflect the seismic behavior of the structures and infrastructure found in the city.

Figure 2.1: A Flowchart of the RADIUS Method



Source: Tung, 2004

Figure 2.1 shows the flow chart of Radius methodology. This methodology divides the building class into 10 categories based on their material type, construction type, seismic code, occupancy type and number of stories (Villacis and Cardona, 1999). This classification is based on the common building type in Latin American cities.

This method can be used for buildings and infrastructures losses at ward or Block level. The earthquake risk assessment process includes the following activities.

Vulnerability functions are determined as a function of acceleration/ MMI based on damage observed during past sample earthquakes (Villacis, 1999). The damage levels considered, in this method, are collapse and heavy damage.

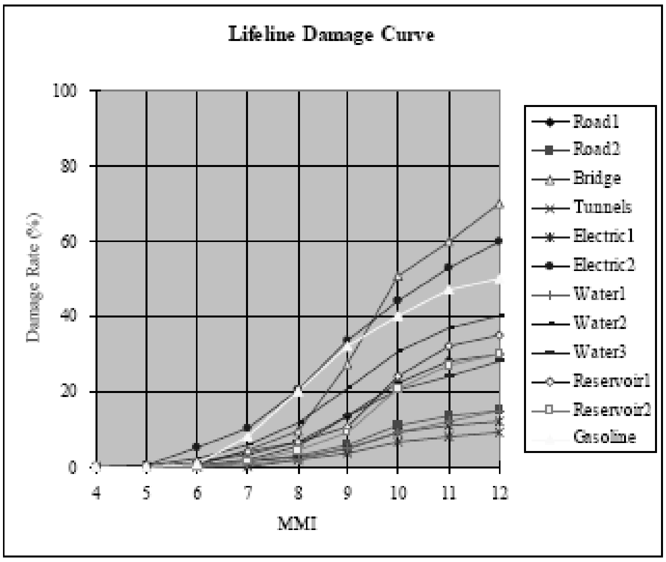
Vulnerability functions in vulnerability assessment includes two steps (Villacis and Cardona, 1999)

a) Identify all the existing structural and infrastructure types of the city and then select representative ones.

b) Existing vulnerability functions for the selected types are calibrated using data of past observed damage as well as the opinions and/or studies of local experts. For important and critical facilities, individual vulnerability studies are carried out.

The vulnerability functions used by RADIUS for lifelines or shown in figure 2.2

Figure 2.2: Infrastructure Damage Curve



Vulnerability functions used by RADIUS can be calculated according to classification of single type of infrastructures. This method is very simple and easy to use. The application of RADIUS varies from city to city. Those criteria were selected based on individual city. Based on the MMI value of all existing structural and infrastructural types of city, damage curves can be calculated. But, this method does not show where the location of damaged road is. Next, the result is more or less influenced by choosing a representative one.

The hazard parameter used in vulnerability function is MMI. However, selection of MMI is very subjective because it is based on descriptive measures of damage, whose performance may vary from one part of the world to another for the same level of ground shaking.

2.5.3: The Method of ATC-25 Developed by FEMA

According to method of ATC-25, the analysis of seismic vulnerability of lifelines system and the economic impact of disruption is based on assessment of three factors.

- Seismic hazard
- Infrastructure inventory
- Vulnerability functions

These factors are used to quantify vulnerability and impact of disruption in terms of direct damage and economic losses resulting from direct damage and loss of function of damaged facilities. Estimates of direct damage to lifelines expressed in terms of percent replacement value and money losses.

Direct damage: It is defined as damage resulting from ground shaking or other collateral loss causes such as liquefaction. For each facility, it is expressed in terms of cost repair divided by replacement cost. Direct damage is also varies from 0 to 1 (o% to 100%). Direct damage can be estimated using-

- ➢ Estimates of ground shaking intensity according to seismic hazard model, Timsina, 2011.

- Inventory data specifying the location and type of facilities affected, and
- Vulnerability functions that relate to seismic intensity and site conditions to expected damage.

The estimation of direct damage considers both damage resulting from liquefaction, landslide as well as resulting from ground shaking.

The analysis for computing direct damage due to ground shaking proceeded are as follows. For each earthquake scenario, MMI levels were assigned to each 25 km grid cell in the affected region. Damage states were then estimated for each lifeline component in each grid cell using the motion damage curves provided by vulnerability functions. The procedure for utilizing motion damage curves varied slightly according to facility type, depending on whether the lifeline was a site specific facility or a regional network of these lifelines.

Four damage states are considered in the method.

- Light damage (1-10% replacement value)
- Moderate damage (10-30% replacement value)
- Heavy damage (30-60% replacement value)
- Major to destroyed (60-100% replacement value)

The total number of affected facilities and the percentage of facilities are differing in each lifeline and scenario earthquake.

Vulnerability Functions

The vulnerability functions developed for each infrastructure consist of the following components.

- General information which consists of a description of the structure and its main components, typical seismic damage in qualitative terms and seismically resistant design characteristic for the facility and its components in particular.
- Direct damage information, which consists of a description of structure type and quality of construction(degree of seismic resistance) default estimated of the quality of construction for present conditions and corresponding motion damage curves, default estimates of the quality of construction for upgraded condition and restoration curves

Motion damage curves and restoration curves define expected lifeline performance for each of these regions and from the heart of the quantitative vulnerability analysis.

Seismic Hazard: It is the expectation of earthquake effects, which is usually defined in terms of ground shaking parameters (e.g. peak ground acceleration, modified mercally intensity, peak ground deformation, peak ground velocity).On the other hand, it can be defined in terms of landslides or liquefaction or other phenomenon resulting from an earthquake.

- Seismic hazard is a function of the size, or magnitude of an earthquake, distance from the earthquake, local soils and other factors. Estimation of seismic hazards can be performed on deterministic or probabilistic basis (FEMA, 2003)

2.6: Empirical studies on earthquake and other hazards

2.6.1: Earthquakes Effect on Infrastructure Services

Earthquake damage is defined as damage resulting from ground shaking or other factors such as liquefaction and landslide. For each facility, it is expressed in terms of cost of repair divided by replacement cost and that varies from 0 to 1 (0% to 100%) (HAZUS-MH, 2003).

An earthquake effect depends on a distance to the earthquake, the magnitude, the depth of hypocenter, the rock types and structure soil between the hypocenter and the site, and the local soil and topographical conditions. In general, the damage is always considered parallel with the type of hazard phenomenon. Survival of lifelines depends on their seismic performance characteristics. Besides, and earthquake also induced secondary type of hazard like tsunami, fire or landslide etc which sometimes are the reasons for many failure of infrastructure. The effects triggered by an earthquake sometimes because more serious damages to elements at risk than the ground shaking of the quake itself. There are various types of earthquake damage according to different types of infrastructures.

2.6.1.1 Effect of an Earthquake to Road Transportation

Road transportation damage can result from failure of the roadbed or failure of an embankment adjacent to the road. Roadbed damage can take the form of soil slumping under the pavement and settling, cracking, heaving of pavement. Embankment failure may occur in combination with liquefaction, slope failure or failure of retaining walls. Such damage is manifested by misalignment, cracking of the roadway surface, local uplift of subsidence, bucking or blockage of the roadway. Sloping margins of fills where compaction is commonly poor are particularly vulnerable to slope failure. Road transportation also could be blocked by damaged buildings, broken underground water and sewer pipes.

An earthquake may harm road in various levels ranging from minor cracks on the top surface to completely ruptured road surface, large potholes. The road surface may also be damaged by slight deformation of base layers. The damage is about less than one inch along with crazing, long cracks also can be seen. Swallow potholes also appeared. These minor damages might not directly affect the function of road, but indirectly degrade the road quality in a long term period. This type of damage requires slight maintaining activities, and vehicles still able to travel on. However, sometimes the whole road section structure is collapsed. So, the road segment is completely malfunctioned requiring reconstruction.

Sometimes, the road surface is still in good condition. There are other types of effect that affect the road functionality caused by earthquake induced hazard like landslide, or debris fell on to the road surface. The road can be blocked by landslide or trees falling down on the road section. The earthquake created stresses that make weak slopes fail. The road can be used again as long as the debris is removed. This type of damage is usually seen in mountainous or hilly region.

2.6.1.2: Earthquakes, effects on Water Supply System

Earthquakes might break pipes that supply water for household purposes and also sewage lines. Diseases might spread due to lack of proper sanitation and hygienic conditions that might exist in open air camps. At an earthquake, the first effect is vibrations of the ground. Reservoir tanks are mainly affected by them. With regard to pipelines, damage is more likely caused by landslides, rock falls, and ground movements. These are referred to as secondary effects of earthquakes. Therefore, any strategy of pipeline protection against earthquakes should emphasize on these secondary effects.

The performance of pipelines is strongly dependent on whether or not the supporting or surrounding soil fails. Failure of a piping system resulting from inertial loads is only rare, more typically severe ground failure (landslide, liquefaction, faulting) causes damage. Regional uplift can alter the hydraulic characteristic of a transmission system. Pipe damage is most common in soft alluvial soils or at interfaces between soft and firm soils. Types of pipe damage include bending or crushing of the pipe, shearing of the pipe, circumferential and longitudinal cracks and joint failure. Damage has been substantial at locations of local restraint such as penetrations to heavy surface structures (including manholes), tees, and elbows- water hammer induced by ground motions can cause damaged by temporarily increasing pressure in pipelines.

Underground pipelines and distribution pipelines (between 4 and 20 inches in diameter) are generally more susceptible to damage because of their construction.

Generally pipelines are located along with sewerage. Drinking water spill caused by a leaking pipe or may be polluted. In this situation, people suffer from diseases like cholera and loss of life and property.

2.6.1.3: Earthquakes Effect on Electricity System

Earthquake can rupture electric wires and lead to short circuits. Many homes have cooking gas cylinders or receive piped cooking gas. These can be damaged by falling debris. Electric systems are more likely to be seriously damaged by rock falls, landslides and collapsing structures than by ground shaking. When slides do occur, electric poles may be damaged. The control house may experience generic building damage ranging from dropped ceiling tiles and crack in walls and frames to partial and total collapse. Substation equipment and ceramics, in particular, are vulnerable to damage. Higher voltage ceramics tend to experience the most damage.

Generally, reducing slopes areas can reduce vulnerability. Transmission towers and the lines they support are particularly subject to damage through secondary effects such as landslides and rock falls, liquefaction and other ground failures. It is possible that the conductors supported by towers can slap each other and burn down. Ceramics used on transmission towers typically perform well in earthquakes because they are in compression rather than in tension or bending. Fault slippage is unlikely to damage underground lines because transmission lines have a thick wall, welded steel pipe jacket. Seismic loads do not generally have much influence on the design of transmission lines and towers. The towers are designed to withstand heavy wind and ice loads, as well as loads due to broken wires.

Transformers are large and heavy pieces of equipment that are frequently unanchored or inadequately anchored. Transformers may shift to the attached conduct, break bushings, damage radiators and spill oil. Transformers are typically damaged only by soil failures. Porcelain bushings, insulators, and lighting arrestors are brittle and vulnerable to shaking and are frequently damage. Major damage to electrical substations includes overturning of extra high voltage (EHV) transformers.

Towers and poles are generally undamaged except by secondary effects such as landslides, liquefaction and other ground failures. Conductors lines swinging together can cause burn outs and (or start fires). Settlement of soils with respect to manholes can sometimes cause underground line routed through the manhole to fail.

2.6.1.4: Seismic Damage on Petrol Pump

On-ground oil storage tanks are subject to a variety of damage mechanisms, including, failure of weld between base plate and wall, rupture of attached rigid piping because of sliding or rocking of tank.

2.6.2: Review of Past Efforts on Vulnerability Assessment on infrastructure Services

International institute for geo-information and earth observation (ITC) has launched a research project, strengthening local authorities in risk management (SLARIM). The main objective of this project was to develop methodologies for GIS based risk assessment and decision support systems for developing countries that can be beneficial for local authorities in medium sized cities of developing countries. As part of SLARIM research project, several studies have been carried out for Kathmandu valley. In this study, some of the past efforts to similar fields have been reviewed.

The Japan International Cooperation Agency (JICA, 2001) carried out a detail study on Earthquake Disaster Mitigation in the Kathmandu valley in 2001. In the JICA study, the base methodology was implemented with specific focus on the community based disaster mitigation, where communities were empowered through participatory decision making process.

Above previous works mentioned about the background efforts and methodologies, are treated as the suggestive and guidance materials. The studies in the related fields conducted out of the country are good to buy in the ideas.

Guragain (2002)'s studied on earthquake disaster mitigation in Kathmandu valley estimated high potential losses and casualty of medical facilities of Kathmandu Valley. Although this was a seismic country, earthquake resistant construction standards have not been applied, and special guidelines have not been considered for hospital facilities in general. For these reasons, there is high possibility of hospital buildings of not functioning after a large seismic event.

Guragain (2002)'s study was conducted by NSET-Nepal with collaboration of NGO/INGOs. The result of study was qualitative assessment of 14 hospitals and quantitative assessment of one hospital. If an earthquake of MMI VII level of shaking occurs, 40% hospitals might be functional, 30% partially functional, 50% out of services and about 10% of the hospital might collapse.

Marco et. al. (2002)'s estimated the vulnerability of lifelines. The main objective of this study is to determine the seismic hazard for pipeline services in Bercelona. This work includes lifeline database preparation, development of seismic scenarios, computation of direct damage for each seismic scenario, and the graphic representation of all these systems using a GIS system. The seismic response of pipeline differs for each structure. The main factors that cause pipeline system damages due to earthquakes are ground shaking and ground faults. Two types of vulnerability models are included in the study. Wang model which considers liquefaction effects and another is the Eguchi model which includes both the impact of ground shaking and deformation failure. Four type of damage (slight, moderate, extensive and complete) has been categorized. Applying Eguchi model to Bercelona, he shows that for intensities below 6 there are no breaks, for intensities between 6 and 8 there is a moderate number of breaks and for greater intensities there is higher number of breaks up to catastrophic cases for intensities 11 and 12 and using Wang model shows that for intensities below the damage is slight, and 5 the damage is destructive.Menoni et. al. (2002) studies concerning lifelines response to earthquakes especially in Lombardia region, Italy. For the study, this large area has been subdivided into three regions. At first, the characteristics of the lifeline systems of the area have been surveyed and the analytical forms filled with the acquired information. Then the vulnerability index has been calculated. The comprehensive model has been developed for assessing lifeline seismic vulnerability. It addresses not only physical factors, but also organizational and function.

The main theme of this study was to search vulnerable elements within each utility system and between the latter and the external environment. The results show that the most vulnerable area is that of Salo, which is threatened by several landslides, it may obstruct not also main road but also networks running beneath.

Based on the analysis of seismic vulnerability assessment of public schools, Dixit et. al (2002) estimated the hazard due to the great earthquake for Kathmandu valley. The main finding of this study is that, more than 60% buildings are built using traditional materials, which behave very poorly during earthquakes? And remaining 40% buildings use modern materials such as brick and cement. Even though modern materials are stronger, the Nepali schools are not safer. Local and traditional artisans built without engineering ideas. These buildings are taller, have longer rooms and longer windows and doors. These features make buildings as dangerous as the traditional ones. Among total 700 school buildings, only 3 buildings are, constructed according to Nepal national building code.

Tung (2004), calculated road and bridge vulnerability of Lalitpur city on the basis of their location, structure, design code, physical condition, age, construction, material and distance to road from buildings. He has developed MMI map, liquefaction maps and calculated spectral acceleration values of the study area. He has used Radius and Hazus method to find out vulnerability assessment in different earthquake scenarios. He finds out that 20% of the total road both ashaphalt and non-ashaphalt will damage. But he has not identified the locations of the damaged roads. On the other hand, the Manahara and the Bagmati south bridge have highest probability of complete damage. Meanwhile, Thapathali new bridge has the lowest probability of damage.

Guragain (2004), in his M.SC. research paper GIS for building loss estimation in Lalitpur sub metropolitan city, has concluded that roads are blocked by collapsed buildings. The debris of collapsed buildings occupies the road surface, reducing speed or preventing the vehicles from traveling due to the fact that buildings are very close to the roads. Furthermore, most buildings are not well constructed according to standard codes. Those buildings have high probability of collapsing once an earthquake happens.

Islam (2004)'s studied on population vulnerability of Lalitpur sub metropolitan city on the basis of building loss estimation by Guragain(2004). This study was carried out with objectives to determine what factors are determining to population vulnerability. He also developed a method for the estimation of population distribution, both in space and time. The whole study has mainly three components, identifying the homogeneous units of buildings, estimating the spatial and temporal distribution of population and estimating the number of casualties in case of an earthquake. The distribution of population has been converted to the number of casualties based on the building vulnerability. Using Hazus method, the study shows that 16 different spatial distribution of different casualty for each earthquake scenarios.

Jimee (2006)'s using three different earthquake intensities. And building information such as age, construction, material, number of floors, space use and type, has researched on building damage and population vulnerability of ward 20 of Lalitpur Sub-metropolitan city. He concluded two types of building damage; partial damage and complete damage. He find out that due to an intensity ix earthquake, 26% buildings have high probability of damage or collapse. In the same way, casualties in different severity levels were estimated for different individual buildings due to possible earthquakes in different time periods; morning, day, evening and night. Thus, assuming intensity of ix and x, at daytime about 1602 and 401 causalities were estimated respectively.

Gulati (2006)'s studied with an aim to analyze the applicability of HAZUS model for risk assessment buildings in Dehradun, India. The whole research work was divided into four sections; Review of risk assessment methods, hazard identification and generation of the dataset (seismic, ground motion, building response and damage functions) included in the study.

The Reinforced Masonry (RM) and Unreinforced Masonry (URM) model classes from HAZUS have been selected as most representative buildings in the study. By applying HAZUS methodology, he has been developed damage probability matrix for four building types. Finally, risk assessments have been evaluated in terms of damage probability. Four type of damage (slight, moderate, extensive and complete) have been examined.

He concluded that HAZUS method does not give very realistic results for earthquake risk evaluation in study ward. Further, he mentions that this method gives good results at the broad level in a risk assessment. So, he suggests modifying Hazus method to get accurate results in an Indian context.

Westen (2007**)** has estimated seismic loss estimation for Lalitpur, Nepal under the SLARIM project. The main objective of the study was to develop spatial information system for municipalities, which will allow local authorities to evaluate the risk of natural disaster in their municipality, in order to implement strategies for vulnerability reduction. The methodology concentrates on the application of methods for hazard assessment, elements at risk mapping, vulnerability assessment, risk assessment and the development of GIS based scenarios for varying hazard scenarios and vulnerability reduction options, using structural and non-structural measures. In this development of elements at risk, database use is made of interpretation of high resolution satellite imagery, combined with extensive field data collection using mobile GIS.

Guragain (2004) carried out the seismic building vulnerability assessment in the Lalitpur area. In order to carry out the seismic vulnerability assessment of building directed field observation was taken by him. For collecting the building information the building was divided into different cluster. A total of 500 of such cluster or homogeneous unit were delineated. The building losses in the Lalitpur for different probable earthquake scenario were calculated using an existing intensity damage matrix of the area prepared during the preparation of building code and modified by JICA and NSET. He calculates two type of building damage i.e. partial damage and complete collapse. On his study he found that for each scenario earthquake, a large number were found damage in the core area. He conclude that for the different earthquake scenarios, the total number of damage building were estimated ranging from 1654 to 22,293 in the worst case scenario, which corresponds to an 8 Magnitude earthquake located close to Kathmandu.

Ghimire (2008), in her studied " application of RADIUS as an earthquake risk management tool in Panauti municipality", two scenario earthquakes, namely North Banepa earthquake and 1934 Earthquake were considered to obtain various results for both causalities, building damages and lifeline damages. She concluded that the cause of North Banepa Earthquake, when struck during the night time will result into 1505 injuries and 150 deaths out of total 25563 population where as earthquake 1934 earthquake during night time will result into 31 injuries and 1 deaths. She also concludes that RADIUS toll was successfully employment for Panauti municipality. During its implementation it was found out that RADIUS was an effective tool for earthquake damage estimation that could be used for municipal earthquake risk planning as well as will its management.

Khatiwada (2008) studied about "Seismic Vulnerability of Buiding: A Case Study of Ilam Municipality". The main objectives his study was about to determine the collapse and damage probability of building under the different probable earthquake scenario. He concluded that most of the buildings have a high probability of damage and collapse by a strong earthquake with an intensity of VII in the study area. Similarly brick in mud and adobe building area more venerable and it has high probability to damage or collapse. Brick in cemented building (less than 2 floors) have less probability to damage. Building height and geometry are also important parameters to loss building in earthquake period.

Chaudhary (2008), on his study "Lifeline Seismic Damage Evaluation in a GIS Environment; a case study of Ilam municipality", has identified that in this municipality most of the lifeline service built-up without seismic coding. He used the HAZUS method to estimate the number of damage or probability of certain damage due to earthquake. For the vulnerability study he considered geological hazard, gourd shaking, and landslides to estimate the potential damage by earthquake scenario and found intensity VII and VIII in the different municipality. On his research he identified the lifeline services in Ilam municipality are located on high MMI (Modified Mercally Intensity).

Sapkota (2008) studies on "Population Vulnerability for Earthquake Hazard" in Ilam municipality. His study has mainly three components i.e. identifying the vulnerability buildings, estimation of spatial and temporal population and to estimation of population vulnerability and population casualties on building vulnerability.

In his study it was found that, large number of peoples is inside the building during the evening than night time period. His study estimates that, 2.40% (773 persons) are consider and living in high vulnerable and among them, 64% people only living in brick in cement. His field survey received 3525 total population in the Illam municipality, among this, total population, 2397 (6.8 percent) person are calculated as injuries and 353 (1 percent) were calculated.

Rai (2009) studied about "Spatial Assessment of Seismic Vulnerability in Inaruwa municipality". The main objectives of his study are determined the collapse and damage probability of building under the different probable earthquake scenario. He conducted for seismic vulnerability assessment of Inaruwa municipality. He used in his research household survey, observation and key informant survey to generate preliminary data as well as GIS and RADIUS tools was also used. RADIS method is found to be effective and easy in estimating building damage as well as human death and injury. He concludes that in his research earthquake hazard is direct relation with poverty because of poor economy, people should bounded in vulnerable area. In market area rich person didn't priority to rebuild up new buildings, they only takes economic and commercial purposes, like giving to stand tower in roof in rent.

Sonar(2009) studied on "Seismic Vulnerability Assessment in Siddharthanager Municipality" with the major objectives to assess nature and types of building, building damage probability and human causality under different probable earthquake scenario, and awareness and preparedness. He used GIS and RADIUS tool in his research. In his research he collected the building information of 2743 both residential and non residential household. He further analysis and estimation the level of building damage in the mid Gulmi earthquake scenario, south Palpa earthquake scenario and east Parasi earthquake scenario. He describes about awareness and preparedness on earthquake and find out most of the people are not conscious on earthquake in the Siddharrthanager municipality.

Siwakoti (2002), made a study entitled "Seismic Risk Evaluation of Framed Residential Building." The major objective was to analyze the resistance of different residential building constructed within Kathamandu municipality. This study gives the clear insight into seismic risk associated with the different residential building accounting to probability of occurrence of Peak Ground Acceleration Pertinent to this area. Maximum drift ratio in the second story and slowly decreasing in upper story is the indication of maximum lateral load in the second story. He concluded that weak and strong beam of building play the great role in building vulnerability.

Rai (2010), made a study entitled “Seismic Risk Assessment of Triyuga Municipality”. The major objective was nature, type, collapse, damage probable scenarios earthquake and find out the existing capacity (Knowledge, awareness and preparedness) of the local people. He used RADIUS method for developing earthquake damage scenario of Triyuga Municipality. He describe about different building characteristics such as building type, height, geometry, age and attachment etc. Further he explains about North Udayapur earthquake scenario, south Udayapur earthquake scenario, north-east Udayapur earthquake scenario and estimation of the building damage and population casualties.

Van (2007) has estimated seismic loss for Lalitpur, Nepal under the SLARIM project. The main objective of the study was to develop spatial information system for municipalities, which would allow local authorities to evaluate the risk of natural disaster in their municipality in order to implement strategies for vulnerability reduction. The methodology concentrated on the application of methods for hazard assessment, elements at risk mapping, vulnerability assessment, risk assessment and the development of GIS based scenarios for varying hazard scenarios and vulnerability reduction options, using structural and non-structural measures. The study used high resolution satellite imagery, assisted extensive field data by several high-tech means.

Shrestha (2009), in his study Seismic vulnerability assessment of building: in Bhadrapur municipality. His major objectives are to identity the nature and types of building, to estimate the buildings damage and casualties that may occur in different probable earthquakes, to assess the knowledge and awareness of the local people about the causes of losses and damage from earthquakes and to suggest measures to reduce losses from earthquake. He applies GIS and RADIS method to analyze data for that study. He further explains about building damage estimation and casualties in north-east Jhapa earthquake scenario, west Ilam earthquake scenario and north-west Jhapa earthquake scenario. Among three earthquake scenario, he estimate the different number of buildings damage and casualties because they have different types parameter like as magnitude, distance, direction, fault line etc.

DOAC (2001), explain entitled “Natural Disaster Response Plan” about detail information of building culture prevention. In this book explain about methodology, approach, quick response, and emergency support function and disaster specific modules. In chapter five explain about quick response, precise actions procedures and responsibilities have to be laid down well in advance in order to ensure timely response in case of any disaster. Therefore, a mechanism that takes into account multiple Hazards and basic preparedness has to be articulated in the form of quick response teams, quick assessment team, reporting procedures, checklist and handbook. The mechanism also lays down crucial parameters, requirements and organizational composition of emergency operations centre and incident command systems. In chapter eight further explain about disaster specific modules related with earthquake and other disaster such as floods and drainage management, cyclones, tornadoes, hurricanes, cloudburst, Sea erosion etc.

UNESCO (1978), in its study on the assessment and mitigation of earthquake risk explain about assessment of earthquake risk, earthquake prediction, induced seismicity, implication of earthquake, engineering measures for loss reduction with buildings codes, materials and design. In chapter seven explain about the rapid increase of the world's population with its industrialization and technical progress has stimulated a rapid development of construction of all kinds. While in the past buildings were mainly of masonry and wood, new structural systems, materials and techniques are now being used, including prefabricated construction, pre-stressed reinforced concrete, metal structures, synthetic materials, etc. The increased urban population and the use of new construction systems whose resistance to earthquake has not been sufficiently studied has led to an increase of the earthquake hazard and calls for an improvement in the methods for the design of earthquake resistant structure.

CHAPTER III
RESEARCH METHODOLOGY

3.1: Background

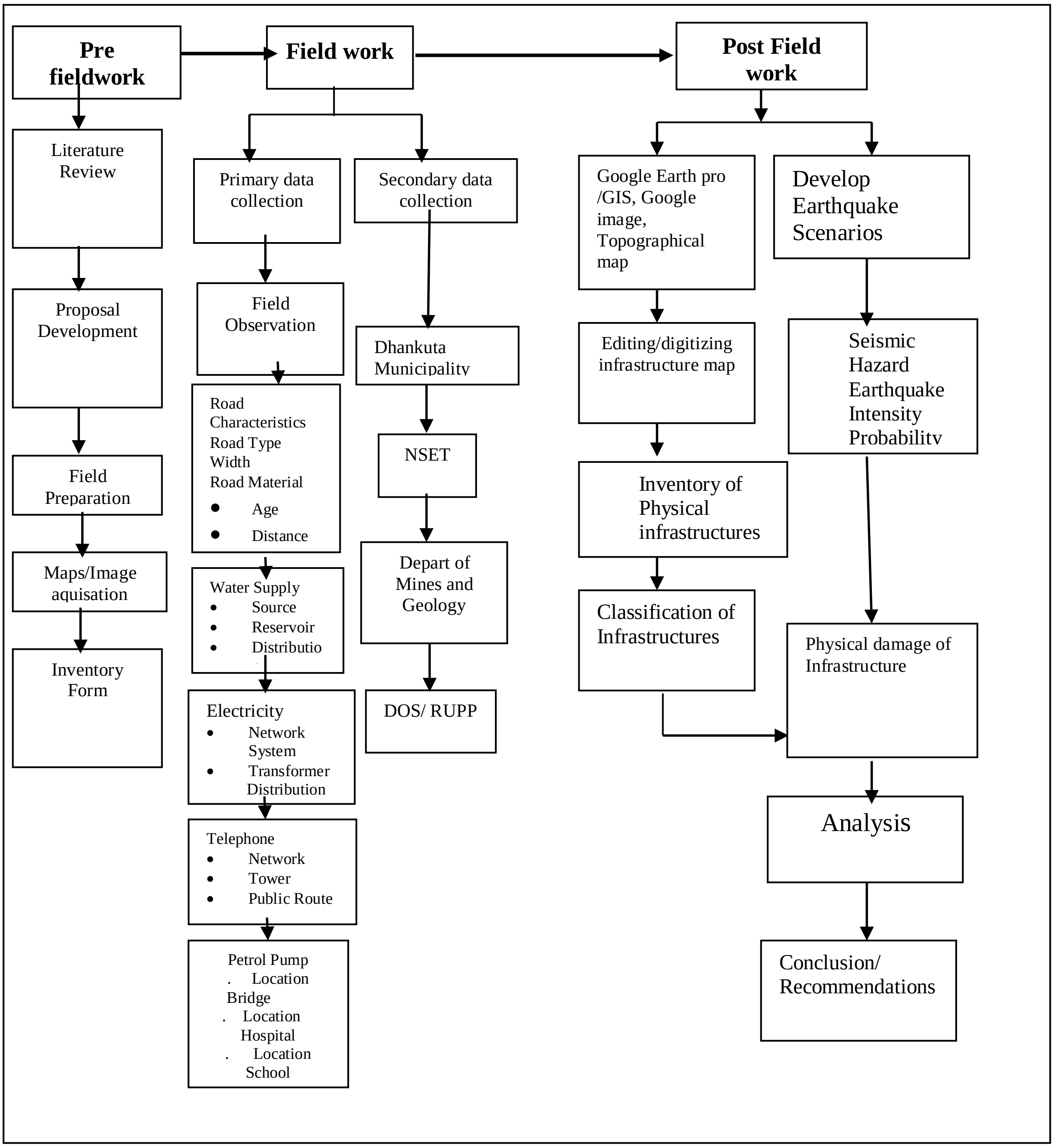
Research methodology provides a whole framework for selecting research gap; analyzes order and exchange of information for a particular issue. The research is always based on collection and analysis of data which are processed to fulfill research questions. To conduct a research in a systematic way requires a method. Methods are sets of techniques or identifying a topic, receiving the related literatures, conducting fieldwork and writing a report. Many initiatives have been launched worldwide to assess and reduce urban vulnerability, such as risk assessment tools for diagnosis of urban areas against seismic disasters (RADIUS, 2000) in which the material properties vary. However, still one of the major issues is how hazards, vulnerability and risk assessments can actually be used, and in practice to reduce risk.

Data is primary input for identifying hazard prone area, vulnerability as well as risk assessments and disaster impact analysis. For any cities data relevant for risk analysis are unavailable or their quality and accuracy does not reflect a comprehensive picture of the situation at hand. There is a need to work towards the standardization and systematization of all issues related to the accuracy, technical soundness, methodologies and process related to the collection, analysis, storage and maintenance of data. This chapter clarifies the methodological approaches applied and put forwarded description on how information was collected and analyzed.

3.2: Research Methodology and Framework

The whole research work has been divided into three major parts. First part considers the pre-field work which included literature review, proposal development, map collection, inventory sheet development and field preparation. The second part is related to field work. During the field work, primary and secondary data were collected and field observation was made. The third part of the study is the analytical work including literature review, digitizing infrastructure foot print, editing, inventory of physical infrastructures, vulnerability and damage estimation. The flow chart of research methodology and framework are shown in figure 3.1.

Figure 3.1 Research Methodologies and Framework



3.2.1: Pre field work

The study started with a review of previous research about earthquake loss estimation and related aspects. The main findings were incorporated in the research proposal and formulating the major objectives to address the existing research problem. Dhankuta municipality was selected as the study area. Google image was used as the main base image to delineate the building units in the field, which was downloaded and printed from NSET Nepal, Kathmandu. The study area was divided in to 12 different blocks and the resulting image was printed in large scale to make easy to identify the building and

Infrastructure service in the field area. But these blocks are not interpret in the data analysis and result because it has been made to make easy data collection process.

3.2.2: Field work

The field work divided into two parts, primary data collection and secondary data collection. A primary data collection field study of one month's was conducted from 7 January to 6 February 2011. During the field survey individual infrastructure were identified visually and traced in the Google image with shape and given unique identity consisting of infrastructure ID like road Id, water tank ID, tele- cabinet ID transform ID etc.

Different type of information especially Attribute data related with Infrastructure services such as roads, telephone, electricity, water supply and petrol pump, bridge, essential facilities (hospital, collage, school) were gathered during the field visit.

Road Network Data: The names of roads, width, construction material, status, types etc were obtained during field visit. The roads were named on map based on these documents provided by Dhankuta municipality.

Electricity System: The details of electricity system is available with the Nepal electricity authority(NEA), Dhankuta division .Electric lines distributional, pole material and transformers capacity ,their locations were delineated on map under the supervision of overseer of NEA Dhankuta division during the field visit. Electric pole distance from road, house and potential hazard near transformers were also observed and noted at the time of filed visit.

Water Supply: water supply system and network is available only as schematic diagrams prepared by the municipality staffs. Water supply system and networks were delineated on map during field visit. The water supply system contains details of pipe material, type of tank, pipe joint, pipe diameter, network; sources along with capacities were delineated under the supervision of overseer of Dhankuta municipality.

Telephone Network: The network system contains distribution lines and telephone cabinets which were represented on map under the supervision of technical personal from Nepal Telecom, Dhankuta Division. Site and situation of cabinet, pole material were also observed during field visit.

And other related secondary data were collected from the Dhankuta municipality office,Local people, District development committee office Dhankuta, NSET office, CBS, Department of survey/NGIIP, Internet, Central library T.U., and Library of Central department of Geography T.U.

3.2.3: Post field work

The infrastructure footprint map was digitized with the help of Google Earth Pro tools to link with the internet and that digitize shape infrastructure file were converted to Kml2shpv2_3.avx extension than that shape file projected with the help of Arc View GIS 3.2a. New infrastructure were added by digitizing with the help of Google Earth Pro tools All attribute information of the infrastructure were entered in excel format and then converted in to dbase file for the GIS format and join the attribute table. After completion of the GIS Map work, infrastructure vulnerability analysis was done. Vulnerability functions describing the relation with seismic intensity map and the damage rate of the infrastructure and damage estimation.

3.3: Data Sources

3.3.1: Primary data

Not available infrastructure detail data footprint in GIS form, so that Google image was the bases for the study. The primary data of infrastructure were collected from the field survey. All infrastructures were visually observed and traced in the printed image. The newly constructed infrastructures were also added in the image. The help of Googol Earth Pro, image of the municipality.

3.3.2: Secondary data

The secondary data were collected from various sources. The base map of the municipality and toposheet were collect from Topographic Department of Survey Nepal. Some other relevant information of the municipality was collected from the Dhankuta municipality office, Different infrastructure services office, District development committee office Dhankuta, NSET office, Central library T.U. and Depart library of Central department of Geography T.U. Beside this other published and unpublished books, journal, reports, newspapers, dissertations etc. related to this tropic were reviewed.

Table 3.1 Sources of data

S.N.	Description	Source	Map scale	Year
1	Digital layer map in GIS	NGIIP/ Topographical survey branch and RUPP	1:25,000	1998/2008
2	Population and household	CBS/ Municipality statistical report		2001/2008
3	Dhankuta toposheet map	Topographical survey branch	1:25,000	1998
4	Primary data	Field survey		Jan, 2011

3.4: Data Processing Tools

The available data from primary and secondary sources has been processed by using descriptive statistical techniques. All spatial data has been analyzed in Google Earth Pro and Arc View GIS 3.2a. Microsoft excel format to calculate the vulnerability of infrastructure, which is describe in below.

3.4.1: Google Earth Pro

The present study used in this tool for downloaded to the main base image of the research area. This downloaded image make very easy for delineate the building units in the field survey. After completed to the field survey, then used in this tool for digitized all infrastructure services foot print map.

3.4.2: Geographic Information System (GIS)

Geographic information system is computer system that records, stores, and analyzes information about the features that makes up the earth surface (Arc View GIS Manual, 2004). A GIS can generate two or three dimensional images of an area showing such features like hills, road with power lines. In this study, researcher used GIS to prepare vulnerability maps by making precise measurements gathering data and testing ideas.

Many GIS database consists of sets of information called layers. Each layer represents particular types of geographic data. For example the layer may include information of roads in an area. Another layer may contain information of water supply in that area, while another records building structures. The GIS can combine these layers into one map showing how the roads, electric line, water supply networks and building structure relate to one another so that policy makers could use this composite map determine whether a particular part of a road is more likely to crumple.

As GIS is used to accept geographic data from a variety of source including maps, satellite images, aerial photographs, printed text and statistics, GIS sensors can scan some of this data directly. For example, a computer operator may feed a map or photographs into scanner and the computer reads the information it contains. The GIS converts all geographical data into digital code and arranges it in database.

3.4.3: Hazard United state (HAZUS)

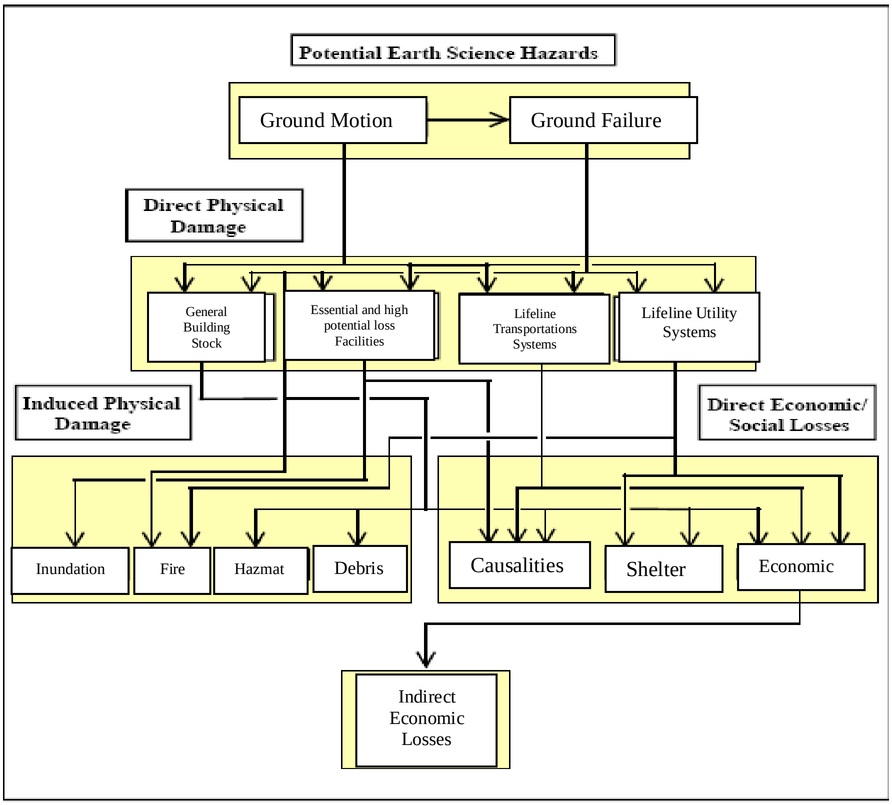
United states Federal Emergency Management Agency developed HAZUS method to provide individual, business, and communities with information and tools to work proactively to mitigate hazards and prevent losses resulting from disasters.

Using GIS technology, HAZUS allows users to compute estimates of damage and losses that could result from an earthquake to support FEMA’s mitigation and emergency preparedness efforts. HAZUS is being expanded into HAZUS-MH, a multihazard methodology with new modules for estimate potential losses from wind and flood hazard.

In addition to estimating losses, HAZUS contains a database of economic census, building stock, transportation facilities, local geology and other information that can be used for a number of steps in the risk assessment process.

The framework of the method includes each of the components shown in figure: potential earthquake hazard, inventory, direct physical damage, induced physical damage, direct economic/social loss and indirect economic loss. These factors are independent with each other. In general, each component will be required for loss estimation. However, the degree of sophistication and associated cost will vary greatly by user and application. It is therefore necessary and appropriates that component in multiple levels.

Figure 3.2: The Overall Framework of the HAZUS Method



Source; HAZUS-MH, (2003)

3.4.4: Potential Earth Science Hazard (PESH)

A potential earth science hazard includes ground motion, ground failure due to liquefaction and landslide and surface fault rupture and tsunami. Ground motion is quantified in terms of peak ground acceleration (PGA) and spectral acceleration (SA), and ground failure is quantified in terms of permanent ground displacement (PGD). For computational and efficiency and accuracy, earthquake losses are generally computed using location specific values of ground shaking are interpolated between PGA, PGV and spectral acceleration contours respectively.

PGA: The peak ground acceleration is the maximum acceleration experienced by a particle location of the places due to course of the earthquake motion. Thus, it is a level of ground motion severity experienced at site due to an earthquake (Georisk, 2004).

SA: It refers what is experienced by any type of infrastructures services as modeled by a particle on a mass less vertical rod having the same natural period of vibration as the building. The unit of spectral acceleration is g (gravity)

SV: It is defined as deprivation of the displacement record with respect to time.

SD: The spectral displacement (SD) is illustrated as displacement of a modeled particle on a certain damping mass-less rod, which is driven on its base by the seismic record.

3.5: Method of Analysis

3.5.1: Vulnerability and damage estimation

For the estimation of damage to the infrastructure, vulnerability functions describing the relation between seismic intensity during the earthquake event and structure of the infrastructure. Damage and collapse probability has been calculated with the help of the earthquake intensity, attribute information of infrastructure, and GIS tools. In this research mainly 3 assumed earthquake scenario depend on near fault from Dhankuta.

3.5.2: Data Analysis and presentation

According to HAZUS method, each facility required for analysis include the geographical location (latitude and longitude), classification and replacements cost of the system components. The system also requires the length and point of each facility. For example roadways are classified as major roads and urban roads. Major roads include interstate and state highways and other roads with four lanes or more (HAZUS-MH, 2003). Urban road include intercity roads and other roads with two lanes.

Public infrastructures have been tabulated to and characterized the infrastructure. GIS used for assessing the spatial and attribute characteristic of services. Furthermore, the data were present in the form of diagram, chart, and table and visualize them in maps.

The analysis of seismic vulnerability of infrastructure systems is based on an assessment of three factors.

- Seismic intensity on geological condition
- Soil liquefaction
- Slope instability
- landslide

In this study, these factors are used to identify vulnerable condition and impact of disruption in terms of direct damage. Estimates of direct damage to infrastructure are expressed in terms of percent value.

Direct damage is defined as damage resulting from ground shaking, landslide, liquefaction and debris block (building damage). For each facility damage may be vary from 0 to 1 (0% to 100%). It has been divided into four categories- none, slight/minor, moderate, extensive.

In this study it is estimated using-

- Estimates of ground shaking intensity provided by the seismic hazard model, Timsina, 2011.
- Inventory data specifying the location and type of facilities.

And, vulnerability condition that is related to seismic intensity and site conditions to expected damage. The analysis approach for computing direct damage due to these factors have been proceeded as follows,

- For each earthquake scenario, intensity map were assigned to each location and, damage states were then estimated for each affected infrastructure component (point or line)

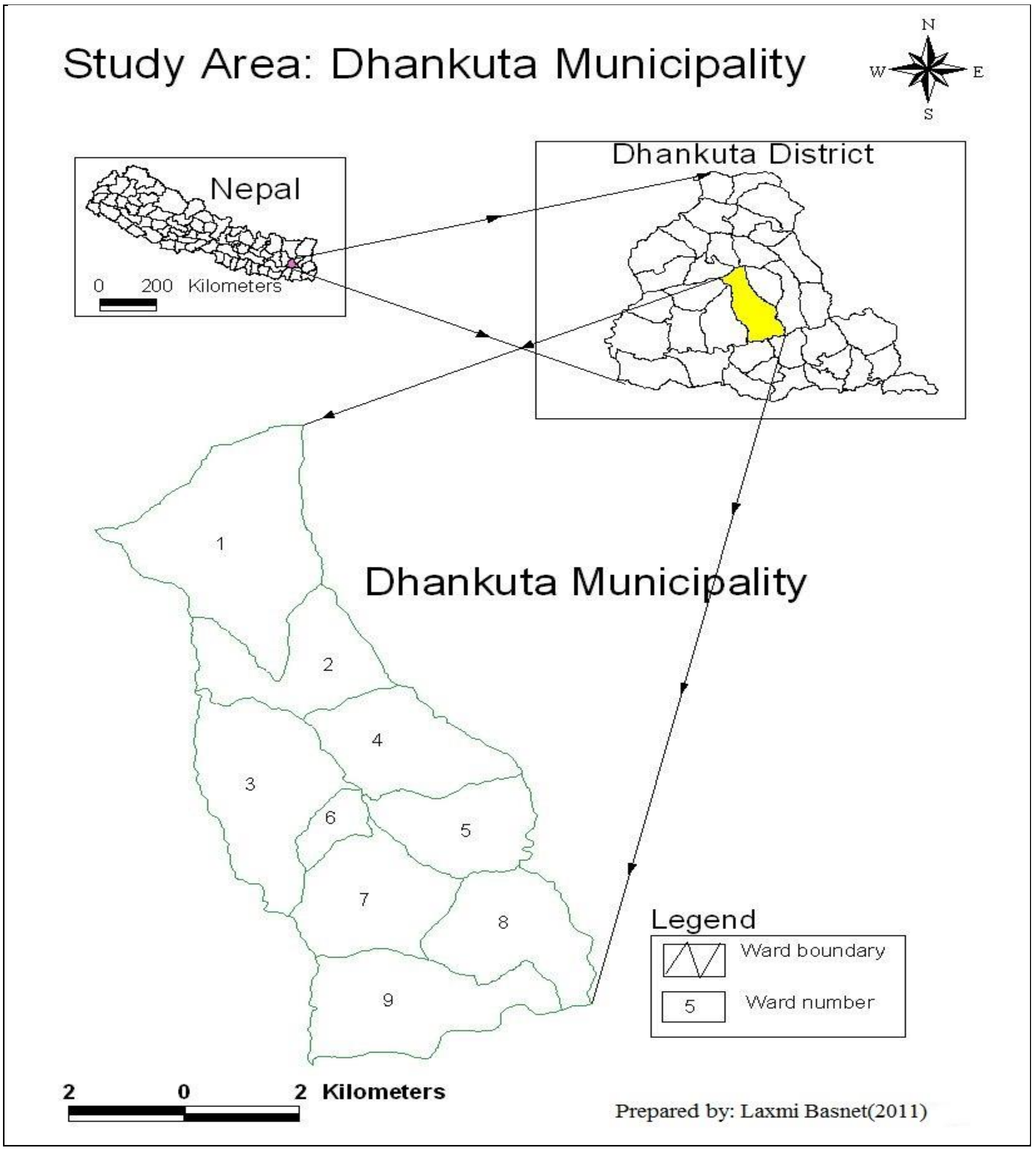
After damage due to ground shaking, landslides were established for each facility and the total direct damage for each facility was calculated.

CHAPTER IV
INTRODUCTION OF THE STUDY AREA

4.1: Background

Dhankuta municipality is study area of this research.The municipality is located in the district of Dhankuta, Koshi zone; Eastern Development Region of Nepal. Dhankuta got municipality status in 2035 B.S. According to Population Census 2001, this municipality had a density of 428.7 persons per sq. km. The following figure 4.1 indicates the location of the Research area.

Figure 4.1: Location map of study area



Source: NGIIP 1998 and RUPP 2008.

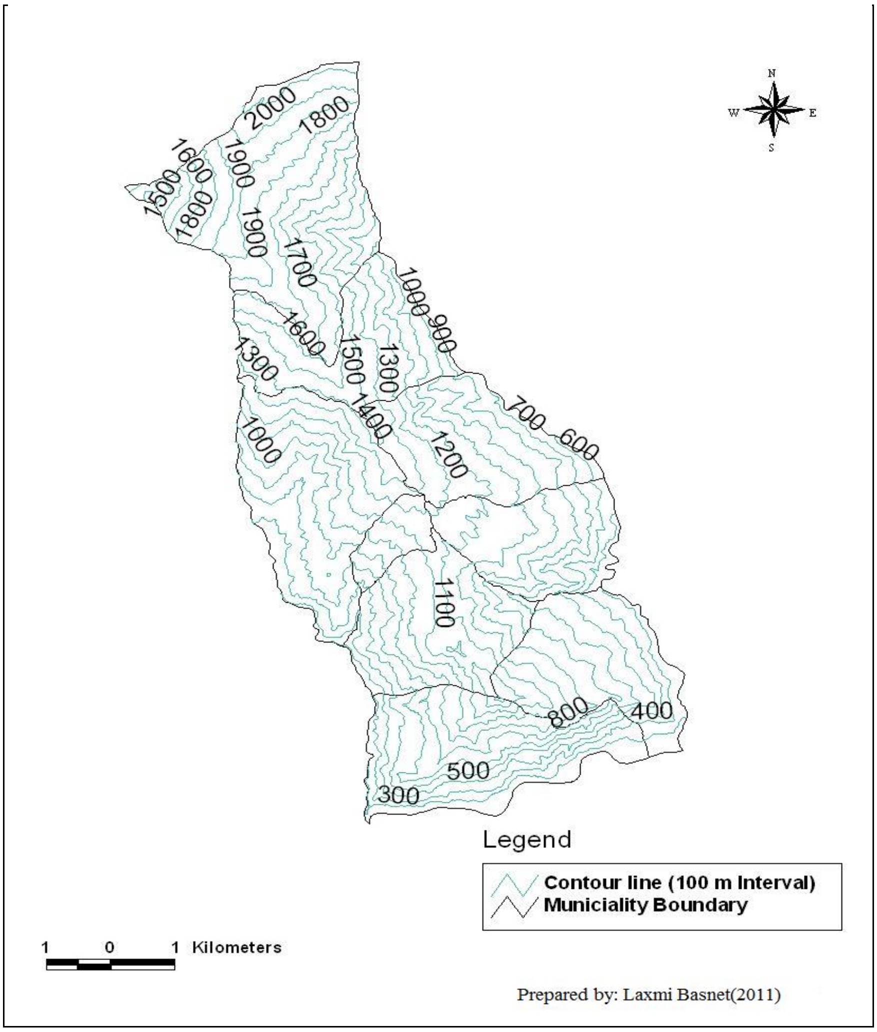
Dhankuta Municipality is surrounded by the Virgaun VDC in the east, Chungmang and Belhara VDC in the west, Pakhribas and Hattikharka VDC in the north and Tamor River in the south. It is district headquarter as well as regional headquarter of Eastern development region. It lies between 26˚59’59” to 27˚02’55” north latitude and 87˚17’52” to 87˚23’09” east longitude. It covers an area of 48.74 sq. km. Historically as well as

other attraction of the municipality is Dhankuta Gauda, Baunna dhoka darbar, Shreepanchamipark, Chuliban, Nishan Bhagawati, Guranse tea estate and so on.
Dhankuta is a hill town with about 20,000 inhabitants. Until about 1963 Dhankuta Bazaar (the town) was the administrative headquarters for the whole of north-eastern Nepal. Located a half mile above the town was the buildings of the Bada Hakim, the feudal district governor of the whole north-eastern region, a man with enormous power. The town also had the regional jail and army post. Because of Dhankuta's isolation from the lowland Terai and from Kathamandu, it was in many ways a self-governing area.
Income to purchase items (cloth, kerosene, batteries, medicines, etc.) that could not be produced locally came from a combination of sales of hill produce (tangerines, potatoes, etc.) and funds repatriated back into the hills by Gorkha soldiers serving first in the British and then more-often in the Indian armies.
The first five (3 male; 2 female) American Peace Corps Volunteers arrived in Dhankuta Bazaar in Fall, 1962 to work as teachers in the two high schools. In October, 1963 three male PCV's arrived to help establish the new Panchayat Development program.
From 1963 Nepal was divided into 75 Panchayat Districts, and the traditional Dhankuta administrative region was divided up into about six of the panchayat districts. The power of the Bada Hakim was transferred to the central government's appointed Panchayat Development Officer and each district's elected Panchayat President.
During the pre-panchayat period Dhankuta Bazaar prided itself as being in the cultural vanguard, a relatively progressive community with its own "intellectual" elite. Dhankuta Bazaar, already in the 1930s, had the only high school in Nepal to be located outside of the Kathmandu Valley. Early on it added a girl's high school and a two-year college.
Then and now there is a sharp contrast between Dhankuta Bazaar and the surrounding rural villages. The town is a commercial center and has a population that is primarily Newar. The surrounding area is agricultural and the population is made up of many caste/tribal groups, notably Rai (aathpaharias), Limbu, Tamang and Tibetan.
Dhankuta Bazaar, on the North-South Koshi Highway, is now the administrative headquarters for the Eastern Development Region, and is home to a number of offices for NGOs and aid agencies serving in the area. The large bazaar of Hile further up the road, is an important trading centre and major road head, serving the remote hinterlands of the Arun valley and Bhojpur. Villagers walk for many days from surrounding districts to trade in Hile and Dhankuta bazaars, although road building in the district may reduce the importance of these centres. The vegetation zones in the district range from sub-tropical Sal forest along the Tamur and Arun rivers, and cooler temperate forests on some of the high ridges that mark the watershed between the two catchments. The altitude ranges from around 300m to 2500m. The majority of the population is involved in agriculture and crops include maize, rice and millet. Important cash crops include citrus fruits, cauliflower, cabbage, ginger, and in recent years, tea. A well-preserved forest (Rani Bhan - Queen's Forest) spreads along a ridge line on the northwest side of the village, with well-developed mature stands of rhododendron and pine trees.

4.2: Relief feature

Dhankuta Municipality lies 250 meter to 2144 meter height from sea level. The contour line of this area shows the slope or relief feature in all parts of the municipality, where is find out maximum parts of the area is steep slope and some part of the area gentle slope or flat slope. Some part of the market area ward number 5, 6, 7 and 1 are find out gentle or flat slope area. Figure 4.2 shows the relief feature of the study area.

Figure 4.2: Relief feature



Source: NGIIP 1998 and RUPP 2008.

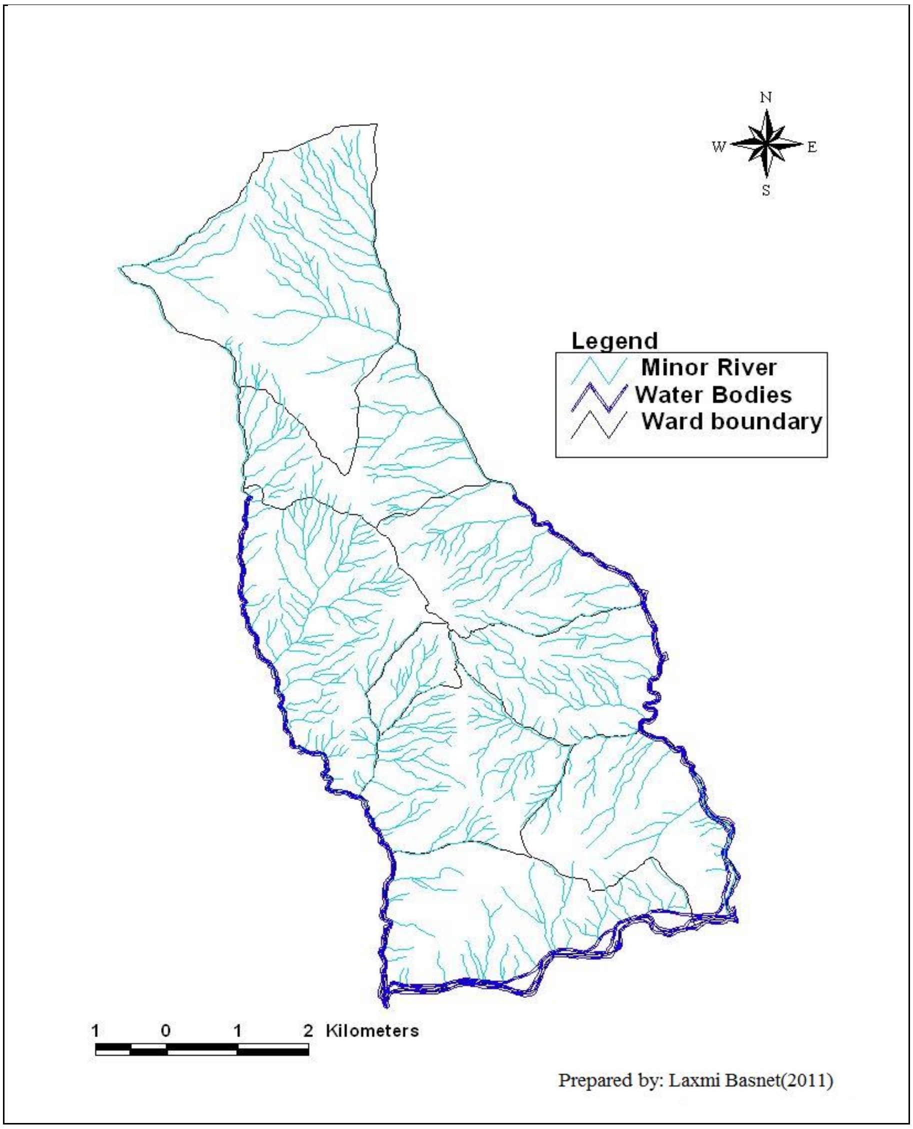
4.3: Climatic Conditions

Dhankuta municipality lies in sub tropical climatic area. However, climate varies with altitude and aspect. The maximum and minimum temperatures lie between 30˚C to 2˚C and the average rainfall is 1000 to 1200 mm per year.

4.4: Drainage pattern

The main river Tamor is situated in the southern part of the municipality and Patle khola in the west part, similarly Andheri khola, Thoka khola and Tankhuwa khola in the east part of the municipality. The drainage system of the municipality is shown in the Figure 4.3.

Figure 4.3: Drainage pattern

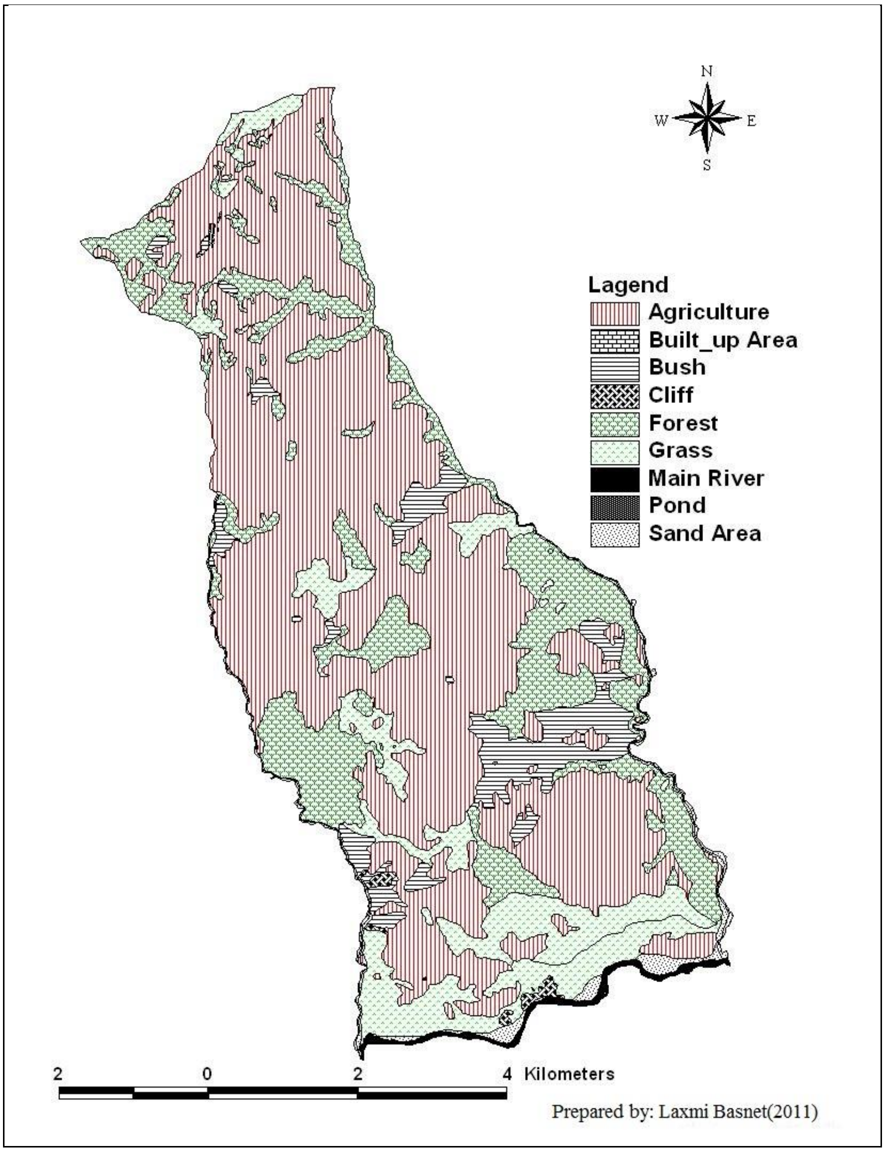


Source: NGIIP 1998 and RUPP 2008.

4.5: Land use / Land cover

The land use pattern of the area is diverse. According data of survey department 1998 in this municipality, the cultivation land comprises 28.22Sq km getting first position followed by forest land 9.76Sq km and grass land 5.99Sq km in second and third position. Other main types of land use/ land cover are buss, built up area, cliff, Main River, pond and sand area. It shown in Figure 4.4 and table 4.1

Figure 4.4: Land use / Land cover



Source: NGIIP 1998 and RUPP 2008.

Table 4.1: Land use/Land covers

Land use type	Area(Sq km)
Cultivation land	28.22
Built up area	0.02
Bush	3.18
Cliff	0.19
Forest	9.76
Grass	5.99
Main River	0.40
Pond	0.0015
Sand area	0.98
Total	**48.74**

Source: NGIIP 1998

Figure 4.5: Land use/ Land cover

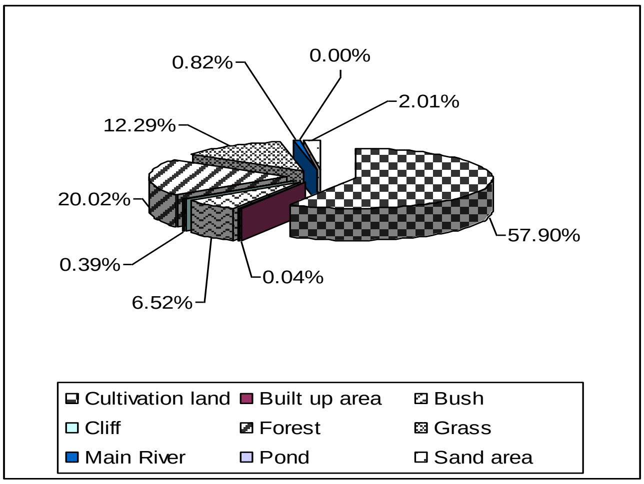


Table 4.1 and figure 4.5 show the distribution of land use/ land cover of the study area. Cultivation land is extensively distributed in the ward number 2 and 3 in this municipality.

4.6: Population distribution

Dhankuta Municipality divided into 9 administrative wards. The municipality counts up 20668 populations representing almost equal share in gender composition. According to population census 2001, this municipality a density of 428.7 person/Sq km and accounting 4789 households with an average number of 532 households/wards and average household size is 4.32 persons (ISRC 2008).

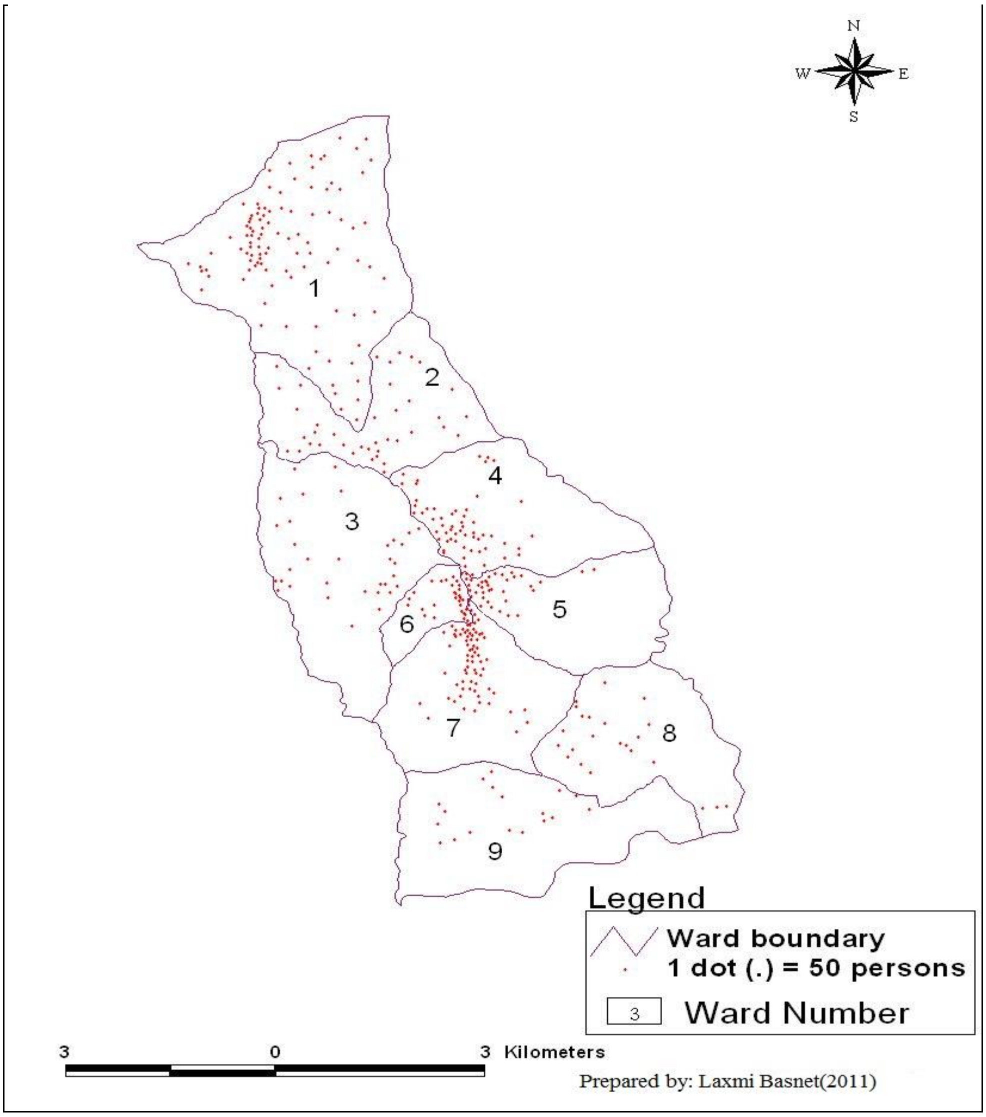
Table 4.2: Ward wise population distribution

Ward No.	Population (2001)		
	Male	**Female**	**Total**
1	2504	2630	5134
2	952	1009	1961
3	860	807	1667
4	1482	1365	2847
5	975	923	1898
6	718	747	1465
7	1858	1791	3649
8	519	628	1147
9	458	442	900
Total	**10326**	**10342**	**20668**

Source: ISRC 2008.

Table 4.2 shows the population distribution of the Dhankuta municipality. According to the data the highest number of population are in the ward number 1 with 5134. Similarly the lowest number of populations are in ward number 9with 900. Figure 4.6 shows the distribution of the population in Dhankuta municipality.

Figure 4.6: Ward wise population distribution



Source: NGIIP 1998 and RUPP 2008.

4.7 Cast and Ethnic Composition

There are many cast/ethnic groups in the Dhankuta municipality.The main inhabitant of the municipality are Rai (28.8 percent), Chhetri (13.6 percent), Newar (13.7 percent), Brahman-hill (12.0 percent), Tamang (8.6 percent), Magar (4.8 percent) and Limbu (3.3 percent) are the main caste/ethnic groups. Others are Kami (2.9 percent), Thakuri (2.4 percent), Damai (1.8 percent) and Sarki (1.6 percent), Teli, Sherpa, Baniya, and Gharti Bhujel are the minor communities in the town. A majority of the population speaks mother tongue Nepali (49.88%) followed by Bantawa (24.46%), Newar (9.75%) and Tamang (6.46%). The main religions of the municipality are Hindu 62.72 percent, Buddist 11.34 percent, Kirat 24.83percent and Christion 0.70 percent (ISRC 2008).

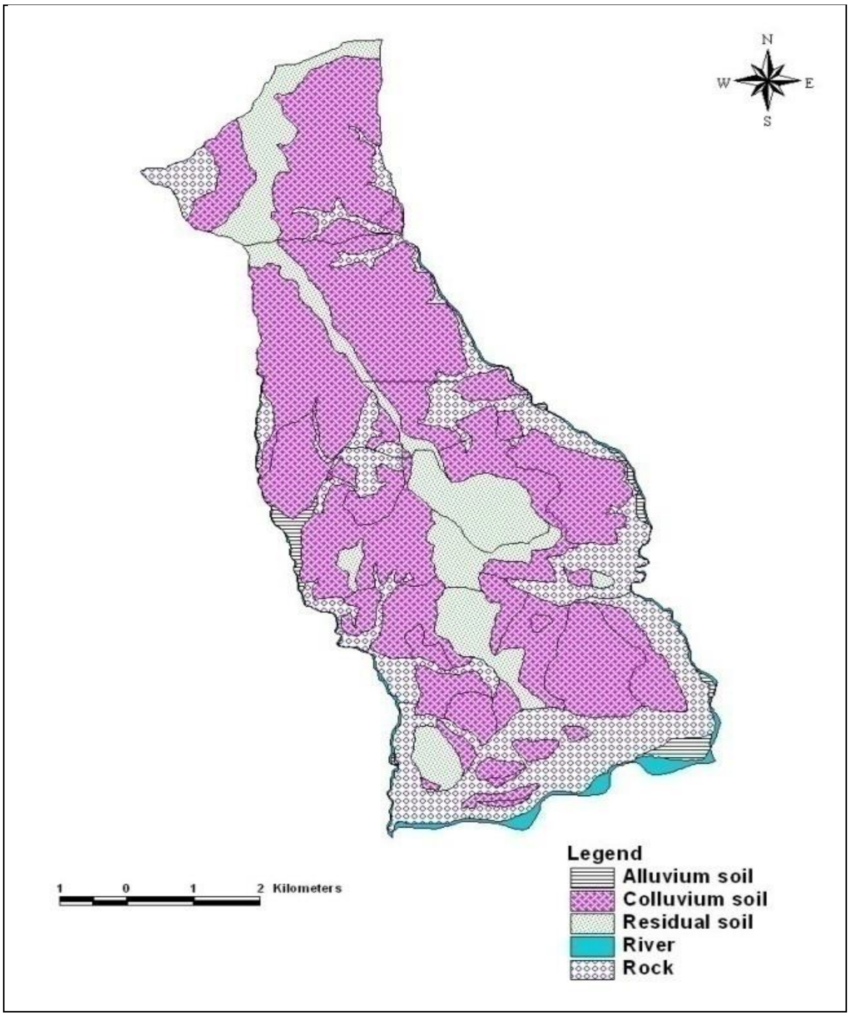
4.8: Soil Condition

The soil of this area is identified on the field basis and classified according to their origin, i.e. alluvial, colluviums and residual soil. In most area the soil have shallow depth (up to 3 meter) and in some places soil have depth up to 6 meter.

The colluvium is the main soil type in the area which distributed on the steep slope. The residual soil is generally distributed along the ridges and on the flat area. The alluvial soil is mainly distributed on the flood plain of the Tamor River and its tributaries.

The main market and the core area of the Dhankuta municipality lies on the fine to course grained, moderately dense, residual soil and almost all village area is covered by colluviums. The detailed sub-surface condition of the area is studied and soil map is prepared by Timsina (2011), which is shown in Figure 4.7 below.

Figure 4.7: Soil Condition

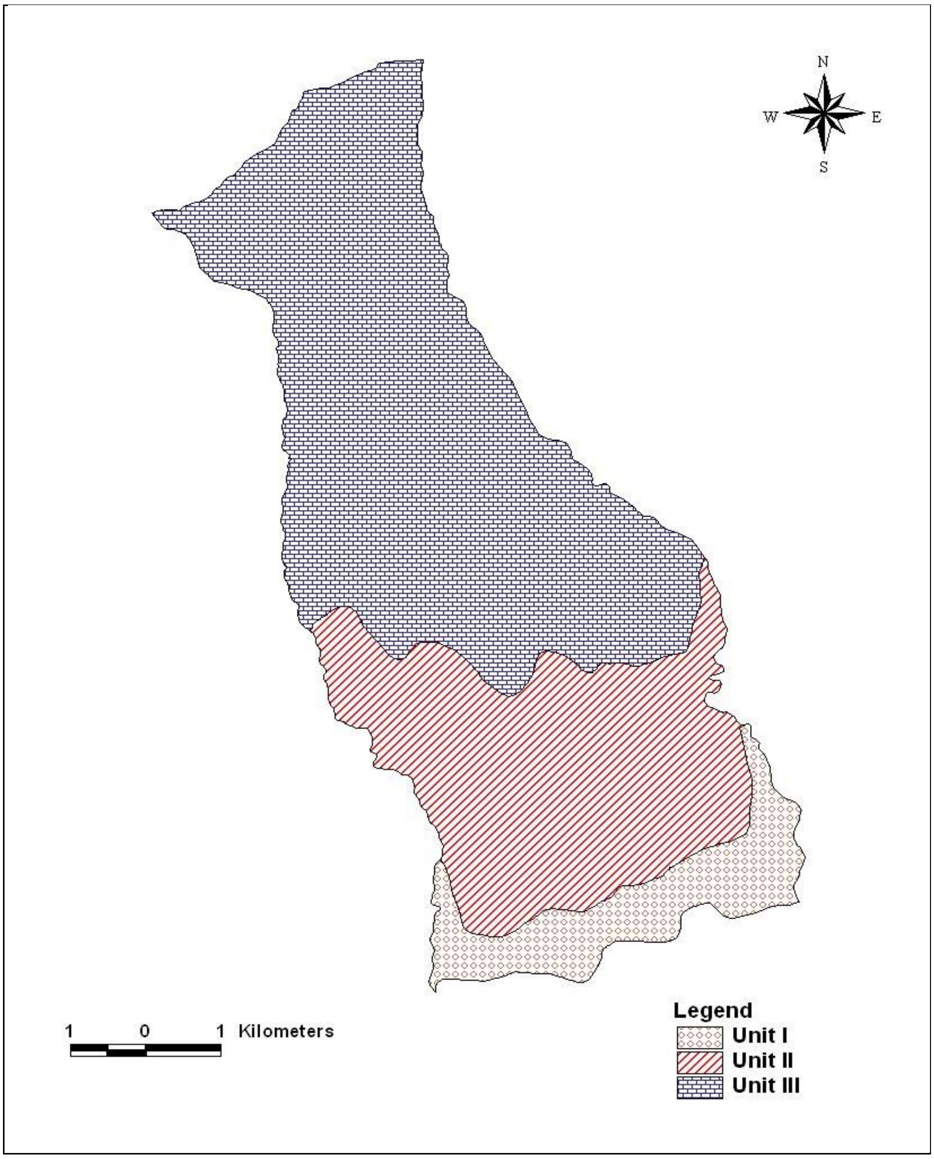


Source: Timsina 2011

4.9: Geological Setting

The study area lies in the eastern part of the Nepal Himalaya. The area is comprised of the Higher Himalayan Crystalline and low to medium grade metamorphic rocks of the lesser Himalaya separated by Main Central Thrust. Timsina (2011) studied the geology of this area and divided the rocks into three units on the basis of lithology and structure (Figure 4.8).

Figure 4.8: Geological Setting



Source: Timsina 2011

Unit I: The unit I comprised of the black to dark gray crenulated, graphic slate with distorted quartz veins and dark gray, thin to medium-bedded, medium-grained, calcareous quartzite.

Unit II: The unit II is mainly composed of dark gray to light gray, garnetiferous schist with few bands of greenish gray, actinolite schist and medium-grained thin to medium banded, white quartzite.

Unit III: The unit III consists of augen gneiss and banded gneiss. The augen gneiss consists the augen of quartz and feldspar and segregation of light and dark minerals contribute to the formation of the banded gneiss. The major geological structure, Main Central Thrust (MCT) is seismically inactive at the present.

4.10: Urban Form and Settlement Pattern

Dhankuta municipality, there is 4287 total buildings. The distribution of settlement pattern in Dhankuta municipality is irregular. The houses are seen in market particularly in ward no.1 Hile, ward no. 6 Bicha Bazar, ward no. 5 Tallo Kopche and Mathillo Kopche and ward no. 7 Bus Park area. 5-15 houses are attached with each other. The built up density gets higher. Moving outside the market there is lot of agricultural and vacant land. There, the built up density is low. Buildings in the market area have multifunctional use. There are 7849 separate floors in their total buildings. About 82.79 percent of all floors are used for residential purposes, 7.86 percent for commercial, 3.81 percent for office/institute, 2.70 percent for school/campus, 1.57 percent for hotel/restaurant and 1.27 percent used for other different purpose (See Table 4.3 and Figure 4.9).

(Urban Form Settlement and Pattern in Dhankuta Municipality)

Table 4.3: Building floors classified by space use

Floor	CO.		RS.		SC.		OI.		HR.		Others		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1st	439	71.15	3432	52.82	130	61.32	146	48.83	61	49.59	79	79	4287	54.62
2nd	168	27.23	2733	42.06	70	33.02	115	38.46	45	36.59	19	19	3150	40.13
3rd	8	1.29	319	4.91	12	5.66	32	10.70	16	13.01	2	2	389	4.96
4th	2	0.33	9	0.13	0	0	4	1.34	1	0.81	0	0	16	0.20
5th	0	0	2	0.03	0	0	2	0.67	0	0	0	0	4	0.05
6th	0	0	2	0.03	0	0	0	0	0	0	0	0	2	0.03
7th	0	0	1	0.02	0	0	0	0	0	0	0	0	1	0.01
Total	617	100	6498	100	212	100	299	100	123	100	100	100	7849	100
%	7.86		82.79		2.70		3.81		1.57		1.27		100	

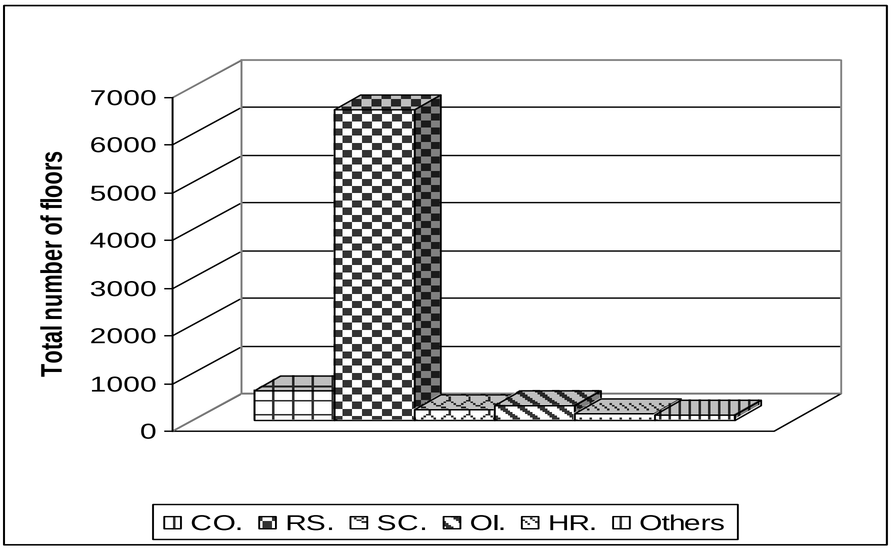
Source: Field survey, Paudel 2011

Where: CO= Commercial, RS= Residential, SC = School/Campus, OI= Office/Institution, HR=Hotel/Restaurant, Others= (Hospital, police/ army station, industry and mixed used floors)

Most of the first and second floors are used for residential and commercial purpose. In this research found 52.82 percent of the first floors and 42.06 percent of the second floors are used for residential purpose and 71.15 percent of the commercial floors found on the first floors. Similarly 61.32 percent of the school/campus, 48.83 percent of the office/institute and 49.59 percent of the hotel/restaurant are used in the first floors.

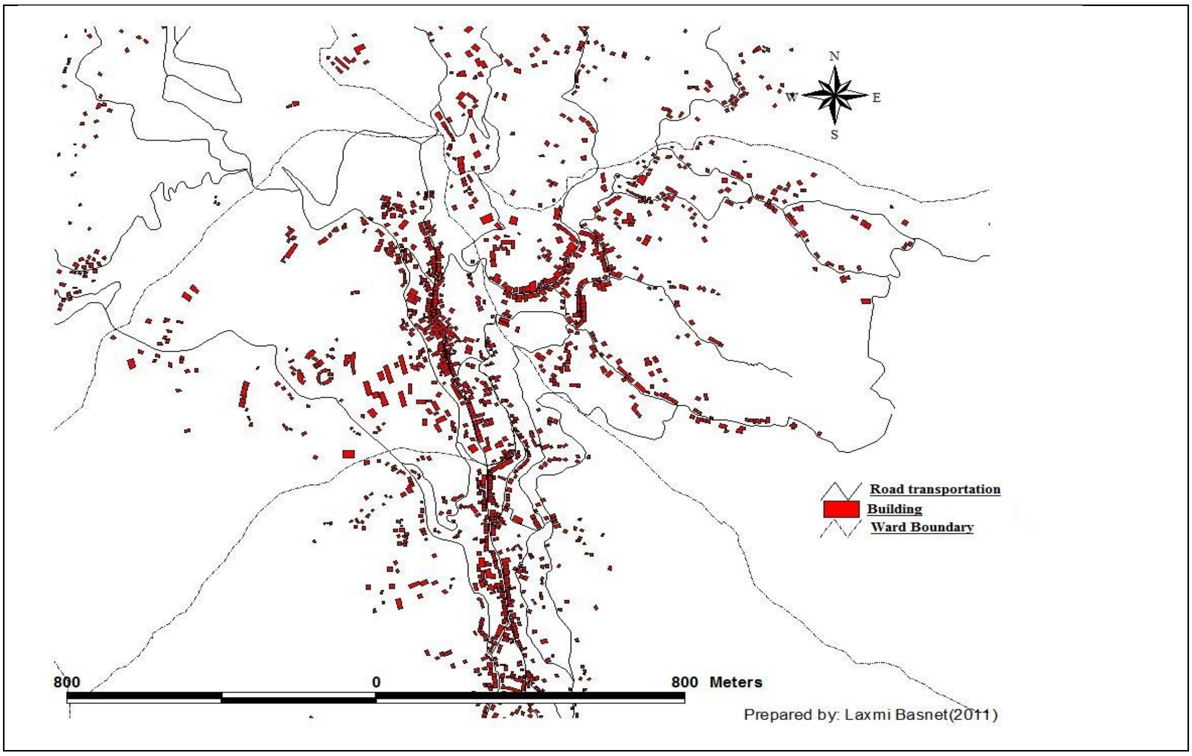
There are connected by highway, major trail or footpath. From the motorbike road the settlement is connected by major trail with gravel, earthen or stone paved .The average height of the building in this area is 3 to 4 floors (about 8m), meanwhile, the average width of the road in these areas is only 3 m. Other types of structures like electric line,

Figure 4.9: Building floors classified by space use



Water supply network, and telecommunication are also located closely to the road. Settlement pattern of this area is shown in Figure 4.10.

Figure 4.10: Urban Form and Settlement Pattern



Source: Paudel 2011

On the basis of the above mentioned analysis, the roads in the market area are blocked by collapsed buildings in an earthquake for three reasons; narrow width, dense built-up along the road and old building nearby road. These areas need to be seriously taken into consideration in the earthquake emergency.

CHAPTER V
INFRASTRUCTURE SERVICES IN DHANKUTA MUNICIPALITY

5.1: Introduction

Infrastructure is a highly valuable asset of a city. For example; road network plays a vital role in emergency responses, electricity for industry as well as domestic use. Thus, disruption of infrastructure such as water supply or electric power for a city or urbanized region would inevitably lead to major economic losses and disturbed on public health and eventually population migration. It is therefore necessary to consider what has to be done to promote development and application of appropriate design and construction within urban area. The country has been defined as underdeveloped regions, in terms of relative scarcity of basic infrastructures and facilities such as road, bridge, drinking water, irrigation, electric power and income generating activities (MLD, 2000). By virtue of diverse relief features, there is a great disparity in different regions of the country. Regional or local sectors suffer from inadequacy of development activities. Industrial development is extremely limited due to poor infrastructure. On the other hand, existing structures of the Nepal are also lack of proper analysis of seismic design (Jaisi, 2002).

Infrastructures are also highly intra- and inter-dependent systems. These can be damaged by collapsing houses or bridges or by landslides and riverbanks, the movement of which can be triggered by earthquakes. The malfunctioning infrastructure leads to immediate danger for people and longer threatening situations. However, most research focus on earthquake phenomenon rather than its possible impact (SLARIM, 2002). The impact of natural disasters such as earthquakes - which account for one of the highest losses amongst all types of disasters in terms of the number of people affected, the properties and infrastructure affected as well as the cost to the local, regional and global economy; is significant as well as alarming. The study indicates how vulnerable urban and regional systems (other than infrastructure) are to the interruption of services like electricity, water, gas, and communication.

They are partially or wholly unsafe due to improper design, construction, material etc. Buildings have been built without earthquakes resistant. Road transportation, water and sewerage pipes, electricity pipes and telecommunication are constructed according to local condition, and aggravated earthquake vulnerabilities. It is mainly because of the lack of awareness in the people and government regarding the important of structural analysis, quality control or good construction process. Therefore, due to a disaster especially in an earthquake will create great impact on population living in earthquake prone area. Such poor social structures will also get exposed to associated secondary hazard like fire, waterborne diseases, epidemics and technological accidents. All of these possible features contribute to higher vulnerability and risk of earthquake disaster (Chaudhary,2008).

Dhankuta municipality is rich in the development of physical and public infrastructure than the other VDC of Dhankuta. The most development infrastructure is road transportation. But ward no.8 and 9 are too much remote area then other ward.Most people of this municipality have been taking advantages from the facilities of this infrastructure like transport, electricity, drinking water and telecommunication etc. Several NGOs and INGO organizations are also helping for its development.

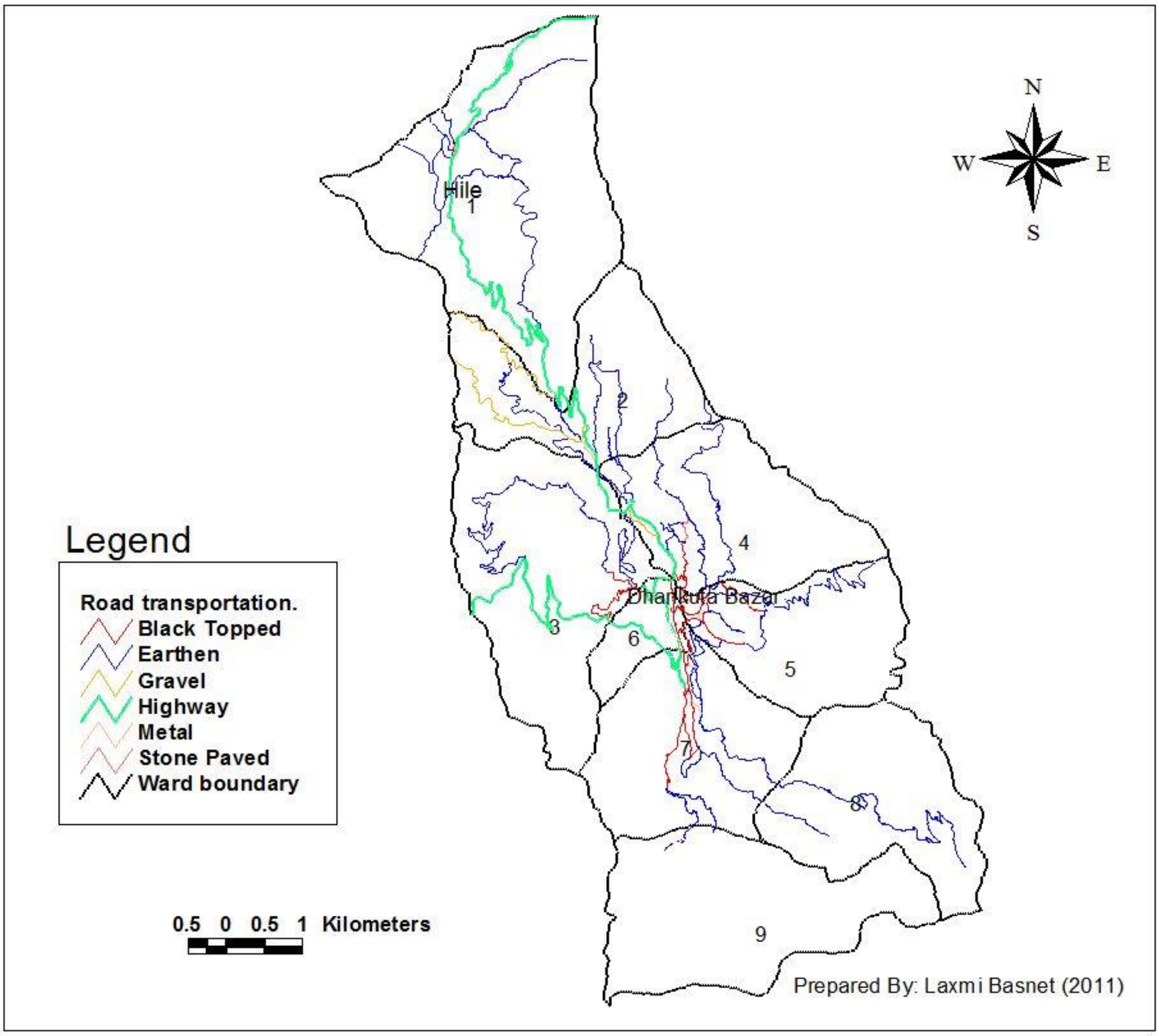
5.2: Road Transportation

For purposes of international statistical comparison, Organization for Economic Cooperation and Development (OECD) defines a road as "a line of communication (travelled way) using a stabilized base other than rails or air strips open to public traffic, primarily for the use of road motor vehicles running on their own wheels" which should include "bridges, tunnels, supporting structures, junctions, crossings, interchanges and toll roads but not cycle paths". In urban areas roads may diverge through a city or village and be named as streets, serving a dual function as urban space easement and route (http://en.wikipedia.org/wiki/road). Road Transportation includes urban and rural freeways. It can be divided into highway, major road, minor road, gravel road and foot trail etc. Road transportation also includes pavement, base and sub base (HAZUS-MH, 2003). Pavement types may be cement, concrete or asphalt concrete. Base and sub base materials include aggregate, cement treated aggregate and lime stabilized, and soil cement bases. Embankments may or may not include retaining walls.

Road transportation is most important infrastructure of human being. Transport plays an important part in economic growth and globalization. It is also related with human civilization. It is needed for exporting and importing various essential things from one place to another place. The development of transportation contributes to develop the whole nation by strengthening the relationship between and among people, transporting goods and peoples from one place to another etc. Moreover, it helps to broaden the horizon of business trade from which the economy of the country gets pregnant. Means of transportation available in the present world are land transportation (Road, railway), water transportation and air transportation. In the context of Nepal, road and air transportation are prevalent.

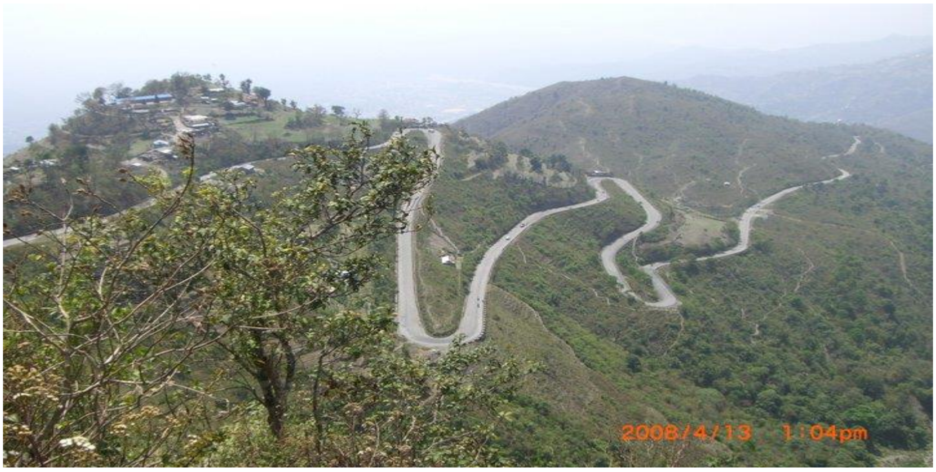
Until about 1963 Dhankuta Bazaar (the town) was the administrative headquarters for the whole of north-eastern Nepal. That reason It is rich in transportation. Dhankuta Bazaar, on the North-South Koshi Highway, is now the administrative headquarters for the Eastern Development Region, and is home to a number of offices for NGOs and aid agencies serving in the area. The large bazaar of Hile further up the road is an important trading centre and major road head, serving the remote hinterlands of the Arun valley and Bhojpur. Villagers walk for many days from surrounding districts to trade in Hile and Dhankuta bazaars, although road building in the district may reduce the importance of these centers. Along with this, there is facility of gravel link roads in each wards of this municipality. The total length of roads within the municipality is approximately 123km, which consists of highway, black-topped, gravel, earthen and stone paved. In spite of these, there is difficulty for linking all of its area with the road. The construction of road needs too much capital and technology and, being a poor municipality, Dhankuta is unable to invest for it. Furthermore, the roads have not been repaired for a long time. Most of roads have already been destroyed special in Hile area. But highway road is too good in this area. So, the condition of transportation in this area is not so good. Moreover, there is still Goreto(trail)and, Ghodeto ways in the hilly area where people survive depending on their arm and backs. The types of road are clearly seen in the Figure 5.1

Figure 5.1: Existing Road Network in Dhankuta



Source: Boundary base map for NGIIP 1998 and RUPP 2008 and road foot prints were digitized by the researcher.

Figure 5.2: Koshi Highway in Dhankuta District

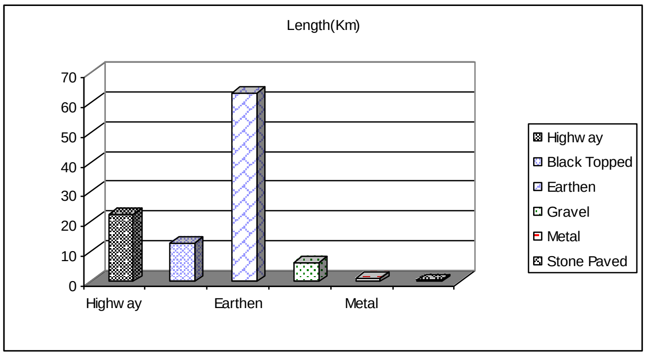


Source: http://cnn4.wordpress.com

Table 5.1: Road length of Dhankuta Municipality

Surface Type	Length(Km)	%
Highway	22.35	21
Black Topped	12.94	12.16
Earthen	63.40	59.59
Gravel	6.16	5.8
Metal	1.10	1.03
Stone Paved	0.44	0.42
Total	**106.39**	**100**

Figure 5.3: Road length of Dhankuta Municipality



The road network of Dhankuta municipality consists of different categories. There are about 12.94 km length black-topped road, highway road 22.35km, gravel road 6.16km,eathen roads 63.40, metal roads 1.10km and stone paved roads having 0.44km in the municipality. Charts in figure and table also display the distribution of road length in Dhankuta Municipality

5.3: Water Supply System

The basic source of water is rainfall, which collects in rivers and lakes, under the ground, and in artificial reservoirs. Water from under the ground is called groundwater and is tapped by means of wells. Most often water must be raised from a well by pumping. In some cases a well will draw water from a permeable rock layer called an aquifer in which the water is under pressure; such a well needs little or no pumping (see artesian well). Water that collects in rivers, lakes, or reservoirs is called surface water. Most large water supply systems draw surface water through special intake pipes or tunnels and transport it to the area of use through canals, tunnels, or pipelines, which are known as mains or aqueducts. These feed a system of smaller conduits or pipes that take the water to its place of use

Water system consists of supply transmission and distribution components such as water reservoir tanks, pipeline network and resources. Water reservoirs tanks may be buried underground, or elevated storage tanks or impounding reservoirs. Underground storage tanks are typically reinforced of pre-tested concrete wall construction with either concrete or wood roofs. They may be circular or rectangular. On ground, water supply storage tanks are typically vertical anchored and/ or unanchored tanks supported at ground level. Construction materials include welded, bolted, or riveted steel, reinforce or priestesses concrete, or wood. Tank foundations may consist of tanks supported by single or multiple columns. Most elevated tanks are steel and or generally cylindrical or ellipsoidal in shape.

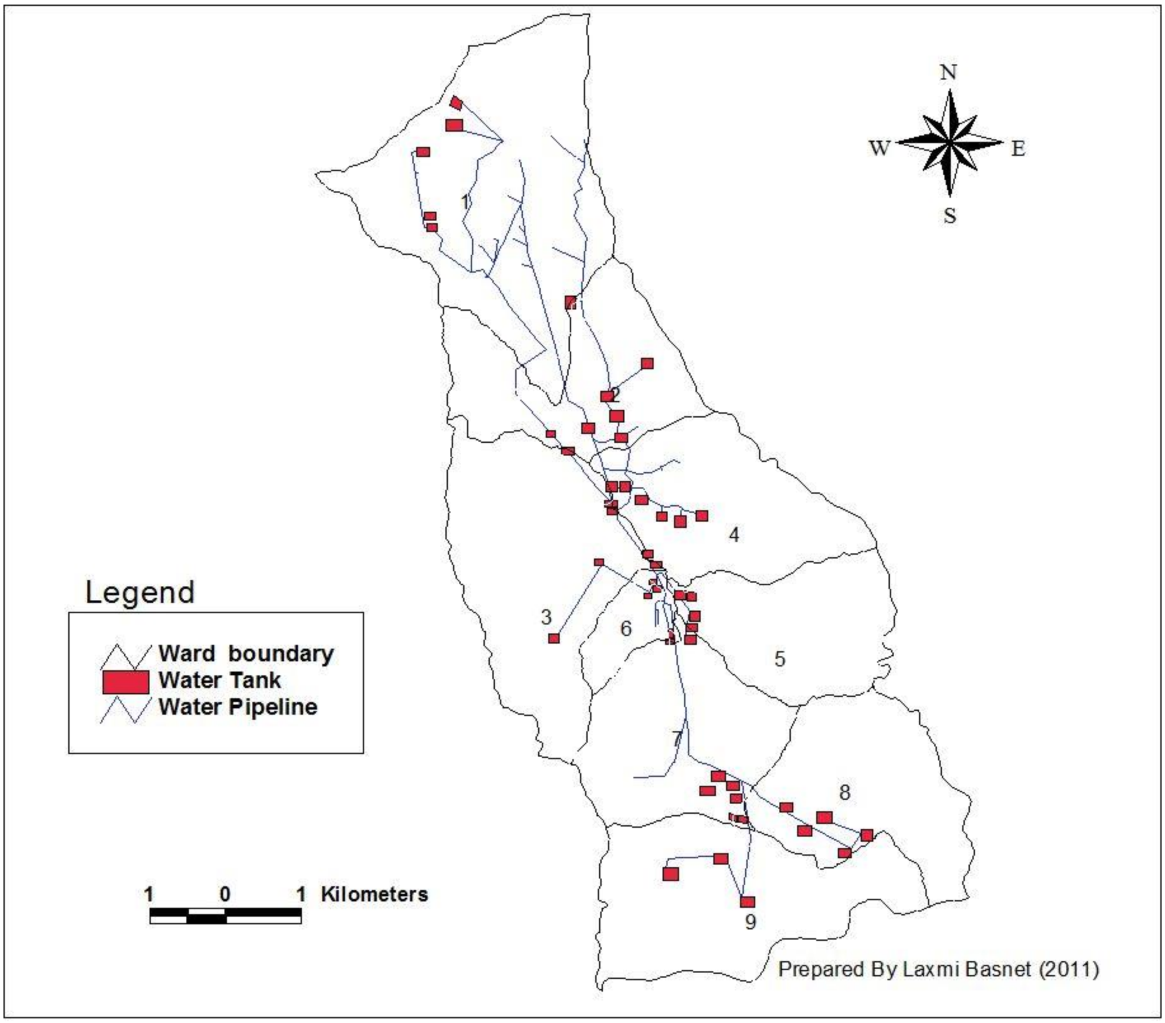
Elevated tanks are more common in areas of flat terrain. There is large variation in tank sizes (height and diameter) so, volumes range from thousands to millions of gallons.
Pipelines may be underground, on ground or supported on elevated frames above ground. However, mostly pipelines in the water supply system are located underground. Pipe materials include cast-iron, welded steel, asbestos cement, and plastic. Typically, pipelines are 20 inches or more in diameter. These are usually welded steel or reinforced concrete and may carry water at high pressures. Joints in steel pipes may be welded or bell and spigot types. In addition to the pipe themselves, pipelines may require gate valves, drains, surge control equipment, expansion joints, insulation joints, and manholes. Check valves are normally located on the upstream side of pumping equipment and at the beginning of each rise in the pipeline to prevent back flow. Gate valves are used to permit portions of pipe or check valves to be isolated.

Figure 5.4: Pipeline Distribution in Dhankuta Municipality

Source: Field Survey, 2011

Dhankuta municipality has also provided in drinking water in their people. There is everywhere not able to supply drinking water due to overpopulation and physical condition. The sources of water supply distance are Mude 13km, Raniban 10km, Tindhovane 9km, Ghattekhola 13km, Ghurase 1600m and Mughakhola 2km. There are three distribution channels to supply of water in Dhankuta municipality. One of them in Hile, which supply water in ward no.1. From the water source of Gurashe and Mughakhola thought six reservoir tanks. Another source of water in Salleri Sarki Tole to supply water in ward no. 2,3,4,5,6, and 7 under the Consumer Committee of Water and Sanitation though 32 reservoir tank. Last one in Chuliban to supply water in ward no.8 and 9 under the water Consumption Committee though eleven reservoir tank. There are averages 1692 tops of this municipality.
Many places I have been seen not repair water pipeline and reservoir tank for a long time. Distribution of pipeline network can be easily seen in Figure 5.5:

Figure 5.5: Water Supply Network in Dhankuta Municipality



Source: Boundary base map for NGIIP 1998 and RUPP 2008 and water tank and pipeline were digitized by the researcher.

Figure 5.5shows pipeline network and water reservoir tanks in Dhankuta municipality. In the map it can be seen that there is limited pipeline network and reservoir tank. Only certain populations are using drinking water facility. Total number of tank and pipeline length has been tabulated in Table 5.2 and 5.3.

Table 5.2: Water Pipeline in Dhankuta Dhankuta Municipality

Material	Count in pipe	Length(m)
GI	21	18443.6
HDP	71	41712.3
Total	**92**	**60155.9**

Source: Dhankuta Municipality Water Supply Division, 2011

Table 5.3: Ward wise Water Tank in Municipality

Ward No.	Water tank	Capacity(lit)
1	6	290000
2	7	155000
3	4	112000
4	8	465000
5	5	455000
6	5	245000
7	6	570000
8	5	145000
9	3	110000
Total	**49**	**2547000**

Source: Dhankuta Municipality Water Supply Division , 2011

Figure 5.6: Pipeline Distribution in DhankutaMunicipality

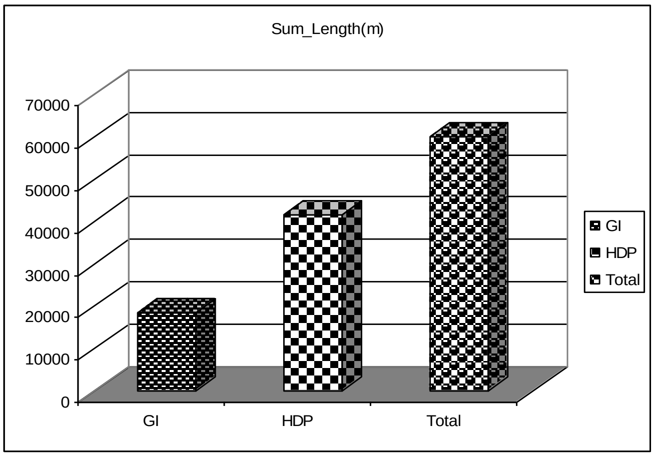


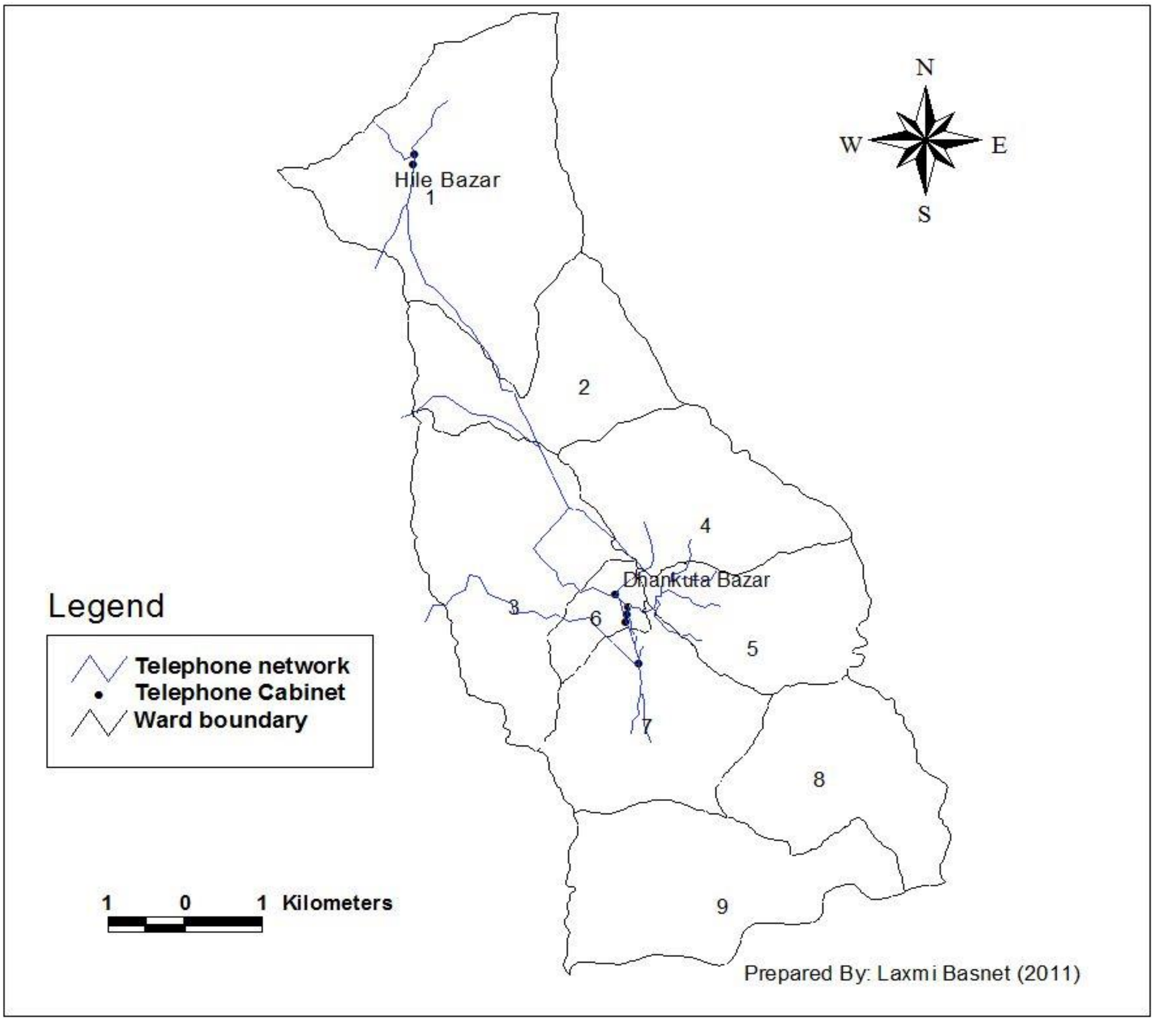
Figure in 5.6 display the pipeline distribution in Dhankuta Municipality. The pipeline network of the Dhankuta Municipality consists of different categories of pipe material. It includes HDP and GI type of Pipes. HDP pipe are main dominant pipe in Dhankuta. The water system forms are shown in tables 5.2. They refer to the parameters to be analyzed to understand the water system, expected behaviors during emergency operations and in the reconstruction phase

5.4: Telecommunication System

The telephone often colloquially referred to as a phone, is a telecommunications device that transmits and receives sound, most commonly the human voice. Telephones are a point-to-point communication system whose most basic function is to allow two people separated by large distances to talk to each other. It is one of the most common appliances in the developed world, and has long been considered indispensable to businesses, households and governments. The word "telephone" has been adapted to many languages and is widely recognized around the world. Now a day, Nepal also rapidly develops in telecommunication system.

Telephone service, an effective media for communication, is increasing rapidly in this area. So far about 18-19 hundreds telephone services have been distributed in this area. Each ward has facility of telephone service. Along with telephone, other media of communication- email, internet, and fax are available in this municipality. Two FM station is there area. Four weekly newspapers are publish, local newspapers in the municipality have made easier for information. Transportation has made easy access for the availability of means of communication. One urban information center and some other private information centers have been established. Post service also facilitate in this area. It is plays critical role for communication especially in rural areas. Post boxes for its effectiveness have been kept in various places of municipality. Most people of municipality are benefited by post boxes. There are also rapidly increase in mobile phone in this area. Telephone network can be seen in the Figure 5.7.

Figure 5.7: Telecommunication System in Dhankuta Municipality



Source: Boundary base map for NGIIP 1998 and RUPP 2008 and telephone cabinet and network were digitized by the researcher.

Figure 5.7 shows distribution of telephone network in Dhankuta Municipality. It means, limited number of have been using telephone facilities.

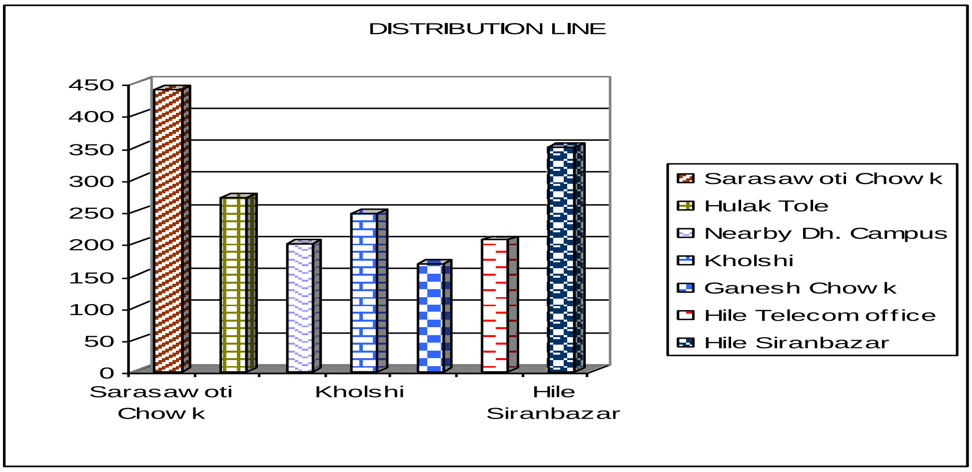
Table 5.4: Telecommunication System in Dhankuta

S.N	location	Capacity	No. of Distributionline	Average of Length
1	Sarasawoti Chowk	500pp	440	3.5KM
2	Hulak Tole	300pp	271	1.75KM
3	Nearby Dh. Campus	300pp	199	4KM
4	Kholshi	300pp	247	2KM
5	Ganesh Chowk	300pp	168	2KM
6	Hile Telecom office	350pp	205	3KM
7	Hile Siranbazar	420pp	350	6KM
	Total	**2470pp**	**1880**	**22.25**

Source: Dhankuta Municipality Tele-communication, 2011

Table 5.4 and Figure 5.7 show that Dhankuta Municipality has limited telephone services here area two distributer center. One is Hile center its provide only Hile ward no.1 than other center is Sarsawoti Chowk in Dhankuta Bazar, its provide in ward no.2,3,4,5,6,7,8, and 9 area. It consist 6 telephone cabinets in different places of the area. The capacity of cabinet also varies. Out of total length, main line covers 22.25km.

Figure 5.8: Distribution of Telecommunication System in Dhankuta



5.5: Electric Network

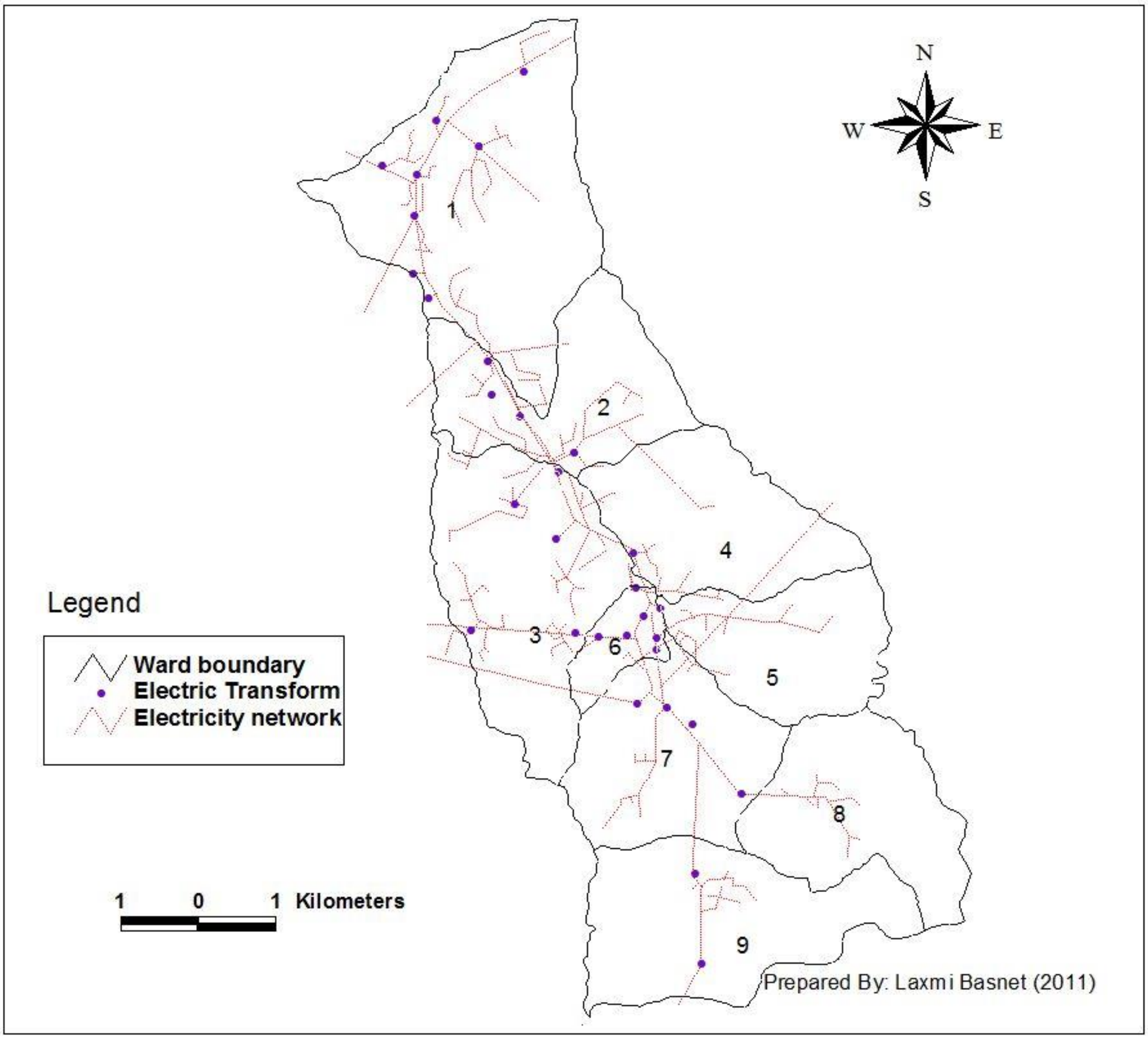
An electrical network is an interconnection of electrical elements such as resistors, inductors, capacitors, transmission lines, voltage sources, current sources and switches. An electrical circuit is a special type of network, one that has a closed loop giving a return path for the current. Electrical networks that consist only of sources (voltage or current), linear lumped elements (resistors, capacitors, inductors), and linear distributed elements (transmission lines) can be analyzed by algebraic and transform methods to determine DC response, AC response, and transient response. An electrical system consists of substation distribution circuits, generation plants, transmission lines and associated equipment including electric pole, and a substation with transformers and switching equipment. Electric transformers are frequently distributed on different area.

Transmission lines may be underground or above ground (supported by towers). Towers are usually steel, wood and iron which carry several circuits out at high voltage. Each circuit consists of three conductors, one for each phase. Towers are provided with reinforced concrete footings and may be supported on piles. Most transmission systems are AC, but some long distance lines are DC. The DC systems require converter stations at each end of the line.

Transmission substations in the electrical system generally receive power at high voltages (220Kv or more) and step it down to lower voltages for distribution. The substation consist one or more control buildings, towers, conductors, ground wires, underground cables, and extensive electrical equipments including banks of circuit breakers, switches,

wave traps, buses, capacitors, voltage regulators, and massive transformers. Circuit breakers protect transformers against power surges due to short circuits.
There is no imagination of world without electricity. The electricity is a main source of energy for the application of household, industries, business service and organization for various purposes. The electrical line is expanded all over the village and urban area in the municipality. The whole network of electricity can be seen in the Figure 5.9.

Figure 5.9: Electric Network in Dhankuta Municipality



Source: Boundary base map for NGIIP 1998 and RUPP 2008 and location electric transform were digitized by the researcher.

Figure 5.9 shows the distribution of electric transformers in the area of Dhankuta Municipality. Transformers are sparsely distributed in the area. It means earthquake produces scattered but wide spread damage

Figure 5.10: Electric Network in Dhankuta Bazaar

Source: Field Survey, 2011

Table 5.5: Electricity Network in Dhankuta Municipality

S. NO	Location	Capacity in (KV)	S. NO	Location	Capacity in (KV)
1	Trisule(n)	15	17	Amalatar(Lok Chowk)	150
2	Near by Ratna Ring Road	50	18	Danabari	15
3	Pani Tanki	25	19	Siran Bazar	50
4	Hile Gairi	25	20	Radio nepal (Hatiya	100
5	Near by Hile Bich Bazar	100	21	Radha Krishna	50
6	Hariyali	100	22	CMA	100
7	Near by Kuwapani Kha	50	23	Near by Rai Kuwa	50
8	Kuwapani Ka (n)	50	24	Patle Khola	50
9	Aaitabare	100	25	Tallo Kopche	150
10	Nigale	25	26	Police Park	150
11	Narayani (jalpadevi)(n)(p)	100	27	Bus Park	200
12	Gurase (p)	100	28	Todke	50
13	Sayaule	50	29	Pelepang	15
14	Mathillo Khallde	50	30	Tekunala	15
15	Singh,Devi	15	31	Sriwani(n)	100
16	Kachide	50		**Total**	**2150**

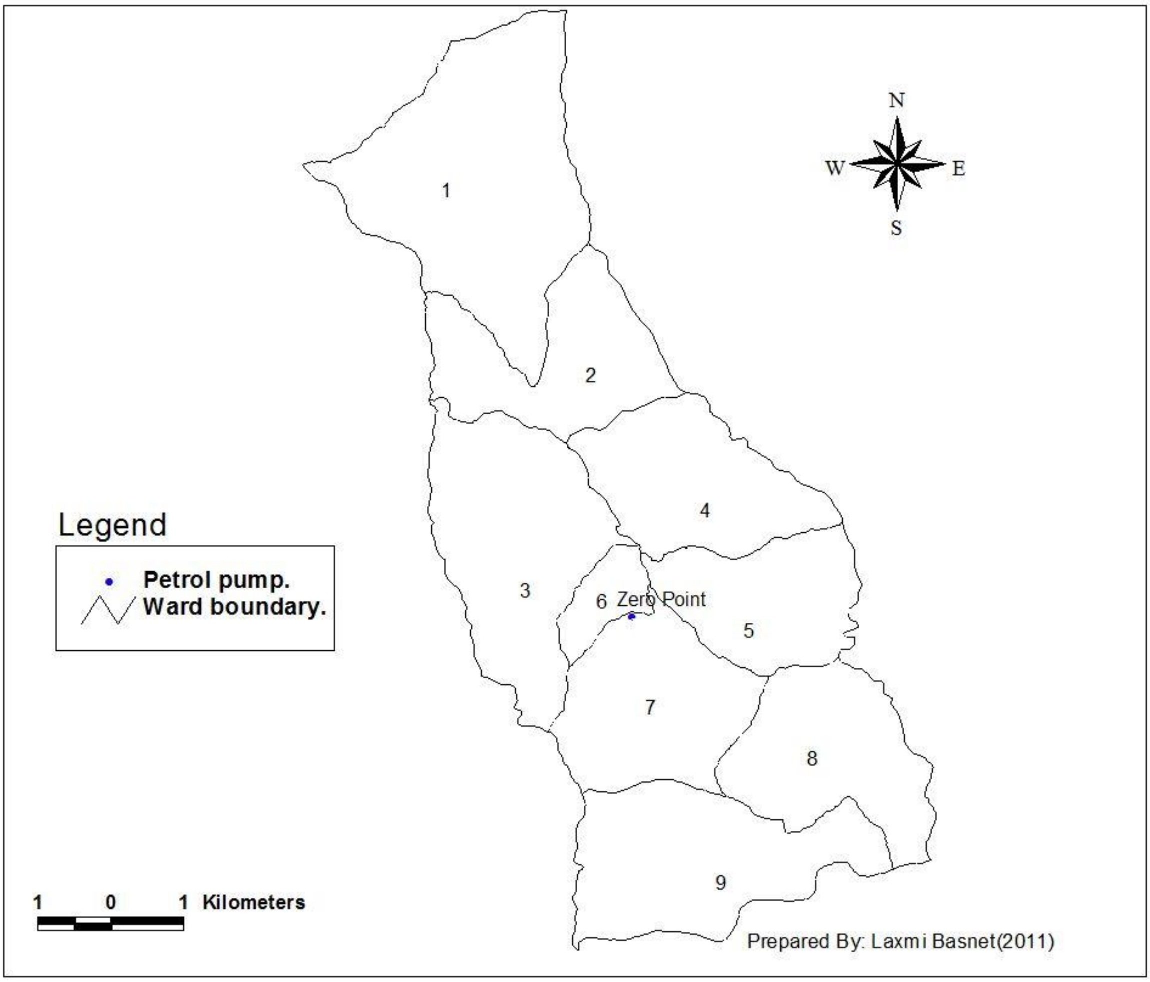
Source: Dhankuta Municipality NEA, 2011

5.6: Petrol Pump

Petrol pumps also one of the parts of infrastructure. It is not only earthquake hazard; it's also secondary type of hazards such as fire. It is one of the most important energy. It always sates in our country. Most petroleum materials (diesel, petrol, kerosene etc) storage tanks are unanchored, cylindrical tanks supported directly on the ground. Older tanks have both fixed and floating roofs, while more modern tanks are almost exclusively floating- roofed. Diameters range from approximately 40 feet to more than 250 feet. Tank height is nearly always less than the diameter. Construction material includes welded, bolted or riveted steel. Tank foundations may consist of sand or gravel, or a concrete ring wall supporting the shell.

There is only one petrol pump located in the municipality area which is shown in the Figure 5.11.

Figure 5.11: Petrol Pump in Dhankuta Municipality



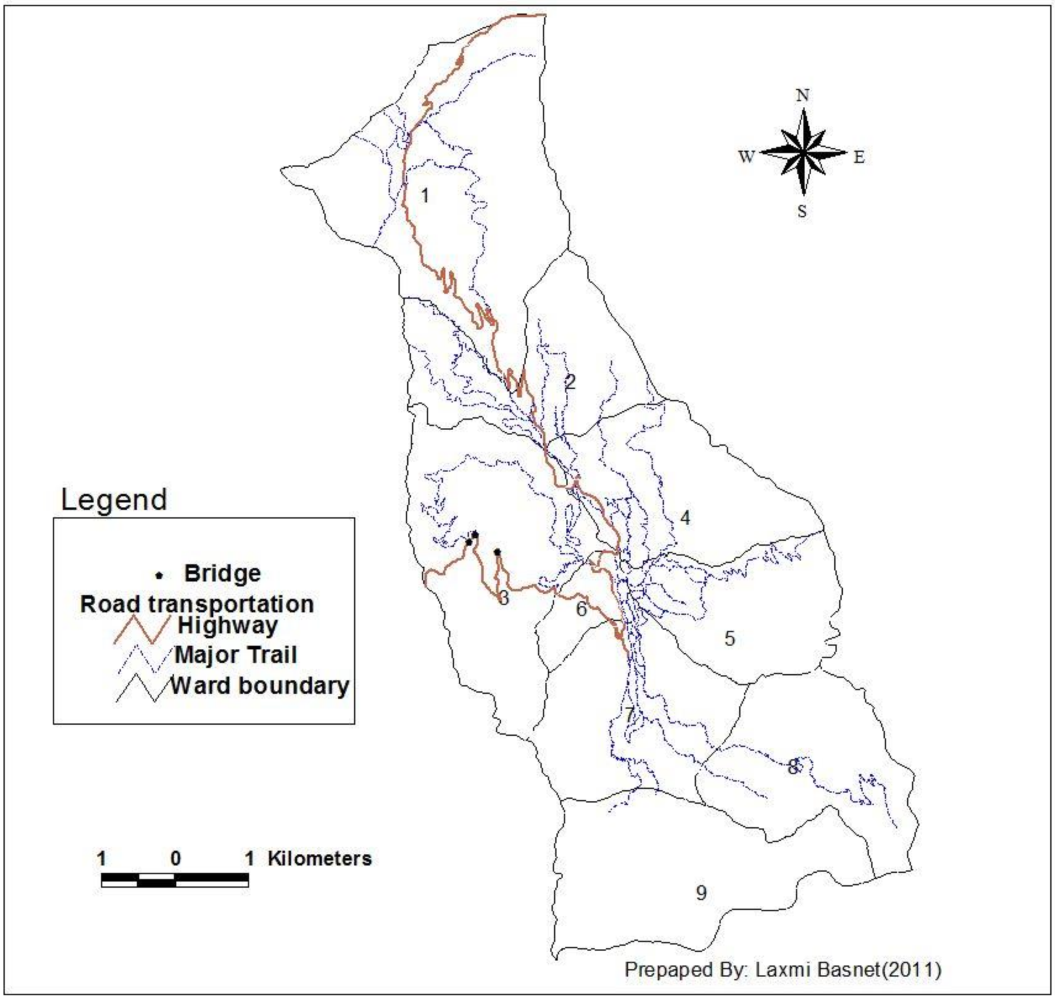
Source: Boundary base map for NGIIP 1998 and RUPP 2008 and Petrol pump were digitized by the researcher.

5.7: Bridge

A bridge is a structure built to span physical obstacles such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed, the material used to make it and the funds available to build it. As often observed from this and other destructive earthquakes, bridges are one of the most vulnerable components of a highway network system subjected to earthquake ground motion. For this reason, bridge damageability information in a succinct from as fragility curve is needed to pursue the seismic risk assessment of a highway networks consisting of as large as thousands of bridges that can be affected by a high magnitude earthquake with in and near the service area of the network.

There are three main bridges in Dhankuta municipality highway, Which is shown in the Figure 5.12.

Figure 5.12: Bridge in Dhankuta Municipality

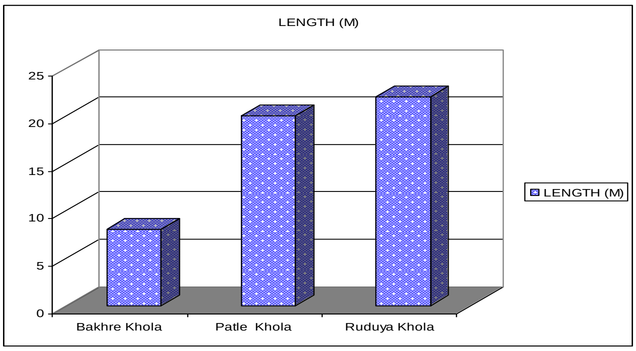


Source: Boundary base map for NGIIP 1998 and RUPP 2008 and Petrol pump were digitized by the researcher.

Table 5.6: Length of Dhankuta Municipality Highway bridges

LOCATION OF BRIDGE	LENGTH (M)
Bakhre Khola	8
Patle Khola	20
Ruduya Khola	22
Total	**50**

Figure 5.13: Length of Dhankuta Municipality Highway bridges



5.8: Essential Facilities

Facilities that provide services to the community and those that should be functional following an earthquake are considered to be essential services. Essential facilities include hospitals, police stations, fire stations and schools. The probability of damage of essential facilities is determined on the basis of ground motion.

The essential facilities are classified on the infrastructure structure type and occupancy class.

5.8.1 Health Service Centre (Hospital)

A hospital, in the modern sense, is an institution for health care providing patient treatment by specialized staff and equipment, and often, but not always providing for longer-term patient stays. Everyone knows that how to importance of our life in hospital. Hospitals are typically housed in one or more buildings. These are classified on the basis of the number of beds. Construction type varies significantly. The structural and nonstructural systems of a hospital are related to the size of a hospital. Smaller hospitals may contain only limited equipments associated with building services but large hospitals may contain water treatment equipment, emergency power diesels, chillers and boilers as well as sophisticated equipment used for treating patients.

After earthquake with high intensity critical medical facilities such as hospitals and ambulance services will be stretched to their limits. Some buildings might even be damaged and the injured and patients alike will have to be treated outdoors in open area. During times like this, most medical services follow a triage system. This basically enables them to focus their efforts and existent supplies on those who require assistance very urgently.

Table 5.7: Health Service Center in DhankutaMunicipality

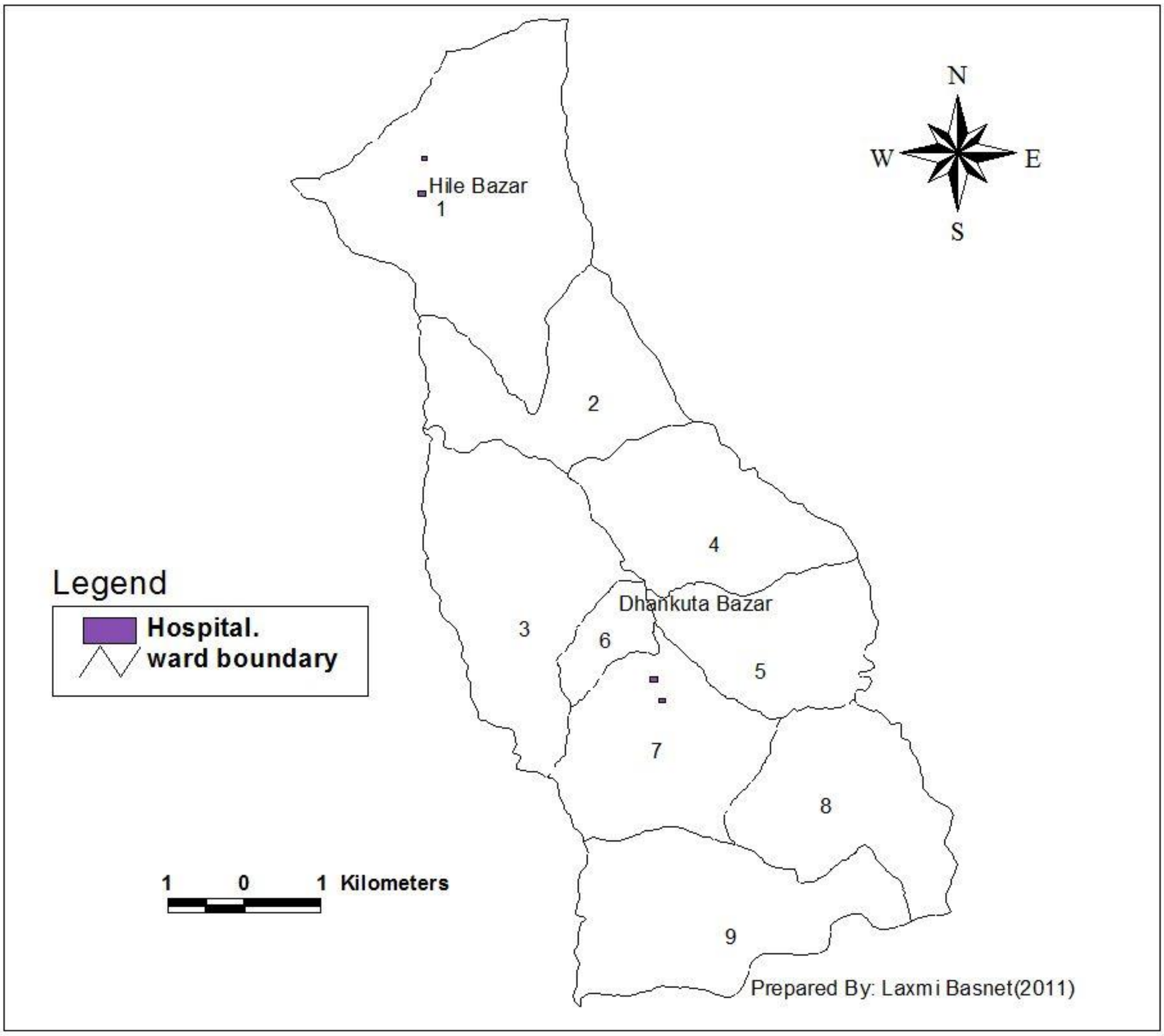
Type	No.	No.of bed
Dhankuta district Hospital	1	25
Homeopathic hospital	1	7
Family planning center	1	-
Eye treatment center	1	-
Lab	2	-
Private clinics	12	-
Private dental hospital	1	

Source: Dhankuta Municipality, 2011

Figure 5.14: Dhankuta District Hospital

Source: Field Survey, 2011

Figure 5.15: Hoapital in Dhankuta Municipality



Source: Boundary base map for NGIIP 1998 and RUPP 2008 and Hospital were digitized by the researcher.

Dhankuta District Hospital is situated in the middle of the town. The hospital has facilities like inpatient service, Ultrasonography and x-ray. Besides the government posted doctors, medical and dental intern doctors from BPKIHS are also posted there.Especially, people of rural area have not got proper treatment as there is not facility of health center, health post, clinic etc. There is a district hospital having 25 beds which are providing health facilities to their public. There are only 2 ambulance services in Dhankuta municipality which are conducted by district hospital. One homeopathic hospital, one family planning center, one eye treatment center, two labs, twelve private clinic and one private dental hospital also facilities in their area.

5.8.2 Educational Center

The imparting and acquiring of knowledge through teaching and learning, especially at a school or similar institution is call education. Public schools in Nepal are the center of social and cultural life in rural and urban areas. Hence, there is greater chance of propagating earthquake awareness from school to the families and from families to the communities.

Public school buildings can serve as emergency shelters. Usually they have open grounds that could be used for establishing tents for shelter or field hospitals following an earthquake.

Usually, children going to the public schools are from middle to low income group. These are also the highly vulnerable group of the society.

Schools play a crucial role after an earthquake in helping a community to get back on its feet. Since schools are typically distributed throughout neighbors, they are an ideal location for homeless shelters, medical clinics, and other emergency functions. Functioning schools provide a feeling of normality to a community, helping people get back on their feet after a disaster.

Public schools, in Nepal, have been built up without trained masonry. Both their buildings and their occupants, face extreme risk from the earthquakes. This is, because of the fact that six thousand schools were destroyed in 1988 Udayapur earthquake (Dixit et al., 2002). Management of the public schools is largely depending on the responsibility of the local community. Usually very low budget is available with the school management system.

Dhankuta municipality is well known as Dhankuta Gauda(Administrative Centre). Dhankuta municipality is not only the headquarters of Dhankuta district but also is the Regional Centre of the Eastern Development Regional of Nepal. That’s a main cause of mountainous municipality of Dhankuta is rich in educational institution than other near district. Several primary schools, secondary schools as well as Dhankuta Multiple campus are situated at the heart of this municipality.

Table 5.8: Education in Dhankuta Municipality

Education centre	No. Education
Multiple college	1
Private collage	2
Gov. High School	5
Private High School	7
Gov. Primary school	16
Private Primary school	3
Private health technical school	2

Source: Dhankuta Municipality

Figure 5.16: Educational Center

Source: Field Survey

CHAPTER VI
SEISMIC HAZARDS IN DHANKUTA MUNICIPALITY

Nepal is small Himalayan country with high probable area of earthquake of the world. The surface area of the country is 147181 sq. km, two third of the territory, which is mountains, lies in the northern part. The country, Nepal is known as on the seismic prone in the world, due to the presence of active faults between tectonic plates (converging plates) along the Himalayas. Another reason for Nepal's high vulnerability to earthquake is the poor construction of infrastructure, public buildings and houses especially in densely populated areas.

The shaking of an earthquake is actually produced by the passage of s shock weave resulting from the sudden fault movement. A variety of different types of shock waves and produced, but the two most important one so called primary wave or preliminary waves that result from the compression, and secondary waves or shear wave that exhibit a side to side motion (Scott, 1989).

Earthquake usually originates some miles beneath the surface, and from the origin or seismic focus the vibrations spread in all directions. They reach the surface first at the point immediately above the origin and this point is called the epicenter. It is at the epicenter that the shock of the earthquake is first experienced, and on the ground it seems to spread outwards on wave spread form a stone thrown into a pool of water (Lake, 2006).

Huge damage in infrastructure services and causalities has occurred due to these events. Scientists have pointed out that plates are moving towards each other at 3 cm per year. It indicates that Nepal is threatened by a strong earthquake which will bring large damages and casualties to the city. So, disaster management community should prepare itself for responding to such huge disaster. When building a house, regional seismic hazard maps are used to find the best (or the worst) place to locate for earthquake shaking. Although greatly confused with its sister, seismic risk, seismic hazard is the study of expected earthquake ground motions at any point on the earth.

Hazard generally refers to physical characteristics that may cause an emergency or potentially damaging physical event, phenomenon, or human activity which may cause loss of life and property damage. For example, earthquake faults, active volcanoes, flood zones, landslide prone areas and highly flammable brush fields are all hazards. Hazards can include latent conditions that may represent future threats and can have different origins-geological, hydro-metrological, biological, human and technological process (UNDP 2004).

Earthquakes hazard include ground motion, ground failure (liquefaction, landslide) and tsunami/seiche. Fault rupture on the ground, produces local concentration of structural damage. A fault is a fracture in the crust of the earth along which blocks have moved on been displaced in relation to each other. Displacement can be either a horizontal or a vertical. Fault displacements produce forces so great that would damage to structures in areas close to ground traces of active faults. This hazard has different types of effects on infrastructure services.

6.1: Earthquake Hazard and Intensity

An earthquake is a sudden shift or movement of the earth's crust caused by the release of stress accumulated along geologic faults or volcanic activity. On the surface, this is manifested by a moving and shaking of the ground, and can be massively damaging to poorly built structures. The most powerful earthquakes can destroy even the best built of structures. Most earthquakes occur at fault zones where tectonic plates collide against each other. They are capable of killing hundreds of thousands of people. Earthquakes, also called temblors, can be so tremendously destructive; it's hard to imagine. They occur by the thousands every day around the world, usually in the form of small tremors. Magnitude and intensity are two measurements to identify physical strength of earthquake.

The effect of earthquake is assessed in terms of intensity. Intensity refers to the severity of ground shaking experienced at site. It is subjective measurement; however it includes all the earthquake variables which are magnitude, hypo-central distance, attenuation media and local enhancing factor. It is generally greatest near the epicenter and decreases outwards from it. Intensity is usually expressed on the Modified Mercalli Intensity scale which ranges from I to XII.

6.2: Earthquake hazard scenario in Dhankuta municipality

The offset or tearing off the earth surface by differential movements across a fault is an obvious hazard to structures build across active faults. variety of structures have been damaged by surface faulting including buildings, railways, roads tunnels, bridges, canals, water wells and water mains, electricity lines and sewers. Surface fluting can be particularly sever to structures partly embedded in the ground and for underground pipelines or tunnels. Surface faulting generally affects along and narrow zone ranging from few meters to more than 100m. Subsidiary branch faults have extended as much as 10km from the main fault and secondary faulting has been observed more than 25km away from the main fault. The length of the ruptures has ranged from few 100m up to about 400km. Their size is important for zoning purpose around active faults.

There are different types of active faults found near by the Dhankuta municipality area. Among them, two active fault of Main Boundary Thrust (MBT) and one active fault of Himalayan Frontal Fault (HFF) were chosen to estimate intensity scenario of building damage and collapse. Three different earthquake scenarios namely; Udayapur Earthquake, North-Sunsari Earthquake and South-Sunsari Earthquake are used for to estimate intensity and infrastructure vulnerability. The main characteristics and direction of these earthquakes
faults are shown in Table 6.1.

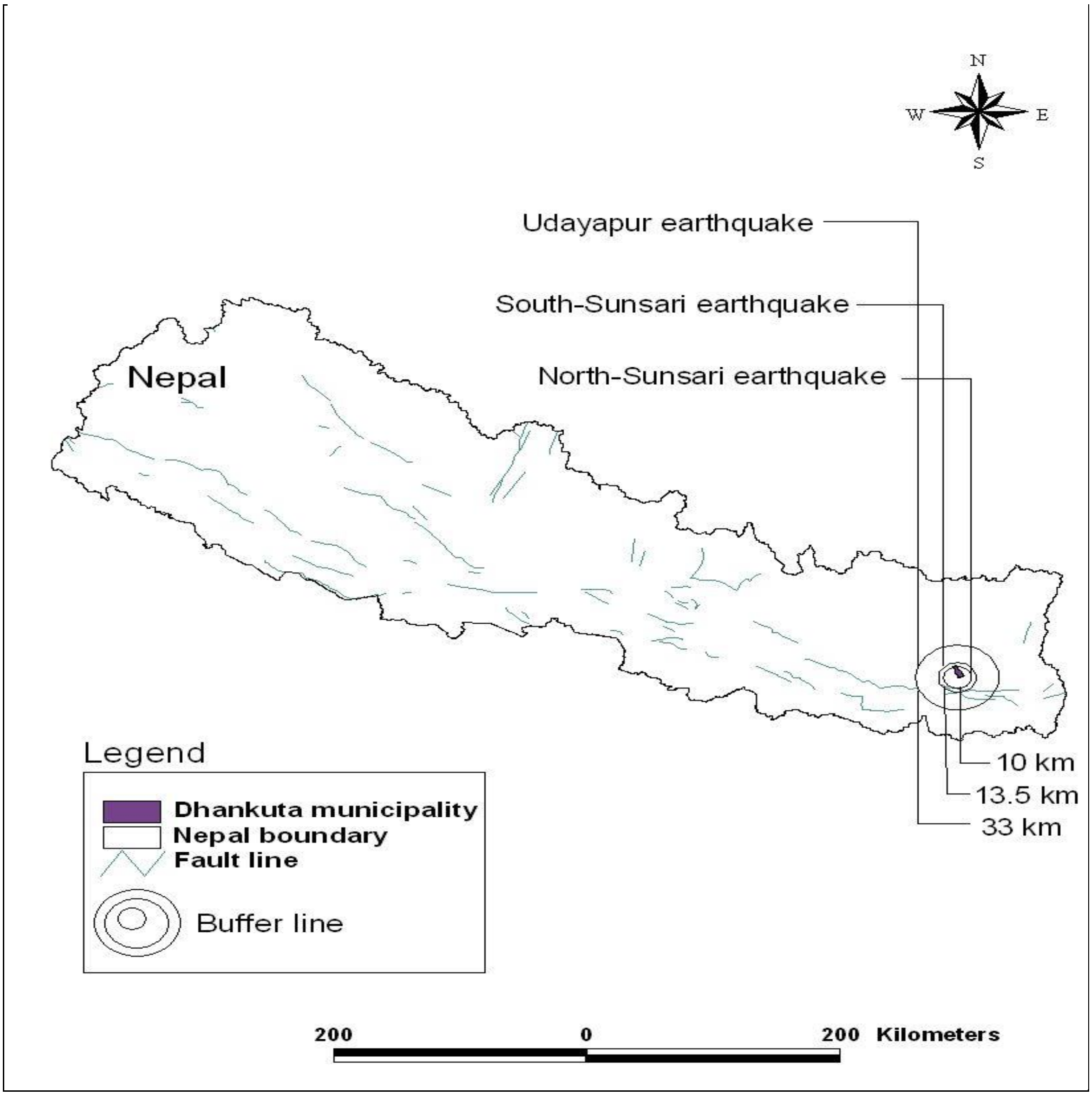
Table 6.1: Earthquake Scenarios in Dhakuta municipality

Earthquake Name	Udayapur	North Sunsari	South Sunsari
Fault Name	Main Boundary Thrust	Main Boundary Thrust	Himalayan Frontal Fault
Magnitude	8.0	7.5	7.2
Distance	33.0 km	10 km	13.5 km
Depth	20 km	20 km	20 km
Direction	South- West	South	South

Source: BCDP, 2008

Table 6.1 shows the characteristics of three earthquake scenarios. The names of the earthquake scenarios are assigned according to their location.

Figure 6.1: Distances and direction of the earthquake scenario



Source: BCDP, 2008

The Himalayan frontal fault is located in southern part of Dhankuta and as such it is named South-Sunsari earthquake. Although all three types differentiate in term of their magnitude, distance and direction get a name, depth of 20 km was considered for all the analysis. Magnitude value of those earthquake faults was already defined by BCDP project. The distance is measured from grid id number 556 of the study area to the nearest point of the earthquake with the help of GIS tool. Direction name is also defined by watching study area and location of the fault line. The distance and direction of these earthquakes are shown in above figure 6.1.

6.3: Intensity Distribution (MMI) of different earthquake Scenario

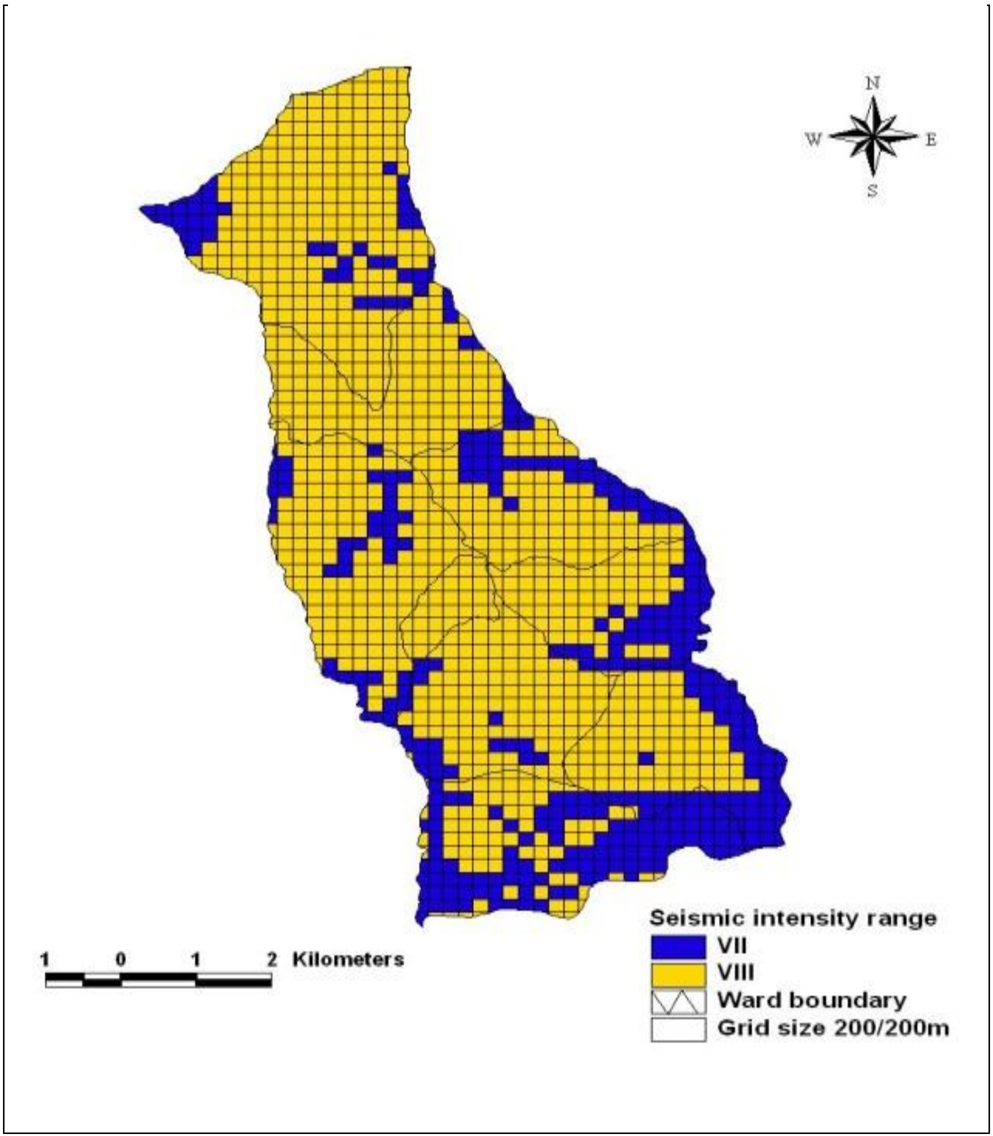
Modified Mercalli Intensity (MMI) is one of the most widely accepted and used earthquake damage estimation scales. MMI is ground shaking that creates by earthquake during earthquake. It does not shake equal in any place, it depends on geology, soil types, building types and nature. It is assumed that higher the intensity range, higher the shaking level. MMI scale is not based on any scientific basis; rather it has evolved based on experiences from observed damages in the aftermath of earthquakes. The MMI scale ranges from 1 – 12, although any damage could be expected only at MMI greater than or equal to 4.0 and this is the reason why MMI values less than 4.0 are ignored in this program. If the high range of MMI scale there will be high of probable damage

The study area mainly three nearest fault lines, that three different fault line have different magnitude, distance, depth and direction. So in these different characteristics, three intensity maps were prepared in above namely earthquake scenario. The intensity map derived from Timsina (2011), which was prepared with the soil condition, seismic hazard contour map and building parameter of the study area to the help of RADIUS tools.

6.3.1 Udayapur earthquake Scenario

Udayapur Earthquake scenario was considered one of the possible hypothetical earthquakes. It is anticipated to occur due to the active main boundary thrust fault which lies about 33.0 km which correspond south- west from the Dhankuta municipality which regarded as huge earthquake of 8.0 magnitudes. Figure 6.2 shows Udayapur earthquake Scenario the higher VIII intensity range in ward 2 and 6. Similarly, the lowest intensity range represents in ward no. 8 and 9.

Figure 6.2: Intensity Distribution of Udayapur earthquake Scenario

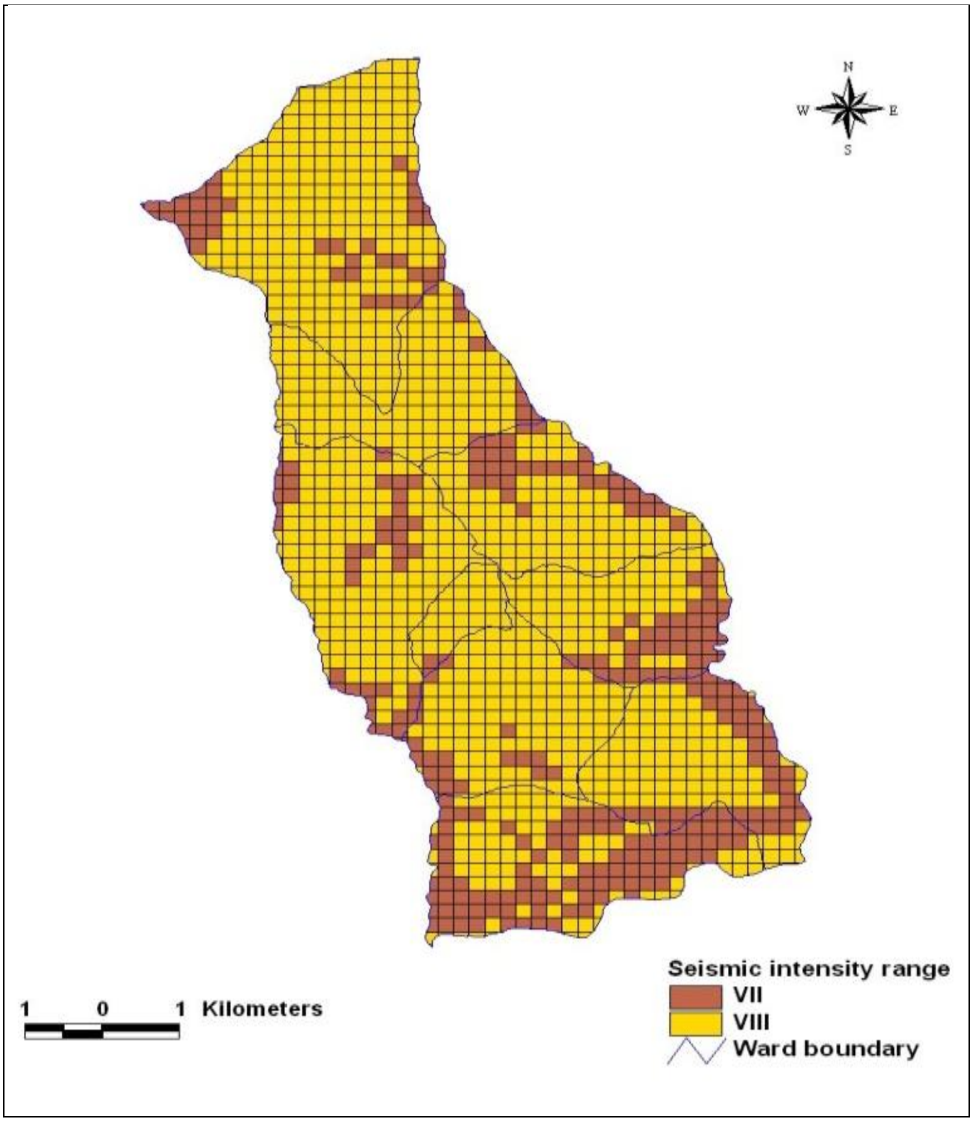


Source: Timsina, 2011.

6.3.2: North-Sunsari earthquake Scenario

North-Sunsari earthquake scenario is the considered second possible hypothetical earthquake scenario in Dhankuta municipality. It is anticipated to occur due to the active main boundary thrust fault which lies about 10 km which correspond south from the municipality which regarded as 7.5 magnitudes. Figure 6.3 shows the intensity scenario of Dhankuta municipality in North-Sunsari earthquake scenario below. Here we show the higher VIII intensity range in ward 2 and 6. Similarly, the lowest intensity range represents in ward no. 8 and 9.

Figure 6.3: North–Sunsari earthquake Scenario

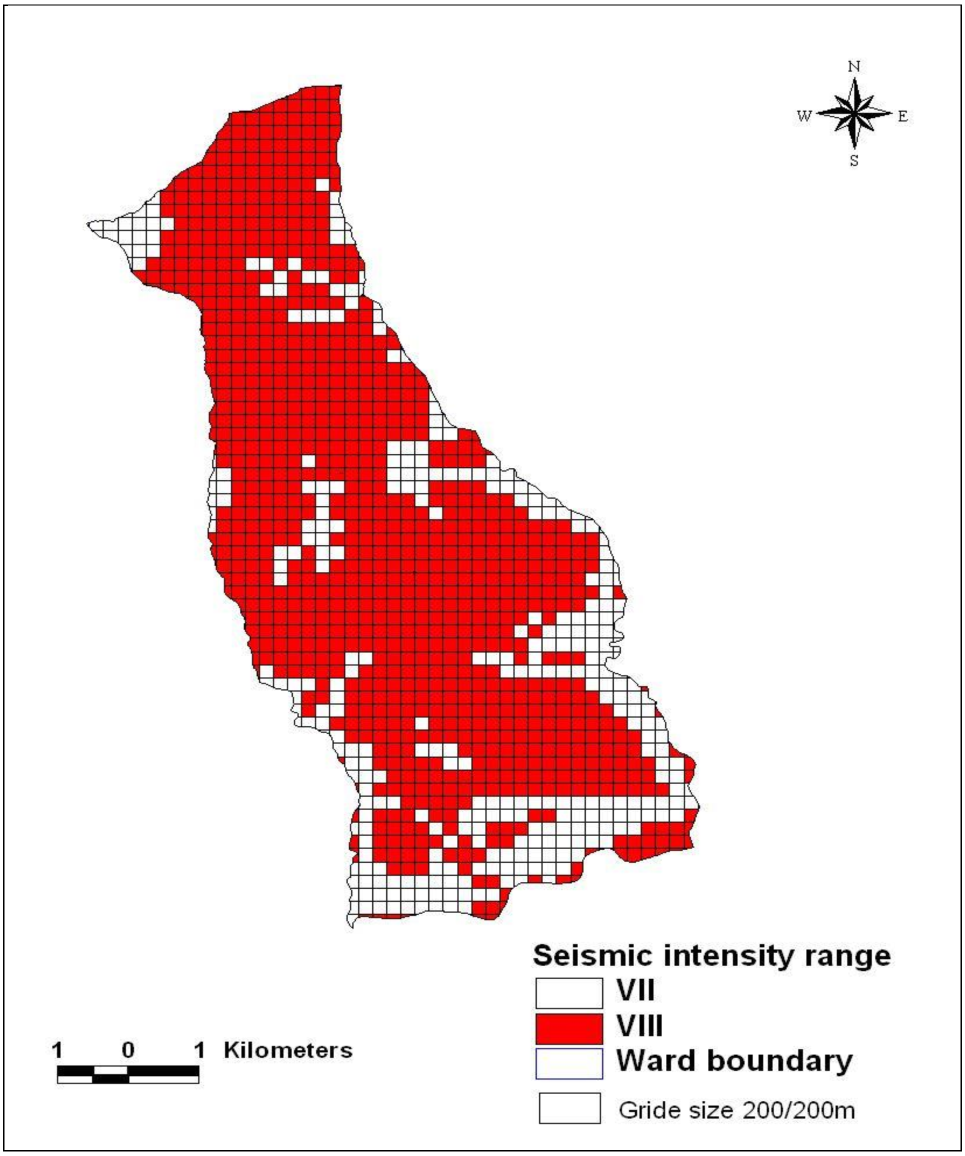


Source: Timsina, 2011.

6.3.3: South- Sunsari earthquake Scenario

South- Sunsari earthquake scenario was considered third possible hypothetical earthquake scenario in Dhankuta municipality. It is expected to occur due to the active Himalayan Frontal Fault, which lies about 13.5 km south of the municipality which regarded as huge earthquake of 7.2 magnitudes. Above namely two earthquake scenarios find that different place different intensity earthquake scenario, similarly in the case of the South-Sunsari earthquake scenario find in different place different intensity scenario, most of the part of above namely two earthquake scenario area is repeated in same intensity because of the different parameter like condition of soil, building characteristics are same, only distance and magnitude of earthquake are different so some area only change in this earthquake intensity map which is shown in Figure 6.4 below. Here also we show the higher VIII intensity range in ward 2 and 6. Similarly, the lowest intensity range represents in ward no. 8 and 9.

Figure 6.4: South –Sunsari earthquake Scenario



Source: Timsina, 2011.

This chapter concluded above three namely earthquake scenario show that most of the settlement area like ward number one Hile bazar,ward number five mathillo kopche and tallo kopche, ward number six bich bazaar and siran bazaar, and ward number seven hulak tole and madanchowk of the municipality lies in high risk intensity VIII area. So that it is necessary to vulnerability assessment of infrastructure and building condition in this municipality area.

Ground motion intensity is site specific, whereas the earthquake magnitude is earthquake specific. It is a function not only of the earthquake magnitude and its distance to site, but on the site soil conditions and the orientation of the fault with respect to site.

Four type of earthquake intensity were selected for this investigation. These events are indicated in Table 6.2.

Table 6.2: Relationship between peak ground acceleration and Earthquake intensity

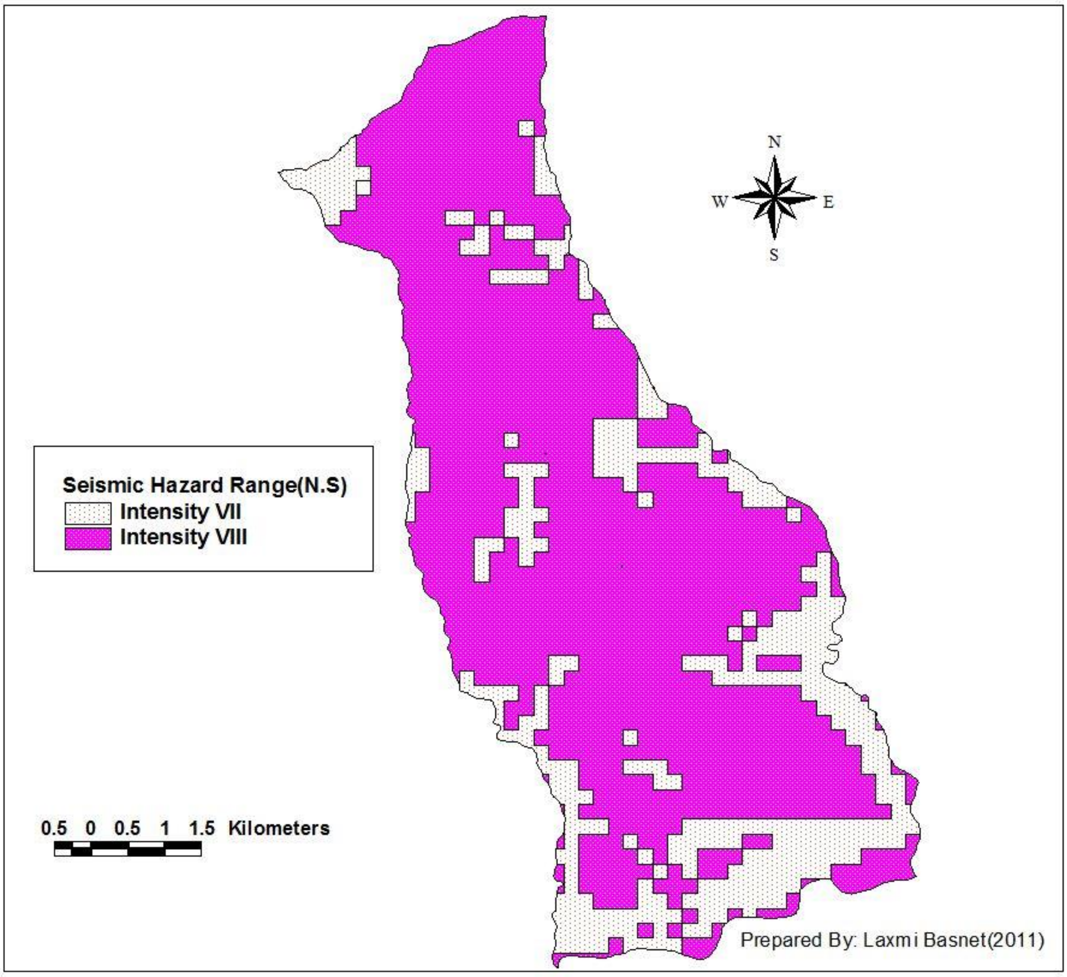
PGA(g)	Earthquake Intensity(MMI)
0.05-0.10	VI
0.10-0.20	VII
0.20-0.35	VIII
>0.35	IX

Source: Timsina, 2011.

In Table 6.2 intensity VII and VIII magnitudes are seen as reflective of the representative earthquake for the region. Scenario VII magnitudes have half unit higher than the representative event. These magnitudes are interpreted as maximum credible for these locations. Magnitude VIII would appear to represent a disruptive an event, and potentially more so. It can be seen the Figure 6.5

We have show three type of earthquake hazard scenario in Dhankuta municipality. But only we have use in North–Sunsari earthquake hazard Scenario map with fine out infrastructure hazard or damage level in Dhankuta municipality.

Figure 6.5: Out of the Grid of North–Sunsari earthquake Scenario



Source: Timsina, 2011.

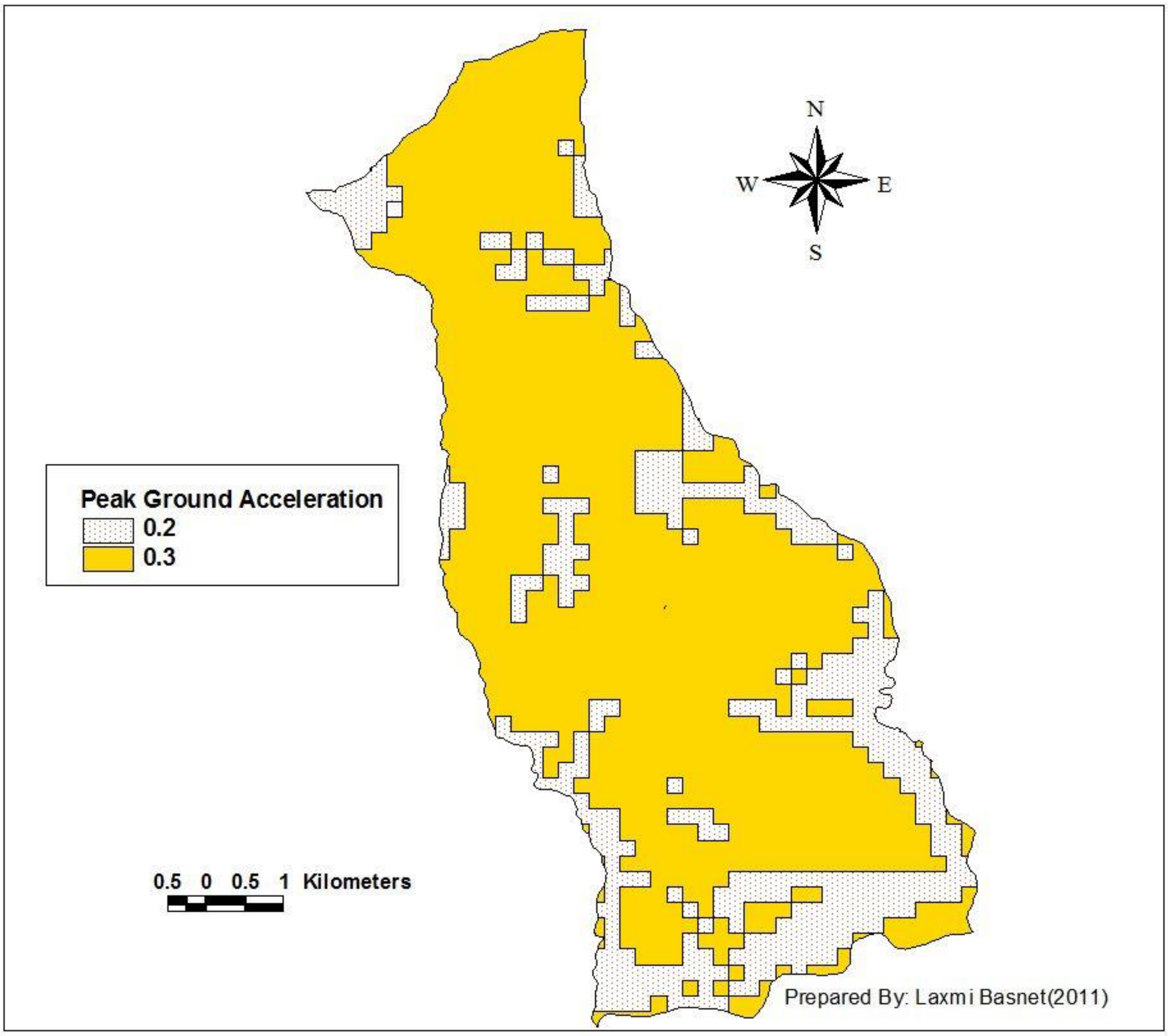
6.4 Ground Shaking Hazard

Ground shaking is the primary cause of earthquake damage to man-made structures. When the ground shakes strongly, buildings can be damaged or destroyed and their occupants may be injured or killed. It is also call associated with earthquakes. It produces scattered but widespread damage. It may be horizontal and vertical motions. Depending on soil conditions, it can be destructive at distances of even hundred kilometers. Ground shaking intensity caused by an earthquake depends upon on distance to the earthquake, the magnitude, and depth of hypocenter, geological condition and structure of soil between the hypocenter and the site and local soil and topographical condition. Ground shaking can be characterized by spectral response, peak ground acceleration and peak ground velocity.

Seismologists have observed that some districts tend to repeatedly experience stronger seismic shaking than others. This is because the ground under these districts is relatively soft. Soft soils amplify ground shaking. If you live in an area that in past earthquakes suffered shaking stronger than that felt in other areas at comparable distance from the source, you are likely to experience relatively strong shaking in future earthquakes as well.

In the study, the ground shaking demand is characterized by spectral contour maps developed by National seismic hazards maps of Nepal developed by Department of Mines and Geology. For a given magnitude, attenuation relationships are used to calculate to ground shaking demand for rock sites, which is then amplified by factors based on local soil conditions. PGA can be estimated on the basis of bed rock acceleration and soil amplification factor.

Figure 6.6: North–Sunsari earthquake Scenario of under Ground Shaking Hazard



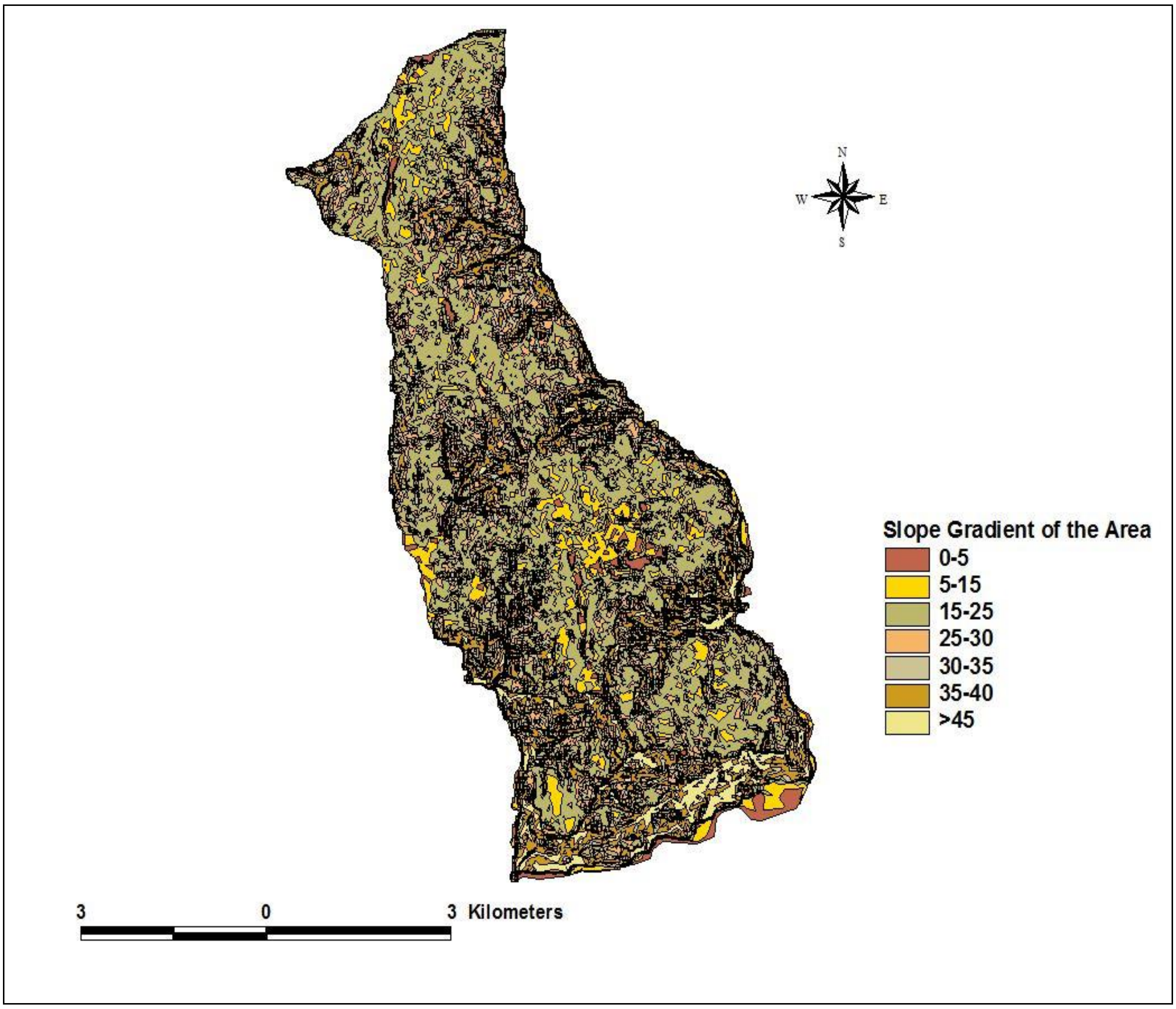
Source: Timsina, 2011.

6.3 Landslide Hazard

A landslide or landslip is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments. Although the action of gravity is the primary driving force for a landslide to occur, there are other contributing factors affecting the original slope stability. Typically, pre-conditional factors build up specific sub-surface conditions that make the area/slope prone to failure, whereas the actual landslide often requires a trigger before being released (http://en.wikipedia.org/wiki/Landslide). Landslide is the down slope movement of masses of earth under the force of gravity (Tianchi, 1996). Landslides induced by earthquakes depend upon the parameters of the earthquake such as magnitude, fault and spatial distance from the epicenter of the earthquake. And, geological, morphological and engineering parameters of the unstable rock or soil mass.

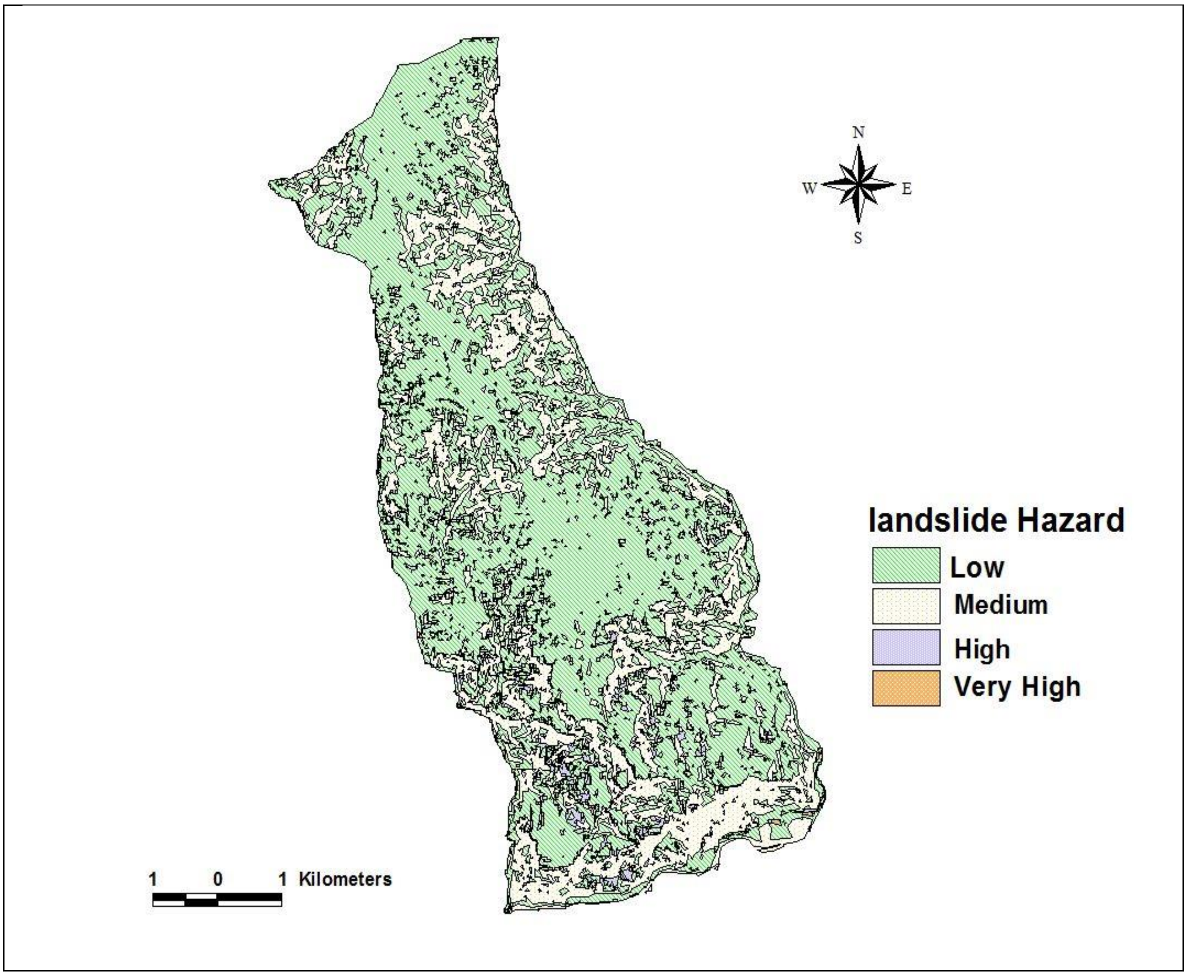
Evaluation of landslide hazards requires the characterization of the landslide susceptibility of soil and geologic conditions of a region. Susceptibility is characterized by the geologic group, slope angle and critical acceleration. Landslide susceptibility is measured on a scale of I to IX (HAZUS99, 1999) with I being the least susceptible. Landslide susceptibility of different geologic groups has been evaluated corresponding to slope angle (Degrees). Generally, the area of more than 15^0 slope angles is hazardous for landslides. Slope angle of the area has been divided on the Figure 6.7

Figure 6.7: Slope Gradient of Dhankuta Municipality



Source: Timsina,2011

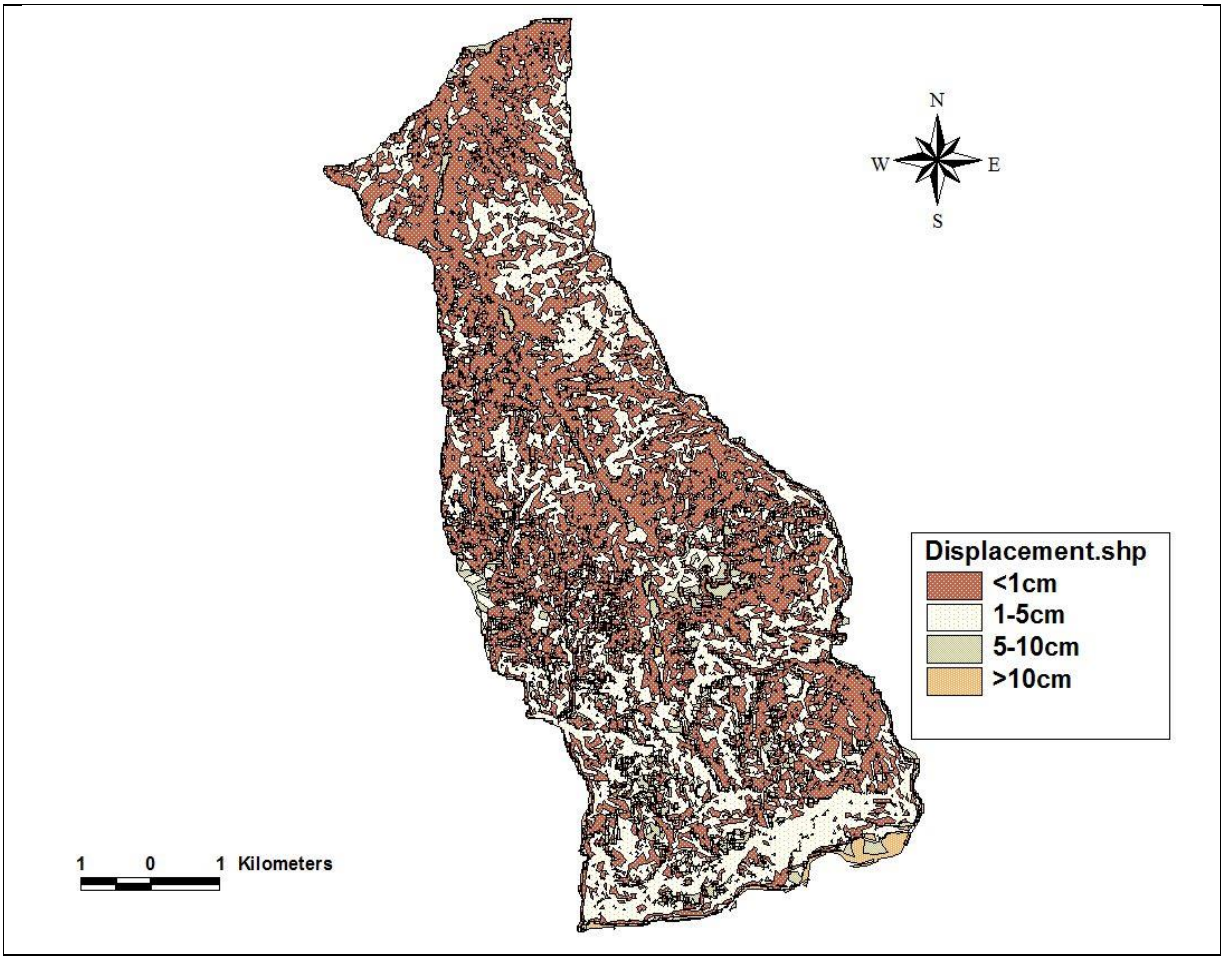
Figure 6.8: Landslide Possible Areas in Dhankuta Municipality



Source: Timsina, 2011

Figure 6.8 show landslide Possible Areas in Dhankuta Municipality. There are 4 types of landslide hazard categories: low, medium, high, very high. Figure 6.6 shows that most part of the Dhankuta Municipality couldn't suffer from landslide. There is many area of low landslide hazard. It mentions if the lifeline service lies in the landslide area, they would sustain heavy damage due to landslide.

Figure 6.9: Displacement of landslide Possible Areas in Dhankuta Municipality



Source: Timsina,2011

Figure 6.9 shows there is displacement map of landslide possible area in dhankuta municipality.it is divided in 4 categories.

The final landslide hazard map of the study area is prepared by classifying the displacement of the slope. The area having the displacement less than 1 cm is categorized as low hzard zone, area with displacement 1–5 cm is medium hazard zone, the high hazard zone is the area of displacement 5–10 cm, and area of displacement greater than 10 cm is assigned as very high hazard zone (Timsina, 2011)

CHAPTER VII
EARTHQUAKE VULNERABILITY ESTIMATION

One of the main objectives of this study is to estimate the vulnerability of the infrastructure in the different probable earthquake scenario of study area Dhankuta municipality. It depends on the different infrastructure parameters like age, capacity, construction materials, length of road and water pipeline and geological condition.

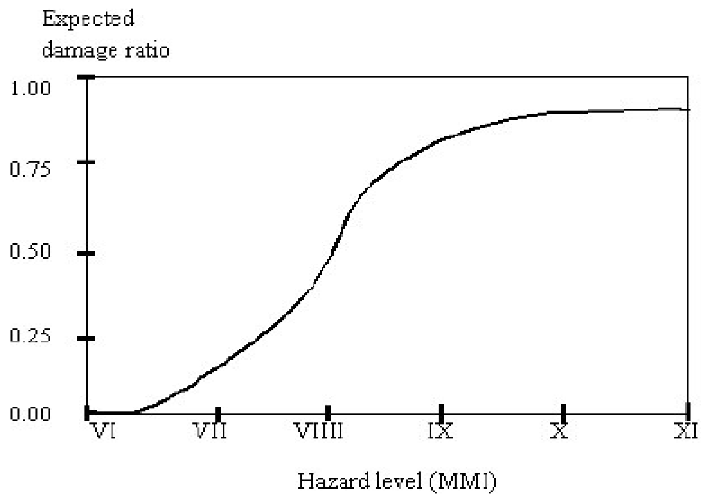
According to United Nation definition (1991), vulnerability is a degree of loss to an element at risk resulting from the occurrence of a natural phenomenon and expressed on a scale from 0 to 1. Vulnerability is not natural, but the result of an entire range of constantly changing physical, social, economic, cultural, political, and psychological factors that shape people's lives and create the environments in which they live. Vulnerability assessments are an indispensable complement to hazard assessment.

Seismic vulnerability of infrastructure is defined as the amount of expected damage induced to it by a particular level of earthquake intensity (UNDP, 2004).

The vulnerability assessment means to identify the hazard and the mapping and the assessing of social, economic and environmental vulnerabilities of the population. It describes as the probability of failure of a structure under different levels of ground shaking. There are two methods for the analysis of infrastructure vulnerability; namely qualitative and quantitative methods (Singh, 2005). The qualitative method is based upon the statistical evaluation of past earthquake damage. This method is suitable for non-engineering structures that have the same type of structural character. The quantitative method is based upon the numerical analysis of the structure. The infrastructure with the same material and construction type are grouped into one class. The performance of the infrastructure is predicted based upon design specifications and construction details.

The vulnerability of infrastructures is normally represented using a vulnerability curve of fragility curve. The curve expresses the expected severity of damage associated with the level of hazard (FEMA-MH, 2003). The physical infrastructure vulnerability describes the expected degree of direct damage to the physical infrastructure, given a specified level of hazard (Davidson, 1997). These are economic loss data, the hazard for which the environment was subjected to and inventory based on location characteristics. The other factors, which contribute to the development of a sound vulnerability function, are hazard-structure interaction, damage statistics and knowledge of socio economic conditions of the region. The final vulnerability of a system could then be considered the aggregation of the vulnerability based on each criterion.

Figure 7.1: Schematic example of a vulnerability curve (NIBS, 1997)



Source: Tung, 2004

Urban sprawl and unplanned settlement with little sensible construction may add to this vulnerability since collapsing buildings increase the number of victims of earthquakes. High rise buildings, large underground shopping centers, basement structures are increasing rapidly. As a result, cost of building construction is also high. This will be a challengeable issue to the authorities.

Due to urbanization and rapid progress in motorization, problems of urban traffic are emerging. Increasing trend in traffic accidents may be anticipated in the future while the overhead bridges and elevated roads may increase the vulnerability of population to earthquakes.

Poverty is the main problem of the country. About 42 percent of the people are living below the poverty line (NLSS, 2004). People, who have to struggle every day just to survive and do not have the time or the strength to worry about more distant environmental and natural hazards, in practice, have to suffer more.

A noticeable feature in many parts is the scarcity of inhabitable land, and the concentration of the industries, factories, commercial centers, official buildings and recreational centers within the urban areas are seen as positively. This aspect is negated by migrant who increases their physical vulnerability. People migrate in large number for employment, recreation and the like. This is the increasing risk of exposure to future disaster events.

There have not been any studies about the physical conditions and damage states of physical infrastructure. Furthermore, there have not been any data of damage states of infrastructure in historic earthquakes in eastern Nepal. For that reason it is difficult to develop curve of earthquake intensity verses damage states for each type of infrastructure with a particular type of physical condition and location. In the study, Vulnerability assessment used to describe the expected or assumed earthquake performance characteristics of lifelines. Damage has been developed to calculate the quantitative relationships for direct damage and residual capacity. It is expressed using estimates of ground shaking intensity based on calculated PGA, specifying the location and type of infrastructures and fragility curves developed by FEMA (HAZUS-MH, 2003).

The hazard parameter used in vulnerability function is Peak Ground Acceleration (PGA) and Permanent Ground Displacement (PGD). The vulnerability evaluated is simply based on ground shaking not on structure of the infrastructures. In physical sense, it is rather not logical. The road transportation and water supply distribution might be physically damaged, if they are suffering from landslide or slope failures. Therefore, hazardous points are only those which are located on landslide areas.

7.1 Road Network under Landslide Hazard

Road transportation consists of roadways, bridges and tunnels. The damage to road that was mentioned above is physical damage, more or less affects road function in different extents. There are also types of effect that affect the road functionality causes by included hazard like landslide, tsunami or by debris felt on to the road surface.

Road transportation are vulnerable to both ground shaking and ground failure. Location of roads is very important in their vulnerability assessment since, the road usually cover large areas with various types of topography and geomorphology condition. Physical condition and material of the road seem less important in road vulnerability assessment. Damage states describe the level of damage to the each road transportation. Damage states related to a damage ratio defined as the ratio of repair to replacement cost for evaluation, if direct economic loss. A total of five damage states are defined for road transportation (HAZUS-MH, 2003). These are:

Slight/ minor (ds2). It is defined by slight settlement (few Inches) or offset of the ground.

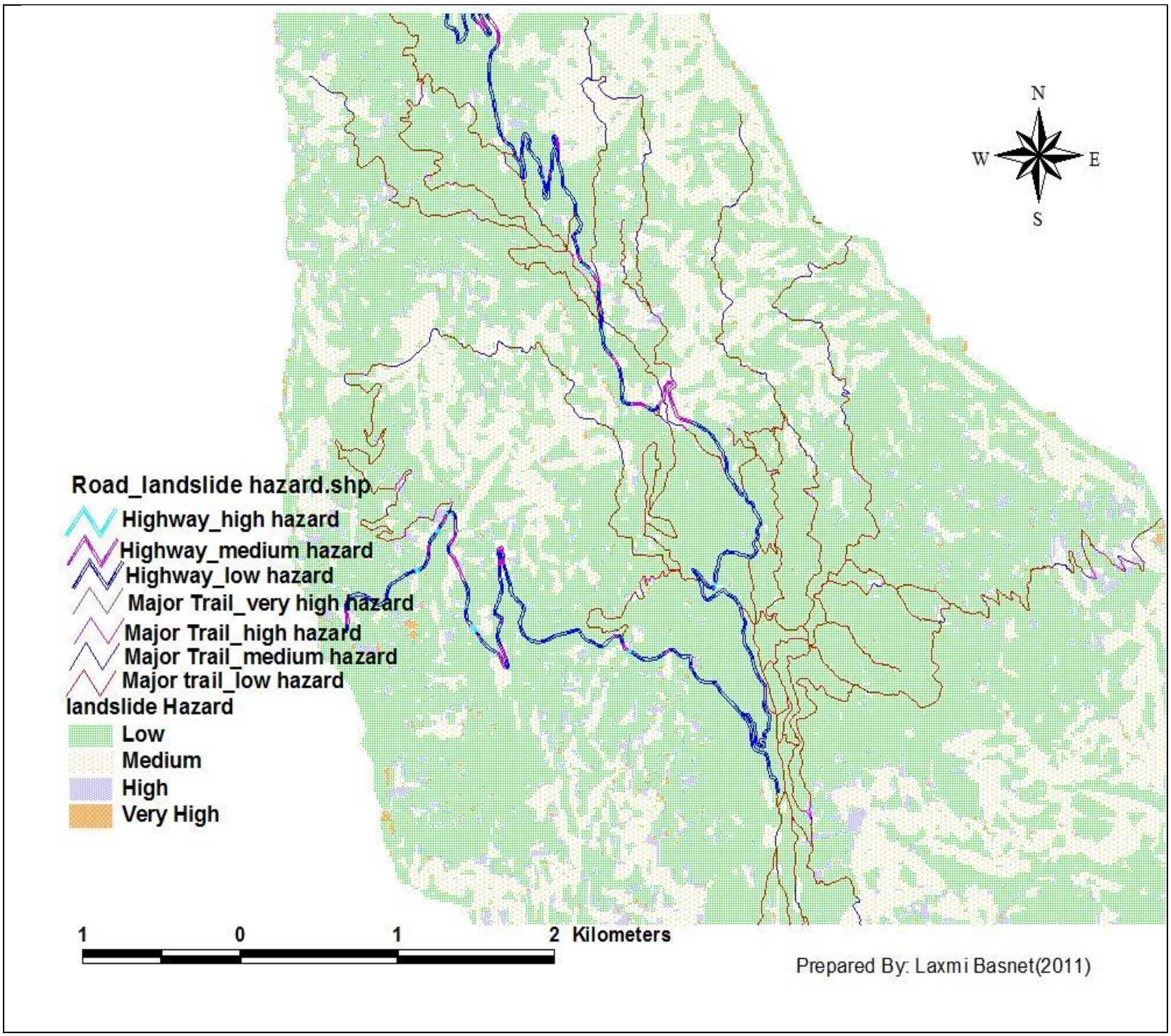
Moderate damage (ds3). Ds3 is defined by moderate settlement or offset of the ground.

Extensive damage (Ds4) is defined by moderate settlement of the ground (few feet).

Complete damage (ds5), it is defined by major settlement of the ground.

The road transportation is a highly redundant system, can be damage due to landslide, which in turn caused by earthquake. Damage is assumed at each location where the road crosses into a landslide zones. Which is shown in the Figure 7.2.

Figure 7.2: Road Damage Map



Source: Base on infrastructure services map and intensity map

Figure 7.2 shows the distribution of damage road due to landslide. Roads, which are located in landslide prone area, consequently, in these locations have high potential damage.

Table 7.1: Potential Damage to Road Transportation by types

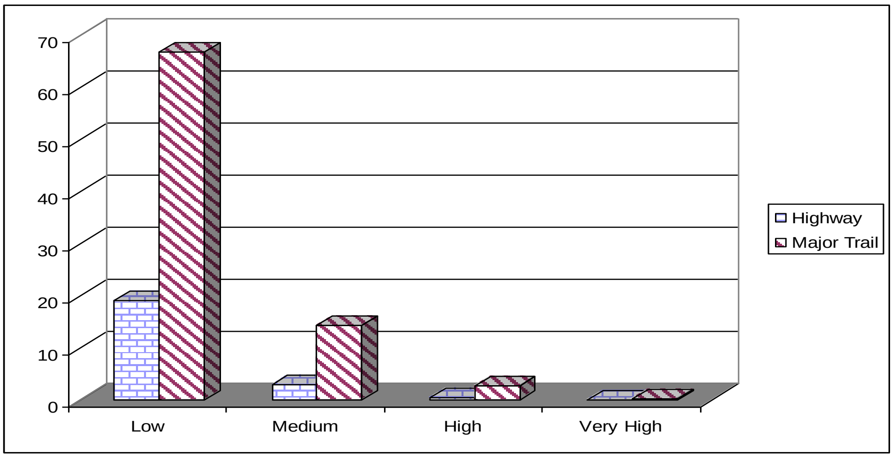
Type	Length(km)	%	Low	%	Medium	%	High	%	Very High	%
Highway	22.35	21	18.98	22.11	3.00	17.26	0.37	12.17	-	-
Major Trail	84.04	79	66.86	77.89	14.38	82.74	2.67	87.83	0.13	100
Total	**106.39**	**100**	**85.84**	**100**	**17.38**	**100**	**3.04**	**100**	**0.13**	**100**

Table 7.2: Potential Damage to Road Transportation by surface types

Sur_type	Length(km)	%	Low	%	Medium	%	High	%	Very High	%
Highway	22.35	21	18.98	21.35	3.00	17.26	0.37	12.17	-	-
Black Topped	12.94	12.16	12.39	14.84	0.48	2.76	0.05	1.64	0.02	15.38
Earthen	63.40	59.59	47.76	55.77	13.19	75.89	2.33	76.64	0.11	84.62
Gravel	6.16	5.8	5.22	6.25	0.71	4.09	0.22	7.24	-	-
Metal	1.10	1.03	1.05	1.26	-	-	0.07	2.31	-	-
Stone paved	0.44	0.42	o.41	0.53	-	-	-	-	-	-
Total	**106.39**	**100**	**85.84**	**100**	**17.38**	**100**	**3.04**	**100**	**0.13**	**100**

Source: GIS Map

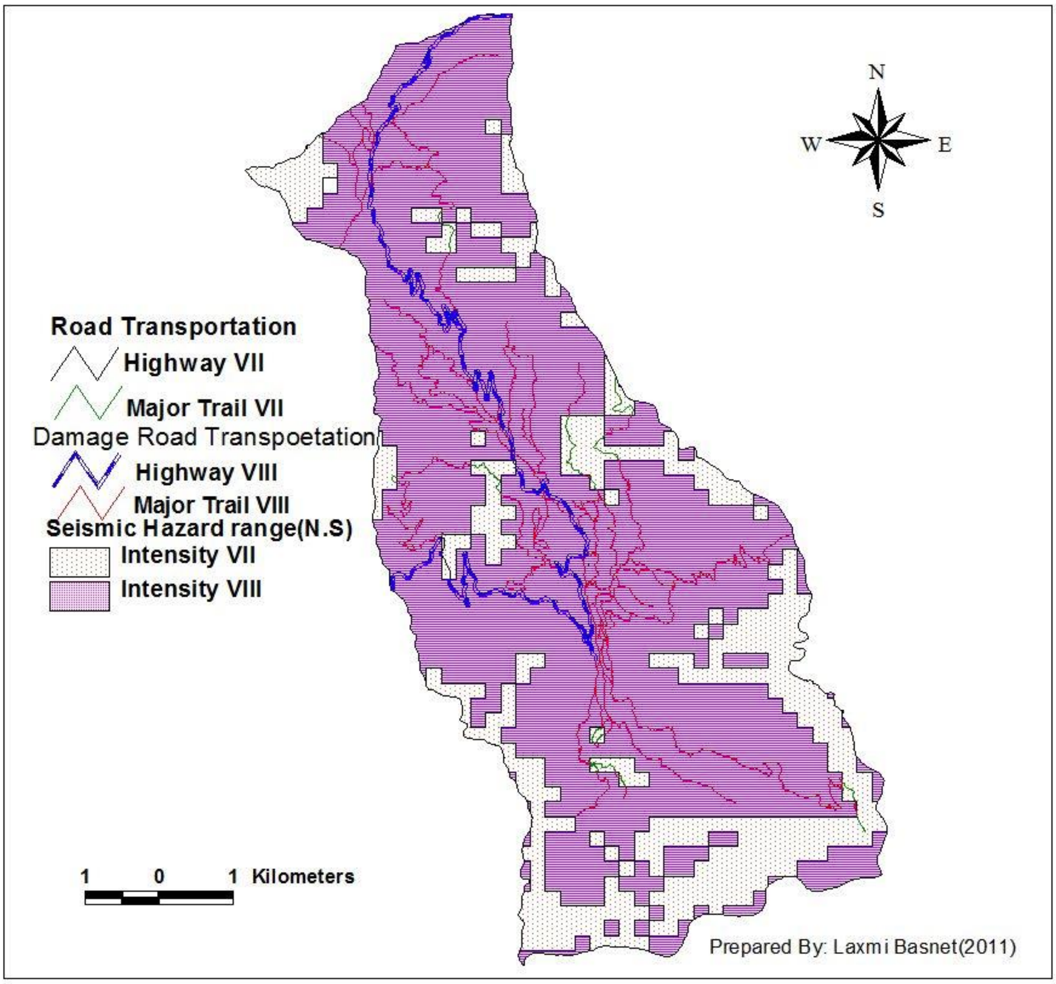
Figure 7.3: Road Damage in Dhankuta Municipality



There are different type of road have possibility to damage due to landslide, which is clearly see in the Table 7.1 and Table7.2.We are show damage level in road types and surface types of Dhankuta municipality. There are four categories in damage level. 18.98 km highway would be low damaged, 66.86km major trail low damage and 0.13km is very high damage of major trail. 15.38% and84.64% in black topped and earthen road are very high damage.

We have also analysis in road transportation with overlay in north sunsari intensity map. This is shown in the Figure 7.4.

Figure 7.4: Road Damage Map



Source: Base on infrastructure services map and intensity map

Table 7.3: Potential Damage to Road Transportation by types

TYPE	Length(KM)	Percent (%)	Damage(KM)	Percent (%)
Highway	22.35	21	21.68	21.97
Major trail	84.04	79	77.01	78.08
Total	**106.39**	**100**	**98.69**	**100**

Table 7.4: Potential Damage to Road Transportation by surface types

Surface Type	Length(Km)	Percent (%)	Damage(km)	Damage (%)
Highway	22.35	21	21.68	21.97
Black Topped	12.94	12.16	12.94	13.11
Earthen	63.40	59.59	56.57	57.32
Gravel	6.16	5.8	6.16	6.24
Metal	1.10	1.03	1.10	1.11
Stone Paved	o.44	o.41	0.44	0.45
Total	**106.39**	**100**	**98.69**	**100**

Source: GIS Map

Figure 7.4, Table7.3 and Table 7.4 are clearly showed many part of road are located in the area of intensity VIII. It can be expected to sustain heavy damage.

7.2 Distribution of Electric Transformers with Ground Shaking

This section presents the earthquake loss estimation methodology for an electric power system. This system consists of generation facilities, substations and distribution circuits. All of these components are vulnerable to damage during earthquakes, which may result in significant disruption of power supply (HAZUS-MH, 2003).

Electricity is a form of energy produced by the movement of electrons. Electricity is electrical power or an electric current. This form of energy can be sent through wires in a flow of tiny particles. It is used to produce light and heat and to run motors. Electric power systems are also damage by earthquake. Facilities such as substations, generation plants and distribution circuits are most vulnerable to PGA, and sometimes PGD, if located in liquefiable or landslide zones. Therefore, the damage states for these components are defined in terms of PGA and PGD.

Five damage states are defined for electric power system components (HAZUS-MH, 2003). These are none (ds1), slight/ minor (ds2), moderate (ds3) and complete (ds5).

Slight/ minor damage: For substations, ds2 is defined as the failure of 5% of the disconnect switches, or the failure of 5% circuit breaks, or by the building being in minor damage state.

For distribution transformers, ds2 is defined by the failure of 4% of all circuits.

Moderate damage: For substations, ds3 is defined as the failure of 40% of the disconnect switches or 40% of circuit breaks or failure of 40% of current transformers, or by the building being in moderate damage state.

For distribution transformers, ds3 is defined by the failure of 12% of circuits.

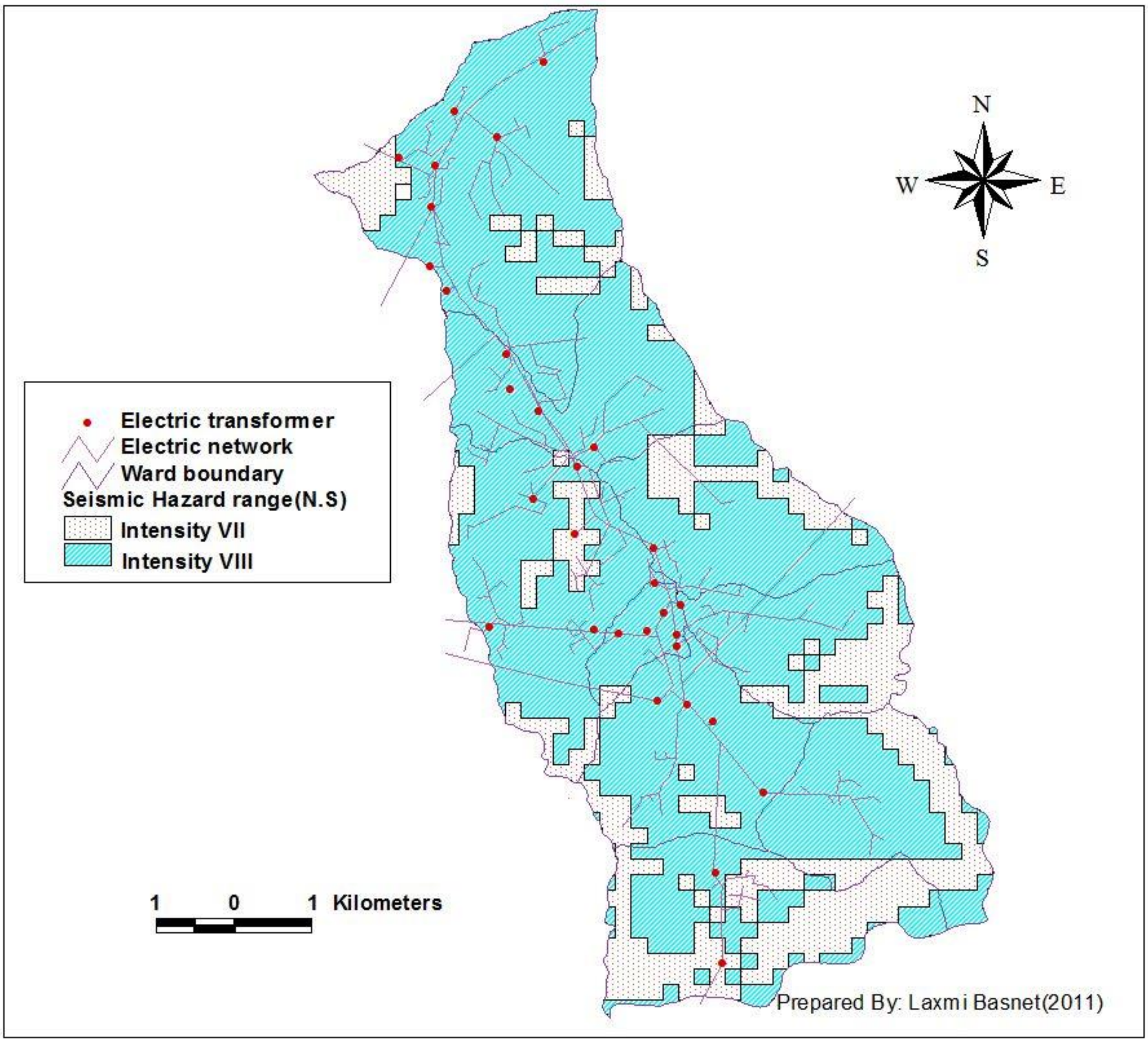
Extensive damage: For substations, ds4 is defined as the failure of 70% of disconnect failure of 70% of disconnect switches, 70% of circuit breaks, 70% of current transformers or by failure of 70% of transformers or by the building being in extensive damage. For distribution transformers, ds4 is defined by the failure of 50% of all circuits.

Complete damage: For substations, ds5 is defined as the failure of all disconnect switches, all circuit breaks, all transformers, or all current transformers, or by the building being in extensive damage state.

For distribution transformers, ds5 is defined by the failure of all circuits.

Ds4 is defined by the failure of 50% of all circuits.

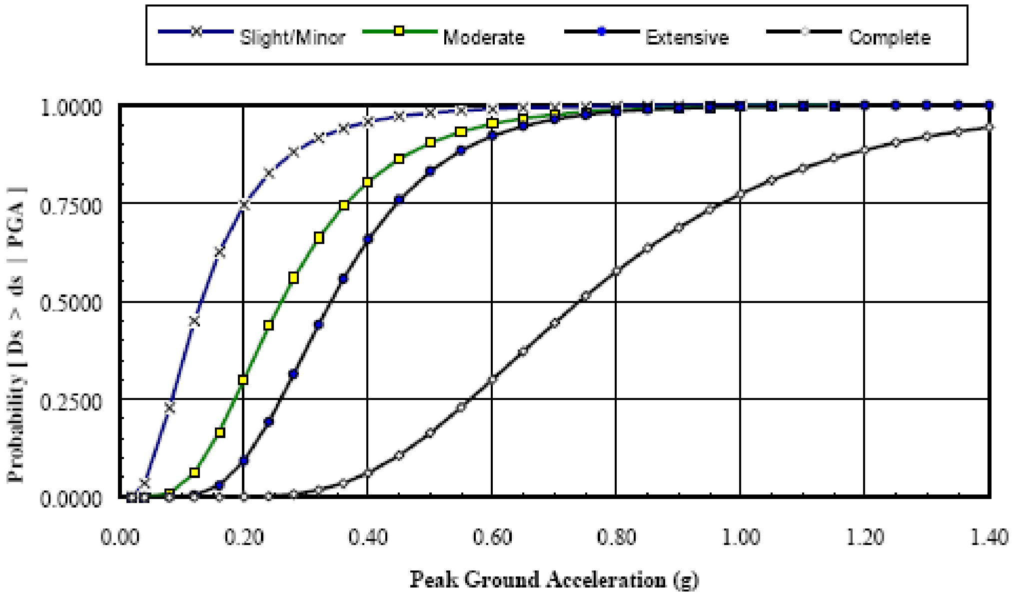
Figure 7.5: Electric Hazard Map



Source: Base on infrastructure services map and intensity map

Figure 7.5 clearly show most of the electric transformers are located in the area of intensity VIII. There are 31 electric transformers in their in Dhankuta municipality area but only 2 electric transformers are in intensity VII. That reason, we can simply say that it can be expected to sustain heavy damage. Direct damage to the electric transformers as a result of the earthquake intensity, estimated using damage curves for electric transformers, is plotted in Table 7.5

Figure 7.6: Damage curves for Electric Transformers



Source: HAZUS-MH, 2003

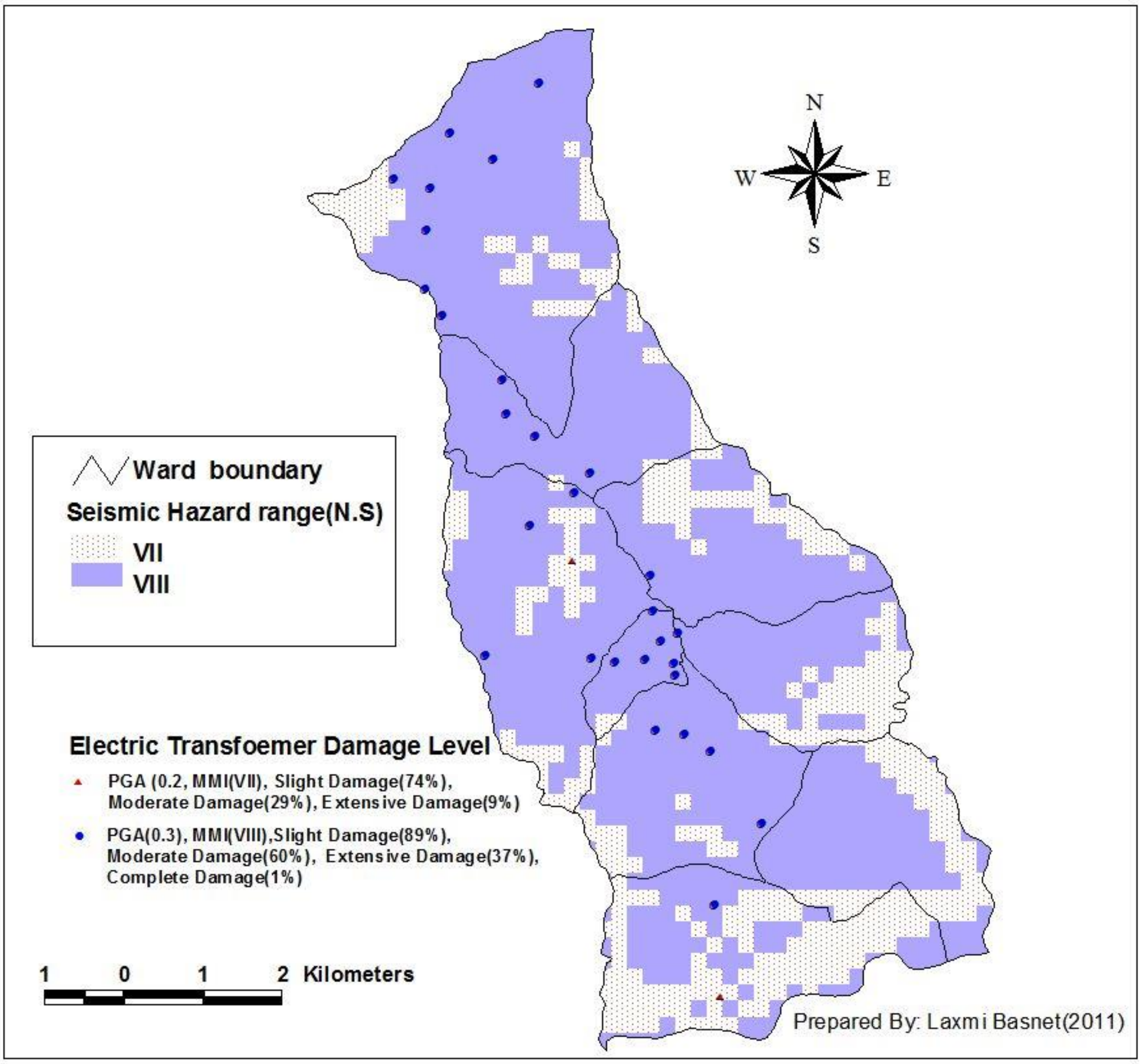
Table 7.5: Potential Damage Percent for Electric Transformers

Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.2	74	29	9	-
Intensity 8	0.3	89	60	37	1

Source: Derived from figure 7.6.

Damage data estimates for the electric systems are based on Figure 7.4 Damage curves for Electric Transformers curves for medium voltage transformers. Damage data for transformers indicate that damage to this facility type is expected to be greatest for the magnitude 8, in which 89% would sustain minor damage, 60% would sustain moderate damage, 37% would sustain extensive damage, and 1% would sustain complete damage.Damage percent of the Electric transformers has been visualized in Figure7.7

Figure7.7: Electric Transformers Damage



Source: Base on infrastructure services map and intensity map

7.3 Telephone Network with Ground Shaking

Communications facilities are one of the most rapidly develop in Nepal. When earthquake have gone, they are also damage in communication facilities. Central offices and broadcasting stations are the only components of the communication system. Therefore, fragility curves are presented for these components only. Other components, such as cables and other lines, usually have enough slack to accommodate ground shaking and even moderate amounts of permanent ground deformations.

Damage states for describing the level of damage to a communication facility are defined (i.e. slight, moderate, extensive, or complete).

Slight/minor (ds2), ds2 is defined by slight damage to the communication facility building,

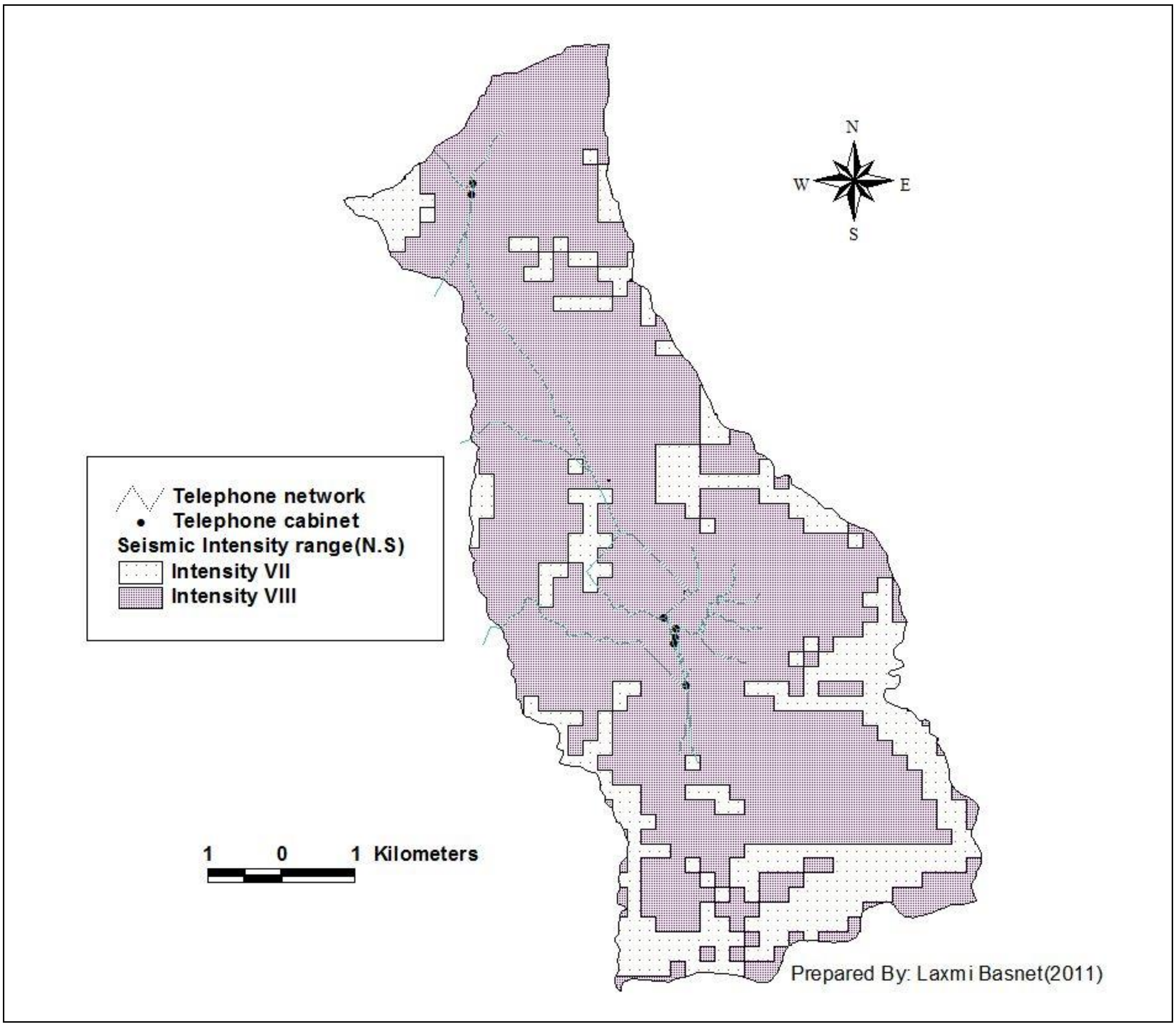
or inability of the center to provide services during a short period due to loss of electric power and backup power, if available.

Moderate damage (ds3*):* Moderate damage is defined by damage to communication facility building, few digital switching boards being dislodged, or the central office being out of service for a few days due to loss of electric power(power failure) and backup power(typically due to overloaded), if available.

Extensive damage (ds4) is defined by severe damage to the communication facility building resulting in limited access to facility, or by many digital switching boards being dislodged, resulting in malfunction.

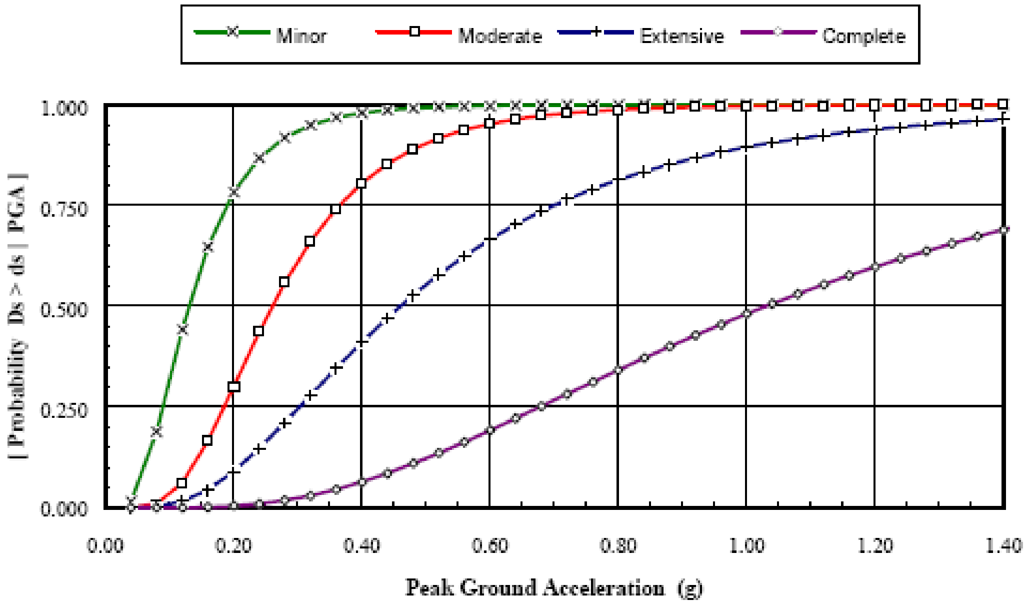
Complete damage (ds5*).* It is defined by complete damage to the communication facility building, or damage beyond to digital switching boards.

Figure 7.8: Telephone Hazard Map



Source: Base on infrastructure services map and intensity map

Figure 7.9: Damage Curve Telephone for Cabinet



Source: HAZUS-MH, 2003

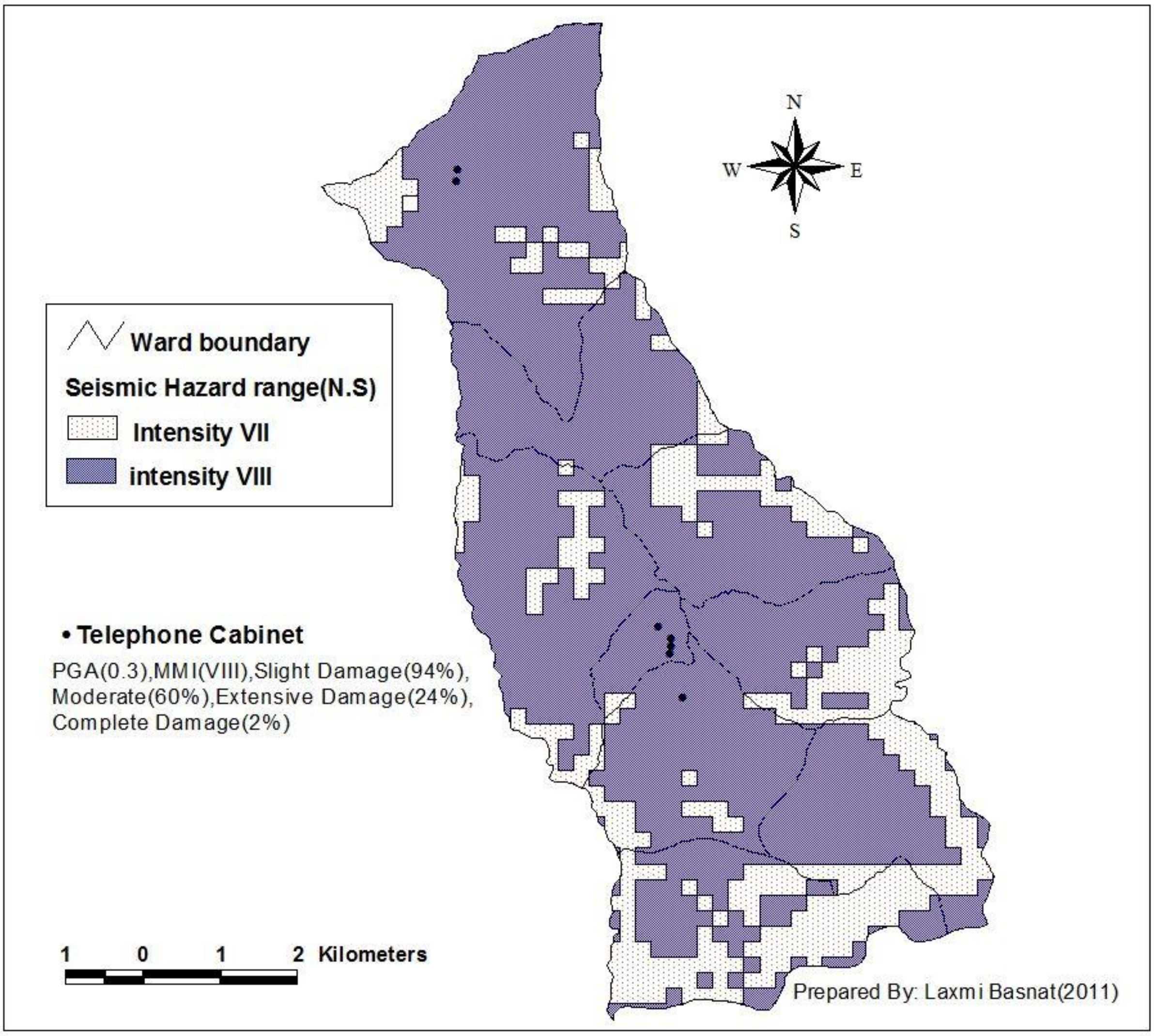
Table 7.6: Potential Damage Losses to Telephone Cabinet

Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.2	79	30	8	-
Intensity 8	0.3	94	60	24	2

Source: Derived from figure 7.9.

The Telephone Cabinet of the area has located in different parts. Based on the location of Telephone Cabinet damage percent of cabinet has been calculated. The direct damage data in table 7.6, suggests that the magnitude 8 events would caused the most extensive damage. 94% would sustain minor damage, 60 % would sustain moderate damage, 24% would sustain extensive damage and 2% would sustain complete damage Figure 7.10 shows the damage probability of telephone Cabinet.

Figure 7.10: Telephone Cabinet Damage Map



Source: Base on infrastructure services map and intensity map

7.4 Water supply system with under Ground Shaking Hazard

Water system consists of supply transmission and distribution components such as pipeline network, water reservoir tanks and resources. If earthquake may be come all infrastructure components and facilities such as water treatment plants, wells, pumping plants and storage tanks are most vulnerable to damage, which may result in a significant disruption to the water utility network. Therefore, the damage states for these components are defined and associated with PGA and PGD.

Damage states describing the level of damage to each of the water system components are defined (slight/ minor, moderate, extensive or complete), while for pipelines, the number of repairs/km is the key parameter. Pipes that are less than 20” m diameter are defined as small, while pipes with diameter greater than 20” are defined as large.

Slight/ minor damage (ds2), For water storage tanks, ds2 defined by the tank suffering minor damage without loss of its contents or functionality. Minor damage to the tank roof to water sloshing, minor cracks in concrete tanks, or localized wrinkles in steel tanks fits the description of this damage state.

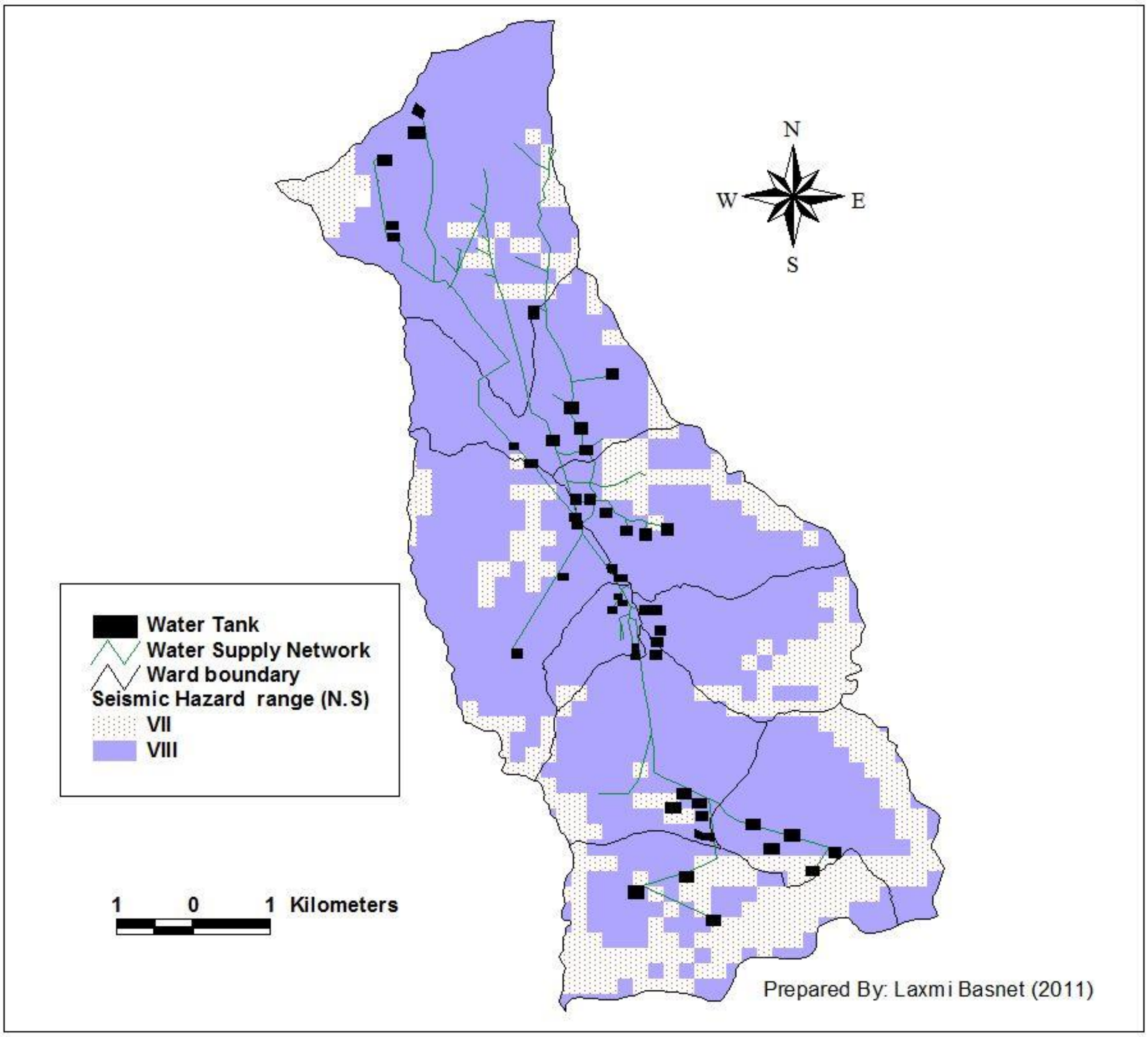
Moderate damage (ds3), it is defined by the tank being considerably damaged, but only minor loss of content. Elephant foot buckling for steel tanks without loss of content or moderate cracking of concrete tanks with minor loss of content fits the description of this damage state.

Extensive damage (ds4), ds4 is defined by the tank being severely damaged and going out of service. Elephant foot buckling for steel tanks with loss of content, stretching of bars for wood tanks, or shearing of wall for concrete tanks fits the description of this damage state.

Complete damage (ds5), is **defined** by the tank collapsing and losing all of its content.

For pipelines, two types of damage states are considered. These are leaks and breaks. Generally, when a pipe is damaged due to ground failure (PGD), the type of damage is break, while when a pipe is damaged due to seismic wave propagation (PGV), the type of damage is likely to be joint pull-out or crushing in the bell. It is assumed that damage due to seismic waves will consist of 80% leaks and 20% breaks, while damage due to ground failure will consist of 20% leaks and 80% breaks.

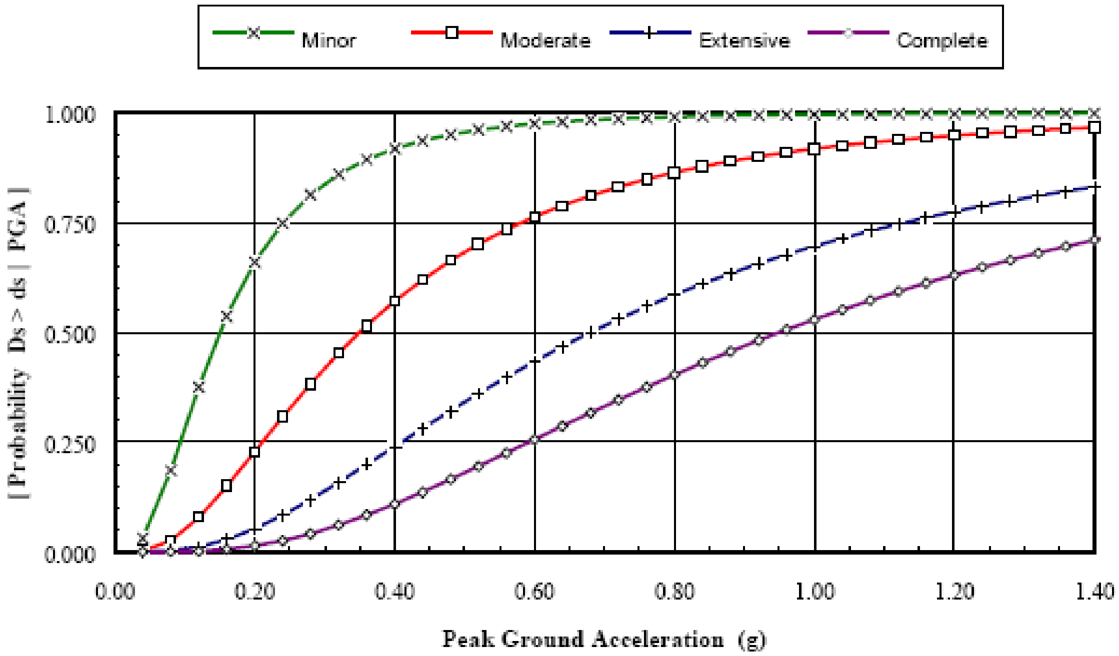
Figure 7.11: Water Supply Hazard Map



Source: Base on infrastructure services map and intensity map

Figure 7.11 shows the location of different type of reservoir tank. Reservoir tank are located in different parts of the area. In the case, earthquake damage can varies according to location of reservoir tank

Figure7.12: Damage curve for Ground Concrete Tank



Source: HAZUS-MH, 2003

Table 7.7: Potential Damage Percent for Concrete Water Tank for Each Scenario

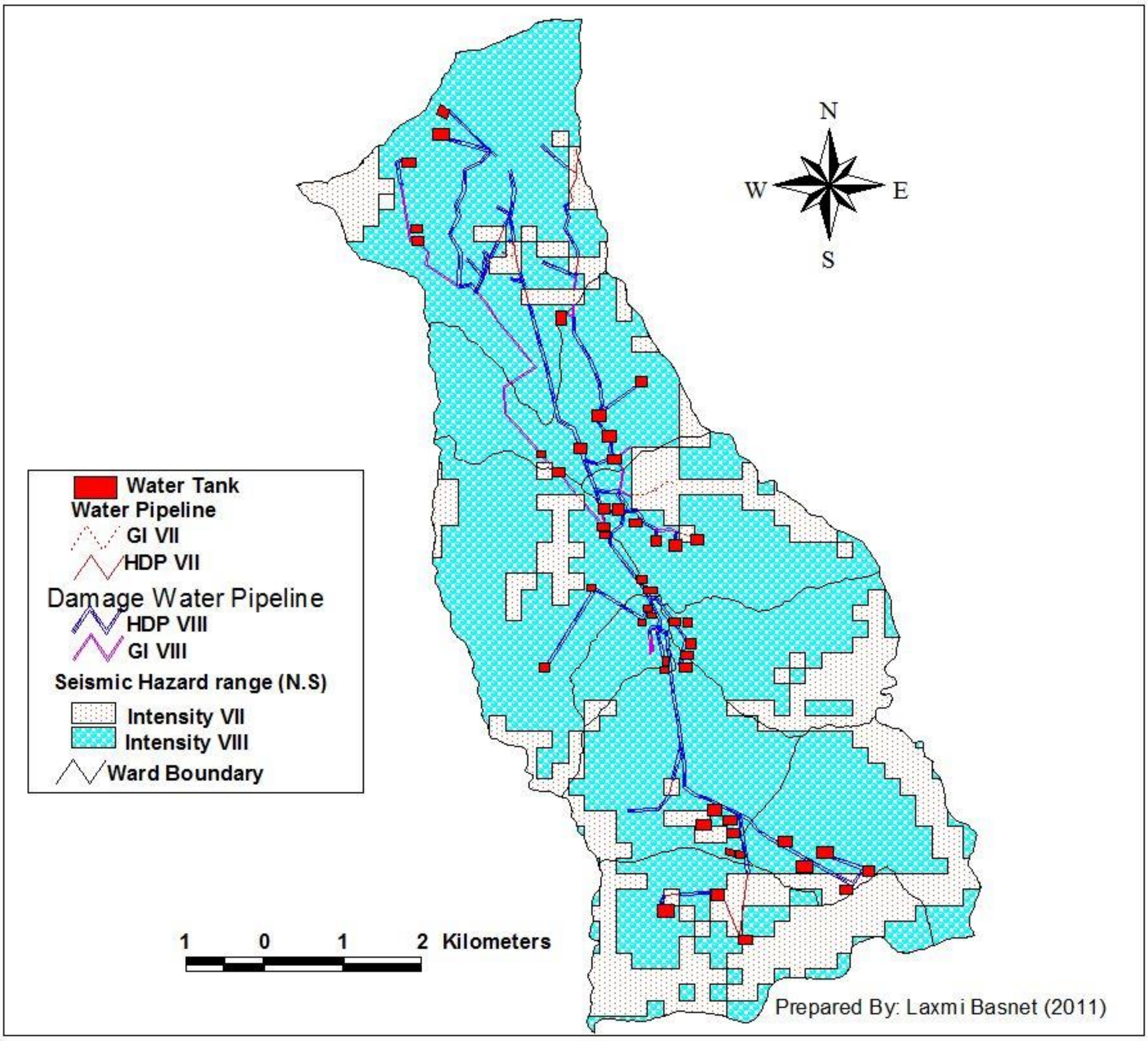
Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.2	66	23	4	1
Intensity 8	0.3	84	42	14	5

Source: Derived from figure 7.12.

Direct damage data for water tanks Table 7.7 indicate that this facility type would be severely impacted in scenario events. The impacts are most severe in the Magnitude 8. For these scenario earthquakes, 84% concrete tank would sustain slight/minor damage, 42% would sustain moderate damage, 14% would sustain extensive damage and 5% would sustain complete damage.

The reason for the severe damage to water tank in the magnitude 7 and 8 is assumed to be strongly correlated with poor ground conditions and construction practices. Damage of water tank has been visualized in Figure 7.13.

Figure 7.13: Water Pipelines Damage Map



Source: Base on infrastructure services map and intensity map

Table 7.8: Damage of Water Pipelines

Pipe Materials	Length (km)	Percent (%)	Damage Pipe length(km)	Percent(%)
GI	18.45	30.67	8.84	24.40
HDP	41.71	69.33	27.39	75.60
Total	**60.16**	**100**	**36.23**	**100**

Source: GIS Map

Figure 7.14: Water Pipelines Damage in Dhankuta Municipality

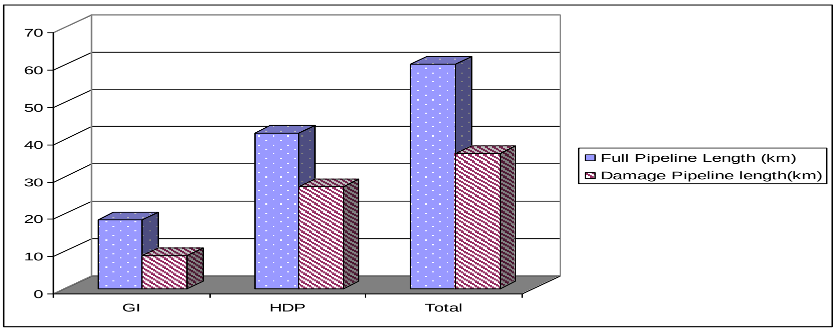
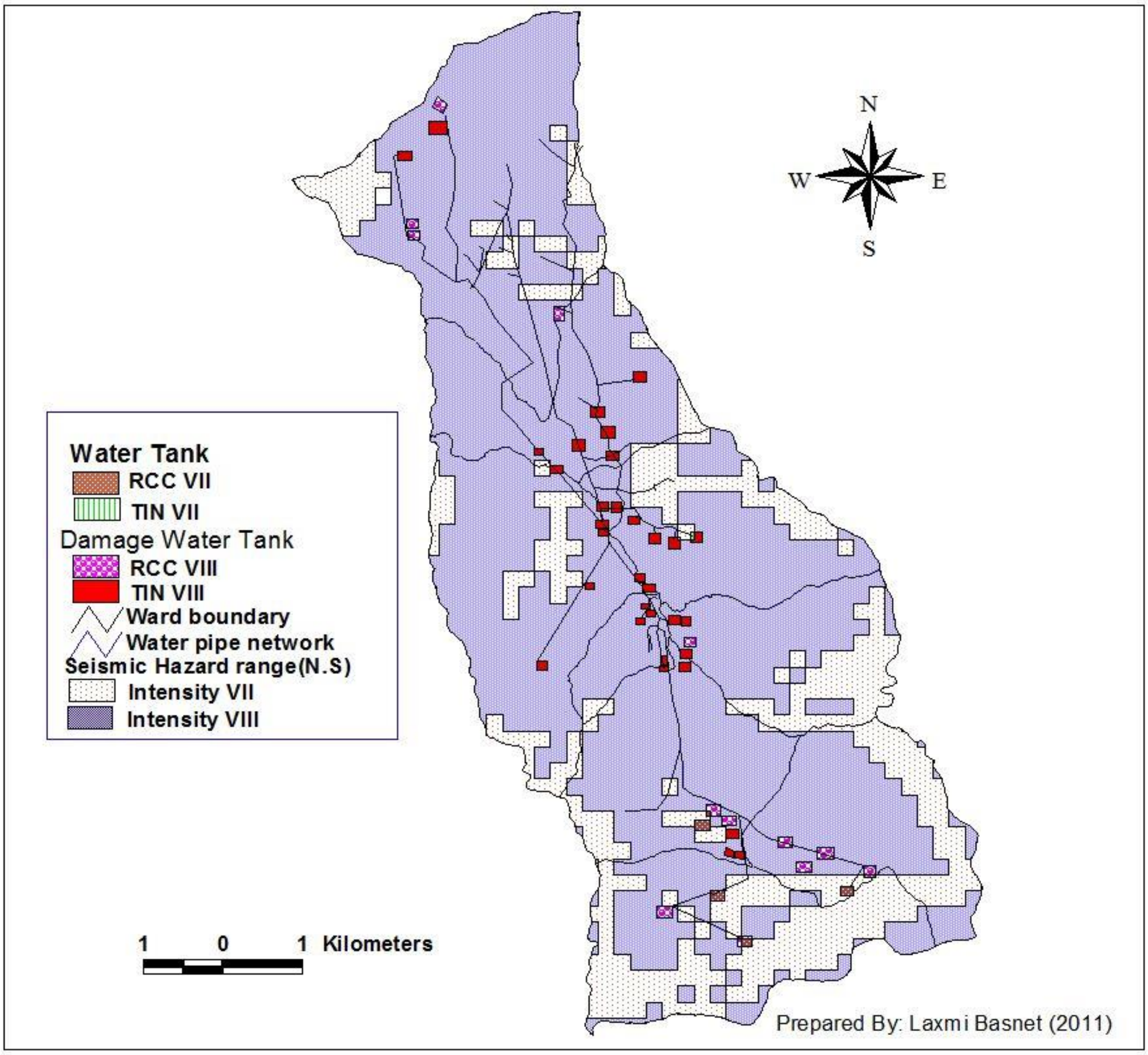


Figure 7.15: Water Tank Damage Map



Source: Base on infrastructure services map and intensity map

Table 7.8 shows the damage of water pipe line in dhankuta municipality. There are two type of pipeline in their one is GI and other is HDP pipe. There is 24.40% damage in GI pipe and 75.60% damage in HDP pipe

Table 7.9: Damage of Water Tank

Types of Tank	Count of Tank	Capacity (L)	Damage Count of Tank	Damage Capacity (L)
RCC	22	705000	15	510000
TIN	36	2115000	33	2072000
Total	**58**	**2820000**	**48**	**2582000**

Source: GIS Map

Figure 7.16: Damage of Water Tank

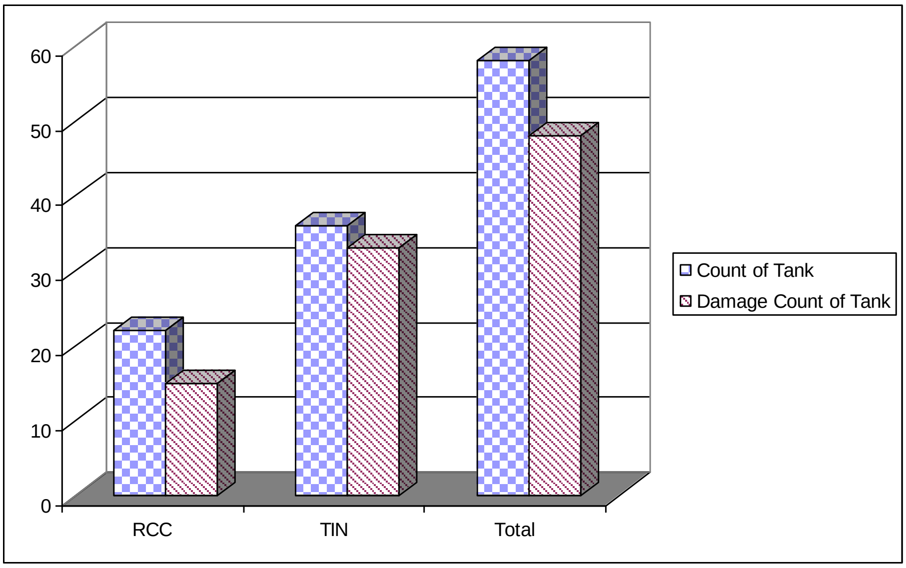


Figure7.16 and Table 7.9 shows that total 58 water tank in their area. It was found that, 48 water tanks are high damage in this situation.

7.5 Petrol Pump with Ground Shaking Hazard

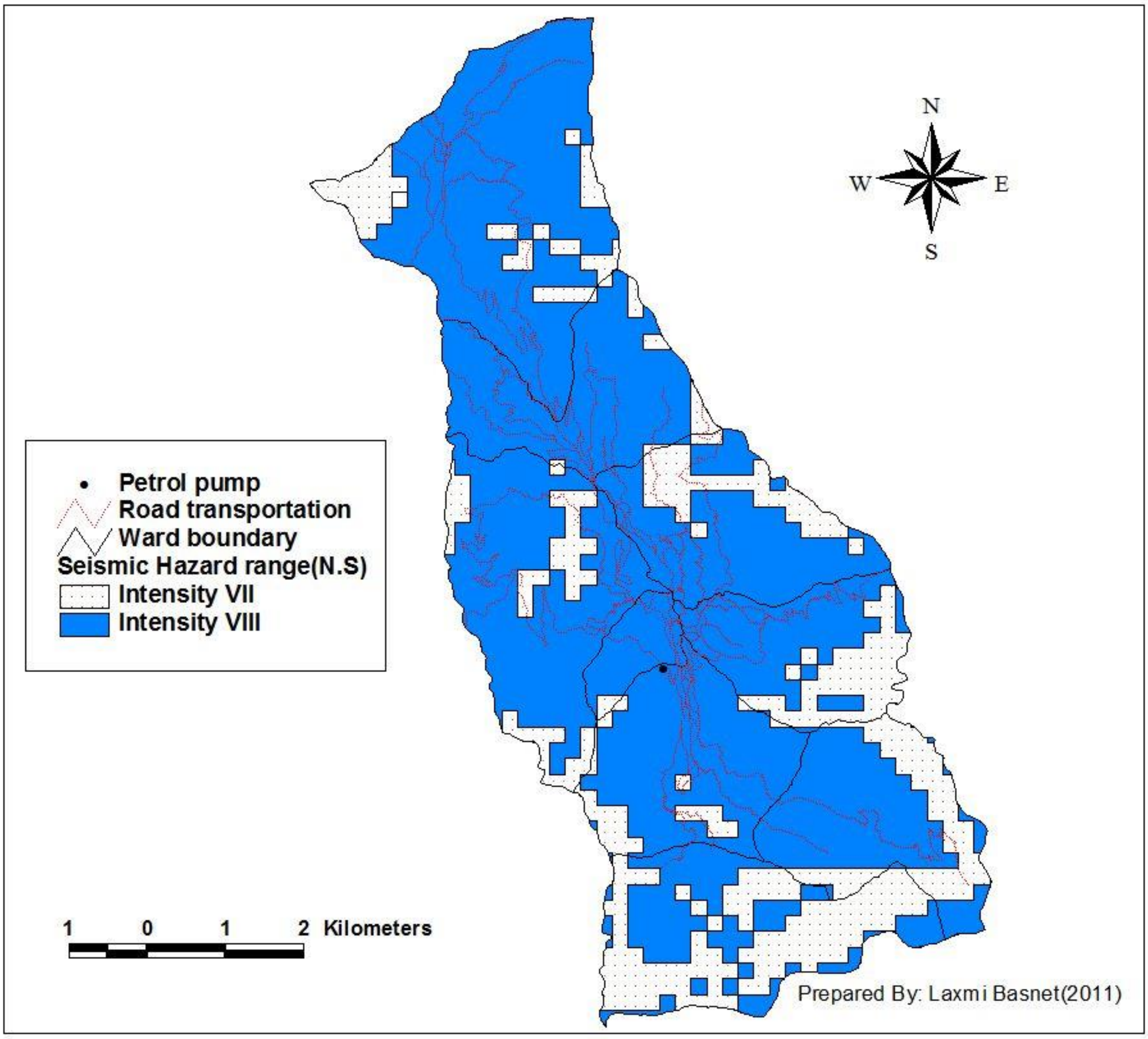
Petrol pumps are one of the vulnerable to damage during earthquakes. These facilities such as pumping plants, refineries and tank farms are most vulnerable to PGA and sometimes PGD, if located in liquefiable of landslide zones. Therefore, damage states for these components are associated with these ground motion parameters.

Five type of damage states are defined for petrol pump. These are none (ds1), slight/minor (ds2), moderate (ds3), extensive (ds4) and complete (ds5).Slight/minor (ds2) is defined by malfunction of plant for short time(less than three days) due to loss of backup power or light damage to tanks.

For tank forms, moderate damage (ds3) is defined by malfunction of tank farm for a week or so due to loss of backup power, extensive damage to various components, or considerable damage to tanks.

Extensive damage (ds4) is defined by the tanks being extensively damaged, or extensive damage to elevated pipes. Complete damage (ds5), ds5 is defined by the complete failure of all elevated pipes, or collapse of tanks.

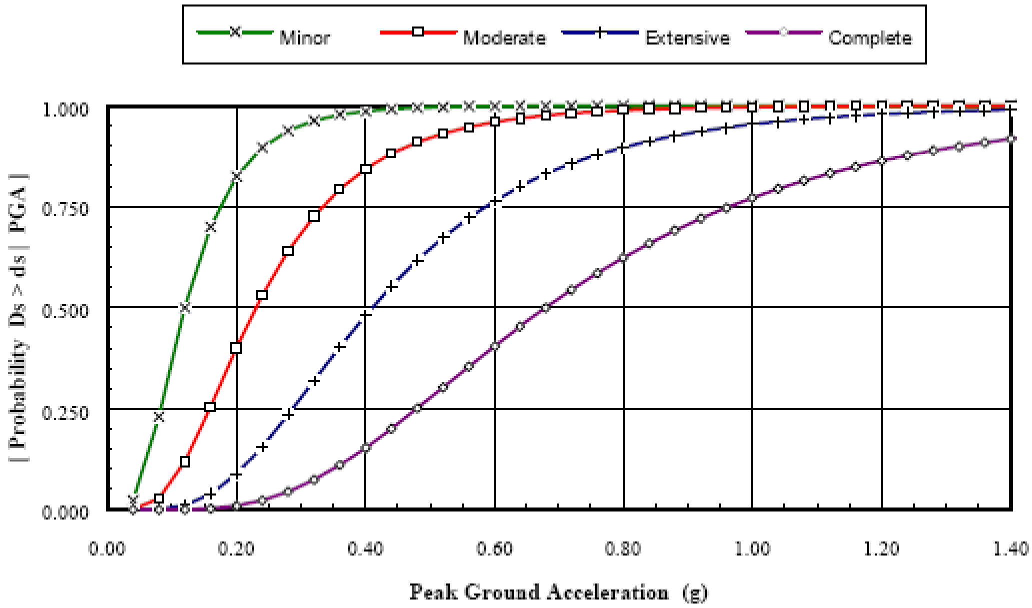
Figure 7.17: Petrol Pump Hazard Map



Source: Base on infrastructure services map and intensity map

Petrol pump behavior during an earthquake can be very complex. There is only one Petrol pumps in Dhankuta municipality area which is located in the area of MMI VIII. Since, Petrol pumps are located with having peak ground acceleration 0.3 regions. Only those scenario earthquakes affecting these regions will negatively impact this facility type. Damage probability of petrol pumps was assessed in table

Figure7.18: Damage Curve Petrol Pump



Source: HAZUS-MH, 2003

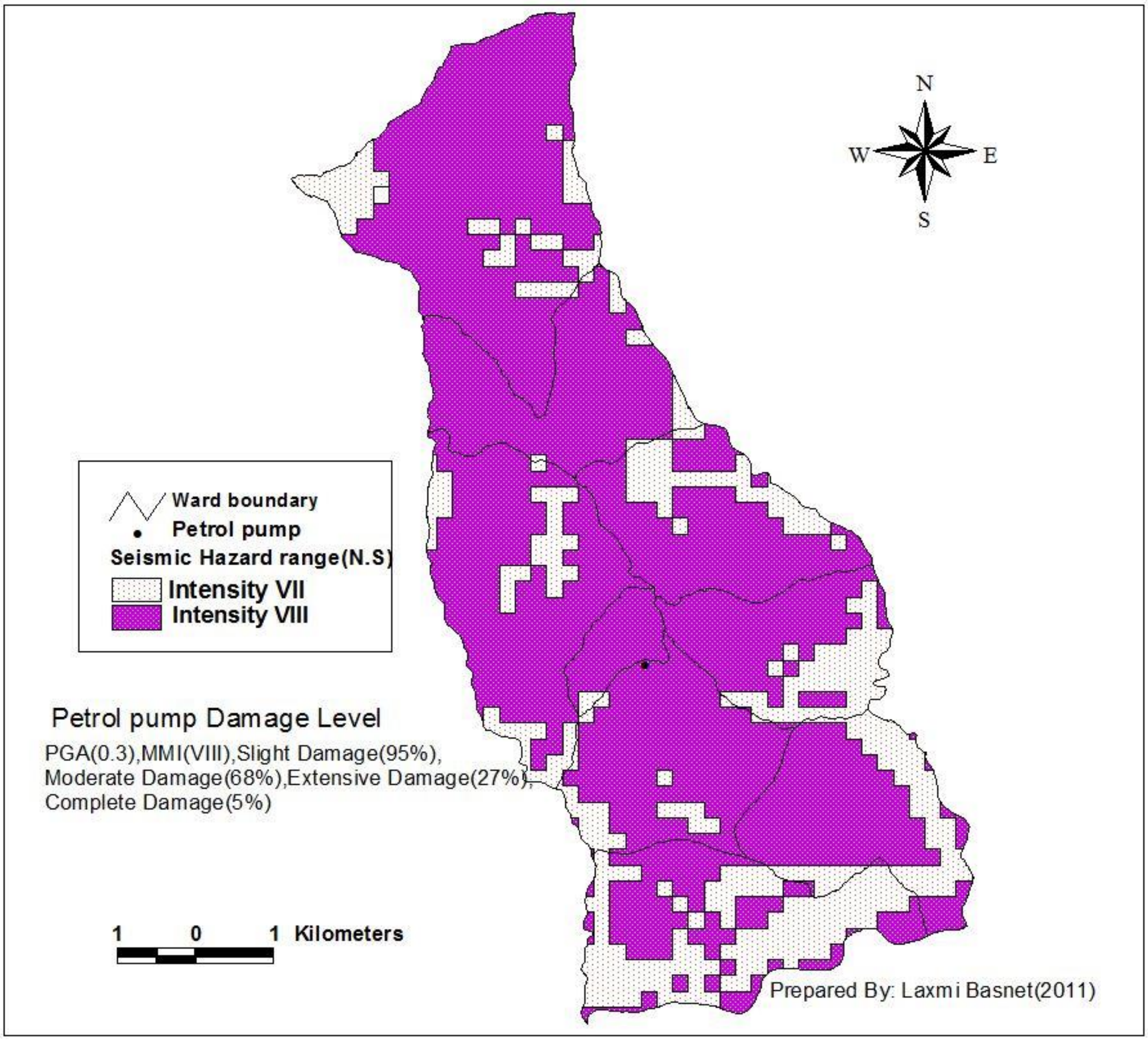
Table 7.10: Potential Damage Losses to Petroleum Tanks

Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.2	82	40	8	-
Intensity 8	0.3	95	68	27	5

Source: Derived from figure7.18.

As in the case of petroleum tank, direct damage to this facility type will be more severe for the magnitude 7 and 8, 95% would sustain slight/minor damage, 68% would sustain moderate damage, and 27% would sustain extensive damage. 5 % would be similarly affected by the magnitude 8. It has been visualized in the Figure 7.19:

Figure 7.19: Petrol Pump Damage Map



Source: Base on infrastructure services map and intensity map

7.5 Bridges with Ground Shaking Hazard

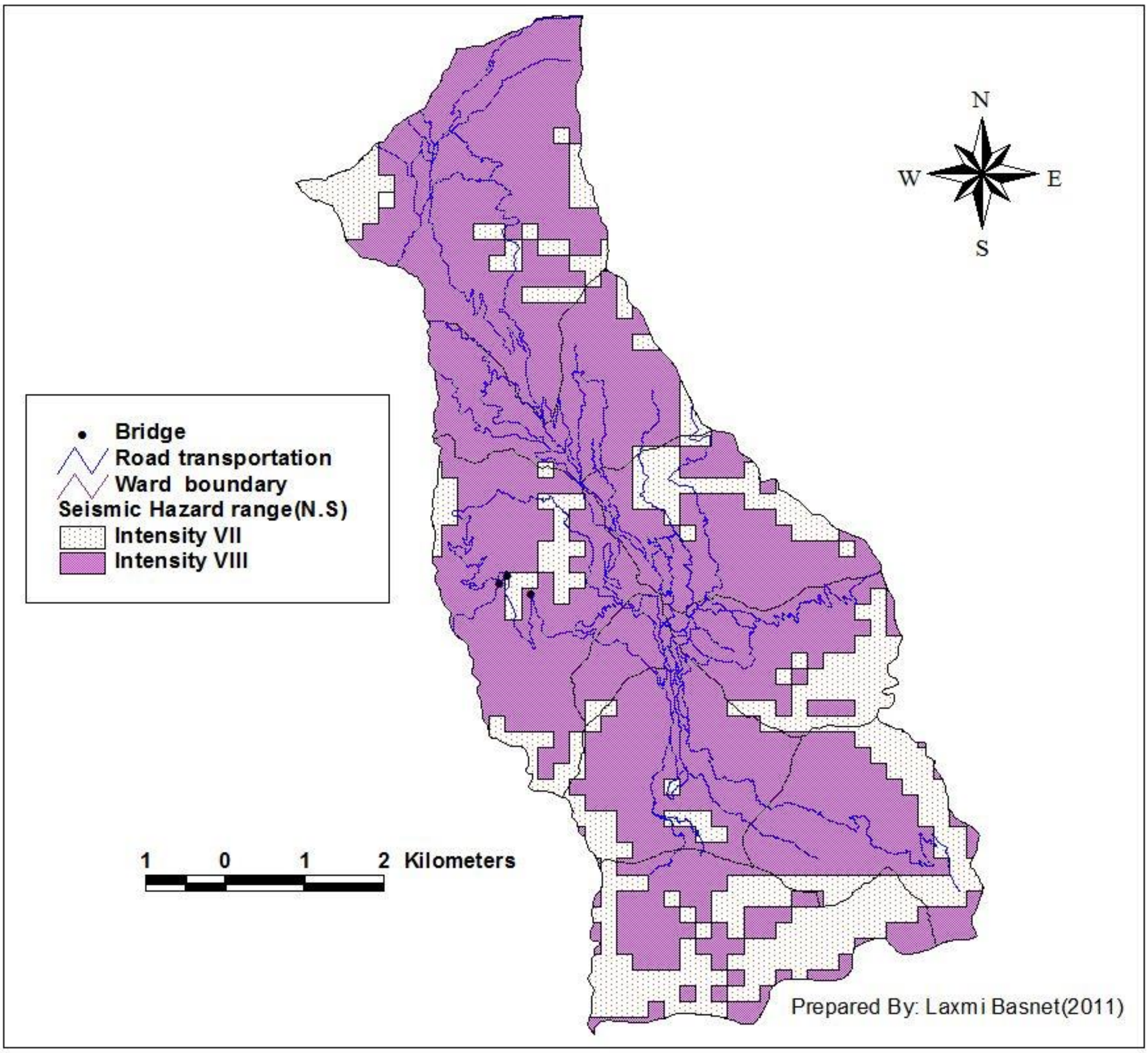
Bridges is one of the vulnerable to damage during earthquakes. This section includes development of methods of earthquake damage to bridges. Bridges that fail usually result in significant disruption to the transportation network, especially bridges that cross waterways. Likewise, tunnels are often not redundant, and major disruption to the transportation system is likely to occur should a tunnel become non-functional. Past earthquake damage reveals that bridges and tunnels are vulnerable to ground shaking and ground failure, while roads are significantly affected by ground failure alone.

Five type of damage states are defined for bridges. These are none (ds1), slight/minor (ds2), moderate (ds3), extensive (ds4) and complete (ds5).

Slight/minor (ds2) is defined by minor cracking and spalling to the abutment, cracks in shear keys at abutments, minor spalling and crack at hinges, minor spalling at the column (damage requires no more than cosmetic repair) or minor cracking to the deck.

For bridges, moderate damage (ds3 is defined by any column experiencing moderate(shear cracks) cracking and spalling (column structurally still sound),moderate movement of the abutment (<2"),extensive cracking and spalling of shear keys, any connection having cracked shear keys or bent bolts, keeper bar failure without unseating, rocker bearing failure or moderate settlement of the approach.

Figure 7.20: Bridge Hazard Map



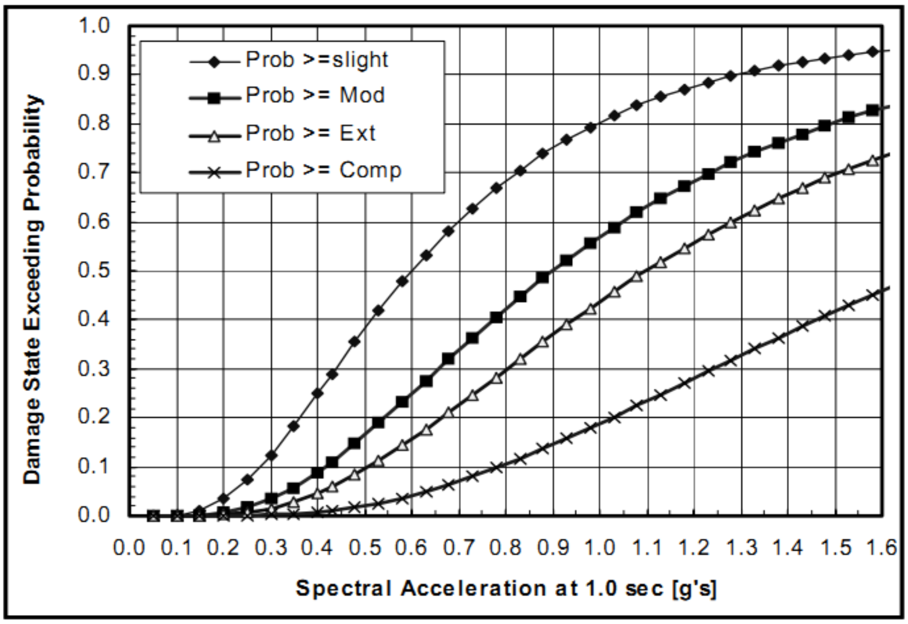
Source: Base on infrastructure services map and intensity map

Extensive damage (ds4) is defined by any column degrading without collapse- shear failure-(column structurally unsafe), significant residual movement at connection, or major settlement approach, vertical offset of the abutment, differential settlement at connection, shear key failure at abutments.

Complete damage (ds5), Is defined by any column collaping snd connection losing all bearing support,which may lead to imminent deck collapse, tilting of substructure due to foundation failure.

Bridges are the one of most importation Infrastructure service. When bridges are collapse all those facilities are block. Bridges behavior during an earthquake can be very complex. There are major three highway bridges in dhankuta municipality area. Bridges are located in the area of MMI VII and MMI VIII. One is located in intensity VII and two bridges are located in Intensity VIII. Since, Petrol pumps are located with having peak ground acceleration o.2 and 0.3 regions. Only those scenario earthquakes affecting these regions will negatively impact this facility type. Damage probability of bridges was assessed in Table 7.11.

Figure7.21: Damage Curve in Bridges



Source: (HAZUS-MH, 2003)

Table 7.11: Potential Damage Losses to Bridges

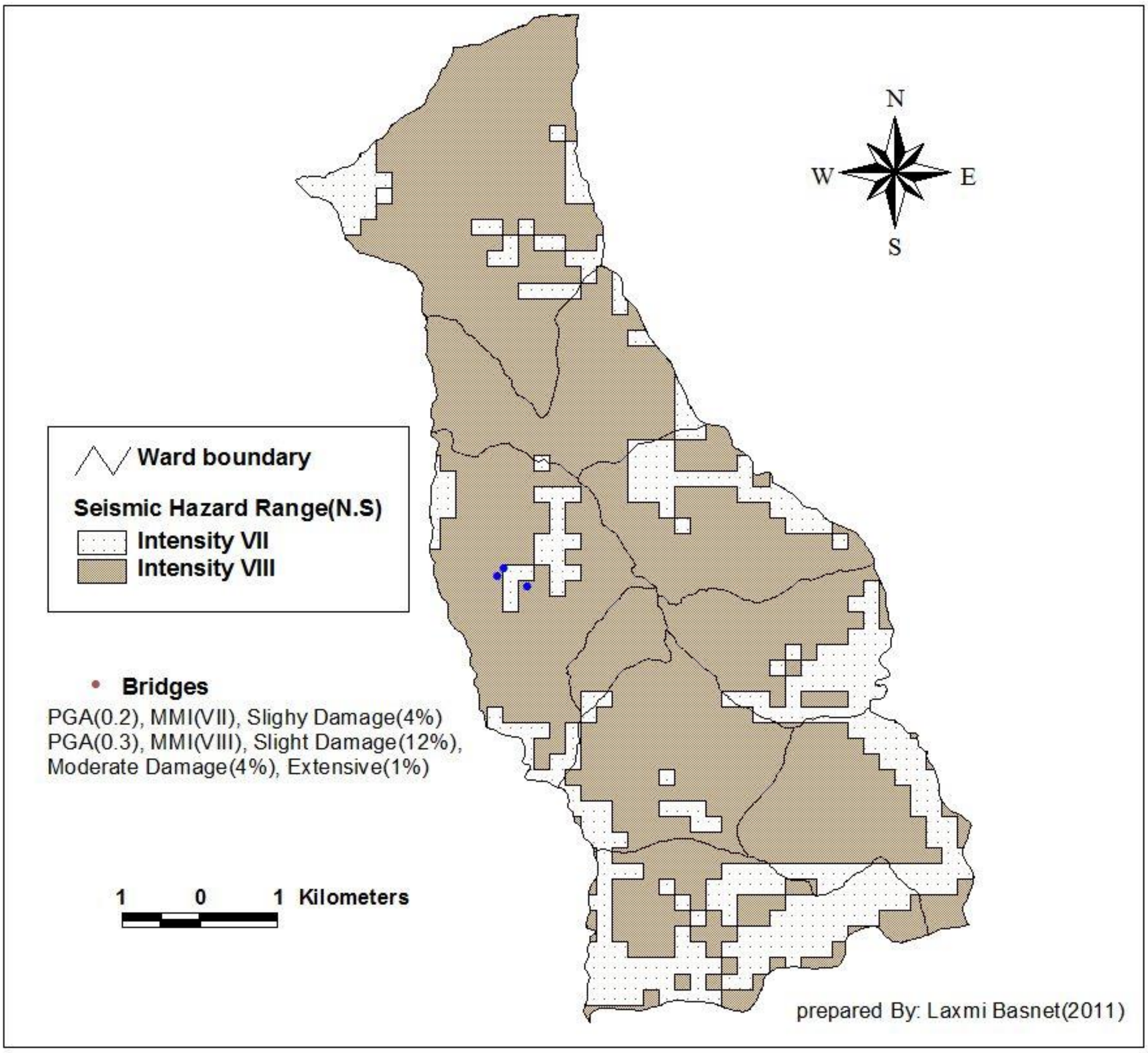
Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.2	4	-	-	-
Intensity 8	0.3	12	4	1	-

Source: Derived from figure 7.21

Direct damage data for bridge Table 7.11 indicate that this facility type would be severely impacted in scenario events. The impacts are most severe in the Magnitude 8. For these scenario earthquakes, 12% concrete tank would sustain slight/minor damage, 4% would sustain moderate damage, and 1% would sustain extensive damage.

The reason for the severe damage to bridge in the magnitude 7 and 8 is assumed to be strongly correlated with poor ground conditions and construction practices. Damage of bridges has been visualized in Figure 7.22.

Figure 7.22: Bridges Damage Map



Source: Base on infrastructure services map and intensity map

7.6 Vulnerability according to floor of building and Block by Road

According to number of floor of the buildings, among the total fourth or above fourth floor buildings, 6.25 percent were high vulnerable. Similarly 4.28 percent of the total three floor buildings, 0.25 percent of two floor buildings and 0.44 percent of the total one floor buildings were high vulnerable. It was found that, 93.75 percent of total four or above four floor, 79.14 percent of three floor, 25.00 percent of two floor and 12.93 percent of one floor buildings were medium vulnerable in the study area. Like this, in the low vulnerability classes, the three floor buildings consisted 16.58 percent where as 74.75 percent of the total two floor building and 86.63 percent of one floor buildings were found in this classes but there are no four or above four floor building in this category. In this way, we can conclude that, four or above four floor building were more vulnerable (high vulnerable) than the three and two floor buildings, it is shown in the table 7.12 below:

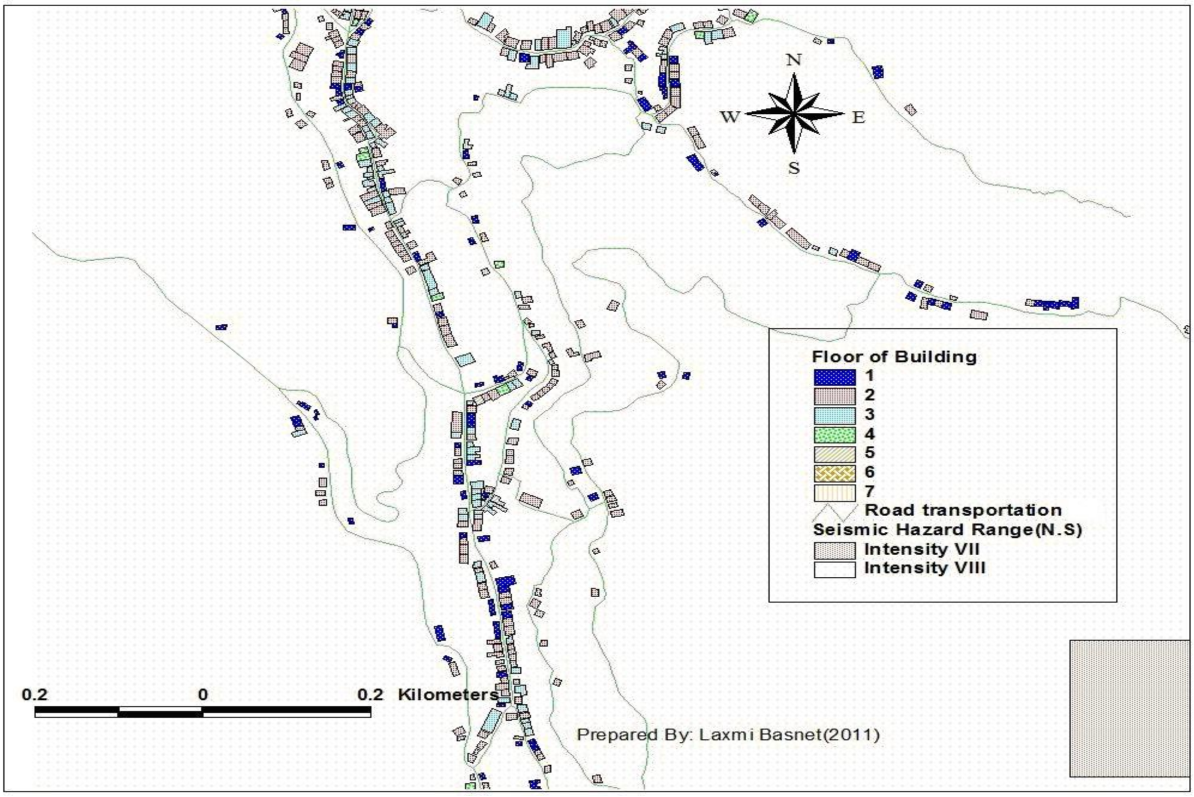
Table 7.12: Vulnerability according to floor of building

Vulnerability class	Number of buildings floors							
	1st	%	2nd	%	3rd	%	4th or >4th	%
High	5	0.44	7	0.25	16	4.28	1	6.25
Medium	146	12.93	692	25.00	296	79.14	15	93.75
Low	978	86.63	2069	74.75	62	16.58	0	0.00
Total	1129	100	2768	100	374	100	16	100

Source: Paudel, 2011

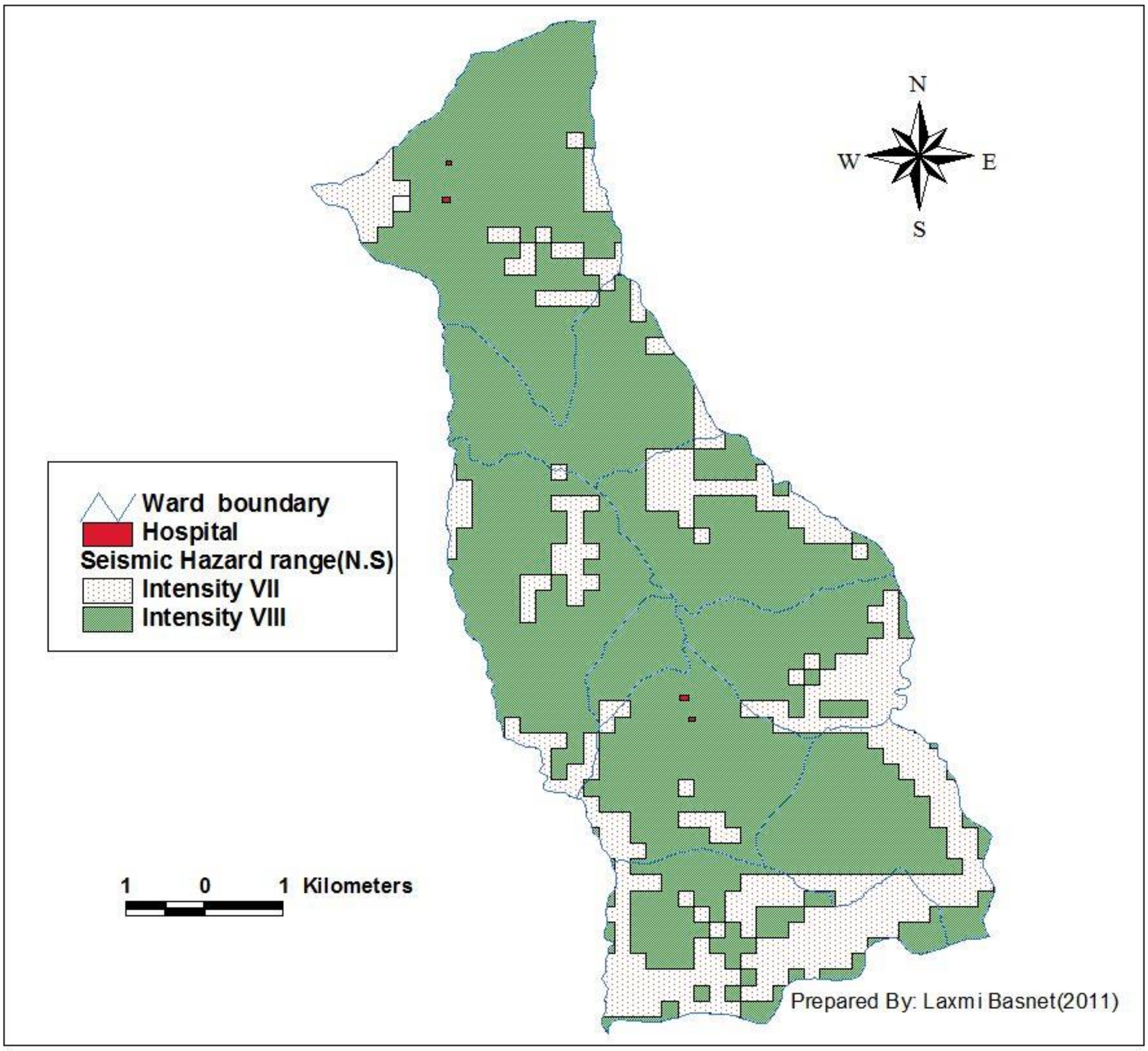
Table 7.12 show there are categories of building their damage level. We can also see and find out road nearby building in 1 to 7 floors. If earthquake may be come all infrastructure and building are damage and block by road. . It has been visualized road near building in the Figure 7.23:

Figure 7.23: Damage Building Block by Road in Dhankuta Municipality



Source: Paudel, 2011

Figure 7.24: Hospital Hazard Map



Source: Base on infrastructure services map and intensity map

Above figure 7.24 show total four hospitals are located in intensity VIII. MMI 8 is assumed to be strongly correlated with poor ground conditions and construction practices.

CHAPTER VIII

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary and Conclusion

The earthquake influence is depending on the level of magnitude, the time of the day when it occurs and the location of the community. Essentially, each dwelling has its own risk. Hazard exposure may vary throughout the neighborhood and the vulnerability is different for each building and infrastructure. Nepal is a high earthquake vulnerable country in the world. It has experienced several earthquakes in the past resulting in a large number of deaths and severe property damage. Situated in the Eastern part of Nepal, Dhankuta municipality is a administrative headquarters for the Eastern Development Region. Most of structures and infrastructure services are built up without seismic coding. The frequent occurrence of earthquake clearly demonstrates the urgent need of study of earthquake risk assessment of infrastructure services to reduce the impact of earthquake in the city. The devastating effect of an earthquake can be minimized to a great extent by hazard mapping, vulnerability analysis and risk mapping.

Infrastructure services are also highly intra- and inter-dependent systems. These can be damaged by collapsing houses or bridges or by landslides and riverbanks, the movement of which can be triggered by earthquakes. The malfunctioning infrastructure leads to immediate danger for people and longer threatening situations. However, most research focus on earthquake phenomenon rather than its possible impact. The impact of natural disasters such as earthquakes - which account for one of the highest losses amongst all types of disasters in terms of the number of people affected, the properties and infrastructure affected as well as the cost to the local, regional and global economy; is significant as well as alarming. The study indicates how vulnerable urban and regional systems (other than lifelines) are to the interruption of services like electricity, water, gas, and communication.

Vulnerability describes the probability of failure of structures under different levels of ground shaking, which can be expressed in percentage. Loss is caused by a particular seismic hazard to the type of structures under consideration. Vulnerability analysis is a function of magnitude of an event and the type of elements at risk. There are different types of vulnerability: physical, social and economic. Especially the social vulnerability is like constant population change through time. It can be in the form of urban expansion or change in population. Vulnerability to ground movement is determined by the structure itself. Therefore, the vulnerability of a system does not depend on the local seismic risk. In the study vulnerability indicates that a structure may be vulnerable in spite of being located in a seismically safe area. Physical vulnerability of an infrastructure is the expected as degree of direct damage to the physical infrastructure given in a specified level of hazard. It is portrayed by vulnerability curves, depicting the expected severity of damage associated with the level of hazard. Several criteria like, design code, shape, material, age, embankment height etc are used to develop the vulnerability curves.

Dhankuta municipality has been taken as the study to research the infrastructure services vulnerability assessment in an earthquake. The main theme of this study is to analyze the vulnerability, level of damage and hazard. It will be helpful to identify most vulnerable areas in the Dhankuta municipality.

The HAZUS method is a data demanding method. The HAZUS methodology requires various parameters, which can be categorized into four main parts: namely, earthquake characteristic parameters ground motion parameters, lifeline inventory classification and damage functions.

HAZUS method estimates the number of damages or the probability of a certain damage to be expected as result of an earthquake. The hazards considered in this vulnerability study were geological hazards, ground shaking and landslide have been considered in the estimation of the potential damage on case of a scenario earthquake resulting in intensities of VII and VIII in different parts of the Dhankuta Municipality.

The infrastructure vulnerability in different earthquake scenario assuming in different intensity are taken for this study. For the calculation of vulnerability of infrastructure, infrastructure damage matrix and GIS tools had been used and seismic intensity map also used for estimation of infrastructure vulnerability assessment. Three different earthquake scenarios namely; Udayapur Earthquake, North-Sunsari Earthquake and South-Sunsari Earthquake are used for to estimate intensity and infrastructure vulnerability.

To estimation the level of infrastructure damage in the study area, Udayapur Earthquake Scenario was considered as first possible hypothetical earthquake. It is likely to occur due to the active main boundary thrust fault which lies about 33 km south-west from the municipality which regarded as huge earthquake of 8.0 magnitudes.

The result shows that most of the buildings, infrastructure services(like Road, Electric transformer, telephone cabinet Water tank, Bridges etc) have a high probability of damage and collapse by a strong earthquake with an intensity of VIII in the study area. Mainly the buildings of the core area of municipality like Ward number 1 (Hile bazzar area), Ward number 5 (Mathilo Kopche, Tallo Kopche area), Ward number 6 (Bich bazzar, Siran bazzar area) and Ward number 7 (Hulak tole, Madan Chowk area) are high probable area for the loss or collapse of buildings, where the buildings are closely concentrates than urban periphery. Similarly Ward number 8 and 9 are less vulnerable area than other wards (paudel, 2011). There were also 1 to 7 floors building in nearby road, when collapse building sure road are block.

The road transportation in dankuta municipality is about 22.35km highway and 84.04km major trail long. The transportation consists mostly of earthen road and black topped road in bizar area also narrow. Transportation infrastructures are not only damaged by an earthquake itself but also by earthquake induced hazards. The main reasons that cause damages to roads are the deformation and movement of the ground. About 18.98km low, 3km medium, 0.37km high highway and66.86 low, 14.38km Medium, 2.67km high, 0.13km very high major trail road will damaged due to landslide.

In the case of water systems, electric network and telecommunication systems, It is shown that no damage occur at intensities below6, a moderate number of damage at intensities between 6-8, and at higher intensities there is a higher number of damages up to catastrophic cases for intensities VII and VIII. Reservoir tank has little chance to work after heavy earthquake.

There is one government district hospital and three privet hospitals in dhankuta municipality. There has been insufficient capacity of dhankuta hospital. To handle large number of victims, hospital bed, medical personals, and the capacity of the blood bank are not sufficient and also only one ambulance in their area.

At most places heavy vehicles like fire engines cannot move due to narrow roads. There is lack of search and rescue team and equipment. It would be better to manage them properly before disaster strikes.

9.2. Recommendations

On the basis of findings and conclusion, following recommendations have been forwarded to the related stakeholders and further researcher in below.

- The earthquake hazard cannot be controlled but its impact can be reduced by following infrastructure services while constructing.
- There is no base map and other information for earthquake in the municipality. So it is recommended that municipality has to be conscious in this regard.
- On the level of vulnerability condition of services Municipal authorities should launched mitigation programmes.
- Work on soil structure interaction of infrastructure structure.
- Awareness and preparedness programme should be launches in the municipality by concern institutions and the municipality itself.
- Verification of analytical results like period experimentally with up to data.
- Further study on economic and technical aspect of infrastructure would complete to this study.

REFERENCES

ATC-25 (Applied technology Council),(1991), *Seismic vulnerability and impact of disruption of lifeline in the conterminous united states*. FEMA/224, September1991.

BCDP. (2008), *Seismic fault line in Nepal*. Kathmandu. Building Code Development Project

Blaikie,P., Cannon,T.,Davis, I. and Wisner, B., 1996, *Risk: Natural Hazards, People's Vulnerability and Disasters,* Routledge, London and Newyork

CBS. (2001), *Statistical Pocket Book*, Central Bureau of Statistic, Kathmandu, Nepal

Chamlagain, Deepak and Vishnu Dangol, 2002, *Landslide Hazard evaluation in and around the Ilam Hydropower Project, Eastern Nepal Himalaya:* journal of Nepal Geological Society, 2002, vol. 27 (Special Issue). PP 131-143.

Chaudhari, S. (2008), *Lifeline Seismic Damage Evaluation in A GIS Environment: A Case Study of Ilam Municipality, Eastern Nepal*. M. A. thesis, Central Department of Geography, T.U.

Dixit, A.M.,(2003), *Community Based Initiatives in Earthquake Risk Management Process in Nepal,* National Society for Earthquake Technology-Nepal (NSET).

Dixit, Amod Mani, B.H. Pandey, R.C. Kandel, R.Guragain, S.N. Shrestha, M. Nakarmi, and S.P. Acharya. (2002), *School Earthquake Safety Program in procedeeings symposium in seismology earthquake hazard assessment and risk management*. 113-122, November(2002), Kathmandu.

DPNET. (2005). *Disaster Preparedness Network Nepal*. Activities Completion Report Series: 2. Kathmandu, Nepal: Disaster Preparedness Network.

DOMG. (2006), *Seismic Hazard Map of Nepal*. Kathmandu. Department of Mines and Geology.

FEMA. (1998), *Recommended Rapid Visual Screening Procedure,* Federal Emergency Management Agency (FEMA), National Institute of Building Sciences (NIBS), Washington DC.

Ghimire, S. (2008), *Application of RADIUS as an Earthquake Risk Management Tool in Panauti Municipality*. Master’s thesis, Environmental Science and Engineering, K.U.

Gulati, B., (2006), *Earthquake Risk Assesment of Buildings: Applicability of HAZUS in Dehradu*n, *India.* Msc Thesis, International Institute for Geo-Information Science and Earth Observation , Enschede

Guragain, J. (2004), *GIS for seismic building loss estimation: A case study of Lalitpur sub metropolitan city*. MSc thesis, the international institute for geo-information and earth observation(ITC), enschede, the Netherlands

HAZUS-MH. (2003), Multi-*hazard Loss Estimation Methodology Earthquake Model.* Technical Mannual. Department of Homeland Security, Washington D.C: Emergency Preparedness and Response Directorate FEMA

Islam, M.,(2004), *Population Vulnerability Assessment for Earthquakes in Lalitpur, Nepal.* MSc. Thesis, International Institute for Geo-Information Science and Earth Observation , Enschede

ISRC. (2008). *Municipality Profile of Nepal 2008.* Kathmandu: Intensive Study and Research Center.

Jaishi, B. (2001), *Seismic capacity evaluation of multi-tiered temples of Nepal*. T.U. Department of Civil Engineering.

JICA, (2001), *the study on earthquake mitigation in the Kathmandu valley, Nepal,* vol I, II, Japan International Cooperation Agency, main report(1/2): blueprint for Kathmandu valley earthquake disaster mitigation, Neppon koei co, ltd, Oyo cooperation.

Jimee, G.K. (2006), *Seismic Vulnerability and capacity Assessment at ward level;* A case study of ward No 20, Lalitpur Sub-Metropolitan city, Nepal. The international institute for Geo-information and Earth observation (ITC), Enscede, The Netherlands

Khanal, N. R. (1996), *Assessment of Natural Hazards in Nepal*, a report submitted to Research division, T.U., Kirtipur, Nepal.

Khanal, N. R.; Shrestha, M. Ghimire, M.(2007), *River Flood Disaster*, ICIMOD, Kathmandu, Nepal.

Khatiwada, N. (2008), *Seismic Vulnerability of Building: A Case Study of Ilam Municipality*. M. A. thesis Submitted to Central Department of Geography, TU.

Krovvidi, A. (2001), *GIS & Mapping for Seismic Risk Assessment, in Seismic risk assessment in India*, RMSI, New Delhi

Lake, P. (2006). *Physical Geography*. Delhi: Surjeet Publication.

LRMP. (1986), *Land Resource Mapping Project; Geological Report*. His Majesty government of Nepal and Government of Canada..

Marco, A. T. and Jose, A. C. (2002), *A lifeline vulnerability in Barcelona, spain: institute de geografia, UNAM, cd universitaria*, cp04510, mexico, departmento de ingeniervia de terreno, UPC, av. Gran capitan S/N campus road 08034 bercelona, Spain.(www.elesevier.com/locate/ress)

Menoni, S., F. Pergalani, M.P. Boni, V.Petrini. (2002), *Lifelines Earthquake Vulnerability Assesment: a Systemic Approch* (www.elsevier.com/locate/soildyn)

National Istititute of Building Sciences(NIBS). (1999), *HAZUS99 Technical and User's Manual. Washington DC*, USA, Federal Emergency Management Agency (FEMA)

Nevi D.D. (1977). *Earthquake, Celestial Arts*. 231, Adrian Road California: USA.

NGIIP. (1998), *Digital layer map of Dhankuta municipality in GIS Environment.* Kathmandu, National Geographic Information Infrastructure Programme: Department of Survey.

NSDRM. (2008), *National Strategy for Disaster Risk Management.* Kathmandu: Nepal

NSET. (2004), *Disaster Inventory/Information Management System in Nepal*. Kathmandu. National Society for Earthquake Technology (NSET) Nepal.

OALD. (2007), O*xford Advanced Learner's Dictionary of Current English*, Seventh Edition, Oxford University Press

Pandey, M.R. (1999), *Earthquakes and landslides; Resource Materials for Regional Training course on Landslide Hazard Management and Control in the Hindu Kush Himalaya Region (12 September- 2 October, 1999, Kathmandu Nepal),* vol. III: lecture notes, ICIMOD Kathmandu Nepal.

Paudel, B. (2011), *Seismic Vulnerability Assessment of Buildings in GIS Environment: Dhankuta Municipality, Nepal* M. A. thesis, Central Department of Geography, T.U.

Prasad, D. (2002). *Seismic Hazard Analysis for Janakpur Area*. M. Sc. thesis, Department of Civil Engineering, Pulchowk R.Guragain, Amod Mani Dixit, Erik Kjaergaard, 2002, *Seismic Vulnerability Assesnebt of Hospitals in Nepal: Structural Components*: *in procedeeings symposium in seismology earthquake hazard assessment and risk management*, 203-208, November 2002, Kathmandu.

RADIUS. (2000), Risk *Assessment Tools For Diagnosis of Urban Areas against Seismic Disasters.* Launched by IDNDR, United Nations, Digital Format

Rai, P. (2010), *Seismic Risk Assessment of Triyuga Municipality.* M. A. thesis, Central Department of Geography, T.U.

Rai, R. (2009), *Spatial Assessment of Seismic Vulnerability in Inarawa Municipality*. M. A. thesis, Central Department of Geography, T.U.

RUPP. (2008), *Digital layer map of Dhankuta municipality in GIS Environment.* Kathmandu, Rural Urban Partnership Programme.

Scott, R.C. (1989). *Physical Geography.* New York: West Publishing Comapany

Sharma, C.K. (1998), *Natural Hazards and Man Made impacts in the Nepal Himalayas*, published by Mrs Puspa Sharma, Bishal Nagar Kathmandu, Nepal.

Shrestha, D. (2009), *Seismic vulnerability assessment of building: in Bhadrapur municipality*. M. A. thesis, Central Department of Geography, T.U.

Singh, P. (2005), *Population Vulnerability for Earthquake loss estimation using community based approach with GIS,* Msc Thesis, ITC, Enschede.

SLARIM. (2002), *Strengthening Local authorities in Risk Management Proposal for the ITC Research program,* Unpublished, The International Institute for Geo-information and Earth observation(ITC), Enschede

Smith, K. (2001), *Environmental Hazards : Assessing Risk and Reducing Disaster,* London.

Sonar, S. (2009), *Seismic Vulnerability Assessment in Siddhrathanagar Municipality*. M. A. thesis, Central Department of Geography, T.U.

Timsina, C. (2011), *Seismic Hazard Analysis of Dhankuta Municipality Eastern Nepal*. M. Sc. thesis, Central Department of Geology, T.U.

TKP. (2011), Millions Face Worsening Crisis: Death toll likely to cross 10,000 mark. *The Kathmandu Post*. Kathmandu, 14 March 2011.Page 1.

TRN. (2011), Record Japan Quake Unleashes Tsunami. *The Rising Nepal*. Kathmandu, 12 March 2011. Page 1.

Tung, P.T. (2004), *Road vulnerability assessment in earthquakes : A case study of Lalitpur, Kathmandu, Nepal.* MSc. Thesis, International Institute for Geo-Information Science and Earth Observation (ITC), Enschede.

UNDP, (2004), *Living with Risk: A global review of disaster reduction initiatives.* In:ISDR(Editor), (2005), United Nations Publications, Geneva. '

UNDP. (1994), *Seismic Hazard Mapping and Risk Assessment for Nepal.* Government of Nepal, Ministry of Housing and Physical Planning. UNDP/UNCHS Habitat.

UNDP. (1994), *Seismic Vulnerability Analysis.* Government of Nepal, Ministry of Housing and Physical Planning. UNDP/UNCHS Habitat.

UNESCO. (1978), *Natural Hazards: The assessment and mitigation of earthquake risk*. Paris, United Nation Educational Scientific and Cultural Organization.

Van Westen, C. (2007), *Seismic Loss Estimation for Lalitpur, Nepal*. International Institute for Geo-information Science and Earth Observation(ITC), Enschede, The Netherlands.(http:/adpc.net/casita/introduction.html)

Van Westen, C. (2001), *Geo-information Science and Earth Observation for municipal risk management* : The SLARIM project: International Institute for Geoinformation Science and Earth Observation (Editor), Risk management. ITC, Enschede.

Villacis, C.A. and Cardona, C.N. (1996), *RADIUS Methodology- Guideline for the Implementation of Earthquake Risk Management Projects*, Palo Alto, California

http;//en.wikipedia.org/wiki/infrastructure (Retrieved on 6 January, 2011).

http;//www.earthquake.usgs.gov (Retrieved on 13 January, 2011).

http;//www.goole.com/crisisreponse/japan (Retrieved on 11 February, 2011).

http;//en.wikipedia.org/wiki/Lists_of_earthquake (Retrieved on 25 February, 2011).

http;//www.seismic.ethz.ch/GSHAP (Retrieved on 17March, 2011).

http;//en.wikipedia.org/wiki/disaster (Retrieved on 28 February, 2011).

http;//en.wikipedia.wiki/road (Retrieved on 3 April, 2011).

http;//cnn4.wordpress.com (Retrieved on 10 April, 2011).

http;//en.wikipedia.org/wiki/landslide (Retrieved on 1 June, 2011).

Appendix

Road Transportation in Dhankuta Municipality

ID	SURF_TYPE	TYPE	NAME	WIDTH	LENGTH(Mt)	FOOTPATH	CONDITION

Electric power systems in Dhankuta Municipality

TRANSF_ID	LOCATION AREA	CAPACITY_KV

Water Supply System in Dhankuta Municipality

Tank_ID	LOCATION	AGE	WARD NO	CAPACITY	PLACEMENT	TYPE	SOURCE AND DISTANCE	PIPE MATERIL	PIPE_SIZE

Telecommunication System in Dhankuta Municipality

CAPACITY	ID	LOCATION	DISTRIBUTION LINE	PLACEMENT	POLE MATERIALS	AVERAGE LENGTH	WARD NO.

Water Pipeline in Dhankuta Municipality

PIPELINE_ID	DIAMETER	LENGTH	MATERIAL	OVERAL CONDITION

Health services center in Dhankuta Municipality

TYPE	NO. OF BED	STAFF	REMARKS

Bridges in Dhankuta Municipality

AGE	MATERIALS	LENGTH	LOCATION	OVERAL CONDITION	REMARKS