CHAPTER I
INTRODUCTION

1.1 Background

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 killing or injuring the inhabitants. In every earthquake most of the loss of life and property is caused by the damage of weakest buildings 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).

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. History shows that the Nepal has experienced a number of major/minor earthquakes even during the last century and thousands of people have lost their lives during that disaster. The devastating earthquakes in the past have proved the vulnerability of most of the vernacular building of Nepal (Sah, 2003).

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).

In most generic sense, the word ea rthquake is used to describe any seismic event—whether a natural phenomenon or an event caused by humans—that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by volcanic activity, landslides, mine blasts, and nuclear experiments. An earthquake's point of initial rupture is called its focus or hypocenter. The term epicenter refers to the point at ground level directly above this.

An earthquake is the result of a sudden release of energy in the earth's crust that creates seismic waves. Earthquakes are recorded with a seismometer, also known as a seismograph. The moment magnitude of an earthquake is conventionally reported, (or the related and mostly obsolete Richter magnitude) with magnitude 3 or lower earthquakes is mostly imperceptible and magnitude 7 causing serious damage over large areas. Intensity of shaking is measured on the modified Mercalli scale.

At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacing the ground. The shaking in earthquakes can also trigger landslides and occasionally volcanic activity.

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 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 form 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).

Figure 1.1 Relationship of seismic focus, epicenter and homoseismal lines

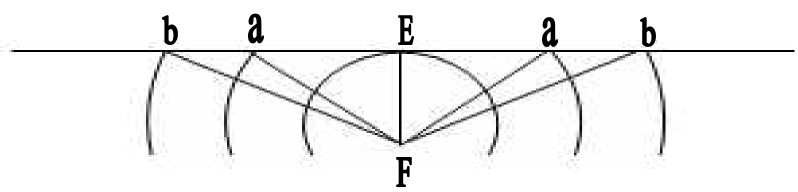


Figure 1.1 illustrates the seismic focus (F), epicenter (E), and wave radiating form the focus of an earthquake in an area. The diagram represents conditions near the epicenter. Lines, Fa, Fb called homoseismal lines, are drawn through places which were affected by the earthquake at the same movement. These lines are generally elliptical in shape, and middle of the ellipse is the epicenter. The actual place or origin of the ellipse is below the epicenter.

Within the last 33 year (1971-2003), Nepal experienced 22 earthquakes with magnitudes ranging from 4.5 to 5.6 Richter scale. In this time span about 34000 buildings were destroyed and 56000 were damaged. More than 126 million dollars was lost because of earthquakes during this time span (NSET, 2004).

Nepal lies in Himalayan region and the Himalayan region is probable area of earthquake. So Nepal is highly earthquake probable area of the world. Figure 1.2 shows the distribution of seismic hazardous area in Nepal.

Figure 1.2 Seismic Hazard in Nepal

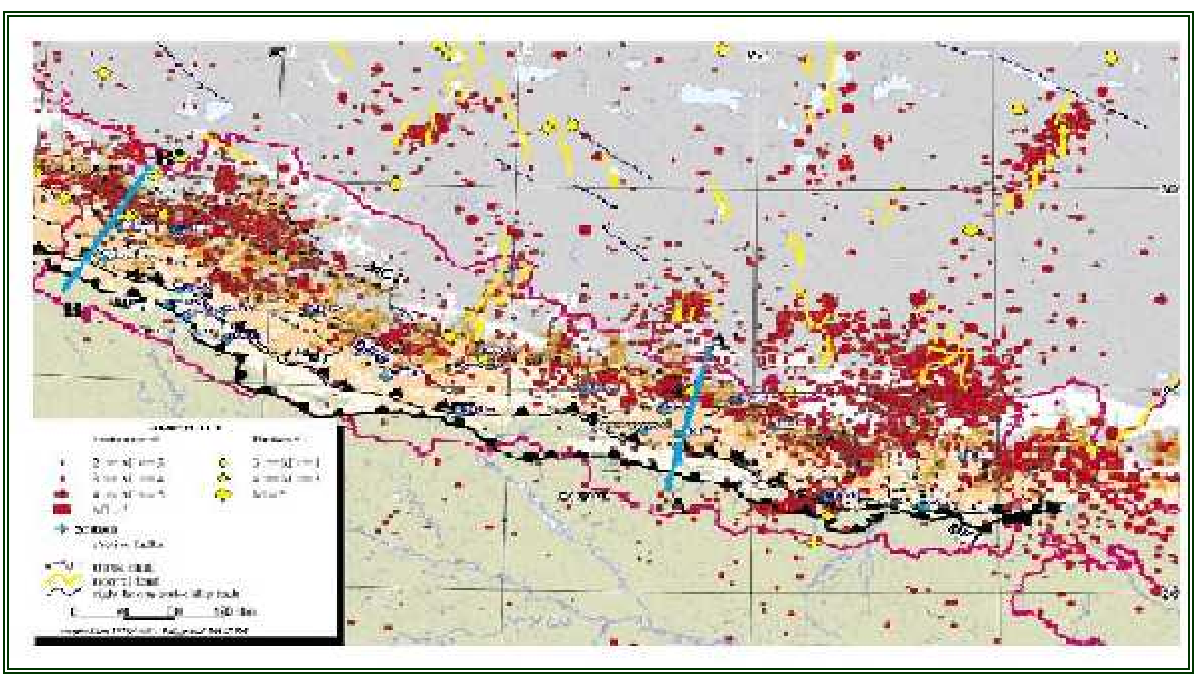
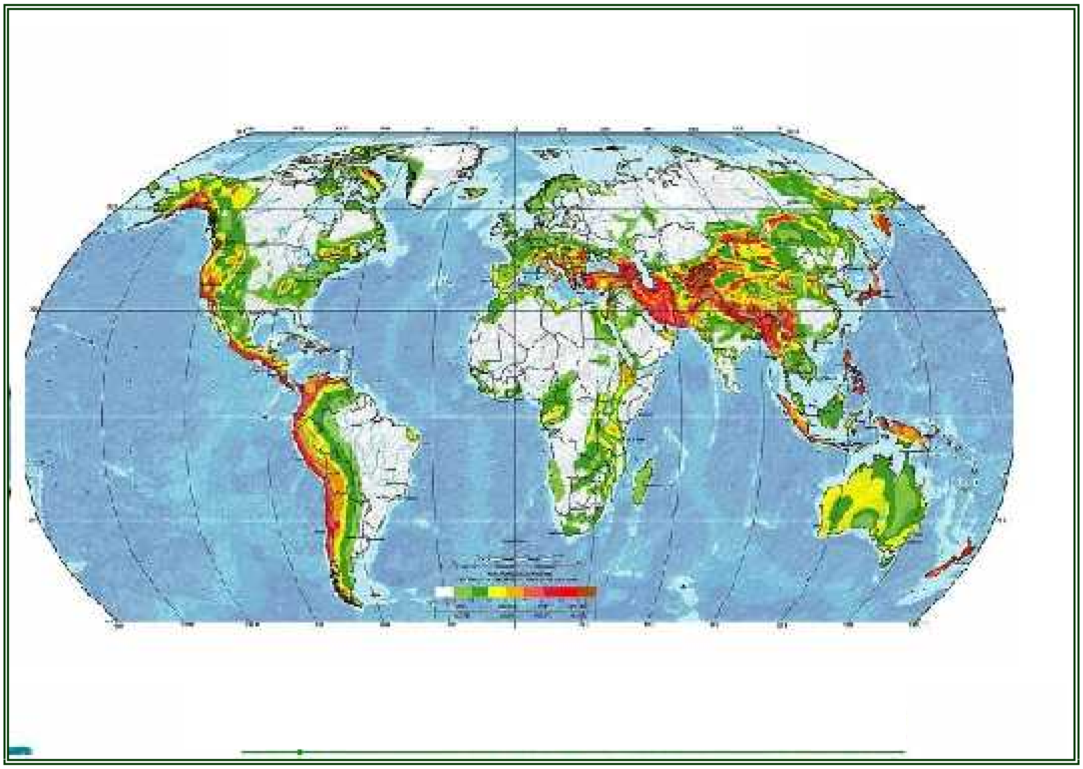


Figure 1.3 shows the seismic hazard area of the world. South west and south east Asia, western part of North and South America are highly probable area of earthquake.

Figure 1.3 Global Seismic Hazard Zones



Urban areas, which are center for huge population concentration, economic and industrial activities are the most vulnerable location for earthquake disaster. The magnitude of earthquakes in cities and towns are comparatively higher than the other areas.

1.2 Statement of the Problem

Nepal has comparatively high hazard potentials due to its location within seismic zones. The great earthquake that occurred in 1990 B.S. it was of 8.4 Richter scale and it took 8,519 people's lives, 126,355 houses damaged and 80,893 buildings completely destroyed. Similarly, the second great earthquake of 2045 BS destroyed 65,432 buildings, caused deaths of 721 lives and 6,553 people especially Dharan north eastern part suffered form that incident. There are further potentialities of occurrence of such incidents in future too. However such losses and damage can be minimized if proper preparedness is formulated and implemented.

Inaruwa municipality which lies in eastern tarai area of Nepal has no any organizations either in government or in private sectors to work earthquake risk reduction. The municipality has experienced continual growth of population, high rate of unplanned urbanization, lack of appropriate technology in construction of buildings, lack of basic infrastructure and lack of awareness. As the experiences of past earthquakes shows that the losses of life and property area cased due to the concentration of buildings at seismically weak area and lack of use of appropriate technology during construction of buildings as well as lack of awareness. In the municipality, the existence of old buildings in the core area and new buildings construction without proper land use planning as well as with inappropriate technology has made this city more vulnerable. Therefore, it is necessary to evaluate the level of susceptibility of building to earthquake hazard and also explore the most vulnerable area for earthquake hazards. The seismic risk assessment of the buildings and population helps to estimate the expected losses of property and life incase of hazards. It is in this context, the present research seeks to explore the existing conditions and the basis to develop strategy for reducing the risk and vulnerability of earthquake hazards, as well as the identify earthquake risk and estimate the damage due to the probable earthquake in the municipality.

1.3 Research Objectives

The main objective of this research is to asses the building vulnerability for earthquake hazard and the specific objectives of this research are as follows:

- to identify the nature and types of building in Inaruwa municipality;
- to estimate the building vulnerability and causalities under different probable earthquakes; and
- to identify the knowledge and awareness of earthquake in Inaruwa municipality;

1.4 Importance of the Research

Earthquake is one of the most frightening and destructive phenomena of nature. Earthquakes strike suddenly, violently, and without warning at any time of the day or night.

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. 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 area 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 building, 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. In this context, the present research mainly based on to reduction of vulnerability of buildings and population due to earthquake hazard could be important one. It also coved play role to improve the awareness to life and building as well as property from earthquake.

1.5 Limitation of the Research

This research has analyzed particularly the earthquake hazards. The research has estimated the causalities related to buildings damage and collapse based on the probability of earthquake scenarios that occurred in different periods at different parts of the country. The explanations are made with the data that were collected through the methods discussed in the methodology section and with limited expertise in this technical field. Therefore, the findings based on the particular local conditions of Inaruwa municipality may not replicate in the situation of other municipalities of the country.

CHAPTER II

REVIEW OF LITERATURE

2.1 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. Figure 2.1 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 (http://en.wikipedia.org/wiki/Earthquake).

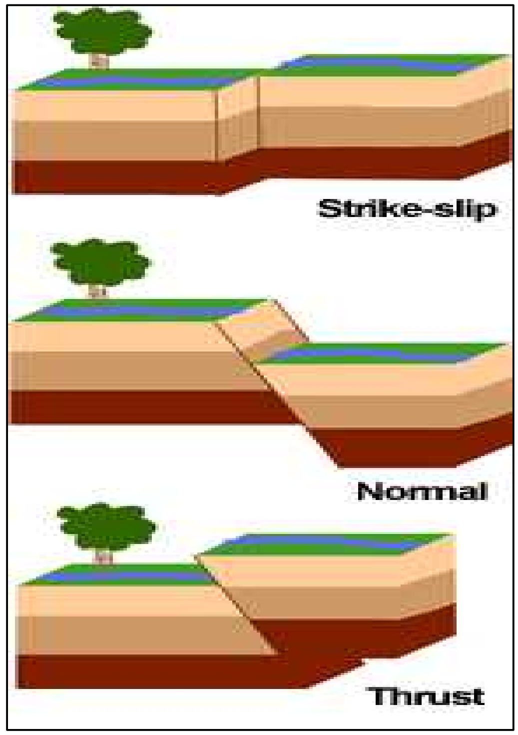


Figure 2.1

The entire process of plate formation, movement, and destruction is known as plate tectonics. First proposed during the 1940s, plate tectonic theory gained widespread acceptance during the late 1950s and 1960s. The movements of the lithospheric plates are caused by the frictional drag of convection current in the underlying asthenosphere. These currents are produced by heat released by nuclear decay of radioactive elements in the mantle and core. Upwelling mantle plumes result in the formation and divergence of new oceanic crust along the oceanic ridge systems. A collision between two plates having different densities results in the subduction and destruction of the denser plate as it is forced downward into the mantle.

The melting and surfaceward movement of some of the lighter and more volatile components of the subducted plate create continental crust material, which is volcanically erupted onto the surface (Scott, 1989).

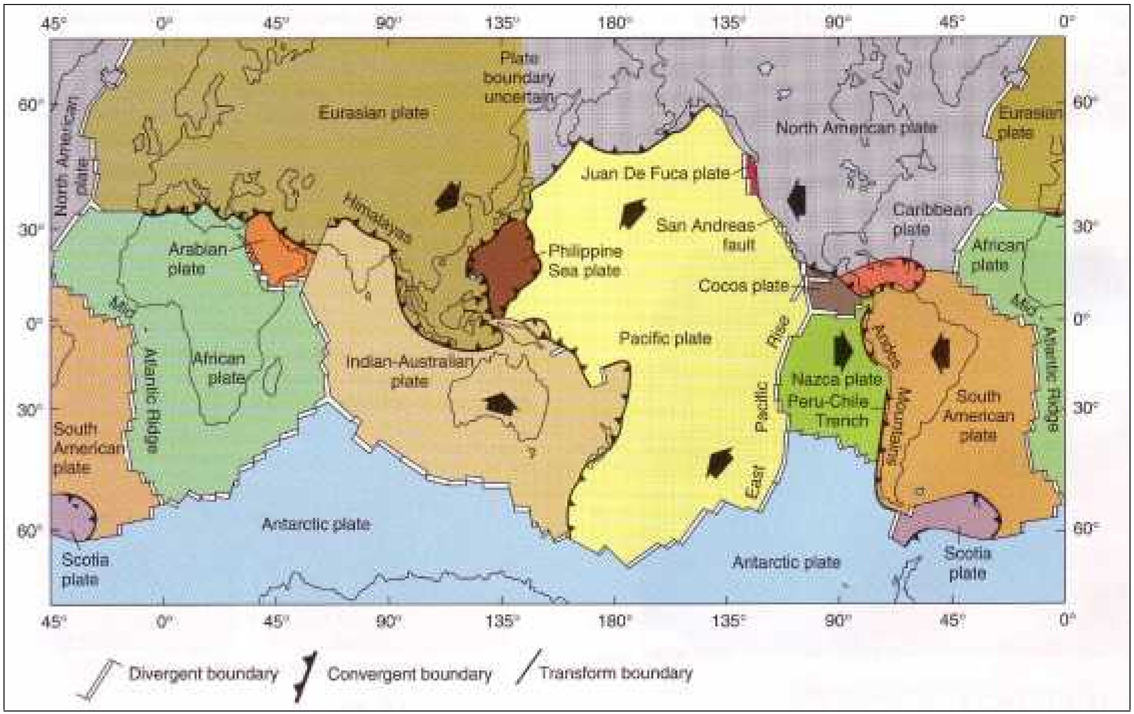
The place on the earth's surface directly above the point on the fault where the earthquakes rupture began. Once fault slippage begins is known as epicenter, it expands along the fault during the earthquake and can extend hundreds of miles before stopping.

The distribution of earthquake is essentially identical to that of active faults; they are concentrated along lithosphere plate boundaries, especially those where convergence and active sub-duction are taking place. Because these boundaries are frequently the sides of active tectonic uplift earthquake on land generally are concentrated in mountain regions (Scott, 1989).

Plate boundaries along the earth surface helps to understand the seismic activities that localized within the globe. The relationship of the plate boundaries could be pointed into three types these are:

1. **Transform boundaries** occur where plates slide or, perhaps more accurately, grind past each other along transform faults. The relative motion of the two plates is either sinistral (left side toward the observer) or dextral (right side toward the observer). The San Andreas Fault in California is example of such types.
2. **Divergent boundaries** occur where two plates slide apart from each other. Mid-ocean ridges (e.g., Mid-Atlantic Ridge) and active zones of rifting (such as Africa's Great Rift Valley) are both examples of divergent boundaries.
3. **Convergent boundaries (or *active margins*)** occur where two plates slide towards each other commonly forming either a subduction zone (if one plate moves underneath the other) or a continental collision (if the two plates contain continental crust). Deep marine trenches are typically associated with subduction zones. The subducting slab contains many hydrous minerals, which release their water on heating; this water then causes the mantle to melt, producing volcanism. Examples of this type are the Andes mountain range in South America and the Japanese island arc.

Figure 2.2 Plate Boundaries



Source: Plummer, Geary and Carlson, 2003

Figure 2.2 represents the major plates of the world with location. Double lines shows diverging plate boundaries, single lines shows transform boundaries. Heavy lines triangles show converging boundaries; triangles point down subduction zones.

Khatiwada (2008) refers to Pandey to the description of characteristic effect on the scale of earthquake intensities and approximately corresponding magnitude. He has measured intensity in MMI, maximum acceleration in gram and magnitude. The scale earthquake intensity and approximately corresponding magnitude is summarized and shown in Table 2.1. It shows the earthquake intensity effect on buildings, infrastructures, and people. Intensity I is not noticeable by human it is only detected by seismometers. Similarly, intensity III is slightly vibration that people can fell of earthquake that magnitude range refers 3.5 to 4.2. Similarly, intensity VII and VIII are very strong and destructive that range of 5.5 to 6.9 magnitude. It destroys the walls and poorly constructed buildings.

In 2037 BS was 6.5 Richter scale of earthquake in Nepal. This quakes were especially in far western region, mostly affected – Baitadi, Bajhang, Darchula, 125 people dead, 248 seriously injured, 11,604 buildings destroyed, 13,414 buildings were damaged (NSET 2009).

1990 Earthquake, Known as Great Nepal Bihar Earthquake, the magnitude of the earthquake was 8.4 on the Richter scale. Casualty figures were highest for any recorded earthquake in the history of Nepal. In total 8519 people lost their lives in Nepal, a total of 126355 houses were severely damaged and around 80893 buildings were completely destroyed (www.nset.org.np_earthquake_history.php1.htm).

Table 2.1 Scale of Earthquake Intensities & Approximately Corresponding Magnitudes

Intensity (MMI)	Description of Characteristic Effect	Maximum Acceleration (g)	Magnitude
I	Instrumental: detected only by seismometers	0.001	
II	Feeble: notice only by sensitive people	0.0025	
III	Slight: like the vibrations due to a passing truck, felt by people at rest, especially on upper floor.	0.005	3.5 to 4.2
IV	Moderate: felt by people while walking, rocking of loose objects including standing objects	0.01	4.3 to 4.8
V	Rather strong: felt generally; most sleepers are awakened and bell rings	0.025	
VI	Strong: trees sway and all suspended objects swing: damage by overturning and falling of loose objects	0.05	4.9 to 5.4
VII	Very strong : general alarm, wall cracks, plaster falls	0.1	5.5 to 6.1
VIII	Destructive: car driving seriously disturbed, masonry fissured, chimney falls, poorly constructed building damaged	0.25	6.2 to 6.9
IX	Ruinous: some houses collapse where ground begins to crack and pipes break open	0.5	
X	Disastrous: ground cracks badly, many building destroyed and railway lines bent, landslides on steep slopes	0.75	7 to 7.3
XI	Very disastrous: few building remain standing, ridges destroyed, all services(railway, pipes and cables) out of action, great landslides and floods	1.0	7.4 to 8.1
XII	Catastrophic: total destruction, objects thrown into air, ground rises and fall in waves		>8.1

Source: Pandey, 1999, Cited in Khatiwada (2008)

2.2 Earthquakes Effect on Buildings

The earthquake hazard is complex in that it may have numerous direct and indirect effects on the earth's surface. Among the direct surface effects area ground motion form seismic waves or tectonic movement of the surface that earthquake may occur any where and it can directly effect on buildings as well as human lives and property. The great earthquake of Nepal 1990 BS took 19,000 buildings heavily damaged (see photograph 4, 5, 6). Similarly, another great earthquake 2045 BS were destroyed 71,373 buildings and 721 people killed by this earthquake (photograph 3). Similarly, the earthquake of Turkey (1967) destroyed 5,000 houses, killed 86 people and injured 332 (NSET, 2008).

The Nugata earthquake of Japan (1964) was characterized by damage of reinforced concrete buildings resulting from liquefaction of sandy layers of soil. The damaged buildings were concentrated in an area of recently abandoned water course, where fine sandy, soils saturated with ground water were thickly deposited. It has resulted 26 casualties of human lives together with 447 injury and damage 15,000 houses by motion, fire or flood. Los Angeles earthquake (1971) had 6.6 Richter magnitudes that destroyed 20,000 houses were damaged.
The worldwide trend towards urbanization on or near areas of high seismic risk would indicate that the potential for earthquake damage and death is increasing rapidly and without adequate human adjustment to the hazard (White, 1977).

2.3 Naturals Hazard in Nepal

Natural hazard such as flood, landslide, earthquake, fire, cyclone storms and hailstorms, cloudburst, draught, famine and epidemic are common hazards that Nepal has been facing frequently. The events during 1971- 2006 reveals that epidemics have taken the largest toll of life every years, likewise landslide, flood and fires are the other major hazards in terms of their extent and frequency of occurrence spread and impacts. Exponential urbanization growth over the past decade with general disregard of earthquake- resistant measures in building construction is the major table cause of ever-increasing earthquake risk. Table 2.2 shows the losses due to the disasters in Nepal during 1971 – 2006 (NSDRM, 2008).

NSDRM has recorded (table 2.2) the disasters in Nepal since 1971 to 2006. Disasters took death of 26,656 people, 49570 injuries and 4,715,828 people are affected. Similarly, 188,875 buildings partially destroyed and 5,482 are damaged by natural hazards.

Table 2.2 Disaster Losses in Nepal During 1971- 2006 (37 Years)

Events	**Human**			**Building**		**Land loss (Ha.)**	**Livestock death**	**Reported direct loss million**
	Death	**Injury**	**affected**	**Destroy**	**Damage**			
Drought	1		1,512			329,332		10
Earthquake	873	6,842	4,539	33,710	63		2,257	22.8337
Epidemic	15,529	37,773	323,896			1	78	0
Fire	1,081	735	218,128	62,634	2,762	352	113,922	6,244
Flood	2,864	349	3,315,781	70,115	1,041	196,955	31,117	3,713
Forest fire	24	13	10,178	1,698	18	3,173	82	1,031
Landslide	3,899	1,188	480,069	16,779	1,209	21,797	9,046	835
Others	2,385	2,670	360,725	3,917	388	290,323	79,935	2,030
Total	**26,656**	**49,570**	**4,715,828**	**188,875**	**5,482**	**841,954**	**236,459**	**13,885**

Notes:

1 Epidemics means peoples seriously affected, hospitalized etc by epidemic events

2 The number "o" does not mean that the events were not occurred, it does mean the event is not reported.

Source: National Strategy for Disaster Risk Management (NSDRM), 2008

2.4 Earthquakes Studies in Nepal

Nepal has experienced a large numbers of devastating earthquakes in the past. The recorded history shows that earthquakes in different time period and number of loss of life and property in different part of the country (table 2.4).

Figure 2.3 Seismic Zone of Nepal

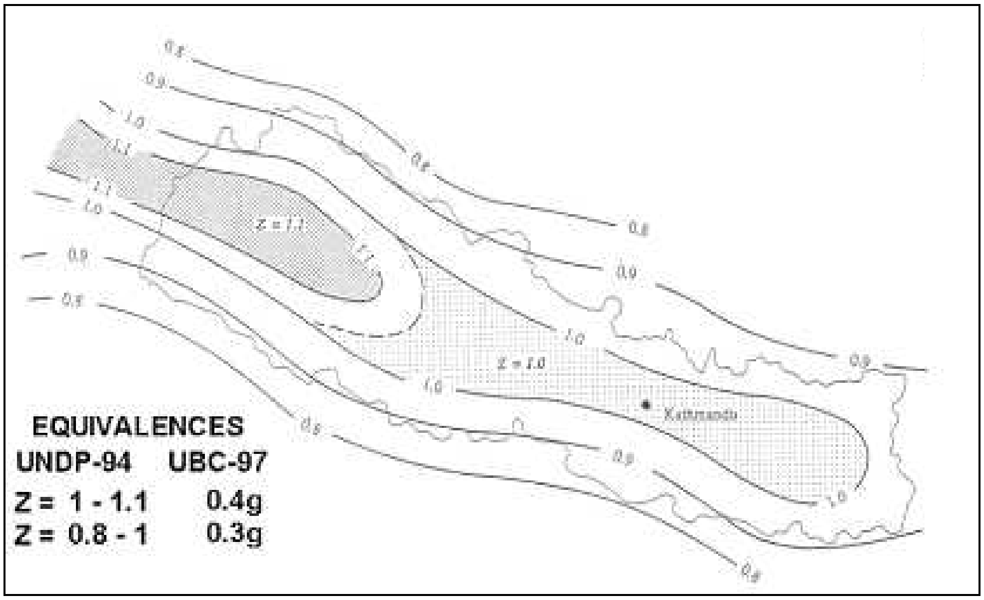
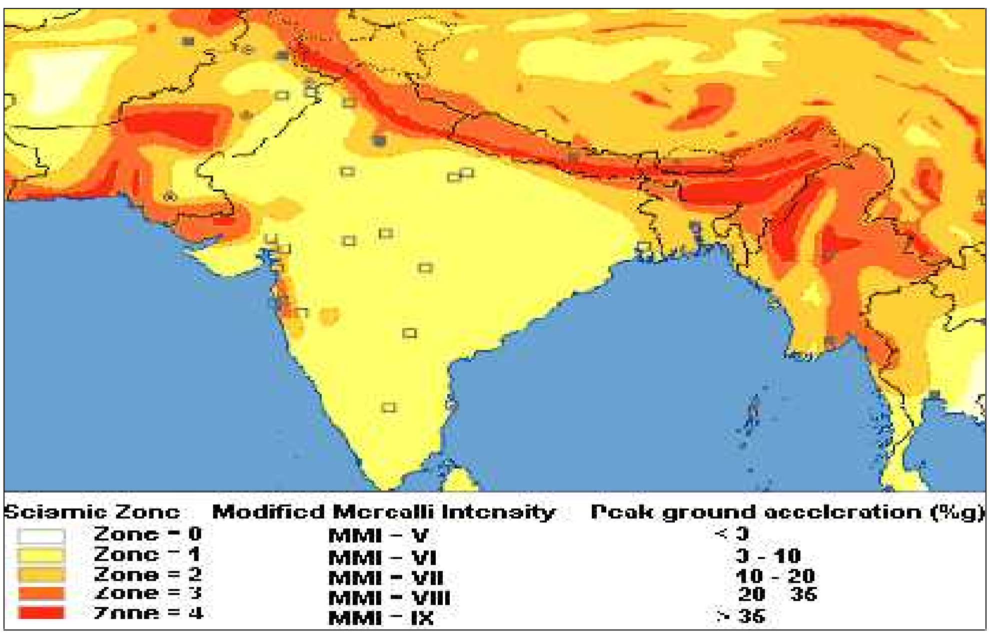


Figure 2.4 Seismic Hazard Map of Nepal



Source: NSDRM, 2008

Nepal lies in a high earthquake intensity belt: almost the whole of Nepal falls in high seismic risk scale of MMI, IX and Xi for the generally accepted recurrence period (figure 2.4). The seismic zoning map of Nepal (figure 2.3), which depicts the primary (shaking hazard), divides the country into three zones elongated in northwest-southeast direction; the middle part of the country is slightly higher than the northern and the southern parts. The flat plains of Tarai in the south of the country show the highest level of susceptibility to liquefaction. The middle hills and the higher mountains are highly susceptible to landslides including earthquake–induced ones.

In the 1934 earthquake damaged 19,000 buildings and 38,000 people were killed and 1,000 people were seriously injured only in Kathmandu valley (JICA, 2002, cited in Guragain, 2004). After 1934, the central part of Nepal has suffered few earthquakes and according to Bilham (1995) the zone may be a “seismic gap” and a huge earthquake could occur when the accumulated stress is released (Guragain, 2004).

Table 2.3 represents the direct losses of property and lives form earthquake since 1970 to 2003. The total events of earthquake has recorded by NSDRM, the 876 people death, 6,840 injured and 4,539 people are affected by earthquake. Similarly 33,706 buildings were destroyed and 55,234 were damaged by earthquake in different times of history in Nepal.

Table 2.3 Direct Losses due to Earthquakes (1970-2003)

Item	Number	Value of Direct Losses (NR)
Total number of events	22	
Death	876	
Injury	6,840	
Affected	4,539	
Building Destroyed	33,706	8,200,838,000
Building Damage	55,234	1,309,606,450
Livestock death	2,215	11,075,000
Total loss at present value (NR)		9,566,605,507
Average loss per year due to earthquake		289,897,136

Source: NSDRM, 2008

NSET (2006) prepared historical of earthquakes incident in Nepal with covering chronologically by years, date of earthquake epicenter, human deaths, injured, building collapse and building damaged. NSET reported that 40% buildings were estimated to be affected in 1993 earthquake.

Table 2.4 Major Earthquakes in Nepalese History

Year	Date	Earthquakes epicenter	Human deaths	Human injured	Building Collapsed	Building Damaged
1255	7 June	NA	One third of total population including king Abhya Malla, killed		Many buildings and Temple collapsed	
1260	NA	NA	NA	NA	NA	NA
1408	NA	NA	Heavy		Heavy	
1681	NA	NA	NA	NA	NA	NA
1767	June	NA	NA	NA	NA	NA
1810	May	NA	Moderate		Heavy	
1823	NA	NA	NA	NA	NA	NA
	25 Sep	NA	NA	NA	NA	NA
1833	26 Aug	NA	NA	NA	18000 in Total	
	11 July	NA	NA	NA	NA	NA
	13 July	NA	NA	NA	NA	NA
	26 Sep	NA	NA	NA	NA	NA
1834	Sep-Oct	NA	NA	NA	NA	NA
1837	17 Jan	NA	NA	NA	NA	NA
1934	15 Jan	Bihar/Nepal	8519	NA	80893	126355
1980	4 Aug	Bajhang	46	236	12817	13298
1988	21 Aug	Udayapur	721	6453	22328	49045
1993	NA	Jajarkot	NA	NA	40 % of Buildings are estimated to be affected	
2002	NA	Mahottari	NA	41	NA	NA
2003	NA	Syangja	1	2	NA	NA
Note: "NA" indicates 'description not available'.						

Source: NSET, 2006

2.4 Literature Review of Past efforts on Seismic Vulnerability Assessment in Nepal

Khanal (1996), on his report "Assessment of Natural Hazard in Nepal" has discussed that among different natural hazards like landslide, flood, storm, drought, etc. the losses and damage by earthquake is extremely high. The author mentioned that in Nepal more than 16 earthquakes of big magnitude have been reported since 1255. The earthquake hazards mitigation measures such as early warning and other preventive works is not effective even in present days. So concluded, building codes system is encouraging to people to construct either earthquake proof buildings or invest less in building infrastructure could be measures to reduce the risk. Likewise, effective emergency management may be most effective ways in this connection.

Siwakoti (2000), 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.

Jaishi (2001), evaluated the seismic capacity of multi- tired temples in Nepal for future earthquakes on within topic "Seismic Capacity Evaluation of Multi- Tiered Temples of Nepal". The results show that masonry temples in Nepal of ancient times are more rigid than contemporary period.

Guragain (2004), carried out a study on "GIS for seismic building loss estimation, a case study, of Lalitpur sub- metropolitan city area". Building survey was performed to collect information on the material and occupancy types of building in this area. The study area was divided into 500 small clusters having homogeneous characteristics in terms of building occupancies and the predominant building information was collect from this cluster in percentage. These percentage values were converted in the number of building per cluster. The vulnerability relation developed by NSET Nepal and NGO working in earthquake vulnerability reduction was used and a series of GIS operation were performed to link this relation to the building type in study area. Building damage estimation was carried out for three expected scenario earthquakes that were used in a JICA study in 2001. For the different earthquake scenarios, the total numbers of damage building were estimated ranging from 1,654 to 22,293 in the worse case scenario to correspond to an 8 magnitude earthquake near by Kathmandu area.

Jimee (2006), made a study on "Seismic vulnerability and capacity assessment at ward level, a case study of ward no 20 of Lalitpur sub-metropolitan city, Nepal". The report estimated building damage and collapse probability for individual buildings based on their conditions and earthquake intensity using damage matrix prepared by JICA and NSET. The same estimation was made for different possible earthquake scenarios defined by previous researcher. An effort was made to develop a method, which can be adopted by municipal authorities in order to assess the vulnerability and to increase the level of capacity of local people. The stud estimated of the building collapse probability and casualties for several earthquake scenarios based on the capacity of local people to cope with earthquake risk in the area.

Westen (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.

Ghimire (2008), study on “Application of RADIUS as an earthquake risk management tool in Panauti municipality”, her major objectives is to estimate the building damage causalities and lifelines under different probable earthquake scenarios and to understand about the use of RADIUS tools as an earthquake risk management tools in Panauti Municipality. Researcher consider two scenario earthquakes, namely North Banepa earthquake and 1934 Earthquake for her study and found that North Banepa earthquake regarded as possible earthquake (due to existing active faults) where as 1934 Earthquake was consider as reoccurring historical earthquake. The overall casualties after the application of RADIUS, from the first scenario

Earthquakes North Banepa earthquake are 63 deaths and 641 injured out of the total 14674 population in the municipality. Out of 5134 buildings, 22 % are destroyed. Same earthquake during the nigh time will result into 1505 injuries and 150 deaths out of total 25567 populations.

In case of second scenario, i.e. 1934 earthquake it resulted only 1 death and 13 injuries. Same earthquake during night time will also result to 1 death and 31 injuries. She concluded that more damage in term of causalities and destruction of building were observed in North Banepa earthquake than in 1934 Earthquake due to shorter distance to the active fault, which are lies about 20 km. north of Panauti municipality. She further found that on her surveyed 62 percent houses in good condition, where as 28 percent in bad, 8 percent were in excellent and 2 percent in worst condition. 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 its management.

Khatiwada (2008), studied “Seismic vulnerability of building: a case study of Ilam municipality”. The main objective was to determine the collapse and damage probability of buildings 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 are more venerable and it has high probability to damage or collapse. Brick in cemented building (less than 2 floors) have less probability to damage. He has emphasized that building height and geometry are important parameters for the loss of building during earthquakes.

2.5 Research Gaps

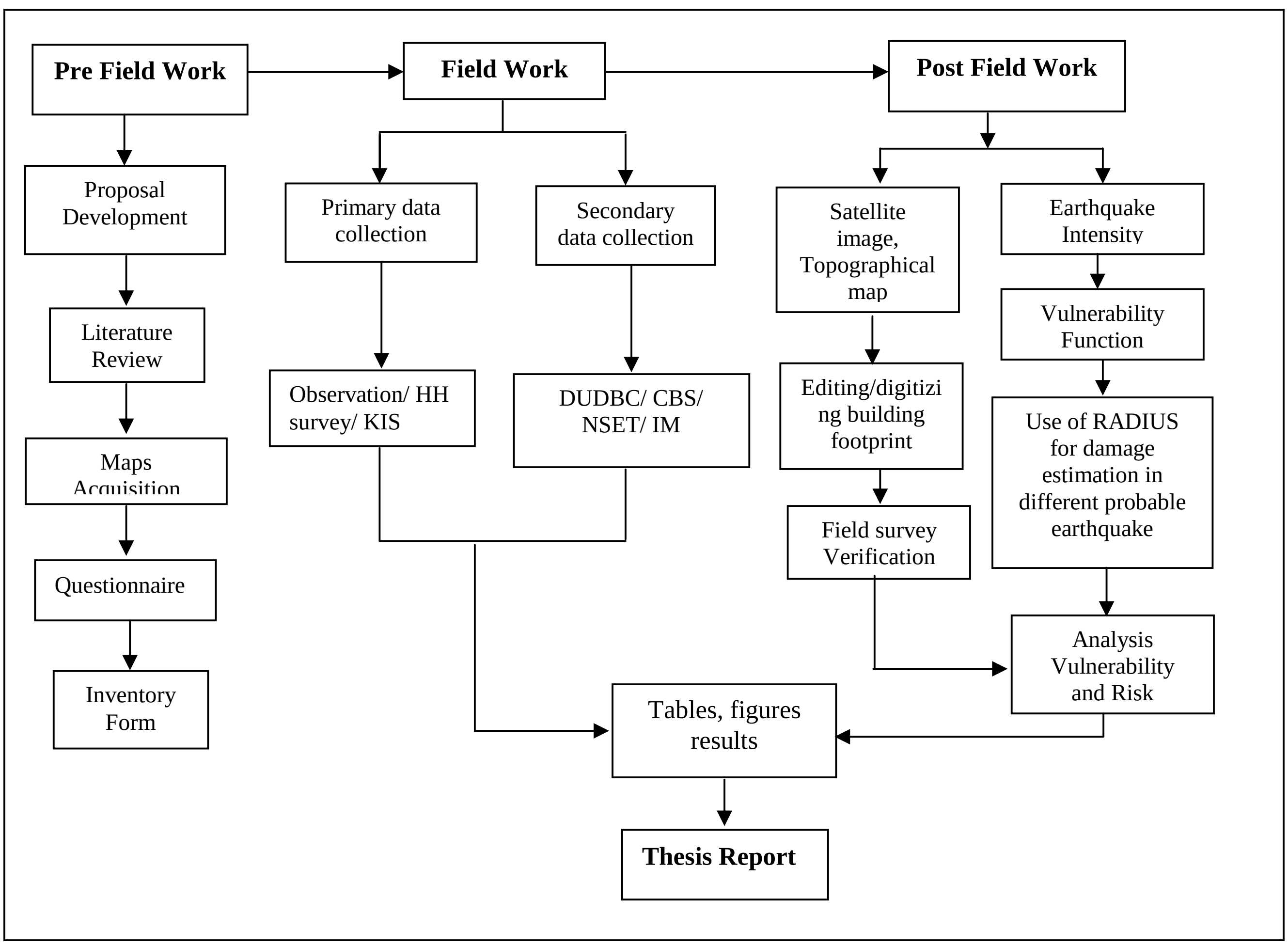
All the previous researches are mainly concentrated within capital city and its hinterland. Most of them have tried to evaluate only residential and historical temples mainly concentrating in construction materials and technical side and less priority has given to socio-economic issue. The present research attempts to cover all types of buildings including temples, government offices and non-government offices with their physical condition for earthquake hazard and prediction with the help of GIS and RADIUS method. Focusing to the outside areas than the capital city, the present research also attempts to assess the knowledge, awareness and preparedness of earthquake within Inaruwa municipality area of Sunsari district of Nepal.

CHAPTER III

RESEARCH METHODOLOGY

The Nepal Himalaya area has always high risk of earthquake hazards that could make heavy toll of human lives as well as loss of man made structure such as buildings, road, dams, etc. The damage of building caused by earthquake has direct relationship with various factors such as; materials used, age of building, number of stories, method of construction etc. Therefore, this study of such types needs to related parameters and to use different techniques to estimate the damages. The methods and techniques used in this study are discussed below.

Research methodology could be important in the study dealing with natural disaster, earthquake is not are exception to it. The flow chart of research methodology is shown in figure 3.1.



Nature of Data

Both primary and secondary data have been employed in this study. Secondary data such as population characterization and maps were collected from different sources such as books, journals, reposts dissertation were reviewed for the necessary information. Primary data on location, geometry and structural condition of buildings and their resistance to earthquake, people's awareness and preparedness are collected form the field adopting different methods.

Table 3.1 Sources and nature of data

S.N.	Description	Source	Map scale	Year
1	Digital map in GIS environment	DUDBC		2001
2	Population and household	CBS		2001
3	Inaruwa toposheet map	Topographical survey branch	1:50,000	1998
4	Primary data	Field survey		Nov. 2008

3.1 Data Collection Methods and Tools

Sampling Procedures for Observation and Household Survey

Census data are not available according to the requirement of the study. So in this research, the purposive random sampling method is adopted in the process of primary data collection. In this research, urban core areas has given more priority and marginal area has given less priority because in margins space has open space that there is less risk than the core. Core areas have high risk of earthquake because of attachment of buildings, infrastructure, lifelines and lack of open space. In this study out of 6349 buildings were observed accordingly building condition. Then sample household were selected form total observed household. In this process 274 household were selected for detail study which represents 14% of the total observed households (table 3.2)

In the process of household survey, questionnaires were completed by asking the head of the household first. In few cases, the head of household was completed by asking questions to other member of the same family and in the absent of responsible family member in next house were asked questionnaire.

Table 3.2 Distribution Pattern of Sample Households in Different Wards

Ward No.	Total Buildings	Observed HHs	Sample Household
1	312	82	11
2	703	284	40
3	1087	382	53
4	508	100	14
5	436	158	22
6	847	286	40
7	840	325	46
8	339	29	9
9	938	168	24
10	339	110	15
Total	**6,349**	**1,960**	**274**

Source: DUDBC and Field Observation, 2008

Table 3.2 shows the total household according to DUDBC. Out of 6,349 building this research observed 1,960 buildings. Among them 274 household were sampled to drive data based on observation sheet and household questionnaire.

3.1 Primary Data Collection

Relevant primary data were collected using field observation, interview and key informant survey methods. To collect the primary data sample frame had been made based on the total household form ward wise.

3.1.1 Observation Method

Observation is one of important method to generate preliminary information. Altogether 1960 buildings were visually observed all types of buildings form different wards. It comprises 30.8% of the total buildings of Inaruwa municipality. The sample used for observation in different wards is shown in table 3.4. This research employed observations mainly for two purposes. First was to know the building information (building condition) where it intended to collect information of building shape, age, roofing system, attachment and building use by purpose. The second purpose was to generate data on preparedness, awareness and knowledge of earthquake within the municipality area. To get information of building this research classified the building in different types such as adobe (A), brick in mud (BM), wooden (W), shrub (Sh), brick in cement (BC) and RCC. According to the age the buildings were classified in to 3 categories (less than 20, 20- 50 and above 50 years). Similarly, building shape classified in regular and irregular shape.

3.1.2 Household Survey

Out of total observed buildings (1,960), 274 (14%) building were purposively selected for household survey. Houses were selected by simple random process every 7 houses were chosen for detail study (table 3.2). The questionnaire shown in appendix is asked during the household survey.

3.1.3 Key Informant Survey

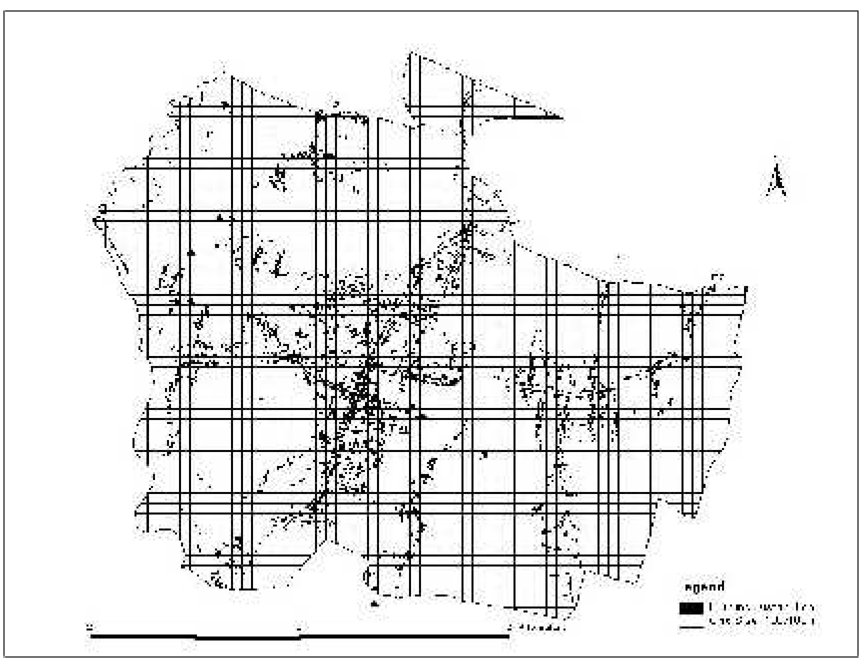
This research used head masters, local elites, social workers and service holders in the form of key informants. This method provided the data on knowledge, awareness and preparedness on earthquake. Besides, it also tried to explore the role of different institution earthquake related activities within the area. Altogether ten key informants are each form the 10 wards were selected for this survey.

3.2 Data Processing Methods and Tools

Primary data are processed by using various methods tools and techniques. Household questionnaires data area process of through Excel, and spatial data by GIS and RADIUS methods.

3.2.1 Spatial Analysis by GIS

Figure 3.2 Building Updating



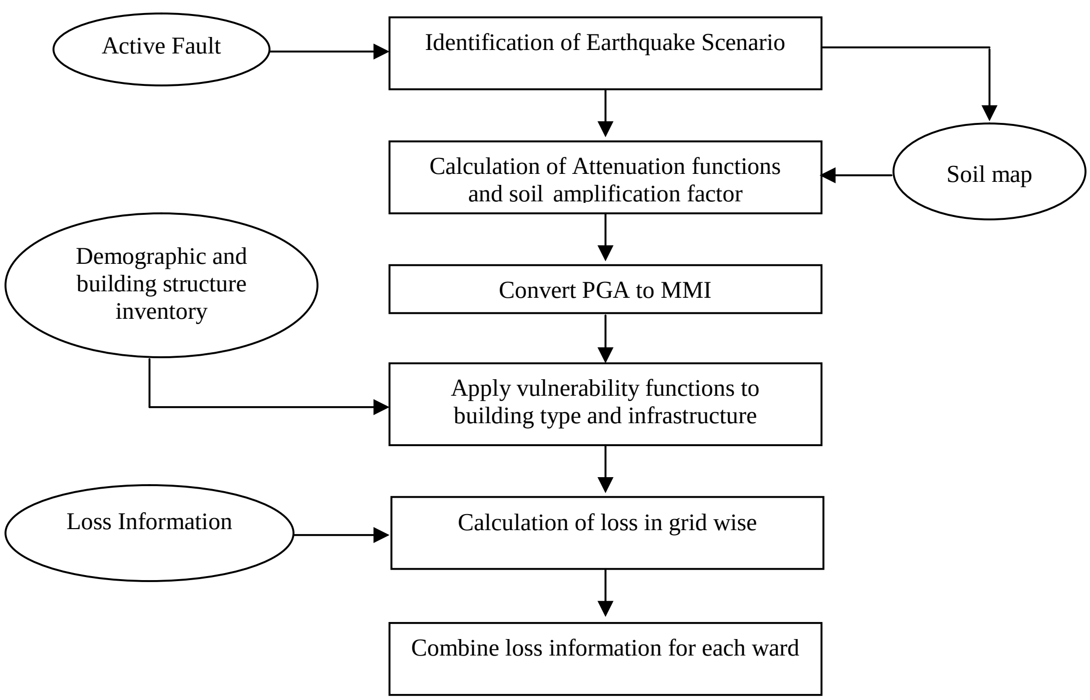
Source: DUDBC and Field Observation. 2008

In this method, observed data transformed into digital attribute and their characteristics. Buildings are updated according to nature of data. The updated map overlapped by 100/100 meter grid for RADIUS analysis that shown in figure (figure 3.2).

3.2.2 RADIUS Method

Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disaster (RADIUS) was used to measure the earthquake vulnerability of building in Inaruwa municipality. It is a simple computer tool and used to estimate the earthquake damage. It helps the seismic risk reduction to concentrate our efforts on prevention and preparedness. RADIUS was lunched by the Secretariat of the International Decade for Natural Disaster Reduction (IDNDR 1990-2000) United Nations and an out come of RADIUS project initiated in 1996 till 1999 with financial and technical assistance from the government of Japan. It aimed to promote worldwide activities for reduction of seismic disaster in urban areas particularly in developing countries. The main purposes of this project were to raise awareness and preparedness for earthquake risk reduction. The RADIUS method is more appropriate to prepare fast earthquake scenarios that better fits the needs of earthquake threatened cities in developing cities.

Figure 3.3 Flow Chart of RADIUS



Source: NSET, 2008

3.2.3. Vulnerability and Damage Estimation

Earthquake Hazard will be estimated from reoccurrence of a past damaging earthquake or active fault. Damage will be estimated from hazard and the existing structures in the area and depends on not only the number of structures but also nature and types of the buildings or lifeline facilities, using vulnerability functions derived for each type of structure. In this research mainly 3 assumed earthquake scenario depend on near fault from Inaruwa.

Vulnerability function reflects the relation between seismic intensity and the degree of damage to the structure. Casualties such as death and injuries are also estimated from the population data. This research estimated 3 earthquake scenarios.

Generate Mesh/ Grid

The mesh/grid is a set of Excel cells, which depends upon the number of grid size in GIS. In the study area 2335 grid numbered. In RADIUS programme, it is most important to create a uniformly spaced grid or mesh over the study area. A uniform mesh spacing of 100m to 500m is usually recommended by considering the size (scale) in RADIUS. The mesh space of this study area is considered as 100m (0.1 km) to estimation for the earthquake scenario (figure 3.4).

Area ID/ Name

Area ID is the unique identification number (ID) given to an area, in the RADIUS programme, imagine a block or district or area made up of several meshes. In this study, 2335 Area IDs were defined considering 10 wards of the municipality in the basic input data sheet on the RADIUS programme (figure 3.4). In the area name this study has given ward number according grid under this ward.

Mesh Weight

Mesh Weights are relative importance factors, in RADIUS programme. Following five Mesh weights can input in the basic Input data sheet.

Table 3.6 shows the identification of mesh weight in RADIUS method. In this study, four types of Mesh Weights; 0, 1, 2, 3 and 4 were used to calculate estimation in this study. Weight refers by the code, where the no settlement there value were given 0 codes.

Similarly, 1 to 4 are increasing order of settlement like village to core area of any particular place. These rates are used for distribution of building counts in each mesh and area.

Table 3.3 Identification of Mesh weight

Code	Description	Rate
0	None (open area)	0.0
1	Low (village)	0.5
2	Average (bazaar area)	1.0
3	High (main area)	1.5
4	Very high (core area)	3.0

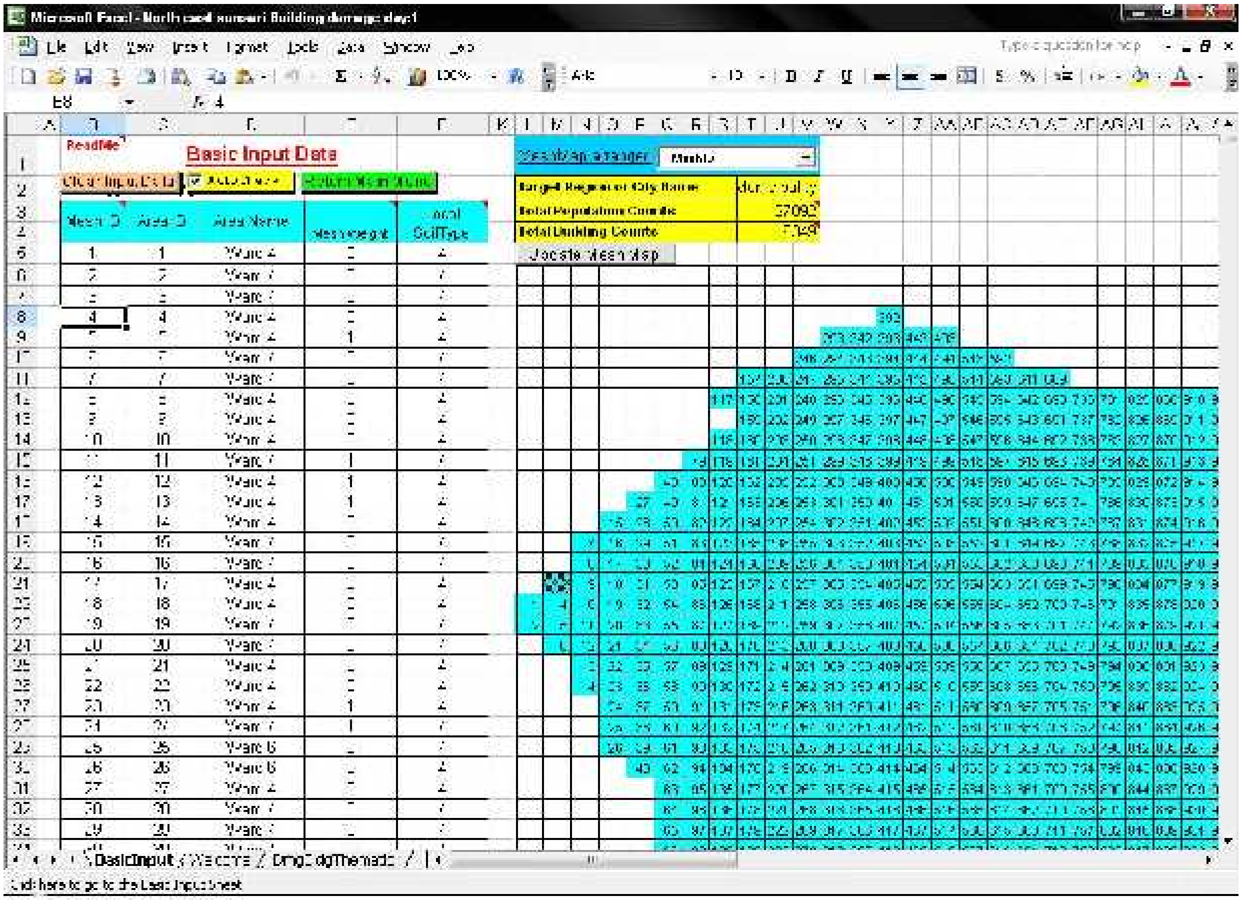
Local Soil Type

Soil type is used for determining the dynamic amplification in the ground shaking. Soil also plays the important role for earthquake hazard. Hard rock is direct linkage with plate so it good for earthquake perspectives. There are four types of soil types considered in RADIUS, In this study, fourth local soil type (soft soil) was considered for all part of the study area. It is because of topography of this area (table 3.4).

Table 3.4 Local Soil types

Soil types		
Code	Description	Amplification Factor
0	Unknown	1.00
1	Hard rock	0.55
2	Soft rock	0.70
3	Medium soil	1.00
4	Soft soil	1.30

Figure 3.4 Generation of Mesh/Grid and Area id in RADIUS



Area ID Inventory

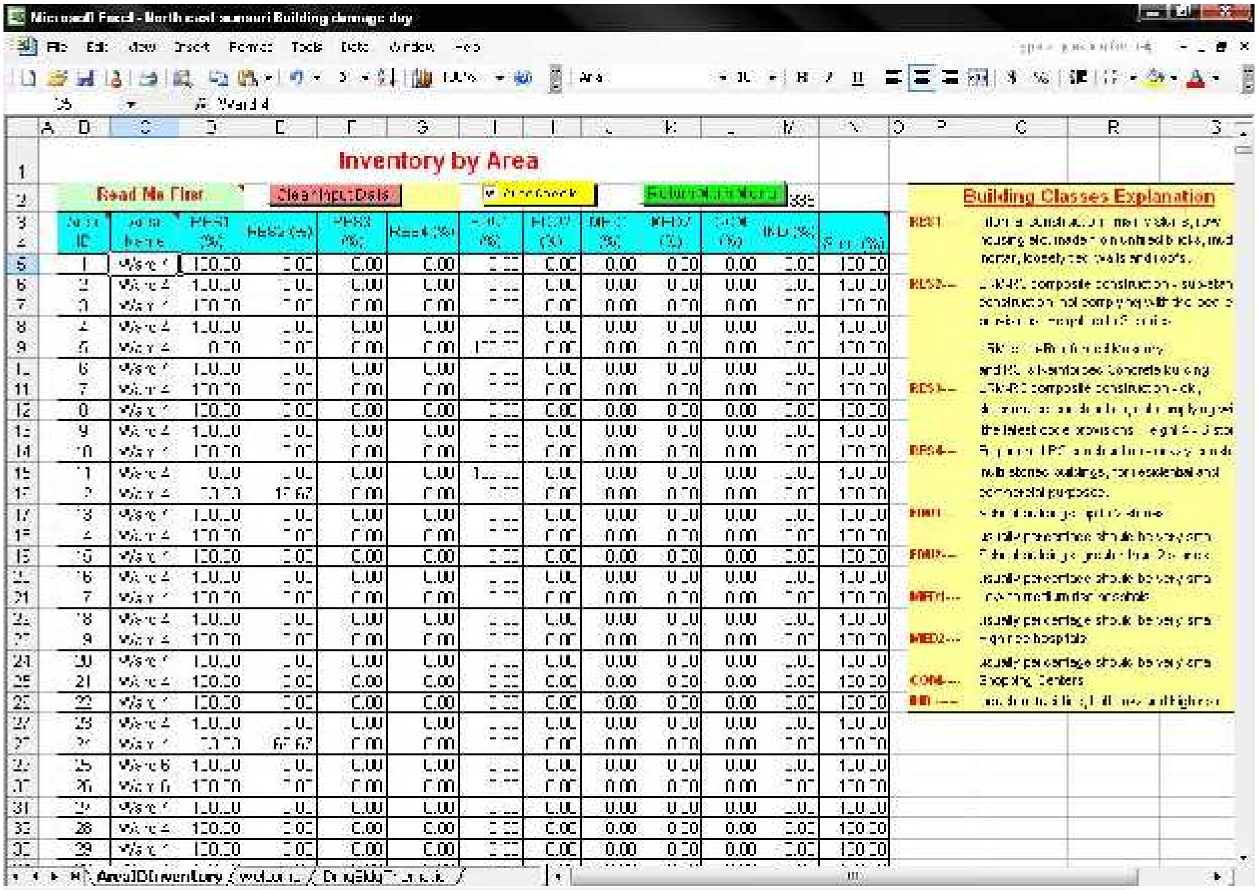
Building may be classified according to the various parameters. There could be many ways to classify building types, but 10 building classes are adopted in RADIUS programme. These have been classified on the basis of the strength of buildings against shaking in an earthquake. All the building class should 100 percent in total (figure 3.5). Area ID, which most closely matches to the building classes in the RADIUS programme. An explanation of the building classes are given below:

Table 3.5 Building Classification in RADIUS Method

RES1	Informal construction: mainly slums, row housing etc. made from unburned bricks, mud mortar, loosely tied walls and roofs, such as adobe.
RES2	URM-RC composite construction: sub-standard construction, not complying with the local codal provisions. Height up to 3 stories. URM is un-reinforced brick or stone masonry, while RC is steel reinforced cement concrete construction.
RES3	URM-RC composite construction: old, deteriorated construction, not complying with the latest codal provisions. Height 4 - 6 stories
RES4	Engineered RC construction: newly constructed multi-storied buildings, for residential and commercial (shops and offices) purposes.
EDU1	School buildings, up to 2 stories: Such buildings usually constitute a very small percentage of the total building counts.
EDU2	School buildings, greater than 2 stories: Such buildings usually constitute a very small percentage of the total building counts.
MED1	Low to medium rise hospitals: Such buildings usually constitute a very small percentage of the total building counts.
MED2	High rise hospitals: Such buildings usually constitute a very small percentage of the total building counts
COM	Shopping Centers and Shopping Malls: Such buildings usually constitute a very small percentage of the total building counts.
IND	Industrial facilities, both low and high risk.

Source: NSET, 2008

Figure 3.5 Area ID Inventory Form



3.3 Fragility Function of the Buildings

Vulnerability functions, which indicate the relation between seismic intensity rate for structural types which are determined as the function of acceleration/MMI based of damage observed during past sample earthquakes. The damage levels consider in this method is collapses and heavy damage. This research followed and changed the MMI value according to building class (table 3.9).

Table 3.6 Fragility Function for Buildings in Nepal

MMI	Damage (%)					
	Adobe/stone in Mud	**Brick in Mud**	**Stone in Cement**	**Brick in Cement**	**9" RC Columns**	**RC**
4	0	0	0	0	0	0
5	1	0	0	0	0	0
6	7	4	3	2	1	0
7	25	15	12	10	4	2
8	60	45	35	25	20	10
9	85	68	65	60	60	45
10	100	95	90	80	75	60
11	100	100	95	95	95	90
12	100	100	100	100	100	100

Source: NSET, 2009

3.4 Defined Earthquake Scenario

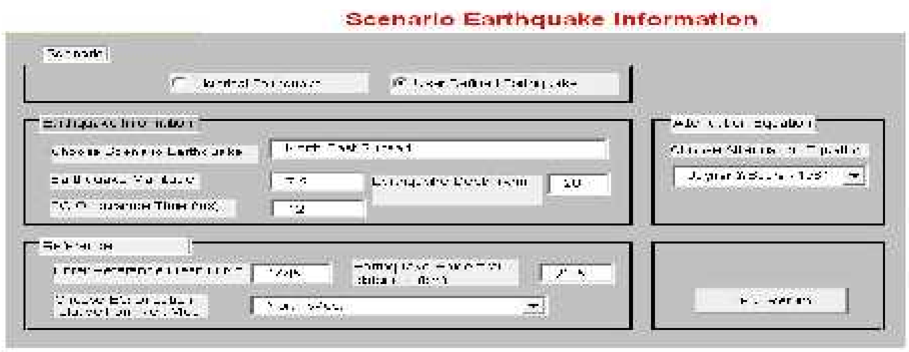
The scenario earthquake, which has been defined by the researcher, earthquake parameters are to be defined by the user. This research has defined three types of earthquake scenario which is based on near fault line form Inaruwa municipality.

Table 3.7 Earthquake Scenario

Earthquake name	North east Sunsari	Mid Udayapur	North west Saptari
Fault Name	Himalayan Frontal Fault	Main Boundary Thrust	Himalayan Frontal Fault
Magnitude	7.2	8	7.2
Distance	22.5 km	31.5 km	26 km
Depth	20 km	20 km	20 km
Direction	North East	North West	West-North

Hypothetical earthquake can be used as the scenario earthquake, it is important to be careful that the hypothetical earthquake supplied in this tool is helpful when deciding scenario earthquake parameter. Inputs parameter for the scenario earthquake is location, depth, magnitude and occurrence time (day and night) of the earthquake (figure 3.6).

Figure 3.6 Information of Earthquake Scenario



Run RADIUS Programme

3.4 Field Work as an Experience

My field experience was some interesting and some bitter too. It was November 2008, that the time was great flood in Saptakoshi river. At that time most of the flood victims were have came in Inaruwa. Due to victims, the thieves are increasing known as flood victims. I had some problem to observed building in inner part of Inaruwa like as residential houses of main market. On the other hand I listened and watched of their painful voices that all was done by flood; they loosed their family and property in this flood. And I prayed to god don’t come such cruel event again in any part of Nepal.

In key informant survey, teacher, villagers old mans and service holders responded well and suggested to bring programmes related to earthquake in this area. In village there are majority of Madhesi indigenous people, some of them a respondent informed his traditional belief on about earthquake hazard. I faced some difficulties to communicate language and to get information of knowledge and awareness of earthquake. Some of them, they felt me that taking high profit by using them. Any way their respect and humanity is very great to new comers.

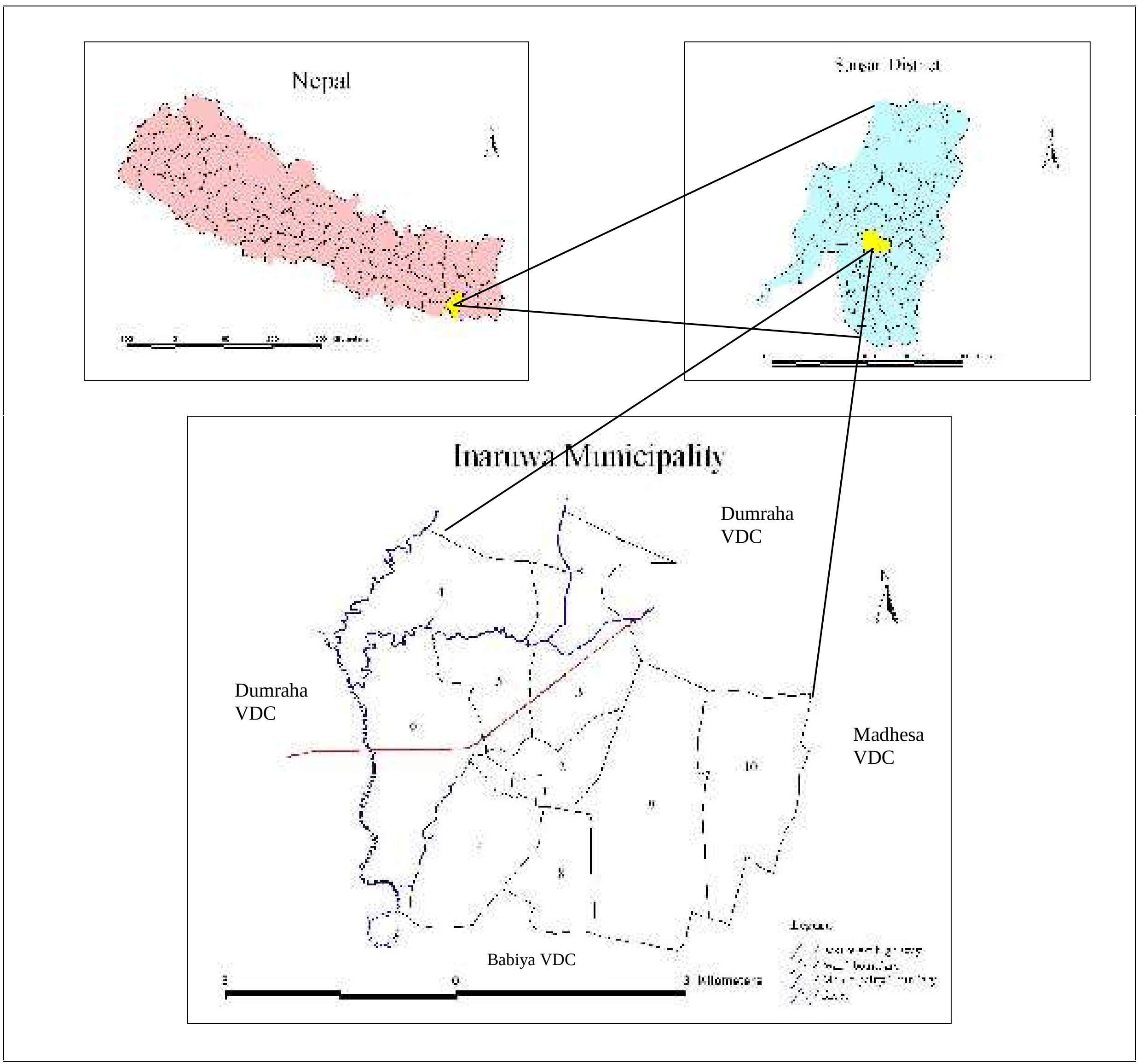
CHAPTER IV

STUDY AREA

4.1 Geographical Settings

Inaruwa municipality, the district headquarter of Sunsari district is located in Koshi zone of eastern development region of Nepal. It got municipality status in 2047 B.S. and is surrounded by the Madhesa VDC in the east, Dumraha VDC in the north and west, and Babiya VDC in the south. It lies between 26˚ 37' 30" to 26˚ 34' 58" north latitude and 87˚ 07' 30" to 87˚ 11' 18" east longitude. The municipality covers the 22.36 sq/km area.

Figure 4.1 Location of Study Area



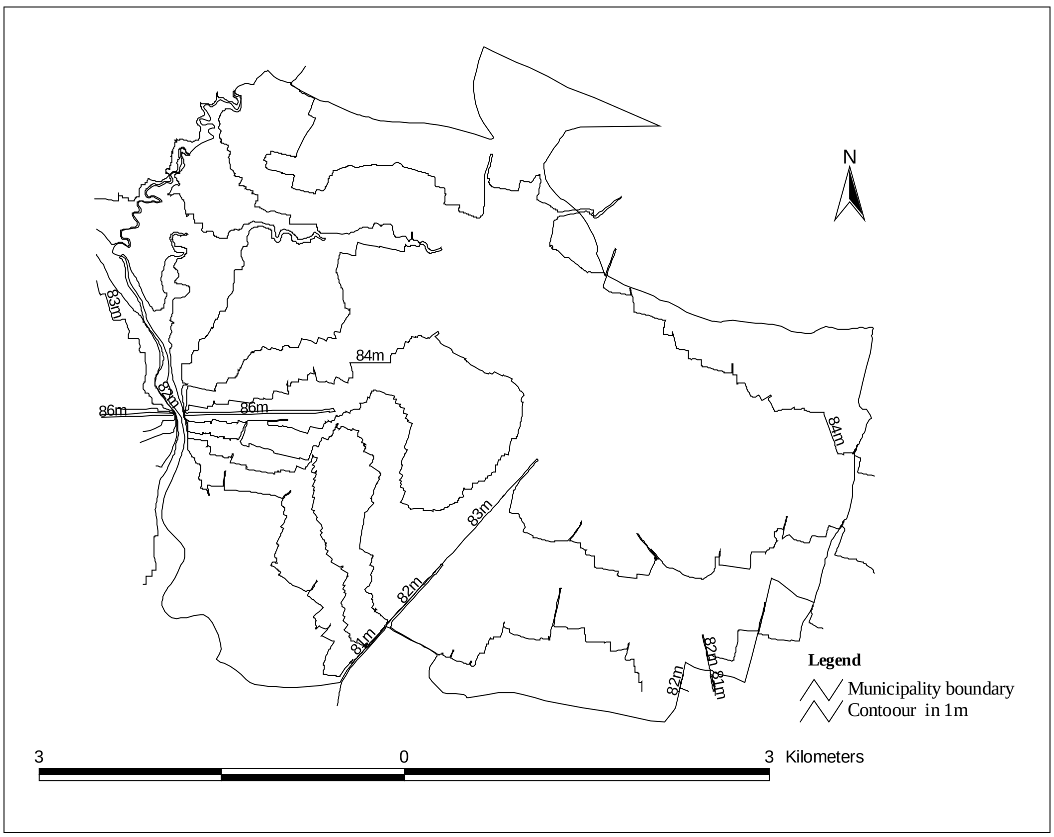
4.1.1 Physical Characteristics

Sub-tropical climate is prevalent in this municipality with summer hot and winter warm the maximum and minimum temperatures range between 39˚ in July to 10˚ C in January. The annual average rainfall is 2000ml. The agricultural land is covered1661 hector and the forest covers the 6 hector in this municipality.

Slope

Inaruwa municipality lies 79 meter to 86 meter from sea level. The contour line of this area shows the ground is uniform slope in all parts. The relief feature of the municipality shown in following figure 4.2.

Figure 4.2 Relief of Inaruwa Municipality



Source: DUDBC, 2001

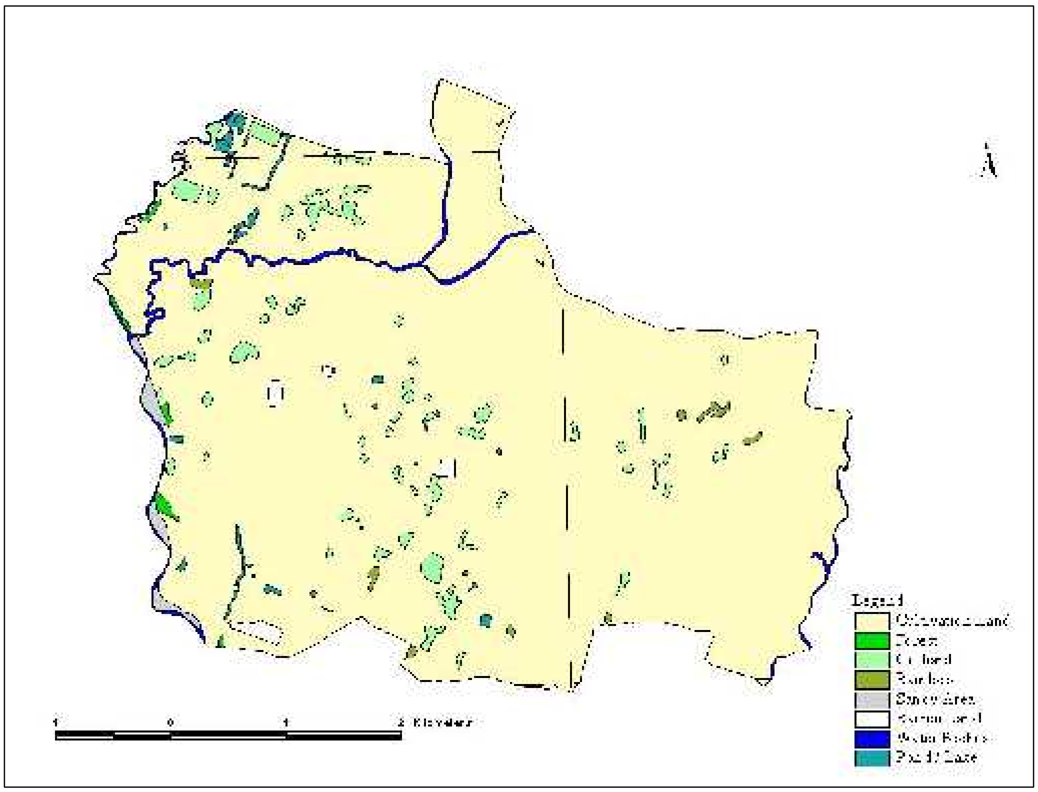
Soil types

Due to presence of same geology, the spatial arrangements of the soil are more or less evenly distributed in this area. The soil types of the terai plan is developed mostly on recently and sub- recently developed alluvial sediments of the broad. Clay loam soil is predominant type of soil in this area. Due to the present of this fertile soil, the production is very good in the municipality.

Land use/ Land cover

The land use pattern of the area is diverse. The main types of land use/ land cover are cultivated land 1661 hector and forest 6 hector, sandy area, barren land, orchard, water body area are very few percent (Inaruwa municipality at a glance, 2001).

Map 4.3 Land use types



Source: Topographical Survey Branch, 1998

4.2 Social Conditions

Population and Housing Condition

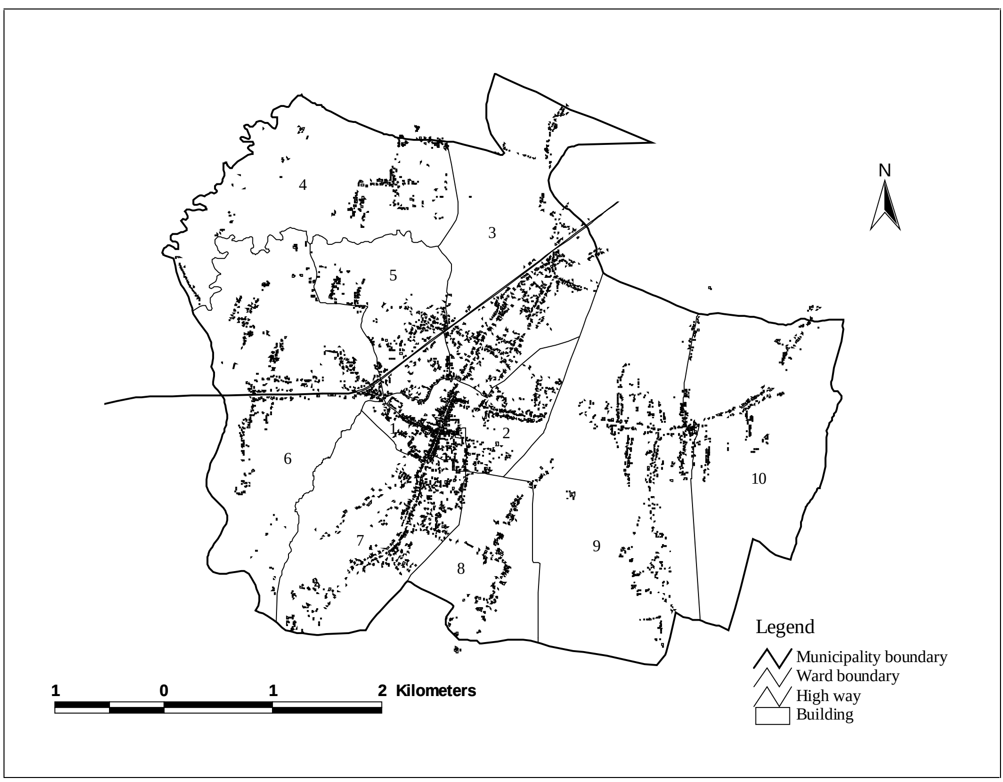
The municipality is divided into 10 wards. The ward boundary is defined using roads, rivers, and foot trails. The municipality constitutes 4,497 households with an average of household size 5.16 people (CBS 2001). Inaruwa holds total population of 23,200 comprising 51.05% male and 48.96% female (table 4.1). The population growth rate is 2.24 according to municipality profile 2001.

Table 4.1 Number of Households and Population

Ward No.	Number of Household	Population			Average Household
		Total	Male	Female	
1	423	1964	1040	1040	4.6
2	435	2230	1136	1136	5.1
3	636	3025	1539	1539	4.7
4	239	1392	702	702	5.8
5	536	2592	1289	1289	4.8
6	571	3096	1586	1586	5.4
7	668	3689	1929	1929	5.5
8	160	988	523	523	6.1
9	600	3063	1514	1514	5.1
10	229	1161	586	586	5.0
Total	**4,497**	**23,200**	**11,844**	**11,356**	**5.1**

Source: CBS, 2001

Figure 4.4 Settlement Distribution



Source: DUDBC, 2001

Figure 4.4 shows the settlement distribution in Inaruwa municipality. Ward umber 1, 2 and 3 are the mostly dense populated and core area of municipality. This municipality crossed the east west highway even there are few settlement only in highway side. In the core area dominant by commercial, government office, non government office, and industrial purposes in buildings, on the other hand others wards are residential and farm area.

Caste and Ethnic Composition

There are many caste/ ethnic groups in the municipality. The main inhabitants of the municipality are hill Brahmins followed by Koiris, Chhetris, Tharus, Newars, Dhanuks and Muslim etc. A majority of the population speaks Maithili and followed by Nepali. Hill Brahmins are the dominant that consist 26.3 percent of the total population. Madhesi ethnic group Koiri (8.8 %), Tharu (5.1%), Chheri (5.9 %), Magar (5.1%), Muslim (4%) are other caste ethnic group of the municipalty. Similarly, other marginalized groups such as Rajvar, Musahar, Pandit (Kumal), Jhagar, Haluwai, Chamar are also distributed in different numbers in different parts of the municipality.

Gender and Household head

There is gender imbalance in terms of household head in the municipality. Male overwhelmingly dominates the number of household head i.e. 88 % of the total in an average; there are about 8 male headed households for each female counterpart. The proportion of female household range between 8-14 % within 10 wards of the municipality (CBS, 2001).

Educational Attainment

Among total literate population (13682) in the municipality 32.1 percent has attained primary education only, 17.2 percent lower secondary and 15.6 percent secondary education. Literates with SLC constituted 13.8 percent. The proportion attaining higher education i.e., beyond SLC is 13.4 percent only (CBS, 2001).

4.3 Economic Conditions

The major populations are engaged in agriculture purpose (59%). Only in ward no. 4, 8, 9 and 10 have the proportion is comparatively higher than the other wards which consists altogether 45% of the total household with land used for agriculture purpose (CBS, 2001). Just over 74% of the households have no economic activity in this municipality. Only about 10% and 9% of the total households have adopted business and services respectively. Other activities are very less. The figure shows that most of the business activities are concentrated in ward no. 1, 2 and 7. All these wards contribute about 65 percent of the households.

Majority of the 10 years and over is engaged in household chores and study which is almost 23% households for activity and followed by wage/salary earning (17%), own agriculture is just over 10% and own non-agriculture is also 10% of the total households of the municipality. Similarly, the proportion of male and female on the household chores is very distinctive, where just less than one percent of the male and 46% of the female are engaged and the situation is in different in the case of wage/salary earning where 27% and 7% as well as in agriculture this proportion is 15% and only 6% male and female population respectively engaged.

4.4 Institutions and Organizations

District headquarters located a number of district levels government line agencies (sectoral offices), local government offices, NGO/INGOs offices and various formal informal sectors. Both permanent and local hat bazaars provide marketing channels in the area.

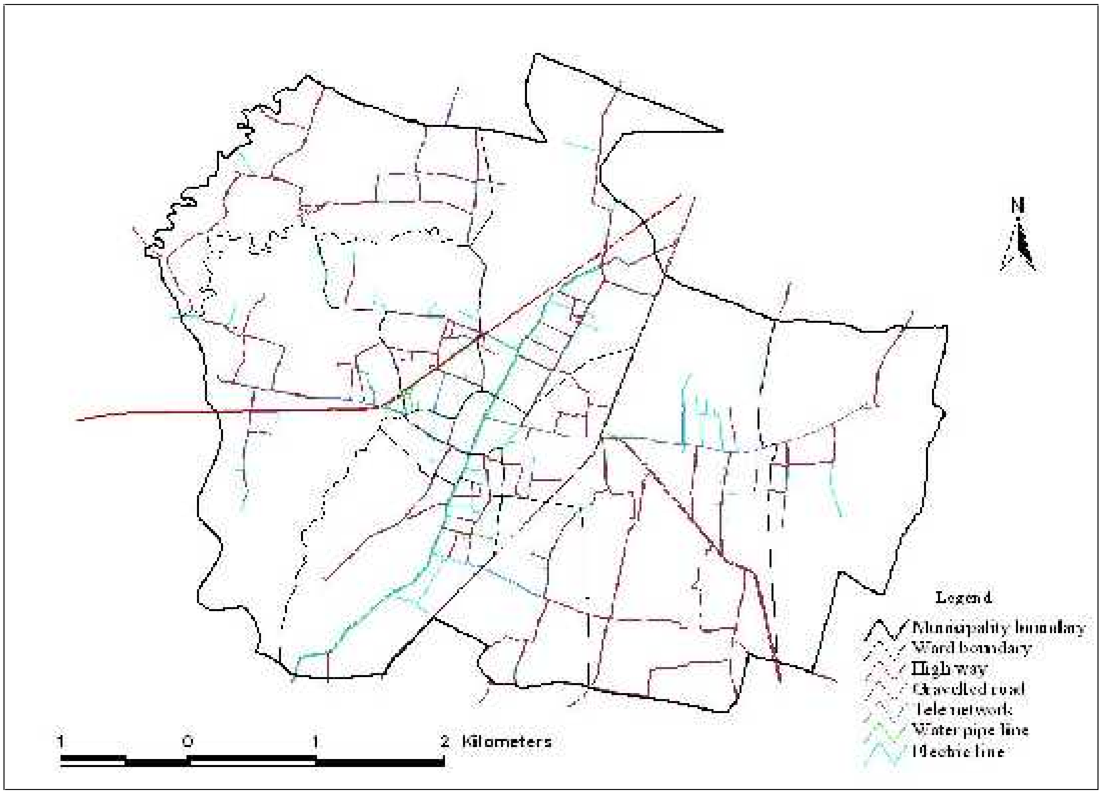
Basic Services

Transport and communication are very important aspects of development. These infrastructures make like easier and faster by bringing goods, people and information from one place to another place. Regarding the Inaruwa municipality, east west highway crossed length into 3.85 km (figure 4.4). Telephone facility is available in all wards except ward no 4 of the municipality.

Lighting is another important sector of energy utilization. The major sources of energy for the purpose for lighting especially in the municipal areas in Nepal are electricity and kerosene. About 70 percent households in Inaruwa municipality use electricity for lighting. Similarly, about 30 percent use kerosene.

Inaruwa Municipality is getting drinking water from various sources, tube well is found as the main source of drinking water. Out of total households of the municipality, more than 95 percent depends on tube well. After the tube well, piped water is the second important source of drinking water, which serves for 2 percent household. Besides these sources, about 1 percent households fetch water from well and other sources. Figure 4.5 represents the basic services all over the wards. Water pipe line facility is available in mainly core area. Gravel road and electric line is facilitated all over the municipality.

Figure 4.5 Basic Services in Inaruwa Municipality



Source: DUDBC, 2001

CHAPTER V

NATURE AND TYPES OF BUILDING IN INARUWA MUNICIPALITY

Houses are affected by physical factors, economic factors, socio-cultural factors, social customs, traditions, social code and religious beliefs. A house is a social institution for man and a cultural landscape of the earth. Socially, houses can be classified into different uses i.e. waiting room, cooking room, store and other socio-religious purposes. The form and structure of a house is also guided by cultural and religious belief of the dwellers (Khatiwada, 2001).

Earthquakes do not kill people but building collapses do kill the people so, to identify the building vulnerability, it is very necessary to know the buildings physical characteristic. Seismic vulnerability of building is highly dependent on the space between buildings, age of building, geometry of buildings and materials used for constructions.

This chapter attempts evaluate information related to types and nature of buildings within Inaruwa municipality. Generally, the core area and the areas along the gravel road and highway characterized RCC building with multiple stories. All individual buildings of the core area were observed very closely and were traced in the building footprint map. Along with the building details like structural type, number of story, shape, age, roofing types, existence of soft story, building attachment, existence of non structural element, space use were recorded in the inventory sheet designed.

5.1 Building Classification

Building classification is based on the common building types in Latin America cities. The number of each type of building in each mesh is estimated by density of building with a weight called “Mesh weight”.

The buildings are classified according to type of the buildings materials used. Building typology was done by NSET based on their experiences on similar other areas of the country, this research also fallowed up to NSET.

1. **Adobe (Ad):** these buildings are mainly dame of sun-dried brick with mud mortar. They are found mostly in the outer part. They are old traditional buildings used residential use.

2. **Brick in Mud (BM):** These are brick masonry buildings with fried bricks in mortar. In These buildings are made by fried brick with mud.
3. **Wooden (W)**: These types of building were made by timber.
4. **Shrub (Sh)**: These types of houses are made by shrub and bush (*Basko Jhikra)*.
5. **Brick in Cement (BC)**: These building are made by brick with cement. This is the most common type of building in the urban area.
6. **Reinforced Cement Concrete (RCC):** these are the buildings with reinforced concrete framed with unreinforced brick masonry infill with cement sand mortar in general.

Depending upon age of the building it was categorized into three categories namely:

- **A1** (within 20 years): buildings that are constructed within 20 years form now.
- **A2** (20- 50 years): Buildings that are constructed within the years 20 to 50years form now.
- **A3** (50 above): Buildings that are constructed more than 50 years before.

The buildings were classified into three categories depending on the geometry (shape).

- **R1 (<=1:3):** Regular shaped buildings with a length width ratio <=1:3
- **R2 (>1:3):** Regular shaped buildings with a length width ratio > 1:3
- **IR:** Irregular shaped buildings.

If the buildings are too close together, pounding induced by resonance may occur between the adjacent structures and add to the destruction therefore it is necessary to have some distance between the two buildings. If the buildings are attached and their floors are high, the building may vulnerable. But in another case where the floor heights are short, it makes low vulnerable (table 5.1). Buildings in the study classified in to different categories such that:

- **At:** Building attached to the other buildings.
- **Sl:** Adjacent buildings separated from each other.

Table 5.1 Building Classifications other Different Parameters;

Building Attachment		**Building Roofing System**				**Physical Condition**		
At	Sl	CN	CGL	Th.	W	G	A	V
Attachment	Singular	Concrete	Steel	Thatch	Wood	Good	Average	Vulnerable

According to needs primary data were collected by household survey. In the core area and other outer area observed the buildings and noted the building information about age, construction materials, shape, story, attachment and roofing system. Most of the household survey questionnaire was asked to household head and office head.

Measures of Vulnerability

Buildings were classified in to different parameters depends on building materials, shape, age and roofing system.

Table 5.2 Scale of Vulnerability

Parameters	**Scale of Vulnerability**		
	High	Medium	Low
Use of construction materials	Adobe, Brick in Mud, Old wooden houses	Brick in cement, wood	RCC, Bamboo, Wood,
Geometry	R3 (Irregular)	R2	R1
Attachment	Attachment	--------------	Separate
Age	A3	A2	A1
Roofing system	Sleet	Cn, CGI	Th.

Table 5.2 shows the different parameters of building and scale of vulnerability of their present conditions. In the construction of materials adobe, brick in mud are high vulnerability and new constructed RCC and bamboo buildings are low vulnerable for earthquake. Similarly, geometry also play the importance role for earthquake, regular shape is more safe than the irregular shape for vulnerable. Earthquakes do not kill people but buildings do so attachment and irregular shape of buildings are risk for human lives during earthquake.

5.2 Age and Structure of Building

The present study has tried to separate the building according to different age. The building age has been presumption and classified into three categories to find out the old and newly constructed building. For example, building aged less than 20 years are categorized as new buildings. The buildings age of 20 to 50 years was categorized as old buildings. Similarly, the buildings which have age more than 50 years are classified as oldest buildings (table 5.3).

Table 5.3 Age of Building in Inaruwa Municipality

Age	Number of Observed Building	Percent
Less than 20 years	961	49.0
20-50 years	951	48.6
More than 50 years	48	2.4
Total	**1,960**	**100**

Source: Field survey, 2008

Table 5.3 represents the age of building, in the study area, out of total 1960 buildings, 49 percent were new buildings which were made within the last 20 years and 48.6 percent buildings were build within 20 to 50 years and only 2.4 percent building was found which was made above 50 years old. Most of the new buildings were made by reinforce concrete and brick in cement, and most of the old buildings were made by brick in mud, wood and other materials.

Construction material used in building play a vital role to damage the building in earthquake. Good construction materials like reinforce concrete used in building have more resistance in compare to the poor construction materials like adobe, and brick with mud. It is not surprising that most of the damage during the past earthquake had been to unreinforced masonry structure constructed of brittle materials.

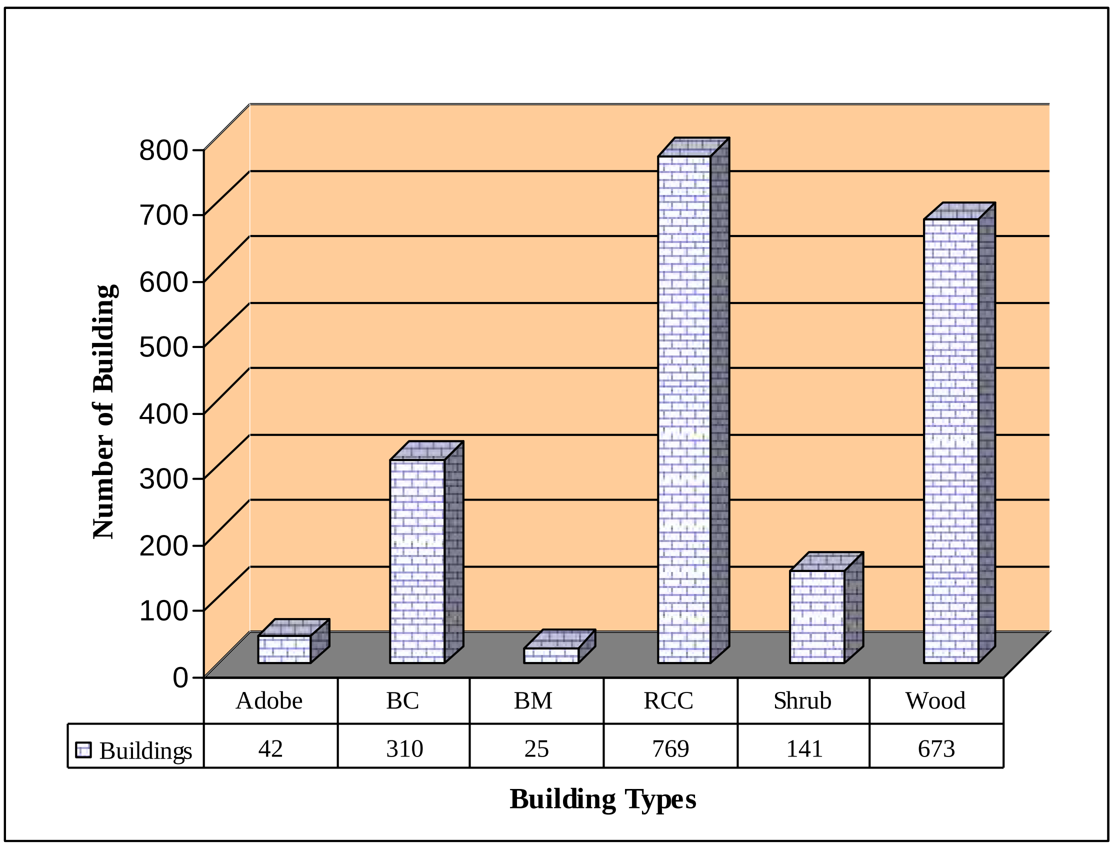
In present study observed the 39.2 percent of the building was made by reinforce concrete. The adobe is only 2.2 percent in study area, this types of building is more vulnerable for earthquake episode. Similarly, the 34.2 percent of buildings were found made by wood, it is assumed that types of houses are safe foe earthquake. Shrub types of building mainly found in firm side and near cannel and small stream most the marginalized and Madheshi indigenous community adopted this area. Similarly adobe and BC, BM building dispersed all over the municipality (table 5.4).

Table 5.4 Building Types (on the Basis of Materials used)

S.N.	Building Types	No. of Building	Percent
1	Adobe	42	2.2
2	BC	310	15.8
3	BM	25	1.2
4	RCC	769	39.2
5	Shrub	141	7.2
6	Wood	673	34.3
	Total	**1,960**	**100.0**

Source: Field Survey, 2008

Figure 5.1 Building Types

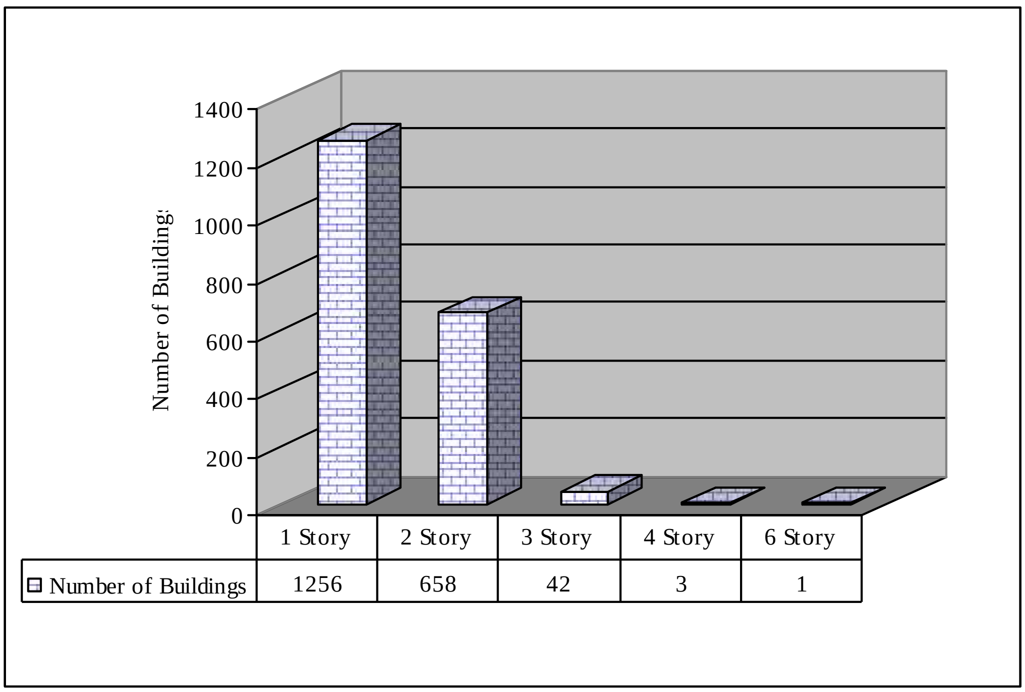


5.3 Building Heights (Story)

Building height and space use play most important role during earthquake. Vulnerability of the building is also influence by the building height. When earthquake occur, building experiences acceleration, velocity and displacement of varying frequency. It is very obvious that higher the building height, higher the vulnerability and perhaps higher will be the human casualties.

In Inaruwa municipality building are classified according to their story such one story and two story. Most of the buildings in the study area are one and two story building (64%and 33.57% percent). The percentage of the 3rd and 4th is very low (2.15% and 1.5 %). Only one building of 6th storey was observed during field study. There was no found 5th story building in field observation. The building number according to different storey is shown in figure 5.2.

Figure 5.2 Building Story



5.4 Building Geometry

To estimate the damage of buildings in certain magnitude of earthquake episodes, geometry of the building also plays the main role. Buildings having large length to width ratio, large height to width ratio and large offset in plan and elevation, or irregular shaped building suffer greater damage during earthquake than regular buildings (Guragain, 2004). National building code in Nepal suggest that to decrease the building vulnerability, building should be regular in plan, elevation and length width ratio of the building must be less than 3(NBC, 1994 cited in Jeemi, 2006). In the study area consists of 40% regular shape with <1:3 ratio, 45 % regular shape out but more than 1:3 ratio and 15% irregular shape buildings (table 5.5).

Table 5.5 Building Geometry

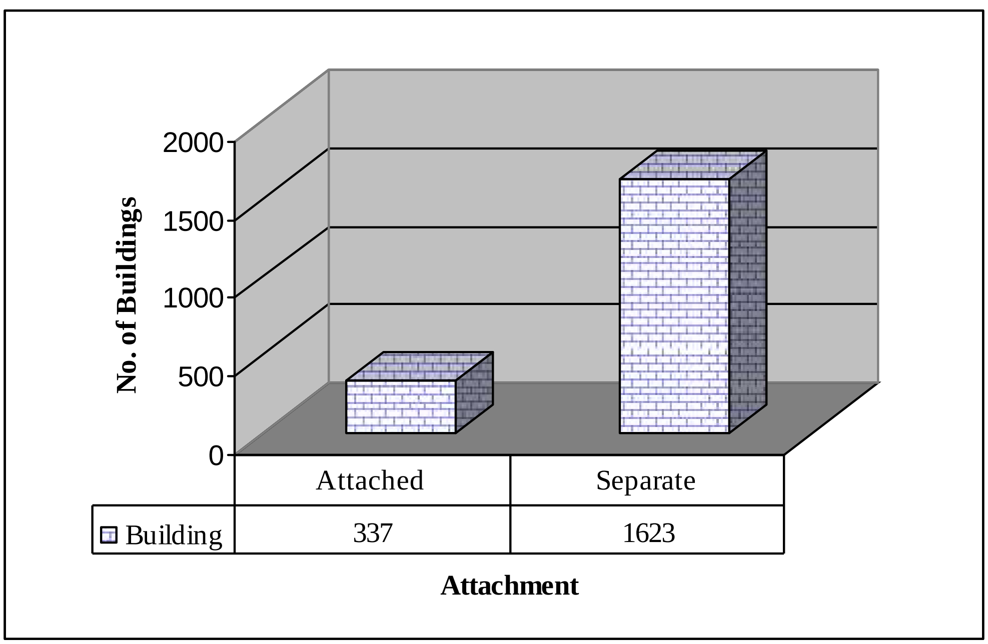
Shape (Geometry)	No. of Building	Percentage
Regular <1:3	801	40
Regular >1:3	892	45
Irregular	267	15
Total	**1,960**	**100**

Source: Field observation, 2008

5.5 Building Attachment

Building attachment and separation also play important role for the vulnerability of the building. Attachment of buildings is more vulnerable than separate building during earthquake. In the core and densely populated area have more chances of casualties by the destroying buildings and infrastructures during earthquake event. In the research area, 17.1% of the buildings were attached and the rest of buildings 82.9 % were found separate in character (figure 5.3).

Figure 5.3 Building Attachment



CHAPTER VI

VULNERABILITY ASSESSMENT OF BUILDING

Buildings experience acceleration, velocity and displacement with varying frequencies during an earthquake shaking. Each of these modes has a period. Among these periods, the longest is called the structural natural period of vibration and the frequency associated to it is called the natural frequency. Mainly the natural frequency of the building depends on its height and stiffness (Jeemi, 2006).

Vulnerability of buildings are resulted by various factors; physical factors (like soil types, slope and fault line) play major one hand, on the other side building materials and socio-economic and cultural aspect also play certain roles. Building materials, height, roofing system, shape, and separation are the major affecting factors to building vulnerability. Morphological and architectural design as well as level of awareness also plays the important role to building vulnerability. An effort has been made in this chapter to evaluate the different parameters and their significance in building vulnerability. Various models also developed in order to exemplify the vulnerability of building under hypothetical earthquake. RADIUS method is one of the important methods now a day. As such the studies intend to evaluate primarily with this techniques to determine the collapse and damage probability of buildings in the study area.

6.1 Earthquake Scenario in Inaruwa Municipality

There are different types of active faults found near by the Inaruwa municipality area. Among them, three active faults; Himalayan Frontal Fault (HFF) and Main Boundary Thrust (MBT) were chosen to estimate the building damage and collapse of the study area. Three different earthquake scenarios namely; North-East Sunsari Earthquake, Mid Udayapur Earthquake and North West Saptari Earthquake are used for to estimate the building and population vulnerability. The main characteristics and direction of these earthquakes faults are shown in table 6.1.

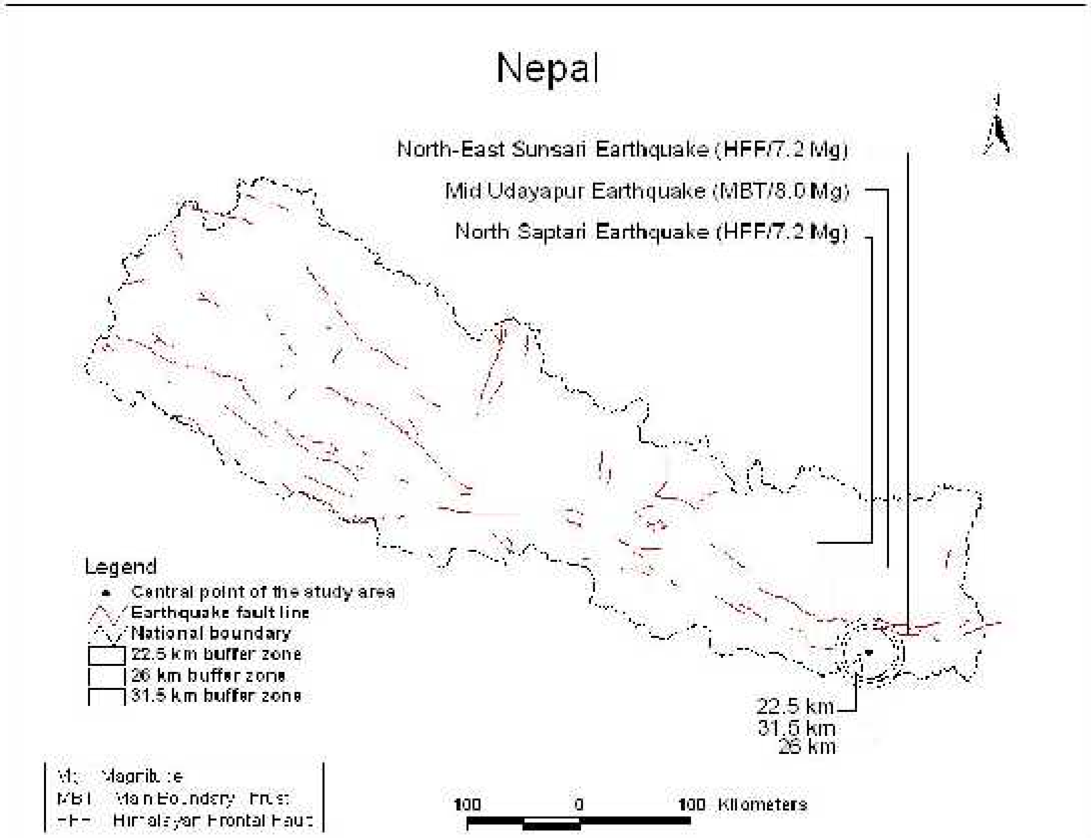
Table 6.1 shows the characteristics of three earthquake scenarios. The names of the earthquake scenarios are assigned according to their location. The Himalayan frontal fault is located in north-east part of Inaruwa and as such if is named north-east Sunsari earthquake. Although all three types differentiate in term of their magnitude, distance and direction get a name depth of 20 km was considered for all for the analysis. Magnitude value of those earthquake faults was already defined by BCDP project. The distance is measured from central point 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 magnitude, distance and direction of these earthquakes are shown in figure 6.1.

Table 6.1: Earthquake Scenarios in the Study Area

Earthquake Name	North East Sunsari	Mid Udayapur	North West Saptari
Fault Name	Himalayan Frontal Fault	Main Boundary Thrust	Himalayan Frontal Fault
Magnitude	7.2	8	7.2
Distance	22.5 km	31.5 km	26 km
Depth	20 km	20 km	20 km
Direction	North East	North West	West-North

Source: NSET, 2008

Map 6.1 Distances and Direction of the Earthquake Scenarios



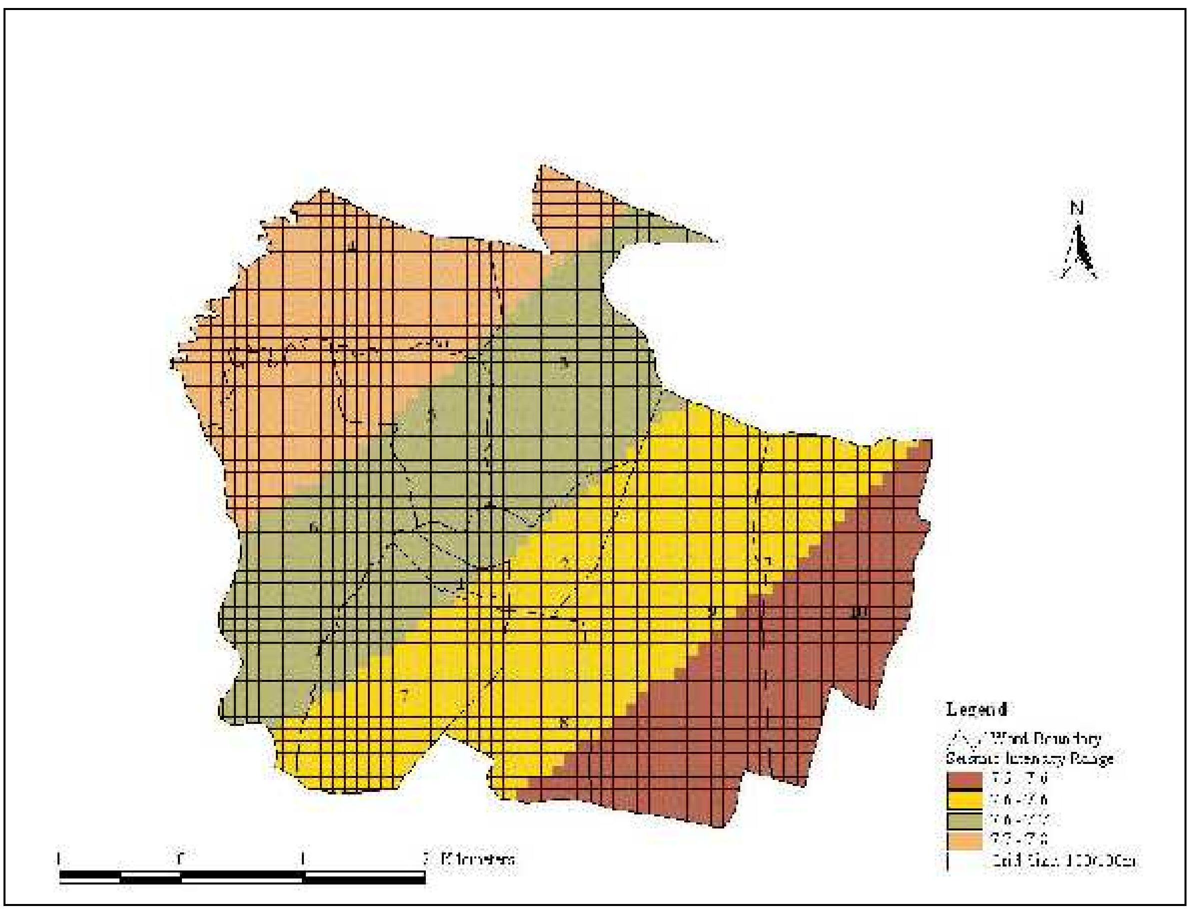
Source: BCDP, 2008

6.2 Earthquake Intensity Distribution (MMI)

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.

Many researchers have proposed relationships between PGA and MMI. RADIUS Program is using the one given by Trifunac and Brady (1970). 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 and casualties. Figure 6.2 shows the higher intensity range in ward 4 and 6. Similarly, the lowest intensity range represents in ward no. 10 and 9.

Figure 6.2 Earthquake Intensity Distribution of Inaruwa



6.3 North East Sunsari Earthquake Scenario

North East Sunsari scenario was considered as a possible hypothetical earthquake. It is expected to occur due to the active fault, which lies about 22.5 km North East of Inaruwa municipality which regarded as huge earthquake of 7.2 magnitudes.

6.3.1 Estimation of Building Damage by North East Sunsari Earthquake Scenario

The total number of building in the study area was estimated is 6349. Out of this, 34% of buildings were estimated to be either partly or heavily damage, when the north east Sunsari earthquake strikes in this municipality.

Table 6.2 Ward wise Building counts and Damage

Ward no.	Building Count	Building Damage	Damage percent
1	312	76	3
2	703	203	9
3	1087	364	17
4	508	233	11
5	436	139	6
6	847	324	15
7	840	278	13
8	339	120	5
9	938	332	15
10	339	128	6
Total	**6,349**	**2,197**	**100**

Source: Field Survey and RADIUS Analysis, 2008

Table 6.2 as well as figure 6.3 depicts that, the highest number of damages buildings were observed in ward no.3 (364). This could be happened because this ward occupied the highest number of buildings of the municipality. This damage depends on building type, materials use and age. Similarly, on the other hand ward no.1 observed as the lowest number of buildings damage (76). This ward is core area of municipality that most of the buildings have used RCC materials. This could be because the ward covers the smaller area with the lowest number of buildings compared to the other ward.

Similarly, if we see the buildings damage within ward, we found that, ward no. 6 and 3 were seemed to be more vulnerable which consist around 15 to 17 percentage of building damage. This ward has high probability to building damage because most of the houses of this area were constructed by adobe; brick in mud and traditional old age house which is high probability of being collapse compare to other building types.

Figure 6.3 Ward wise Building Counts, Building Damage

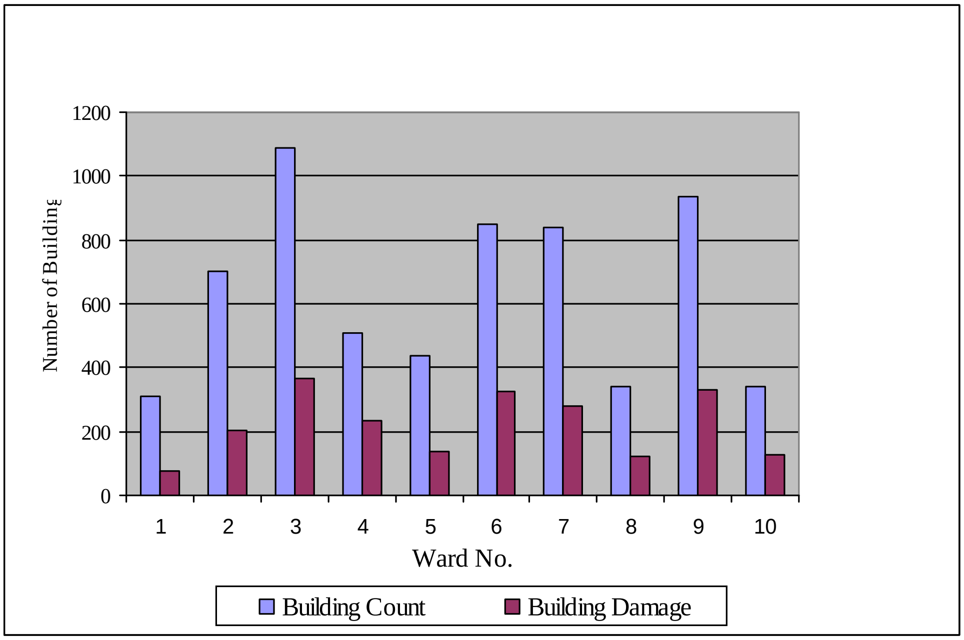


Figure 6.4 Estimation of Building Damage

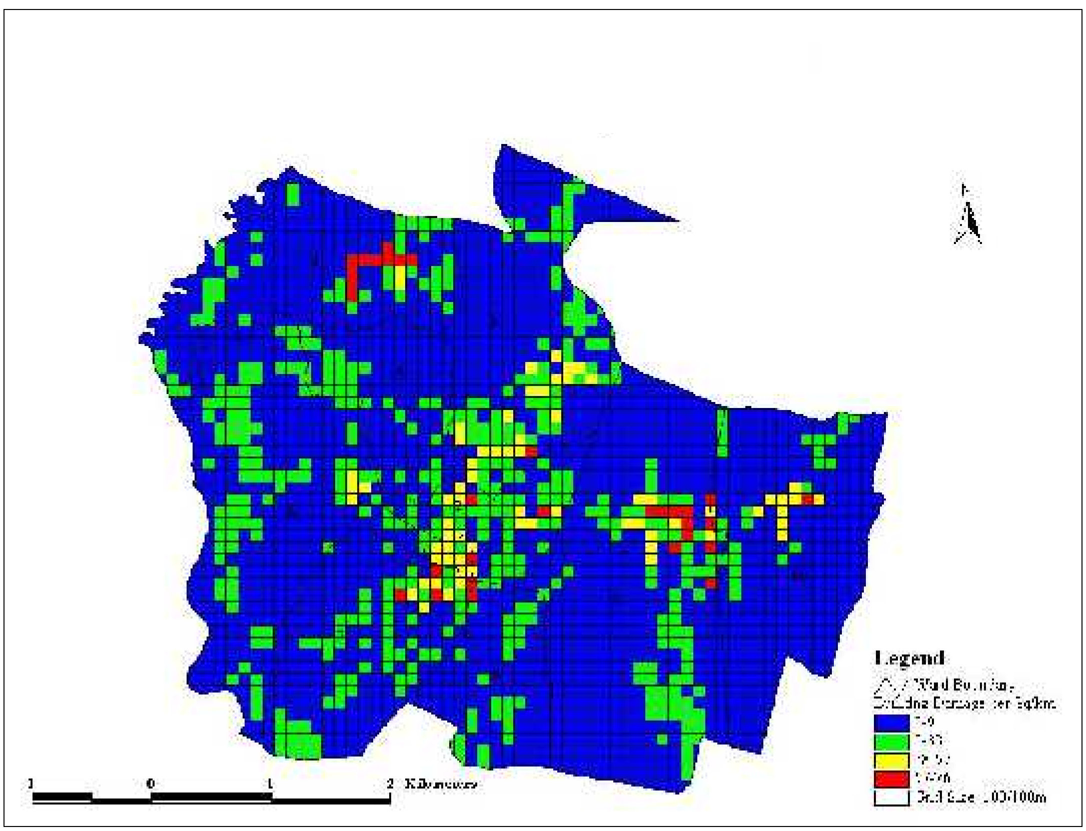


Figure 6.4 show the building damage distribution within 10 wards. In figure, blue color represents damage ratio of 0 to 9 building per sq/ km. The ratio is low because most of the space is used by farm and open area. Similarly, green color shows 9 to 38 building ratio. Field observed also found that are village and small chock having some shops. Most of the wooden and shrub types of houses with separation were found in this area. Ward no. 3, 6, 7, and 9 are having high ratio of damage it is due to building attachment and age. These areas have shown in figure with yellow and red colour that consist 38- 57 and 57- 76 damage ratio.

6.3.2. Estimation of Casualties in North East Sunsari Earthquake during Day

Injuries

It is estimated from the RADIUS that, out of the total 27092 population in the day time, 1440 people were found to be injured when north east Sunsari earthquake hits the municipality. The overall total percentage of injured were recorded as around 6.4% in the municipality. Among them, ward no.6 possess the highest number of injured (table 6.3). Similarly, ward no. 1 is less number of people will be injured; it is due to found having newly constructed buildings, and followed by construction materials during built up.

Table 6.3 Estimation of Casualties Injury and Death

Ward no.	Day Population	Casualties	
		Injury	Death
1	1488	54	5
2	2417	139	15
3	2836	205	26
4	1617	147	21
5	1067	76	10
6	3815	255	31
7	3097	191	22
8	1343	85	10
9	2823	192	23
10	1684	96	10
Total	**22,187**	**1,440**	**173**

Source: Field Survey and RADIUS Analysis, 2008

Figure 6.5 Estimation of Casualties (Injury and Death)

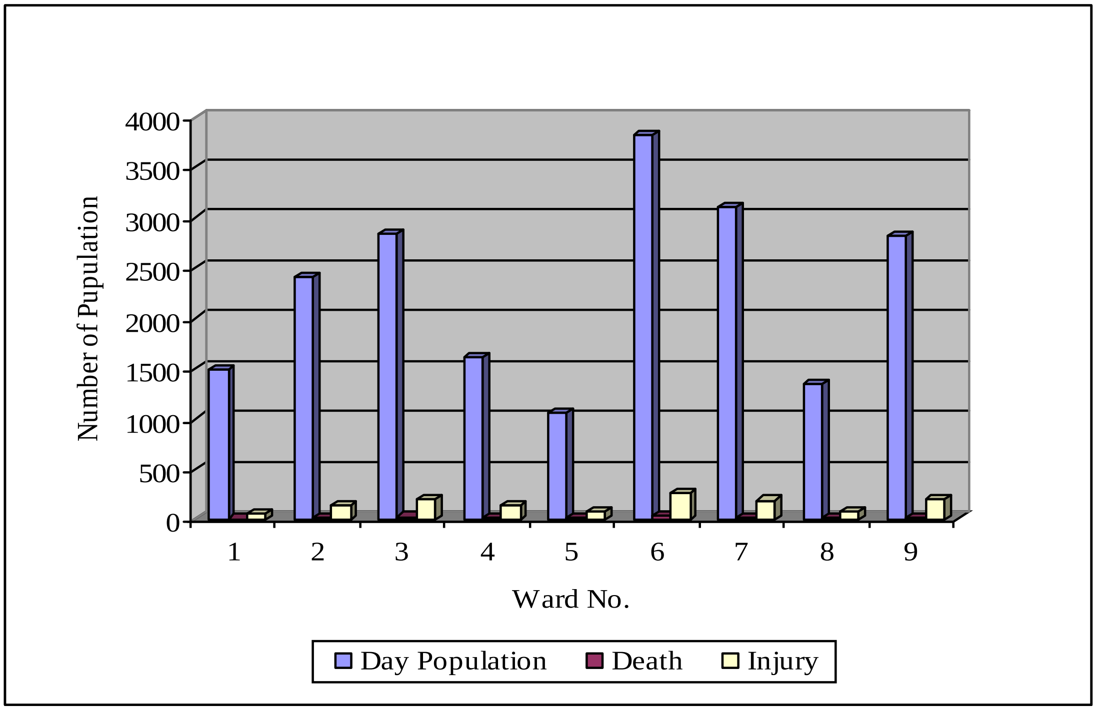
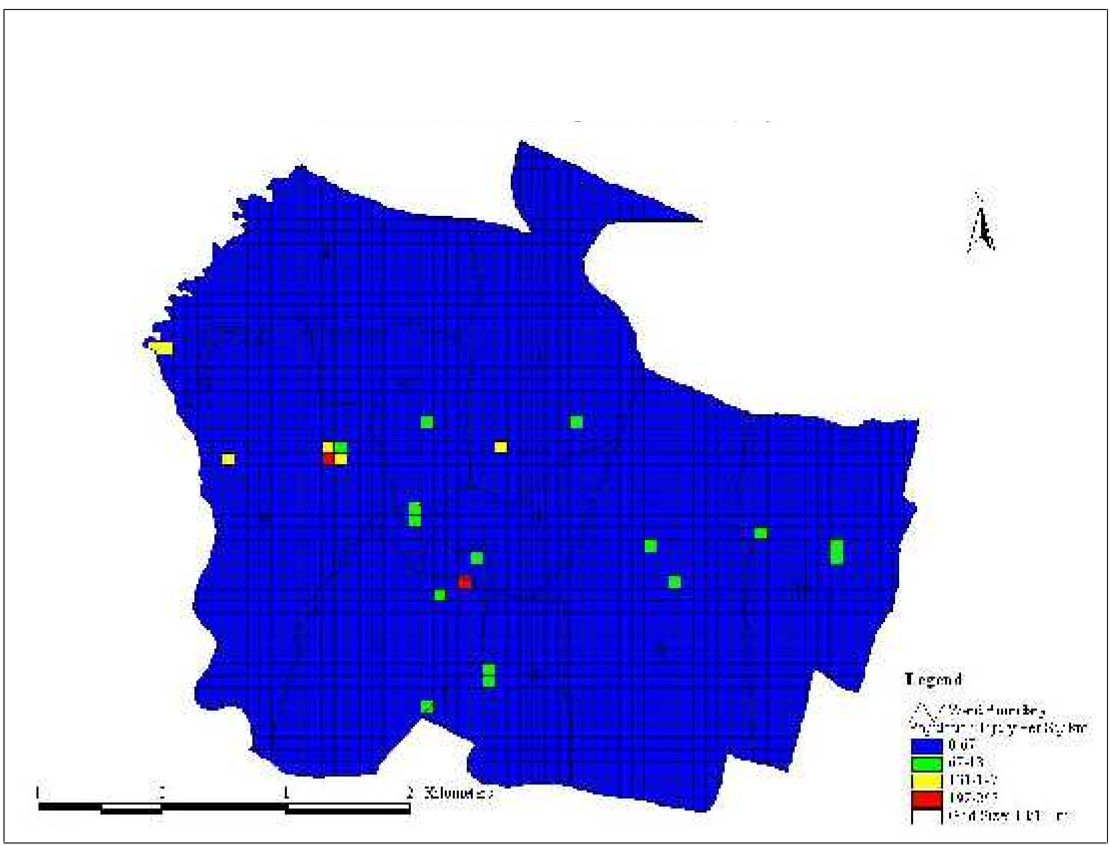


Figure 6.6 Population Causalities (Injury) during Day



Deaths

Out of total day population, 22187 people, around 173 populations died when north east Sunsari earthquake strike in Inaruwa municipality. In overall, the percentage of death represents toll is 0.7 %. Most of the death toll in ward no.6 and 3, the lowest death toll in ward no. 1. This could be happen because higher the population higher the probability of human casualties and vice versa.

Figure 6.7 Population Casualties Deaths in Day

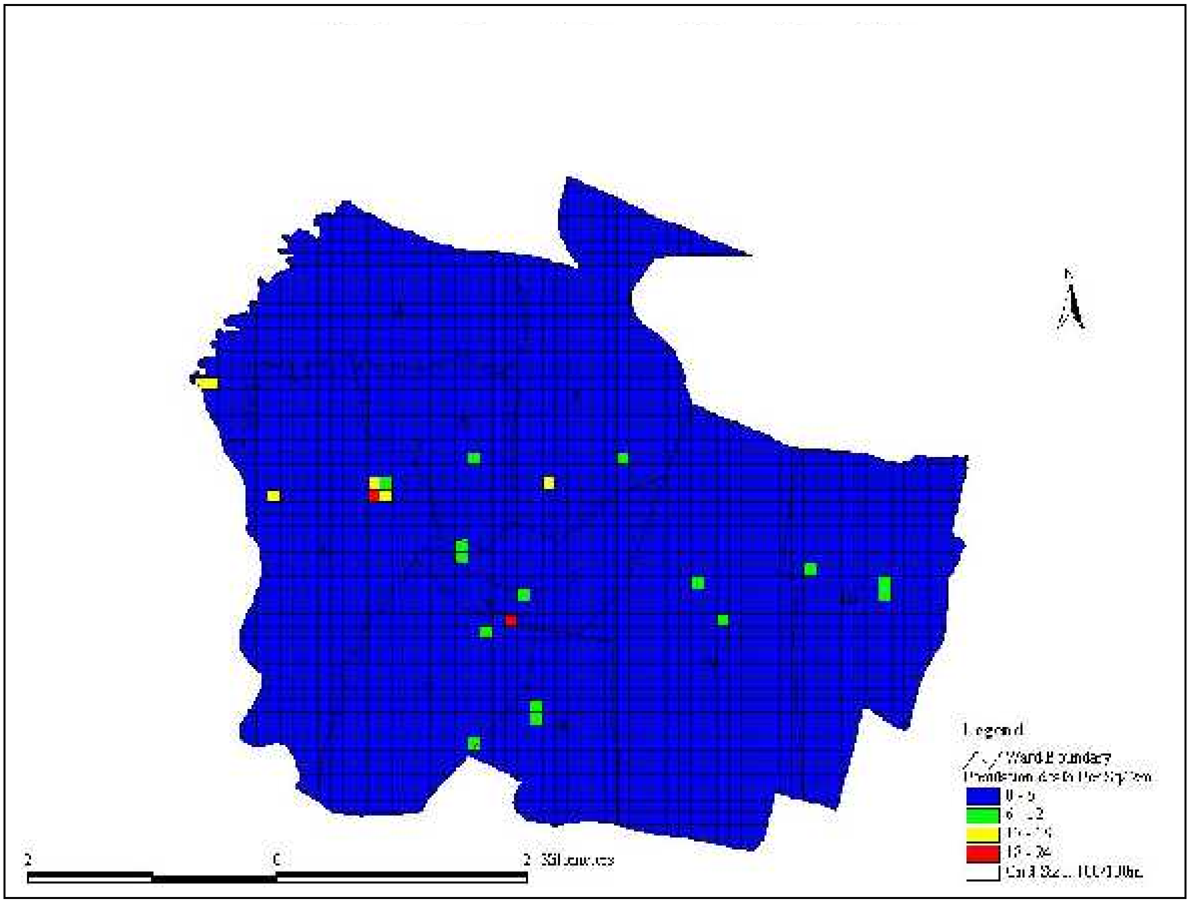


Figure 6.7 represents the death distribution within 10 wards. In figure, blue and green color represents 0- 6 and 6 to 12 person's death per sq/ km. Similarly, yellow and red colour represents high death ration per square kilometer. Red color shows the high number of death that consist in ward 6 and 7. It is done due to building types, age, and building materials.

6.3.4 Estimation of Causalities in North East Sunsari Earthquake during Night

Injuries

Out of the total 27092 population 2705 people were found to be injured when North East Sunsari Earthquake hits the municipality in night (24 o'clock), 9% population will be injured out of the total population. Ward no. 4 is highest number of injured found within 10 wards (Figure 6.8 and table 6.4).

Table: 6.4 Estimation of Casualties (Injury and Death) during Night

Ward no.	**Night Population**	**Casualties**	
		Injury	**Death**
1	1502	96	10
2	3120	252	30
3	4635	452	59
4	2130	298	45
5	1857	175	23
6	3435	399	56
7	3485	335	43
8	1398	144	18
9	4143	402	51
10	1387	152	20
Total	**27,092**	**2,705**	**355**

Source: Field Survey and RADIUS Analysis, 2008

Deaths

The total death when north east Sunsari strikes the municipality in night time is 355 (1.3%) people deaths, out of total 27092 night population. More causality was observed during night times because during night time most of the people are assumed to be inside their homes. Life line services might also run out. The death ratio is very in night time than the day it is obviously all the people live in their homes in the night. So at that time, there are high possibilities of casualties (death and injury).

In figure 6.10 shows, ward 3, 4, and 9 have high number of death ratio in yellow and red color. It is because of old traditional houses with building attachment and tree garden in this area.

Figure 6.8 Estimation of Casualties (Injury and Death)

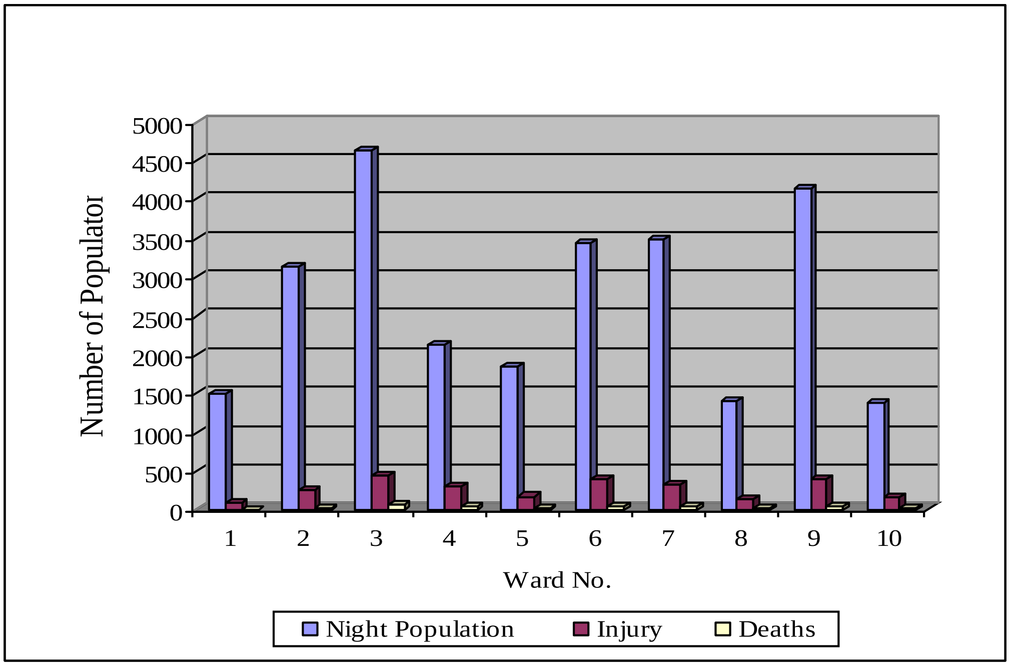


Figure 6.9 Estimation of Population Casualties (Injury)

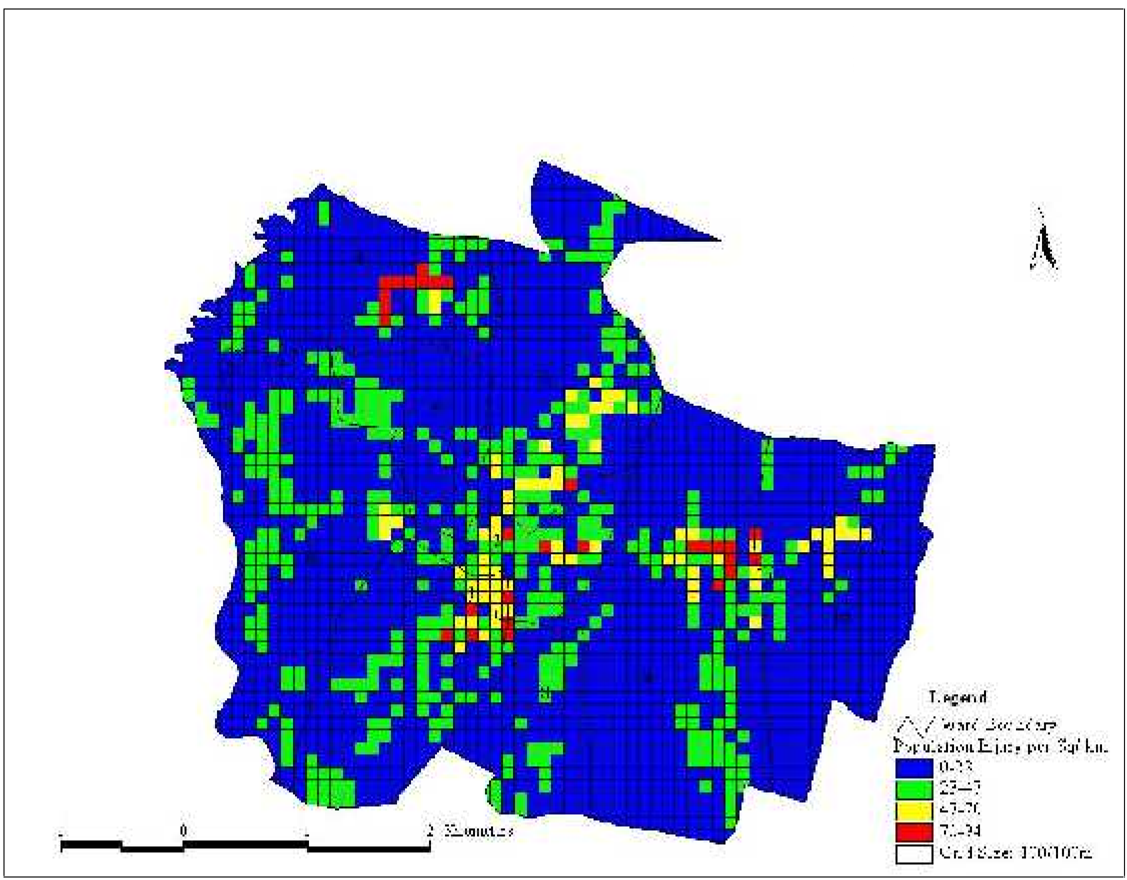
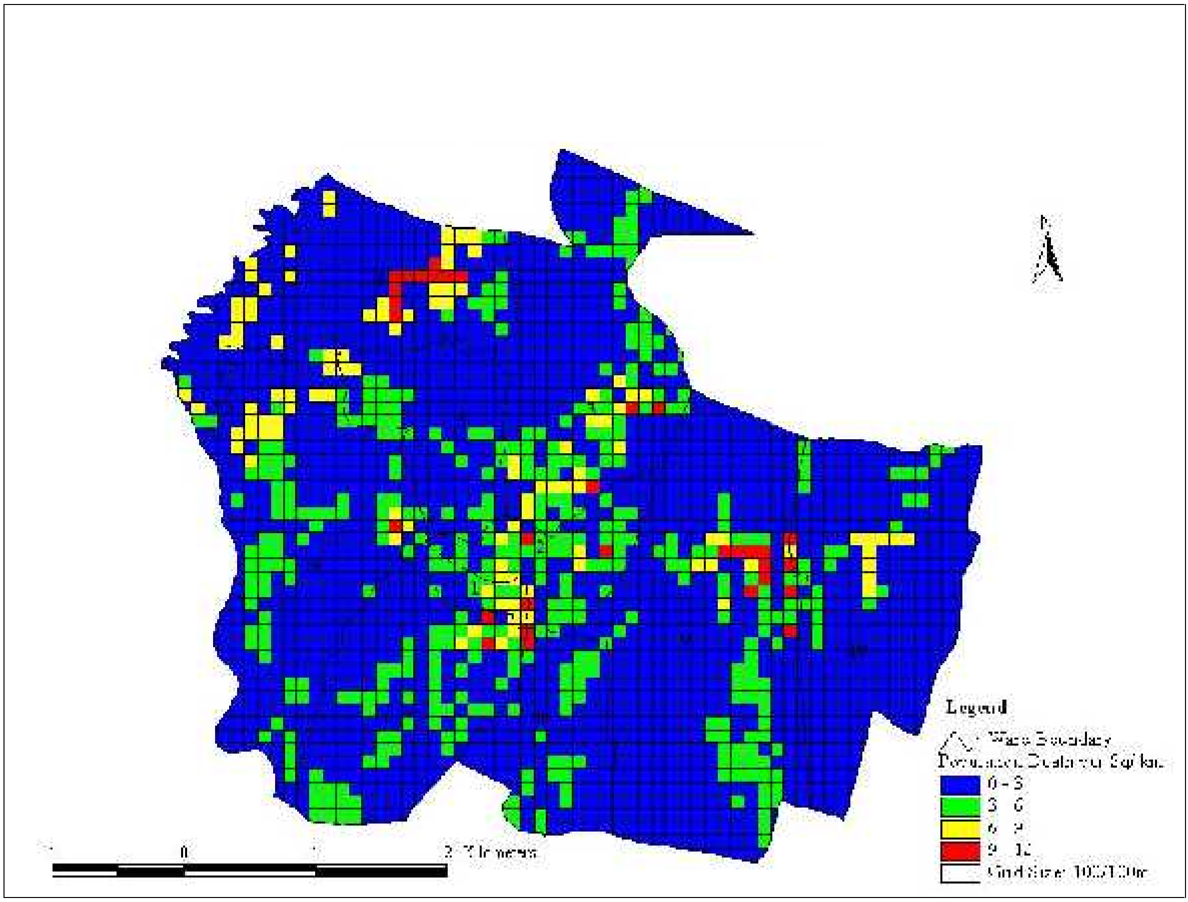


Figure 6.9 represents injury distribution by different colors in municipality. Green color shows 23 to 47 people's injuries per sq/ km. Yellow color represents the 47 to 70 persons' injury. Similarly, red color shows high numbers of injury mainly ward 4 and 9.

Figure 6.10 Estimation of Casualties (Deaths) during Night



6.4 Mid Udayapur Earthquake Scenario

For estimation the level of building damage and casualties in the study area, mid Udayapur Earthquake scenario was considered another as a possible hypothetical earthquake. It is anticipated to occur due to the active main boundary thrust fault which lies about 31.5 km which correspond north from the Inaruwa municipality which regarded as huge earthquake of 8 magnitudes (table 6.1).

6.4.1 Estimation of Building Damage by Mid Udayapur Earthquake

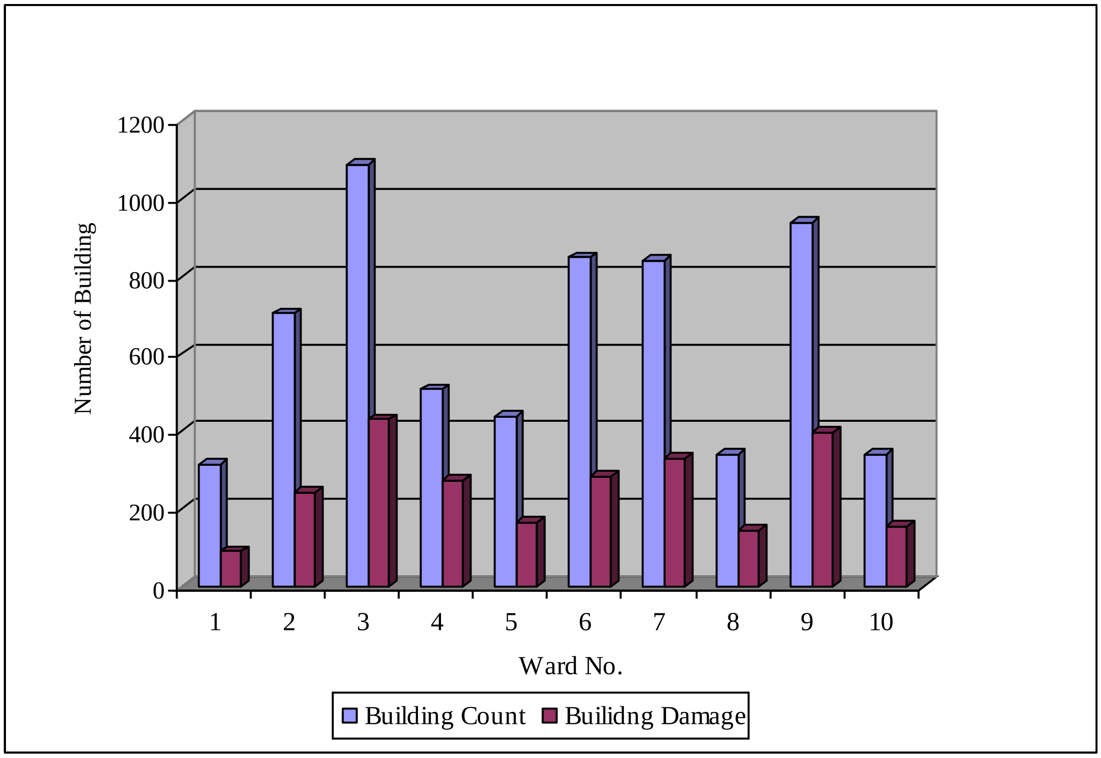
Out of total building 6349 in the study area, 41% buildings could be damage when the Mid Udayapur earthquake sticks in the municipality. Table 6.5 and figure 6.11 shows the number of building damage distribution within 10 wards. According to the RADIUS result on the 6.5, ward no.3 and 9 depict the highest number of building damage about 17% and 15%. And the ward no.1 possesses the less number of building damage. The more building damage is because this ward located nearer to the fault line among all other wards and also most houses of this ward constructed by adobe, traditional old houses and unfired brick.

Table 6.5 Estimation of Building Damage in Mid Udayapur Earthquake scenario

Ward no.	Building Count	Building Damage	Damage percent
1	313	90	3
2	703	242	9
3	1087	430	17
4	508	273	10
5	436	165	6
6	847	283	15
7	840	331	13
8	339	144	6
9	938	398	15
10	339	153	6
Total	**6,349**	**2,609**	**100**

Source: Field Survey and RADIUS Analysis, 2008

Figure 6.11 Estimation of Building Damage by Mid Udayapur Earthquake



6.4.2. Estimation of Causalities (Injury and Death) in Mid Udayapur Earthquake Scenario during Day

Injury

Out of 22,187 day population, the total injures are found to be 8.4% people in Inaruwa, when Mid Udayapur earthquake strikes the municipality. The number of injury emerged highest in ward no.6 which is 47%. On the other hand ward no1 is lowest number of injured which occupied 8% (table 6.6).

Death

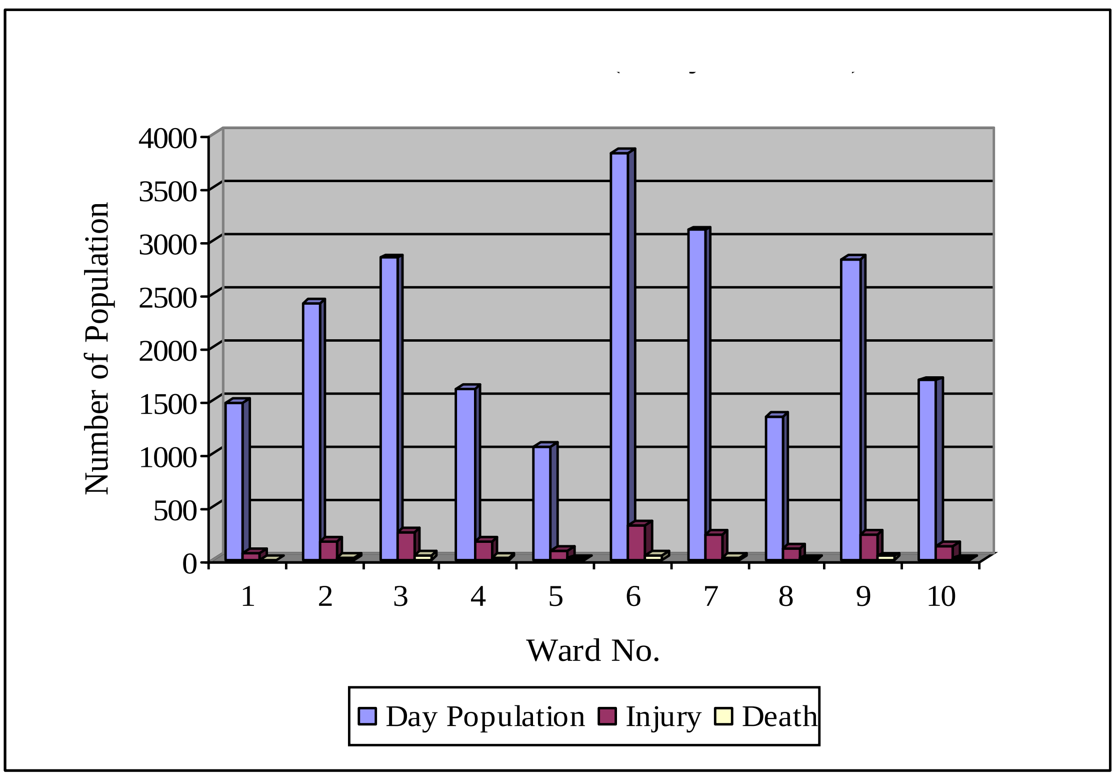
When Mid Udayapur Earthquake strikes the municipality in day time, the death found to be 1.2% out of the 22,187 day population. Ward no. 6 is the highest number of deaths compared to others wards it is because of near of fault line for the ward. There is highest number of day population death in this scenario than the others two scenario (table 6.6) It is obviously that where the high magnitude there is high number building damage and casualties. This scenario is having the high number of magnitude value in this scenario. Figure 6.12 represents the casualties (death and injury) in day time.

Table 6.6 Estimation of Casualties (Death and Injury) during day

Ward no.	Day Population	Casualties	
		Injury	Death
1	1488	71	8
2	2417	181	24
3	2836	264	39
4	1617	187	31
5	1067	98	15
6	3815	330	47
7	3097	250	34
8	1343	112	16
9	2823	252	36
10	1684	128	17
Total	**22,187**	**1,873**	**267**

Source: Field Survey and RADIUS Analysis, 2008

Figure 6.12 Estimation of Casualties in Day



6.4.3. Estimation of Causalities in Mid Udayapur Scenario Earthquake during Night

Injury

Out of the total 27092, 12.9 % people were found to be injured, when Mid Udayapur earthquake hits the municipality in night time. The highest number of injury consists in ward no. 3 that shows 583 people. Similarly, the lowest number of population injured found in ward no. 1 (table 6.7)

Death

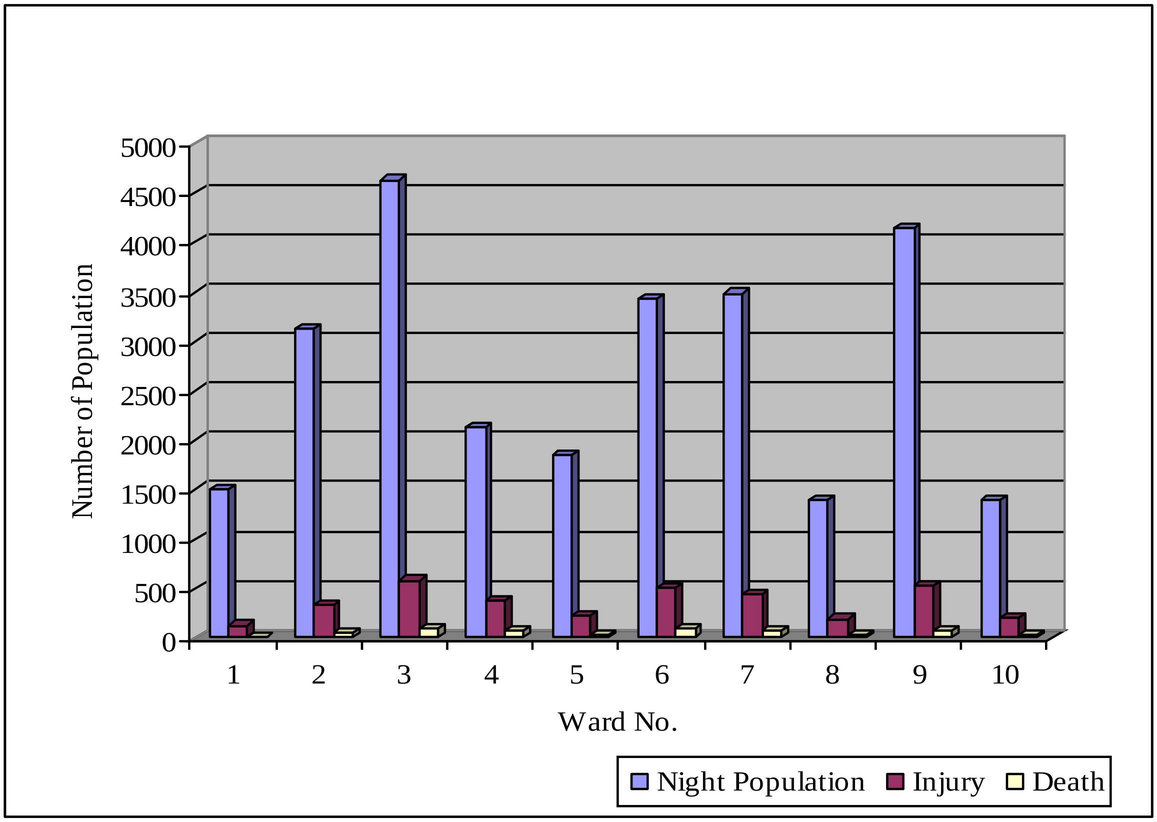
The total deaths are found 549 (2.3%) people in out of the 27092 when Mid Udayapur earthquake hits the municipality in night time (2 o'clock). The death covers the 2 percent in the total population. The result found that ward no. 3 and 6 are high number of death (table 6.7), it is because of high number of buildings with its nature and types and the number of population is another factors to be casualties. Where the high number of injures there will be high number of death. The number of death is high in this scenario than the other two earthquake scenario, it depends on earthquake magnitude, depth, fault line near by municipality and also play the important roles by building types, using materials, age etc.

Table 6.7 Estimation of Casualties by Mid Udayapur Earthquake Scenario in Night

Ward no.	Night Population	Casualties	
		Injury	Death
1	1502	125	16
2	3120	328	47
3	4635	583	90
4	2130	379	66
5	1857	225	35
6	3435	514	85
7	3485	438	67
8	1398	190	30
9	4143	528	81
10	1387	200	32
Total	**27,092**	**3,510**	**549**

Source: Field Survey and RADIUS Analysis, 2008

Figure 6.13 Estimation of Casualties



6.5. North West Saptari Earthquake Scenario

For estimation the level of building damage in the study area, the named of North West Saptari earthquake scenario is the considered as a possible hypothetical earthquake. It is anticipated to occur due to the active Himalayan Frontal Fault which lies about 26 km which correspond north west from the Inaruwa municipality which regarded as 7.3 magnitudes.

6.5.1. Estimation of Building Damage by North West Saptari Earthquake Scenario

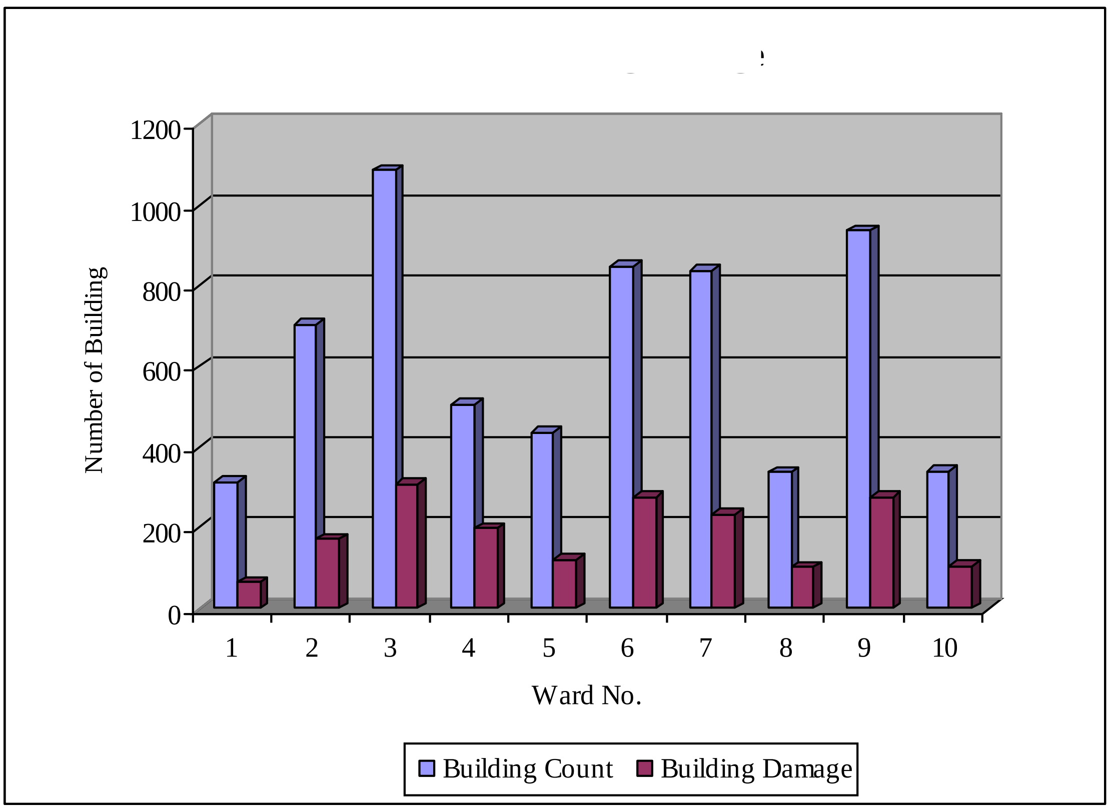
Out of total building 6349 in the study area, 29.2% buildings could be damage when the North West Saptari earthquake sticks in the municipality. Table 6.8 shows the ward wise building number and damage. According to the table ward no.3 depict the highest number of building damage about 17%. And the ward no.1 possess the less number of building damage. The more building damage in ward no. 3, it is because this ward located nearer to the fault line and also has poor condition of houses in this ward.

Table 6.8 Building Damage by the North West Saptari Earthquake Scenario

Ward no.	Building Count	Building Damage	Damage percent
1	313	64	3
2	703	172	9
3	1087	307	17
4	508	199	10
5	436	119	6
6	847	277	15
7	840	235	13
8	338	102	6
9	938	278	15
10	339	106	6
Total	**6,349**	**1,859**	**100**

Source: Field Survey and RADIUS Analysis, 2008

Figure 6.14 Estimation of Building Damage



6.5.2 Estimation of Causalities (Injury and Death) in North West Saptari Earthquake Scenario during Day

Injuries

It is estimated from the RADIUS that, Out of the total 22187 population in the day hours, 1,118 people were found to be injured when Norht West Saptari earthquake hits the municipality. The overall total percentage of injured were recorded as around 5.0% in the municipality. Among them, ward no.6 possess the highest number of injured (table 6.9).

Table 6.9 Estimation of Casualties (Injury and Death)

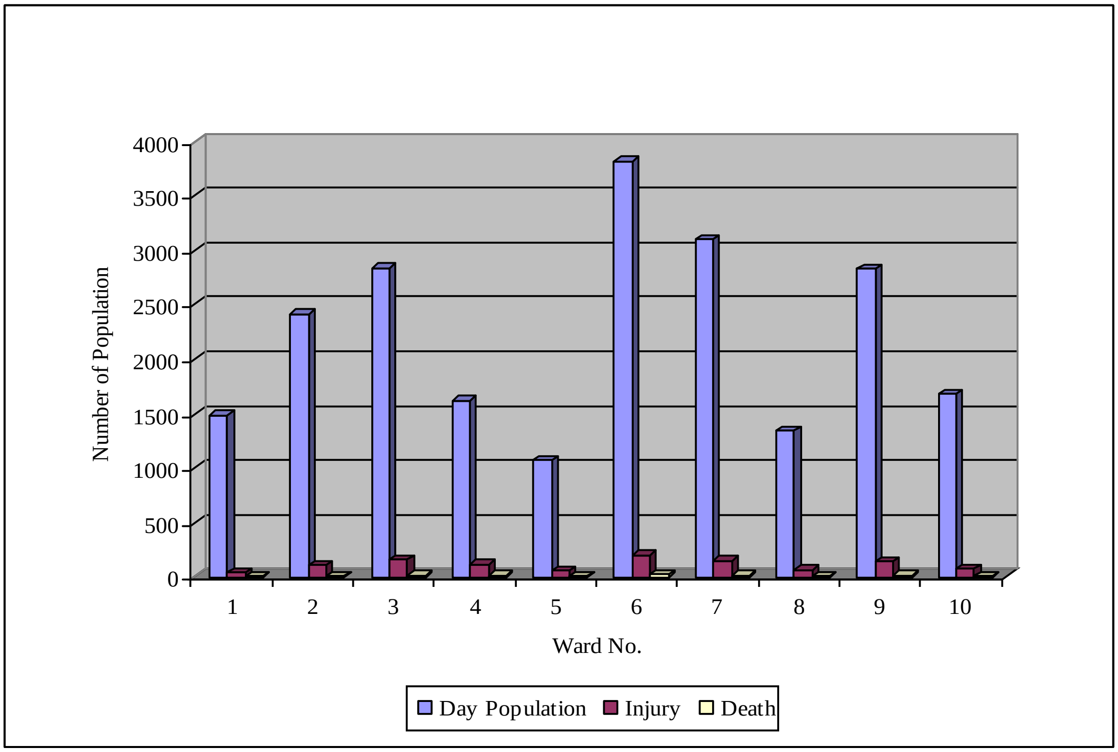
Ward no.	Day Population	Casualties	
		Injury	Death
1	1488	40	3
2	2417	108	10
3	2836	158	16
4	1617	116	14
5	1067	60	7
6	3815	202	20
7	3097	149	14
8	1343	66	6
9	2823	147	14
10	1684	72	6
Total	**22,187**	**1,118**	**110**

Source: Field Survey and RADIUS Analysis, 2008

Deaths

Out of total day population, 22,187 people, around 110 (0.5%) populations died when North West Saptari earthquake strike in Inaruwa municipality. In overall, the percentage of death toll is 0.5%. Most of the death toll in ward no.6 and the lowest death toll in ward no. 1 (table 6.9 and figure 6.15). This could be happen because higher the injuries, high the probability of death.

Figure 6.15 Estimation of Casualties (Injury and Death)



6.5.3. Estimation of Causalities in North West Saptari Earthquake Scenario during Night

Injures

If hits the North West Saptari Earthquake to Inaruwa in night time, there found to be 2,104 injured out of the 27092. Where the ward no. 3 consist the highest number of injured (16.6%), it is because of high number of population and near by the fault line form this ward. Ward 1 is lowest number of found injured that represents 3.3% (table 6.10). During night hours (1 o'clock) overall 7.7 % of population found to be injured in Inaruwa.

Deaths

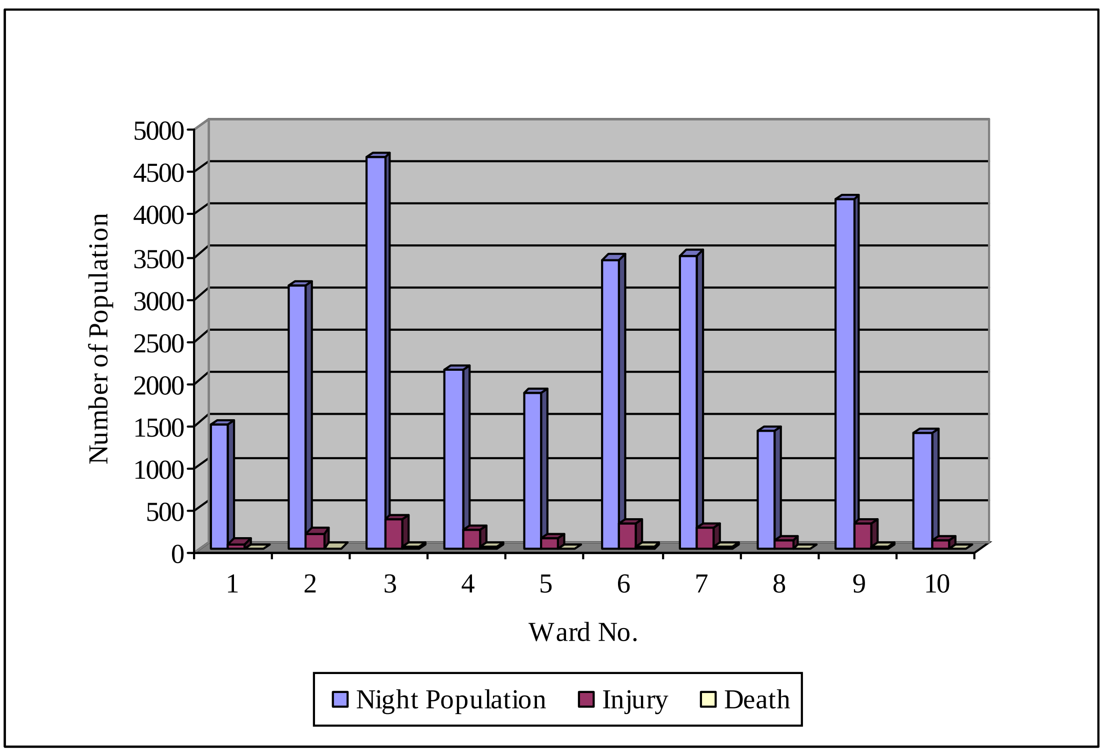
The total 226 (0.8%) people deaths were found in out of 27092 populations when the North West Saptari Earthquake strikes the municipality. The numbers of death peoples were more than the day death. Due to high number of casualties are probable the high number death. In night hours most of the people live in their homes and less chances to safe than the day so the night hour earthquake is more crucial than day. Table 6.10 shows the highest number of death in ward no. 3 and 6 around 37%, it is because of high number of injuries found and on the other hand fault line form this area as well as building condition, magnitude, awareness, preparedness also play the important role to make vulnerable.

Table 6.10 Estimation of Casualties (Injury and Death)

Ward no.	Night Population	Casualties	
		Injury	Death
1	1474	71	6
2	3120	196	19
3	4635	351	37
4	2130	235	29
5	1857	137	15
6	3435	316	37
7	3485	262	28
8	1398	112	12
9	4143	308	31
10	1387	116	12
Total	**27,092**	**2,104**	**226**

Source: Field Survey and RADIUS Analysis, 2008

Figure 6. 16 Estimation of Casualties



CHAPTER VII

KNOWLEDGE AND AWARENESS OF EARTHQUAKE IN INARUWA MUNICIPALITY

An earthquake is the sudden release of accumulated strain energy that takes the form of waves and vibration (seismic waves) that are transmitted through the earth in all directions. It results damage of buildings as well as infrastructures together with loss of properties and casualties of human lives. Nepal has faced lots of small and some great earthquakes with losses of lives and property. Scientists also have challenges in prediction of earthquake precisely but generally in fifty years gap the greater or smaller earthquake may occur. Earthquake can occur anytime and at anyplace. There is a general tendency that building practices do not take adequate building codes seriously in the context of unplanned rapid urbanization and growing land value in the city area (Guragain, 2004).

In developing countries, the disastrous effects are further increased by lack of awareness and education, concentration of population in seismically vulnerable house, lack of communication and transportation facilities, deficient financial resources, and other weakness. In fact the, poorer the population, the more vulnerable it is to natural disasters (Arya and Srivastava, 1998)

On the other hand, people irrespective to their living places (rural or urban) have low level of awareness on causes and consequences of earthquake. In this context, knowledge, awareness and properness are very important in assessment of seismic vulnerability. This section evaluates implication of factors in reducing earthquake risk in the study area.

Knowledge and Awareness of Earthquake in Inaruwa Municipality

In Inaruwa municipality lots of the people have knowledge about earthquake and they have listened and watched some information by radio and television. In key informant survey found, UPCA Nepal Dharan has conducted the programme about earthquake, respondent informed that the programme taught them how to make safety building, what we do during and after earthquake occurrence, how to save others etc. But he also added only few teachers and students only participated in that programme and therefore, this might not be beneficial for larger section of population.

Table 7.1 Knowledge and Awareness of Earthquake Events

Participation		Listening/ Watching		Institution		Early warning		Living risk		Safety measure		Safe place		Temporal Lodge		Discussion		Blame				
Y	N	Yes	No	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	God	Gov	Eng	Your	Nature
3	271	234	40	4	270	0	274	140	134	4	270	0	274	0	274	2	272	80	4	4	50	136

Note: Y = Yes, N = No, Gov. = Government, Eng. = Engineer,

Table 7.1 represents the knowledge and awareness of earthquake in Inaruwa municipality, which described as below.

During field survey, not a single respondent able to state the forecasting of earthquake. Neither the local people have any knowledge on safety codes of the buildings nor any NGO/ INGOs have made any awareness or training on such aspects.

Only vary few among the total houses observed are found to be under safety measures. However, the owners of those buildings too seem to be unaware of the actual earthquake resistive capacity of these houses. One of the residential houses too is found to have followed the safety measures. According to the houses owners, the house has can resist the earthquake waves, but he too is found unaware regarding up to what magnitude it can resist. The house was found designed by his engineer son who was absent these in cause of out survey.

Concept of safe place and temporal lodging seems to be out of question for the people of Inaruwa. When they were asked, they replied that they had never though of it. But in the outer part of the municipality, some poor inhabitants' houses are found to be safe ones, accidentally. They have used bamboo, wooden, and even shrub that are safe for earthquake. However, all buildings of Inaruwa are not safe; some of them are adobe houses of over 50 years which are found to be vulnerable. Because of poverty, they are unable to substitute those houses with safer ones. Even if they can, they want to save them as ancestral gift. So, they are preferring risk over traditional property. So, even the knowledge regarding earthquake disaster has not reduced the risk.

Further, the local inhabitants are highly superstitious regarding the matter of earthquake. They believe that it is not under our control. They also relate this phenomenon with myth. According to the myth the god, which dwells inside the earth in the forms of large fish moves its body part that result into earthquake waves. They too believe that such assumption take place mostly in those areas that are full of impious or criminal activities. Because of such traditional beliefs, earthquake risk is increasing. They are found to be unaffected of the modern development of science and technology. However, there seems to be some scientific relation behind this misbelieves. That is, the cause of earthquake is the movement of the large tectonic plates to which they believe to be a fish.

Among the various participants involved, 50 respondents among the total interviewer blamed this own fate (because some of these believed that it is unavoidable phenomenon) as well as this poor economic condition. However, about 50% the participants believe it to be a natural phenomenon.

One is satisfactory matter; however is that most of the people are aware of the precautions or safety methods they are required to follow at the time of earthquakes such as hiding under bed on tables, away form tree, electric poles and buildings.

CHAPTER VIII

SUMMARY, CONCLUSION, AND RECOMMENDATIOS

8.1 Summary

The present study was conducted for seismic vulnerability assessment of Inaruwa municipality with three objectives. To fulfill the objectives, this research used household survey, observation and key informant survey to generate preliminary data as well as GIS and RADIUS tools was used. The methodology for the estimation of building damage and human casualties with different probable earthquake scenarios with customized with new fragility function for Nepal.

The findings on the nature and types of the buildings within Inaruwa municipality characterize the followings;

Regarding the age of buildings with in the municipality, almost halves are characterizes by less than 20 years. Only 2% of the buildings were more than 50 years of age. The rest of the buildings are characterizes by 20 to 50 years of age.

In the same way, regarding the types of buildings were found out on the basis of construction materials. RCC buildings which consists 39% out of total observed buildings are dominant. Similarly, 34% wooden, 15% brick in cement, 7% shrub based buildings are observed during field survey in the study.

Almost two third of the total building in Inaruwa municipality are comprised of one story type. Likewise almost one third buildings are of two story types. A very small percentage of buildings are of more than two story types.

Regarding the geometry of the buildings only 40% buildings are regular in shape and remaining buildings are in irregular shape.

The seismic vulnerability assessment of buildings are analyzed which three different earthquake scenarios such as North East Sunsari, Mid Udayapur and North West Saptari types. These scenarios are based on the fault line near by Inaruwa. The probable scenarios for three different types as follows:

The North East Sunsari scenario could make damage of 34% buildings of the municipality. The occurrence in the day time could result injuries of 6% and death of 1% population. And similarly, the occurrence in night time could result 10% injuries and 2% death.

The Mid Udayapur scenario results a loss of 41% buildings in the area. It is estimated 8.4% injury and 1.2% death during day time. Similarly, the same scenario of night time may result 12% injury and 2% death.

The North West Saptari earthquake scenario reveals a damage of 29% of buildings. The casualties (5% injury and 0.5% death) were estimated in day. On the other hand, in night 8% injury and 0.8% death could be resulted.

The knowledge and awareness of earthquake in Inaruwa municipality is based on questionnaires administed on different households and information based on key informants.

Almost 85% of peoples have listened and watched about earthquake either on television or radio and they are aware about the consequences of an earthquake. However almost halves of the total population still live in risky situation due to their poverty and low income.

A larger number (50%) believes occurrence of earthquake as natural event. Similarly, almost 29% believes as the angriness of god to human being.

8.2 Conclusion

The research has tried to estimate of building vulnerability and human casualties under different probable earthquake scenarios. Many researchers have studied about earthquake but concentrate within and around Kathmandu only. In the same way, most of technical types and analyzed only the temples, masonry buildings etc. But the present research has attempted to estimate all types of buildings within Inaruwa municipality and also tried to understand the knowledge and awareness of people an earthquake in the area.

Different field methods were use to generate ground realties and rigorous analysis was made with GIS software to make a reliable methodology. The following conclusion could be make form the present study:

- Earthquake hazard is direct relation with poverty. Because of poor economy, people should bounded in vulnerable area (photograph 9). In market area rich person didn't priority to rebuild up new buildings, they only takes economic and commercial purposes, like giving to stand towers in roof in rent (photograph 7, 8).
- RADIUS method is found to be effective and easy in estimating building damage as well as human death and injury.

8.3 Recommendations

- This research is based on visual observation of the buildings. However, a technical evaluation of the buildings could make better estimation of risk arises due to occurrence of earthquake.
- The assessment of casualties and injuries are based on due to damage of the buildings. However, further research could think of the damages that could be made by other probable losses due to infrastructures such as fall of electric pole, fall of water storage tank, breaking of bridges and so on.

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ANNEX 1: Building Inventory Form

Building Inventory form Inaruwa Municipality											
Form No		Ward No		Block No			Tole:		Date		
Building ID	Story No	Use	Building Type	Soft story	Age	Building attached	Roofing System	Shape	Potential near by hazards	Physical condition	Non structural element

ANNEX 2: Index of Short Form

INDEX								
Building type	Use	Shape	Age	Attachment	Roofing system	Potential near by hazards	Non structural element	Physical Condition
Ad: Adobe	Res: Residential	R1: Regular (<1:3)	A1: <20	SL: Separated	CGI: Steel	T: Tree	Hb: Hording board	V: Vulnerable
BC Brick in cement	Com: Commercial	R2: Regular (>1:3)	A2: 20 -50	At: Attached	Cn: Concrete	EP: Electric Pole	T: Towers	AV: Average
RCC: Reinforce Concrete	Sch: School	IR: Irregular	A3: >50		Th: Thatch		OT: overhead water tank	G: Good
W: Wood	H: Hospital				S: Sleet			
Sh: Shrub	PS: Police station				W: Wood			
BM: Brick in mud	C: Club							
SC: Stone in Cement	HR: Hotal Restaurant							
	OI: Office Institute							
	Ind: Industry							
	Mx: Mix							

ANNEX 3: Household Survey Form

Inaruwa Municipality							
Household Head Age:				**Major occupation:**			
Cast /ethnicity:				**Religion:**			
Form No.		Ward No.		Tole:		**Supervisor:**	
Block No.		Building ID:		Date:	065/ /	**Surveyor:**	

Population Distribution					
Total population		Male		Female	

1. How many persons (Average) work/stay here during ;				
Age Group	**Day (6am-6pm)**		**Night (6pm-6am)**	
	Male	Female	Male	Female
Below 10				
11 – 15				
16 – 69				
Above 70				

2. Socio-economic characteristics of household ;								
Activities	M	F	**Education**	M	F	**Work place**	M	F
Trade			Uneducated			Same ward		
Agriculture			Primary			Another ward		
Household			Secondary			Out of municipality		
Govt. Sector			Higher Sec.			Another Region		
Industry/			Higher Edu.			Another country		
Handicapped								

Knowledge and Awareness		
Have you participate any earthquake awareness programs?		
Have you listened/watched the earthquake awareness programs on radio or TV?		
Do know any organization that can aid you in reducing earthquake vulnerability?		
Do you know about early warning systems?		
Do you think you live risk?		
Preparedness		
Have you used any earthquake safety measures in your building?		
Have you identify a safe place inside and outside your house if there is an earthquake?		
Incase of disaster do you have temporal lodging?		
Do nyou discussed with each other reducing earthquake vulnerability?		
Whom do you blame for the losses (lives and property) due to earthquake?		

God		Government		Nature		Engineer		Municipality		Yourself	

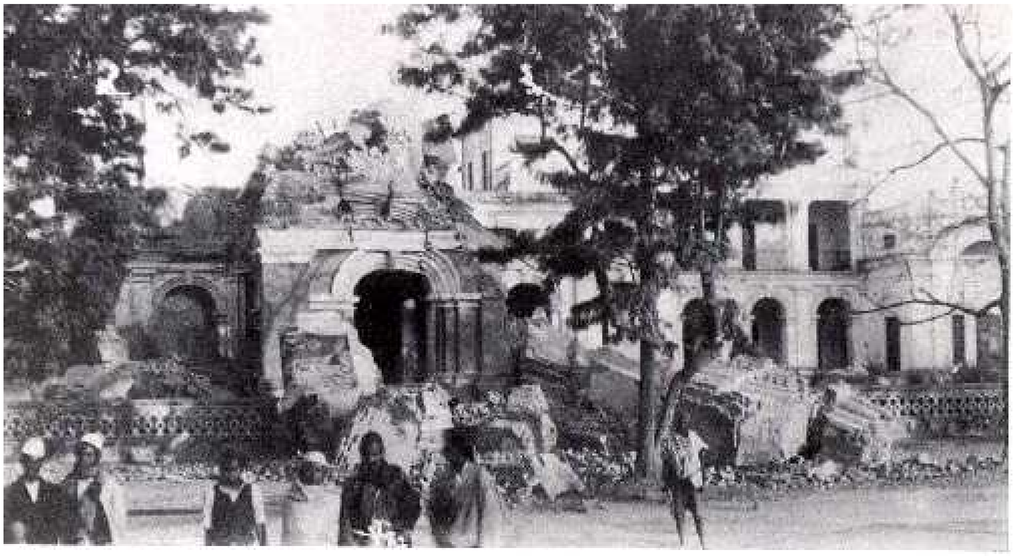
What do you think about earthquakes?

……………………………………………………………………………………………………...…

……………………………………………………………………………………………..

Which places are suitable during the earthquake time?

ANNEX 4: Photographs



Photograph 1. Earthquake in Kathmandu (1990).

Photograph 2. Bhaktapur Darbar Squar before and after 1990 Earthquake

Photograph 3. Earthquakes in Nepal (Dhading and Dharan)

Earthquake in Sunsari (Dharan) 2045

Earthquake in Dhading 2045 BS

Photograph 4. 2045 Earthquake in Nepal

Photograph 5. 2045 Earthquake in Nepal

Photograph 6. Earthquake in India

Photograph 7.Earthquake in Pakistan

Sources: NSET, 2008

Photograph 8. Inaruwa municipality (Towers on the roof)

Photograph 9. Vulnerable Building (Inaruwa municipality)

Photograph 10. Local type of building of Madhesi Indigenous (Inaruwa municipality)

Photograph 11. Earthquake Safe Buildings (Inaruwa municipality)

Photograph 12. Shrub types of buildings (Inaruwa municipality)