

SPATIAL ASSESSMENT OF SEISMIC VULNERABILITY  
IN INARUWA MUNICIPALITY

A THESIS  
SUBMITTED TO CENTRAL DEPARTMENT OF GEOGRAPHY  
FACULTY OF HUMANITIES AND SOCIAL SCIENCE IN PARTIAL  
FULFILLMENT OF THE REQUIREMENTS  
FOR THE MASTER'S DEGREE  
IN GEOGRAPHY

BY  
RAJU RAI

CENTRAL DEPARTMENT OF GEOGRAPHY  
TRIBHUVAN UNIVERSITY  
KIRTIPUR, KATHMANDU  
NEPAL

2009

## RECOMMENDATION LETTER

This is to certify that the thesis submitted by **Raju Rai** entitled “**Spatial Assessment of Seismic Vulnerability in Inaruwa Municipality**” has been prepared under my supervision in the partial fulfillment of the requirements for the degree of Master of Arts in Geography. I recommend this thesis to the evaluation committee for examination.

Date.....

---

Dr. Hriday L. Koirala  
Supervisor

TRIBHUVAN UNIVERSITY  
FACULTY OF HUMANITIES AND SOCIAL SCIENCES  
CENTRAL DEPARTMENT OF GEOGRAPHY

SPATIAL ASSESSMEN OF SEISMIC VULNERABILITY IN  
INARUWA MUNICIPALITY

Approved By

Head of the Department

---

Internal Examiner

---

External Examiner

---

**Dissertation Committee**

## ACKNOWLEDGEMENTS

At first, I would like to convey my sincere gratitude to Prof. Dr. Pushkar K. Pradhan, head of the central department of geography, T.U., for permitting me to carry out this research.

I would like to express my heartfelt gratitude to my supervisor Dr. Hriday L. Koirala, associate professor, central department of geography for his inexhaustible support, valuable suggestion, encouragement, and for priceless guidance in all stages of the study from the field work to the compilation to the work. I also express gratitude to my teacher Mr. Shambhu P. Khatiwada, associated professor, Dhankuta multiple campus, T. U for his invaluable suggestions.

I am extremely grateful to National Society for Earthquake Technology – Nepal (NSET-Nepal) for their technical and financial support to complete this thesis. I specially thanks to Mr Ganesh Kumar Jimme, EPR (Emergency Preparedness Response) Manager, NSET-Nepal for giving all the necessary support during the field and providing facilities for this research work. I extend also my sincere thanks to Mr Ramesh Guragain (Director, Earthquake Engineering & Research unit) Mr. Suresh Chaudhari (Geographer and Urban Planner) and all its member for their valuable suggestion.

I would like to extend my sincere thank to Department of Urban Development and Building Construction (DUDBC), Babarmahal Kathmandu for providing necessary spatial data. I am thankful to Mr. Rajendra Pradhan (DUDBC) for his support and suggestions.

At last, I would like to thank Mr. Mahesh Pathak, Mr. Yograj Gautam, Mr. Dipak Shrestha, Mr. Suraj Sonar, Mr. Ambika Khanal, Mr. Praksha Rai and my college friend for the intriguing academic and general discussions to complete this thesis.

Last but not the least this research would not be in this form unless the supports, inspiration and encouragement from family members and well wishers, therefore I would like them all.

Raju Rai  
August, 2009

# TABLE OF CONTENT

	<b>PAGE NO.</b>
<b>Approval Sheet</b>	
Acknowledgements	I
Table of Content	II
List of Tables	V
List of Figures	VI
List of Photographs	VII
Abbreviations	VIII
Glossary	X
<b>CHAPTER I: INTRODUCTION</b>	<b>1-6</b>
1.1 Background	1
1.2 Statement of the problem	4
1.3 Objectives of the research	5
1.4 Importance of research	5
1.5 Limitation of the research	6
<b>CHAPTER III: REVIEW OF LITERATURE</b>	<b>7-18</b>
2.1 Explanation of earthquake in relation to fault and plate boundary	7
2.2 Earthquake effect on building	11
2.3 Natural hazard in Nepal	11
2.4 Earthquake studies in Nepal	12
3.5 Seismic vulnerability assessment in Nepal	16
3.6 Research gaps	18
<b>CHAPTER II: RESEARCH METHODOLOGY</b>	<b>18-30</b>

3.1 Data collection methods and tools	20
3.2 Data processing methods and tools	22
3.3 Fragility function of building	28
3.4 Define earthquake scenario	29
3.5 Field work as an experience	30
<b>CHAPTER IV: RESEARCH AREA</b>	<b>31-37</b>
4.1 Geographical settings	31
4.2 Social conditions	33
4.3 Economic conditions	33
4.4 Institutions and organizations	36
<b>CHAPTER V: NATURE AND TYPES OF BUILDINGS</b>	<b>38-44</b>
5.1 Building classification	38
5.2 Age and structure of buildings	40
5.3 Building heights	43
5.4 Building geometry	43
5.5 Building attachment	44
<b>CHAPTER VI: BUILDING VULNERABILITY ASSESSMENT</b>	<b>45-64</b>
6.1 Earthquake scenario in Inaruwa municipality	45
6.2 Earthquake intensity distribution	47
6.3 North East Sunsari earthquake scenario	48
6.4 Mid Udayapur earthquake scenario	55
6.5 North west Saptari earthquake scenario	60
<b>CHAPTER VII: KNOWLEDGE &amp; AWARENESS OF EARTHQUAKE</b>	<b>65-67</b>

## **CHAPTER VIII: SUMMARY, CONCLUSIONS & RECOMMENDATIONS**

**68-70**

8.1 Summary

68

8.2 Conclusion

69

8.3 Recommendation

70

## **REFERENCES**

**71-73**

## **ANNEX**

**74- 80**

1. Building inventory form
2. Index of short form
3. Household survey form
4. Photographs

74

75

76

77

## LIST OF TABLES

<b>List of Tables</b>	<b>Page No.</b>
Table 2.1: Scale of earthquake intensity & approximately corresponding magnitudes	10
Table 2.2: Disaster losses in Nepal 1971 – 2006	12
Table 2.3: Direct losses due to earthquake	14
Table 2.4: Major earthquake in Nepalese history	15
Table 3.1: Source and nature of data	20
Table 3.2: Distribution pattern of sample households in different wards	21
Table 3.3: Identification of mesh weight	25
Table 3.4: Local soil types	25
Table 3.5: Building classification in RADIUS method	27
Table 3.6: Fragility function for buildings in Nepal	29
Table 3.7: Earthquake scenario	29
Table 4.1: Number of household and population	34
Table 5.1: Building classification other different parameters	39
Table 5.2: Scale of vulnerability	40
Table 5.3: Age of building in Inaruwa municipality	41
Table 5.4: Building types	42
Table 5.5: Building geometry	44
Table 6.1: Earthquake scenarios in the study area	46
Table 6.2: Ward wise building counts and damage	48
Table 6.3: Estimation of casualties injury and death	50
Table 6.4: Estimation of casualties injury and death during night	53
Table 6.5: Estimation of building damage in Mid Udayapur earthquake	56
Table 6.6: Estimation of casualties (death and injury) during day	58
Table 6.7: Estimation of casualties (death and injury) during night	59
Table 6.8: Building damage by the North West Saptari earthquake	61



Table 6.9: Estimation of casualties (death and injury) during day	62
Table 6.10: Estimation of casualties (death and injury) during night	64
Table 7.1: Knowledge and awareness of earthquake events	66

<b>List of Figures</b>	<b>Page No.</b>
Figure 1.1: Relationship of seismic focus, epicenter and homoseismal lines	2
Figure 1.2: Seismic hazard in Nepal	3
Figure 1.3: Global seismic hazard zones	4
Figure 2.1: Types of fault	7
Figure 2.2: Plate boundaries	9
Figure 2.3: Seismic zones of Nepal	13
Figure 2.4: Seismic hazard map of Nepal	13
Figure 3.1: Flow cart of research methodology	19
Figure 3.2: Building updating	22
Figure 3.3: Flow chart of RADIUS	23
Figure 3.4: Generation of mesh/grid and area id in RADIUS	26
Figure 3.5: Area id inventory form	28
Figure 3.6: Information of earthquake scenario	30
Figure 4.1: Location of stud area	31
Figure 4.2: Relief of Inaruwa municipality	32
Figure 4.3: Land use types of Inaruwa	33
Figure 4.4: Settlement distribution	34
Figure 4.5: Basic services in Inaruwa municipality	37
Figure 5.1: Building types	42
Figure 5.2: Building story	43
Figure 5.3: Building attachment	44
Figure 6.1: Distances and direction of the earthquake scenario	46
Figure 6.2: Earthquake intensity distribution in Inaruwa municipality	47
Figure 6.3: Ward wise building counts, building damage	49
Figure 6.4: Estimation of building damage	49

Figure 6.5: Estimation of casualties (injury and death)	51
Figure 6.6: Population casualties (injury) during day	51
Figure 6.7: Population casualties deaths in day	52
Figure 6.8: Estimation of casualties (injury and death)	54
Figure 6.9: Estimation of population casualties (injury)	54
Figure 6.10: Estimation of casualties (deaths) during night hours	55
Figure 6.11: Estimation of building damage by Mid Udayapur earthquake	57
Figure 6.12: Estimation of casualties in day	58
Figure 6.13: Estimation of casualties	60
Figure 6.14: Estimation of building damage	61
Figure 6.15: Estimation of casualties	63
Figure 6. 16: Estimation of casualties	64
<b>List of Photographs</b>	
Photograph 1. Earthquake in Kathmandu (1990).	77
Photograph 2. Bhaktapur Darbar Squar before and after 1990 Earthquake	77
Photograph 3. Earthquakes in Nepal(Dhading and Dharan)	77
Photograph 4. 2045 Earthquake in Nepal	78
Photograph 5. 2045 Earthquake in Nepal	78
Photograph 6. Earthquake in India	78
Photograph 7.Earthquake in Pakistan	78
Photograph 8. Inaruwa municipality (Towers on the roof)	79
Photograph 9. Vulnerable Building (Inaruwa municipality)	79
Photograph 10. Local type of building of Madhesi Indigenous	79
Photograph 11. Earthquake Safe Buildings (Inaruwa municipality)	80
Photograph 12. Shrub types of buildings (Inaruwa municipality)	80

## ABBRAVIATION

Ad	Adobe
Bc	Brick in Cement
BCDP	Building Code Development Project
Bm	Brick in Mud
Cam	Campus
CBS	Central Bureau of Statistics
CGL	Steel
Cn	Concrete
Com	Commercial
DEPENET	Disaster Preparedness Network Nepal
DUDBC	Department of Urban Development and Building Construction
E	Epicenter
F	Focus
GIS	Geographical Information System
GPS	Global Positioning System
H	Hospital
HH	Households
HR	Hotel Restaurant
IM	Inaruwa Municipality
INGO	International Non Governmental Organization
IR	Irregular
ITC	International Institute of Geo-information Science and Earth Observation
JICA	Japan International Cooperation Agency
KIS	Key Informant Survey
MBT	Main Boundary Thrust
MCT	Main Central Thrust

MDR	Mean Damage Ratio
MMI	Modified Mercally Intensity
MuAN	Municipal Association of Nepal
NA	Not Available
NGO	Non Governmental Organization
NSET	National Society for Earthquake Technology
NSDRM	National Strategy for Disaster Risk Management
OI	Office Institute
Ps	Police Station
PESH	Potential Earth Science Hazard
PGA	Peak Ground Acceleration
PGD	Peak Ground Deformation
R1	Regular (ratio less than 1:3)
R2	Regular (ratio more than 1:3)
RADIUS	Risk Assessment tools for Diagnosis of Urban Areas against Seismic Disasters
RCC	Reinforced Cement Concrete
Res	Residential
RS	Remote Sensing
SA	Spectral Acceleration
Sch	School
SD	Spectral Displacement
Sh	Shrub
Th	Thatch
UNDP	United Nations Development Program
VDC	Village Development Committee
W	Wood

## GLOSARRY

**Seismic Waves:** Vibrations that travel outward from the earthquake fault at speeds of several miles per second. Although fault slippage directly under a structure can cause considerable damage, the vibrations of seismic waves cause most of the destruction during earthquakes.

**Intensity:** The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. There is much intensity for an earthquake, depending on where we are, unlike the magnitude, which is one number for each earthquake.

**Magnitude:** The amount of energy released during an earthquake a magnitude of 7.0 on the Richter scale indicates an extremely strong earthquake. Scientists assign a magnitude rating to earthquakes based on the strength and duration of their seismic waves. A quake measuring 3 to 5 would be considered minor or light; 5 to 7 is moderate; 7 to 8 is major, and 8 or more is great. Each whole number on the scale represents an increase of about 30 times more energy released than the previous whole number represents. Therefore, an earthquake measuring 6.0 is about 30 times more powerful than one measuring 5.0.

**Vulnerability:** Vulnerability is a set of conditions and process resulting from physical, social, economic and environmental factors which increase the susceptibility of a community to the impact of hazards, (UNDP, 2004). Positive factors that increase the ability of people and the society they live in to cope effectively with hazards that increase their resilience or reduce their susceptibility are considered as capacities.

**Risk:** Risk is the probability of harmful consequences or expected loss. Another definition of risk is the potential or likelihood of an emergency to occur. Risk results from the interaction between natural/ human induced conditions.

This can be calculated by the equation.

$$\text{Risk} = \text{probability of hazard} * \text{vulnerability} / \text{capacity}$$

### **Fault**

The fracture across which displacement has occurred during an earthquake. The slippage may range from less than an inch to more than 10 yards in a severe earthquake.

