PART II

EARTHQUAKE DISASTER ASSESSMENT
AND
DATABASE SYSTEM

CHAPTER 7 EARTHQUAKE DISASTER ASSESSMENT

The ultimate purpose of this earthquake disaster assessment is to recognise the phenomena involved when an earthquake occurs near the Kathmandu Valley in the future. To determine the damage and influence that would be caused by a future earthquake, data on current conditions must be identified. The necessary data include both natural conditions such as earthquake history, soils and geology, meteorology, topography, etc., social conditions of the population, buildings, urban structure, land use, infrastructure and lifeline facilities and so on.

One earthquake scenario study was conducted a few years ago by a NGO for the Kathmandu Valley based on a very simple disaster assessment considering recurrence of the 1934 earthquake using available data. It provided an image of the future damage that would be caused by an earthquake in the Valley and has been useful for disaster management planning.

In this study, we will provide a more detailed and more reliable assessment. Nevertheless, there are still limitations of data and time that prevent a full assessment. For example, there are almost no official building inventory data for the Kathmandu Valley, so the total number of buildings was estimated from population and household data of the 1991 census. Building types have been estimated both from an inventory survey of only 1,000 buildings and from onsite observation of the main sites.

Since the assessment results show an outline of current conditions and probable damage status in some areas, when examining the scenario and damage assessments, the above limitations should be taken into account. The team is strongly hoping that more detailed and appropriate data can be prepared at the next opportunity. The various levels of government should prepare statistics of the various items required, not only for disaster management planning but also for usual and effective governmental management. This is a fundamental issue that needs to be addressed in Kathmandu. Despite the limitations outlined above, the following presents a disaster assessment in the Kathmandu Valley for possible earthquake scenarios.

Basic unit for the study

The municipal wards and the VDCs were adopted as the basic administration units in this study because of the limitations and convenience of the available data. For various analyses, especially earthquake motion and ground condition, a grid with a mesh of 2,826 grid cells, 500 m X 500 m, was used. The mesh covered the whole valley area.

7.1 Scenario Earthquakes

(1) Seismicity

Nepal lies in an active seismic zone that extends from Java, Myanmar, the Himalayas, Iran, to Turkey. This zone has experienced many large earthquakes in the past. The epicentral distribution of the past earthquakes around Nepal is shown in Figure 7.1.1.

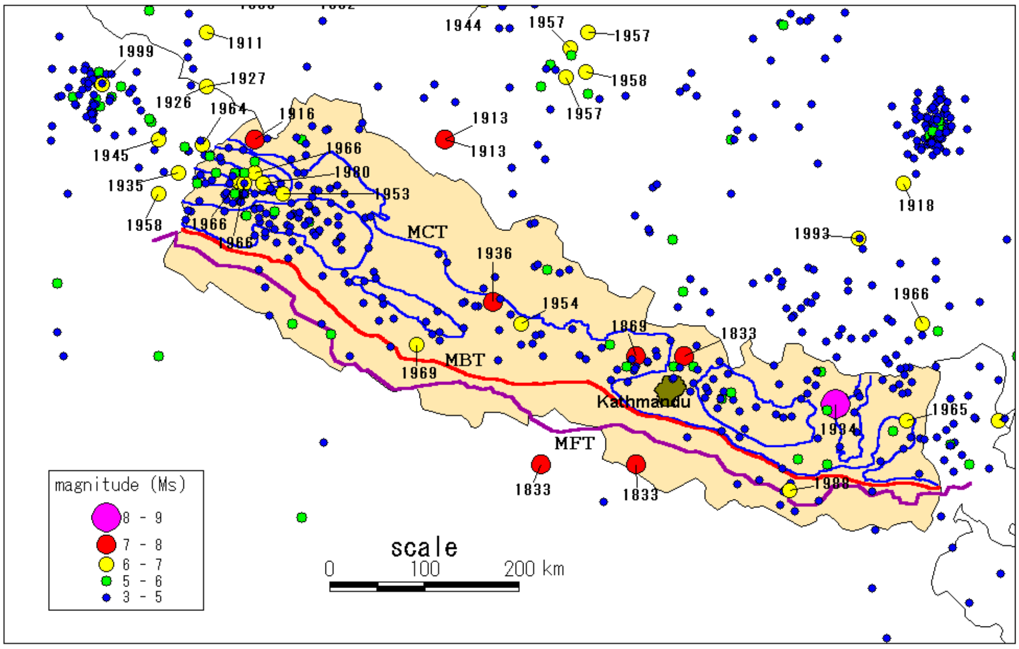


Figure 7.1.1 Epicentral Distribution around Nepal from 1255 to 2001

*** Locations of some epicentres have been adjusted, based on hazard records in Nepal, Source: DMG**

(2) Lineament in the Kathmandu Valley

There are several faults in the Kathmandu Valley. In order to identify the possible source of a small to middle-scale earthquake occurring in the Valley, data about the lineament in the Kathmandu Valley were collected as shown in Figure 7.1.2.

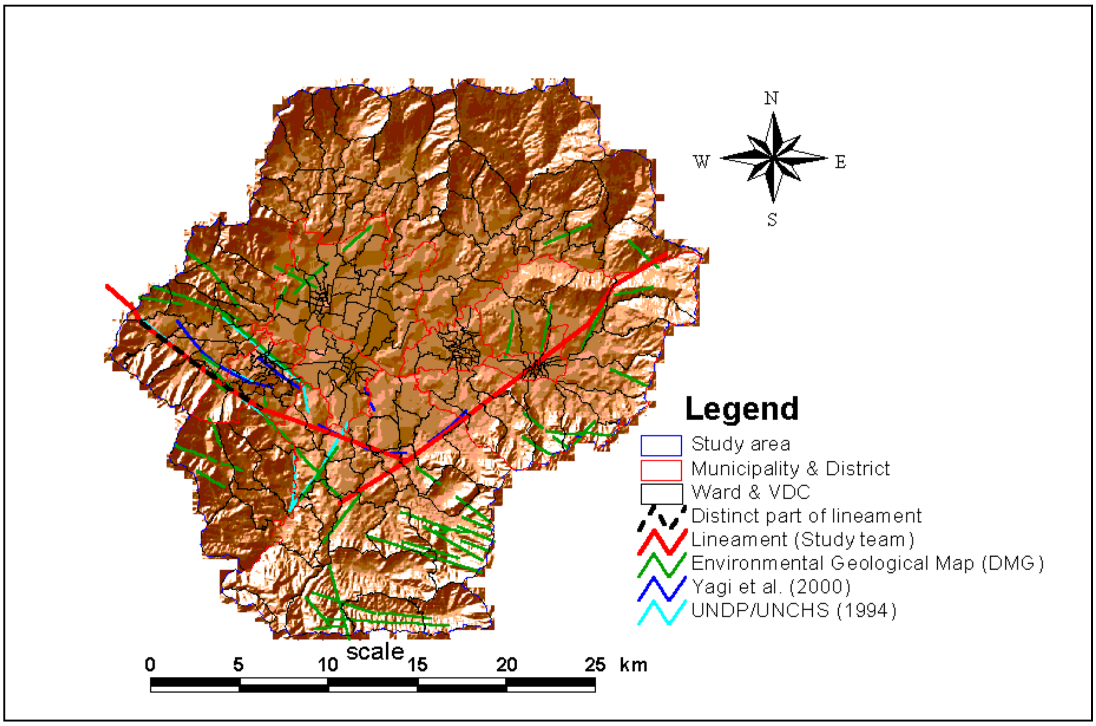


Figure 7.1.2 Faults and Lineaments in Kathmandu Valley

(3) Scenario Earthquake Models

In this study, three new fault models were selected based on the seismic, seismo-tectonic and geological condition around the Kathmandu Valley. The fault model of the 1934 Bihar-Nepal Earthquake is also included for comparison as shown in Figure 7.1.3.

a) Mid Nepal Earthquake (Ms=8.0)

According to Pandey et al. (1999), the seismic gap in the middle of Nepal and the segmentation boundary of the Himalaya seismic zone exists between 82° and 85° E in mid Nepal. The fault surface of this earthquake corresponds to the east half of this segmented region. This is regarded as a huge earthquake.

b) North Bagmati Earthquake (Ms=6.0)

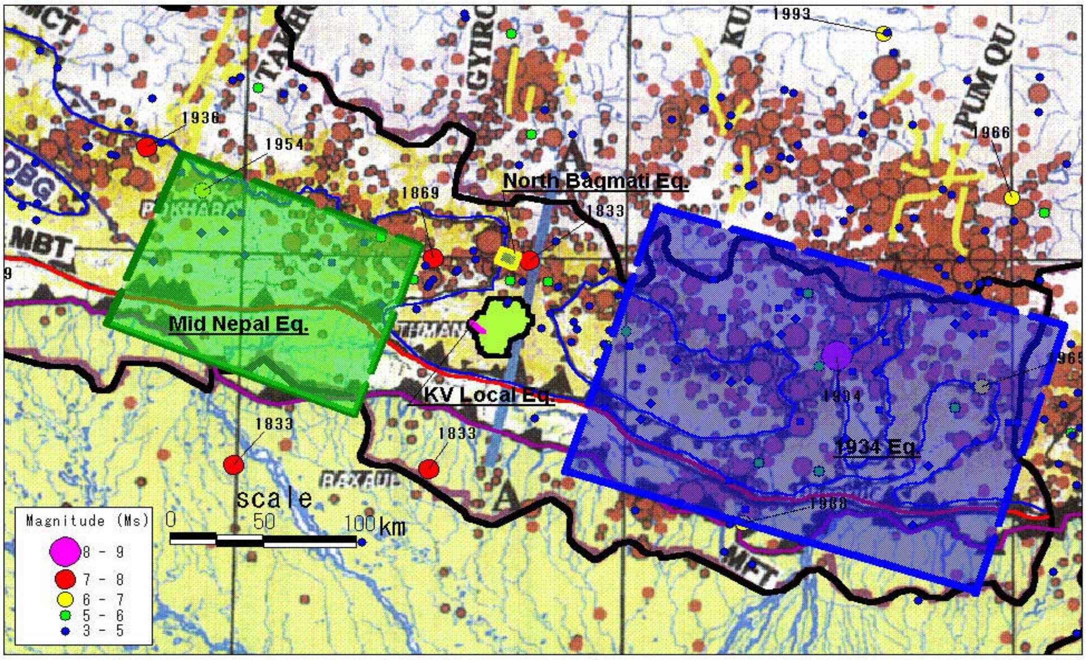
Small earthquakes frequently occur just north of the Kathmandu Valley. This earthquake model has been set, based on this earthquake cluster. This is regarded as a middle-scale earthquake.

c) KV Local Earthquake (Ms=5.7)

This earthquake model has been adopted, based on a distinct part of the lineament in the Valley. This is regarded as a local earthquake under the foot.

d) 1934 Bihar-Nepal Earthquake (Ms=8.4)

This earthquake model has been adopted for comparison with the above three earthquakes.



modified from Pandey et al.(1999)

Figure 7.1.3 Scenario Earthquake Fault Model

7.2 Ground Classification

The ground condition of the Kathmandu Valley was analysed and classified to establish the ground model for seismic analysis such as calculation of the amplification of seismic motion, evaluation of liquefaction and slope stability. The Study Team collected the related geological data and drilled five boreholes in order to collect essential ground properties such as shear wave velocity, density, N value, groundwater level and mean particle size.

(1) Ground Model

As a result of the data examination, the whole Valley has been classified into 90 kinds of typical geological sections. The spatial distribution of the typical sections is shown in Figure 7.2.1.

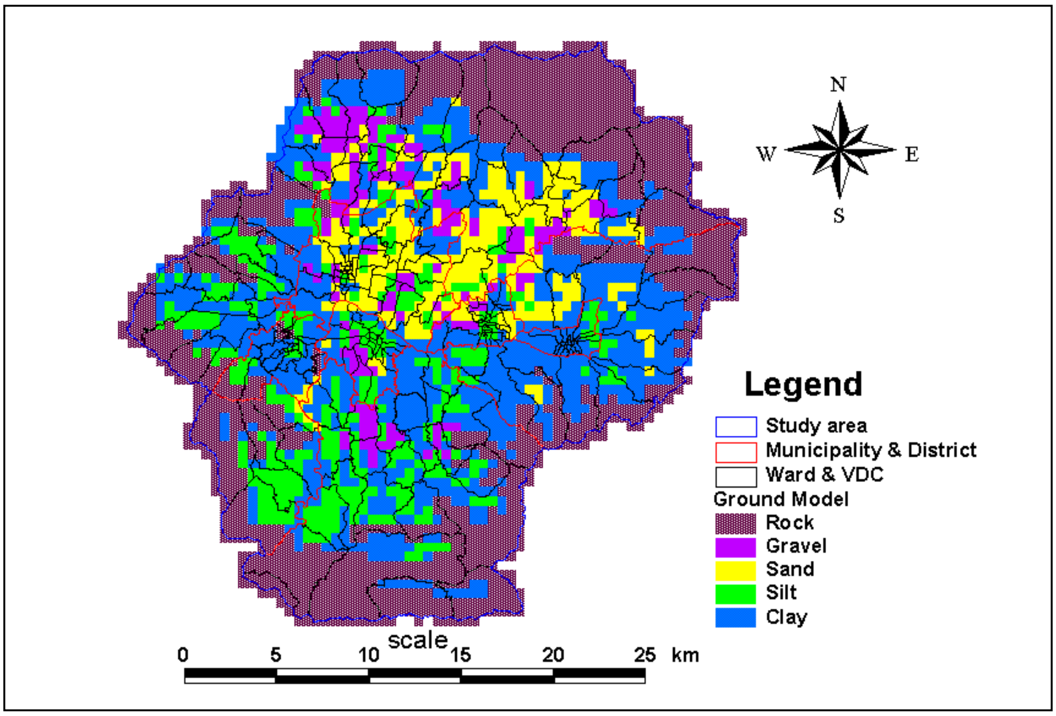


Figure 7.2.1 Ground Model for Seismic Analysis

(2) Soil Properties of the Ground Model

The following soil properties were decided based on the collected data, the drilling survey and the laboratory soil test.

a) N value

b) Groundwater level

c) D_{50} (Mean particle size) and Fc (Fine content)

d) Vs (Shear wave velocity)

e) Density

7.3 Earthquake Motion

(1) Analysis Method

It is important to evaluate the differences in subsurface amplification site by site to know the distribution of earthquake motion across a wide area. Therefore, it is common to evaluate the earthquake motion at the engineering seismic bedrock at first and then multiply the subsurface amplification that is analysed separately using soil conditions as established as the ground model in the previous section.

A flowchart for the analysis is shown in Figure 7.3.1.

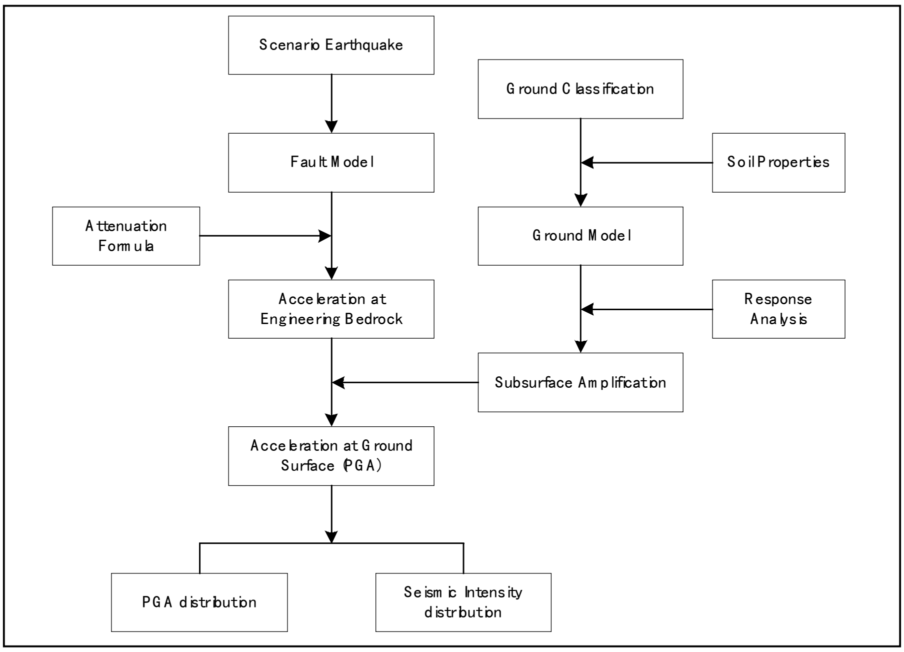


Figure 7.3.1 Flowchart for Earthquake Motion Analysis

(2) Acceleration at Engineering Seismic Bedrock

An attenuation formula was selected to evaluate the acceleration at engineering bedrock. In this study, the engineering bedrock was assumed to be the layer at which the shear wave velocity (Vs) exceeds 400m/s, which exists almost 100m below the surface. Based on the comparison between the earthquake motion data of the 1988 Udayapur earthquake and the existing formulae, the formulae by Boore et al. (1997) were selected for this study.

(3) Amplification of Subsurface Ground

The amplification of the subsurface layer was analysed using one-dimensional response analysis. The ground model for response analysis was made from typical column data, by indentifying several layers based on the soil type and shear wave velocity.

The amplification factor for each ground model was almost 1.0 to 2.0.

(4) Peak Ground Acceleration

The PGA distribution maps of the three newly selected scenario earthquakes are shown in attached Figure 7.3.2

a) Mid Nepal earthquake: Except for the mountainous areas, the Valley would experience over 200 gal. Some areas would experience more than 300 gal.
b) North Bagmati earthquake: The whole Valley would experience less than 200

gal. The Valley would experience the smallest peak ground acceleration in these four scenario earthquakes.

c) KV Local earthquake: The area along the fault would experience over 300 gal. The peak ground acceleration would decrease rapidly with distance from the fault line. The Valley would experience less than 100 gal in mountainous areas.

(5) Seismic Intensity

The seismic intensity in Modified Mercali Intensity (MMI) scale was derived from PGA values based on the relationship proposed by Trifunac and Brady(1975). The seismic intensity distribution maps of the three scenario earthquakes are shown in attached Figure 7.3.3.

a) Mid Nepal earthquake: Except in mountainous areas, MMI VIII would be experienced in the Valley.
b) North Bagmati earthquake: Except in mountainous areas, the Valley would experience MMI VI or VII.
c) KV Local earthquake: The area along the fault would experience MMI IX. Other parts of the Valley, except the mountainous areas, would experience MMI VII or VIII.

7.4 Liquefaction

(1) Analysis Method

A combination of the F_L method (Japanese Design Specification of Highway Bridge, 1996) and the P_L method (Iwasaki et al., 1982) was adopted in this study. This combined method is commonly used in Japan for practical purposes. The flowchart of the liquefaction analysis used in this study is shown in Figure 7.4.1.

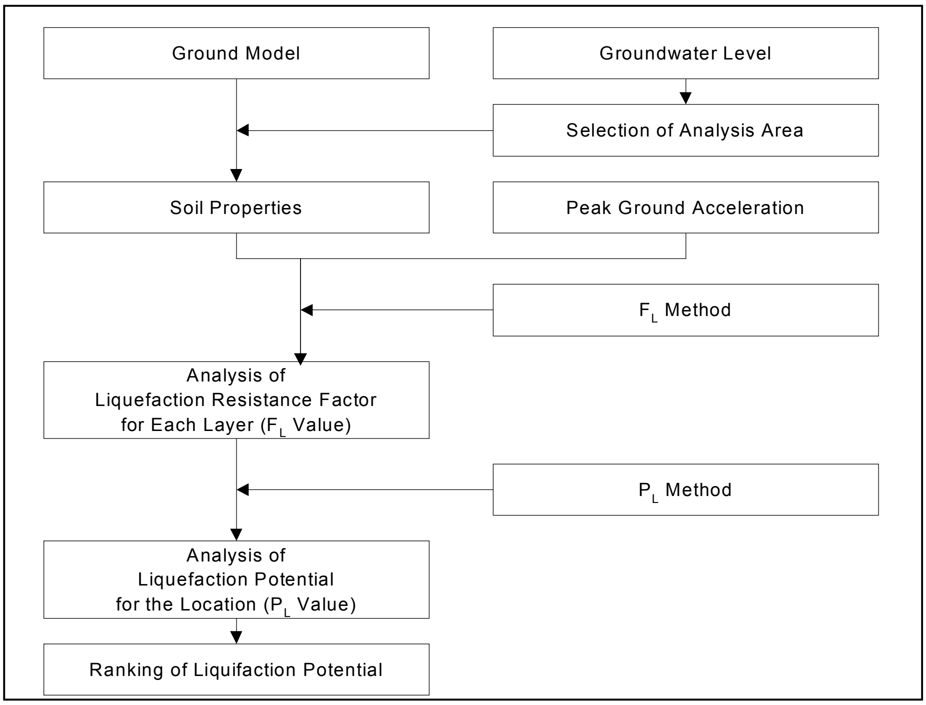


Figure 7.4.1 Flowchart of Liquefaction Analysis

(2) Groundwater Model

Based on the data on groundwater level by JICA(1990), the groundwater distribution in dry season and rainy season was estimated. The F_L method defines that areas with groundwater level of less than 10 m from the ground surface are stable in terms of liquefaction. The ground water level along the river was estimated to be less than five meters from the ground surface.

(3) Liquefaction Potential

The liquefaction potential distribution maps in case of High Water Level are shown in attached Figure 7.4.2. It can be common that liquefaction potential is very low in most of the Valley. But the following features of the three scenario earthquakes can be identified.

a) Mid Nepal earthquake: Moderate potential was identified in some areas along the Bagmati River.
b) North Bagmati earthquake: No part of the Valley would be liquefied because there is only very low liquefaction potential.
c) KV Local earthquake: A few grid cells close to the fault were judged to have high liquefaction potential. Along the Bagmati River, there are some grid cells with moderate potential.

7.5 Slope Stability

The examination on slope stability was based on slope gradient and slope height in this study. Geomorphologically, the Kathmandu Valley is roughly divided into two areas, 1) a mountainous area surrounding the Valley and 2) a gentle area in the centre of the Valley. In the mountainous area, the areas of slope failure shown on "Engineering and Environmental Geological Map" are re-shown in Figure 7.5.1 as areas with high possibility of slope failure. In the gentle area, narrow zones of steep slopes are seen along the edge of terrace surfaces. The potential hazard was determined on the basis of relative height of the terrace surface as shown in Table 7.5.1.

Table 7.5.1 Potential for Slope Failure

Possibility	Gentle Area	Mountainous Area
	Relative height (RH)	Slope failure
Low	RH ≤ 15 m	-
Moderate	15 m < RH ≤ 50 m	-
High	50 m < RH	Identified on air-photos

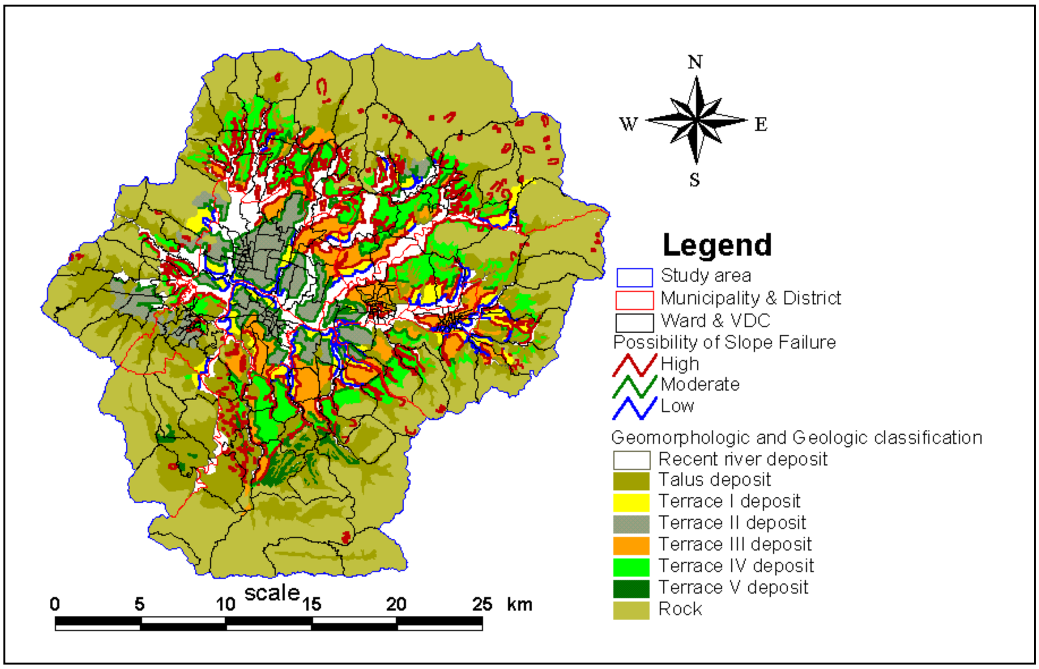


Figure 7.5.1 Slope Stability

7.6 Fundamental Social Data

(1) Administration Boundaries

The Kathmandu Valley consists of the three Districts of Kathmandu, Lalitpur and Bhaktapur. Each District consists of municipalities and VDCs. Municipalities and VDCs are divided into Wards as shown in Table 7.6.1 and Figure 7.6.1.

Table 7.6.1 Administrative Classification

	District	Municipality & VDC	Number of Wards
Kathmandu Valley	Kathmandu District	Kathmandu Metropolitan City	35
		Kirtipur Municipality	19
		56 VDCs	9 Wards in a VDC in general
	Lalitpur District	Lalitpur Sub-Metropolitan City	22
		26 VDCs	9 Wards in a VDC in general
	Bhaktapur District	Bhaktapur Municipality	17
		Madhyapur/Thimi Municipality	17
		16 VDCs	9 Wards in a VDC in general
Total	3 Districts	5 Municipalities & 98 VDCs	110 Municipal Wards

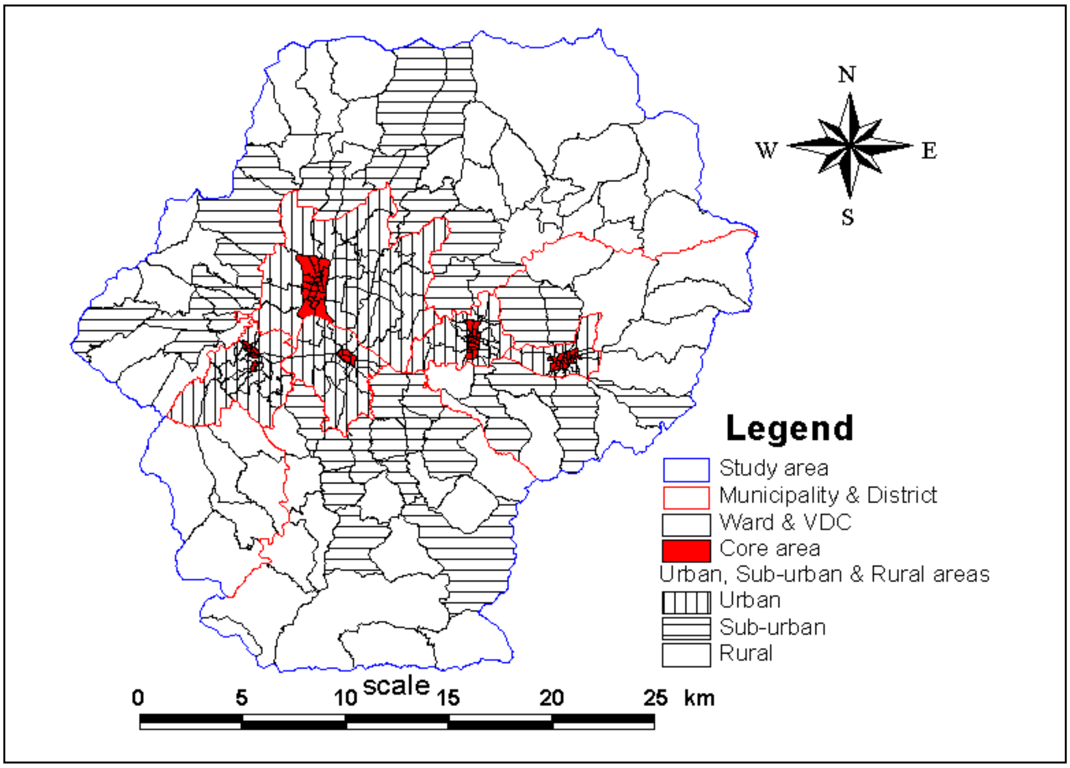


Figure 7.6.1 Administrative Boundary and Locality Classification

(2) Locality Classifications

According to the Kathmandu Valley Town Development Committee and Gorkhapatra (the national daily newspaper), the Valley is divided into locality categories as follows.

a) Urban area: urbanised area corresponding to the five municipalities; population density is mostly over 100 persons/ha.

b) Sub-urban area: relatively urbanised and adjacent to the municipalities.

c) Rural area: non-urbanised area consists of VDCs other than the sub-urban VDCs.

(3) Population and Households

Record on Nepalese Development NEPAL District Profile (National Research Associates, 1999) forecasts the population and number of households for the year of 1998 as summarised in Table 7.6.2 and Figure 7.6.2, based on the result of the census in 1991

Table 7.6.2 Population and Household Projection in the Kathmandu Valley

Area	Area (km^2)	Population	Household	Density (person/ha)	Person in Household	Growth Rate (%)
Kathamndu District	373.9	908,672	171,405	24.3	5.3	4.5
Kathamndu Metropolitan City	50.5	578,738	111,711	114.5	5.2	
Kirtipur Municipality	18.0	43,803	7,928	24.4	5.5	
Kathmandu VDC	305.3	286,132	51,766	9.4	5.5	
Lalitpur District	171.1	292,095	54,907	17.1	5.3	3.3
Lalitpur Sub-Metropolitan City	15.4	145,696	28,537	94.4	5.3	
Lalitpur VDC	155.7	146,399	26,370	9.4	5.6	
Bhaktapur District	122.6	187,059	29,891	15.3	6.3	0.8
Bhaktapur Municipality	6.9	64,927	9,714	94.7	6.7	
Madhyapur-Thimi Municipality	11.1	37,526	5,545	33.8	5.6	
Bhaktapur VDC	104.7	84,606	14,632	8.1	5.8	
	667.6	1,387,826	256,203	20.8	5.4	3.7

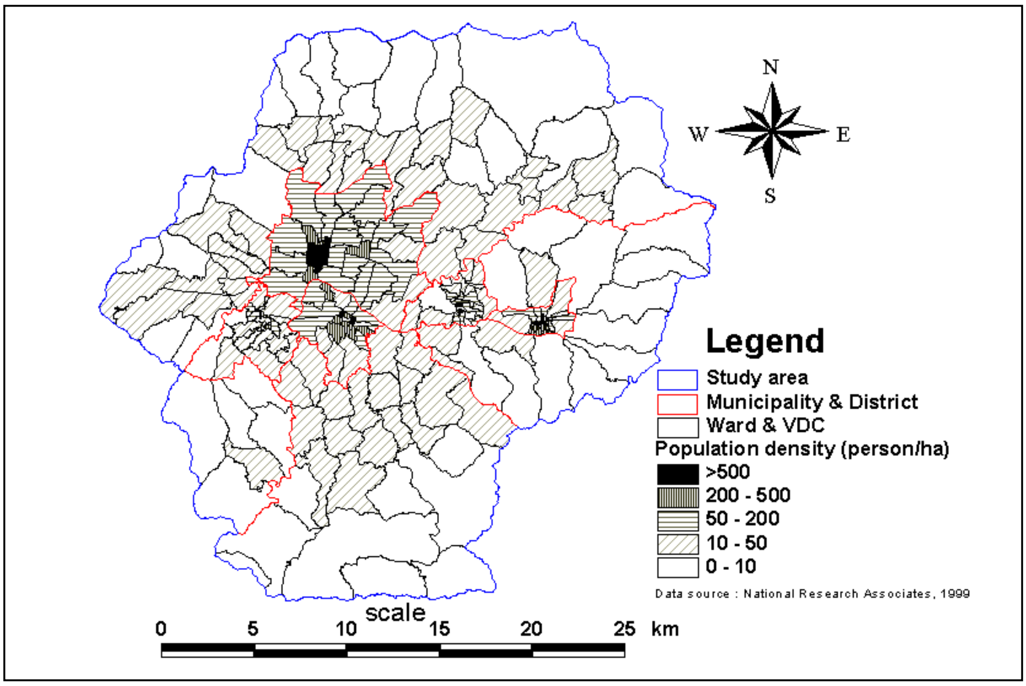


Figure 7.6.2 Population Density in Ward and VDC

(4) Land Use

Agricultural land is predominant in the Kathmandu Valley followed by forests and grasslands. Over the past few decades, the urban built-up area has sprawled across agricultural land and recently to more fertile agricultural land along the river flood plains closer to the developed urbanising areas of the five Municipalities.

Agricultural land in the Kathmandu Valley has reduced and urban land has increased correspondingly as shown in the Table 7.6.3.

Table 7.6.3 Land Use in the Kathmandu Valley

	1984 *1)		1994 *1)		2000 *2)	
Land Use	Area (ha)	%	Area (ha)	%	Area (ha)	%
Urban	3,096	4.8	8,378	13.1	9,193 *3)	13.8
Agriculture	40,950	64.0	33,308	52.1	27,570	41.4
Forest/Grassland	19,439	30.4	20,945	32.7	20,677	31.0
River	479	0.8	583	0.9	496	0.7
Others (airport/pond, etc)	NA	-	336	0.5	310 *4)	0.5
Abandoned land	NA	-	414	0.7	NA	-
Rural Settlement *5)	NA	-	NA	-	8404	12.6
Total	63,964	100	63,964	100	66,655	100

1) Source: Regulating Growth: Kathmandu Valley IUCN 1995
2) Source: Draft Development Plan 2020 for Kathmandu Valley; KVTDC, 2000
3) Includes 2,593 ha of new residential development in VDCs which are mainly urban sprawl
4) Covers transportation only
5) Consists predominantly of traditional village settlements.

7.7 Damage to Buildings

(1) Inventory

A Building Inventory was carried out by the Study Team to clarify the nature, distribution and strength of buildings in the Kathmandu Valley. The distribution of each type of building was also clarified to assess likely damage due to earthquakes. The procedure of the inventory was: inventory of over 1000 sample buildings; onsite observation; and data analysis for hazard assessment and mitigation planning.

The number of buildings was assumed to be 256,200; the same as the number of households projected to1988 on the basis of census data in 1981 and 1991.

(2) Building type and its distribution

The grade of damage depends on the intensity of ground motion and the strength of the buildings. Since strength is closely related to the type of building, classification of the buildings was conducted as the first step in estimation of damage. Buildings were classified into the following seven types.

a) Stone (ST)
b) Adobe (AD)
c) Brick with mud mortar, Type 1; Regularly built (BM)
d) Brick with mud mortar, Type 2; Well built (BMW)
e) Brick with cement mortar (BC)
f) Reinforced concrete frame with masonry, Type 1; 4 stories or more (RC5)

g) Reinforced concrete frame with masonry, Type 1; 3 stories or less (RC3)

The distribution of building types was mapped by visual observation supplemented with building inventory survey data, topographic maps and aerial photographs as shown in Figure 7.7.1.

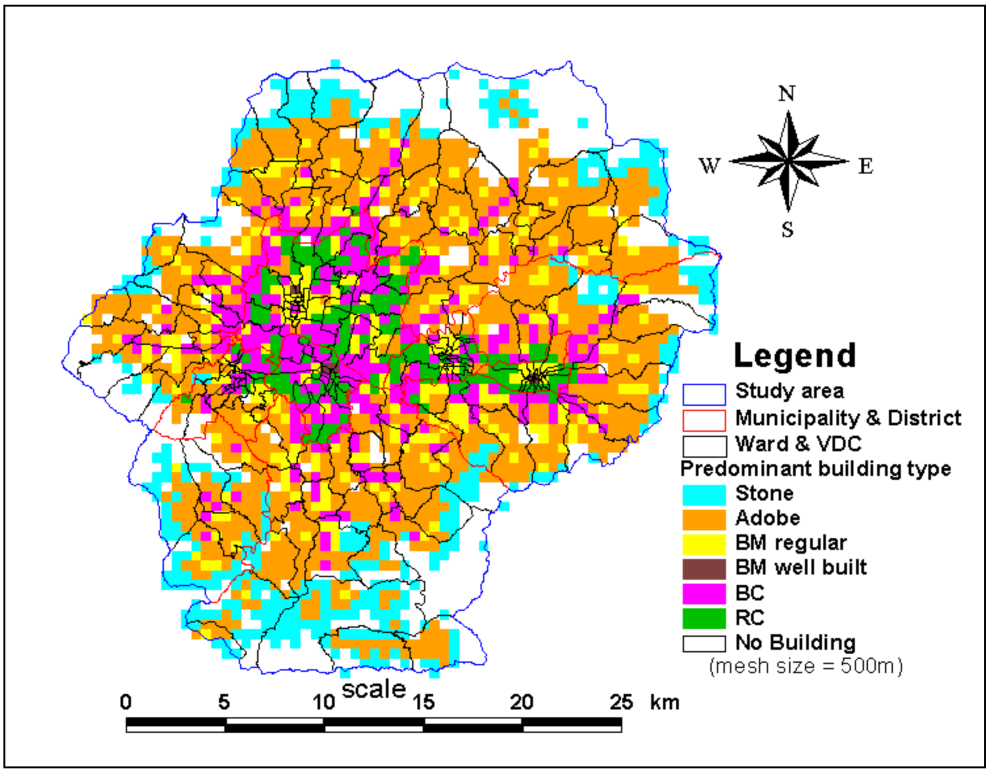


Figure 7.7.1 Classification Map showing Predominant Building Type

(3) Fragility Curves

The second step in estimating damage to buildings was to determine the relationship between damage ratio and ground acceleration for each type of building. The graph showing this relationship is called the "Fragility Curve". In this study, fragility curves for buildings in the Kathmandu Valley were determined as shown in Table 7.7.1 and Figure 7.7.2.

Table 7.7.1 Existing and Calibrated Fragility Curves

Type of Buildings	Existing curve		Fragility Curve for this Study	
	Prof. Arya	UNDP	Damage Rate	Collapse Rate
Stone (ST)	A		A++	B
Adobe (AD)	A to A+		A++	B
Brick with mud mortar (BM)	B- to B		B	B++
Well-built brick with mud mortar (BMW)	B+		B++	C1
Brick with cement or lime mortar (BC)	B to C1		B++	C1
RC frame with masonry of 4 stories or more (RC5)	C1	K5	1/2[(K5)+(B++)]	1/4[(K5)+(B++)]
RC frame with masonry of 3 stories or less (RC3)	C2	K3	1/2[(K3)+(B++)]	1/4[(K3)+(B++)]

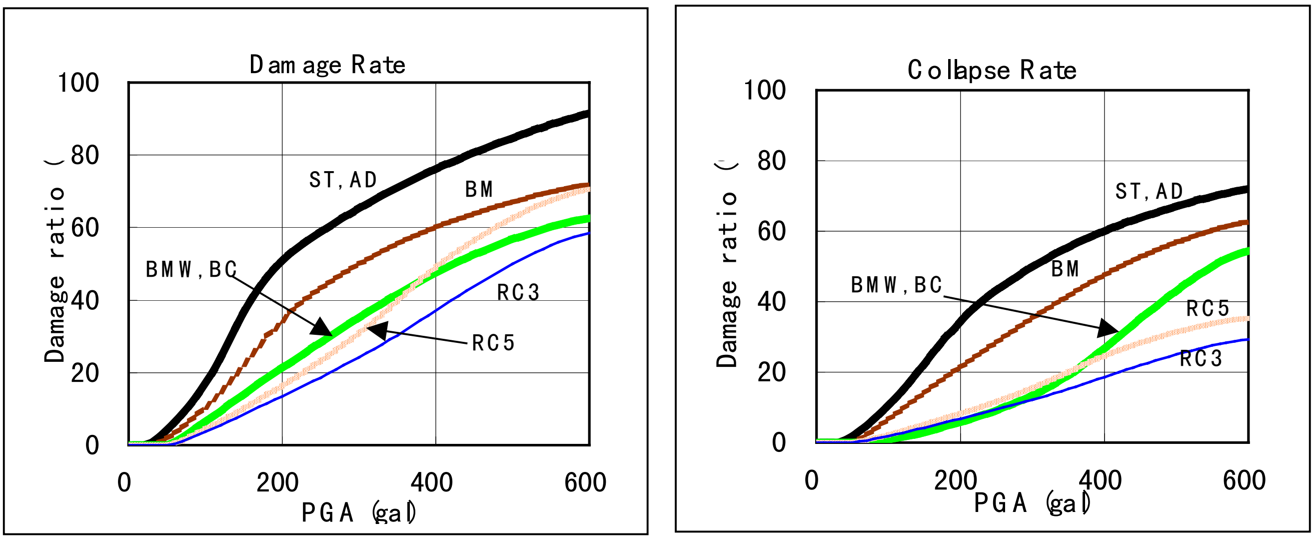


Figure 7.7.2 Fragility Curves Used in the Study

(4) Damage Estimation

The building damages were estimated for four scenario earthquakes: Mid Nepal, North Bagmati, Kathmandu Valley Local and the 1934 Earthquake. In addition to the four scenario earthquakes, another scenario earthquake, that is the 1934 earthquake occurring in the present conditions, was prepared in order to show the increase of vulnerability due to recent urbanisation. The basic factors for the calculation of damage are the strength of the buildings and seismic vibration. Other triggered factors such as liquefaction, landslide and fire were not considered in the calculation. The outline of the damage estimation criteria is summarised in Table 7.7.2.

Table 7.7.2 Outline of Building Damage Estimation

Object	Residential building
Calculation unit	Each building
Cause of damage	Seismic vibration
Definition of damage	Heavily: Collapsed or un-repairable (unliveable) Partly: Repairable (available for temporary evacuation)

Damage and collapse rates from the fragility curves of the previous section are based on the figures for reconstruction or repair. Heavily damaged and partly damaged rates in this section are based on the number of buildings. The relation between the categories is accordingly as follows.

a) Damage rate = Heavily damaged rate + 1/2 partly damaged rate

b) Collapse rate = Heavily damaged rate

The damages were calculated for each grid cell and structure type. The results are shown in attached Figures 7.7.3 to 7.7.4 and summarised in Table 7.7.3.

Table 7.7.3 Estimated Damage of Residential Buildings

	Heavily	Partly	Total
Mid Nepal Earthquake	53,465 (20.9%)	74,941 (29.2%)	128,406 (50.1%)
North Bagmati Earthquake	14,796 (5.8%)	28,345 (11.1%)	43,141 (16.8%)
KV Local Earthquake	46,596 (18.2%)	68,820 (26.9%)	115,416 (45.0%)
1934 Earthquake in present	58,701 (22.9%)	77,773 (30.4%)	136,474 (53.3%)
1934 Earthquake in 1934	19,395 (36.2%)	16,197 (30.2%)	35,592 (66.3%)

Characteristics of estimated damage for each scenario earthquake are as follows:

a) Mid Nepal Earthquake

The total number of heavily damaged buildings in the Valley was estimated as 53,000 (21%). In total, 50% of the buildings were estimated to be heavily or partly damaged. The estimated number of damaged buildings was large in the core areas of Kathmandu, Lalitpur and Bhaktapur municipalities. The reason for the large number seems to be due to the high density of buildings in these areas. On the other hand, the damage ratio is larger in rural areas than in urban areas. The reason for the larger proportion of damage in these rural areas seems to be due to the type of buildings, i.e., comparatively stiff RC buildings are dominant in the urban area, while weak Stone or Adobe buildings are dominant in rural areas.

b) North Bagmati Earthquake

The total number of heavily damaged buildings in the Valley was estimated to be 15,000 (6%). In total, 17% of the buildings were estimated as being partly or heavily damaged. The estimated number of damaged buildings was large in the Kathmandu municipality core area. The damage ratio in the northern part of the Valley was comparatively high because the seismic intensity is large in the northern area.

c) KV Local Earthquake

The total number of heavily damaged buildings in the Valley was estimated to be 47,000 (18%). In total, 45% of buildings were estimated to be either partly or heavily damaged. The number of damaged buildings was estimated to be large in the core areas of Kathmandu, Lalitpur and Bhaktapur Municipalities. The damage ratio of the western part of the Valley is much higher than that of the other area in the Valley because the seismic intensity is higher around the earthquake fault in this model.

7.8 Damage to Major Public Facilities

Building damages for the following major public facilities were estimated by the same method as that for residential building damage estimation.

a) School.
b) Hospital.
c) Fire station.

(1) Schools

There are 2,497 schools in the Kathmandu Valley, 689 of them are public and 1,808 are private. Public schools provide 10 years of education from primary to secondary. In this study, only 347 public schools (almost half the total number) could be inventoried. The estimated damages are summarised in Table 7.8.1.

Table 7.8.1 Damage to Schools

Scenario Earthquake	Heavily	Partly	Total
Mid Nepal Earthquake	74 (22%)	102 (30%)	196 (57%)
North Bagmati Earthquake	20 (6%)	37 (11%)	57 (17%)

The damage ratio for schools is worse than that for residential buildings, because the percentage of comparatively weak structure types of schools is higher than that of residential buildings as shown in Figure 7.8.1.

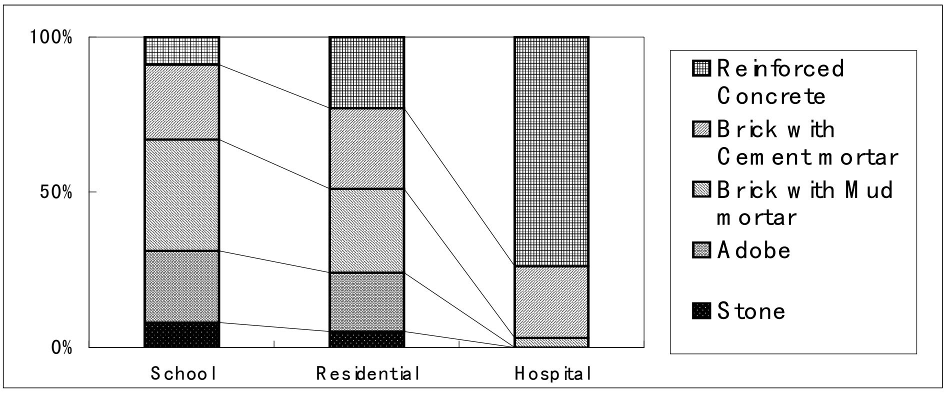


Figure 7.8.1 Structure Type Ratio of Schools, Residential Buildings and Hospitals

This result would indicate that school buildings could not be used for shelters after an earthquake.

(2) Hospitals

There are 47 hospitals in the Valley, almost all of which are located inside the municipalities. The number of buildings is usually one or two for each hospital. The buildings are 3 or 4 storied of brick with cement mortar or reinforcement that will be less vulnerable to earthquakes as shown in Figure 7.8.1, although fixtures, lifelines and equipment are still vulnerable. The estimated damages are summarised in Table 7.8.2.

Table 7.8.2 Damage to Hospitals

Scenario Earthquake	Heavily	Partly	Total
Mid Nepal Earthquake	5 (11%)	12 (26%)	17 (36%)
North Bagmati Earthquake	1 (2%)	4 (9%)	5 (11%)

The damage ratio for hospitals is lower than that for residential buildings, because the dominant type of hospital building is relatively strong RC.

(3) Fire Stations

There are only three fire stations in the Valley. They are located in Kathmandu, Lalitpur and Bhaktapur Municipality. The structure type of all station buildings is brick with cement mortar or brick with lime mortar. The estimated damages are summarised in Table 7.8.3.

Table 7.8.3 Damage to Fire Stations

Scenario Earthquake	Heavily	Partly	Total
Mid Nepal Earthquake	8%	37%	45%
North Bagmati Earthquake	1%	13%	14%

This result indicates that it might be possible to dispatch fire engines to fire scenes after an earthquake, although the number would not be sufficient.

7.9 Casualties

Building collapse was the most notable cause of human casualty in past earthquakes. The human casualties caused by building collapse were taken into account in the Study.

(1) Analysis Method

To estimate the death toll, the empirical relation between the number of heavily damaged buildings and death toll was used. Figure 7.9.1 shows the relationship between the number of heavily damaged or collapsed building and death toll from the 1934 Bihar-Nepal earthquake and the 1988 Udayapur earthquake. The black line defined by least square method in Figure 7.9.1 is the empirical relationship that was used to calculate the death toll in this study.

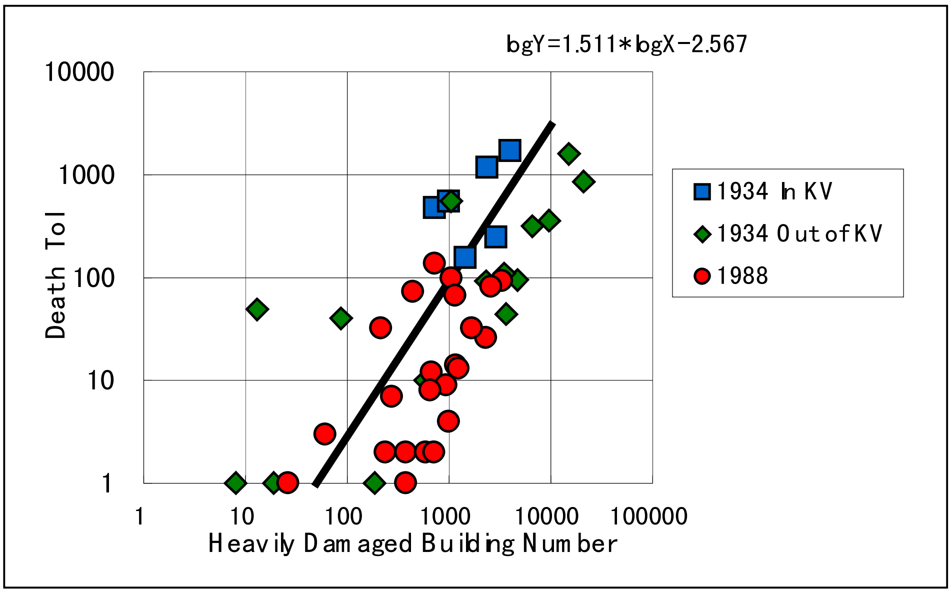


Figure 7.9.1 Empirical Relation of Building Damage and Death Toll in Nepal

To estimate the number of injured people, the empirical relation between death toll and number injured is adopted. Figure 7.9.2 shows the relation of the seriously injured or moderately injured and the death toll from the 1988 Udayapur earthquake.

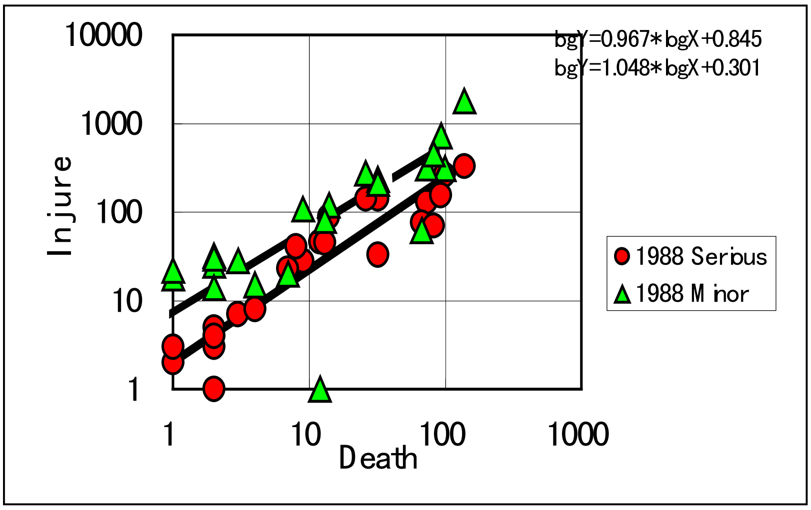


Figure 7.9.2 Empirical Relation between Death Toll and Injured in Nepal

(2) Estimation of Casualties

The death toll and number of injured due to the scenario earthquakes were estimated. The cause of casualties is only building collapse and not because of any other cause. In large-scale earthquakes, people might die from diseases in refugee camps but this source of casualty was not included in the assumption. The definition of the estimation is shown in Table 7.9.1.

Table 7.9.1 Definition of Casualty Estimation

Casualties	Death, Seriously Injured, Moderately Injured
Unit	Person
Cause of Damage	Collapse of Buildings

The casualties were calculated for each ward and VDC. The results are shown in attached Figures 7.9.3 to 7.9.4, and summarised in Table 7.9.2.

Table 7.9.2 Estimated Casualties

Scenario Earthquake	Death	Injured	
		Seriously	Moderate
Mid Nepal Earthquake	17,695 (1.3%)	53,241 (3.8%)	93,633 (6.7%)
North Bagmati Earthquake	2,616 (0.2%)	7,204 (0.5%)	14,709 (1.1%)
KV Local Earthquake	14,333 (1.0%)	42,667 (3.1%)	76,399 (5.5%)
1934 Earthquake in present	19,523 (1.4%)	58,728 (4.2%)	103,313 (7.4%)
1934 Earthquake in 1934	3,814 (1.3%)	10,635 (3.6%)	21,263 (7.2%)

The characteristics of the casualties for each scenario earthquakes are as follows:

a) Mid Nepal Earthquake

The death toll is estimated as 18,000, i.e. 1.3% of the total people in the Valley. The seriously injured people are about 53,000. The number of fatalities in Ward/VDC is largest in the Kathmandu Municipality. The density of both the death toll and total casualties is large in the core areas in Kathmandu, Lalitpur and Bhaktapur municipalities.

b) North Bagmati Earthquake

The death toll is estimated as 2,600, i.e. 0.2% of the total people in the Valley. The number of seriously injured is 7,200. The number of fatalities by Ward/VDC is large in the north of the Kathmandu Municipality. The Valley would experience the smallest damage in three scenario earthquakes.

c) KV Local Earthquake

The death toll is estimated as 14,000, i.e. 1.0% of the people in the Valley. About 43,000 people would be seriously injured. The density of both death toll and total casualties is large in the core areas in Kathmandu, Kirtipur, Lalitpur and Bhaktapur Municipalities. The Ward/VDC around the model fault is seriously affected.

(3) Validation

The relations between building damages and human casualties calculated in this study are compared with the relations of previous earthquake in order to check whether the calculation results accord with the general relation.

Coburn and Spence (1992) surveyed worldwide earthquake damages to identify the relationship between building damages and human casualties as shown in Figure 7.9.5. The general trend of the relationships and the results of the Study are added onto this figure. "Building damages" consist of only heavily damaged buildings, excluding buildings destroyed by fire or tsunami.

The relationship of weak masonry is positioned between the upper and lower trend lines. Four earthquake scenarios were prepared in this Study. In all cases, the relationship between the number of damaged buildings and the number of dead people agrees with those of weak masonry.

7.10 Damage to Bridges

(1) Bridge Data

The inventory database of bridges in the Valley was obtained from the Bridge Unit of DOR. An inventory survey was also carried out to obtain further information needed for damage estimation and planning that was not available in the DOR database and also to verify the actual conditions.

(2) Damage Estimation Method

The seismic damage possibility judgement of bridges is based on the method proposed by Tsuneo Katayama, which is widely used in Japan for practical purposes. The score of each factor is decided by the field reconnaissance of the Study Team. The results of the analyses are expressed as the product of the ten scores, one for each category. Judgement of the stability of bridges is generally defined as follows:

a) Score 26 and above : Collapsed
b) Score 20 to 26, and highly scoured : Unstable
c) Score below 26, and not highly scoured : Stable

(3) Damage Estimation

The results of the damage estimation for the bridges are shown in Figure 7.10.1.

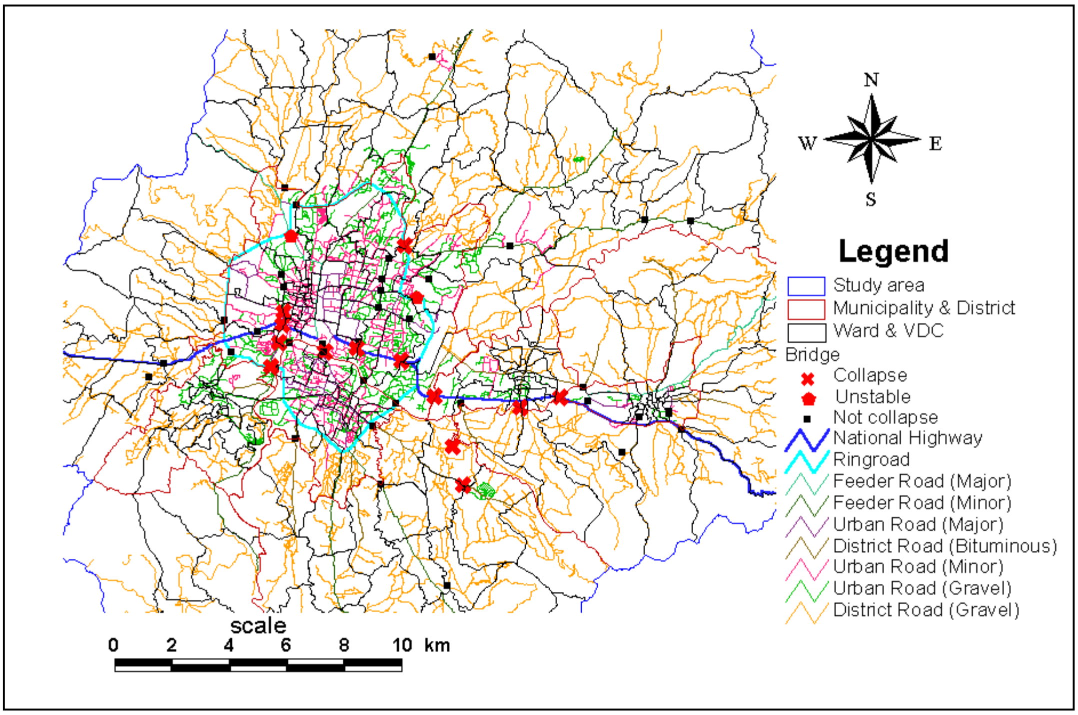


Figure 7.10.1 Bridge Damage Distribution -Mid Nepal Earthquake-

7.11 Damage to Roads

(1) Road Data

Digital maps of the Valley have been prepared by the Kathmandu Valley Town Development Committee (KVTDC, Ministry of Physical Planning and Works) under the "Kathmandu Valley Urban Development Project (KUDP)" in 1998 and "Development Plan 2020 of the Kathmandu Valley" in 2000. The KUDP data cover all the urban and sub-urban areas except for some of the rural areas near the boundary limits. These data outside the KUDP limits were obtained from the "Kathmandu Valley GIS Database" of the International Center for Integrated Mountain Development (ICIMOD), 2000.

(2) Damage Estimation

There are no roads with thick fill-embankment in the Valley. In this study, places where roads cross slopes more than 50 m high were taken as hazardous points. Figure 7.11.1 shows the hazardous points of the National Highway, Feeder Road Major, Feeder Road Minor, District Road Bituminous, Ring Road and Urban Road Major, which will be used as emergency access roads after a disaster.

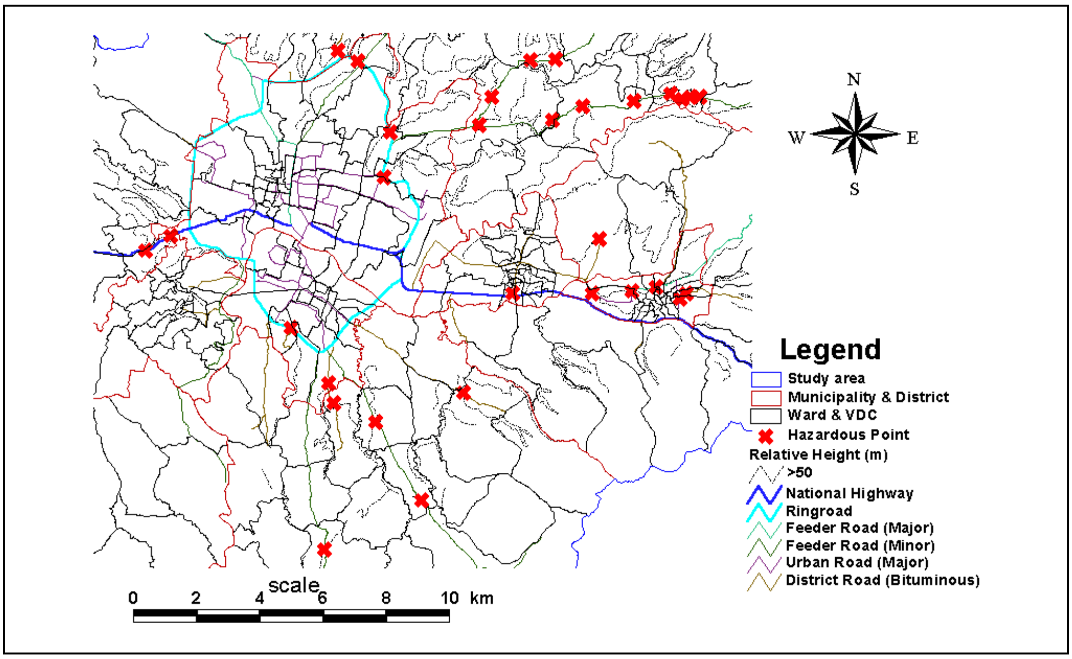


Figure 7.11.1 Hazardous Points of Roads

7.12 Damage to Lifeline Facilities

The following four lifeline facilities are considered in this section:

a) Water supply pipelines.

b) Sewerage pipelines.

c) Electric power supply lines.

d) Telecommunication lines.

Lifeline facilities are to be classified into two major categories, nodes and links. Nodes include facilities such as purification plants and substations. Links include facilities such as pipes or lines for supply and distribution purposes. A statistical approach for damage estimation of links, i.e. distribution pipes and lines, is applied in the Study.

(1) Water Supply Pipelines

A new damage function used in this study estimates a higher damage ratio than that of Kubo and Katayama (1975) because the construction quality in Nepal is poorer than in Japan, according to our field reconnaissance. But this new damage function is almost the same as that of ATC-13.

The damage estimation definition is as shown in Table 7.12.1.

Table 7.12.1 Definition of Pipeline Damage Estimation

Object	Distribution Pipeline
Content of Damage	Break of pipelines or joints
Amount of Damage	Number of damage points

The results of the damage estimations are shown in attached Figure 7.12.1 and summarised in Table 7.12.2.

Table 7.12.2 Estimated Damage of Water Supply Pipelines

Scenario Earthquake	Damage points
Mid Nepal Earthquake	588
North Bagmati Earthquake	63

(2) Sewerage Pipelines

The evaluation formula used for sewerage pipelines was the same as that for water supply pipelines. Data were provided on the type and diameter of pipes.

The damage estimation definition is shown in Table 7.12.3.

Table 7.12.3 Definition of Sewerage Damage Estimation

Object	Pipeline and channel
Content of Damage	Break of pipelines or joints
Amount of Damage	Number of damage points

The results of the damage estimations are show in attached Figure 7.12.1, and summarised in Table 7.12.4.

Table 7.12.4 Estimated Damage of Sewerage Pipelines

Scenario Earthquake	Damage points
Mid Nepal Earthquake	52
North Bagmati Earthquake	5

(3) Electric Power Supply Lines

A new damage function, used in this study, was based on the damage from the 1988 Udayapur earthquake. Dikshit (1991) reported that several electric pylons were damaged in areas of experiencing MMI VI (approximately 65 gal after Trifunac & Brady, 1975) in the 1988 Udayapur earthquake. From this damage, the smallest PGA that may cause damage to electrical power lines was estimated to be 65 gal.

There are several types of damage that can occur to electric power supply link facilities, such as breakage of poles, the falling down of transformers and severing of wires. Only damage to wires is treated in this Study, because of the limited data availability. The damage estimation definition is shown in Table 7.12.5.

Table 7.12.5 Definition of Damage Estimation of Power Supply Lines

Object	Electrical power lines over 11 kV
Content of Damage	Cut cables
Amount of Damage	Length of cables to be replaced

The results of the damage estimations are shown in attached Figure 7.13.2, and are summarised in Table 7.12.6.

Table 7.12.6 Estimated Damage of Electric Power Supply Lines

Scenario Earthquake	Damage length (km)
Mid Nepal Earthquake	6.2
North Bagmati Earthquake	1.2

Because only information about lines of more than 11 kV high voltage was available, the damage estimation was limited to the high voltage lines. The actual damage to lines of less than 11 kV would be much greater and should be taken into consideration at the time of disaster mitigation planning.

(4) Telecommunication Lines

Almost all “Primary” telecommunication cables are laid underground. The damage to underground lines in the 1995 Kobe earthquake was almost half that of overhead cables in areas with the same seismic intensity. From this experience, the damage function for telecommunication lines was estimated to be half that of the electrical power line damage function. The damage estimate definition is shown in Table 7.12.7.

Table 7.12.7 Definition of Damage Estimation of Telecommunication Lines

Object	Primary line
Content of Damage	Cut of lines
Amount of Damage	Length of cables to be replaced

The results of damage estimations are show in attached Figure 7.13.2, and are summarised in Table 7.12.8.

Table 7.12.8 Estimated Damage of Telecommunication Lines

Scenario Earthquake	Damage length (km)
Mid Nepal Earthquake	0.9
North Bagmati Earthquake	0.2

In this study, only the information about “Primary” lines was available as already mentioned. Therefore, the damage estimation was limited to the “Primary” lines. The actual damage to the lower level of lines would be much greater and this should be taken into consideration at the time of disaster mitigation planning.

7.13 Fire

The possibility of fire outbreaks from petrol stations and gas refilling stations was estimated. The distribution of vulnerability rating for each Ward/VDC under the scenario earthquakes is shown in Figure 7.13.1. There should be little possibility of fire spreading to other buildings because the buildings are mainly made of bricks. However it should be kept in mind that many fires occur immediately after an earthquake when fire fighting capacity is severely diminished. According to the statistics, electricity is a common cause of non-earthquake fires.

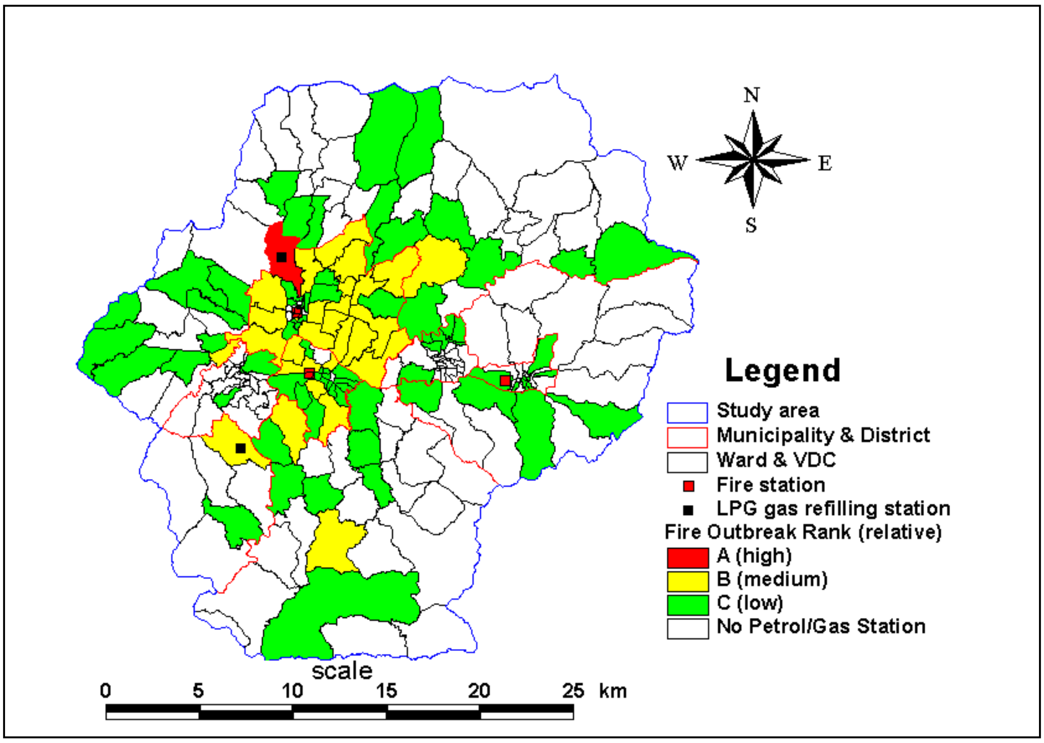


Figure 7.13.1 Fire Outbreak Rank by Petrol/ Gas Station – Mid Nepal Earthquake –