Urban Multi-Hazard Risk Analysis Using GIS and Remote Sensing: A Case Study of a Part of Kohima Town, India

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Urban multi-hazard risk analysis using GIS and Remote Sensing: A case study of landslide, earthquake and fire hazard in a part of Kohima Town, India

by

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Disclaimer

This document describes work undertaken as part of a programme of study at the International Institute for Geo-information Science and Earth Observation. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

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Abstract

A utopian city, which is totally free from any hazard, can not be achieved on this mother earth. Conversely, there are many hazards that a city confronts. This study tries to look into some of the hazards such as Landslide, Earthquake and Fire hazards in a part of Kohima town, and prepare a multi-hazard risk map. Keeping in mind the non-availability of the required data for the study, due to security and other reasons, the study also looked into the role of remote sensing, field mapping and historical data for acquiring data for a data scarce situation like Kohima town.

Building inventory details such as building structure, material, condition of buildings, socio-economic, population, etc., were collected through physical survey with the help of the digital footprint map that was extracted from aerial photo, having individual building blocks. Along with the data collected from remote sensing data, field mapping and historical data, individual hazards were analyzed using vector operation in GIS environment, and all the individual hazard maps were integrated to prepare a multi-hazard map. The number of household/ family in each building was calculated to derive the population at risk to different individual hazards and multi-hazard.

Remote sensing data was found to be not so useful in mapping landslide in a small and highly built up area. However, terrain information such as geomorphologic information, lineaments and faults and regional rock pattern could be extracted from Remote Sensing data. Field mapping of landslide is found to be a useful method for a small area, while collecting building attributes for each and every building is time consuming and not practical for a big towns.

Individual buildings with both single and multi-hazard were identified and population at risk was calculated. A comparison of the existing situation in the study area with that of the standard prescribed at the national level was made. The condition in the study area is falling short of the norms and standard recommended as an ideal town.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Literature Review

1.1.1. Introduction

Natural hazards are part of the environment in which we live. They do not discriminate between people or countries. And yet, no disaster is entirely natural (UNDRO, 1991). We cannot stop the forces of nature, but we can and must prevent them from causing major social and economic disasters (Kofi Annan, 1999). Tobin (Tobin, *et al.,* 1997), while quoting Atkinson, *et al.* (1984), cited that there are 516 active volcanoes with an eruption every 15 days (on average) somewhere in the world; global monitors record approximately 2,000 earth tremors everyday, and there are approximately 2 earthquakes per day of sufficient strength to cause damage to homes and buildings, with severe damage occurring 15 to 20 times per year; there are 1,800 thunderstorms at any given time across the earth's surface; lightning strikes 100 times every second; during the late summer there are something like 5 hurricanes developing at any one time; and tornadoes average 4 day or 600 to 1,000 per year.

1.1.2. Natural Hazards

A Natural Hazard is defined as the probability of occurrences of a potentially damaging phenomenon within a given period of time in a given area (Tobin *et al*., 1997; Leroi, 1997). A hazard can therefore be a threat to the society that is ever present, representing an intrinsic force with which all societies must cope in one way or another. The hazard becomes a risk because humans or their activities are constantly exposed to natural forces (Tobin, *et al*., 1997).

1.1.3. Hazards in Urban Areas

An urban hazard is a potentially damaging phenomenon that threatens a city, its population and related socioeconomic activities. If a hazard threatens a large city, the risk may resonate beyond the area of impact. The fast-growing world population is concentrating more and more into urban areas. Nowadays, almost half of the world's 6 billion inhabitants already live in cities, and in the next thirty years it is predicted that out of a total of 2.2 billion newcomers, 2.1 billion will be urban citizens, and 2.0 are expected to be born in cities in developing countries (Source: USAID, 2001). In the world, many urban centers are growing at a high rate, especially in the developing countries. This is due to the uncontrolled natural growth of population and the migration from rural areas to the urban centers in search of better standard of living. In 1960, only one city – Shangai had a population of more than 1 million. In 2000, 450 cities worldwide, each shelter a population of more than 1 million. Of these 50 cities have a population of grater than 3.5 million and 25 cities have populations greater than 8 million (Sokhi, 2003). While estimating the global population, USAID (2001), pointed out that between 1990 and 2015, the population of cities with more than a million residents is expected to increase dramatically:

- In Latin America, it will double – from 118 to 225 million.
- In Asia, it will nearly triple – from 359 to 903 million.
- In Africa, it will quadruple – from 59 to 225 million.

The demand of land for expansion of urban centers is getting higher than the supply availability of suitable land, leading to haphazard urban sprawl and deliberately locating the settlements on areas highly vulnerable to natural hazards. The economic and social impact of disasters is very high when it strikes such densely populated urban areas. While addressing the financial impact of disaster Berz

(1999) pointed out the main causes are due to the increasing urbanization, the settlement in and industrialization of highly exposed regions, the vulnerability of modern technologies and also anthropogenic changes in the environment. Human activity invariably aggravates the risks through insufficient attention to where and how settlements are built, or natural resources are exploited (UNDRO, 1991). Many cities develop within any proper urban development planning, let alone that within these development plans natural hazards, such as landslides or earthquakes, and the risk they pose to the city and its inhabitants, are taken into account. The most reliable way to prevent landslide-induced casualties and economic losses is to avoid building towns or cities on or in the vicinity of steep terrains. But, this is considered impracticable or impossible in many countries due to the rapid growth of historical city centers into the surrounding steep hill slopes, and the unwillingness of the human population and the expensive costs to relocate. Thus, regional and local landslide hazard analysis and risk management is becoming an important task for city planners and officials (Chau, *et al*., 2004).

1.2. Statement of the Problem

Kohima, the capital of the East Indian state of Nagaland, is an example of such as rapid developing city in a hilly environment with serious landslide hazards. Every year during the later part of the rainy season, i.e., July-September, the town suffers from landslides. Roads are blocked by landslides every year, obstructing the only means of transport and communication with the other parts of the country.

Nagaland, like all other North-Eastern states of India lies in the seismic zone V (fifth), liable to seismic intensity IX and above on the Modified Mercalli Intensity Scale. This is the most severe seismic zone and is referred to as the Very High Damage Risk Zone. The growth of Kohima town did not follow the guidelines prescribed by the Master Plan of 1974, prepared by the Urban Development Department. The state Government of Nagaland is unable to impose the strict rules that are provided in Indian laws. Nearly all buildings are still constructed without any control or regulation. As a result the existing buildings are very vulnerable and there is no sufficient space left between buildings.

As Kohima town has a rather difficult access route, it always had the problem of transporting construction materials for Reinforced Concrete Cement (RCC) buildings from surrounding areas. As the region has always been rich in forest resources, most of the old building stock is wooden structure. Therefore, the buildings can be ignited by fire easily, and once they catch fire, it can spread very fast since the buildings are built very close to each other. Till lately, Kohima did not have a Building Bye-law. The prevalence of landslide, earthquake and fire hazards in the town needs to be assessed and a multi-hazard risk map should be produced. This can be helpful for policy formulation and guidelines to urban planners and other spatial planning agencies in preparing development plans, and urban building control mechanisms.

The state government in its initiation to protect the towns from such natural hazards provides financial assistance under the Town Protection Scheme, which is assigned to the Urban Development Department as the nodal agency. However, the scarce resources are not sufficient to tackle the problem of landslide mitigation. Besides, other departments dealing with spatial planning such as the Roads and Bridges of the Public Works Department (PWD), Border Roads Organization (BRO), etc., which could provide assistance have difficult times themselves in emergency response during the rainy season. There were times when the National Highway 39, which is the main lifeline of connecting Nagaland and Manipur, is cut off for several days by landslides. Due to the scarcity of land, lack of provision of infrastructure and facilities for expansion of the town in the peripheral areas, and the difficult terrain, people deliberately continue to build on old landslides and on steep slopes. The figure below shows a photograph of typical buildings on steep terrain in the study area.

Figure 1.1: Photograph showing the condition of buildings in the study area

The study was conducted in three wards: New Market, Midland, and Hospital Colony wards, which are centrally located and highly affected by landslides and have potential fire hazard (see figure 1.1) due to construction material and closeness of the buildings. The study area occupies about 1.03 sq. km. (Ref. Table 2.1) with an approximate 2105 inhabited buildings and some buildings blocks which can not be called as buildings such as separate kitchens, toilets and abandoned buildings (For details Ref. 2.1.2).

1.3. Multi-Hazard Analysis

Hazard Analysis is also referred to as Hazard Evaluation or Hazard Assessment. According to UNDRO, hazard assessment is the process of estimating, for defined areas, the probabilities of the occurrence of potentially-damaging phenomenon of given magnitude within a specified period of time.

There is no denying the fact that the urban centres are not free from natural hazards ranging from earthquake, landslide, hurricane, flood, drought, etc. There is mostly not only a single hazard, but many hazards to which a city is vulnerable, though the probability of occurrence and intensity may differ from hazard to hazard. It is therefore rational to take into account a multi-hazard approach, considering the natural hazards, which are damaging and frequent in nature. Emphasis should be given to the reduction of vulnerability in urban areas, which requires an analysis of potential losses in order to make recommendations for preventive, preparedness and response actions (Ingleton, 1999). The risk assessment, which combines information on the nature of hazard with information on vulnerability of the targets, is helping to clarify decision making for disaster management and the development of mitigation strategies (Rodda, 1999). Most of the data required for disaster management has a spatial component, and also changes over time. Therefore use of Remote Sensing and GIS has become essential in urban disaster management (Westen, *et al*., 2002).

1.4. Background of the Study Area

1.4.1. Location

Kohima is the state capital of Nagaland located between 94^{0}4’12.14” E to 94^{0}8’56.68”E Latitude and 25^{0}37’26.35” N to 25^{0}45’2.72” N Longitude. The town lies between 800 to 1500 meters above mean sea level. The temperature of Kohima is moderate, ranging from 5^{0}C in winter to 30^{0} C in summer. The rainy season begins in the second half of May and continues till September and sometimes October. The five months of intense rain cause landslides and soil erosion in the region. The population of Kohima, according to the Census of India, 2001 is 78,584. Being the capital town of the state, the population is growing at a fast rate of about 6% per annum. The population has increased from 51,418 in 1991 to 78,584 in 2001 (Ref. Figure 2.5). As a consequent of the additional population, the problem of scarcity of land led to haphazard growth and settlement on hazard prone areas.

Kohima is a hill town constructed on the top of a series of hills with most of the buildings constructed on steep slopes (See figure 3.2.5). The roads are narrow, leaving no further scope for widening due to its topographic setting. There is only one main road connecting the north and south part of the town. A critical situation will arise if the main road at Razhü point – having no parallel road running connecting the northern and southern side – is disrupted by any disaster event, the town will be totally cut off from road communication. Infrastructures and facilities are not allocated judiciously due to natural constraints. For instance, there is only one fire service station in the town, which is located on the south where there is availability of water. The location of the fire station in the extreme south makes the service unable to reach the north on time whenever there is any major fire incident. There is only one government owned hospital and only a few private nursing homes, which not only serves the town, but also are suppose to give service to the surrounding villages. The Figure 1.2 shows the location map of the study area.

1.4.2. Administrative Set-Up

In Kohima, a separate administrative department dealing with Disaster Management does not exist, and the disaster management tasks of other organizations are not well defined. The Relief Branch of the Home department is assigned with the affairs of natural calamity relief, only. However, other than receiving applications of natural calamity reports and disbursing relief to the affected persons, there is no initiative for disaster mitigation by the Relief Branch. Recently, the Home department has initiated the preparation of a disaster management plan for the state under a UNDP funded project. This may be considered as a stepping-stone for disaster management in the state. However, it is felt that it might not be able to address problems at local or settlement level and specific hazard that are pertinent in a hazard prone state like Nagaland. There are departments such as the Urban Development Department, Public Works Department, Irrigation and Flood Control, Waste Land Development Department, etc., that takes up issues pertaining to natural hazards. But there is no adequate coordination among these departments.

Initiated by the Urban Development Department, a Building Bye-law have been prepared and finally passed by the state Legislature in 2001 (Reference). However, there are problems to successfully implement the building Bye-law. Because of the fact that land cannot change owner (Non-Transferable of Land laid down in the constitution of India, Article 371), the government agency cannot impose strict rules on the land owned by the private parties. This is a major hindrance for the government agencies to fully implement the development programmes.

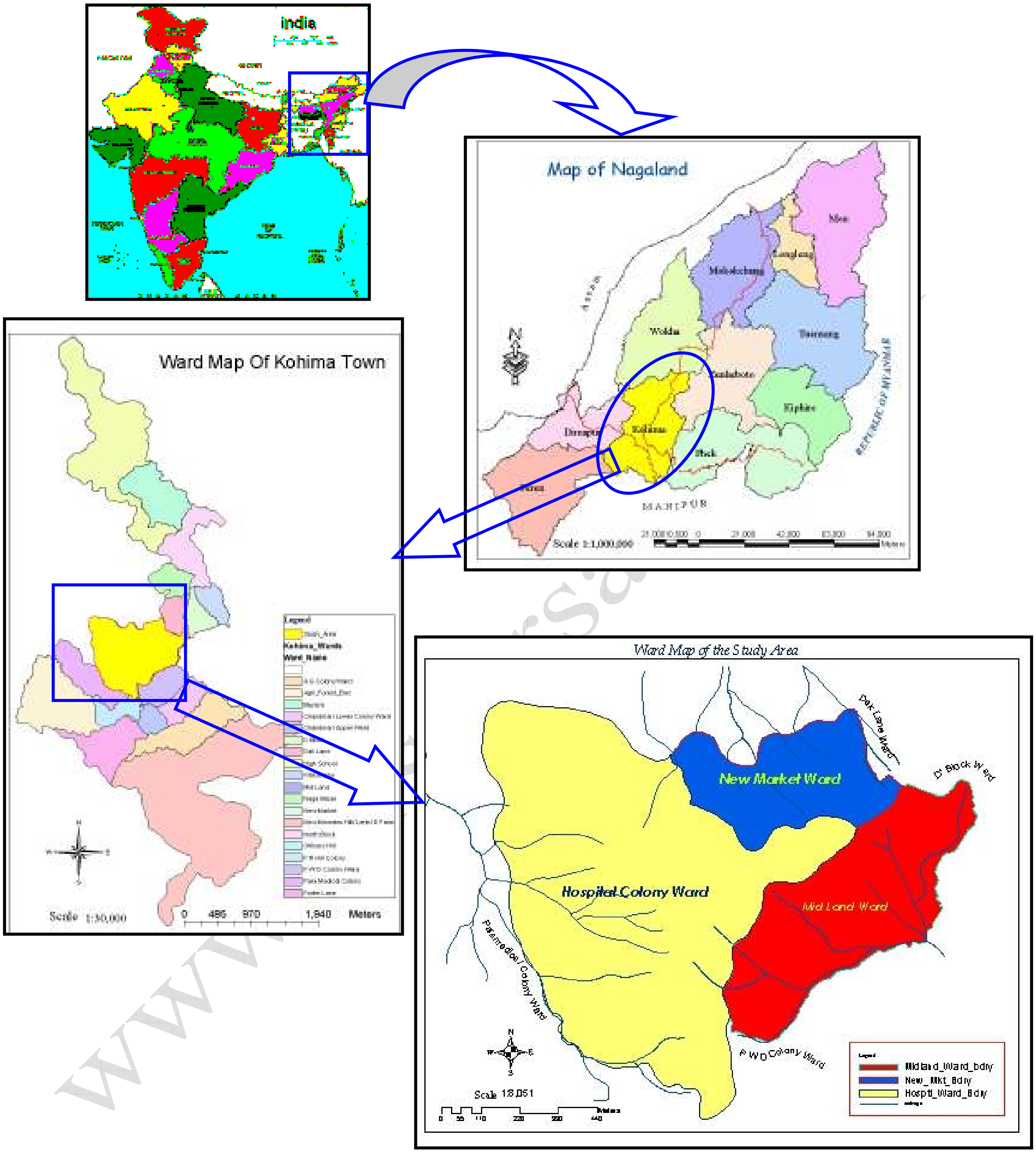


Figure 1.2: Map showing Location of the Study Area

1.5. Objectives and Research Questions

The main objectives of the study is to analyze Landslide, Earthquake and Fire Hazards in a part of Kohima town (New Market, Midland, Hospital Colony wards), based on historical analysis, a mapping survey and a questionnaire survey combined with elements at risk inventory to derive a multi-hazard risk map, which can be used as base map for reallocation of facilities and infrastructure, formulation of plans for future expansion and emergency planning.

1.5.1. Specific Objectives

1. To prepare a building inventory map using available digital building foot print maps
2. To make an inventory of landslides through interviews and field mapping
3. To map Elements at Risk using both basic walk over survey and sample survey
4. To prepare a Landslide Risk Map using a Landslide Inventory Method
5. To prepare an Earthquake Risk Map and a Fire Hazard Risk Map
6. To prepare a Multi-Hazard Risk Map.

1.5.2. Research Questions

1. How far will be historical methods for earthquake, landslide and fire risk assessment applicable in Kohima, given the scarcity of other types of data?
2. What are the data requirements for these methods, and how much could be obtained from interviews and field mapping and how much from remote sensing imagery?
3. What types of buildings, infrastructure and critical facilities are likely to suffer damage by these multi-hazards, and how to express this (semi) quantitatively?
4. What are the vulnerable areas prone to earthquake, landslide and fire hazard?

1.6. Methodology

1.6.1. Materials

Geo-referenced Digital footprint and road maps were used as the base map for the study. A Toposheet of 1:5,000 scale at 5 meters contour interval was used to generate the altimetry information. Satellite data such as ASTER and LISS III and PAN merged data of IRS were used for the extraction of geological features.

1.6.2. Hardware and Software:

ArcGIS was used for the analysis of vector data, and image processing software such as Erdas Imagin and ILWIS were used for processing the satellite imageries. Mobile GIS (Pocket PC with ArcPad and GPS) was used to locate/identify the individual buildings in the field.

1.6.3. Steps followed (Methodology)

a. Defining of topic and formulation of objectives
b. Literature review
c. Collection and processing of secondary data
d. Interpretation of Satellite Imagery for landslide identification at a small scale (digital and visual interpretation).
e. Primary Survey
    i. Questionnaire Survey:
        a) Collection of historical data for earthquakes and landslides through interviewing geologists and local people.
        b) Field verification of landslide areas.
    ii. Mapping of building stock and elements at risk using Mobile GPS (Palm top with ArcPad and GPS) to derive a building inventory map.
    iii. Landslide mapping survey
f. Integration of Hazard maps to arrive at a multi-hazard map
g. Analysis.

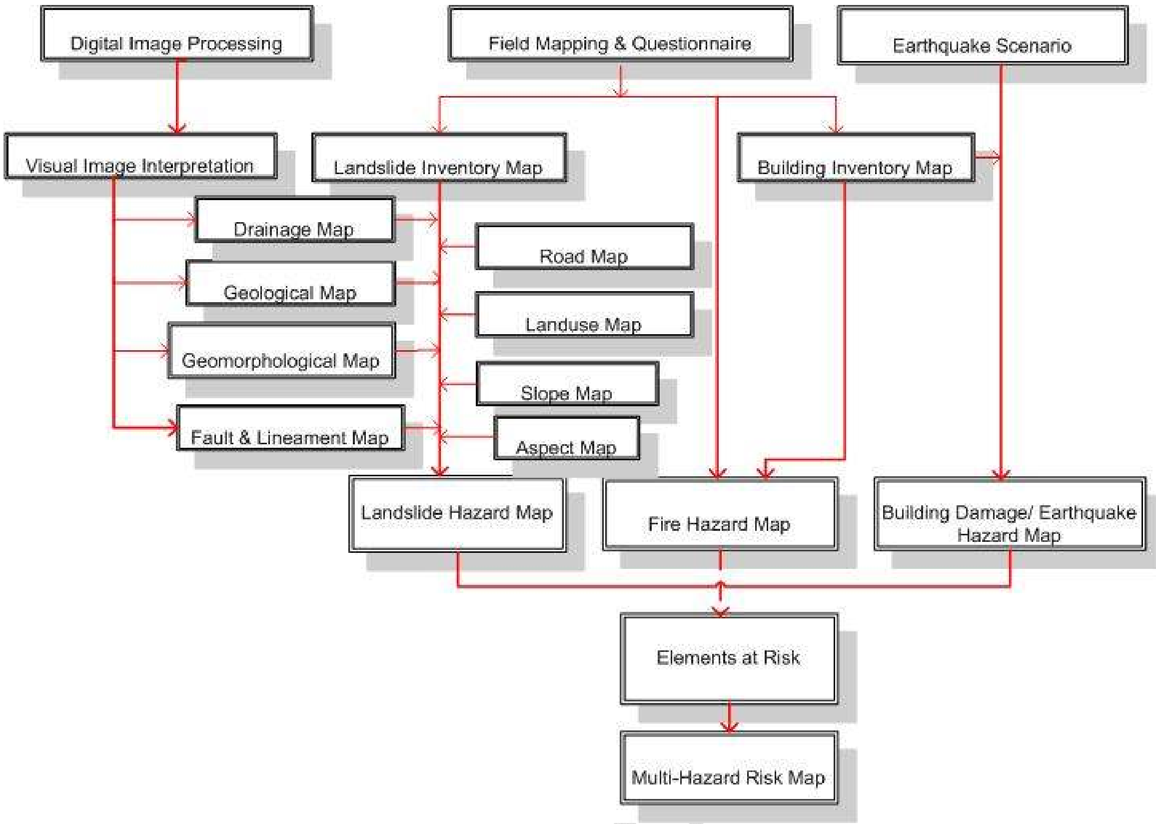


Figure 1.3: Flow Chart showing the Methodology

The methodology adopted is presented in the form a flow chart (Figure 1.6). In order to generate a Multi-Hazard Risk Map firstly, individual hazard maps such as: Landslides, Fire and Earthquakes were made, which were derived from respective hazard maps. To arrive at a multi-hazard risk map, different hazard maps were integrated. The numbr of household in the buildings with multi-hazards are multiplied with the average population to get the population at risk. The landslide hazard map was prepared from a landslide inventory map through walkover survey. Information Value method was adopted for preparing a landslide hazard zonation map (Ref Chapter 3.3). The input data that were used for landslide hazard zonation were geological data, geomorphologic, slope and aspect, lineament, fault, drainage, landuse information, and lineaments and fault map. The parameters used for fire hazard are: building inventory - construction material, space between buildings, distance from fire station, and distance from hazardous buildings (Ref Chapter 3.1). Meteorological data could not be incorporated due to unavailability of data. Due to lack of data and constraint in time, scenario earthquakes of different intensities (at Modified Mercalli Intensity VII, VIII and IX) were assumed for calculation of earthquake damage assessment, without including information on return periods (Ref Chapter 3.2).

1.7. Limitations

Being located near the international border, Kohima is located in so-called "border zone" for which there is a serious constraint on the use of spatial data, such as aerial photos and maps, due to security reasons. The political situation in the state is also not conducive to let scholars carry out their research activities. Some pertinent data are not available to carry out the study. There were also instances where data is available, but the agency was not willing to share it because of security reasons. The relevant departments also indicated that they do not have the data that are suppose to be available. For instance, the Geology Department of the Nagaland University, Kohima does not have a geological map and the Directorate of Soil and Water Conservation could not produce a soil map of Kohima.

In addition, the Indian satellite imageries are not freely available for this region. Unfortunately, the study area lies between two scenes of IRS data that sometimes it could not capture the study area by either of the scenes. The study area is on steep slopes and building density is high. As a result, collection of samples of rocks and lithological data could not be taken at regular intervals. In most of the cases, the rocks are not exposed due to the retaining wall constructed on the roadsides.

The population of the different wards is not been made available by the Census department. At the same the ward boundaries of the wards were redefined by the Department of Home, Government of Nagaland in 2003, by a notification, but maps indicating the new boundaries were not made available. So based on the notification statement, ward boundaries were demarcated, which may be erroneous is some cases. Consequently, the estimation of population of the wards may not be very accurate.

2. Data Collection

Data collection was done in two phases: Phase I, Secondary data collection and, Phase II, Primary data collection. A major portion of the data collected was through primary survey. After the conception of the idea of the topic, literature review was carried out to have a better understanding of the problems, and the methods and approaches to be used were decided. The problems in the study area were analyzed and compared with the prevailing situation in the regions where such type of case studies has been carried out. Accordingly, objectives and methodology were framed depending on the pre-conception of the data availability. The flow chart showing the data that were collected is presented in the Figure 2.1 below.

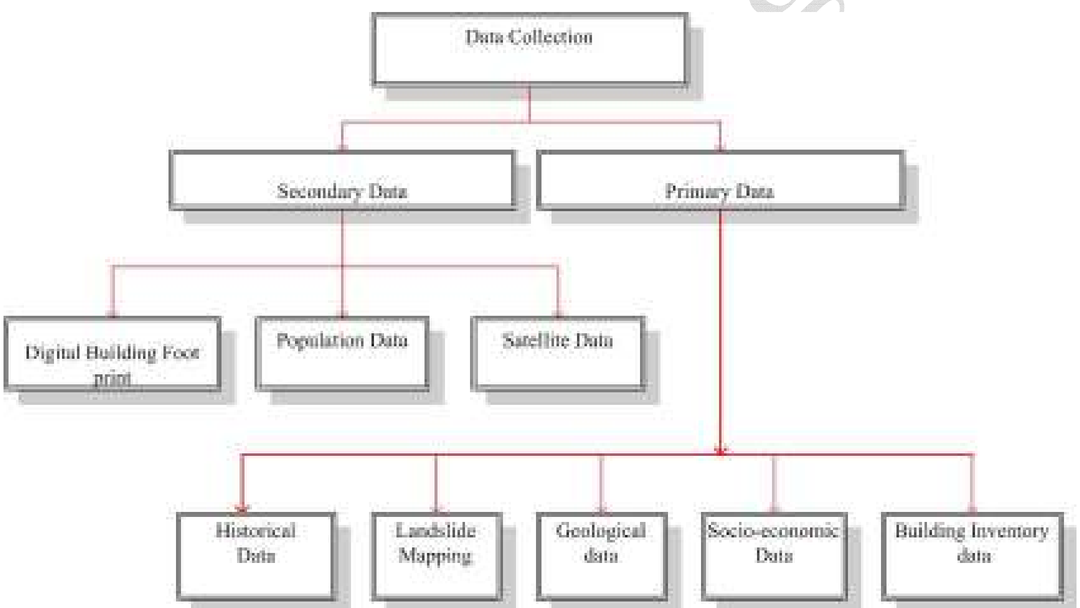


Figure 2.1: Flow chart showing the steps followed for data collection

2.1. Ward Boundary Demarcation

The geo-referenced building footprint map was made available in digital format by the Urban Development Department, Government of Nagaland. The footprints of the buildings were extracted from the aerial photograph that was taken by the National Remote Sensing Agency (NRSA) on 29th December 2001. All the building features till 29th December, 2001 are present in the footprint map as line feature. With the upcoming municipal election in the city, in December 2004, the Government of Nagaland has re-demarcated the ward boundaries of Kohima town in 2003. This re-demarcation of boundaries has reshaped the whole of Kohima town and also the study area. The boundaries of the wards were redrawn as per the Notification No. TC/HOME-43/2003, Dated, Kohima, the 20th Nov./

2003 by the Government of Nagaland (Home Department, 2003) in consultation with the existing local body, namely Kohima Town Committee (KTC).

2.1.1. Building Features Extraction

The geo-referenced line features were converted to polygons and processed to arrive at the individual building plot area using ArcGIS software. The ward maps with buildings, roads and drainage were printed at a scale of 1:1,000 in order to use as a base map for subsequent field survey. Each building block on the footprint map was given a unique identification number in order to use as reference number to identify the individual buildings in the field. Since the digital map is geo-referenced by NRSA using differential GPS (Global Positioning System), the new buildings that have come up after December 2001 were marked tentatively with co-ordinates from the GPS.

2.1.2. Separation of Buildings Blocks

The footprint map consists of all the buildings and other regular blocks seen on the aerial photographs, irrespective of their size and shape. It was therefore, required to make a threshold of what type and sizes of blocks will be considered as a building unit for the analysis, since some of the blocks are not habited buildings. There is a practice of keeping a kitchen or toilet/bathroom built away from the main building. Also, there is a practice of rearing pigs, for which a shed - pig-sty - are constructed. So, it is necessary to separate these small structures from the main buildings. For this, a threshold of 15 square meters was used for separating the small blocks of buildings. Blocks which are 15 square meters or more in area are considered as a building. ArcGIS spatial query was used to exclude the small buildings. However, there are still some toilet/bathroom, pig-sty, garage, etc., that could not be excluded due to their size that is bigger than the threshold. After the collection of the buildings attributes, it was found that there are 2105 inhabited buildings (Ref. Table 2.1) in the study area. In addition to the habitated buildings, there are 124 blocks of buildings that were not been able to be excluded by the threshold criteria were considered for analysis. This is because kitchen built close to the main building may be a cause of fire. With the inclusion of the small block of structures, the number of building blocks totalled to 2229. Analysis was performed on all the building blocks including the additional 124 (kitchens, toilets/bathroom, pigs-sty, store room, garage, etc.).

Table 2.1: Area and number of buildings in different wards

Area and number of buildings in the Study Area			
Wards	***Area in Sq M***	***Area in Sq Km***	***No. of Buildings***
Hospital Colony Ward	64,0717	0.647	964
New Market Ward	1,45,795	0.14	401
Midland Ward	2,44,879	0.24	740
Total	1,03,1391	1.03	2105

2.2. Building Inventory

The printed maps of the building footprints were used in the field for collecting the building information. Based on the objectives defined, a format was prepared which contains necessary data to be collected in respect of buildings type, use, construction material, etc., and other associated parameters like presence or absence of cracks/ displacement on drainage, foot-path or retaining walls. The format used for the survey is given in Table 2.2 below.

Table 2.2: Format for Building Inventory Survey

SL NO	*FID* (Bldg code No)	*NO. OF FLOOR* (Stories)	*STRUCTURE* 1.Load Bearing=LB 2.Reinfornced Concrete= RCC/FS	*ROOF* CGI=C Cement=CC Others=O	*WALL* Brick=BR CGI=C Bamboo=B Wooden=W Stone=S Mixed=M( )	*FLOOR* (Mud-M Cement= C Wooden =W Mixed= M( )	*USE* Residential=R Institutional =Inst Commercial=C Industrial=Ind ( ) Public=P( ) Mixed=M ( )	*CRACKS* Wall=W Displacement/ Tilt=D Drainage=DR Footpath=F Retaining Wall=PW	*NO OF HH*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1									
2									

There are few buildings that have one or more floors whose walls rests on the steep slope (Ref. Table 2.2, Col No 3). For convenience, the number of floors from the basement was considered as a floor in this study.

The format was used during the survey with the parameters in codes were used to fill up the form. The following table (Table 2.3) shows the codes that were used during the survey. The empty brackets () in the format indicates that codes was used to fill them up with reference to the codes in Table 2.3. For instance, M (BC) in column 6 of table 2.3 indicates that the wall material is of mixed wall material of Bamboo and CGI.

Building information such as number of stories, structure (Reinforced Concrete/Frame Structure, and Load Bearing), roof material, wall material, floor material, visible cracks - on the wall, retaining wall/ protection wall, drainage, footpath, roads, differential settlement, etc., number of households in the building based on local practices of separate kitchen and visible chimneys on the sides of the building, etc., were collected by physically verifying the buildings. With the assistance of the staff from the Office of the Chief Town Planner, Urban Development Department, the survey was conducted. The field survey team tried to make observation on the buildings from all the four sides of the buildings. But in certain circumstances, observations could not be made on all the four sides of the walls due to space constraints and protection walls being constructed around the building.

Table 2.3: Codes used for Building Inventory Survey

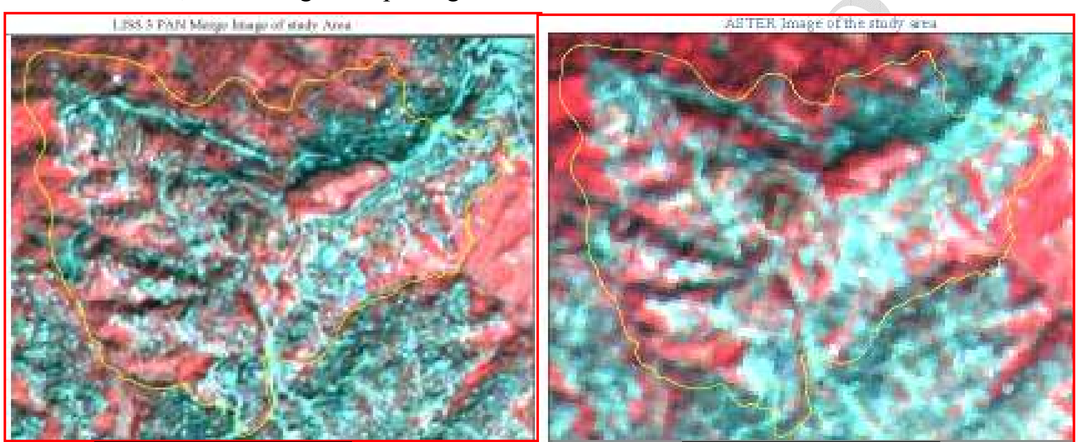
FID	Field Index Number (Building No.)		
STRUCTURE		**SCHOOLS/COLLEGES**	
LB	Load Bearing	Inst (S)	School
RCC/FS	Reinforced Concrete/Frame Structure	Inst (SPG)	Govt., Primary School
ROOFING		Inst (SPP)	Pvt., Primary School
CGI	Corrugated Galvanized Iron Sheet (Tin)	Inst (SMG)	Govt., Primary School
CC	Cement Concrete	Inst (SMP)	Pvt., Middle School
WALL		Inst (SHG)	Govt., High School
BE	Wall with Exposed Brick	Inst (SHP)	Private High School
BP	Brick Wall with Cement Plaster	Inst (SHsG)	Govt., Higher Secondary School
B	Bamboo Wall	Inst (SHsP)	Private Higher Secondary School
W	Wooden Wall	Inst (C)	College
S	Stone Masonry Wall	Inst (CG)	Govt., College
M(BC)	Mixed wall (Bamboo and CGI)	Inst (CP)	Private College
M(BW)	Mixed wall (Bamboo and Wood)	Inst (U)	University
FLOOR		Inst (B)	Banks
M	Mud Floor	Inst (HG)	Govt., Hospital
C	Cemented Floor	Inst (HP)	Private Hospital
W	Wooden Floor	Inst (D)	Dispensary
USE		Inst (N)	Nursing Home
RO	Residential Owned	Inst (PO)	Post Office
RR	Residential Rented	**INDUSTRIAL**	
RG	Residential Government Quarters	Ind (A)	Automobile Repairing
Inst (O)	Institutional Offices	Ind (W)	Woodcraft/Furniture shops
COMMERCIAL		Ind (E/W)	Electronics/ Watch Repairing Shops
Com (E/G)	Essential Goods / Grocery Shops	Ind (R)	Rice / Flour Mill
Com (H)	Hardware/ Construction Material	Ind (S)	Saw Mill
Com (S)	Stationery Shops	Ind (H)	Hotel
Com (Veg)	Vegetable Shops	Ind (HL)	Lodging Hotel
Com (P)	Pan Shop	Ind (HF)	Food Hotel
Com (Ph)	Pharmacy	Ind (HT)	Tea Stall
Com (O)	Others (Specify)	Ind (O)	Others (Specify)
CRACKS		**CRACKS**	
W	Wall	D	Displacement/tilt on roof
DR	Drainage	F	Footpath
PW	Protection/Retaining Wall		

2.3. Mapping Landslides

Different methods were adopted for Landslide mapping. They are: interpretation of satellite imageries, walk-over survey, and through historical data. The former was not so much helpful in identifying landslide due to the poor spatial resolution of the satellite data that were used, while the latter two methods have been found useful for the study. A brief description of how these methods were used for landslide is mentioned in the following sections.

2.3.1. Interpretation of Remote Sensing data

Remote sensing data of merged IRS LISS III - PAN and ASTER data were tested for their usefulness to identify landslides. However, due to the poor spatial resolution of the satellite data and high density of the buildings in the study area, landslide could not be mapped from these imagery. Due to the scarcity of land in the town, residents continue to build on instable slopes and on old landslides zones that may get re-activated in the coming year. The Figure 2.2 shows the LISS III PAN merged image and ASTER image of the study area. The resolution of the LISS III PAN merged data with a spatial resolution of 5.8 meters is too small for the small landslides to be seen. However geological features such as lineament, fault and geomorphologic information were extracted from satellite data.



LISS III + PAN ASTER Image

Figure 2.2: Image showing LISS III Pan merged data and ASTER image

Anaglyph stereo-pair generated from the ASTER data was also used. This was helpful to compare the regional rock settings of the area. Though the resolution was poor and the scale was small, Geomorphologic units and the regional pattern of rocks were extracted with the help of anaglyph image in combination with the ASTER FCC and LISS III FCC and PAN merge images. The figure 2.3 below shows the Anaglyph image of Kohima town derived from ASTER data.

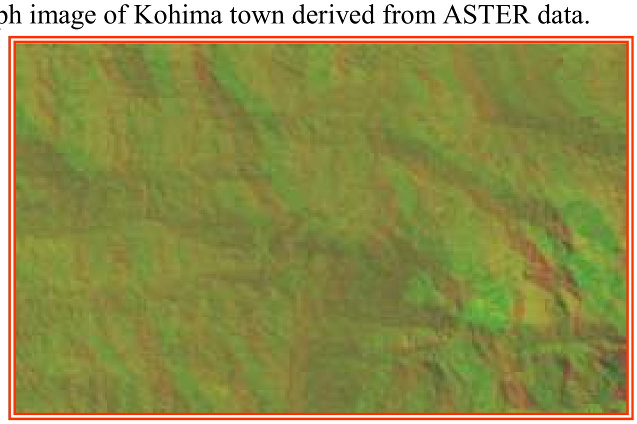


Figure 2.3: Image showing Anaglyph Image of Kohima and surrounding areas

2.3.2. Walkover Survey

Many parts of the study area are affected by landslides (mass movement), which are mostly slow moving. As a result, the buildings and infrastructure are taken away slowly down the slope without the movements being felt. Most of the individual landslides are difficult to identify within the built-up areas. The landslide area was mapped through a walkover survey, by observing the displacement on the ground, damage to buildings and the facilities, etc., within the study area. The presence and the patterns of cracks on building walls, retaining walls, drainage channels, concrete footpaths, roads, etc. were mapped to record the location of instable zones. Wherever there was a recognizable landslide, mobile GIS (Palmtop with ArcPad and GPS) was used to draw polygons indicating the extent of the slide, and at the same time, the landslide area was plotted on the base map of the study area at a scale of 1:1,000. Mass movements were categorized into: old landslide and active (sinking/subsidence and creeping). The Figure 2.4 shows the photographs of landslide mapping.

Figure 2.4: Photographs showing Landslide Mapping

2.3.3. Collection of Historical Data

During the field study elderly people were consulted to obtain information on the occurrence of historical data on damaging events, such as landslides, fires and earthquakes. This involved interviewing of local residents and also old people that are living in the study area and outside the study area, who know the area well. Common people in the study area were also interviewed to know their views and suggestions for tackling the landslide problem. For the collection of historical data, two categories of people were interviewed (Table 2.4):

1. Elderly people from the study area and outside.
2. Sample from houshold questionnaire survey.

Table 2.4: Categories of Respondents and number of sample

Sl No	Respondents	No of Respondents	Percentage of the total buildings
1	Elderly people	7	-
2	Sample through survey	105	5%

The second category of the respondents belongs to the household survey category. Random sample survey was conducted for collection of historical data and socio-economic data. However, historical information could also been collected from them (Ref. 2.5). Questions pertaining to the occurrence of hazards namely earthquake, landslide and fire were asked.

2.4. Geology and Geomorphology

The geological data of the town was not available. So with the support of the Geology Department of the Nagaland University, Kohima, geology data was collected. A total number of 21 samples were collected from different locations where the rocks are exposed. Lithological units were collected from the sample points. The dip direction and amount were collected to see the pattern of rocks. The types of rocks are also collected so as to use for analyzing the landslide hazard (Ref. Chapter 3.3 for more details). Sampling at regular interval could not be carried out due to high density of buildings and retaining walls constructed on the sides of the roads. The collection points of the samples are done mainly on the road sides. The following information was collected at each sampling point: Rock type, dip amount and direction, and slope steepness. Geomorphology map was prepared from the satellite data and digital terrain model generated from the contour map and readings from GPS.

2.5. Household Survey

As the information on the economic and demographic data are collected through a random household survey, an approximate sample of about 5% from the total buildings in the study area is physically surveyed (Ref. Table2.4). The household survey was conducted during the day time, so the majority of the respondents were housewives. No formal recording were done in the presence of the respondents due to sensitivity of social and political situation in the area. This has an advantage of not raising the curiosity of the respondents, which may prevent them from answering certain questions. Latter, the information collected were recorded in the format that is prepared for the survey. The questions also includes the information on all the hazards namely landslides, fire and earthquake.

The household survey considered the following aspects: number of household members, age of household members, and occupation of the head of household, estimated income, fuel type used for cooking, etc. For instance, the reason for collecting the information on fuel-wood used for cooking is to see whether the material is a cause of fire hazard. Likewise, information on the size of the household and age composition is important; because this will help to know how the household will respond if a disaster strikes the household. The young and the older people are unable to help themselves in times of emergencies. The economic aspects of the survey are collected to assess the economic status of the people living in that particular area. The existence of community based organizations such as women organizations, youth organizations, clubs, etc., and their activities were also asked.

2.6. Infrastructure and Facilities

Infrastructures and critical facilities, such as roads, hospitals, post offices, police stations, fire service stations, community buildings, schools, community well, etc., were mapped through the physical survey and information from local residents. Major roads in the study area were readily available in digital format by the Urban Development Department. Minor roads and streets were redrawn and updated in the existing map with the help of GPS in the field. Infrastructures and critical facilities such as community buildings, schools, medical centers, gas stations, fire service station, police stations, etc. were collected through the field survey and local knowledge. Bridges and culverts were obtained from the digital map provided by the Urban Development Department.

2.7. Elevation Data

In order to find out the slope and aspect of the study area, Survey of India (SOI) toposheet was used. Slope and aspect were generated by using Survey of India Toposheet at 1: 5,000 scales with 5 meters contour interval. This information was further used to carry out landslide hazard zonation. Digital Elevation Model was created using the points information on height collected in the field using GPS that helps in visualizing the 3D effect of different parts of the study area and also for extraction of geomorphologic features.

2.8. Population data

Kohima, being the capital and administrative head of the state of Nagaland, is attracting people from the different districts of the state. It also serves as the business centre for many of the small towns and villages in the district. The concentration of educational institutions in the town attracts students from all over the state. The population of Kohima in 1991 was 51418 persons and in 2001 it has risen to 78584 persons. The decadal population growth rate of Kohima between 1991 and 2001 is 52.83%.

The population of Kohima is shown in the Figure 2.5 along with the population projection of Kohima and the Greater Kohima (including Kohima village and Meriema village) by the Urban Development Department, Government of Nagaland, 2002. It should be noted that the population up till 2001 census in the Figure 2.5 is the population of Kohima town. The population of Kohima that has been projected by the Urban Development Department includes the two villages that are included in the Perspective Structure Plan of the Greater Kohima. The population growth rate of the town is uneven over the years. The highest rate of growth of population is recorded in the decade 1961-1971 with a rate of 197.34% per decade. This is the decade when Nagaland was given the status of a State. The decadal growth rate of Kohima over the decade is shown in Figure 2.6 since 1901.

Source: Urban Development Department, Nagaland, 2002.

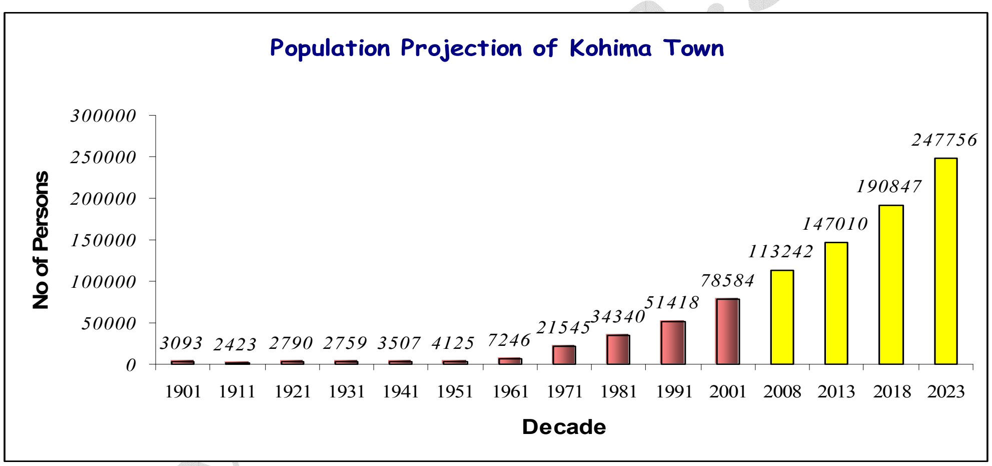


Figure 2.5: Graph showing Population Projection of Kohima Town

Source: Perspective Structure Plan of Kohima: 2003-2023, Urban Development, 2002.

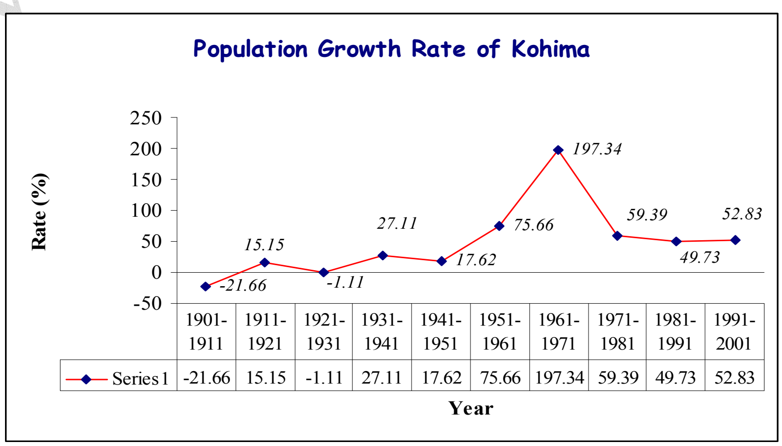


Figure 2.6: Graph showing Population Growth Rate (decadal) of Kohima Town

3. Multi-hazard Risk Assessment

A Multi –Hazard Risk Assessment is the process of estimating the impact that a natural hazards would have on the people, services, facilities, and structures in a community. The risk assessment process is important because it provides the foundation for the rest of the hazard mitigation planning process. The hazards that are analyzed in this study are earthquake, landslide and fire hazards. Individual hazard were analyzed individually and combined them to get a multi-hazard map.

3.1. Fire Hazard (Domestic)

3.1.1. Introduction

Humanity has had to live with potential dangers from fire immemorial. Fires cause fatal and serious injuries to occupants and inflict direct material damages to buildings and their household goods. Some fires cause indirect consequential losses such as loss of production and unemployment (Subramaniam, 2004). Fire is a rapid combination of fuel, heat and oxygen. All the three elements have to be present before a fire can start and continue burning. The fires can be natural or manmade. It can be caused by biotic interference either intentionally by a person’s negligence/ carelessness or deliberately and intentionally. However, fire in the urban centres is mostly manmade.

In Kohima, many of the old buildings are made of wood with Corrugated Galvanized Iron Sheets (CGI) roofing. The material of the buildings includes timber, bamboo, GCI sheets and brick. The cause of accidental fire in the town is from LPG (Liquefied Petroleum Gas) accidents, candles, and fire-wood as fuel used for cooking. Fire takes place usually during March to May when the weather is dry and windy. The place is moderately cold throughout the year – temperature ranges from 5^0 C in the winter to 30^0 C in summer. Most common the fire-place in the kitchen is used for warming in the winter. A regular supply of electricity was absent until recently, so parrafim-wax candles are mainly used for lighting the rooms. The use of LPG for cooking is increasing in the last few years. The aforesaid practices of the local people, with the construction material of buildings existing in the area are the main causes of fire.

3.1.2. Methodology

To prepare Fire Hazard Risk estimation for the study area, several steps were followed. Based on the local conditions, parameters such as building typology, building material, space between buildings, distance from the road, distance from fire service stations, etc. were taken into consideration. A total of 2229 buildings were analyzed that includes some separate kitchens, toilets, garage, etc.

3.1.2.1. Classification of Building Materials (Wall and Roofing)

Buildings materials were classified into: i) brick, ii) wooden, iii) bamboo, iv) CGI (Corrugated Iron Sheet) and, v) mixed (a combination of brick, wooden, bamboo and CGI). For fire risk assessment these building material were broadly re-classified into three major classes: i) Wooden and Bamboo, ii) Mixed (CGI, wooden, brick, bamboo) and iii) Brick and cement. In GIS, Logical Operators namely ‘OR’ and “AND’ were used to select the buildings with different materials.

3.1.2.2. Space between Buildings (Proximity)

The fact that most of the buildings in the town are constructed on steep slopes is a cause for the construction of buildings close to each other. It is assumed that the closer the buildings are, the higher the chances of fire spreading. From the digital footprint map, distance measurements were done at three levels using buffer operations. Buffers of 0.5 meter and 1.0 meter were made to assess the proximity of the buildings 1 (one) meter and 2 (two) meters margin between two buildings respectively. Three classes of buildings based on the space between buildings were made: i) spacing between buildings less than 1 meter, ii) spacing between buildings less than 2 meters and, iii) spacing between buildings that are more than 2 meters.

3.1.2.3. Proximity to the Roads:

Distance plays an important role for emergency personnel in times of crisis. The further the house is constructed away from the road, the more difficult it will be for the fire fighting service to reach the house, once it has catches fire, and the higher is the risk. In hilly terrain, the accessibility is limited because most of the built-up area is not properly connected by a road due to the difficult terrain and the closeness of the buildings. Most buildings in the study area are within a distance of 200 meters from the road. To classify the buildings located at different distances from the road, buffers of 50 meter interval were created and clipping operation was used to calculate the number of buildings that are within each 50 meters interval zone.

3.1.2.4. Proximity to Fire Station and Hazardous Buildings

Fire service plays an important role in dousing the fire. There is only one fire station in the town, which is located on the southern part of the study area. A classification with intervals of 200 meters buffer was made to assess the proximity of buildings to the fire service station. The aerial distance from the fire station to the fringes of the study area is about 1600 meters. However, the planimetric distance to the fringes of the study area is much more than the aerial distance.

There are many factors that can cause fire or explosion such as petrol pumps, gas stations, fireworks industries, etc. On 31 December 2001, a tragedy occurred in the capital of Peru, Lima due to Fire-works, in which at least 282 people died and 134 were injured in the disaster (DPM, 2002). The existence of a petrol pump and two gas stations in the area have been considered as a threat of fire hazard. It is assumed that not only fire can be triggered by these buildings, but also explosion. A buffer of 50 meter interval up to 200 meters was created to measure the extent of fire that can be caused by these buildings. More recently, on 22nd Novermber, 2004, there occurred a fire incident that ravaged a building about 500 meters away from the study area.

3.1.2.5. Fire Hazard Assessment

A Fire Hazard Risk map was prepared based on the parameters such as building material (wall material), space between neighbouring buildings, distance of the buildings from the road, and distance from fire station. Weightage was assigned to different themes depending on the severity observed in the local condition. Building material is assumed to be the most important parameter for the fire hazard. The weightage of themes ranking of the contents were taken a value from 1 (low) to 10 (High) based on the number of contents and location condition of the place. The maximum weightage of 10 is assigned to Building material considering the type of material, past experiences, prevalent in the locality. Space between buildings is given weightage value of 6 because; once a building is gutted by fire it easily spreads to the neighbouring buildings if they are very close. Distance from road is assigned a lower weightage of 4 since the distance of the buildings from the road are within a distance of 200 meters and considered to be a easily accessible existing technology of the fire service. Distance from Fire service/station is given a relatively low weightage of 2 because the service is said to be not very efficient as had been manifested by the local residents through the past experiences. The weightage and ranking of the parameters assumed are given in the following Table 3.1.1.

Table 3.1.1: Weight-age and ranking for Fire Hazard

Weightage and Rank for Fire risk				
Sl No	*Theme*	*Weightage*	*Contents*	*Rank*
1	Building Material	10	Wooden & Bamboo	10
			Mixed & CGI	5
			Brick	2
2	Space Between Buildings	6	1 m	10
			2m	6
			> 2m	4
3	Distance from Rd	4	150-200m	10
			100-150m	7
			50-100m	4
			0-50m	1
4	Distance from Fire Station	2	1400-1600m	10
			1200-1400m	9
			1000-1200m	8
			800m-1000m	7
			600-800m	5
			400-600m	3
			0-400m	1
5	Distance from Hazardous Bldg (Petrol Pump & Gas Station).	3	0-50m	10
			50-100m	6
			100-150m	4
			150-200m	2

Using ArcGIS SQL vector operations, calculation of individual buildings that are at different levels of fire hazard were calculated. The output was classified into: i) Very High, ii) High, iii) Moderate, and iv) Low. The expression used for calculation of Fire hazard:

Risk Value = 10 * (WT_Bldg) + 6 * (WT_Space) + 4 * (WT_D_Rd) + 3*(WT_Ftr) + 2 * (WT_D_FS)

Note: WT_Bldg = Rank of Building Material; WT_Space = Rank Space between Buildings; WT_D_Rd = Rank Distance from Road; WT_D_FS = Rank Distance from Fire Station; WT_Ftr= Rank Distance from Hazardous Buildings (Petrol pump & Gas Stn).

3.1.3. Building Materials (Wall and Roof)

Buildings in the study area are predominantly mixed consisting of wooden, CGI, bamboo, brick, etc. Accordingly, the buildings are classified into four major classes: i) Brick, ii) Wooden or Bamboo, iii) CGI, and iv) Mixed (brick, wooden, bamboo and CGI). The Table 3.1.2 below shows the number of buildings with different materials.

Table 3.1.2: Building Material

Building Material			
Sl No	Material	No of Bldgs	Percentage
1	Brick	689	30.91
2	Wooden/ Bamboo	235	10.54
3	CGI	374	16.78
4	Mixed	931	41.77
Total		2229	100.00

The dominant building material found in the study area is the mixed type that occupies about 41.77 % of the total buildings stock. Under mixed wall, the contents are mainly wooden and bamboo with a small component of brick and CGI. Brick is emerging as a major material used for the construction, which occupies about 31 % of the building stock at the present situation. CGI, and wooden and bamboo have a share of 16.78% and 10.54% respectively. The Figure 3.1.1 below shows the distribution of building materials in the study area.

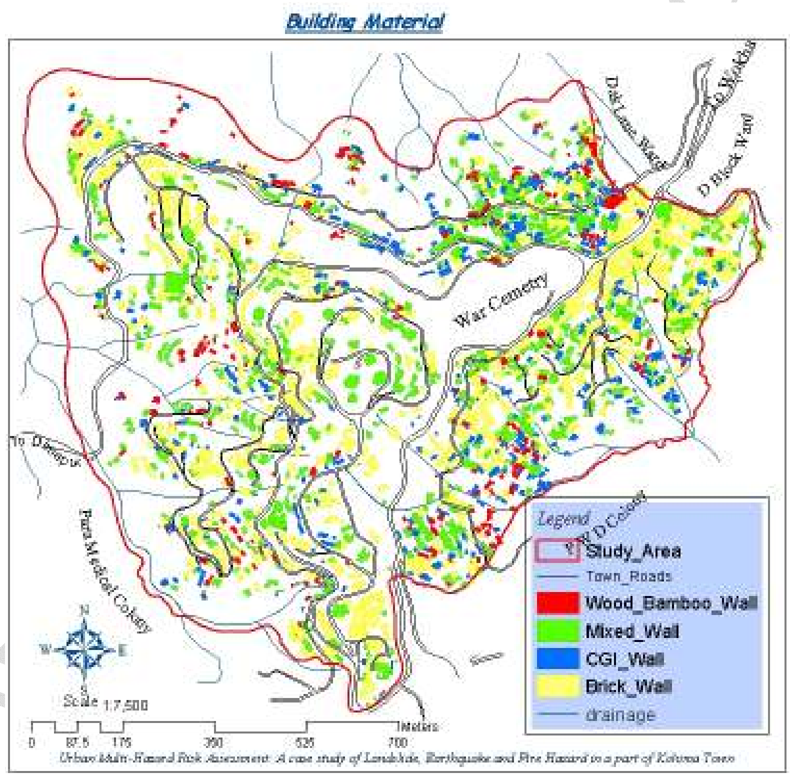


Figure 3.1.1: Map showing Building Material

3.1.4. Space between Buildings

It is found that about 77% of the buildings are built within a distance of 2 meters from its neighbour. Out of this, 1323 buildings constituting 59.35% of the total building stock are within a space of 1 meter. Only 513 buildings are built with space wider than 2 meters between neighbouring buildings. The Table 3.1.3 below shows the number of buildings falling under different class of margin. The Figure 3.1.3 below shows the spread of buildings under different categories of margin/space. The Figure 3.1.2 below shows photographs of congestions of buildings.

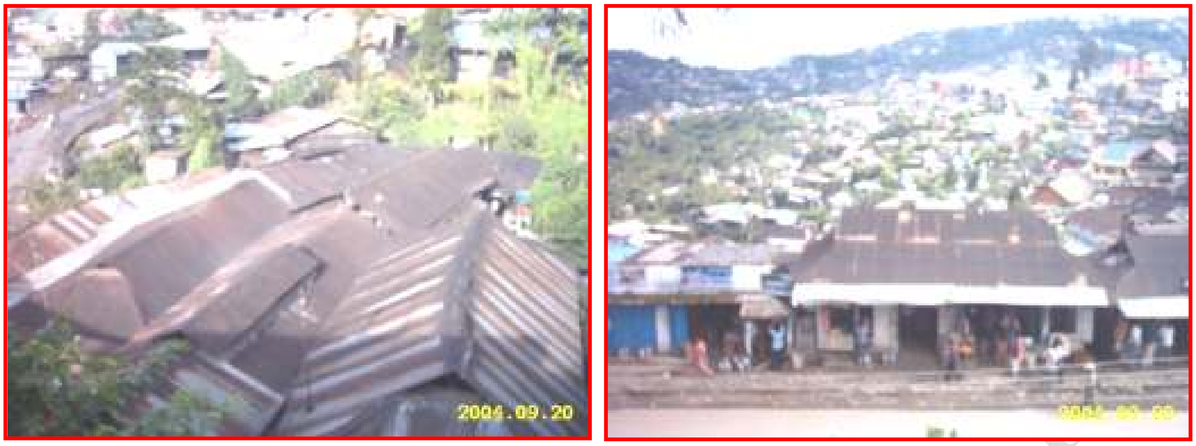


Figure 3.1.2: Photographs showing congestion of buildings

Table 3.1.3: Space between Buildings

Space Between Buildings			
Sl No	Bldg Space	No of Buildings	Percentage
1	Bldgs within 0.5m	1323	59.35
2	Bldgs within 1m	1716	76.99
3	Bldgs beyond 1m	513	23.01

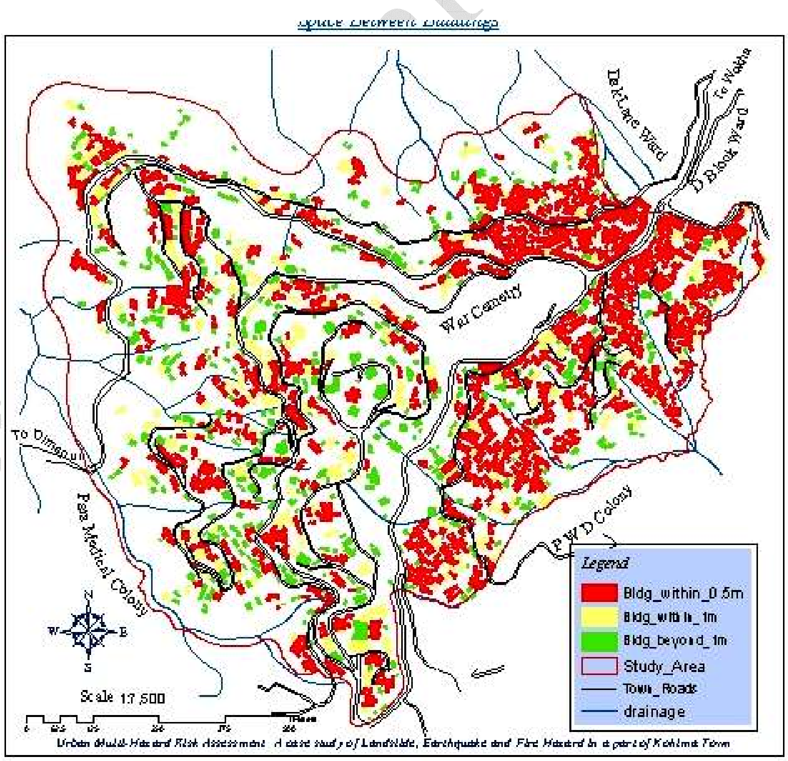


Figure 3.1.3: Map showing Space between Buildings

3.1.5. Proximity to Road

It is found that a major building density is higher on the roadside (Table 3.1.4). With a distance of 50 meters from the road, there are 1914 buildings (84.24%), followed by 307 buildings (13.51%) between 50 to 100 meters. The two outer intervals between 100 to 150 meters and 150 to 200 meters have 48 (2.11%) and 3 (0.13%) buildings respectively**.**

Table 3.1.4: Distance from Road

Distance from Road			
Sl No	Distance from Road	No of Bldg	Percentage
1	Within 50m	1914	84.24
2	Between 50-100m	307	13.51
3	Between 100-150m	48	2.11
4	Between 150-200m	3	0.13

The graphical representation of the spread of buildings in different distance (buffering zones) interval is shown in the Figure 3.1.4 below.

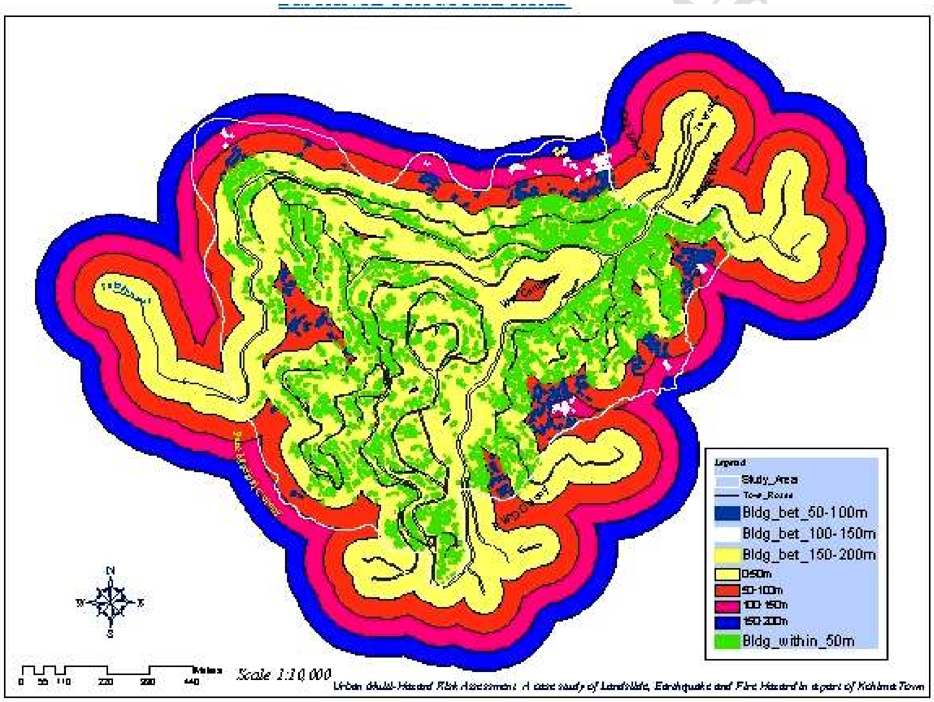


Figure 3.1.4: Map showing Distance from Road

3.1.6. Proximity to Fire Station and Fire hazardous buildings

The aerial distance that the fire brigade has to travel to the extreme periphery of the study area is about 1600 meters. The actual distance to travel by the fire brigade is much more than the aerial distance since the roads are not straight. The Table 3.1.5 below shows the aerial distance from the Fire Brigade station different parts of the study area.

Table 3.1.5: Distance from Fire Station

Distance from Fire Station			
Sl No	Buildings	No of Bldgs	Percentage
1	Bldg_0_400m	39	1.70
2	Bldg_400_600m	191	8.35
3	Bldg_600_800m	347	15.17
4	Bldg_800_1000m	498	21.77
5	Bldg_1000_1200m	560	24.48
6	Bldg_1200_1400m	554	24.21
7	Bldg_1400_1600m	99	4.33

The Figure above reveals that 653 buildings are located at 1200 to 1600 meters from the Fire Service Station and 560 (25%), 498 (22%), 347 (15%) buildings within 1000 to 1200 meters, 800 to 1000 and 600 to 800 meters respectively from the Fire Service Station. The percentage given in the brackets indicates the percentage of the total building stock. However, the road condition and the traffic congestion is not so conducive for the fire service to travel.

There is one Petrol Pump and one Gas Station (LPG) distribution station within the study area and another LPG distribution station located close by. These are the three potential centres that can cause fire and even explosion in the area. About 37 buildings are located within a radius of 50 meters from these triggering points. Within a distance of 50 to 100 meters there are 113 buildings and from 100 to 150 meters and 150 to 200 meters, there are 166 buildings and 229 buildings indicated in the Table 3.1.5 below. The buffers in the figure below show the number of buildings that are located in different radius of hazardous buildings potential to trigger fire and explosion. The proximity of the buildings to fire stations and hazardous buildings are shown in Figure 3.1.5.

Table 3.1.5: Distance from Hazardous Buildings

Distance from Hazardous Buildings		
Sl No	Distance	No of Bldgs
1	Bldg0_50m	37
2	Bldg50_100m	113
3	Bldg100_150m	166
4	Bldg150_200m	229

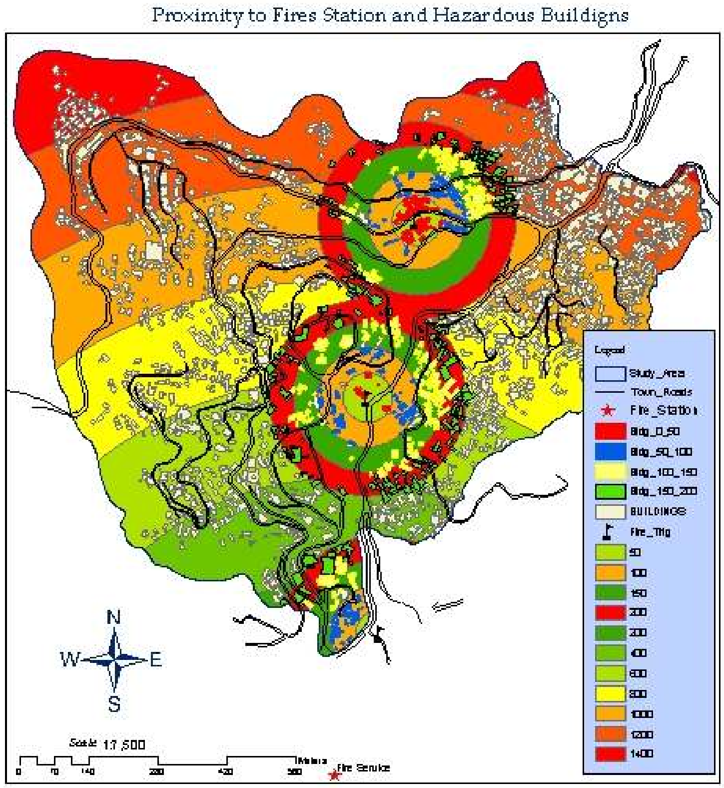


Figure 3.1.5: Map showing Proximity to Fire Station and Hazardous Buildings

3.1.7. Fire Hazard

Fire hazard was calculated based on assumed weightage (based on local condition) on building material, space between buildings, distance from the road and distance from the fire station and the distance from the hazardous buildings (Petrol Pump and Gas Station). The Table 3.1.6 shows the number of buildings under different categories of risk.

Table 3.1.6: Fire Hazard Classes

Fire Hazard Categories			
Sl No	*Category*	*No of Bldgs*	*Percentage (%)*
1	Very High Fire Hazard	107	4.80
2	High Fire Hazard	783	35.13
3	Moderate Hazard	951	42.66
4	Low Fire Hazard	388	17.41
Total		2229	100.00

There are 107 buildings falling under very high fire hazard class with a share of 4.80% of the total buildings stock. The numbers of buildings that are under High fire hazard class are 783, which is 35.13% of the total buildings. These two categories, i.e., Very High Fire Hazard and High Hazard constitute about 40% of the total building stock. The other two classes namely, moderate and Low constitutes about 60% of the total buildings stock with 951 buildings with Moderate and 388 buildings under low hazard zone. The following figure (Figure 3.1.6) shows the spatial distribution of buildings under different fire hazard zones.

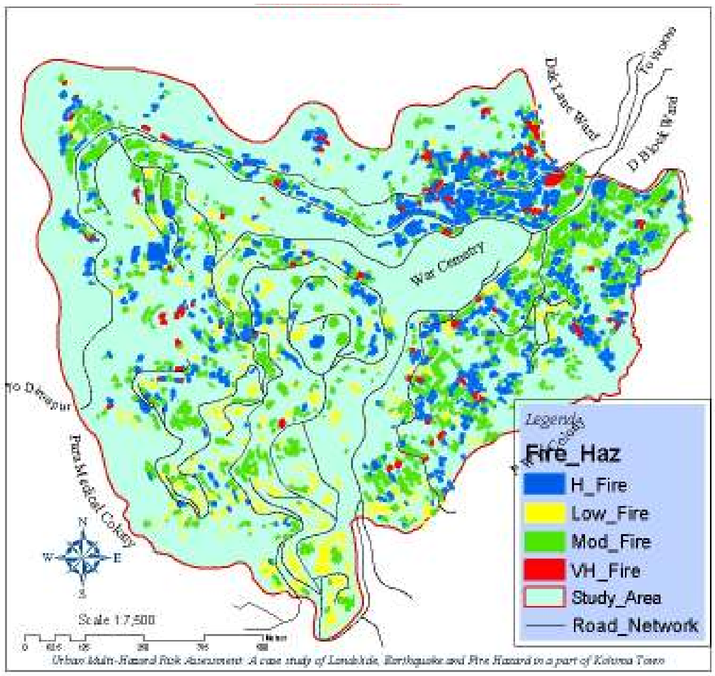


Figure 3.1.6: Map showing Fire Hazard Classes

3.2. Earthquake Loss Estimation

3.2.1. Introduction

Earthquakes are one of the most unpredictable natural phenomenon and most destructive and cannot be prevented. For example, the Spitak destructive earthquake measuring M=7.0 occurred in December, 1988 in Armenia has caused 25000 death, over 20,000 injuries, 515000 homeless (Balassanian, 2000). More recently, on 16th January 2004, an earthquake flattened the ancient Silk Road City of Barn that killed 41000 people (DPM, 2004). It is therefore, important to study the expected damage that may be caused in a city by an earthquake. The earthquake loss estimation provides local, state and regional officials with a state-of-the-art decision support tool for estimating potential losses from scenario earthquakes. This forecasting capability will enable users to anticipate the consequences of future earthquakes and to develop plans and strategies for reducing risk (HAZUS, 1999). Recently, on 26th Devember, 2004, an earthquake induced tsunami rocked the South Eastern Asian region with its epicenter in Sumatra, killing more 1.7 million.

3.2.2. Location of Study Area in the Seismic Zone

Northeast India is seismically one of the six most active regions of the world. It is placed in zone 5, the highest zone, of the seismic zonation map of India (Figure 3.2.1). The region experienced 18 large earthquakes (M≥7) during the last hundred years including the earthquakes of Shillong (1897, M≥7) and Assam-Tibet border (1950, M=8.7), (*Tiwari)*. According to the USGSS, there were three earthquakes that had its epicentres near Kohima. One is at about 20 km towards the eastern parts of Kohima in Phek district with magnitude of 4.5. The second is about 41 km towards the south with a magnitude of 5.7, and the third is about 58 kilometres from Kohima in the east with a magnitude of 5.4. However, there was no casualty or loss to property reported. According to Tiwari of Mizoram University, an earthquake occurred in Nagaland in1932 with a magnitude of 7.0 that caused destruction to property.

Source: Revenue (Scarcity Department), Govt., of Uttar Pradesh.

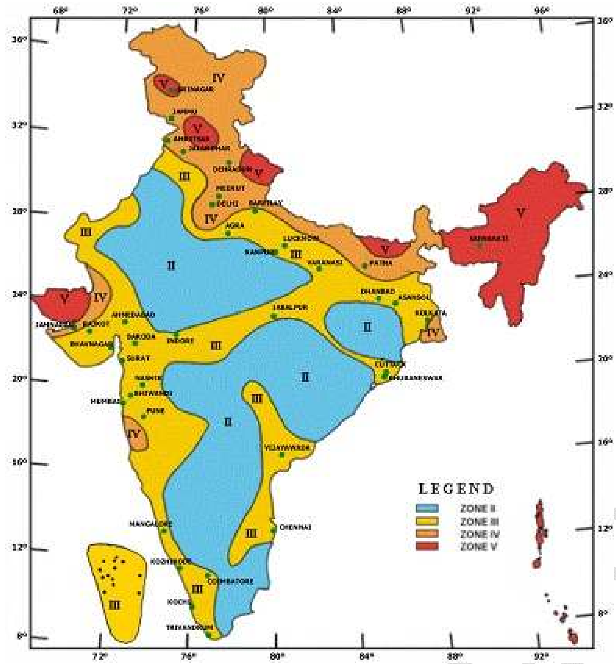


Figure 3.2.1: Map showing Seismic Zones of India

3.2.3. Methodology

Earthquake at intensities VII, VIII and IX on the Modified Mercalli scale were taken for the assessment of expected building damage. The standard formulated by A. S. Arya: seismic intensity versus expected damage to buildings (Table 3.2.1) based on the damage scenario in Kangra region of Himachal Pradesh (Arya, 1990) was adopted for this case study. The seismic intensity versus expected damage was designed for a quick assessment of building damage in the Indian subcontinent. The table 3.2.1 below describes the expected damage at intensity VII, VIII and IX that has been used for the analysis.

Table 3.2.1: Seismic Intensity Vs Damage to Buildings

Source: A. S. Arya

Building type	Intensity VII	Intensity VIII	Intensity IX
Mud and Adobe houses, random-stone constructions.	*Most have large deep cracks. Few suffer partial collapse.	Most suffer partial collapse.	Most show partial collapse. Few completely collapse.
Ordinary brick buildings, building with large block and prefab. type, poor half timbered houses.	Many have small cracks in walls.	Most have large and deep cracks.	Many show partial collapse. Few completely collapse.
Reinforced buildings, well built wooden buildings.	Many have fine plaster cracks.	Most may have felt cracks in walls. Few may have deep cracks.	Many may have large deep cracks. Few may have partial collapses.

*Most= about 75%, Many = about 50%, Few = about 5%

Buildings were classified according to structure, material, cracks and displacement/ tilt on the roof, roof material, proximity of the buildings to each other, and the height of the buildings. The building structure is categorized into three categories based on the existing conditions in the field with the consultation of local engineers and architects. The three categories of buildings are: i) Reinforced Concrete Cement (RCC), ii) Load Bearing (mostly mixed material and brick masonry) and iii) Conventional Wooden structures. Cracks were prominently seen in many of the brick walls and displacement/tilt seen in wooden buildings due to the mass movement (landslide) prevalent in parts of the area. It is assumed that buildings that have cracks on the wall, retaining/protection walls will have less resistance to earthquake ground shaking.

3.2.4. Building Weightage and Ranking

In consultation with the geologists, engineers and urban planners, the weightage and ranking were assigned, keeping in mind the buildings in the locality, and seismic intensity vs. damage to buildings formulated by Arya (Table 3.2.1): weightage and ranking were assigned ranging from 1 (low) to 10 (High). The following table shows the weightage and rankings (Table 3.2.2) that has been assigned. Structure of the building is given the highest value (10) of ranking because; the weight of the building rests mainly on the structure. It is also assumed that buildings with cracks on the wall, protection and retaining walls, drainages, etc. are more likely to suffer damage than that of the intact buildings. Therefore, it is given the weightage value 8. Since there is no PGA map available, the response of the buildings to hazard could not be known. Therefore, it is assumed that the taller the building, the more vulnerable the building is to the hazard. Proximity of the buildings is given a weightage value of 6. The buildings are constructed close to each other, and there are cases where cracks on the retaining wall. So it is assumed that tensional effect of a building may cause damage to the neighbouring building. Also, once the retaining walls fails, the neighbouring building will also be affected. Roof material is given the least weightage of 2, because, dominant roof material is CGI which has less weight and flexible, and most of the RCC buildings with RC roofs are recently constructed and is considered to be strong to withstand earthquake to a certain extent. A typical mixed building in the study area with wooden, bamboo and brick masonry having cracks on the protection wall are shown in Figure 3.2.2.

Figure 3.2.2: Photograph showing typical Mixed Buildings with cracks on Protection/ Retaining Walls

Table 3.2.2: Weight-age and ranking for Building Damage Assessment

Sl No	Rank	Theme		Class	Weightage Intensity VII	Weightage Intensity VIII	Weightage Intensity IX
1	10	Structure	1	Reinforced Concrete/ FS	3	6	9
			2	Load Bearing	1	3	6
			3	Wooden Structure	1	2	3
2	8	Cracks and Displacement	1	Wall	3	9	10
			2	Retaining wall	3	6	9
			3	Displacement/Tilt	2	4	6
			4	No Cracks	1	2	3
3	6	No of Storey	1	7	3	6	9
			2	5			
			3	4	2	4	6
			4	3			
			5	2	1	2	3
			7	1			
4	5	Proximity of buildings	1	Brick wall within 0.5m	3	6	9
			2	Brick wall within 1.0m	2	4	6
			3	Brick wall beyond 1.0m.	1	2	3
			4	Other buildings	1	1	1
5	2	Roof material	1	Concrete Cement	3	6	9

3.2.5. Calculation of Damage Assessment

The values, which express qualitatively the vulnerability of the buildings to damage at different earthquake intensities (VII, VIII, & IX) were calculated using Spatial query operations. The query statement used for the calculation of buildings damage is given below:

Intensity VII=[10(Str_VII) + 8 * (CR_VII) + 6 * (Stor_VII) + 5 * (Prox_VII) + 2 * (Roof_VII)]*

Intensity VIII= [10(Str_VIII) + 8 * (CR_VIII) + 6 * (Stor_VIII) + 5 * (Prox_VIII) + 2 * (Roof_VIII)]*

Intensity IX= [10(Str_IX) + 8 * (CR_IX) + 6 * (Stor_IX) + 5 * (Prox_IX) + 2 * (Roof_IX)]*

Note: Str= Structure, CR=Cracks and displacement/ tilt, Stor=No of Stories, Prox= Proximity of buildings, Roof= Roof material.

3.2.6. Classification of damage

The value of the damage based on the parameters mentioned in table 3.2.2 at different intensity on the Modified Mercalli i.e., Intensity VII, VIII and IX were classified into six groups based on the standard given by A. S. Arya: i) Complete Collapse, ii) Partial Collapse, ii) Large Cracks, iii) Small Cracks, iv) Fine Cracks and, vi) No damage. The Mud and Adobe houses, random-stone constructions in Aray's standard (Ref. Table 3.2.1) are not prevalent in the study area. While calculating the damage the buildings were broadly categorized into two: i) Reinforced Concrete with Wooden and Bamboo and ii) Ordinary brick buildings, buildings with load bearing structure (in this case Mixed wall). The RCC and all wooden and bamboo buildings were put into one class because of the information collected on wooden and bamboo buildings are not sufficient enough to separate the condition of the buildings into well built and poor construction.

3.2.7. Structure of Buildings

Load bearing structure is the dominant structure in the study area, which occupies1212 buildings, which is 54.37% of the total building stock. Most of the old buildings are conventional wooden structures, which amount to 609, which is 27.32% of the total buildings stock. There are 408 (18.30%), Reinforced Concrete buildings in the study area. The following Table (Table 3.2.3) and figure below (Figure 3.2.3) shows the distribution of structures in the study area.

Table 3.2.3: Structure of Buildings

Structure of Buildings			
Sl No	***Structure***	***No of Bldg***	***Percentage***
1	Reinforced Concrete	408	18.30
2	Load Bearing	1212	54.37
3	Wooden	609	27.32
Total		2229	100

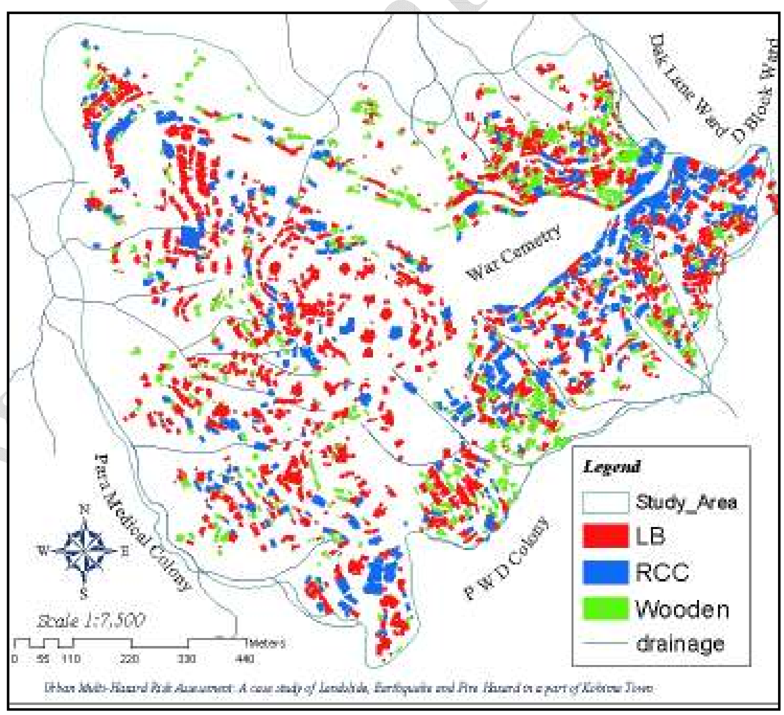


Figure 3.2.3: Map Showing Structure of Buildings

3.2.8. Cracks, displacements and tilts

There are a number of buildings which have visible cracks on the walls, retaining walls, drainages, footpaths, and tilting of roof on the wooden buildings caused by mass movement (landslide). It is assumed that these buildings will have less resistance to ground shaking than that of the other buildings. As is evident in the table below those 273 buildings, which is about 12.25% to the total buildings have tilted roofs or displaced walls. The number of brick walled buildings, which have cracks, is 51 (2.29%) in number followed by cracks on the wall and 13 (1%) of the buildings have cracks on retaining walls. The Table 3.2.4 below shows the status of buildings in the form of cracks and displacements.

Table 3.2.4: Cracks and Displacement/ Tilts

Cracks (wall, retaining wall, footpath, drainage)			
Sl No	Status	No of Bldg	Percentage
1	Displacement/ Tilt	273	12.25
2	Drainage	5	0.22
3	Foot Path	4	0.18
4	Retaining Wall	13	0.58
5	Wall	51	2.29
6	No Cracks	1883	84.48
	Total	2229	100.00

The ward severely affected by cracks and displacement is the New Market Ward, and is also seen above the Paramedical – Hospital landslide in the Hospital Colony Ward. The field visit to this part of the area shows that houses are built on a sinking area or a slow moving landslide, which may be accelerated in case of an earthquake. The buildings indicated with red colour in Figure 3.2.4 are buildings that are on active landslide that is vulnerable to earthquake damage.

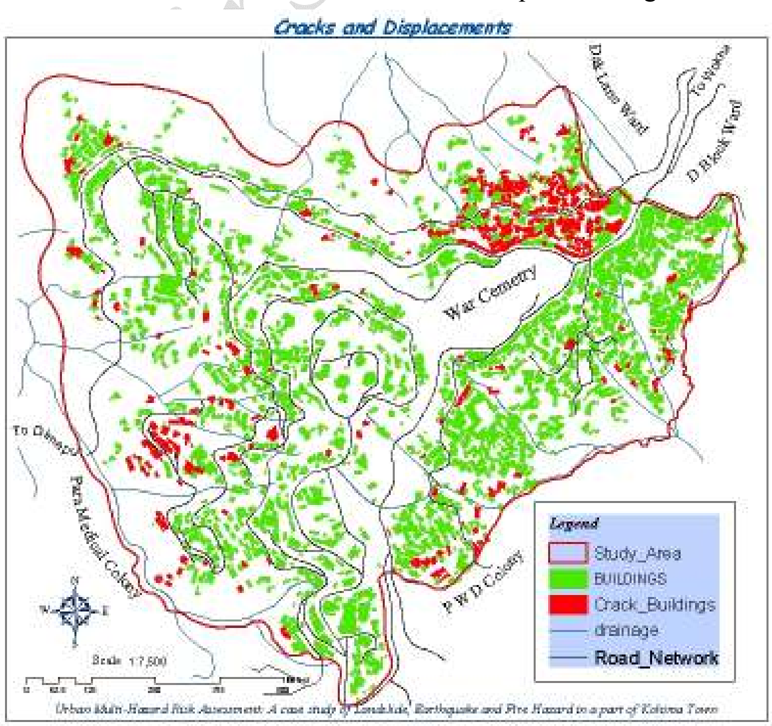


Figure 3.2.4: Map Showing Cracks and Displacements/ Tilts on the roofs

3.2.9. Building Height

It is assumed that the taller buildings is more vulnerable to ground shaking. The tallest building in the study area is a 7 (seven) storied building. One-storied buildings occupy about 70% of the building stock with 1544 buildings. There are only one 3 five storied buildings and 27 buildings with 4 stories. A total of 561 buildings which 25.18% of the total building stock, and 92 buildings, which 4.13% of the total buildings are 2 storied and 3 storied buildings respectively (Ref. Table 3.2.5). The Figure 3.2.5 shows the status of building height in 3D (exaggerated building blocks on DEM surface), depicting the construction of the buildings on the undulating hill slope.

Table 3.2.5: Number of Stories

Number of Floors/ storey			
Sl No	Stories	No of Bldg	Percentage
1	1 Storey	1544	69.30
2	2 Stories	561	25.18
3	3 Stories	92	4.13
4	4 Stories	27	1.21
5	5 Stories	3	0.13
6	7 Stories	1	0.04

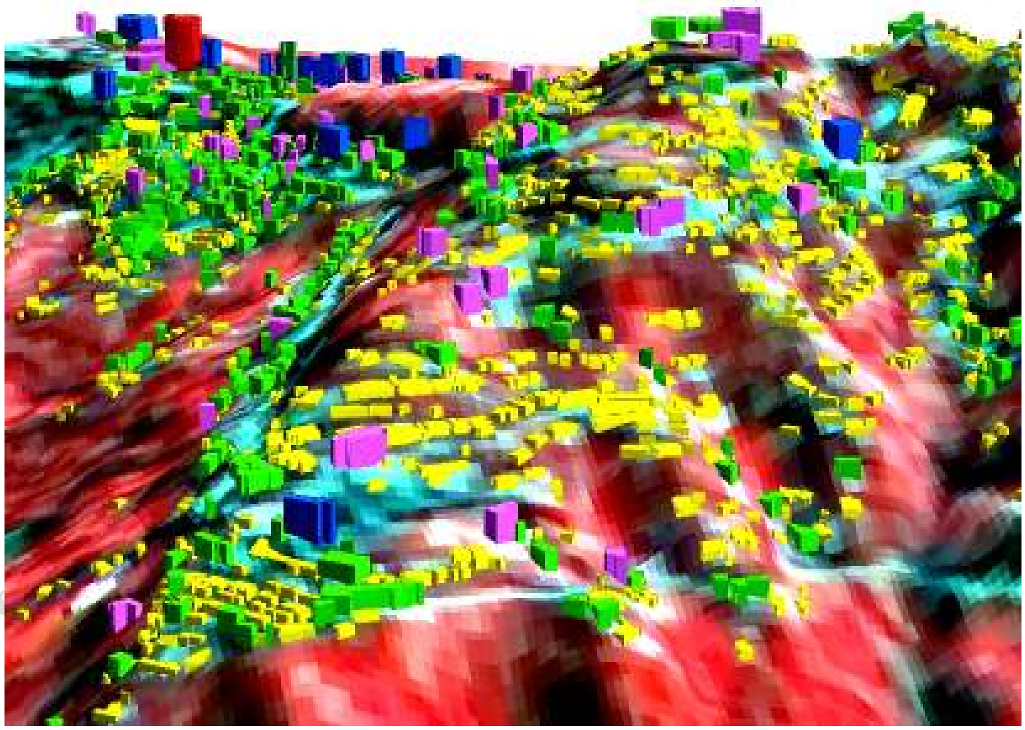


Figure 3.2.5: Exaggerated Buildings draped on DEM (a part of the study area)

3.2.10. Building damage at different intensities

The expected number of damaged buildings at different intensities is given below. The structure, type of building, construction material, number of stories, etc., with respect to different intensity scales are presented separately in Chapter IV. The calculated hazard value of the buildings from the weightage and weights mentioned in section 3.2.4 were used in combination with Arya's Seismic Intensity Vs. Damage to Buildings standard (Ref Table 3.2.4). The standard specifies the percentage of buildings belonging to different classes that will be damaged at different intensity. Therefore, the percentage of buildings at different classes of buildings was calculated. For instance, many of the reinforced buildings and well built buildings will have fine plaster cracks in the VII intensity. Damage in this case is calculated taking 50% of the buildings on the higher range. Similarly damage at intensity VIII and IX were calculated.

3.2.10.1. Probable Damage Scenario Earthquake at Intensity VII

At intensity VII, 941 buildings, i.e., 42.44% of the total building stock (load bearing structures) are expected to suffer from small cracks on the walls. A total of 38 cement plastered buildings, which is 1.70% of the total buildings, will manifest fine cracks. The rest of the buildings 1245 that is 55.85% of the buildings stock belonging to the wooden/bamboo and reinforced structure will have no visible damage. The Table 3.2.6 and Figure 3.2.6 shows the number and the distribution of the numbers of buildings and percentages that will suffer damage at Intensity VII.

Table 3.2.6: Expected Damage at Intensity VII

Expected Damage at Intensity VII			
Sl No	Damage	No of Bldgs	Percentage
1	Small Cracks (LB)	946	42.44
2	Fine Plaster Cracks (RC_W)	38	1.70
3	No Damage	1245	55.85

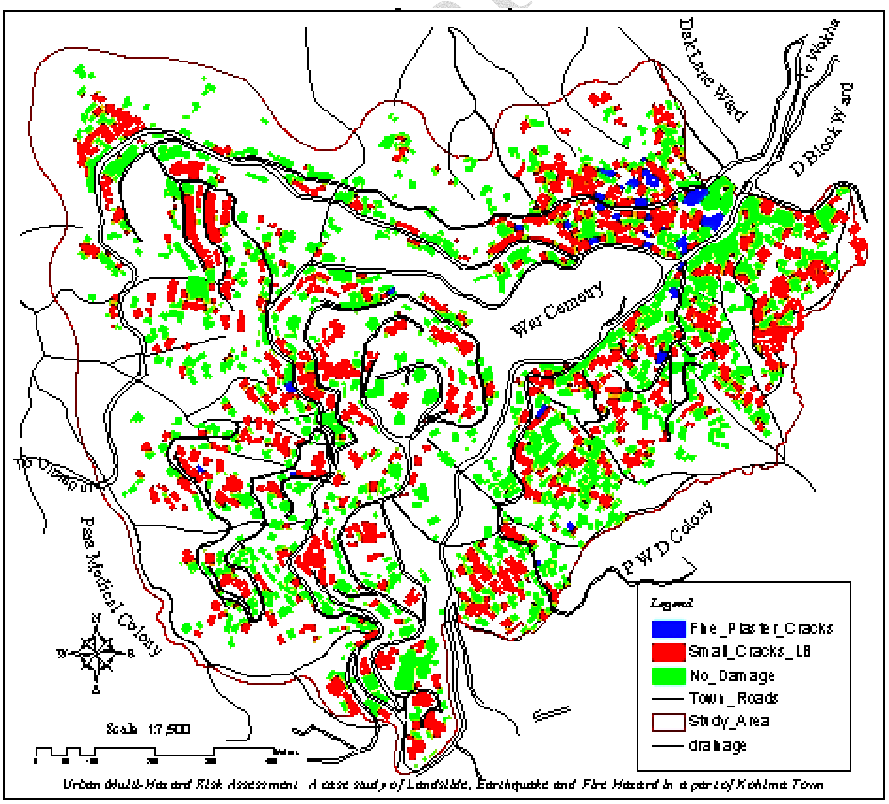


Figure 3.2.6: Map Showing Expected Damage at Intensity VII

3.2.10.2. Probable Damage Scenario Earthquake at Intensity VIII

At intensity VIII, 1212 buildings which is about 54.37% of the total building stock of load bearing structure will suffer large cracks, followed by 141 buildings i.e., 6.33% of the total buildings will have small cracks on the RCC wall. A total of 876 buildings which is 39.30% of the total buildings, mainly the wooden and RCC structures will have no visible damage (Refer Table 3.2.7). The Figure 3.2.7 shows the distribution of damage at intensity VIII.

Table 3.2.7: Expected Damage at Intensity VIII

Damage at Intensity VIII			
Sl No	Damage	No of Bldgs	Percentage
1	Large Cracks (LB)	1212	54.37
2	Small Cracks (RC/W)	141	6.33
3	No Damage	876	39.30

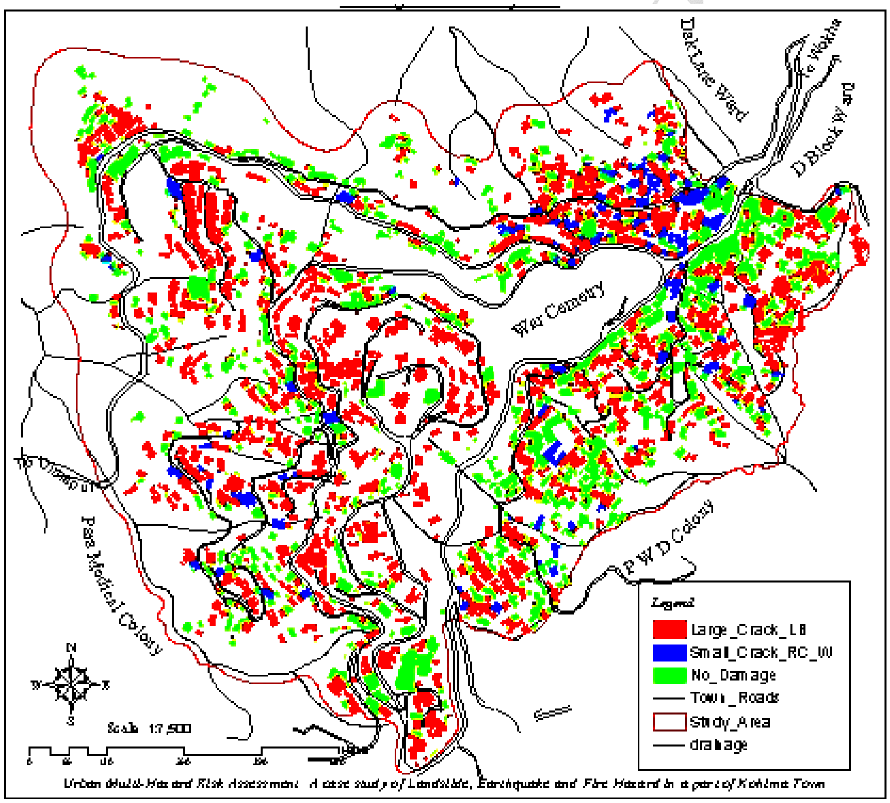


Figure 3.2.7: Map Showing Expected Damage at Intensity VIII

3.2.10.3. Probable Damage Scenario Earthquake at Intensity IX

At intensity IX, only 2 buildings will have complete collapse. These two buildings are 3 storied buildings, located in the New Market Ward with load bearing structure and have cracks on the walls. A total of 520 buildings, which is 22.69% of the total building stock, may be safe with no cracks on the wall. A total of 730 Load bearing buildings, which is 31.79% of the total building stock, will partially collapse. Large cracks on RCC and wooden buildings constitute 1.79% of the total buildings. Small cracks will be visible on 482 buildings which constitute 21% of the buildings and small cracks on RCC will be visible on 521 buildings, which is 22.69% of the total building stock (Ref. Table 3.2.8 and Figure 3.2.8).

Table 3.2.8: Expected Damage at Intensity IX

Probable Damage Scenario Earthquake of Intensity IX			
Sl No	Damage	No of Buildings	Percentage
1	Complete Collapse (LB)	2	0.09
2	Partial Collapse (LB)	730	31.79
3	Large Cracks (RC/W)	41	1.79
4	Small Cracks (LB)	482	20.99
5	Small Cracks (RC/W)	521	22.69
6	No Damage	520	22.65

Where:

LB=Load Bearing

RC/W= Reinforced Concrete Cement/ Wooden

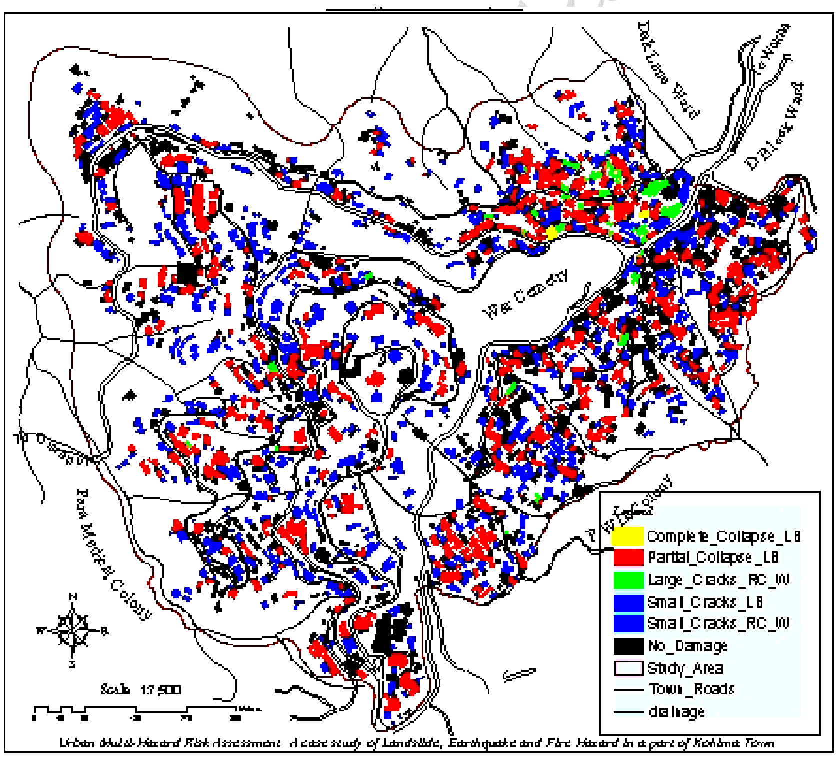


Figure 3.2.8: Map Showing Expected Damage at Intensity IX

3.3. Landslide Hazard analysis

3.3.1. Introduction

The term "Landslide" comprises almost all varieties of mass movements on slopes, including some, such as rock-fall, topples, and debris flows, that involve little or no true sliding (Varnes, 1984). They can be triggered by variety of external stimuli, such as intense rainfall, earthquake shaking, water level change, storm waves or rapid stream erosion that cause a rapid increase in shear stress or decrease in shear strength of slope-forming materials (Dai, at., al. 2000). Landsides are prevalent mostly on steep terrains. The most reliable way to prevent landslide-induced casualties and economic losses in a hilly town is to avoid building constructions such as buildings in the vicinity of steep terrain.

3.3.2. Landslide hazard Assessment

Landslide risk assessment is the integration of the hazard and vulnerability assessments, in order to defensibly predict the likely number and severity of injuries, magnitude and costs, and duration and degree of loss of seismic due to slope failure (Roberds, et. al., 1997). According to International Union of Geological Sciences (IUGS, 1997), there are two types of landslides risk analysis widely used: Qualitative and quantitative. Qualitative landslide analysis involves acquiring knowledge of hazards, the elements at risk and their vulnerabilities (which may be expressed verbally, or ranked). The quantitative risk analysis of slopes and landslides is a multidisciplinary endeavour, consisting of the following activities: hazard analysis – analysis of the probability and characterization of the potential landslides; identification of the elements at risk, i.e., their number and characteristics (including their temporal variability and vulnerability to the hazard; analysis of the vulnerability of the elements at risk; calculation of the risk from the hazard, elements at risk and vulnerability of the elements at risk.

3.3.3. Method Adopted

For landslide hazard assessment various types of methods exist, which can be classified into various groups (Soeters and Van Westen, 1996): landslide inventory analysis, heuristic methods, statistical methods and deterministic methods. The method adopted for landslide hazard in this study is a bivariate statistical method, namely the Information Value method (Yin and Yan, 1988). The information value method is calculated using the following formula (Van Westen, 1993):

Prior Probability = nslide/nmap

Information Value = log [(nsclass/nclass)/Prior Probability]

Where:

nmap= Total number of pixels in the map

nslide=Total number of landslide pixels

nclass= Number of pixels in each class.

nsclass= Number of pixels containing slide

The figure 3.3.1 below shows the flow of the methodology adopted for landslide hazard analysis.

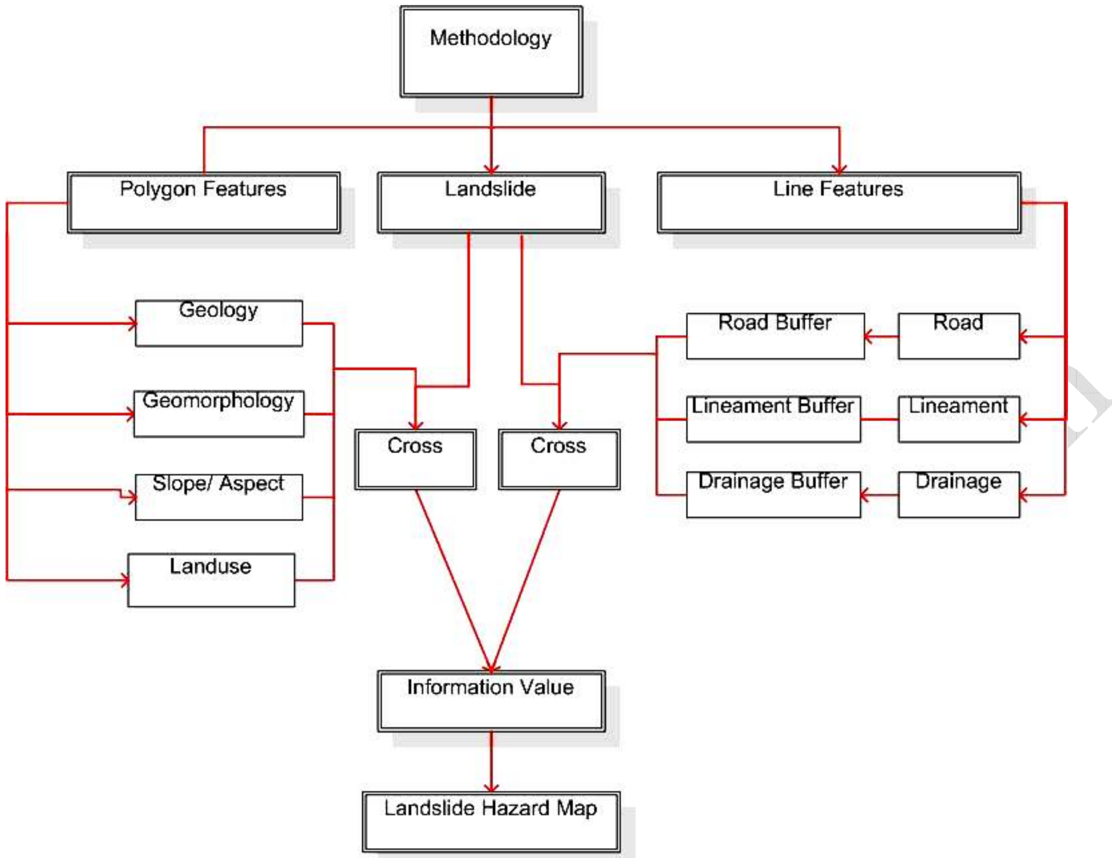


Figure 3.3.1: Flow chart showing methodology for Landslide hazard zonation

The layers or thematic maps that were used for the landslide hazard analysis are listed below:

i. Landuse
ii. Geology
iii. Geomorphology
iv. Slope Amount
v. Aspect
vi. Faults
vii. Lineaments
viii. Drainage Density
ix. Distance to Roads
x. Landslide Incidence

To calculate the information value, each class of the thematic map is crossed with the landslide map (map x) with the active landslides. Cross tables were created which contain the pixel information value for the various classes of the individual layers. After crossing the landslide with all the individual layers, all the final maps were integrated together to derive a landslide hazard map. The equation used for the final map is:

Landslide Hazard Map = Slide_Geol + Slide_Geom + Slide_Slope + Slide_Asp + Slide_Linea + Slide_Faul + Slide_L_Use + Slide_Drain + Slide_Rd

Where: *Slide_Geol = Landlide and Geology Cross Weighted Map*

Slide_Geom = Landslide and Geomorphology Cross Weighted Map

Slide_Slope = Landslide and Slope Cross Weighted Map

Slide_Asp = Landslide and Aspect Cross Weighted Map

Slide_Linea = Landslide and Lineament Cross Weighted Map

Slide_Fault = Landslide and Fault Cross Weighted Map

Slide_Slide_L_Use = Landslide and Landuse Cross Weighted Map

Slide_Drain= Landslide and Drainage Density Cross Weighted Map

Slide_Rd = Landslide and Road Cross Weighted Map

The output map resulted from the above formula contained values ranging from -0.56 to 3.22. Three classes of landslide hazard zonation were made from these given value: High hazard (2.5 to 3.22), Moderate (1 to 2.5) and, Low (- 0.56 to +1). The area falling under each category was calculated and the number of buildings falling under each class was also calculated using spatial query operations. The final landslide hazard map (Figure 3.3.6) generated by integrating the above thematic layers, using Information Value method, shows three hazard classes.

3.3.4. Landuse

The area is dominantly covered with built-up area. The landuse of the study area is classified broadly into six classes (See Table 3.3.1). Among the landuse classes, the share of built up is 66.51 per cent of the total study area constituting about 0.68 sq km, which is mostly residential. Patches of scrubs, agriculture (gardens), and degraded vegetation patches are found on the dormant landslide areas and steep slopes. Vegetation occupies about 7% of the total landuse followed by an area of 0.049 sq km (4.76%) road coverage. There is also a park (War Cemetery), which occupies about 3% of the area. Table 3.3.1 and Figure 3.3.2 shows the distribution of landuse in different classes in tabulation map respectively.

Table 3.3.1: Landuse/ Land cover

Landuse/ Land cover				
Sl No	Landuse Class	Area (sq m)	Area (sq km)	Percentage
1	Built up	685972.13	0.686	66.51
2	Mixed (Agri, Veg, Scrub)	184179.92	0.184	17.86
3	Park	32934.32	0.033	3.19
4	Scrub	6247.27	0.006	0.61
5	Vegetation	72967.23	0.073	7.07
6	Road	49090.13	0.049	4.76
	Total	1031391.00	1.031	100.00

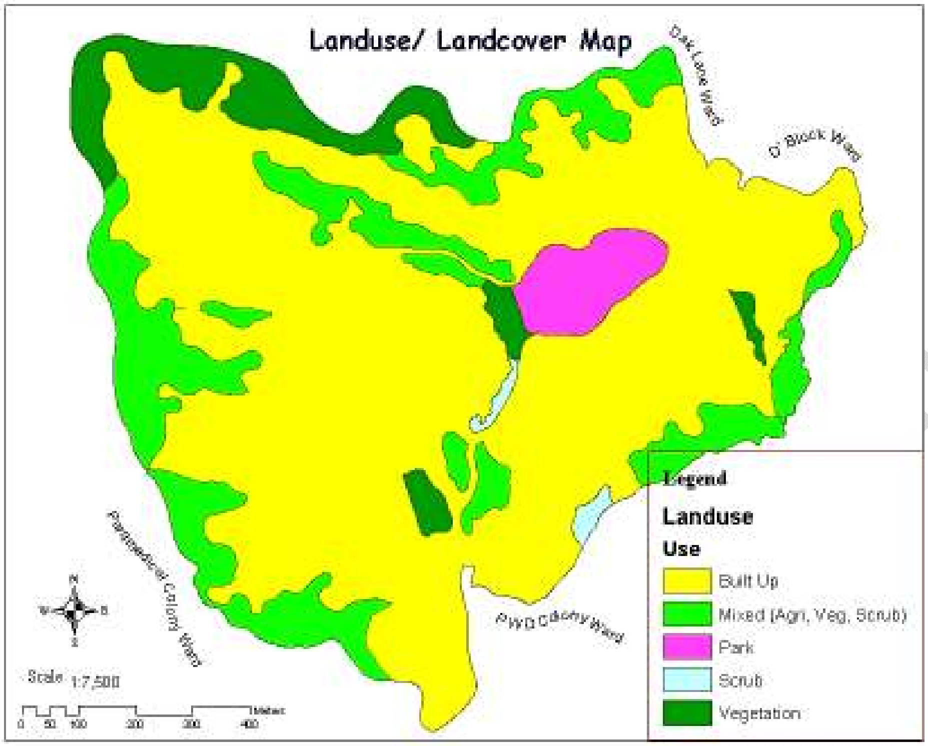


Figure 3.3.2: Map Showing Landuse/ Land cover

3.3.5. Landslides

Landslide is the main hazard, crippling Kohima town every year during rainy season. There are a number of occurrences of small patches of landslide everywhere specially along the drainage, which gets reactivated during rains. There is a marked variation in the size of landslide ranging from 3x5 m (is smallest) approximately to 55283 sq m (biggest). The smallest landslide that has been mapped is a slide with an area of 6136 sq m (78.33m x 78.33 m). It is difficult to map the entire small landslide covering an area less than 49 sq m (7x7) on a scale of 1: 7500 (the scale used for present study).

The intensity of these small landslides is difficult to quantify. Most of the Landslide movements in Kohima is slow. There are many buildings that have been affected by landslide every year. Some of the types of damages that are inflicted to the buildings and small landslides triggered by rain are shown in Figure 3.3.3 and Figure 3.3.4 respectively.

Most of the slides in the study area have been identified/ delineated by field survey. On the basis of their activity, these slides have further been divided as active, old and dormant. The active landslides are those slides that gets activated almost every year or that occurs in the recent past. There are many slides on the sides of the natural drainages that get activated every year. Most of the landslides in the study area are slow and creeping in nature. In some cases, the movement of the slides is in terms of centimetres per year. The dormant slides are those old slides that are likely to be reactivated in the near future. Some of the types of damages that are inflicted to the buildings and small landslides triggered by rain are shown in Figure 3.3.3 and Figure 3.3.4 respectively.

Figure 3.3.3: Photographs showing Buildings affected by Creeping Slides

Figure 3.3.4: Photographs showing Landslides in the study area

On the basis of field survey two major landslides were identified that had occurred during the past. One is in the north-eastern part of the study area below T. C. P. Gate - at the boundary between New Market and Hospital Colony Wards. This had occurred in the year 1943 just a year before the World War II. This old or dormant landslide reactivated during the middle part of 1980's. According to the local residents and respondents, the presence of seepage of water present in that area may be the cause of the slide. The seepage is a source of water supply to the surrounding area. During the mid 1980's slide, the location of the well was shifted about 100 meters downstream from the original source due to landslide movement. It is said that the amount of water availability through the well has not reduced with the shifting of the source.

The second is a slide below the Mezhür Higher Secondary School in the Midland Colony Ward in the south-eastern parts of the study area. This slide had occurred in 1962. No damage to property was reported since the areas had no buildings at that time. However, there were some paddy fields which were taken away by the landslide. The area below this old slide zone is still creeping. According to the local residents, no concrete or brick buildings could be constructed in this area since the land is slowly moving downstream. There are some wooden and CGI buildings that have been constructed over the years. There are visible cracks and displacements/ tilts on the roof. The Figure 3.3.5 below shows the landslide map of the study area.

Landslides start mainly during the second half of the monsoon season. When the run-off of the streams increases, small slides and riverbed erosion takes place on the sides of the streams. There are many areas especially along the natural drainages that are being affected by landslides. These small areas are not possible to map in detail due to the small size of the individual landslides and the buildings constructed very close to them.

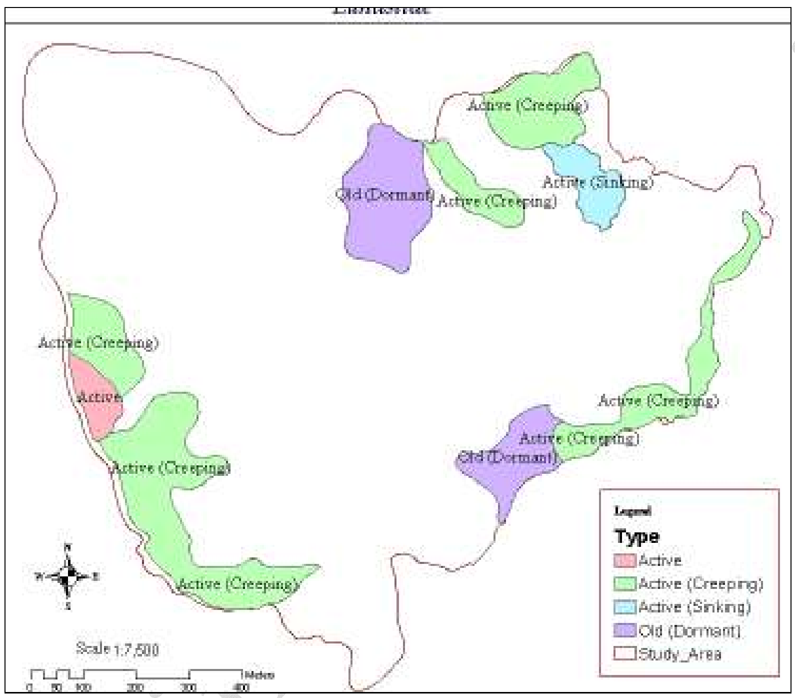


Figure 3.3.5: Map Showing Landslides in the study area

3.3.6. Geology and geomorphology

Most part of the study area is dominated by shales, belonging to the so-called “Disang shale” group. The type of shales found in the study is classified into four major groups: i) Black shales, ii) Splintery shales, iii) Shales with sandstone, iv) shales with mudstone. The north-south portion of the middle part of the study area has the concentration of shales with sandstone, where the land is comparatively less prone to landslide (Ref. Figure 3.3.6).

The geomorphologic units were extracted from the satellite data (LISS III and PAN merge data and ASTER Anaglyph image). There are three main Geomorphologic units identified in the area namely, i) Highly dissected hill, ii) Moderately dissected hill and iii) Low dissected hill (Ref. Figure.3.3.6).

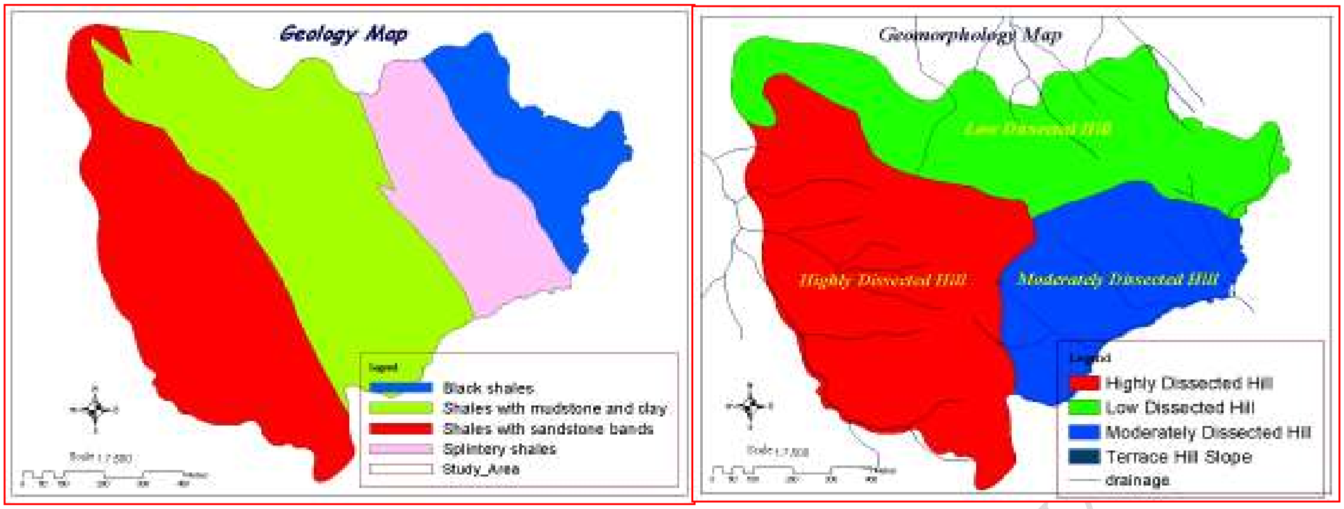


Figure 3.3.6: Map showing Geology and Geomorphology

3.3.7. Slope amount and aspect

Slope and aspect maps were prepared from the digital elevation model and topographic map with the help of contour. Slope was classified into five classes: i) 0-15^0 , ii) 15-25^0 , iii) 25-35 ^{0} , iv) 35-45^0 and v) 45^0 and above. Aspect was classified into nine classes. The Figure 3.3.7 shows the slope and aspect map of the study area. The value of aspect given in the map below are indicated in different color: 1=North; 2=North East; 3=East; 4=South East; 5=South; 6=South West; 7= West; 8=North West and 9=North.

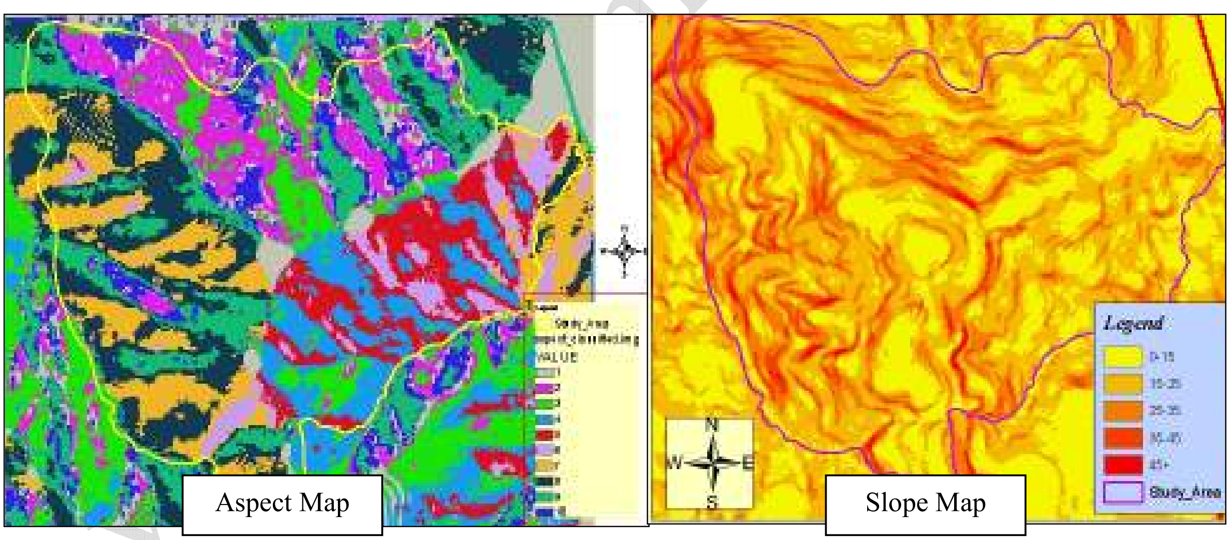


Figure 3.3.7: Map showing Slope and Aspect

3.3.8 LINEAMENT AND FAULT

The area is encountered with a number of lineaments which may be faults, fractures, joints or major shear zones. The major lineament trend of lineaments are NE to SW and NW to SE. There is one major fault along the study area extending from North-West to South-East cutting all across the major rock units. There is also a minor fault towards the south almost parallel to the major fault. Fault and lineament map was prepared from the satellite imagery and by referring to the existing geological information, lithological map, and drainage pattern, dissection and field observation. The Figure 3.3.8 shows the major fault and lineaments in the study area.

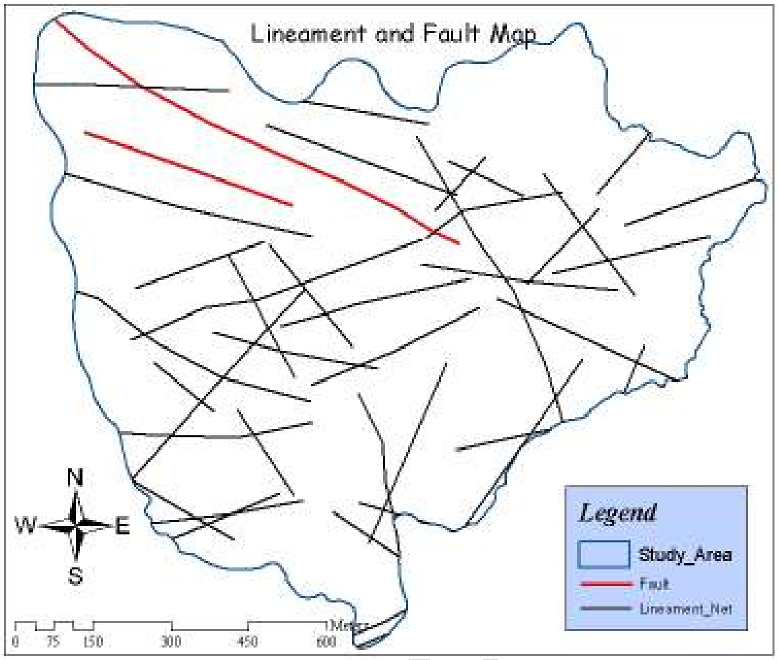


Figure 3.3.8: Map showing Faults and Lineaments

3.3.8. Landslide Hazard Zonation

Out to the three landslide susceptibility zones, a total area of 63181.25 sq meters (0.06 sq km), which is about 6% of the study area lies in high landslide hazard zone. There are about 0.36 sq km, which constitutes about 35% of the study area falls under Moderate zone, and about 0.60 sq km, which is about 59% of the study area fall under Low zone. Table 3.3.2 and Figure 3.3.9 shows the area under different Landslide zones and active landslide overplayed over landslide zones respectively.

Table 3.3.2: Area under different Landslide zones

Area under Landslide zones				
Sl No	*Class*	*Area (Sq m)*	*Area (Sq Km)*	*% of the Total*
1	High	63181.25	0.06	6
2	Moderate	355111.25	0.36	35
3	Low	598022.19	0.60	59

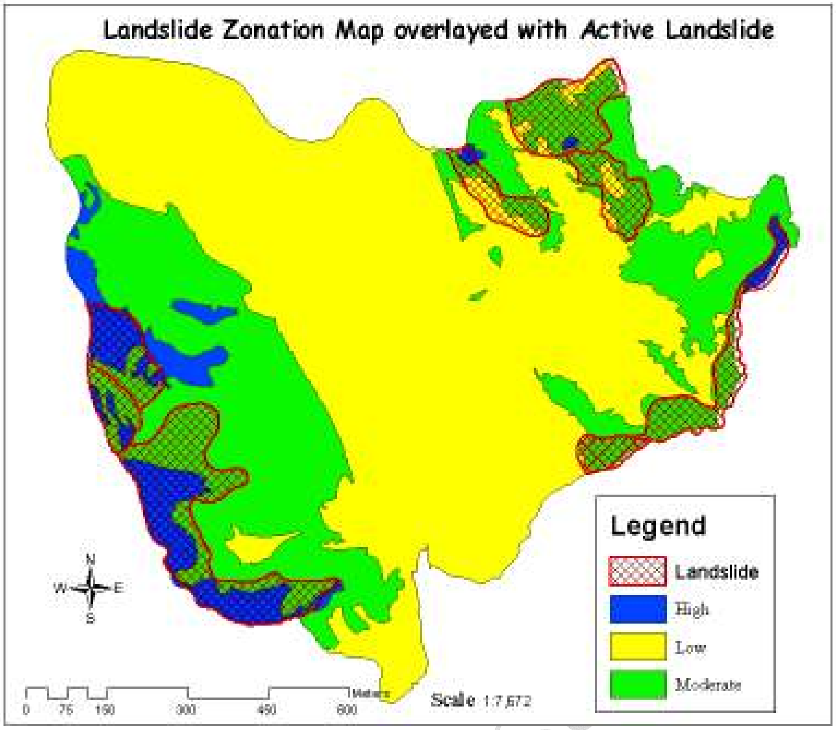


Figure 3.3.9: Map showing Landslide zonation overplayed with Active Landslides

The number of buildings under different classes of landslide zones is given in Table 3.3.3. There are four buildings in the High Landslide hazard zone. Under Moderate Landslide zone, there are 930 buildings, which is about 41% of the total buildings in the study area. A total of 1295 buildings which is about 58.10% of the total buildings in the study area lies in Low Landslide zone. The location of buildings in different landslide hazard zones is indicated graphically in the Figure 3.3.10.

Table 3.3.3: Buildings in different landslides zones

Buildings in different categories of Landslide zones			
Sl No	Class	No of Bldgs	% of the total
1	High	4	0.18
2	Moderate	930	41.72
3	Low	1295	58.10
	Total	2229	100.00

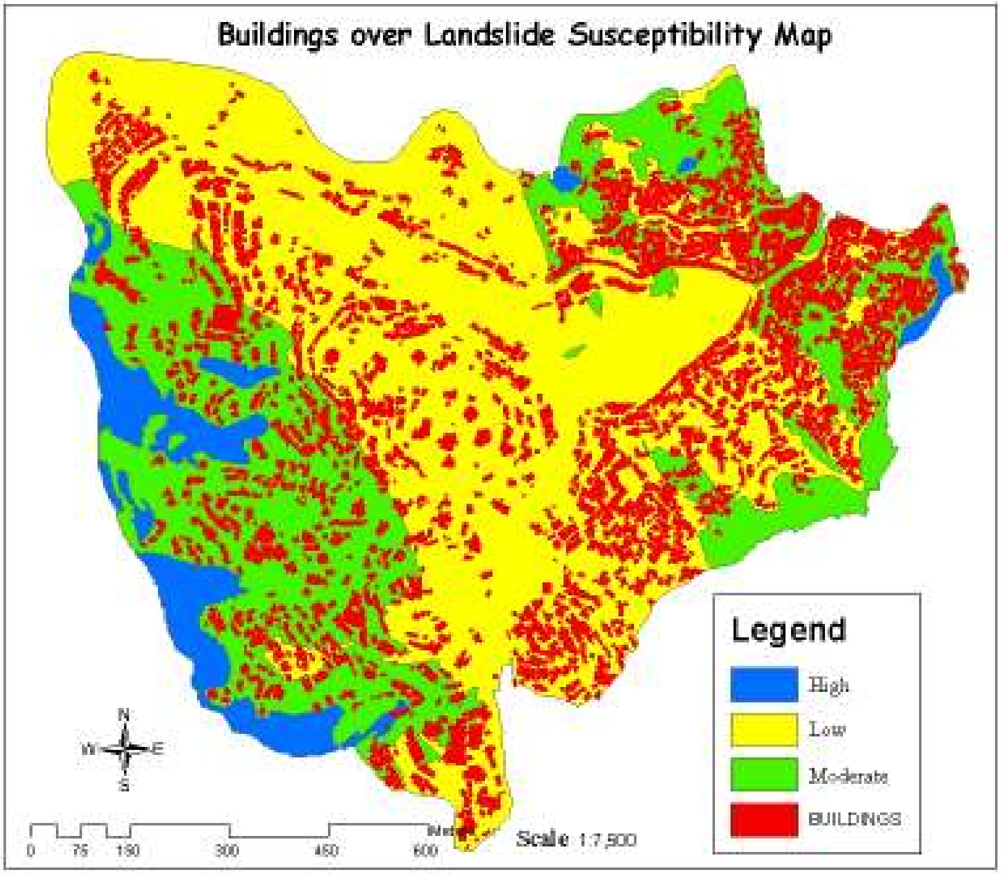


Figure 3.3.10: Map showing Buildings in Different Landslide Hazard Zones

3.4. Multi-Hazard Risk Assessment

A city is not vulnerable to only one particular hazard and totally free from other hazards. At the same time, hazards are interlined with one another. For instance, an earthquake may cause fire and landslide. It is therefore, important to investigate the different potential phenomenon that can cause adverse affects on a city. This is the concept of multi-hazard analysis. By definition, risk is the expected damage of a particular hazard. The multiple hazard maps are often called composite, synthesis or overlay map, are an excellent tool for fomenting the awareness of natural hazards and for analyzing vulnerability and risk, especially when combined with the mapping of critical facilities.

Multi-hazard mapping is usually carried out with new land use and urban development in mind. Valuable information on individual natural hazards in a study area may appear on maps with varying scales, coverage, and detail, but these maps are difficult to use in risk analysis due to the inability to conveniently overlay them on each other for study. Information from several of them can be combined in a single map to give a composite picture of the magnitude, frequency, and area of effect of all the natural hazards (Weerasinghe, 2003).

3.4.1. The Approach

The study assessed three types of hazards and the vulnerability of the buildings and population to arrive at a Multi-hazard risk map. Different hazards namely, earthquake, fire and landslide were analyzed individually. The outcome of the multi hazard analysis is combined to prepare a multi-hazard map. Then the vulnerability of population in the study area is assessed and finally, the product of the multi-hazard is the outcome of the multi-hazard risk map.

3.4.2. Multi-hazard analysis

As has been discussed in the earlier part of the chapter, the hazards were classed into different categories from very high to very low. The amount of weight that is given to a certain factor and the way this factor is classified is highly subjective. Weight values ranging from 1 (low) to 10 (high) were given to different levels to all the hazards. The different hazards with their weighted values were combined into a hazard map. The three hazards types were assumed to be of the same rank, though in real world some hazards have severe impact on human activity. The following table (Table 3.4.1) shows the ranking of the different classes for different hazards. The worst situation is taken into consideration while assessing the multi-hazard. For instance, in the case of earthquake the worst scenario i.e., damage at Intensity IX in the Modified Mercalli Scale is taken for the analysis. So also, the same criterion is applied to both fire hazard (very high and high fire hazard) and landslide hazard (high landslide hazard).

Table 3.4.1: Hazard Rankings of Different classes

Sl No	*Hazard*	*Class*	*Weight*
1	Landslide	High	10
		Moderately High	6
		Low	2
2	Earthquake	Complete Collapse	10
		Partial Collapse	8
		Large Cracks	6
		Small Cracks	4
		No Damage	0
3	Fire	Very High	10
		High	8
		Moderate	6
		Low	2

With the spatial operation tools in GIS environment, the different hazards with different class were added to arrive at different combinations of hazards. The equation used for the calculation of multi-hazard is given below:

Multi_Hazard = [Ln_Haz + Eq_Haz + Fr_Haz]

Where: *Ln_Haz = Landslide Hazard*
Eq_Haz = Earthquake Hazard
Fr_Haz = Fire Hazard

A Matrix for every two hazard combination was created based on the weightage value given in Table 3.4.1. The range of the output values were then classified into three categories: i) High Hazard (14-20), ii) Moderate Hazard (7-13) and iii) Low Hazard (0-6). The Subsequent figures below (Table 3.4.2; Table 3.4.3; Table 3.4.4) shows the combination of hazard in form of matrix.

Table 3.4.2: Building Damage and Fire Hazard Matrix

Fire Hazard and Bldg Damage				
Bldg_Dam\ Fire	*VH_Fire*	*H_Fire*	*Mod_Fire*	*Low_Fire*
Compt_Coll	**H**	**H**	**H**	**M**
Part_Coll	**H**	**H**	**M**	**M**
Large_Cr	**H**	**M**	**M**	**M**
Small_Cr	**H**	**M**	**M**	**L**
No_Dam	**M**	**M**	**L**	**L**

Table 3.4.3: Building Damage (Earthquake) and Landslide Hazard Matrix

Building Damage and Landslide			
Bldg_Dam\ L_Slide	*High_Slide*	*Mod_Slide*	*Low_Slide*
Compt_Coll	**H**	**H**	**M**
Part_Coll	**H**	**H**	**M**
Large_Cr	**H**	**M**	**M**
Small_Cr	**H**	**M**	**L**
No_Dam	**M**	**M**	**L**

Table 3.4.4: Landslide Hazard and Fire Hazard Matrix

Fire and Landslide				
L_Slide\ Fire	*VH_Fire*	*H_Fire*	*Mod_Fire*	*Low_Fire*
High_Slide	**H**	**H**	**H**	**M**
Mod_Slide	**H**	**M**	**M**	**M**
Low_Slide	**M**	**M**	**L**	**L**

Where:

H = High Hazard
M = Medium Hazard
L = Low Hazard

The combination of the hazards was done using ArcGIS spatial query operation. The numbers of buildings that are under different hazard combination are given in the Table 3.4.5 below.

Table 3.4.5: Combination of Hazards

Sl No	Code	Multi-Hazards	No. of Buildings
1	ELF	Earthquake, Landslide & Fire	187
2	EL	Earthquake & Landslide	127
3	EF	Earthquake & Fire	246
4	LF	Landslide & Fire	187
5	E	Earthquake	157
6	L	Landslide	433
7	F	Fire	252
8	NIL	No Hazard	622

There are 187 buildings that are confronted with the three hazards, i.e., earthquake, landslide and fire (EFL). The combination of earthquake and fire hazards (EF) has the maximum number of buildings with 246 buildings. The combination of earthquake and fire are inter-related, in the sense that, an earthquake can cause fire, but this may not be true in the other way round. Landslide and Fire hazard combination is a coincidence. The chances of landslide causing fire or vice versa, may be very less. There are 187 buildings that are having the combination of both landside and fire hazards (LF). There is a possibility that earthquakes can cause landslide, but a landslide may not cause earthquake. The numbers of buildings that have the combination of earthquake and landslide hazards (EL) are 127 in number. There are many buildings that are prone one hazard. For instance, there are 433 buildings that are under high landslide susceptible zone, followed by 252 buildings in high fire zone, and 157 building in high earthquake zone. The spatial distribution of the combination of hazards is shown in the Figure 3.4.1 below.

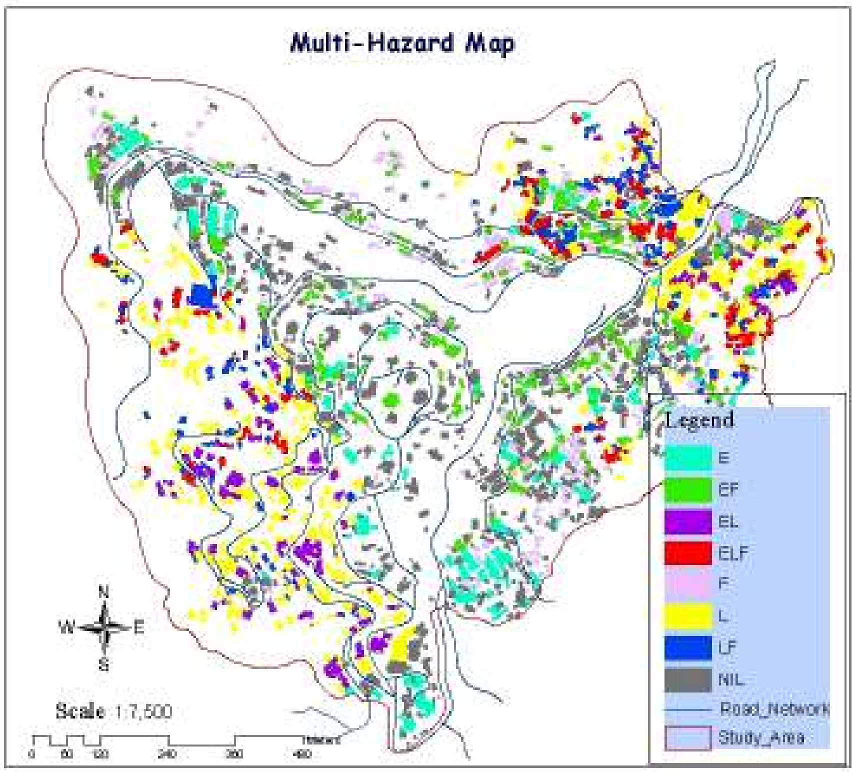


Figure 3.4.1: Map showing the combinations Multi-Hazard

Among the three wards in the study area, New Market Ward has the highest number of buildings belonging to all the three hazards (EFL) with 69 buildings. This number is about 17.21% of the total buildings in the ward. New Market ward is also having 78 buildings with the hazard combination of Landslide and fire, which constitute about 19.45% of the buildings in the ward. Hospital Colony ward and Midland ward have 57 buildings and 61 buildings in the three multi-hazard, which is about 7.7% and 5.91% of the total buildings in the wards respectively. Among the wards, New Market is most vulnerable wards to fire hazard with 61 buildings, which is about 15.21% of the building in the ward. Hospital Colony ward has the highest number of buildings that is prone to Landslides with 253 buildings, which is about 34.19% of the total buildings in the ward belonging to high landslide hazard. In case of landslide, among the three wards, Hospital colony has the highest percentage (8.78%) of buildings in high earthquake hazard. The Table 3.4.6 shows the number and percentage of buildings in different multi-hazard and single hazard zones.

Table 3.4.6: Combination of Multi-hazard in different Wards

	Buildings in different wards				*% to total bldgs in respective wards*		
Combination\ Wards	*New Market*	*Midland*	*Hospital*	*Total*	*New Market*	*Midland*	*Hospital*
EFL	69	61	57	187	17.21	5.91	7.70
EL	9	23	95	127	2.24	9.85	12.84
EF	72	113	79	264	17.96	8.20	10.68
LF	78	33	76	187	19.45	7.88	10.27
E	13	79	65	157	3.24	6.74	8.78
L	51	100	253	404	12.72	26.24	34.19
F	61	115	76	252	15.21	7.88	10.27

3.5. Multi-Hazard Risk Assessment

The calculation of multi-hazard risk involved the identification of buildings that are falling under high hazards and consequently multiplied with the number of persons in each building. The individual hazard risk were first analysed and then the multi-hazard risk was analysed. All the individual risk map were added to arrive at a multi-hazard map. For calcution of Population at risk, the number of households in the building is multiplied with the average household/ family size.

3.5.1. Earthquake Hazard Risk

The vulnerability of the buildings and population were calculated for assessing risk. The total number of buildings that will have complete collapse and partial collapse were calculated (Ref. Chapter 3.2) and then the number of household/family living in these buildings - that was derived from the field observation of the buildings - was multiplied with the average size of family (Ref. Chapter 4, section 4.2).

There are 2 (two) buildings that are expected to collapse completely in the IX intensity earthquake. These two buildings are three storied buildings, one purely residential and the other is mixed, with commercial use in the ground floor. There are two household/families each in these two buildings. Assuming a population density of 4.5 persons per family, the population in these two buildings are 18 persons. It is difficult to quantify the total number of death that will be caused by the collapse of these buildings, but if an earthquake happens at night, the casualty will be high.

In the intensity IX, the expected buildings that will suffer partial collapse are 730, which is about 32% of the total buildings in the study area. Out to the buildings that will have partial collapse, buildings under residential uses are 497, which is about 65% of the total buildings. This indicates that if earthquake occurs at night, there will be high casualty in the residential areas. For calculation of Earthquake Hazard Risk, the number of buildings under Complete Collapse and Partial Collapse are taken into account. The Table 3.5.1 shows the number of buildings and population that are at risk in Earthquake Hazard.

Table 3.5.1: Buildings and Population at Earthquake Hazard Risk

Earthquake Hazard Risk		
Wards	No. of Bldgs	Popn. at Risk
New Market Ward	165	833
Midland Ward	271	1350
Hospital Colony Ward	296	1229
Total	732	3412

The total number of persons that will be left homeless is 3412. The expected number of people that will be affected by the residential buildings alone will amount to about 2910. There are other buildings such as mixed uses that are used both for residential and commercial, so the total number of person that will be affected will be much more.

There are 14 buildings belonging to the category of institutions and public use. Among them there are two school buildings that will have partial collapse, namely Government Lower Primary School, Midland with 322 students. The age of the students ranges from 4 years to 10 years old. The casualties in these buildings are expected to be high, if the disaster events occur during the day, because the school children are so young to take care of themselves. In addition, 18 buildings belonging to commercial use will have high floating population may have high casualties during the day. Figure 3.5.1 shows the distribution of buildings with population density that is at risk. The density of population in the buildings are given in range from 0-1 (buildings with no population to 10 persons), 11-20 (population in the building with 11-20 persons), and 21- 32 (buildings with population range from 21-32 person).

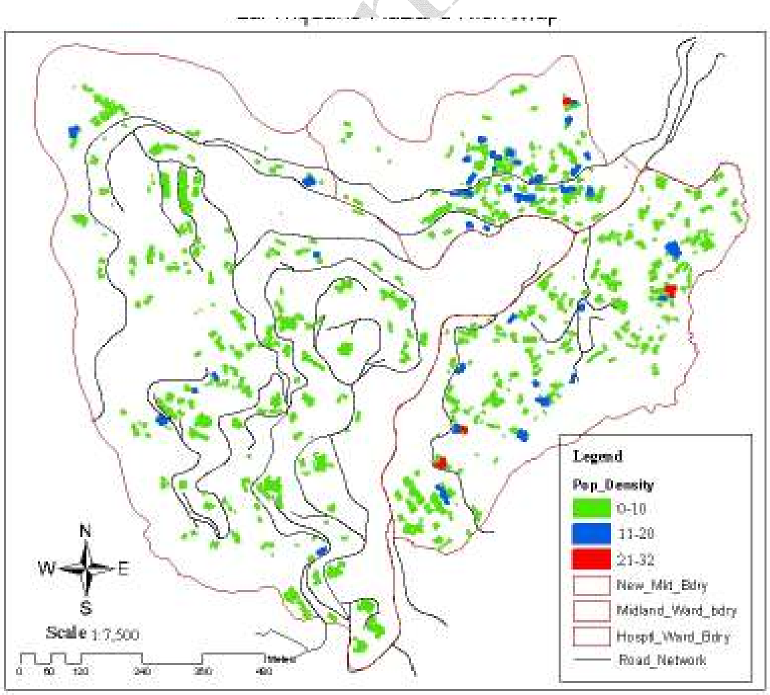


Figure 3.5.1: Map showing buildings and population with Earthquake Hazard Risk

3.5.2. Fire Hazard Risk

There were two major fire incidents that had occurred in the study area in the near recent years. Both the incidents took place in New Market area. The first one occurred in the year 1984 where 5-6 buildings were completely burnt down. However, except property damage, there was no life or casualty caused. The other incident that occurred was in 1999, where three persons were reportedly injured severely. The injury caused in the second case of fire incidents was due to the congestion of buildings which leaves no sufficient space for evacuation.

It may not be possible to predict the occurrence of fire. However, considering the local conditions such as the building material, space between buildings, time of year, etc., it may be qualitatively summarized: how many buildings are at risk and what time of the year the buildings are more vulnerable. The two incidents referred above reveals that the spread of fire may depend on the seasons of the year. The 1999 fire incident occurred in a very congested area, during the monsoon season where the availability of water is present and the humidity was high, the fire could not spread to the neighbouring buildings may be because of other reasons also. In the case of the 1984 incident, the buildings that were gutted by fire were all along the road side. However, it could not be doused in spite of the efforts put by the local people and the personnel of the Fire Brigade. This happened during the driest season of the year (March).

There are 890 buildings that are under high fire hazard in the study area. The Table 3.4.2 below shows the number of buildings that are under Very High and High Fire Hazard Zone. There are 890 buildings that are under high fire risk with a population of 4443 persons. The Figure 3.5.2 shows the spatial distribution of buildings and population density of the buildings that are at high fire risk.

Table 3.5.2: Buildings and population at Fire Hazard Risk

Fire Hazard Risk		
Wards	No. of Bldgs	Popn at Risk
New Market Ward	280	1,454
Midland Ward	322	1,643
Hospital Colony Ward	288	1,346
Total	890	4,443

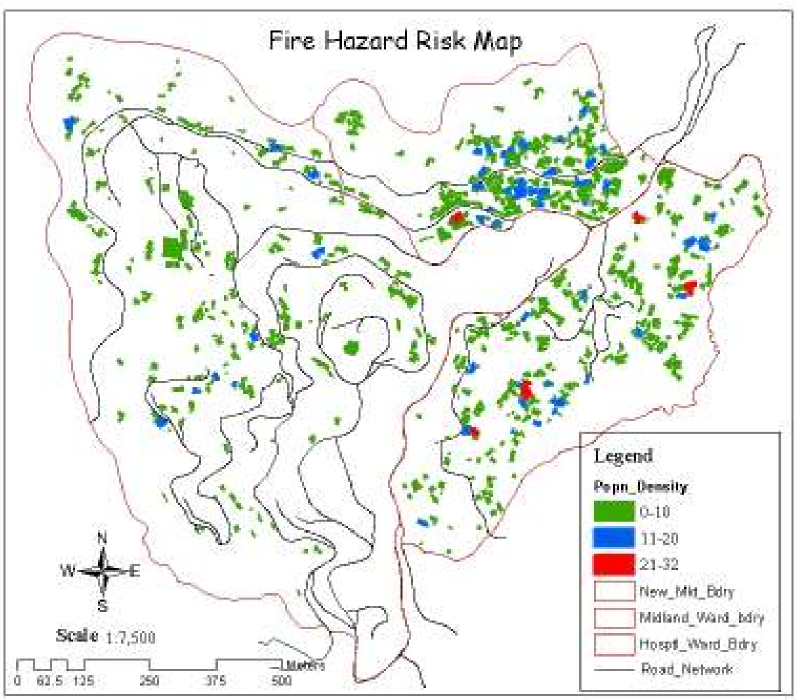


Figure 3.5.2: Map showing buildings and population with Fire Hazard Risk

3.5.3. Landslide Hazard Risk

The movement of landslide in the study is slow and continuous (yearly). It is evident that due to its slow movement, the buildings are cracked and the roofs tilted, etc. According to the information derived from the interview, there is no case of death or injury caused by landslides. It is only the damage to property in the form of building loss specially the structure. Since it is slow movement, damage to building contents are also not reported. There are four buildings under high landslide hazard. The four buildings that are within the High Hazard zone may have severe damage.

The geology of the study area is dominated by shale (Refer 3.3.6). Though there are variations in the type of shale that may have different susceptibility to landslide, the whole area can be said to be susceptible to landslide. The area under high and moderate hazard zone will have higher chances of landslide due to the contributing factors such as geology, geomorphology, slope, aspect, lineament, etc. A total of 905 buildings are under high landslide hazard zone. The total number of population at stake is 4559 persons. The Table 3.5.3 shows the number of buildings and population that are at risk. The Figure 3.5.3 shows the distribution of buildings with population that are at risk.

Table 3.5.3: Buildings and population at Risk (Landslide)

Landslide Hazard Risk		
Wards	No. of Bldgs	Popn. at Risk
New Market Ward	207	1049
Midland Ward	217	1350
Hospital Colony Ward	481	2160
Total	905	4559

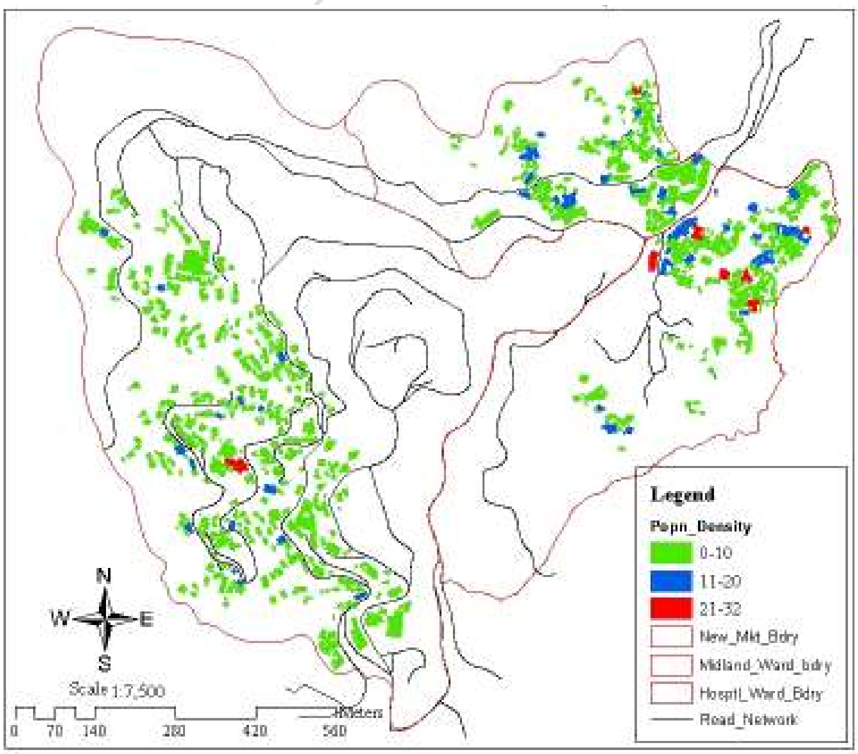


Figure 3.5.3: Map showing buildings and population with Landslide Risk

The probability of these buildings to be damaged may not be able to precisely predict. It may take years to see the activity of landslide in these zones, depending on factors such as meteorological parameters like the intensity and duration of rainfall in the rainy season.

3.5.4. Buildings and Population at Risk (Multi-Hazard)

The buildings that are under high hazard are selected and population at risk was calculated. The population at risk in different buildings are categorized into two: i) buildings that are under only one hazard and ii) buildings that are having multi-hazard. The following tables (Table 3.5.4 and Table 3.5.5) show the number of buildings and population that are at risk. The Table 3.4.10 shows the number of buildings that are at risk and the population that are at risk under different hazards.

The maximum number of buildings under landslide hazard is found in Hospital Colony Ward with a total of 253 and a population of 1157 persons. The highest number of buildings under high fire risk is the Midland ward with a total of 115 buildings and a population of 657 persons. There are 79 buildings under high seismic risk with a population of 450 persons. A comparison of the percentage share of buildings under fire hazard is the highest in New Market Ward with 15.21% of the total buildings. About 10.68% of the total buildings in Midland ward are under high seismic hazard. The total number of buildings as well as the percentage share of buildings under landslide hazard is highest in Hospital Colony ward with 26.24% of the total buildings.

Table 3.5.4: Ward-wise distribution of Buildings and population at risk (single hazard).

No of bldgs in different wards with different Hazards				
Wards	*Hazard*	*No of Bldgs*	*% of the ward Bldgs*	*Popn at Risk*
	Landslide	51	12.72	252
	Earthquake	13	3.24	86
New Market Ward	Fire	61	15.21	369
	Landslide	100	13.51	724
	Earthquake	79	10.68	450
Midland Ward	Fire	115	15.54	657
	Landslide	253	26.24	1157
	Earthquake	65	6.74	306
Hospital Ward	Fire	76	7.88	396
Total		813		4397

The number of buildings and population that are at multi-hazard risk are given in Table 3.5.5 below. Among the three wards studied, New Market is the ward that has the maximum number buildings with multi-hazard. New Market ward has the highest number of buildings under multi-hazard of all the three hazards - Earthquake, Landslide and Fire (EFL) - with 69 buildings, which is 17.21% of the total buildings in the ward. The population at risk in this category is about 306 persons. About 17.96% of the total buildings in New Market ward has Earthquake and Fire hazard (EF) with a population of 356 persons. There are 78 buildings in New Market that are in Fire and Landslide (FL) hazard which is about 19.45% of the total building in the ward. The combination of Earthquake and Fire (EF) hazards are found to be the highest in Midland with a total of 113 buildings. The population at risk under this multi-hazard is about 504 persons. The maximum number of buildings that have the combination of Earthquake and Landslide (EL) are found in Hospital Colony Ward with 95 buildings, which is almost 10% of the total buildings in the Ward. There are 387 persons at risk in this multi-hazard combination.

The table 3.5.6 below shows the number of buildings, population and the percentage share of buildings in multi-hazard.

Table 3.5.5: Ward-wise distribution of Buildings and population at risk (Multi-Hazard Risk).

Buildings in different wards with Multi-Hazard				
Wards	*Multi-Haz*	*No of Bldgs*	*% of the ward Bldgs*	*Popn at risk*
New Market Ward	ELF	69	17.21	306
	EL	9	2.24	68
	EF	72	17.96	356
	FL	78	19.45	423
Midland Ward	ELF	61	8.24	279
	EL	23	3.11	144
	EF	113	15.27	504
	FL	33	4.46	203
Hospital Colony Ward	ELF	57	5.91	203
	EL	95	9.85	387
	EF	79	8.20	333
	FL	76	7.88	414
Total		765		3620

An overview of the study shows that the study area is at high risk. The Table 3.5.6 gives the summarization of the ward-wise buildings and population that are at high risk (single hazard + multi-hazard). The share of buildings that are at high risk is more than 70% of the buildings in all the cases. In the New Market Ward, 353 buildings out of the total of 401 buildings, which is about 88%, are in High Risk. This is followed by Hospital Colony Ward with 701 buildings, that is 72.72% of the total buildings in the ward is in High Risk. The Midland Ward has the lowest percentage of buildings and population under High Risk with 524 buildings which is 70.81% of the total building in the study area.

Table 3.5.6: Ward-wise buildings and population at Risk

Population and buildings in the High Hazard Risk Zones			
Wards	No of Bldgs	% of the ward Bldgs	Popn at Risk
New Market Ward	353	88.03	1859
Midland Ward	524	70.81	2961
Hospital Colony Ward	701	72.72	3195
Total	1578		8015

The population of the buildings was calculated based on the information collected from the field. The number of household/ family in each building is multiplied with the average family size at the wards in the study area to estimate the population at risk. The range of population is from 0 (no habitation) to 32 persons (high dense) in a building. The density of population in the buildings is further classified into three groups: i) 0-10 persons, ii) 11-20 persons and, iii) 21-32 persons. The density of population at risk is shown in a map in Figure 3.5.4 below.

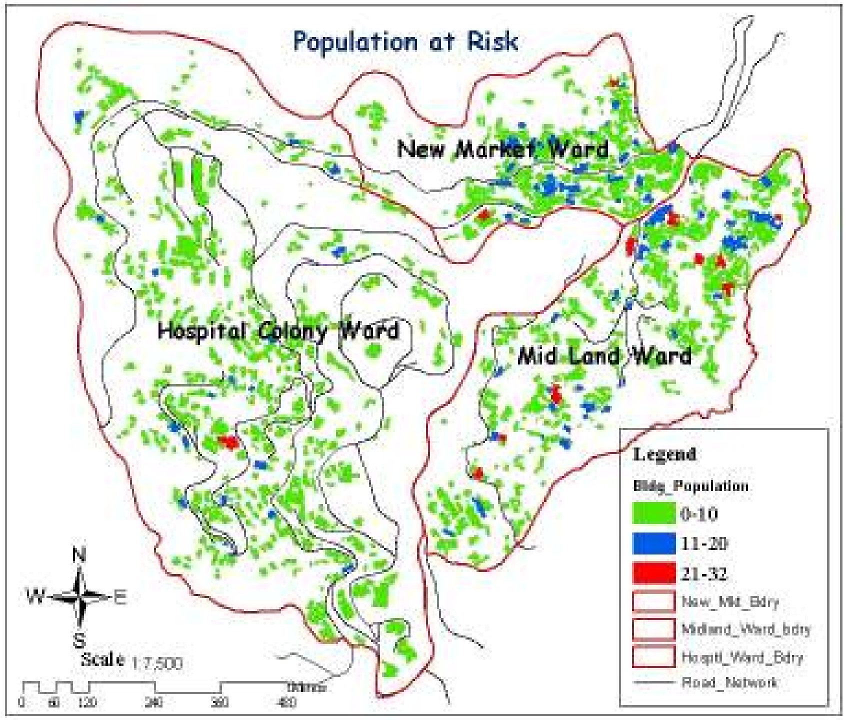


Figure 3.5.4: Map showing Population with Multi-Hazard Risk

4. Vulnerability Assessment

4.1. Introduction

Vulnerability is defined as the degree of damage to a specific element at risk (building, infrastructure, population etc.) for a specific endangering phenomena (e.g. earthquake) with a certain intensity, and is expressed on a scale between 0 (no damage) to 1 (total loss) or as a percentage. Vulnerability is a function of the hazard intensity (in this case the earthquake intensity) and the characteristics of the elements at risk (in this case building type and height), (Westen, 2004).

There are two methods for vulnerability analysis, namely qualitative and quantitative. Qualitative methods refer to the expression of degree of vulnerability in terms of high, moderate or low. Whereas, in quantitative methods, the expression of vulnerability in terms of values. In the quantitative method buildings of the same material and type are grouped together. In the case study, the quantitative method is used for vulnerability. The case study has taken into account, the vulnerability of the Buildings and population for analysis for quantitative analysis and some social and economic aspects are also discussed.

4.2. Population of Kohima

The population of the town was collected from the Census of India. The total population of Kohima town is 78,584 persons in 2001 (Census of India). The ward-wise population of the town is yet to be announced officially. But even if the population of the wards were been made available, it would not be useful for this study since the boundary demarcation of the wards have changed in 2003. As a result, population figures in the study area were estimated based on the official population of the town, and the number of buildings in the town and the average household size in the study area. For further information on demography of the town, refer to Chapter 2. The estimated ward-wise population is given in Table 4.1 below.

The population estimation of the study area was done based on the observation of the number of household in each building, which is multiplied by the average household size in the study area that was arrived from the sample survey collected from the field. There are 2509 households in the study area. The average household size derived from sample survey is 4.5 persons. The population of study area is therefore 11290 (2509 x 4.5).

[*Estimated Population] = [No. of Household] * [Average Household size (4.5)*].

Table 4.1: Estimated Ward-wise Population

Estimated Ward-Wise Population	
Wards	**Population**
Hospital Colony Ward	4531
Midland Ward	4626
New Market Ward	2133
Total	11290

The estimated population of the wards in the study area seems to be on the higher side when compared with the share of buildings in the study area with that of the total number of buildings in the town. The estimated population in the study area is about 14.37% of the total population of the town, whereas, the percentage share of the number of buildings in the study area is only 10.61% of the total buildings in the town. One reason for the high share of population in the study area may be due to the increase in the number of newly constructed buildings in the study area. There is no denying the fact that the study area is highly dense in population, but the ratio population and buildings show a high variation. Table 4.2 shows the population and number of buildings of the study area with respect to population and number of buildings at the town level.

Table 4.2: Percentage of Population and Buildings (Study area : Kohima Town)

Percentage of inhabited Buildings and Population			
	Kohima	*Study Area*	*Percentage*
Population	78584	11290	14.37
No of Buildings	21000	2229	10.61

4.3. Vulnerability Assessment

The study analyses the structural, population and some aspect of social vulnerability of the three wards of Kohima town. The study comprises of the vulnerability of the buildings in the area, critical facilities such as schools, public buildings like the churches and Panchayat hall/ community hall, medical centers, etc., that can be used as an emergency and shelter in case of a disaster event. The Figure 4.1 below shows the map of buildings (Public and institution buildings) that can be used during emergency. A total of 94 buildings are existing, which can be used as emergency shelter during an disaster event well spread in the study area. The area coverage of these buildings is about 20451 sq m (143.01 x 143.01m appx) ground/floor coverage. The location, structure, and population of the school children are also examined. Day and night population is also examined through different uses of the buildings such as residential, public places, commercial or shopping complexes. Further, a linear radius of 50 meters and 100 meters from these potential emergency shelters are drawn and an estimate of number of persons located beyond these two buffers are further discussed in section 4.11.

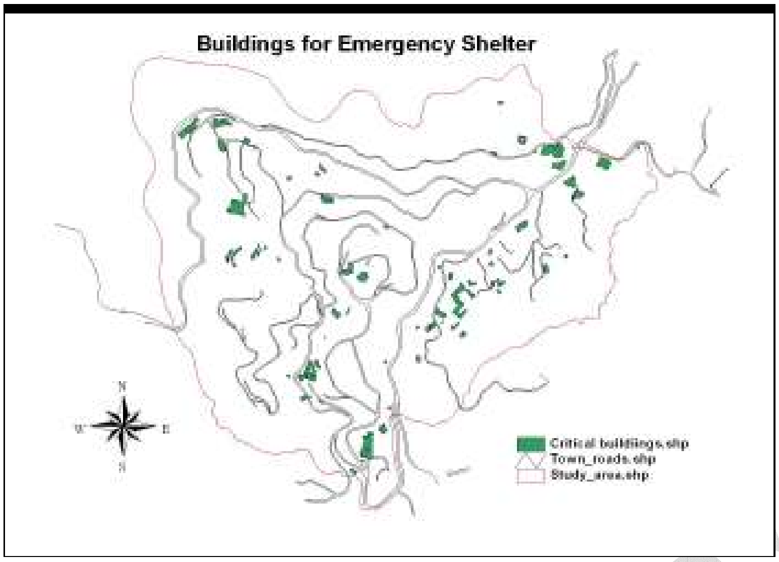


Figure 4.1: Map showing Buildings that can be used for emergency shelter

4.3.1. Structure vulnerability

Vulnerability of buildings means, expected damage distribution, conditional upon severity of seismic action (Sandi, 1999), landslide and fire. There are mainly two type of building vulnerability namely Structural and Non-structural. Structural damage refers to the building's structural support systems such as beams, columns, foundations, etc., while non-structural damages refers to the damage that does not affect the integrity of the structural support system such as chimney collapsing, window breaking, ceiling falling, etc (Montoya, 2003).

Depending upon the earthquake and the building strength, building may get damaged during an earthquake ranging from fine cracks to complete damage. The expected damage to buildings at different intensity on the MMI scale is been presented. Buildings were classified into two main classes and the expected damage of buildings into six classes presented in Chapter 3 (3.2.5).

4.3.2. Social vulnerability

Earthquake affects not only the built environment, but also the social organization and harmony in a community. By destroying the individual buildings, critical facilities, or economic or cultural centers, an earthquake or any natural hazard disturbs or destroys the existing interrelationship and interaction between or among the different groups and activities of a society. It is therefore, important to identify the vulnerabilities of the sections of the society, which are more vulnerable to natural disasters of different types.

4.4. Population Vulnerability

The status of population density in buildings in the study area is shown in Figure 4.2. Density of population is grouped into three classes: Low Density (< 8 persons per Bldg); Moderate Density (9 – 13 persons per bldg); and High Density (> 14 persons per bldg). There are 1814 buildings falling under low density with population less than 8 persons per building. The moderate density class consists of 365 buildings with a density of population between 9 to 13 persons per building. There are only 50 buildings belonging to high density class with population more than 14 people per building (Ref. Table 4.3).

Table 4.3: Estimate Density of Population in the study area

Population Density			
Sl No	*Density Class*	*No of Persons per bldg*	*No of Buildings*
1	Low Density	< 8	1814
2	Moderate Density	9-13	365
3	High Density	> 14	50

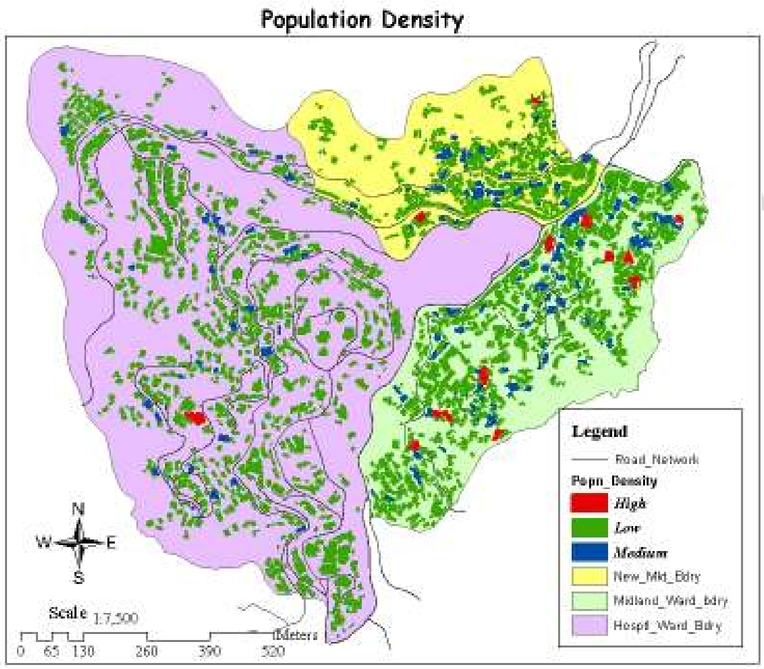


Figure 4.2: Map showing Density of Population per building

The buildings with red coloured legend indicate the high density class and buildings with blue coloured legend indicates the moderate and low density is indicated by green coloured legend.

4.5. Classes of Buildings

The classification of buildings into different uses is important, because, it will help the decision makers to know which time of the day are the different types of uses are more vulnerable. The practice, habit and way of living of the area are also important to determine the hours of use of different buildings.

The use of buildings are categorized into seven classes namely, i) Residential, ii) Commercial, iii) Institutional, iv) Public Buildings, v) Industrial, vi) Mixed use and, vii) Abandoned/ No use. The Table 4.4 below shows the number of buildings under each class. There are 1505 buildings, which is about 67.52% of the total buildings is purely used for residential purposes.. The category "public buildings" includes churches, stadium, panchayat halls (community hall), etc. "Industrial" in this case implies small income generating units, such as automobile repairing centers and woodcraft workshops, is about 15 buildings in total. The reasons for the low industrial activity in the study area are mainly because: the area is mostly residential; and the local body discourages the establishment of this type of activity to the periphery of the town. Buildings used for institutions are mainly offices, schools, colleges, hostels, nursing homes, etc, which are 59 in number. Mixed buildings are those buildings that are used for more than one activity which occupies 103 buildings amounting to about 4.6% of the total buildings. The mixed use comprises of residential on one floor and commercial or other uses on the other floors such as commercial use. Two National Highways (NH 39 and NH 61), pass along the study area along which the commercial activities are concentrated. There is a category of buildings amounting to 419, which is about 18.8% of the total buildings that are not in active use such as toilets, kitchens, garage, store, etc., a good number of them are abandoned.

Table 4.4: Buildings with Different Uses

Sl No	*Use*	*No of Bldgs*	*% of the total building*
1	Residential	1505	67.52
2	Commercial	93	4.17
3	Institutional	59	2.65
4	Public Buildings	35	1.57
5	Industrial	15	0.67
6	Mixed	103	4.62
7	Abandoned/ No use	419	18.80
Total		2229	100

Due to unfavorable situation created by the insurgency activities in the state, the people in the town Due to unfavorable situation created by the insurgency activities in the state, the people in the town have the practice of returning to their homes early in the afternoon by 3.00 pm to 5.00 pm. This makes the duration of the night time longer, so the population vulnerability of the residential buildings higher. Institutions such as schools and colleges will have more causalities if the disaster event occur during the day time. The density of people per building is shown in Table 4.3 and Figure 4.1. Figure 4.2 shows the different uses of building in different parts of the study area.

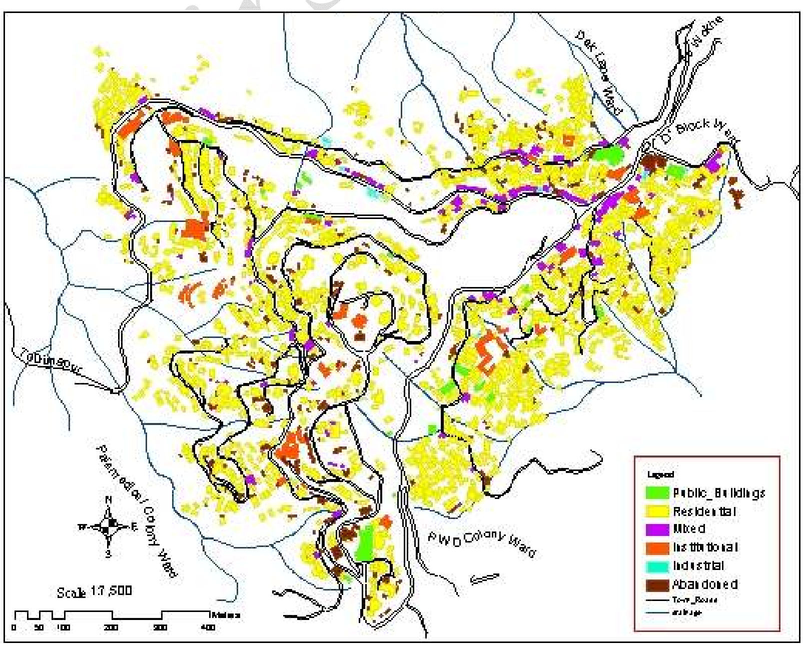


Figure 4.3: Different Uses of Buildings

4.6. Earthquake Vulnerability Curves of buildings

The vulnerability curve was constructed with different types of structures of building and the number of floors (stories). The classes of building structures that were considered are:

1. Load bearing with two stories and less
2. Load bearing with more than three stories,
3. Mixed structures with two stories and less,
4. Mixed structures with three stories and more,
5. Frame structure/ RCC with two stories of less, and
6. Frame structure/ RCC with 3 stories and more.

Earthquake vulnerability curves were obtained from the literature for different types of structures of building and the number of floors (stories). The classes of building structures that were considered are: i) Load bearing with two stories and less ii) Load bearing with more than three stories, iii) Mixed structures with two stories and less, iv) Mixed structures with three stories and more, v) Frame structure/ RCC with two stories of less, and vi) Frame structure/ RCC with 3 stories and more.

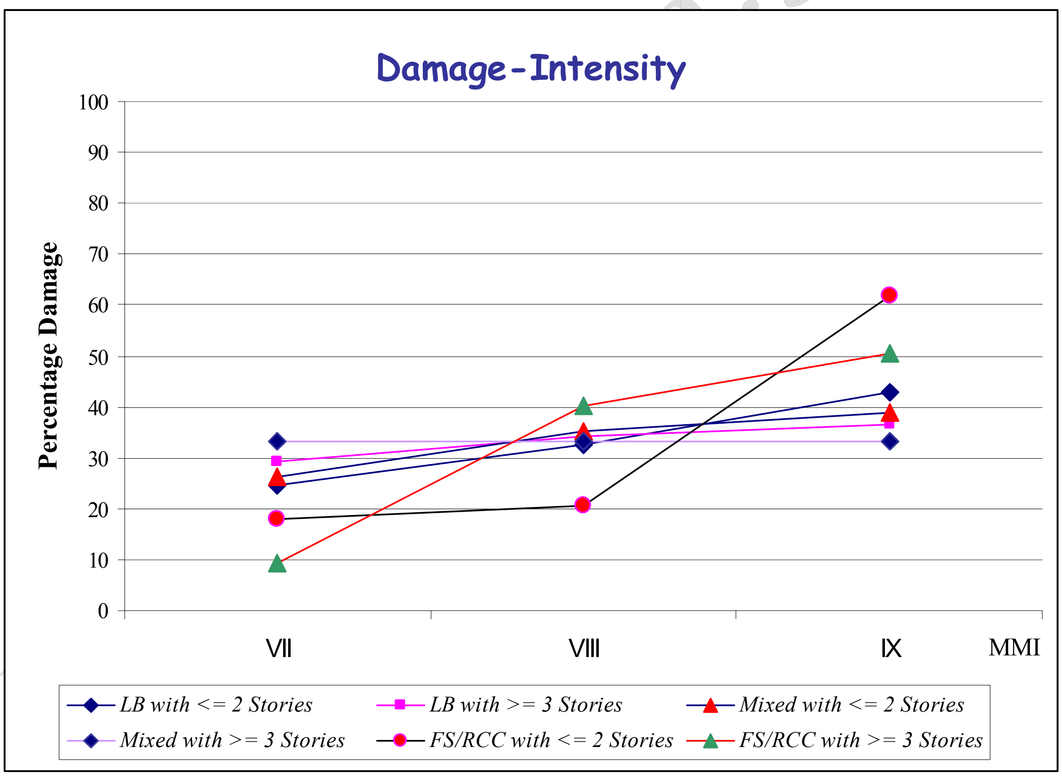


Figure 4.4: Vulnerability curves in relation with MMI for different structures with number of stories

4.7. Vulnerability during day time

Depending on the habit and practice of the people, the time of day is classified. Day time starts from 6 hrs in the morning and ends at 17 hrs in the evening, while Night begins after 17 hrs in the evening till 6 hrs in the morning. The buildings that have more activity during the daytime will have more casualties than that of those buildings that has less activity during the day. Institutional buildings, commercial and industrial centers have more activities at daytime than in the night. The density of these buildings depends on the type of activity. For instance, schools and colleges, and commercial centres have high density of population during the working hours (peak hours), i.e., from 9.00 am to 3.00 pm, and also the commercial complexes. Institutions such as schools, colleges, offices, nursing homes, etc. can be used for shelter during an emergency. At the same time, if a disaster strikes a school or a college during daytime, the casualties may be high. So it is important to consider the spatial distribution and the condition of these buildings.

4.7.1. Institutions

There are five schools and one college in the study area. The college functions also in the evening, so it is put under the vulnerability at night. The standards and number of students of the schools are given in the Table 4.5 below. It is assumed that the population of schools is from within the study area itself, since there are school children coming to study in these schools from outside the study area, and also students are going to other schools outside the ward.

Table 4.5: Schools with Standards and Enrolment

Sl No	Name of the Institution	Standard	No of students
1	Mezhur Higher Secondary School, Midland	Nursery to Class XII	2250
2	Modern English School, New Market	Class A to X	270
3	Govt. Middle School, New Market	Class A to VIII	322
4	Govt Lower Primary School, Midland	Class A to IV	120
5	A. G. English School, Hospital Colony	Class A to X	820

4.7.2. Commercial Areas

Commercial areas have a high floating population during the daytime than morning and evening. There are 93 commercial buildings in the area. The mixed buildings comprises of mostly commercial complexes and residential. These types of buildings are found mostly along the National Highways, which passes through the middle of the town. There are 103 such buildings found under this category.

4.7.3. Public Buildings

There are 35 buildings belonging to the Public Building category in the study area. These buildings are churches, offices, community halls, stadium, etc. The general practice is that, except for churches that are only full on Sundays, these buildings are in use only during the daytime. Therefore, the population of these buildings is more vulnerable during the daytime, i.e., working hours (9.00hrs to 15hrs). The day-time and night-time population is shown in the table 4.6 and graphically represented in the figure below.

4.8. Vulnerability during night time

The residential buildings form the major bulk of the buildings stock. A total of 1505 buildings which is about 68% of the total buildings in the study area are residential, which is an alarming number if a disaster event happens during the night time. As mentioned earlier, the practice of the people going home early in the evening indicates that the duration of vulnerability of the residential buildings are longer (Refer Section 4.5). There are mixed buildings, which are used for both commercial and residential, are vulnerable both during the daytime and nighttime. There are 103 mixed buildings in the study area. There is also a night college (Kohima Law College) in the study area that is also vulnerable to a hazard if a disaster happens at night.

The table below shows the number of buildings under different times of day. Buildings that are populated during the day time comprises of Commercial, Industrial, Public Buildings and Institutional Buildings. These buildings amount to 202 in total. There are 1505 residential buildings in the study area. Another group of buildings amounting to 103 buildings have mixed use, which are used both during the day time and night time. Their use is mainly commercial and residential.

Based on the observation in the field, the day time population of buildings in the commercial and mixed uses is calculated. For buildings having purely commercial uses, it is assumed a day time population of 5 persons (2 shop keepers and 3 customers) per buildings during day time. In mixed uses, 3 persons (1 shop keeper and 2 customers) are assumed. For institutional and public buildings, it is not realistic to assume average number persons occupying the buildings since they do not occupied on daily basis. For instance the Church has a high population during the early hours of the Sundays. While on other days of the week, the Church is almost empty. So also, the population of community buildings such as Panchayat is empty when there is no meeting or public gathering. The day time and night time population is given in table 4.6 below. There in this analysis, the population and in institutions and public buildings are not included in calculating the vulnerability of population during different times of day.

The table 4.6 below shows that the night time population is about 13693, and day time population is about 23001 persons. The day time population is much higher due to the concentration of commercial establishment located in the locality. The day population figure represented may not be uniform throughout the day. The density of population in the early hours of the day and the latter part of the day is less compared to the noon time. The vulnerability of building population during different times of day are represented graphically in Figure 4.5.

Table 4.6: Day and night Population

Time of day	Use	Buildings	HH No	No of persons	Total Popn
Night	Residential	1505	2096	12733	13693
	Mixed (Res & Comm)	103	158	960	
Day	Schools popn	17	-	3782	23001
	Commercial	202	-	18910	
	Mixed (Res & Comm)	103	-	309	

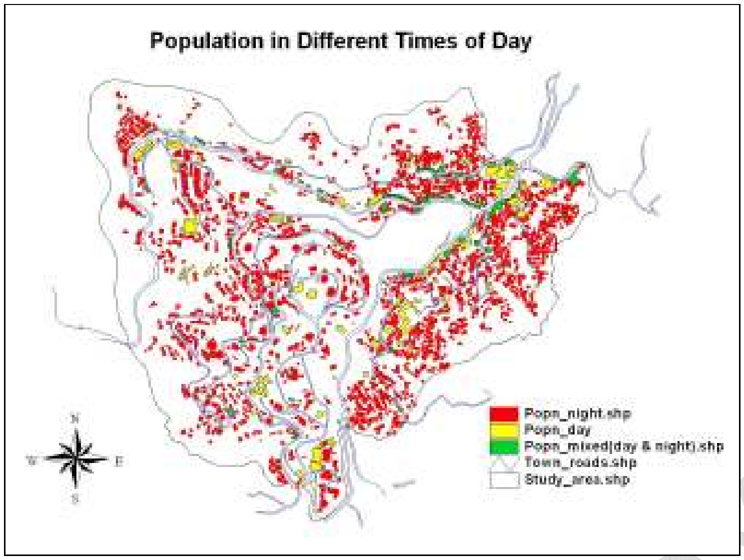


Figure 4.5: Map showing population in different times of day

4.9. Economic vulnerability

The people belonging to the same economic status tend to live in the same social and physical environment. The affordability of the houses is determined by the level of income of the people. It is therefore, necessary to understand the different income groups living in different localities. Low-income groups are likely to be living in congested and dense areas. The response to a disaster or a crisis of these people will vary from the people of the higher income groups. Attention may be given to those areas that are economically weak. It is therefore, important to know the status of the different sections of the society living in different parts of the town.

The income of the household was assessed from the sample survey that was conducted at the household level. The average income of a working person in the study area is Rs. 13745/- (approximately € 250) per month. New Market ward has the least monthly income with Rs 9393/- per month followed by Midland with Rs 14875/- (€ 270), and Hospital Colony with an average monthly income of Rs. 19060/- (€ 346) (Sample Survey). Figure 4.6 shows the ward-wise comparison of monthly income. The variation in the income of the wards studies indicates the people in the congested and highly dense area have a lower average income. There is a high co-relation between income and density of population with a coefficient value of 0.96. The New Market Ward has the lowest average income and the density of population is the highest.

A qualitative comparison of the income of the household income with the condition of the buildings was made. New Market colony is having the least monthly income among the wards studied and it is also found that the buildings conditions is the worst in terms of margin of space between neighboring buildings, building materials, cracks on the wall. It may be concluded that the inhabitants in New Market area are forced to be living in this situation due their poor economic condition. The income in the other two wards is relatively higher. Hospital Colony Ward that has the highest household income. The reason may be due to the concentration of government officers in the locality.

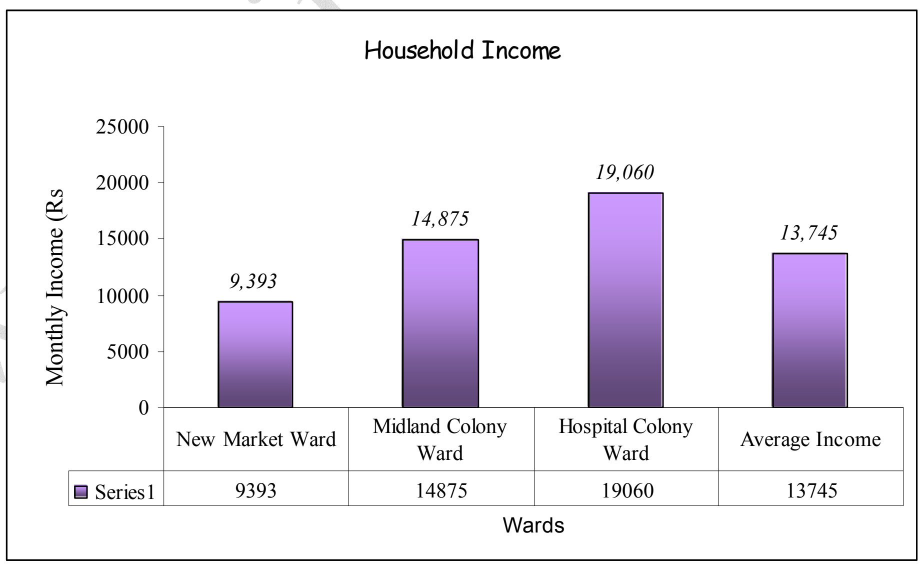


Figure 4.6: Ward-wise Monthly Income

4.10. Social vulnerability

An effective disaster management and loss reduction depends on networks of individuals and organizations united by a common good if protecting lives, investments, and the environment (Mattingly, 2000). Disasters not only bring physical or tangible damage to the mankind, but also disturb the social interrelationships. It is therefore, important to build and direct the damage done to the society by the disaster event. This can be done best by the social organizations that are already established in the local area.

Non-governmental and community-based organizations, if they existed prior to the earthquake event, especially those that have experiences in assisting the community in previous disasters are invaluable assets of any community. It is these local organizations that have the knowledge and understanding of the weaknesses and strengths of the locality that increases the importance of the involvement.

In the study area there are organizations that are well established. Organizations such as women groups, students, youth, club, Churches, political organizations, etc. are actively engaged in social service. The most prominent organizations are the Church, students' and youth organizations. Every ward has got its own youth organization and churches. The percentage of Christianity been 95 %, the role of the church is vital in mitigating disaster. There are 26 churches in the study area, in an area of 1.03 sq km. Since the church meets every Sunday, information on early warning on disasters and information dissemination can be done effectively through the church institution. Even the non-active members of the Church strongly values the moral education imparted at the Church and thus encourage the child to attend the Sunday school. It is therefore, here in the Church that children can be made aware the basics of disaster.

The Church in Nagaland is multi-denominational; profess varied denominations such as Roman Catholic Church, Baptist Church, Christian Revival Church, Pentecostal Church, etc. Every Church has different branches/ departments, like the youth fellowship, women fellowship, Child Evangelism, etc. These branches are well organized and functions according to the guidelines of the Church. However, they also have their own plans of activities with the approval of the Church. The youth fellowship is one of the most active wings of the Church, which is also engaged in economic activities and social service also. Therefore, if proper training can be given, the different branches of the Church can be a very effective in dissemination, prevention and carry out rescue operation during disaster event.

4.11. Lifelines and critical facilities

The term 'critical facilities' mean all man-made structures or other improvements whose function, size, service area, or uniqueness gives them the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if they are destroyed or damaged or if their services are repeatedly interrupted (ADPC, 2003). Critical facility has a specific functionality requirements and life-safety protection during a disaster event. Lifelines are the critical facilities on which a city depends for the continued existence of its population, such as water, power system, communication, etc. Transportation systems include roads and bridges, airports, ports, etc.

4.11.1. Distance from Potential Emergency Centres

There are 94 buildings belonging to public and institutional category that can provide shelter. However, if these buildings are damaged, it can create panic among the locality. It is therefore important to know the condition of these buildings. Some of the aspects of lifelines and critical facilities that were taken into consideration area: hospitals/ medical centers, public buildings such as schools, churches, offices, community buildings, etc. There are two schools namely Government Middle School, New Market; and Government Lower Primary School, Midland are lying in high multi-hazard zone. The Lower Primary School, Midland falls under high earthquake zone, which will suffer partial collapse in the IX intensity earthquake. The population and the standard of the schools refer to table 4.5. The standard of Government Primary School in New market is Class VIII and the LP School is up to Class IV. It is therefore, evident that the population is more vulnerable since majority of the students are too young to take care of themselves during a disaster event. There is a medical centre, namely Oking Clinic in New Market ward falling under high multi-hazard.

Considering the availability of buildings that can be used as emergency shelter (Ref. Fig. 4.1), an assessment of how many buildings are beyond these buildings are made. The table 4.7 shows the number of buildings, household and population that are located beyond a radius of 50 meters and 100 meters from the potential emergency buildings such as Church, schools, Panchayat hall, stadium, etc. Among the three wards, Hospital colony ward has the maximum number of buildings that are located far from the potential emergency centers with 180 buildings beyond 100 meters and 619 buildings beyond 50 meters radius. These buildings will have less accessibility to the emergency centers due to their locational disadvantages. The Figure 4.5 shows the number of buildings beyond the buffer of 50 meters and 100 meters from the potential emergency buildings.

Table 4.7: Buildings Potential Emergency Centers

Buildings from Critical Buildings				
Distance	*Wards*	*No of Bldgs*	*No of HH*	*Population*
Beyond 100m	New Market	131	154	936
	Midland	82	96	583
	Hospital Colony	180	191	1160
Beyond 50m	New Market	263	313	1901
	Midland	397	537	3262
	Hospital Colony	619	663	4028

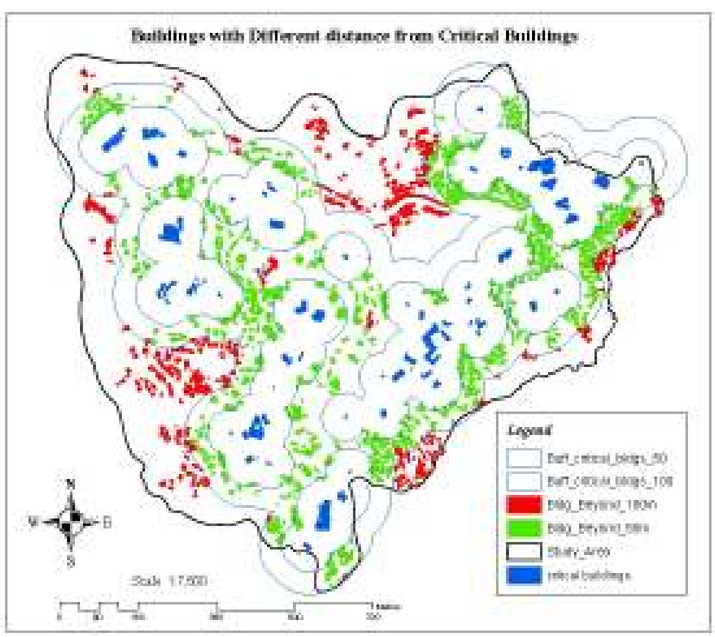


Figure 4.7: Buildings located beyond 50m and 100m from Potential Emergency Centres.

4.11.2. Distance from Road

Road is a critical facility that plays an important role during an emergency event. Relief and rescue operation are done efficiently if there are proper road networks. Distance from the road is important while calculating the probable number of buildings or population that can be served. It is easier to serve the buildings and population that are located closer to the road. A buffer of 50 meters is made on the existing roads in the study area to assess the number of buildings and population falling beyond 50 meters from the roads. Table 4.8 and Figure 4.8 shows the number of buildings and population that are located 50 meters away from the road.

It is evident that Midland has the highest number of buildings and population located beyond 50 meters from the road. A total of 368 buildings with 2788 persons are living beyond 50 meters from the road, this is followed by New Market with 132 buildings and 887 populations.

Table 4.8: Distance of Buildings from the road

Buildings from Road				
Distance	Wards	No of Bldgs	No of HH	Population
Beyond 50m	New Market	132	146	887
	Midland	368	459	2788
	Hospital Colony	102	104	632

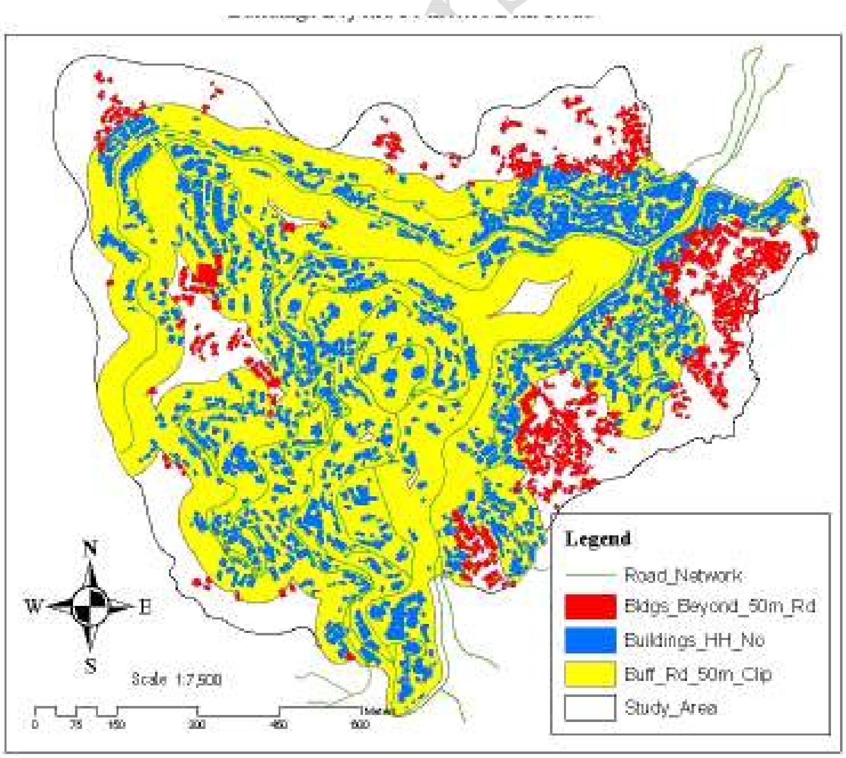


Figure 4.8: Map showing Buildings beyond 50 meters from Road.

5. Discussion

This chapter begins with the view to answer the research questions such as availability of data; data requirement and methods for collection of historical data; buildings in different hazards and risk categories; institutions and public buildings in multi-hazard. A comparative analysis of urban development standards were made with the recommendation made by the national level body with that of the existing conditions in the study area. The chapter is concluded with the limitations that the study had confronted with.

5.1. Data availability

Historical data is useful in places where there is no sufficient secondary data available. As has already been mentioned earlier in Chapter I. the study area is categorized as 'restricted area' on ground of security reason, so there is a paucity of data required for carrying out the research. Due to the proximity to the international border with Myanmar, restrictions are imposed on data and information. For example the official topographic maps from the Survey of India cannot be used due to security reasons. A digital footprint map of Kohima town was prepared from the aerial photographs taken by the National Remote Sensing Agency (NRSA) at the request of the Town and Country Planning Organization (TCPO), Ministry of Urban Development and Poverty Alleviation, Government of India. However, neither the hard copy nor the soft copy of the aerial photographs was given to the concerned department (Urban Development Department, Government of Nagaland), on ground of security reasons.

In addition to security reasons, there are also certain other constraints leading to non-availability of data. One such reason is the lack of cooperation on the part of the concerned departments within the local administration. Basic data for research such as a geological map, soil map, ward map, etc. were not available with the departments dealing with these aspects. It is because of these reasons that the researcher had to spend a large amount of time and resources pursuing the basic inputs for the study.

In the face of insufficiency of data and uncertainty, historical data coming from interviews with local population are the main source of information for the study. Historical data was collected for the analysis of the three hazards that were taken into consideration for the multi hazard risk analysis: earthquake, landslide and fire were derived from interviews with the local residents and the elderly people from within and outside the locality. Among the three hazards, mapping landslide is the most applicable hazard using historical data. Data relating to the occurrence of landslides were acquired though historical data and field mapping.

5.2. Data requirement and Methods for collection of historical data

5.2.1. Data Requirement

Collection of historical data though interviews does not require much initial data. The first and foremost requirement is the information from the population of the locality. A fair idea about the community living in that area, identify the social setup – administration (if any) prepares the researcher a good beginning. The study area has an organized administration headed by a chairman and associated members representing different localities within the wards that are elected by the local people and duly recognized by the district administration. An authorization letter issued by the local authority, here in this case by the chairman of the ward was helpful for conducting the questionnaire survey.

There are also Town Committee members in each ward that are directly elected by the local electorate.

5.2.2. Method for collecting Historical data

The method of collecting historical data is simple. Some of the techniques were found helpful in conducting the questionnaire survey:

1. Convince the respondents
2. Innovative techniques attracting the attention of the respondents
3. Convenient time of the respondents

The first and foremost requirement for the collecting historical information is to win the confidence of the respondents and make them understand the objective of the study. This is very important in cases such as the situation in Kohima, where the situation is sensitive due to insurgency problem and security reasons.

Innovative techniques may be used for convincing the respondents. While conducting the questionnaire survey, the problem in the locality is mentioned and the concern of the government to address the issues is mentioned. Since the Urban Development Department is the nodal agency for developing the town, the respondents were happy to share their grievances with the expectation that the department will take up the issues. People are also aware that the ongoing scheme/project "Town Protection Scheme" under the Town Planning (Urban Development Department) should be expanded. In this study, since landslide is a severe problem faced by the localities, mentions were made to the governments' concern about the landslide measures.

5.2.3. Data acquisition through Interviews

The amount of historical data acquisition though interviews highly depends on the extent of the study area and the time. The sample data collection was done to acquire historical information (Ref. 2.3.3). The memory of the respondents does not go beyond a certain time period. The event that has happened during the lifetime of a person could be recollected. In this case study, the historical records of two landslides that occurred during the 1940's and 1960's could be recorded. There is no record that could be collected on the occurrence of landslide prior to 1940. The information on the magnitude of the disaster event also diminishes with time. A vague idea about the extent of the area that has been affected by the landslide before a year of the World War II in T. C. P. gate could only be derived from the respondents. So it is learnt that precise data of date and time may be difficult to achieve through historical data.

Two categories people were interviewed, one with the elderly people and the other with the respondents from the household (mostly housewives). An interesting observation from the field revealed that elderly people are the best source of historical information. Once the elderly people are convinced, they are able to spare more time, since they are relatively free than most young working people. For small area or town it is also learnt that not only the local people who knows the situation of a particular area, but also information obtained from elderly people from outside the locality is helpful.

Socio-economic and demographic data were collected through household survey. The type of information that has been collected from the field is discussed in Chapter 2: Data Collection. One limitation of the household survey was that, the respondents are mainly housewives. This is because the head of the household is out for work elsewhere during the daytime. The historical information that may be availed through the head of the household may be more authentic than that from the housewives because there are certain cases where the wife belonged to a different part of the town. In this case, events such as occurrences of landslides and fire in the area are not been correctly conveyed.

5.2.4. Field Mapping

The ward boundary of the wards of Kohima town as a whole and the wards in the study area in particular are demarcated based on the notification of the Home Department of the Government of Nagaland (Ref. 2.1). The re-demarcation of ward boundaries had to be done because the old ward boundary of the town was modified for additional wards that were created within the town. Three wards in the town namely: New Market Ward, Midland Ward, and Hospital Colony Wards were taken for study.

The information on the buildings and the extent of landslides were collected through field mapping. Success and accuracy of the field mapping depends on the size of the area and time availability. There was no constraint in time in mapping the landslides in the study since the area is small. But one problem is the small landslides along the streams and roadside that could not be mapped to scale on the map due to their small size. Markings of the extent of the boundary of the slide are made on the printed maps containing the building footprints with the help of Mobile GIS (Palm Top with ArcPad and GPS). However, collection of detailed information on the buildings (type, material, cracks on the wall, etc.) requires a lot of time. Collecting detailed information on buildings for a city level as a whole may be difficult to make it in a short time.

5.2.5. Remote Sensing data:

In a data scarcity place like Kohima, remote sensing data is helpful to a certain extent. The accuracy of the output highly depends on the spatial resolution of the satellite data. Since no geological data is available, geological maps were prepared using the lithological sample collected from the field with remote sensing data. The remote sensing data that were used are LISS 3 and PAN merged data with 5.8 meters resolution, and ASTER data with 15 meters spatial resolution. An anaglyph image of Kohima town at a scale of 1: 75,000 was used to see the regional setting of the area.

There are four reasons that are contributing to the inability of the landslide visibility on the satellite image in the study area:

- i) Low Spatial Resolution of the satellite imagery
- ii) Smaller size of the landslide
- iii) Uncharacteristic Spectral signature
- iv) High Building density masking spatial signature (Surface cover)

Identification of landslide using remote sensing data depends on the size of the landslide. The poor spatial resolution satellite data (LISS and ASTER in this case) is found to be a major setback. One of the reasons is that, the size of the active landslides in the area is so small that it is not visible on the image. The spectral signature of the bare soil in the sliding area and the buildings are sometimes confusing. It is found that the density of buildings are high in the study area, buildings have been constructed on the old and even active landslides. Therefore, the visibility of the landslide is diminished. With the higher resolution satellite data, it may be possible to have a better visibility of the landslides in highly dense urban area. So the ultimate solution for mapping landslide is mapping through walk-over survey or through historical data.

5.3. Buildings and population in different multi-hazards and risk

Comparative assessments of buildings that are expected to suffer damage by multi-hazards are given, taking the worst scenario.

5.3.1. Structures under Multi-hazard

Buildings that are under very high multi-hazard category are load-bearing structures. A total of 404 buildings with load bearing structures fall under very high multi-hazard zone. This is followed by mixed structures and RCC structures with 119 buildings and 5 buildings respectively.

5.3.2. Ward-wise comparison

A ward-wise comparison of Multi-hazard shows that New Market Ward has the highest number of buildings belong to the three combinations of hazards, i.e., Earthquake, Fire and Landslide with 69 buildings, which is about 17% of the total buildings in the ward (Ref Table 3.4.6). This is followed by Midland with 61 buildings under multi-hazard, which is 5.91% of the total buildings in the ward. The percentage share of buildings belonging to multi-hazard in Hospital colony ward is 7.7% of the total buildings in the ward, which constitute 57 buildings.

The multi-hazard combination of Earthquake and Fire (EF) has the highest percentage share in New Market ward with 17.96% of the total building in the ward. This is followed by Hospital colony with a share of 10.27% of the buildings with Earthquake and Fire hazard, followed by Midland ward with a share of 8.20% of the total buildings.

About 13% of the buildings in the Hospital Colony Ward, i.e., 95 buildings have the multi hazard of Earthquake and Landslide (EL) followed by Midland ward with 9.85% of the total buildings belonging to Earthquake and Landslide. New Market ward has the least number of buildings (9) with earthquake and landslide hazards, which is only 2.24% of the total buildings in the ward.

5.4. Buildings and population at risk

5.4.1. Earthquake hazard risk

Two buildings will have complete collapse and 730 will have partial collapse in the IX intensity earthquake. The total number of population that will be left homeless is about 3412 persons (Ref Table 4.5.1). Out of the total number of buildings, Hospital colony has 296 buildings with a population of 1229 person followed by Midland ward with 271 buildings and a population of 1350 person. New Market ward has 165 buildings with 833 persons at risk.

5.4.2. Fire hazard risk

A total of 890 buildings with a population of 4443 persons are at high fire hazard risk (Ref Table 3.5.2). The ward-wise share of fire risk shows that Midland ward has the highest number of buildings with 322 buildings in high fire hazard with a population of 1643 persons. This is followed by Hospital colony ward with 288 buildings with 2346 persons. The New Market ward has 280 buildings with 1454 persons under this hazard risk. Though the number of buildings in high fire hazard is less in New Market ward, the percentage share of buildings belonging to this category is quite high. About 70% of the total buildings in the New Market ward fall under high fire hazard.

5.4.3. Landslide hazard risk

The number of buildings under high landslide hazard is 905 with a population of 4559 persons (Ref. 4.5.3). Among the wards in the study area, Hospital Colony Ward has the highest number of buildings falling under high landslide hazard risk with 481 buildings and 2160 persons. This is followed by Midland ward with a total of 217 buildings with 1350 persons. The New Market ward has 207 buildings with 1049 persons under this risk zone. Though the number of buildings in this hazard risk seems to be the least, the share percentage of share of buildings in New Market in this hazard risk is the highest with 51.62% of the total buildings, followed by Hospital colony ward and Midland ward with 49.90% and 9.35% respectively.

5.5. Institutions and Public buildings in Multi-hazard

There are no institutions or public buildings belonging to very high-risk class. There are two buildings belonging to Police department under high-risk class.

There are 14 institutions and public buildings belonging to very high multi-hazard class. This includes three Churches (Khasi Baptist Church, Garo Baptist Church and Pentecostal Church, New Market) and one Panchayat/community hall (New Market), one nurse hostel and few buildings belonging to police department.

There are two schools under High Multi-Hazard class, namely: i) Government Lower Primary School, Midland and ii) Government Middle School, New Market. Out of the two Nursing homes in the study area, one of them, i.e. Oking Clinic and Nursing Home falls under High Multi-Hazard category. These are some of the institutions, which will provide shelter and used as emergency centers. With the damage caused to these critical facilities during a disaster, it is not only the economic loss, but the role it is supposed to be playing will be hampered.

5.6. A comprative analysis with URBAN development standards

A comparative analysis of the condition prevalent in the study area was done with the standards or guidelines at the national level, namely Urban Development Plan Formulation and Implementation (UDPFI), prescribed by the Ministry of Urban Development Affairs for different for towns in both hilly regions and plain areas (ITPI, 1996). Settlements are classified into Small Towns, Medium Towns, Large Cities and Metro Cities based on population. The population of the settlements is re-classified based on the location of the towns or cities in plain and hilly areas.

Table 5.1: Classification of Urban Centres for UDPFI Guidelines.

Sl No	*Classification*	*Pop. Range*	
		Plain Areas	***Hill Areas***
1	Small Towns	Less than 50,000	Less than 20,000
2	Medium Towns	50,000 – 5,00,000	20,000 – less than 80,000
3	Large City	More than 5,00,000	80,000 and more

Source: ITPI, UDPFI Guidelines,1996.

According to the aforementioned classification, Kohima having a population of 78,584 persons, and being located in a hill area belong to the Medium Town category.

5.6.1. Population Density

The population density recommended in UDPFI Guidelines (Table 5.1) states that an ideal population density for a medium town is 60-90 persons per hectares.

Table 5.2: Developed Area Average Densities

Settlement type	*Persons per hectare (pph) in*	
	Plain Areas	*Hill Areas*
Small towns	75-125	45-75
Medium Towns	100-150	***60-90***
Large Cities	100-150	60-90
Metro Cities	125-175	

Source: ITPI, UDPFI Guidelines, 1996.

The population density in the study area is higher than the standard prescribed by under UDPFI Guidelines. The average density of population in the study area is 124 persons per hectare against 60-90 pph. Midland Colony Ward and New Market Ward have a density of 184 and 167 persons per hectares respectively. This figure is almost double the standard norms prescribed by UDPFI Guidelines. Hospital Colony Ward has a population density of 91 pp/ha, which is close to the standards prescribed in UDPFI.

Table 5.3: Population density in Study area

Population per hectare (pph)			
Wards	Area in Sq M	Population	Persons/ha
Hospital Colony Ward	640717	5856	91
New Market Ward	145795	2436	167
Midland Ward	244879	4496	184
Average	1031391	**12788**	**124**

5.6.2. Land use Structure

The primary purpose of Landuse planning is to control human activities in hazard prone areas (zoning) to avoid fatalities and loss. This involves re-location of communities to safer locations. The landuse structure in the hill towns in UDPFI guidelines are given in the table 5.3.1. The share of built up area to the study area is about 66% (Ref. Chapter 3, Table 3.3.1). Roads in the study area occupy 4.76% which is less than the standard guidelines that is 5-6% of the total area. There is only one stadium and one park (3.19%) and a stadium existing as recreational centers as against 8-10% of the total area.

Table 5.3.1: Proposed Land Use Structure in Hill Towns

Land use	***Percentage of Developed Area***		
	Small Towns	*Medium Towns*	*Large Cities*
Residential	50-55	48-52	45-50
Commercial	2-3	2-3	4-5
Industrial	3-4	4-5	5-7
Public & Semi Public	8-10	8-10	12-15
Recreational	15-18	18-18	16-20
Transport & Communication	5-6	5-6	6-8

Source: ITPI, UDPFI Guidelines,1996.

The share of residential area to total area in the UDPFI guideline is 48-52 %. The study area is highly residential in nature with a share of about 67 % (Ref. Table 2.4). Under this situation, the population is at higher risk in the night than during the day time.

5.6.3. Building Byelaw

A building bye-law is a legal document that includes the engineering and architectural designs taken in to consideration after the assessment of the forces created by natural hazards in a particular area. Until recently, the town was without a building bye-law. The new building bye-law that has been approved in 2001 is a brief document of only 15 pages, yet to be implemented. Due to absence of any legal regulation, most of the buildings were constructed close to each other, by local masons and carpenters who lack formal training. The section 3.1.3 of Chapter 3 shows the status of space between buildings. About 18% of the buildings in the study area lie within a distance of 1 meter from its neighboring buildings.

5.7. Limitations and constraints of the study

5.7.1. Population estimation

Unavailability of population at the ward level is a major setback of the analysis. Assumption was made to fill the gap. However, the certainty and accuracy of population estimation made may be erroneous. Population of the study area was calculated based on the observation of the visibility of chimneys and separate kitchens on and near the building blocks. One kitchen or chimney is considered to be a household. Further, from the field sample survey, the average household size is multiplied with the number of household in the wards and derive the population. It is quite possible that while verifying the existence of kitchens or chimneys in the buildings, some of them is not visible from the observation from the outside. There may also be cases where the existence of two chimneys in the building may be occupied by only one household. The ratio of buildings to population is 1:1.43, ie the percentage of buildings in the study area to the total buildings in the town is 10.02% and the share of population in the study area to total population of the town is 14.37%. This indicates that there exaggeration in the estimation of population.

5.7.2. Time of day and respondents

The time of day for collection of primary survey (questionnaire survey) might not be very appropriate. The survey was done during the working time of the day, when the male head of the family is not available at home. In most cases, housewives were the respondents. The response from the male head of the household might be better in giving the correct information on historical data. The memory of the housewives could not go beyond the incidents that have happened before their marriage if the wife belong to another ward before marriage.

5.7.3. Data availability

Data constraint is a set back for the study. Due to security reasons, the data could not be readily available. The word ‘security’ has created a taboo in the mind of the people that even the non-classified data are considered to be a threat. The proposed satellite data, ie LISS 4 MX with 5.8 meter spatial resolution was not been able to be delivered by the NRSA on ground of security reason.

There are also other constraints on the part of the government agencies that are not keeping the data it is supposed to be maintaining. Soil data and geological data were not been able to be availed from the Directorate of Soil and Water Conservation Department, so also the geological map is not available with the Directorate of Geology and Mining. The population data is yet to be officially declared. These are some of the basic data that is required for the study.

5.7.4. Adoption of Standards

The expected damage of buildings at different intensity earthquake is much higher than that had resulted in the analysis. There is no buildings that will suffer complete collapse in the intensity VII and VIII. Even in the Intensity IX, there are only two buildings that are indicated to have complete collapse. This may be due to the assumption of the standard that was adopted. The standard formulated by A. S. Arya, formulated from the experience of a hilly region was adopted for this case study. No doubt the terrain in this study area is also hilly, the geology and geomorphology may be different.

There are also differences in the typology of buildings. The study area has not buildings built with adobe and random stone construction. Whereas, the separation of well built wooden buildings in the study area is not been able to separate from the poorly construction. This is also a major setback in the calculation of building damage due to seismic hazard.

5.7.5. Adoption of Information Value Method for landslide

Information value method was adopted for landslide hazard. The result is found to be not very accurate. While overlaying the existing landslide map over the resultant landslide hazard map, using information value method, the active landslide area are bigger than the high hazard zone. It is therefore felt that this method may not be very good for a small area.

5.8. Recommendations

Using of low resolution satellite imagery (for instance LISS III and ASTER in this case), is not useful in mapping landslide in a small area. High resolution satellite images like that of IKONOS with spatial resolution or Aerial photo may be used in mapping landslide of a small area. Though it is time consuming, the method of collecting data through field mapping and historical data using Pocket PC with GPS may be used for mapping landslide of small area.

Physical observation of individual buildings is important to have a better understanding of structure and construction material for analysis of fire hazard and earthquake damage assessment. For a small area with heterogeneous building type and construction material, this method can be used. It may be expensive and time consuming for collecting individual building data if the area is large and the study is time bound. For large areas, semi-manual (physical observation with high resolution satellite data) can be used.

For hilly towns, it is not easy to strongly impose the building byelaws. However, the designated authority should try its best to successfully implement the building byelaws. The hilly towns are constrained with the provision of infrastructures such as roads that are incentives to the teeming population to spread out from the city center. As are result, the inelasticity of land within the town leads to construction of buildings on the old landslides and on the steep and erosion areas of the streams within the city. This is why the damage to property is high in hilly town. It is therefore important for the authority to regulate the construction of building close to the streams and old landslide.

6. Conclusion and Scope for Research

Kohima is a hilly town with a lot of natural hazards challenges. The government agencies that deal with spatial planning are frequently confronted with the management of scarce financial resources to deal with a number of problems in the town. Given the limited financial resources to deal with enormous problems, it is sometimes difficult to correctly understand what are the critical problems that need immediate attention. This study therefore, tries to understand how to address some of the hazards that are widespread in the town such as landslide, earthquake, and fire and develop a methodology that can be adopted for other towns that have similar problems using Remote Sensing data and Geographic Information System (GIS) techniques. It also tries to make a comparison between the standards that are prescribed for an ideal town by the national level authority.

Constrained with the problem of data scarcity due to security reason, the study tries to look into the method, adequacy and usefulness of data that is derived from historical data, field mapping and remote sensing data to understand and deal with multi-hazard confronted by a hill town. The approach of collecting data through historical data and field mapping is useful in case like Kohima town, where there are no records of hazards. The use of remote sensing data, namely IRS- LISS III and PAN merge data, and anaglyph of ASTER data is found to be useful in identifying the regional pattern of rocks and geomorphologic units. However, it is not possible to identify landslide through poor resolultion satellite data, where the size of landslide are small and the buit up is highly dense.

Population at the ward level could not be availed since it was officially not declared. So estimation of population at the ward level was made based on the population of the town in 2001 census. The figure of number of household in each building was collected through the field survey. The average household size is multiplied with the number of household in the wards to get the population figure of the study area. As a result, the accuracy of the population estimation highly depends on the household observed in the buildings.

Three wards of Kohima town were taken for the study, namely, New Market Ward, Midland Ward and Hospital Colony Ward with a total of 2229 buildings. These wards are the wards that are located in the central part of the town and have severe problem of landslide; buildings are built so close to each other; and the material that is used for the construction is highly conducive to ignite fire. Building inventory map was prepared using the digital foot print map and building attributes were collected through field survey and analyzed in GIS environment.

Mapping of landslides involved collection of information on the history of landslides and walkover survey. Landslides were marked on the printed map and also on the digital map using GPS in ArcPad environment. Elderly people were interviewed to get the information on landslides of the past. Information on landslide was also acquired from the household questionnaire survey.

Landslide risk map was prepared using the landslide hazard zonation map that was prepared using Information Value Method and the population. Number of buildings and the population in the buildings that falls under different classes of landslide hazard zones were calculated to understand the number of persons at risk.

Fire hazard map was prepared using parameters such as building material, space between buildings, distance of buildings from the road, distance from fire station, and distance from hazardous buildings. Weightages and ranks were assigned to different themes and associated attributes to calculate the fire hazard map. Finally, the fire hazard was classified into Very High Fire Hazard, High Fire Hazard, Moderate Fire Hazard and Low Fire Hazard. The worst situation (Very High and High Fire Hazard classes) was considered in calculating the fire hazard risk.

For calculation of buildings damage assessment, weightages and ranks were assigned to different parameters such as structure of buildings, cracks and displacements, number of stories, proximities between buildings, and roof material were used based on the local condition. Building damage was calculated at three different scenario earthquakes at Intensity VII, VIII and IX on Modified Mercalli Intensity Scale. Standards formulated by A. S. Arya, was adopted to calculate the number of buildings that will have different level of damages. The damage levels were classified into i) Complete collapse, ii) Partial collapse, iii) Large cracks, iv) Small cracks and v) Fine cracks, and vi) No damage. For calculation of the population at risk, damage at intensity IX was taken into consideration. The population in the buildings that are under high seismic damage (complete collapse and partial collapse) were taken for risk assessment.

The individual hazards were analyzed and integrated to derive a multi hazard-map and finally multi hazard risk map. The three hazards were summed up together to get the combination of hazards. Combination of hazards such as i) Earthquake, Fire and Landslide (EFL), ii) Earthquake and Fire (EF), iii) Earthquake and Landslide (EL), and iv) Fire and Landslide (EL) and also buildings with high individual hazard such as i) Earthquake, ii) Landslide, and iii) Fire hazard were derived.

The building and population vulnerability were assessed and risk was calculated accordingly. The number of buildings falling under high hazard was identified and subsequently the number of household was multiplied with the average size of the family. This gives the population at risk in different buildings.

Among the wards studied, New Market Ward has the maximum number of the combination of of the three hazards (Earthquake, Fire and Landslide) followed by Midland Ward and Hospital Colony Ward. Whereas, in case of individual hazard, Midland has the highest number of buildings that are under high seismic hazard followed Hospital Colony Ward and New Market ward. Midland Ward has the highest number of buildings in high fire hazard among the wards studied followed by New Market and Hospital Colony Ward.

A comparison of standards formulated by the national level authority (UDPFI Guidelines) with the situation prevailing in the study area was made. The average density of population in the study area is almost double the standard norms prescribed for an ideal town. The absence of a building bye-law in the town makes the growth haphazard, and buildings were built close to each other, without considering impact of any hazard.

Though the town is small, there are a lot of research to be done. The present study has taken into consideration three hazards. There is a scope for indepth analysis of these hazards need be done individually to have a more accurate prediction of the hazard situation. It is evident that the basic data requirement for any hazard analysis is lacking. Such data as geological data, soil data, water table, etc. that are absent are required to be prepared. Other man-made and environmental problems such as sewage, solid waste, etc. need to be assessed in depth.

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