Chapter I

INTRODUCTION

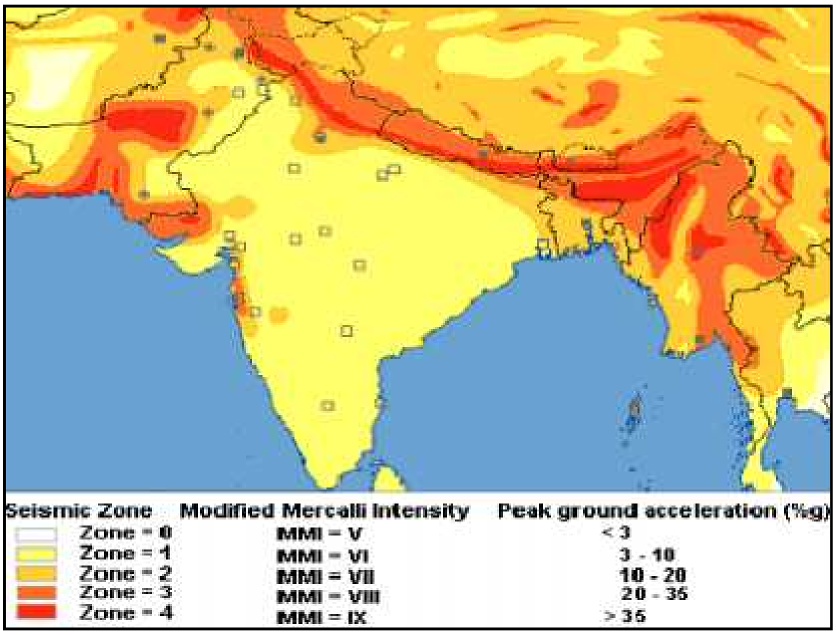
1.1. Introduction:

Nepal is a beautiful Himalayan country locating in the middle of Hindu-Kush Himalayan Region. The Himalayas is one of the youngest mountain ranges on earth. They are still tectonically very active with ongoing uplift leading to physical implications such as fragile bedrock, steep slopes and a high rate of soil erosion. The constant movement of Indian plates at the rate of 2 cm per year towards the Eurasian plates has built up force that pushes up the Himalayas upwards and move horizontally making the Himalayas the most restless mountain range in the world. Intense neo-tectonic activities make this region very dynamic in the globe as well as several tectonic discontinuities such as Main boundary Thrust, Main Central Thrust, Himalayan Frontal Fault system, etc. *soared up its dynamism.* So, Nepal lies in high seismic zone (Figure: 1.1) and faces earthquake shock of different magnitude frequently.

An earthquake is the product of a sudden release of accumulated energy in the crust of the earth, creating seismic waves. Earthquake may occur naturally or as a result of human activities; an earthquake is either caused by tectonic plates getting struck and putting a strain on the ground or it can be caused by volcanic activity, landslide, mine blasts and nuclear experiments. Earthquake in Nepal is very familiar hazard/ disaster. It is one of the important disasters that can damage and destroy buildings and infrastructure, lifeline facilities as well as injure and take the life of human beings and livestock.

According to NSET studies (2007), with in 36 years (1971-2006), Nepal experienced 22 earthquakes with magnitude of ranging from 4.5 to 6.5 Richter scale. During this period, 876 people were died and 6840 injured due to earthquake. About 34000 buildings were destroyed and 56000 damaged. Similarly, more than 9.5 Hundred million Rupees was lost due to earthquake within this time span.

Figure 1.1: Seismic Hazard Map of Nepal



Source: NSDRM, 2008

1.2 Statement of the problem

Nepal lies in high seismic risk zone and earthquake shake this nation frequently. Earthquake is a unique natural hazard because of its unpredictable nature. This hazard has been neither predicted nor controlled or stopped by human knowledge and endeavour till now. But the proper preparedness, awareness and knowledge to mitigate its impact can reduce the damage. Human carelessness increases the level of risk, vulnerability, and damage. It is said that though earthquake doesn't harm any people directly, but the weak infrastructures do as a result of violent shaking. So it is necessary to know the probable scenarios of damaged buildings and human casualties due to inevitable earthquake in future. So, research question have been raised as follows:

- What types of buildings are there and how many of them are earthquake resistant?
- What is the pattern of population distribution, and what is the level of their capacity (awareness and preparedness)?
- What is the level of casualties including death and injury?

1.3 Objectives of the research

The overall objective of this research is to develop a seismic damage scenario, which describes the consequences of a possible earthquake for which specific objectives are as follows:

1) To find out the nature and types of buildings in Triyuga municipality.
2) To find the collapse and damage probability of buildings under the different probable scenarios earthquake.
3) To estimate probable casualties (injury and death) due to scenario earthquake.
4) To find out the existing capacity (knowledge, awareness and preparedness) of the local people.

1. 4 Significance of the study

Great earthquake in Himalayan Region Nepal (1934), India (2001), Iran (2003), Pakistan (2005), China (2008) caused great loss of lives and properties. Nepal also lies in the same region and has equal probability of the occurrence of same intensity earthquake. Similarly, infrastructures, buildings in this country have high vulnerability. They are not constructed with proper planning as well as implementing the building construction code and regulation. High hazard and high vulnerable indicates high risk. According to UNDP (2004), among 200 countries, Nepal stands 11th position with regard to relative vulnerability to earthquake. In the history of Nepal with moderate intensity of earthquake, 6.5 Richter scale in 1988 killed 721 people and loss more than 126 million dollars.

Risk assessment is a very strong awareness raising and planning tool. Earthquake risk evaluation is the first step for realistic and effective planning and implementation of earthquake risk reduction as well as preparedness initiatives as it helps to understand the underlying problems and its magnitude, (Guragain, 2008). But unfortunately, very limited cities of Nepal have been carried out such risk assessment. So, it is acute need of the country to conduct risk assessment of all urban centre and rural area. In this context, this study may help in awareness raising and effective planning for all. As the population is high in urban area it is better to select urban centre first.

1.5 Limitation of the study:

Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters (RADIUS) itself a simple computer program in excel for simplified earthquake damage estimation. It requires input of simple data set and provides visual result with medium accuracy indeed. Furthermore, research done with time bound and resource constrain have several shortcomings and it is not exceptional. Sample was done instead of census for data collection. The rate of urbanisation is very high of this municipality so the result may not be applicable even a single year latter. Similarly, this research is confined only in one municipality- Triyuga municipality so the result won’t necessarily represent the situation of other remaining urban centre of the country.

Chapter II

LITERATURE REVIEW

2.1 Terms definition

1.Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

2. Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Example may include poor design and construction of buildings

3. Risk: The combination of the probability of an event and its negative consequences. Risk can be expressed as a function of vulnerability and it can be change or reduce through human coping capacity. It is calculated by the equation: Risk= probability of hazard*vulnerability/capacity.

4 Disaster: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources. Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences.

5. Magnitude and Intensity

Magnitude of an earthquake is a measure of its size. For instance, one can measure the size of an earthquake by the amount of strain energy released by the fault rupture. This means that the magnitude of the earthquake is a single value for a given earthquake. On the other hand, intensity is an indicator of the severity of shaking generated at a given location. Clearly, the severity of shaking is much higher near the epicentre than farther away. Thus, during the same earthquake of a certain magnitude, different locations experience different levels of intensity, (Murty, 2002)

2.2. Earthquakes in Nepal

The fact that Nepal lies in high seismic region is proved by the presence of more than 100's active fault between tectonic plates. Three parallel fault zones created by tectonic movement are the source of earthquake in Nepal. Several earthquake events shake this nation frequently though the scientific and technical recording of them was not available and their loss was not recorded. In the history of earthquake in Nepal, 1934 earthquake was the most dreadful earthquake and unforgettable nightmare event in Nepali history. 8.3 magnitude Richter scale earthquake killed 8,519 people and thousands were injured as well as the collapse of 80893 buildings and the damage of 126355 buildings.

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

Item	Number	Value of Direct Losses (NR)
Total number of responds	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 :*Nepal *DesInventar Database: NSET, 2007*

Nepal has experienced 22 earthquakes (Table 2.3) with magnitude ranging from 4.5 to 6.5 on Richter scale have been recorded through the country during the period of 33 years (1971-2006). About 34000 buildings were destroyed and 55000 were damaged and the loss of 9.56 billion Rupees. Similarly, 876 people lost their life in this period. During the period, 1980 and 1988 earthquakes were larger and more disastrous as compare to the rest. The further one caused heavy damage in the far-western development region whereas the latter in Eastern Development Region. Recent studies indicate that the presence of seismic gap in Western part of the country (NSET, 2007). This region has had very few large earthquakes as compared to neighbouring areas and hence it is thought to have the potential large great earthquake in future.

Table 2.4: Major Earthquakes in Nepalese History

Year	Date	Earthquakes epicentre	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

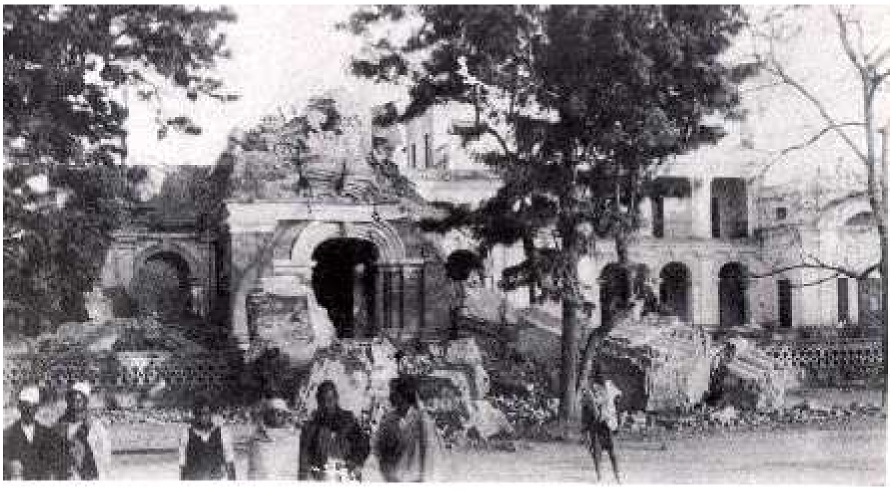
Note: "NA" indicates 'description not available'.

Source: NSET Website

Table 2.4 shows that Nepal faces several moderate and large intensity of earthquake frequently and loss of human life and property. In the history of Nepal earthquakes of 1255, 1833 and 1934 were unforgettable. Earthquake of 1255 killed one third of total population including King Avaya Malla. Recent large earthquake in Nepal:

2.2.1. Bihar- Nepal earthquake of 1934

The largest earthquake in the history of Nepal was happen in 1934, 15 January with an approximate magnitude of 8.4 Richter scale. The epicentre of this earthquake was in Indian city, north of Darbhanga and Muzaffarpur. The depth of focus was 14.8 km. It had affected in three hubs severely i.e. from Motihari to Madhubani, Munghyer city and Kathmandu valley. In the context of Nepal, the earthquake caused huge damage and affect is in Kathmandu valley. Around 80,893 buildings were collapsed and 126,355 were damaged as well as 8,519 people lost their life.



Photograph 1. Earthquake in Kathmandu (1990),

Photograph 2: Before and after of Bhaktapur Darbar Square

2.2.2. Udayapur earthquake of 1988

The latest large earthquake in Nepal was happened in Udyapur District, Eastern part of the country. It occurred at 4:40 on 21st August, 1988 with its latitude 26.7˚N, longitude 86.6˚E. The magnitude of this earthquake was 6.6 Richter scale and the depth was 71 km. This earthquake damaged huge amount of property and life in Dharan municipality as compare to other area. The total life loss was 721 people where as 22,328 buildings were collapsed and 48,045 damaged.

Photograph 3: Earthquake in Udayapur (2045)

Earthquake in Sunsari (Dharan) 2045

Earthquake in Dhading 2045 BS

Source: NSET Website

2.3. Disaster reduction effort in Nepal

The history of disaster risk mitigation in Nepal is relatively short compared to the rest of the world. Only in the recent time mainly after the shock of Udayapur earthquake of 1988 people as well as government have been aware of the potential risk and have been active in disaster risk mitigation program. Governments, non-governments and international sectors have been working in the field of disaster reduction in Nepal. Government of Nepal has tried to address the challenges of natural disaster through the implementation of Natural Disaster Relief Act. This act was enacted in 1982 A. D. and is the only legal instrument to tackle the problems faced in the disaster mitigation. To implement this act, under the chairpersonship of home ministry centre disaster relief committee was constitute as well as various committees at various level was formulated such as regional, district and local disaster relief committee.

Local self government act, 1999, has given authority to local bodies in carrying out necessary function on the controlling of natural calamities and to carry out preventive and relief works to lessen the loss of life and property caused from natural disaster. Chief District Officer is the chairperson of district level disaster relief committee. Regional and local level relief committee is not in practice in Nepal till now though it is mentioned in act.

Department of Urban Development and Building Construction (DUDBC), which is the focal agency for the building safety has prepared building act, 1998, and is providing seismic safety training to technicians. Building act gives authority to the division of DUDBC for supervising the construction works and penalizing persons, institutions etc. for violating the directives. Penal provision consists of construction withheld , monetary fines and full or partial demolition of structure. (Upreti, 2008)

From 10^{th} plan onwards, disaster has been taken incorporated in the planning document as well as local government bodies of Kathmandu Valley takes disaster management issue seriously to some extent and established disaster management section and published informative booklets, brochures, pamphlets etc. Lalitpur Sub-metropolitan city is the very first time implemented the building codes in Nepal, since 2003.

Ministry of Home Affair, Ministry of Physical Planning, Defence Ministry, Health Ministry, Department of Mine and Geology, Nepal Seismological Centre are the major organisation involved in the disaster reduction efforts in Nepal.

Emerging NGOs has played a significant role in the awareness creation and technology transfer. Nepal Red Cross Society (NRCS), Nepal Scout are the leading NGOs in the field of disaster management. National Society for Earthquake Technology (NSET), Centre for Disaster Society (CDS), and Centre for Disaster Risk Studies (CDRS) are the recent institution working on disaster. Disaster

Preparedness Network (DPNet) has been co-ordinating all the working agencies like government and non- government organisation as well as international organisation since 1996.

2.4. Literature Reviews of Past efforts on Seismic Vulnerability Assessment in Nepal

Nepal is among the countries with the highest seismicity in the world, related to the presence of active faults between tectonic plates along the Himalayas. Nepal has not good research in totality about earthquake vulnerability and risk reduction. Maximum research areas are bounded in Kathmandu valley. Some related literature reviews are as following.

Jimee (2006) studied about “Seismic Vulnerability and Capacity Assessment at Ward Level; A Case Study of Ward No. 20 Lalitpur Sub-Metropolitan City, Nepal.” His study is an effort to develop a method which can be adopted by municipal authorities in order to assess vulnerability and level of capacity of local people. It concluded estimating the building collapse probability and causality for certain scenarios earthquake and also measuring the capacity of local people to cope with earthquake risk in ward no. 20 in Lalitpur Sub-Metropolitan city. According to his study, proportionally more casualties were estimated non residential buildings during day time and in residential in night time. More over proportionally very high casualties areas were estimated in school class rooms day time and in hotel at night. He also concluded that the respondent have a medium level of awareness but very low level of capacity. Therefore his study has recommended to increase the efforts in raising effective awareness addressing each sector of the local communities i.e. teachers, students, housewives and others persons to improve public preparedness and to cope with earthquake risk.

Khanal (1996), on his report “Assessment of Natural Hazard in Nepal” has discussed different natural hazards like landslide, flood, storm, drought, etc. He also mentions that in Nepal more than 16 big earthquake of magnitude 6 or larger rector scale have reported since 1255. Similarly, 67 earthquakes with magnitude larger than 4.5 Richter scale were reported between 1978 to 1988 resulting an average of more than 6 events in a year. A pocket area was developed where frequently earthquake strikes. Eastern pocket includes Udaypur to Sankhuwashava, middle pocket includes Gorkha- Rasuwa- Sindupalchowk and Western pocket includes Bhajhan-Doti- Darchula Districts. The losses and damage by earthquake is extremely high though large magnitude earthquakes are rare. He further stated that, the earthquake hazards mitigation measures such as early warning and other preventive works is not effective in present days. So finally he stress that to check the vulnerability to earthquake, building codes system is encourage to people to construct either earthquake proof buildings or invest less in building infrastructure. In order to adjust losses and effective emergency management is most effective.

Guragain (2004), carried out a study on "GIS for Seismic Building Loss Estimation; A case study, from Lalitpur Sub-Metropolitan City Area Katmandu". A 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, an 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 number of damage building were estimated ranging from 1654 to 22293 in the worse case scenario, which corresponds to an 8 Magnitude earthquake located close to Kathmandu.

Ghimire (2008), studied the “Application of RADIUS as an Earthquake Risk Management tool in Panauti municipality”, and she did splendid in using RADIUS Tool. She prepared two scenarios earthquake of North Banepa Earthquake and 1934 earthquake. The former scenario was 20 km far where as the latter one was

170 km away. With the same intensity and magnitude the number of casualties and injuries was different because of distance from epicentre. Similarly, time of occurrences i.e. day and night also determined the number of casualties and death. Her study showed that slightly more than one percent injuries and death increase in night time occurrence than in day time of north Banepa earthquake scenario. The 1934 earthquake scenario showed little impact on Panauti municipality leaving only 13 injuries in day time and 31 injuries and 1 death in night time occurrence of earthquake.

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

Sapkota (2008) studied about population vulnerability for earthquake hazard in Ilam municipality. The objectives of his study were to estimate probable injuries and casualties of population in terms of spatial and temporal vulnerability of them. His findings were 53.24% people used second floor and 95% people used first floor for official used. Similarly, large people lived inside the houses during the night time than day or evening time.

Regarding his findings, injuries and causalities are increase as the earthquake intensity increased. Similarly residential lodges are building were more injuries and causalities happen in evening and night time and school area in day time. In adobe less causality happen than stone in mud building is the same intensity of earthquake. In totality out of 35254 people 2397 (6.8%) persons are calculated injuries and 353 (1%) people are calculated as death. According his study no awareness and preparedness for earthquake have found about 95% respondent of his study heard about earthquake through TV and radio. Similarly, rules and regulation of building construction codes wasn't followed while building a new infrastructure. He used the HAZUS method to estimate the population vulnerability for earthquake.

Chaudhari (2008) studied about "Lifeline Seismic Damage Evaluation in a GIS Environment; A Case Study of Ilam Municipality, Eastern Nepal". The main theme of his study was to analyze the seismic behaviour of public infrastructures. He concluded that the most of the services are located and the high Modified Mercally Intensity (MMI) areas. Transportation infrastructures are not only damages an earthquake itself but also by earthquake induced hazards such as landslide. The main reasons that cause damage to road are the deformation and movement of the ground. There is no damage occur at intensities below VI, a moderate number of damage intensities between VI- VIII in the case of water system, electric network and communication systems. There is a higher number of damages up to catastrophic cases for intensities VII – VIII. Reservoir tank has little chance to work after heavy earthquake.

NSET (2000) prepared the earthquake scenario of Kathmandu valley with assuming the hypothetical earthquake similar to the earthquake of 1934. The scenario describes the physical and socio-economic impact of the earthquake. According to this scenario, about 40,000 people lost their life and 95000 people injured. The number of dead is also includes those dying weeks later from conditions caused by the earthquake, such as serious injuries or kidney failure. The damage percentage of buildings which have been significantly estimated at about 60 percent in Kathmandu, 60 percent in Lalitpur, 75 percent in Bhaktpur and 60 percent in the valley whole. Lifeline facilities such as road, hospitals, electricity, drinking water, telephone etc. are severely damaged. Cremation of the dead body is very big problem. Group cremation is done due to the crisis though it is not accepted as non-traditional idea.

Chapter 3

RESEARCH METHODOLOGY

3.1. Research Sequence and Component:

3.1.1. Pre-field work:

The study started with a review of previous research, literature about earthquake and its loss estimation and related aspects. Research gaps were tried to find out and major objectives were formulated to address the existing research gaps.

Triyuga municipality was selected as the study area. Building footprint, taken from Department of urban development and building construction, DUDBC, was used as the main base map to delineate the individual building unit in the field. The study area was divided into forty five different blocks and resulting maps were printed in small scale so that the individual buildings can identify easily in the field. Making these blocks have no any reason and made arbitrarily except to make easy in data collection. These blocks were not used further in data interpretation and analysis.

Building inventory forms were developed to collect buildings parameter, which will be most important in the analysis such as building types, geometry, height, age, soft-story, building separation, attachment, non-structural element such as tank, tower etc. were included.

Questionnaire sheet was prepared for household survey containing household information and their knowledge and preparedness towards hazards like earthquake. Similar questionnaire sheet was developed for non-residential buildings.

3.1.2. Field Work:

Buildings footprint map taken from DUBDC was checked and updated through visual observation in the study area. It took one month long. The drawing of new buildings and the separation of large building polygon into separate building unit which was done manually without using precise measure because of limited time and resource available. Sampling, instead of Census was done for buildings inventory survey. Each building received a unique code consisting of block number, ward number and household ID. Limited roads, track, and temples were also traced on the map.

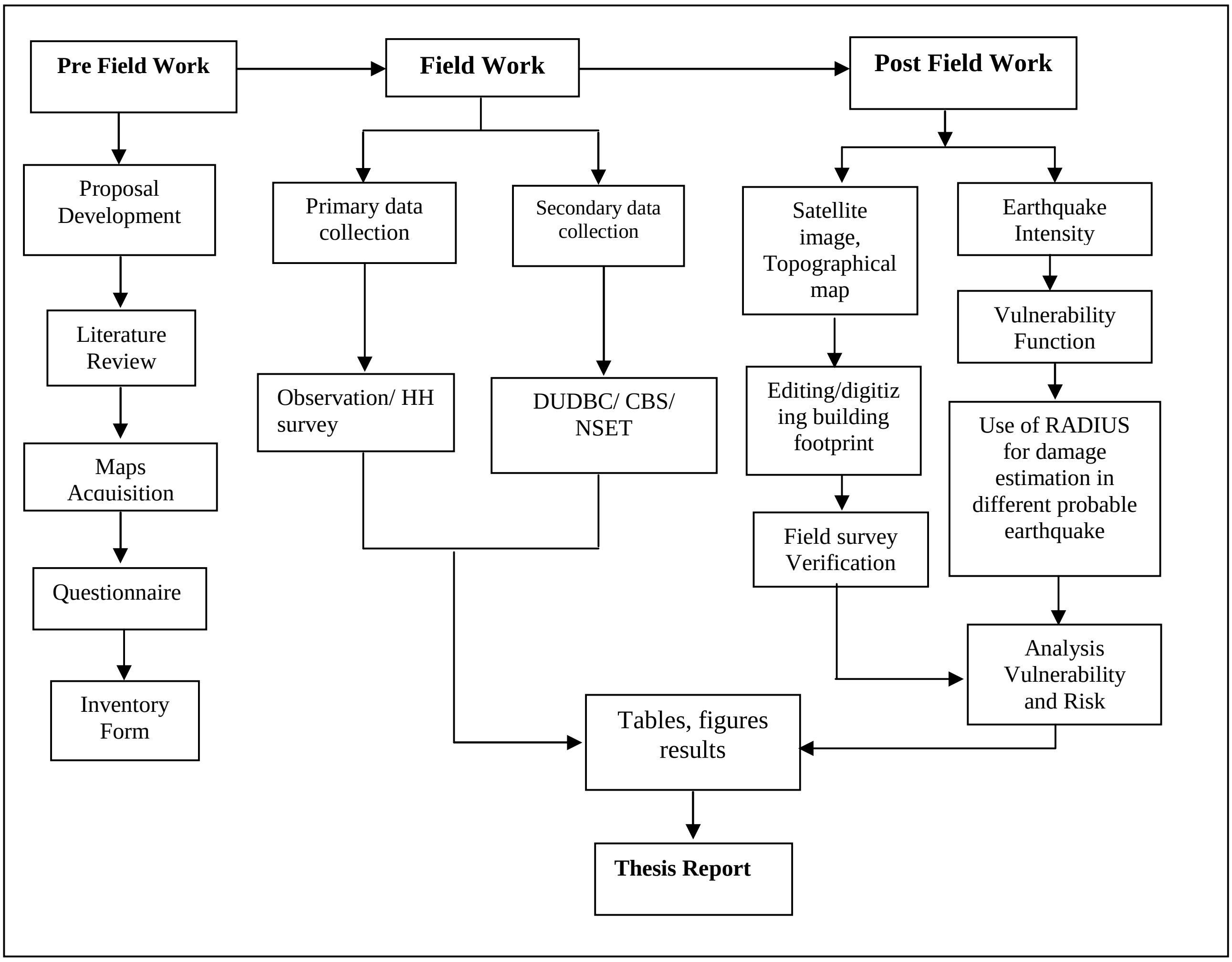
Different offices and institution were visited for secondary as well as primary data collection during this period. Several individual persons were interviewed for their knowledge and preparedness about disaster like earthquake.

3.1.3. Post Field Work:

During this period, extensive computer work was done. Different software such as ArcView, Microsoft Excel, and Word were used. The building footprint map was updated as verified during field survey. With the help of GIS based software ArcView, new buildings and road and infrastructure were updated. All attribute information of buildings were entered in excel format and then converted into DbaseIV, file for GIS supporting format. Socio-economic information and public awareness and preparedness towards earthquake were too, recorded in excel. Several charts and diagrams were generated from the calculated result for better representation.

RADIUS Methodology is used for developing building vulnerability scenario for which earthquake intensity, local soil type, population and damage rate of buildings' relation were described. An intensity damage matrix prepared by NSET and JICA was used.

Figure 3.1: Flow chart of research methodology



3.2. Data collection method:

For better analysis data is very necessary. Various methods and sources were used to collect data. Buildings' different characteristics were recorded as well as peoples' knowledge and preparedness towards earthquake was taken. Similarly, different maps, images etc. were used.

Table 3.1 Sources and nature of data

S.N	Description	Source	Map scale	Year
1	Digital map in GIS environment	DUDBC		2006
2	ALOS Image	NSET		
3	Population and household	CBS		2001/2008
4	Municipality toposheet	Topographical survey branch	1:50,000	1998
5	Primary data	Field survey		Nov. 2008

3.2.1. Primary data collection: During field survey, most of the primary data was collected. Different characteristics of buildings such as types, heights, age, storeys, etc. were recorded as well as the collection of population characteristics, socio-economic information and knowledge and preparedness towards earthquake in household level. Buildings different characteristic (Detail in chapter V) was collected through the observation method in the field. Census of buildings recording was not possible because of limited time so purposive random sampling was used. About 20% i.e. 2729 buildings' different characteristics was recorded. While recording such information, giving insight to the nature of study focused on core area so the information is more concentrated in core and market place. Similarly, out of total observed buildings, 283 household including both residential and non-residential was interviewed. Through this method population characteristic, socio-economic information and knowledge and preparedness towards earthquake population characteristics, socio-economic information and knowledge and preparedness towards earthquake was collected.

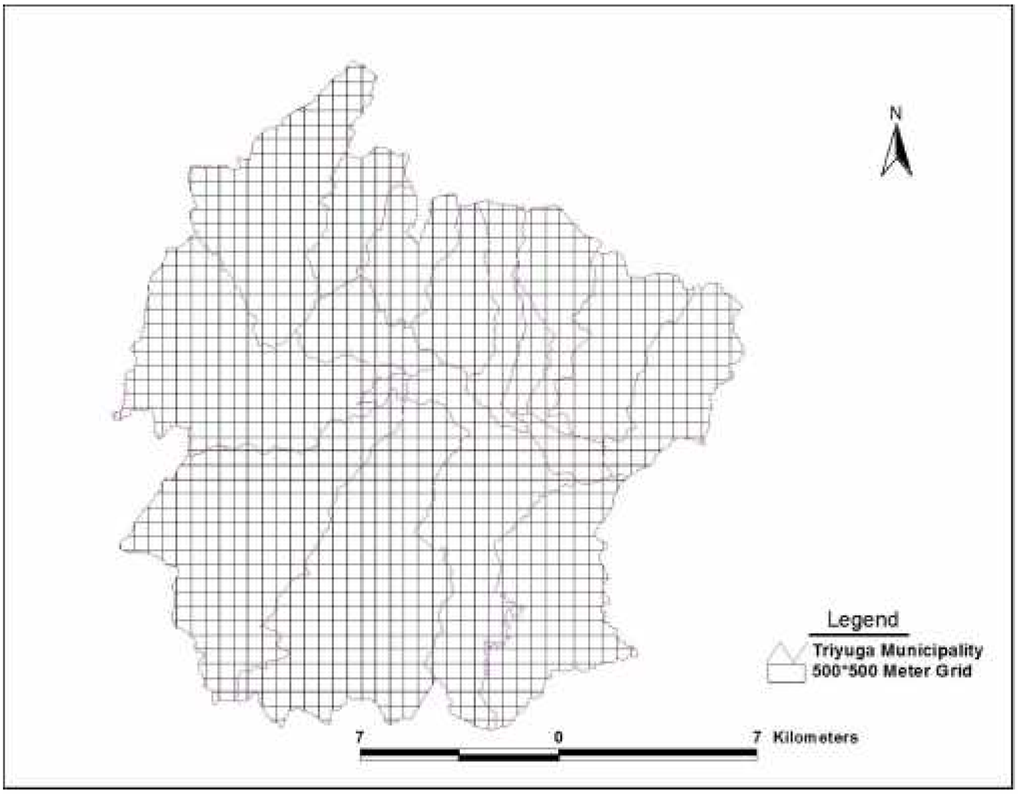
3.2.2. Secondary data collection: Secondary data was collected through the reviews of existing literature, published by different sources such as Central Bureau Statistic (CBS), DUDBC, DMG and NSET. Similarly, unpublished thesis and dissertation were also used as secondary data.

3.3 Data Processing Methods and Tools

Primary data are processed by using various methods tools and techniques. Socio-economic and population information was process of through Excel, and spatial data by GIS and RADIUS methods.

3.3.1. Geographic Information System (GIS) Methodology: With the help of GIS based software ArcView, new buildings and road and infrastructure were digitised and updated. Updated map was overlapped with 500*500 meter grid. Results from RADIUS were in simple raster map which was shown by GIS in ward-wise level.

Figure 3.2: Municipality map overlapped with 500*500 meter grid



3.3.2. RADIUS methodology

This is a simple-to-use earthquake damage estimation tool. It has been developed under the support of UN-IDNDR to promote worldwide activities for reduction of seismic disasters in urban areas, particularly in developing countries. The program aims to raise awareness and understanding of earthquake disasters and methodology of damage estimation in the earthquake prone areas, (IDNDR, 2000)

RADIUS was lunched by the Secretariat of the International Decade for Natural Disaster Reduction (IDNDR 19990- 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.

3.3.2.2. RADIUS Analysis procedures:-

For damage estimation, scenario earthquake, ground condition, demographic data and vulnerability function are critical input data (Guragain, 2004). For earthquake scenario modelling, probable earthquake in the region is taken with magnitude, epicentre, depth, and occurrence time. Such earthquake is postulated according to active fault. Himalayan Frontal Fault system in south and Main Boundary Thrust system in East and North are prominent in the periphery of study area. PGA and MMI are calculated using empirical formula.

Table 3.2: Possible Earthquake sources for Triyuga Municipality

Earthquake Name	North Udayapur	South Udayapur	North East Udayapur
Fault Name	Main Boundary Thrust	Himalayan Frontal Fault	Main Boundary Thrust
Magnitude	8.0	7.2	7.5
Distance	2.6 km	0 km	41 km
Depth	20 km	20 km	20 km
Direction	North	South	North-East

Soil Types

The ground is classified into five types on the basis of soil: Hard Rock, Soft Rock, Medium Soil and Soft Soil and the corresponding fixed amplification factors is taken for probable amplification in that area.

Table 3.3 Local Soil types

Code	Types	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

Fragility Function of the Buildings

Vulnerability functions, which indicate the relation between seismic intensity and damage rate for structural types, are determined as the function of acceleration/MMI based on damage observed during past sample earthquakes. The damage levels considered in this method are collapse and heavy damage. Buildings' damage probability rate in terms of MMI in the context of Nepal is shown in table 3.4.

Table 3.4: Damage probability of Buildings in Nepal

MMI	Damage (%)					
	Adobe/stone in Mud	Brick in Mud	Stone in Cement	Brick in Cement	9"RC Column	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

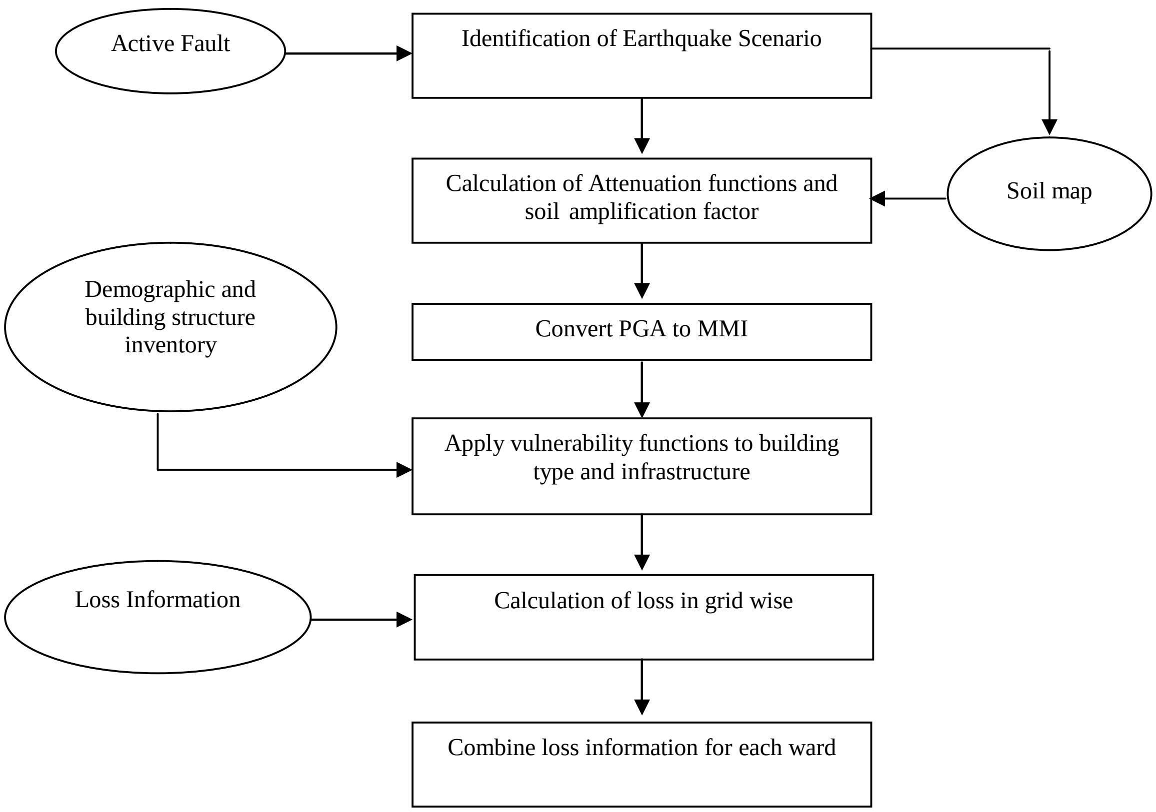
Area ID Inventory

Buildings in this program are classified into 10 different classes on the basis of the strength of buildings against shaking in an earthquake. The total percentage of the different classes building in each row must be 100. This is the unique feature of Radius.

3.3.2.3. Steps of RADIUS

The study area is subdivided into zones which are called grid or mesh of 100 to 500 m^2. By the use of these meshes the number of houses and probable population are mapped as well as input and output can be visualised spatially as a simple Raster map. 500 m^2 grids are used for this analysis though the small grids may give more actual scenario, because of huge area of the study area. Unique identity number i.e. 1 to 1406 is given to all grids or meshes. Similarly, local area name or ward number is given as area name. Mesh weight, according to housing number, population etc. is given to all meshes. Mesh weight 0 to 4 is used. Open space or no settlement area is given 0 value and according to this scattered settlement to village, market area to core area is give 1,2,3 and 4 respectively.

Figure 3.3: RADIUS flow chart



Different classes of buildings percentage is filled in building inventory by area form. Buildings are classified into 10 different classes (Table: 3.6). Scenario earthquake is defined with its different characteristics such as magnitude, depth, and distance etc. Earthquake occurrence time is defined 2 o'clock in both day and night time. The last step is to run the program.

Figure 3.4: RADIUS program and Generation of mesh/grid an area ID

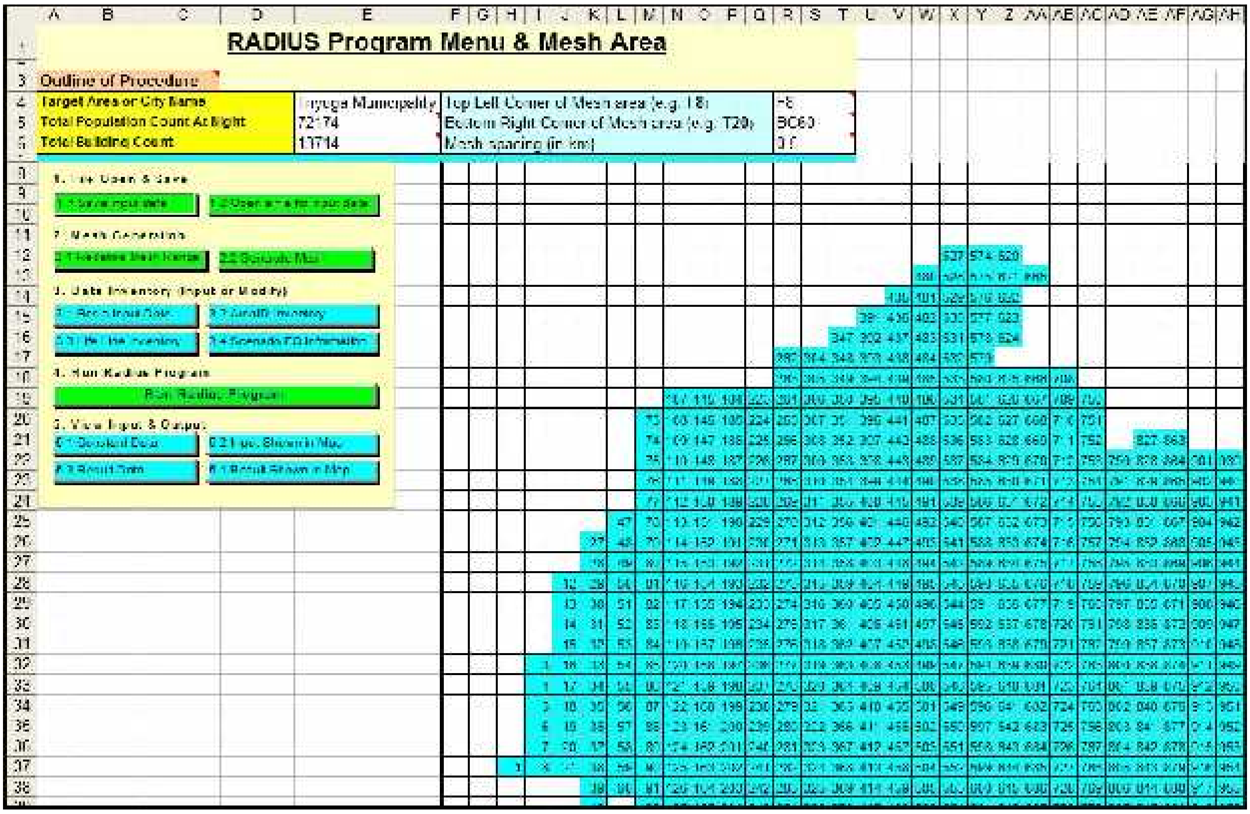


Table 3.5: Building Classification in RADIUS method

RES1	Adobe buildings as well as made from unburned bricks, mud and wooden buildings is categories as this class buildings
RES2	Brick in cement and Reinforced concrete buildings having height up to 3 stories. Other characteristics sub standard construction not applying or complying with National Building Codes. Both new and old buildings were included.
RES3	Brick in cement and Reinforced concrete buildings having height 4 to 6 stories. Other characteristics sub standard construction not applying or complying with National Building Codes. Both new and old buildings were included.
RES4	Newly constructed multi-storey building with high engineered construction for residential and commercial purpose.
EDU1	Building for educational purpose having less than 2 stories
EDU2	Educational buildings having more than 2 stories.
MED1	Buildings for hospitals having low rise. Less than 2 stories buildings are categories in this category.
MED2	High rise hospitals, more than 2 stories.
COM	Buildings for commercial purpose
IND	Buildings for industrial purpose.

Source: RADIUS

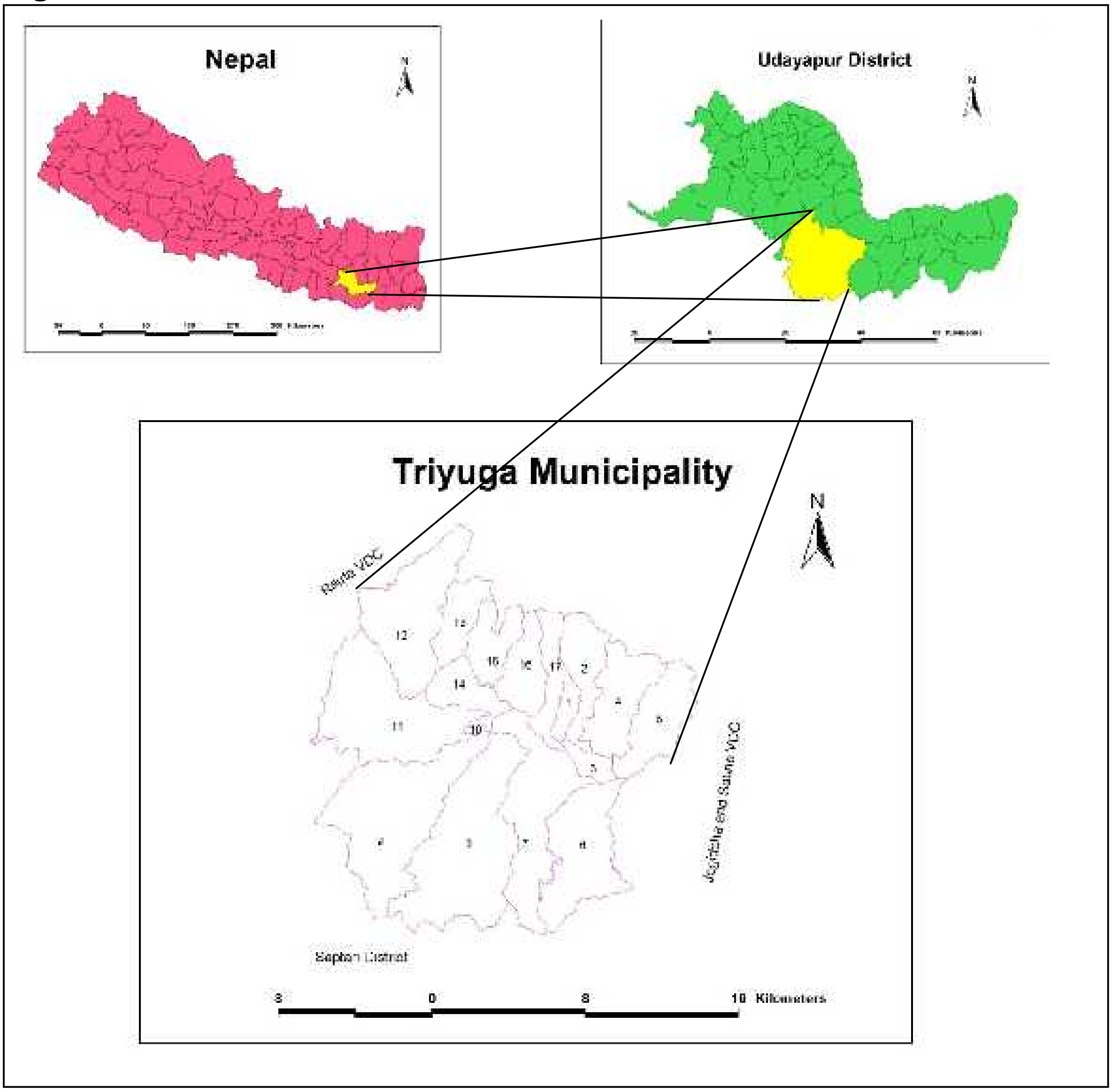
Chapter 4

INTRODUCTION OF THE STUDY AREA

4.1 Geographical background

Triyuga municipality is located in the district of Udayapur, Sagarmatha Zone, Eastern Development Region of Nepal. It is the district headquarter. It is surrounded by the Jogidaha and Saune VDCs in the East, Bhalayadanda and Rauta VDCs in the West, Saune and Khabu VDCs in the North and Saptari District in the South. Geographically, it lies between 26˚ 45' 0" to 26˚ 52' 30" north latitude and 86˚ 37' 30" to 86˚ 45' 0" east longitude. Triyuga got municipality status in 2053 B.S. The municipality covers the area about 320sq.km.

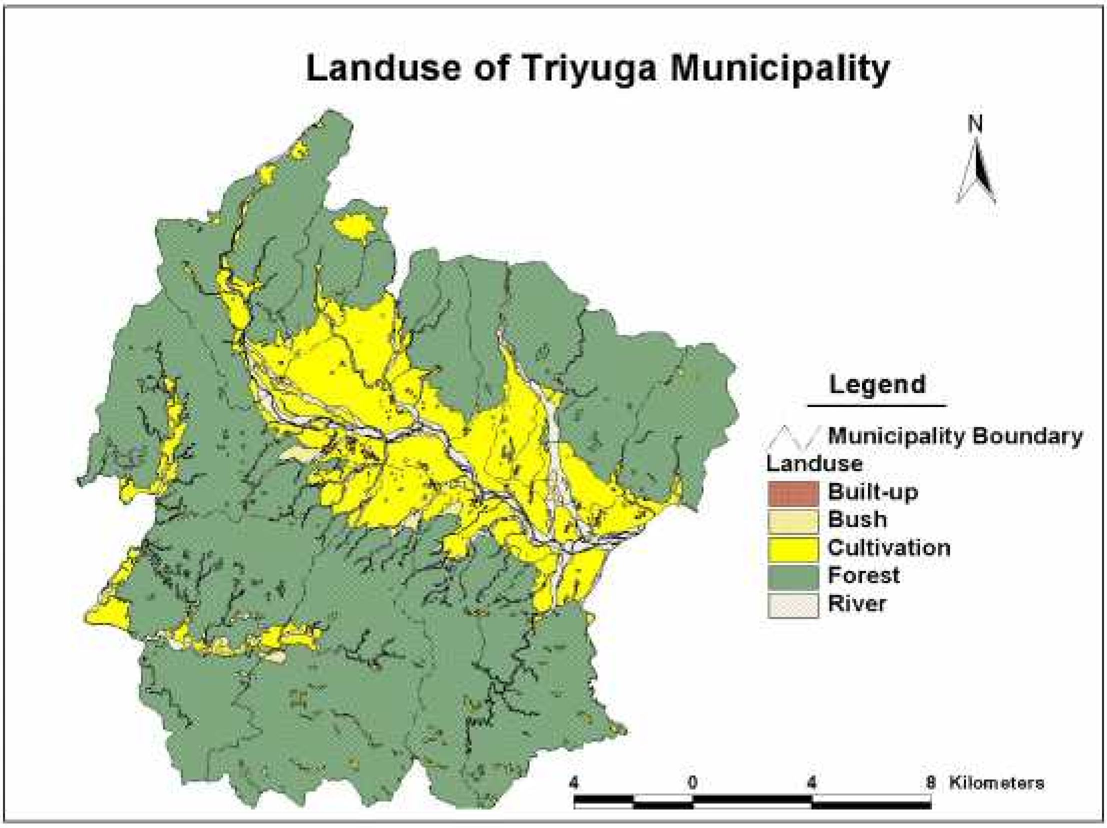
Figure 4.1: Research area



4.2 Land use Pattern of Triyuga Municipality

Land use/ Land cover pattern of the area produced a multidisciplinary survey of natural and man made features. It is important for improved planning and long-term development and utilization of the land. For example, where should a road be constructed? Where should be a utilizing area? Which will serve an area effectively? Land use/ Land cover pattern can be visualized in Map 4.2.

Figure 4.2. Landuse pattern of Triyuga Municipality

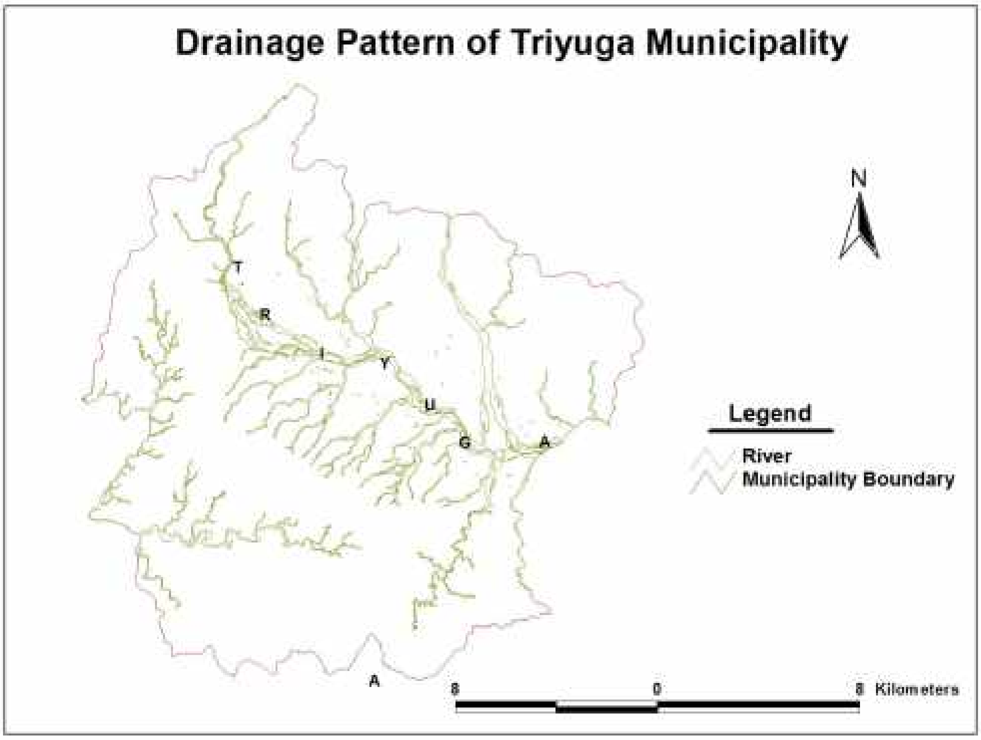


The biggest municipality in the country, Triyuga, has the very few portion land for built-up area. Forest dominates in the whole municipality. About three fourth areas is forest. Cultivated land followed with 20% area. Sandy area and water body too have enormous portion.

4.3 Drainage Pattern of Triyuga municipality

The name of this municipality is taken from the name of river which runs through it, Triyuga River. Baruwa and other different ephemeral rivers run as tributaries of river and itself is one of the most important tributary of Sunkoshi River. Drainage pattern of Triyuga municipality is shown in map 4.3.

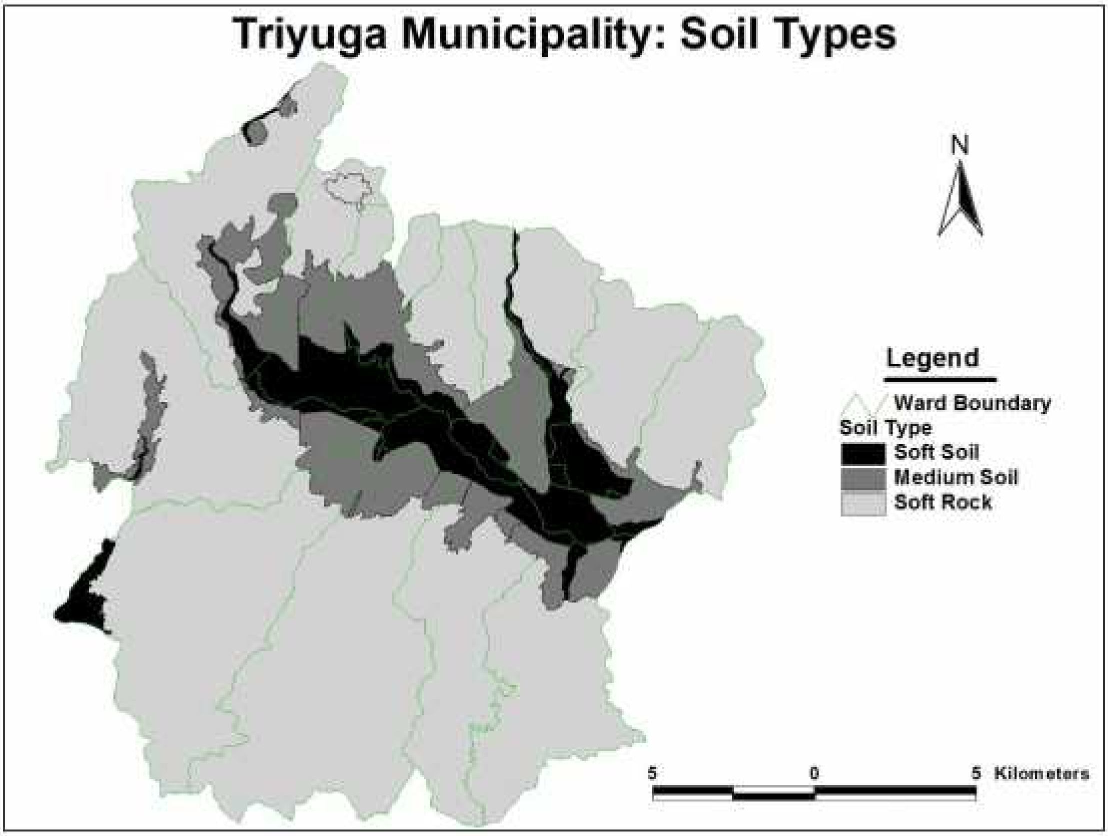
Figure 4.3: Drainage pattern of Triyuga municipality



4.4 Soil Types:

Soft soil and medium soil is found in and bank of the river where as soft rock surround them and expand in whole municipality. The soil distribution of Triyuga municipality is shown in map 4.4. However, regarding the soil classification no detail study was carried out.

Figure 4.4: Soil Types of Triyuga Municipality



4.5. Population and Housing condition

Triyuga Municipality spread in 17 wards accounts 10566 households with an average number of 621.5 households/wards and average household size 5.3 (Census, 2001). The ward number 11 has the leading number of households (1711) and the least in ward number 10. The municipality counts up 55,291 population representing 50.0 per cent male and 50.0 per cent female. There is no remarkable difference in the distribution population by gender. Table 4.1 shows the household and population at ward wise level. Projected population of 2008 also given in the table. Total population of Triyuga municipality would 72174 by the year 2008 (ISRC, 2008)

Table 4.1: Ward wise household and population

Ward	Household (2008)	Population (2001)	Projected 2008		
			Male	Female	Total
1	1405	5004	3272	3259	6532
2	1470	5517	3612	3590	7202
3	730	3064	2006	1993	4000
4	480	1940	1274	1258	2532
5	453	1980	1267	1317	2585
6	452	2008	1300	1321	2621
7	1112	4725	3075	3092	6168
8	1096	4407	2877	2876	5753
9	972	3943	2612	2535	5147
10	440	1602	1057	1034	2091
11	1711	6883	4617	4368	8985
12	615	2584	1673	1700	3373
13	704	2917	1910	1898	3808
14	248	1053	659	715	1375
15	594	2661	1684	1790	3474
16	475	1879	1220	1232	2453
17	757	3124	2005	2073	4078

Source: ISRC, 2008.

CHAPTER V

NATURE AND TYPES OF BUILDINGS IN TRIYUGA MUNICIPALITY

The noticeable effect of earthquake is structural collapse or damage. The level of destruction of those structures is depending upon the intensity of earthquake as well as their condition *per se*. The level of intensity or time of earthquake cannot be stopped or predicted so to estimate the level of vulnerability of structures or buildings, their condition should be known. Damage of buildings are depend upon primarily their construction materials, age, height, number of stories, attachment etc.

5.1 Building's classification

Building type is categories in terms of their construction material. Use of materials for house construction influences the loss or effect of earthquake. Wall materials, floor and roofing system control the strength of the building. Poor construction materials may increase the vulnerability of the building in the period of earthquake as well as may increase in casualties. Buildings in the study area were classified into six categories according to the use of construction materials.

1. Adobe: These buildings are mainly made of mud and having thatch roof with highest risk of collapse.

2. Wooden: Simply wooden buildings were made by timber. Houses built with bamboo and shrubs were also included in this category.

3. Brick in Cement: Buildings made by bricks with cement with moderate risk.

4. Brick in Mud: Buildings made by bricks with mud with high vulnerable.

5. RCC: Reinforced concrete building made by with low vulnerable.

In the study area, about 41% building were found reinforce concrete (RCC) were as wooden followed with 23% and then Brick in cement, Adobe and Brick in mud respectively constitute 18.8%, 15.5% and 1.14%.

Ward wise distribution of building types is quite different and uneven. RCC buildings were primarily found in only ward no 1, 2, 3, 10 and 11. Almost 63% buildings were RCC in ward no-2. Adobe buildings dominance in ward no 4, 5 and

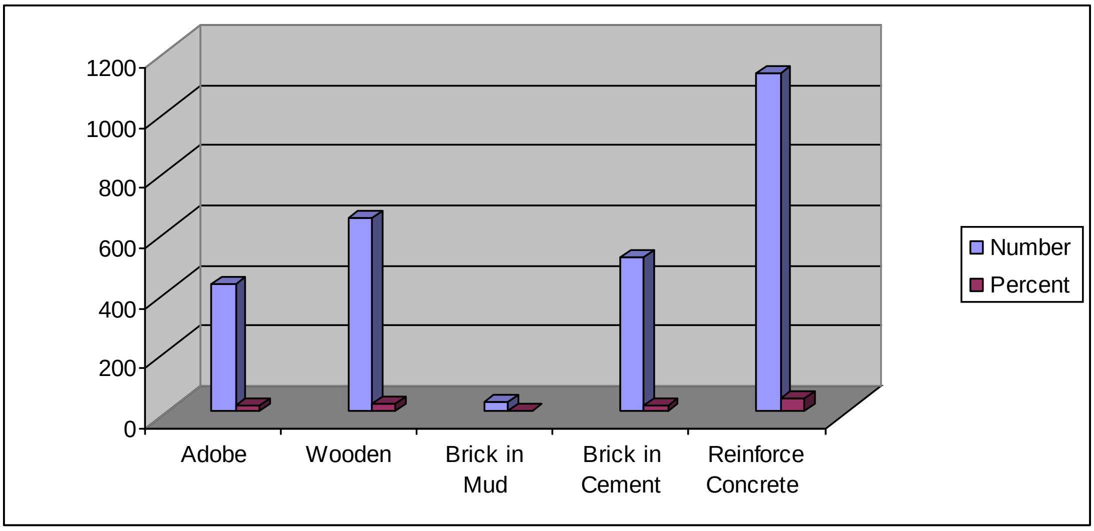
6 where as in rest of the wards wooden buildings were prominence. Virtually in ward no 5 no RCC building was found except school.

Table 5.1: Types of buildings on the basis of material used

Building Type	Number	Percentage
Adobe	423	15.50
Wooden	641	23.46
Brick in Mud	31	1.14
Brick in Cement	513	18.80
Reinforce Concrete	1121	41.10
Total	2729	100

Source: Field survey, 2008

Figure 5.1: Building's Types



5.2 Building's Height

Buildings height in this study is taken as the number of floors. In general, higher the buildings, greater the vulnerability.

In the study area, building having 2 stories is the highest number of 1359 i.e. 49.8% followed by 1 story having 44%. RCC and wooden buildings are maximum of 2 stories where as Adobe, BM and BC are of 1 story. Taller buildings were concentrated in ward no 1 and 2 only.

Table 5.2: Number of buildings according to number of story

Story	Number	Percentage
1	1212	44.41
2	1359	49.80
3	131	4.80
4	26	0.95
5	1	0.04
Total	2729	100

Source: Field survey, 2008

5.3 Building's Age

Building vulnerability is also depends upon its age. Older buildings are more vulnerable than new buildings. During the field work, recording of building age was also done. Building age was classified into three broad categories because taking exact building age is impossible in terms of time. Building age class was determined. According to this buildings are classified into three categories-

1. A1: (<20 years), recently constructed buildings, i.e. younger than 20 years. Buildings in this category have lower vulnerability than other categories.
2. A2: (20 to 100 years), Buildings that were constructed in between 20 to 100 years. Buildings in this category have moderate vulnerability.
3. A3: (>100), buildings that were older than 100 years. Building in this categories has highest vulnerability.

During the field study, about 59% buildings were found newly constructed and 41% were constructed in between 20 to 100 years period. No building was found older than 100 year. Being the one of the youngest municipality in the country, newly constructed buildings are prominent in urban centre and periphery. Rapid growth in new buildings number is due to high urbanisation growth rate due to high migration as well as the tendency of replacement of old building with new one.

Table 5.3: Building's age

Age	**Number**	**Percentage**
A1(less than 20 years)	1608	58.92
A2 (20 to 100 years)	1121	41.08
A3 (more than 100 years)	0	0
Total	2729	100

Source: Field survey, 2008

5.4 Building's 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 earthquakes 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).

Geometry or shape of the buildings too, as taken as important component in this analysis. According to this, buildings were categories into three category:

1. R1(<=1:3): Regular shaped buildings with a length width ratio <=1:3. Such types of buildings have less vulnerability.
2. R2(>1:3) : Regular shaped buildings with a length width ratio >1:3.
3. IR: Irregular shaped buildings.

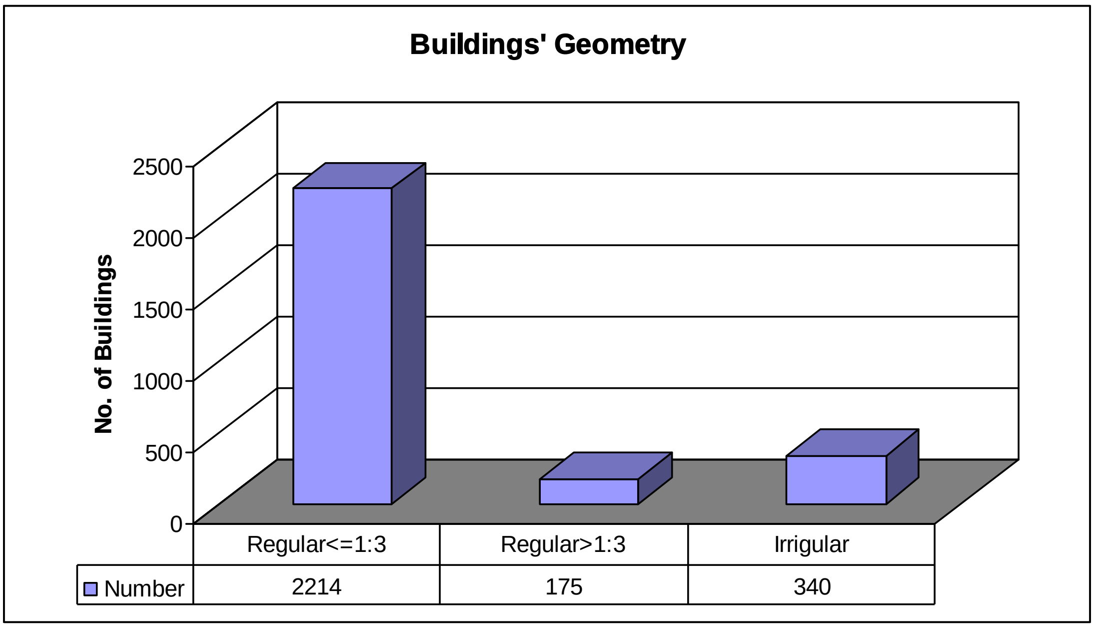
Table 5.4: Building's Geometry

Geometry	Number	Percentage
Regular1(R1)	2214	81.12
Regular2(R2)	175	6.413
Irregular(IR)	340	12.45
Total	2729	100

Source: Field survey, 2008

In the study area 2214 buildings (81.13 %) were found with regular shape (length width ration <1:3), 175 buildings (6.41 %) buildings were found with the ratio of >1:3 and 340 buildings (12.46 %) of the total buildings were found irregular shape (Table 5.4).

Figure 5.2: Building's Geometry



5.5 Building Attachment

Building attachment and separation also play important role for the vulnerability of the building because attached buildings are more vulnerable than separate building. In the study area, it was found that, 63.7 percent of the total buildings were attached with the other nearest building and about 989 buildings were found separate building.

Table 5.5: Number of buildings according to their attachment

Attachment	Number	Percentage
Separate	1740	63.76
Attached	989	36.24
Total	2729	100

Source: Field survey, 2008

Chapter VI

BUILDING VULNERABILITY ASSESSMENT

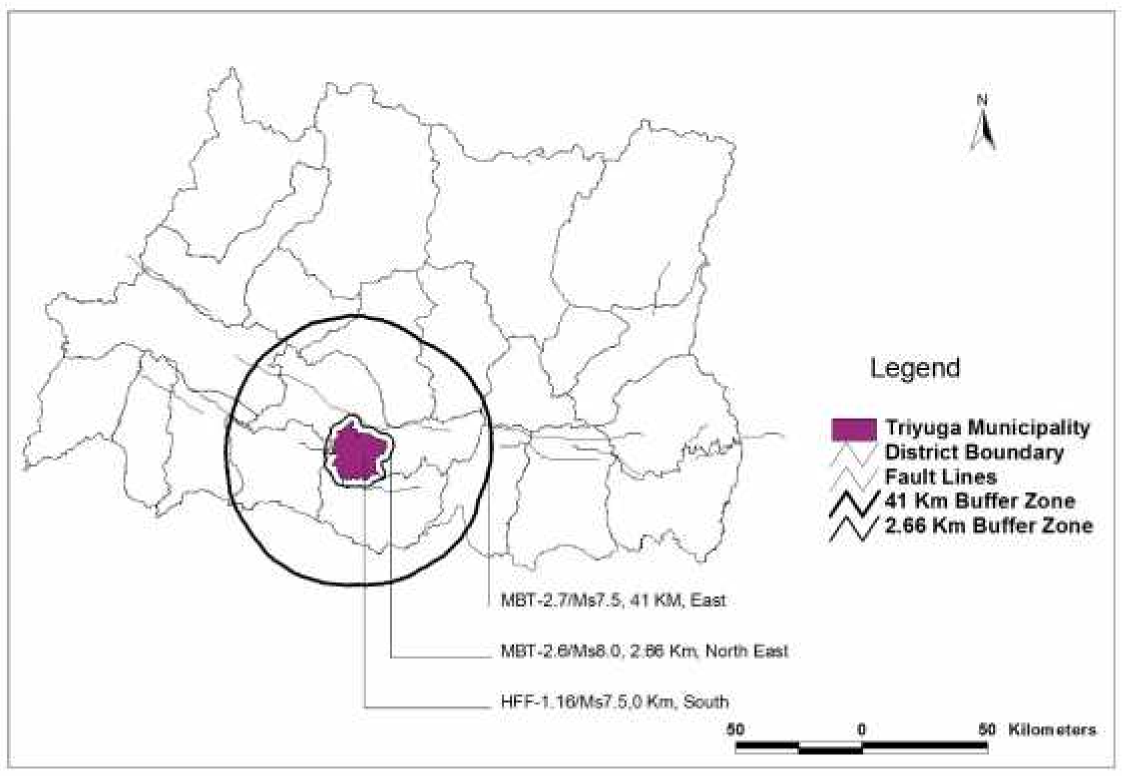
6.1 Scenario earthquake in Triyuga municipality:

Different scenario earthquakes are assumed according to the presence of active faults. Two active faults Himalayan Frontal Fault System and Main Boundary Thrust Fault system are prominent in the periphery of the municipality. According to this, three scenario earthquakes – North Udayapur, South Udayapur and North-East Udayapur is taken. The name of the scenario earthquakes is given according to the location of the fault from municipality. All three scenario earthquakes depth is considered as 20 Km. North Udayapur scenario earthquake is the biggest among three assumed earthquake. The epicentre of the North East Udayapur earthquake is 41 Km away whereas South Udayapur earthquake's epicentre is in the municipality.

Table 6.1: Possible sources of Earthquake

Earthquake Name	North Udayapur	South Udayapur	North East Udayapur
Fault Name	Main Boundary Thrust	Himalayan Frontal Fault	Main Boundary Thrust
Magnitude	8.0	7.2	7.5
Distance	2.6 km	0 km	41 km
Depth	20 km	20 km	20 km
Direction	North	South	North-East

Figure 6.1: Distances and Direction of the Scenario Earthquake



Source: National Building Code Implementation Project, 1994

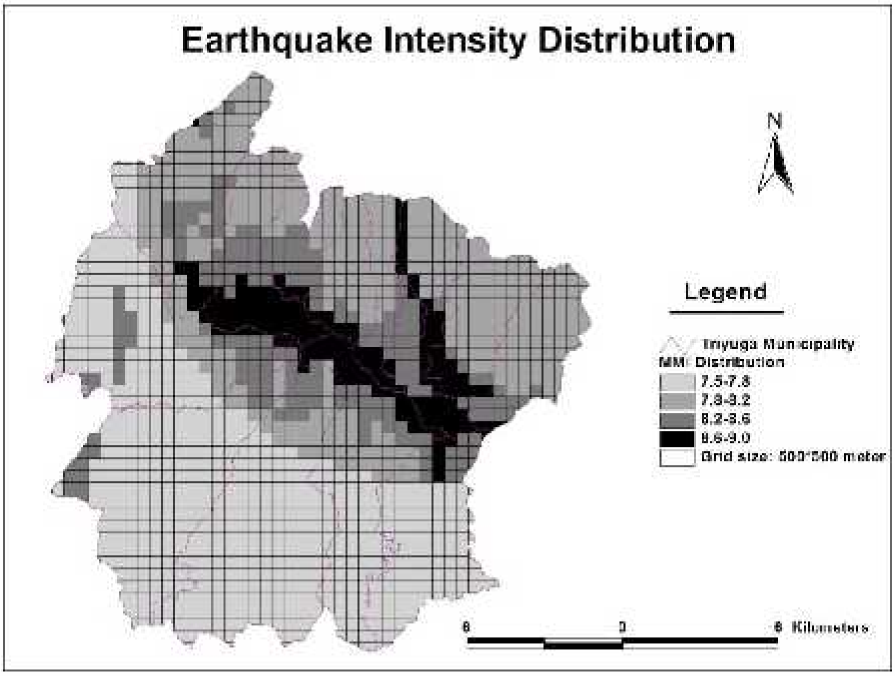
6.2. Damage scenario due to possible earthquakes

The affect of earthquake is different according to time of occurrence. Although the damage in infrastructure and building is same, injuries and death of people may be different in night time and day time. So the analysis is done in considering that the earthquake may happen in 2 AM and 2 PM.

6.2.1. North Udayapur earthquake scenario

North Udayapur earthquake is taken as possible earthquake due to an active fault, MBT-2.6, locating 2.6 Km, North of the Triyuga municipality. The possible earthquake will be 8 Richter scale and 0.3% PGA. Map 6.2 shows the MMI distribution of this earthquake. MMI is high in soft soil and medium soil where, the settlement is dense so the infrastructure damage and casualties would high.

Figure 6.2: Earthquake Intensity Distribution of Triyuga municipality



6.2.1.1. Estimation of building damage due to North Udayapur earthquake:

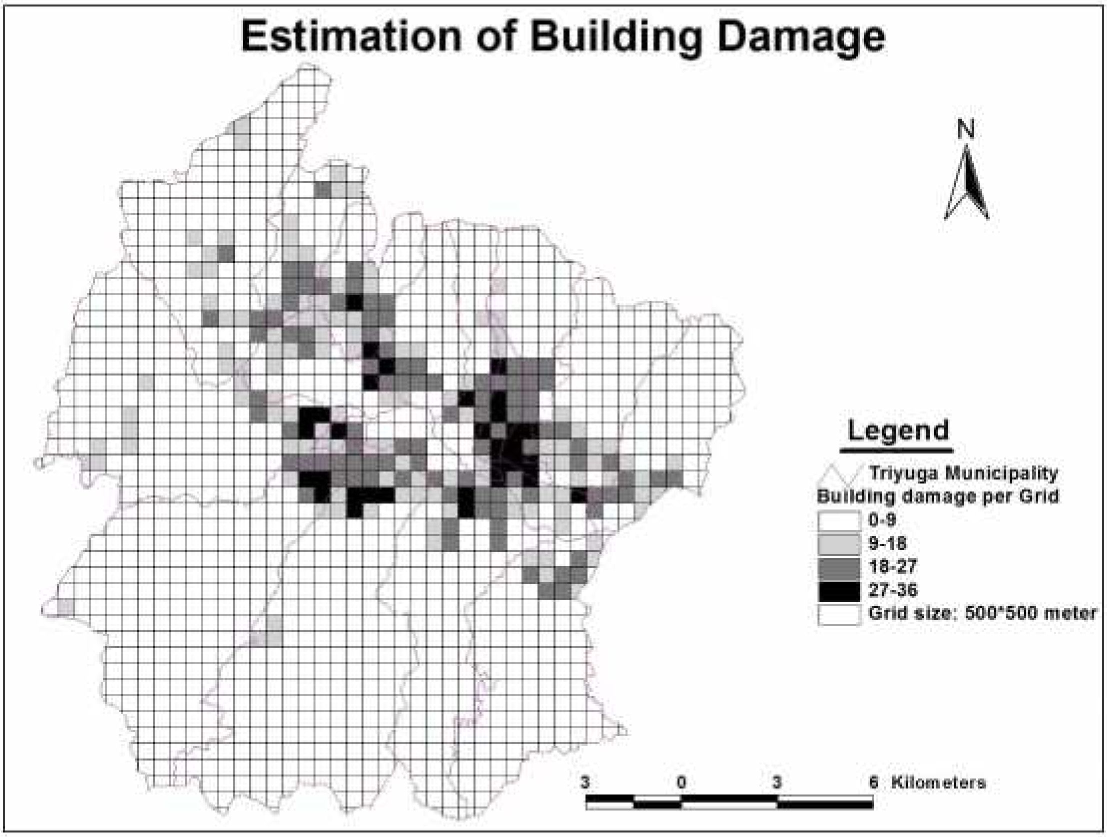
The estimated result of building damage shows that 56% (7656 buildings) would be damage (Table 6.2). About 55% residential buildings providing housing to 39412 people would damage. Educational buildings would suffer most.

Table 6.2 Estimation of Building's Damage due to North Udayapur earthquake

Wards	PGA (%)	MMI	Buildings	Damage	MDR
1	0.3	8.2	938	514	54.8
2	0.3	8.1	797	484	60.7
3	0.3	8.2	586	348	59.4
4	0.3	8.1	516	356	68.9
5	0.3	8	516	308	59.7
6	0.3	8.2	445	293	65.8
7	0.3	8.1	1383	804	58.1
8	0.3	8.1	1383	760	54.9
9	0.3	7.9	1008	466	46.2
10	0.3	8.1	305	134	43.9
11	0.3	7.9	1618	719	44.4
12	0.3	7.9	1031	458	44.4
13	0.3	8	563	369	65.5
14	0.3	8.1	539	382	70.8
15	0.3	8.1	1055	634	60.1
16	0.3	8.1	609	374	61.4
17	0.3	8.1	422	253	59.9
	0.3	8	13714	7656	55.8

About 79% educational buildings would damage. One third percent of all rest buildings would damage. The earthquake affects the most in ward no-14, damaging about 71% building and 804 buildings would damage in ward number 7. About 44% building would damage in ward number 11 and 12 ward which is the lowest percent among 17 wards.

Figure 6.3: Estimation of Building damage due to North Udayapur earthquke



6.2.1.2. Casualty scenario due to North Udayapur Earthquake during Day

This scenario earthquake may cause 16% people injured when it strike in Triyuga municipality. Out of total injured 7997 people, 2374 will be seriously injured and other rest may need only required normal hospitalization or first aid treatment. Ward no-7 has the highest number of injured people. The count is 914. Ward no 15 and 1 will rank in 2 and 3 with 846 and 871 injured people, respectively. Ward no 10 will have the lowest number of injured people. Only 113 people are injured, this is because the lowest number of total population.

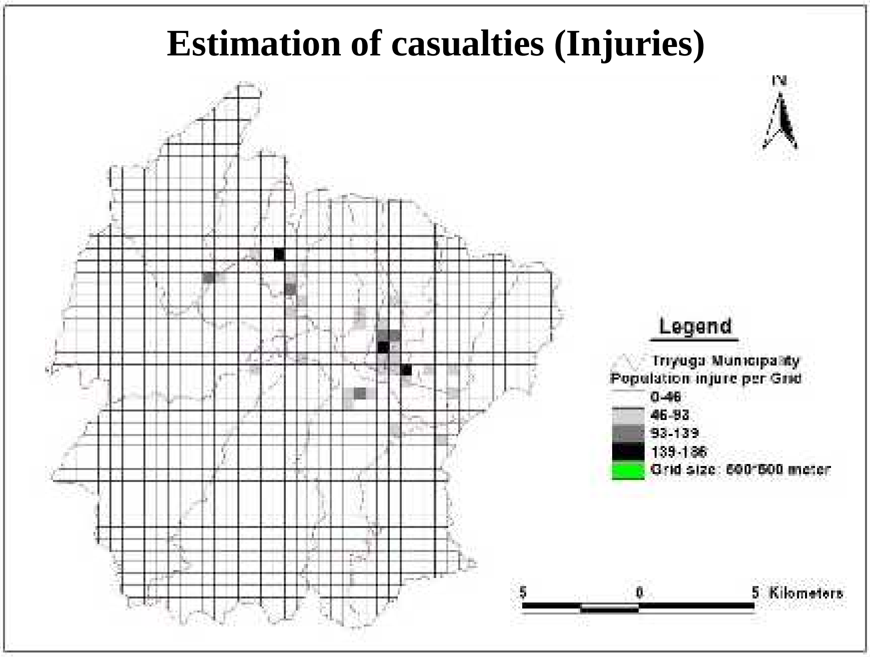
Table 6.3 Estimation of Casualties (Injuries and Deaths) in day

Ward no	Population	Injuries	Deaths
1	5699	817	133
2	3386	596	109
3	2070	356	74
4	1944	381	80
5	1807	292	58
6	1593	286	61
7	5911	914	179
8	3448	615	121
9	3001	387	73
10	984	113	21
11	4361	572	113
12	3562	461	90
13	1508	291	63
14	1806	384	89
15	5208	846	161
16	2406	382	77
17	2211	304	59
Total	50905	7997	1561

Source: Field survey and RADIUS Analysis, 2009

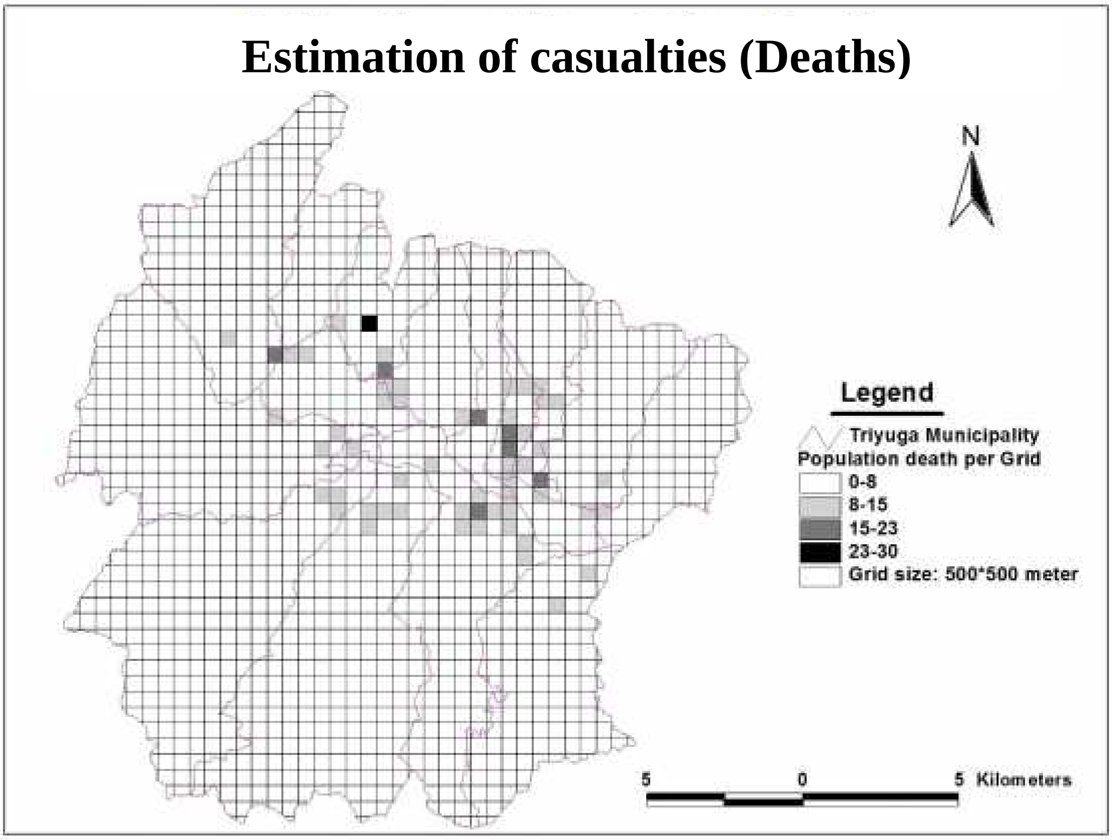
Map 6.3 shows possible population injuries due to North Udayapur earthquake during day time. The total injuries are distributed in gridwise. The distribution is not even. Population density and MMI create unevenness in distribution. The highest injury is (139-186) people in a single grid. The maximum grid has (0-46) injuries.

Figure 6.4: Estimation of Casualty (Injuries)



Out of total day population, about 3% i.e. 1561 people would die when this assumed earthquake strike in this municipality. Ward number 7 lose the highest number of population where as ward no-10 lose the lowest, 179 and 21 people 8 respectively. Ward number 8 has the highest proportion of death having 5%. In gridwise population death (Map 6.4), is categories in different four classes. The lowest class (0-8) person death per grid is in maximum number. The number of highest death (23-30) people per grid is only one.

Map 6.5: Estimation of Casualty (Deaths)



6.2.1.3. Casualty scenario due to North Udayapur Earthquake during night

Out of total 72174 populations, 15409 would be injured due to this earthquake. Among them 4632 are seriously injured and rest are moderately injured which need only normal hospitalisation or first aid treatment. 3291 people would die due to this earthquake. 352 people from ward number 7 would die which is the highest count among 17 wards. Only 49 people would die from ward number 10.

Table 6.4: Estimation of Casualties (Injuries and Deaths) in night

Ward No	Night Population	Injuries	Deaths
1	4560	997	208
2	4331	1059	232
3	3111	738	164
4	2687	739	173
5	2721	601	126
6	2355	602	137
7	7217	1624	352
8	7398	1466	293
9	5381	883	169
10	1617	261	49
11	8673	1422	281
12	5465	915	189
13	3018	728	157
14	2861	831	203
15	5434	1271	276
16	3185	757	167
17	2160	513	114
	72174	15407	3290

Source: Field survey and RADIUS Analysis, 2009

6.2.2. South Udayapur earthquake scenario

South Udayapur scenario earthquake is another possible earthquake. It is accepted to occur due to the presence of active fault Himalayan Frontal Fault System, HFF-1.16, which goes through in the southern part of the municipality. It will be 7.4 Richter scale with PGA 0.2%.

6.2.2.1. Estimation of Building Damage due to South Udayapur Scenario Earthquake

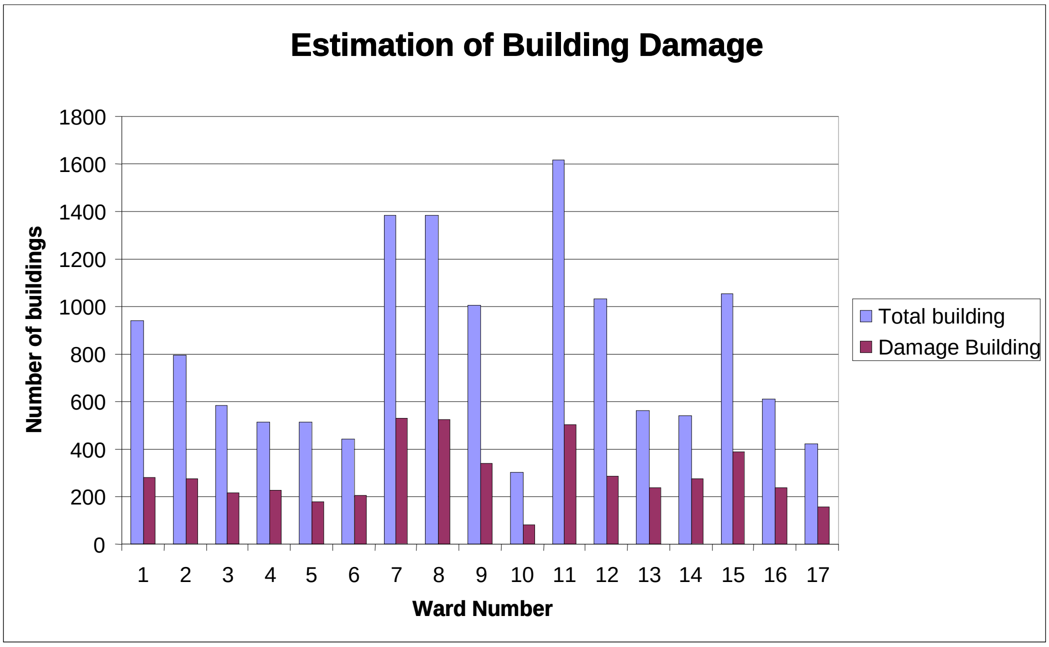
36% buildings would damage when this earthquake strike in this municipality. Ward number 12 has the highest proportion of building damage with 51%. In ward number 7, highest number of buildings, 528 would damage whereas wars number 10 has just 82 buildings (Table 6.4). Total buildings and damage buildings is shown in figure 6.2.

Table 6.5: Estimation of Buildings' damage due to South Udayapur Earthquake

Ward no	No. of Building	Building Damage	MDR %
1	938	283	30.2
2	797	276	34.6
3	586	215	36.7
4	516	225	43.6
5	516	176	34.1
6	445	204	45.8
7	1383	528	38.2
8	1383	525	37.9
9	1008	338	33.5
10	305	82	26.9
11	1618	502	31.0
12	1031	288	27.9
13	563	238	42.3
14	539	278	51.6
15	1055	387	36.7
16	609	236	38.7
17	422	158	37.4
Total	13714	4939	36.0

Source: Field survey and RADIUS Analysis, 2009

Figure 6.6: Estimation of Building damage due to South Udayapur Earthquake



6.2.2.2. Casualties scenariodue to South Udayapur Earthquake during Day time:

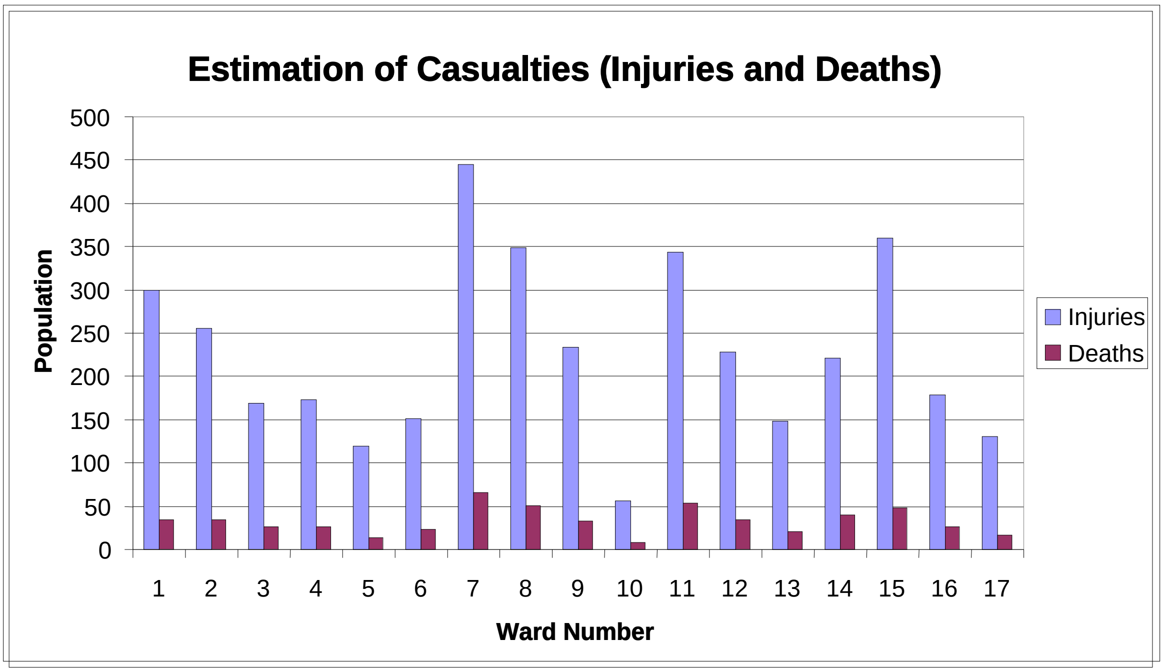
This assumed earthquake may injure 3859 people about 5% , among them 804 would be severe injured and rest may only need normal hospitalization or first aid treatment. Ward number 7 has a great impact of this earthquake too, 445 people would suffer injuries. Being the smallest ward in terms of area and population as well as building count ward number 10 has a lowest impact is seen. Only 56 people would injure in this ward. Out of total day population, 556 people about 1 % would die because of this earthquake. Ward number 7 lose highest count of 66 people where as ward number 10 lose only 8 people. Population injuries and deaths by this earthquake are shown in table 6.5 and figure 6.3.

Table 6.5: Estimation of Casualties (Injuries and Deaths) in day

Ward no	Day population	Injuries	Deaths
1	5699	300	35
2	3386	255	35
3	2070	169	26
4	1944	173	26
5	1807	119	14
6	1593	151	23
7	5911	445	66
8	3448	349	51
9	3001	233	33
10	984	56	8
11	4361	343	53
12	3562	228	34
13	1508	148	21
14	1806	221	40
15	5208	360	48
16	2406	179	26
17	2211	130	17
Total	50905	3859	556

Source: Field survey and RADIUS Analysis, 2009

Figure 6.7: Estimation of Casualties (Injuries and Deaths) in day



6.2.2.3. Casualty scenario due to South Udayapur Earthquake during Night

8142 people would injure if this earthquake happen, among them 1724 people would severely injured whereas rest of them would only required normal hospitalization or first aid treatment. As in other cases, ward no 7 faces severe impact than other wards.

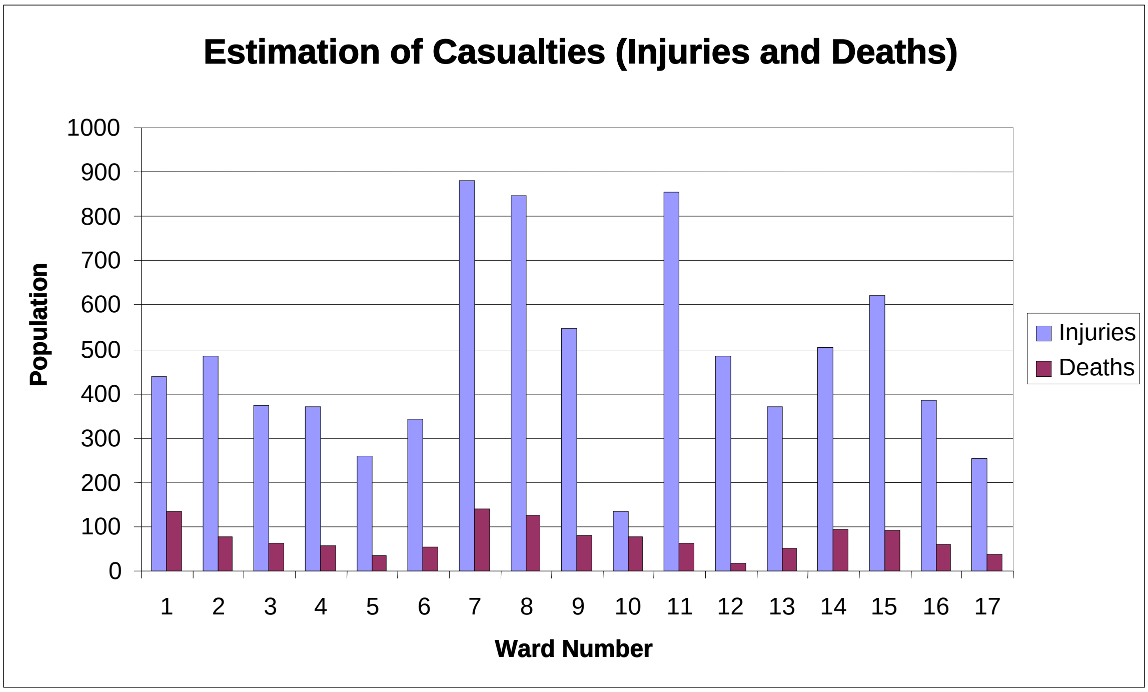
Table 6.6: Estimation of Casualties (Injuries and Deaths) in night

Ward no	Night Population	Injuries	Deaths
1	4560	440	133
2	4331	483	77
3	3111	373	62
4	2687	369	58
5	2721	260	33
6	2355	341	55
7	7217	881	141
8	7398	846	124
9	5381	548	79
10	1617	133	77
11	8673	854	63
12	5465	483	18
13	3018	369	52
14	2861	504	93
15	5434	620	92
16	3185	385	60
17	2160	253	38
Total	72174	8142	1255

Source: Field survey and RADIUS Analysis, 2009

Out of total night population, 1255 people would die due to this assumed earthquake in night time. About 5% people would die in ward number 10 because of greater earthquake intensity.

Figure 6.8: Estimation of Casualties (Injuries and Deaths) in night



6.2.3. North-East Udayapur earthquake scenario

North-East Udayapur earthquake is also possible earthquake due to one of the active faults Main Boundary Thrust, MBT-2.7. This fault is located in North East direction at the distance of 41 kilometres from the municipality. If the earthquake strikes due to this fault, the magnitude will be 6.1 Richter scale and PGA will be 0.1%.

6.2.3.1. Estimation of building damage due to North East Udayapur Earthquake

If this earthquake strikes in Triyuga municipality, about 10 % i.e.1391buildings would damage. In this scenario ward number 4 has highest proportion of building damage whereas ward number 7 lose highest number of buildings of 151 (Table 6.7).

Table 6.8: Estimation of Buildings Damage due to North East Udayapur

Ward no	Total buildings	Damage buildings	MDR%
1	938	87	9.3
2	797	91	11.4
3	586	69	11.8
4	516	83	16.1
5	516	65	12.6
6	445	69	15.5
7	1383	151	10.9
8	1383	119	8.6
9	1008	67	6.6
10	305	18	5.9
11	1618	107	6.6
12	1031	76	7.4
13	563	69	12.3
14	539	86	15.9
15	1055	114	10.8
16	609	70	11.5
17	422	50	11.8
Total	13714	1391	10.1

Source: Field survey and RADIUS Analysis, 2009

6.2.3.2. Estimation of Casualties due to North East Udayapur Earthquake during Day time

The last possible earthquake has the lowest impact in this municipality as compare to other previous one. Only one percent population i.e. 559 would injure among them 45 would severe injured and rest of them would only need normal hospitalization or first aid treatment. 63 people injured in ward number 7. The total death due to this earthquake would be 30 (Table 6.8) in Triyuga municipality. Ward number 7 and 15 lose equal 3 people each and ward number 10 lose no one.

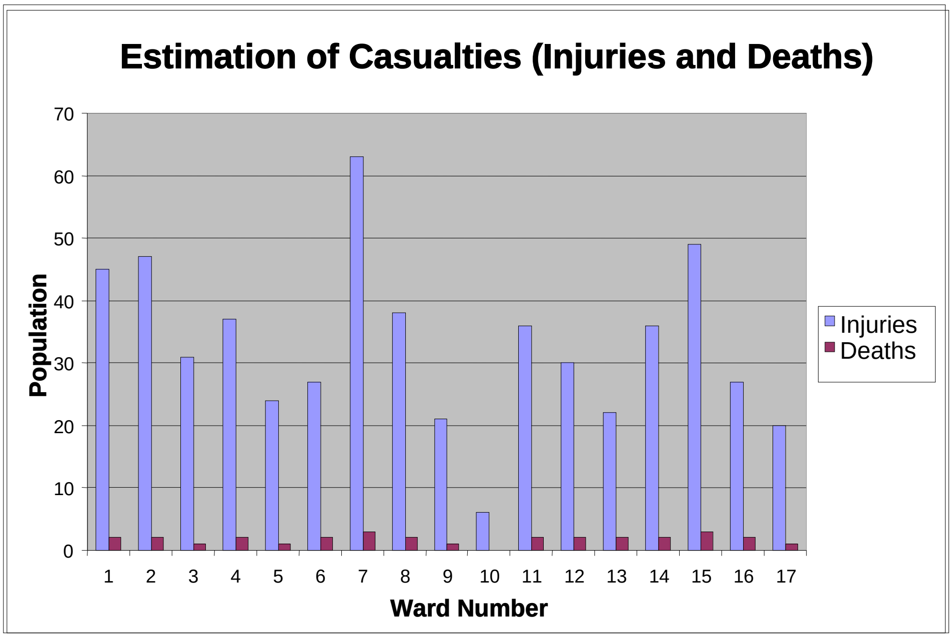
Table 6.9: Estimation of casualties (Injuries and Deaths) in day

Ward no	Day population	Injuries	Deaths
1	5699	45	2
2	3386	47	2
3	2070	31	1
4	1944	37	2
5	1807	24	1
6	1593	27	2
7	5911	63	3
8	3448	38	2
9	3001	21	1
10	984	6	0
11	4361	36	2
12	3562	30	2
13	1508	22	2
14	1806	36	2
15	5208	49	3
16	2406	27	2
17	2211	20	1
Total	50905	559	30

Source: Field survey and RADIUS Analysis, 2009

Figure 6.5 shows the population injuries and death due to this earthquake in day time occurrence. More than 28 times people would injured than death. Similarly, casualties in night time are more two times than day time.

Figure 6.9: Estimation of Casualties (Injuries and Deaths) in day



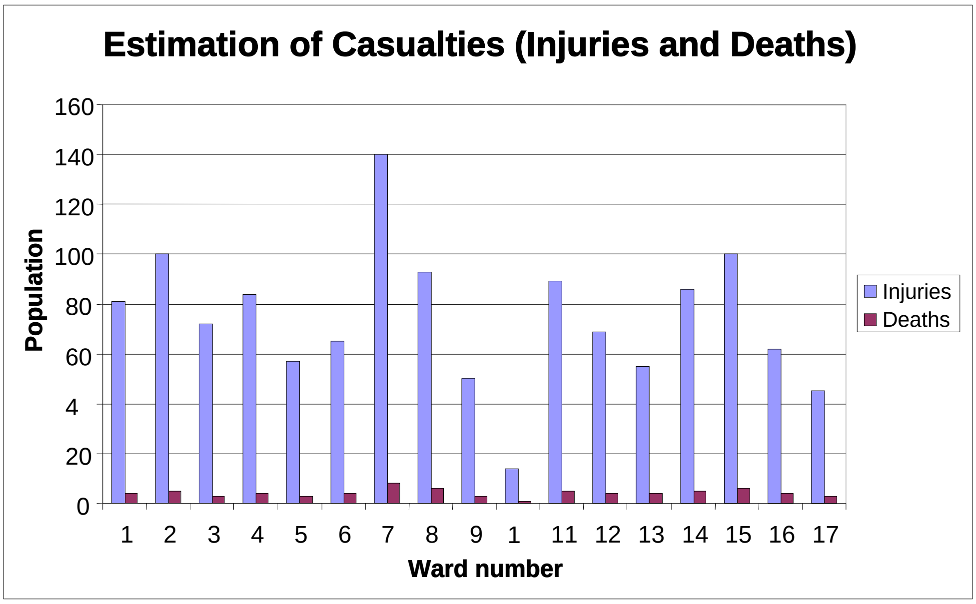
6.2.3.3. Estimation of Casualties due to North East Udayapur Earthquake during night time

Out of total population, 1262 people would injured among them 105 would seriously injured while rest of them would need only normal hospitalization or first aid treatment. Table 6.9 shows the total 72 people would die due to this assumed earthquake. As previous scenarios, ward number 7 lose highest number of population of 8 counts.

Table 6.10: Estimation of Casualties (Injuries and Deaths) in night

Ward no	Night population	Injuries	Deaths
1	4560	81	4
2	4331	100	5
3	3111	72	3
4	2687	84	4
5	2721	57	3
6	2355	65	4
7	7217	140	8
8	7398	93	6
9	5381	50	3
10	1617	14	1
11	8673	89	5
12	5465	69	4
13	3018	55	4
14	2861	86	5
15	5434	100	6
16	3185	62	4
17	2160	45	3
Total	72174	1262	72

Figure 6.10: Estimation of Casualties (Injuries and Deaths) in night



Chapter VII

AWARENESS AND PREPAREDNESS OF PEOPLE TOWARDS EARTHQUAKE

During one month field survey, different questions were asked to find out the level of knowledge and preparedness towards earthquake. 273 household among them 245 residential building and 28 non-residential buildings was selected randomly for interviewed and given priority to household owner or head of house for interview.

7.1. Awareness of people toward earthquake

Though the significant loss was estimated in the municipality, knowledge, awareness and preparedness of residential was not good enough. Only about 76% replied that they heard about earthquake in radio or Television and 7 % people take part in different earthquake awareness raising programme. Similarly, only 4 % think they were living in risk. Very few numbers of household knew about such organisation, which can help to reduce risk through training or teaching as well as early warning system was very unfamiliar to them.

Non residential buildings cover government offices and NGO and INGO. Respondent from non-residential buildings were more knowledgeable than from residential building. All of the respondents were familiar with earthquake but very few were involved in risk reduction program. Staffs of Nepal police, Nepal Army and Red Cross are trained manpower for during and post disaster relief work.

Table7.1: Knowledge of people toward earthquake

Particular	Residential	Non-residential
Listen/ Watch about earthquake	187(58)	28(0)
Participation	16(229)	0(58)
Organisation	1(224)	2(26)
Early Warning system	2(223)	2(26)
Living in risk	11(234)	2(26)
Total	245	28

Source: Field survey,2008.

Note: number in parenthesis indicate ‘No’ answer

7.2. Preparedness of people towards earthquake

Low level of knowledge reflects low level of preparedness and low level of preparedness is high vulnerable. Very few were prepared to hazards (Table 7.2). Building code is not implemented in this city. About 27 % respondent told that they used earthquake resistant technology while construction building but this was only in city core area. Safe place during the earthquake was known by 41% of respondent of residential building and 61% of non-residential buildings. Temporal lodging was not habit for post hazard utilisation. But the traditionally gained knowledge and belief can help to manage them after the disaster. Such as not keeping empty pot or keeping food in community base etc. Discussion about earthquake and other hazard in home is not a habit for both residential and non-residential building's dweller in home. About 61% people blame themselves for the losses (lives and property) due to earthquake.

Table 7.2: Preparedness toward earthquake hazard

Use of safety measure		Knew Safe Place		Temporal Lodging		Discussion		Blame for losses				
Residential	Non-residential	Residential	Non-residential	Residential	Non-residential	Residential	Non-residential	GOD	GOVT.	ENGI.	SELF.	NATURE
66 (179)	6 (22)	100 (145)	17 (11)	0 (245)	0(28)	9 (236)	4(24)	19	0	20	151	10

Source: Field survey, 2008.

Note: number in parenthesis indicate 'No' answer

7.3. Socio-economic factors of population vulnerability

Though the effect of earthquake is equal to all, socially disadvantaged groups and poor are more vulnerable than other. At the household level, poverty is the single most important factor determining vulnerability to earthquake (NSET et-al, 2002, cited in Jimee). At the individual level educational attainment, age, disability etc. may have important influence in the effect of earthquake.

7.3.1. Education and awareness

It is an important factor for vulnerability reduction. It is suppose that risk=hazard*vulnerability/capacity. Education and awareness boost up the capacity of people and reduce risk. In the context of study area, 56.7% population is literate among them 68% male and 45.4% female are literate, (CBS, 2001). Though more than half of the population is literate, educational attainment is not good enough. Only 5.6% population among literate people attain higher education. Similarly, 43.3% people attain primary level education, 17.9% Lower Secondary and 22.1% Secondary level.

7.3.2. Age and Gender

Generally, old and children are more vulnerable to earthquake. Similarly, in patriarchal society women have less access to resource and decision making as well as less mobility. So, gender composition may change in estimated casualty (death and injury) result.

7.3.3. Economy and activities

Poverty is one of the major vulnerability factor for developing countries which also an effect on housing that constitute a usually high damage percentage in case of earthquake. However, “Being poor” is not a synonym for “Being vulnerable” and being rich is not being non-vulnerable (NSET, 2002, cited in Jimee). In Triyuga municipality, notable proportion of household i.e. 69% is depend on agriculture.

Chapter VIII

CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

The research was done to develop an earthquake damage scenario for which four different objectives are taken. RADIUS method was used for developing earthquake damage scenario. For scenario modelling, probable earthquake in the region was taken with Magnitude, Epicentre, Depth and Occurrence time for which ground condition, demographic data and vulnerability functions are critical. Soft soil, Medium soil and Soft rock was found in the study area. Similarly, buildings were categories into 10 different types and each have different vulnerability. Buildings' fragility function developed by NSET was used.

Three different scenario- earthquakes were considered. These earthquakes were assumed according the presence of active fault. Two active faults Himalayan Frontal Fault system and Main Boundary Thrust were found in nearby of Triyuga municipality.

Different buildings characteristics such as buildings' type, height, geometry, age attachment etc. were gathered from field through one month field survey. Similarly, population characteristics were taken from central bureau statistic (CBS), and other related books and journals.

In Triyuga municipality, about 41% buildings was found reinforce concrete (RCC), 23% wooden and Brick in cement, adobe and brick in mud building constitute respectively 18.8%, 15.5% and 1.1%. Ward wise distribution of building types and number is not even. Similarly, about 50% buildings were observed 2 strayed and 44% were single story. Most of the taller buildings were observed in ward number 2. Buildings age was classified into three categories. According to field observation about 53% buildings were observed newly constructed and 41 % buildings were constructed in between 20 to 100 years. Buildings older than 100 years were virtually not existed in the study area. 88% buildings were found in regular shape whereas 12% in irregular shape.

North Udayapur earthquake is the first assumed scenario earthquake which is the biggest and most devastating among three. It is 8.2 magnitude big and epicentre distance is 2.6 kilometre from the municipality. Due to this scenario earthquake 7657 buildings were estimated to be damaged. In case of earthquake in night time 3291 people would die and 15,409 injured. Among injured people 4632 are seriously injured and the rest are moderate or normal injured to whom need only normal first aid treatment. Similarly, in day time occurrence, of the earthquake, 1,561 people would die and 7,997 are injured. In this case, out of total injured people only 2,374 are severely injured and the rest of them are moderate injured.

The second assumed earthquake is South Udayapur earthquake which is 7.2 magnitude big and its epicentre would be in Triyuga municipality. About 36% buildings would damage when this earthquake hit this municipality. In day time occurrence, 556 people would die and 4939 would injured. Among injured people, 804 are severely injured. Similarly in night case, 1255 people would die and 8142 injured. 1723 injured were severely injured.

Similarly the next possible scenario earthquake is North East Udayapur earthquake which has the possibility of 7.5 Richter scale and its epicentre is 41 Km far from the municipality. About 10% buildings would damage due to this earthquake. In day time occurrence of the earthquake, 30 people would die and 559 would injured among them 45 is seriously injured. Similarly, in night case, 72 people would die and 1262 would injured among them 105 are seriously injured.

Ward number 14 is the most affected ward with high MMI in all three earthquakes among 17 wards in this municipality. Up to 71% buildings would damage in this ward. Similarly, ward number 7 loss highest count of buildings in all three cases as well as highest count of human life and have injured people.

245 residential buildings and 28 non residential buildings were visited to acquire the information about knowledge and preparedness of people towards earthquake and its impacts. Virtually, all people replied earthquake as simple trembling of earth but very few of them are prepared against its impacts. Except staffs of Red Cross, Nepal Police and Nepal Army no one is participate in risk reduction training and very few know about early warning system and feel living in risk. 66 respondents from residential building told that they used earthquake resistant measures while constructing building but these numbers are concentrated in newly

constructed RCC building in ward number 1, 2, 3 and 11. Nominal household discussed about earthquake and its impacts and virtually null household feel the necessity of temporal lodging. More than half respondents replied that they blame themselves of possible loss by earthquake.

8.2. Recommendations

- Individual building footprints were drown just by visual observation which may not provide sufficient accuracy for estimation of population and ultimately for casualties. Updating of the spatial database is recommended.
- More detail survey for socio-economic and demographic information.
- Municipality should take a lead in awareness and preparedness programs and training for different levels teachers, officials, students, masons etc.
- Urbanisation rate is very high so, in order to find out the updated result frequent assessment is necessary.

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ANNEX 1: Building Inventory Form

Building Inventory form Triyuga 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

Triyuga 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: The Modified Mercalli Scale

Intensity	Description of damage

I	Not felt by people, only detected by seismographs
II	Felt only by a few persons at rest, especially on upper floors of buildings
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy turck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all many frightened. Some heavy furniture moved; a few instances fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction: slight moderate in well-built ordinary structures; considerable damage in poorly built badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structure; well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted of foundations.
X	Some well-built wooden structures destroyed: most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Brides destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Annex 5: Building Typology

Building classes	Index	Description
Adobe	A	Sun dried bricks with mud mortar
Brick in Mud	BM	Brick with mud mortar

Brick in Cement	BC	Brick with cement or lime mortar
Stone in Mud	SM	Stone with mud mortar
Stone in Cement	SC	Stone with cement
Reinforce Concrete	RCC	
Wooden	W	Wooden by Timber

Annex 6: 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.

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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

Triyuga 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?

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

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

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Which places are suitable during the earthquake time?

Annex 4: The Modified Mercalli Scale

Intensity	Description of damage

I	Not felt by people, only detected by seismographs
II	Felt only by a few persons at rest, especially on upper floors of buildings
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy turck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all many frightened. Some heavy furniture moved; a few instances fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction: slight moderate in well-built ordinary structures; considerable damage in poorly built badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structure; well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted of foundations.
X	Some well-built wooden structures destroyed: most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Brides destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Annex 5: Building Typology

Building classes	Index	Description
Adobe	A	Sun dried bricks with mud mortar
Brick in Mud	BM	Brick with mud mortar

Brick in Cement	BC	Brick with cement or lime mortar
Stone in Mud	SM	Stone with mud mortar
Stone in Cement	SC	Stone with cement
Reinforce Concrete	RCC	
Wooden	W	Wooden by Timber

Annex 6: 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.