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## Seismic Vulnerability Assessment of Buildings Using Geographic Information System

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**ABSTRACT:** Seismic vulnerability is the possibility of occurrence of damage or loss due to a seismic event. Vulnerability estimation is an important process in seismic risk assessment. In this study a new approach is introduced for vulnerability assessment using Analytical Hierarchical process. In this work vulnerability assessment of buildings in part of Sasthamangalam ward was carried out. Vulnerability assessment of buildings was done for high frequency and low frequency earthquakes. The results indicate that during high frequency earthquake most of the buildings in study area comes under high vulnerable class and during low frequency earthquake most of the buildings in study area comes under less vulnerable class. Population at risk during earthquake was also analyzed in this study.

**KEYWORDS:** Seismic vulnerability, risk assessment, vulnerable classes, Analytical Hierarchical process.

### I. INTRODUCTION

Earthquake is one of the most destructive natural hazards. It cannot be predicted accurately although we know the probable region. Hence it leads to huge amount of loss to human and property. A seismic risk assessment study helps to reduce the impact of earthquakes and is also helpful to formulate disaster management plans for local authorities.

Seismic risk is the product of seismic hazard and vulnerability. Hence during the seismic risk assessment studies seismic vulnerability assessment of buildings, people and lifelines have important roles. Vulnerability of buildings is defined as the strength of constructions to resist physical forces exerted by ground motion, wind and water. Structural vulnerability of buildings due to earthquake can be defined as probability of physical loss that buildings would face when a particular level of shaking occurs. Studying seismic vulnerability of buildings in an area is a complex process because enormous amount of data is required for proper assessment. But after the advancement of space technology these difficulties can be overcome by integrating remote sensing and Geographic Information System.

The currently available methods for the seismic evaluation of the existing buildings have been formulated with statistical criteria based on a rapid observation and expert opinion. Other methods are based on the analysis of the building by using simple analytical models or detailed procedure analyses. The detailed procedure analysis, takes more time and serves for the evaluation of individual buildings only and consequently do not remain very practical for earthquake scenarios [1].

The purpose of this paper is to present an approach for the detection of seismic vulnerability index of buildings in an urban area using remote sensing and GIS. In this paper Analytical Hierarchy process (AHP) is used to find out the

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vulnerability index of buildings. AHP is one of the methods in Multi criteria decision Analysis (MCDA). MCDA refers to making decisions in the presence of multiple, usually conflicting, criteria [2].

## II. RELATED WORK

Sandeep (2007) has done a seismic risk assessment in Dehradune city using remote sensing and GIS. The main aim of his work was to find out the urbanization growth occurred in a span of 5 years, the impact of earthquake on various types of buildings, quantification of vulnerable buildings, number of person at risk during various times of earthquake, and the effect on roads after earthquakes.

In his study the earthquake assessment was made by doing a detailed analysis of hazard intensity and vulnerability of buildings. He considered the socio economic data, housing statistics along with vulnerability functions of buildings for quantifying the risk. In order to find out the level of urban density he studied the urban densification of study area with the help of satellite images.

For urban densification study he used merged IKONOS images such as IKONOS PAN and IKONOS MS image. Then through visual interpretation techniques using image elements such as tone, texture, shape, size, shadow pattern, association and location the building footprint map of the study area was prepared.

Then in order to obtain the information about the population and buildings, field survey was done. The building inventory data included building use, roof materials, building materials, number of stories, maintenance, age of buildings, building shape and proximity. The population data included number of members in the house, population during day time, population during night time and occupation. Other data such as road width in front of the buildings, presence of open spaces around the buildings, assets in the buildings etc. were also collected for risk assessment. The data base has been generated using Arc GIS after acquiring all the above information.

With the help of building attributes collected he found out the damage probability of each buildings using damage probability matrix from the RADIUS hand book. Then based on the damage probability, the vulnerability assessment of all buildings was done. Various queries were developed to find the most risky areas containing buildings that are residential, having close proximity, asymmetrical, older or moderately old buildings.

Jose and Alvaro (2005), conducted a study on preliminary quantitative assessment of earthquake casualties and damages. They used a quantitative model consisting of a correlation between the number of casualties and the earthquake magnitude as a function of population density. In their study the macroseismic intensity field was determined in accordance with an updated inelastic attenuation law, and the number of casualties within areas of different intensity was computed using an application developed in a geographic information system (GIS) environment. They derived the direct economic cost due to damage on the basis of the relationship of the macro seismic intensity to the earthquake economic loss in percentage of the wealth.

Mahdi and Ali (2011), have done a work on GIS-based earthquake damage assessment and settlement. They proposed a GIS-based model for earthquake loss estimation for a district in Tehran, Iran. They calculated building damages only for the ground shaking effect of one of the region's most active faults, the Mosha Fault. Earthquake intensity for each building location was estimated based on attenuation relation and the ratio of damage was developed from customized fragility curves. Human casualties and street blockages caused by collapsed buildings were taken into account in their study. Finally, they found out the accessibility of locations without clear passages for temporary settlements by buildings via open streets. Then they validated that model using the 2003 Bam earthquake damages.

Wielandand Pittore (2011), conducted a study to estimate building inventory for seismic vulnerability assessment. Their approach was based on a multi-stage stratified sampling .In that method they focused on two different scales such as building scale and block scale. At building scale, any information will be defined at the most detailed level, while at the block scale, usually refer to aggregated information. The input data used for their analysis were images from the Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS), with 30m spatial resolution for TM and 60m for MSS. Landsat TM data covers a spectral range of 0.45–2.35  $\mu\text{m}$  in 6bands, whereas MSS data covers a range of 0.5–1.1  $\mu\text{m}$  in 4 spectral bands.

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## III. STUDY AREA

The area selected for seismic vulnerability assessment of buildings is a portion of Sasthamangalam ward in Thiruvananthapuram Corporation. Sasthamangalam ward is located between latitudes  $8^{\circ}50'20''N$  and  $8^{\circ}51'70''$ , longitudes  $76^{\circ}58'30''E$  and  $76^{\circ}58'12''$ . It is a popular residential area in Tivandrum city and is one of the wards having high population density. Hence study about seismic vulnerability of buildings of this area is important and is useful for future seismic risk assessment processes. As the building inventory data, and population data of individual buildings required for analysis was not available with the authorities field study was carried out to collect these information. Since collecting information of entire Sasthamangalam ward is a tedious process a buffer of 500 meter diameter from Sasthamangalam junction is drawn and buildings within this buffer are selected for analysis.. About 500 buildings were identified from high resolution satellite image of this selected study area.

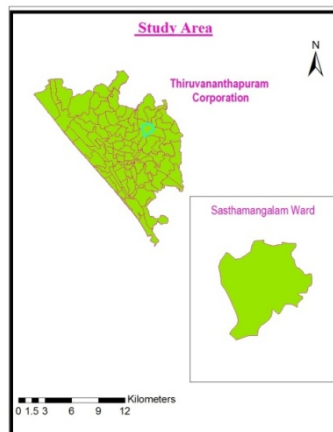


Figure 1: Study Area

## IV. DATA USED

The data used for this study are administrative boundary of study area, building inventory data, population data, road map, satellite images etc. Administrative boundary of Sasthamangalam ward is collected from Regional town planning office. The building inventory data contains information about different attributes of buildings such as building use, number of storey, age of building and structure of building. Population data contains information about number of members in the house, population during day and night time. Building inventory data and population data is collected by field survey. Road maps of the study area are necessary to make base map. Road map of Thiruvananthapuram Corporation is collected from corporation office. Then road map of study area is sub set from the entire road map of Thiruvananthapuram Corporation. A satellite image of study area is also necessary for base map preparation. Google image from Geoye satellite is used for base map preparation.

## V. METHODOLOGY

Earthquake assessment can be done by a detailed analysis of hazard intensity and vulnerability of buildings. In order to quantify the risk of an area socio economic data and building vulnerability data are necessary. The building vulnerability can be found out by considering several parameters such as material type used, number of stories, type of structure, age and proximity of building. Thus, according to available time and resources, analysis is done by taking the main building parameters into consideration.

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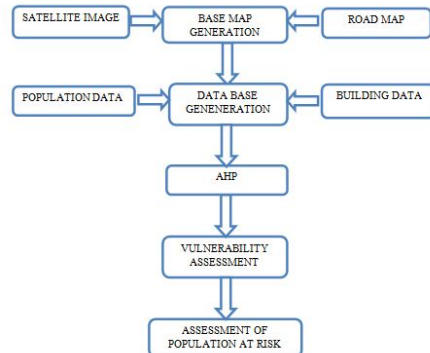


Figure 2: Flow chart of methodology

Base map generation, data base generation, vulnerability assessment of buildings, assessment of population at risk during the earthquakes etc are the main steps involved in this study.

## VI. BASE MAP GENERATION

A base map displays the fundamental data set such as buildings, roads, railway network, rivers, slum boundaries, schools, other landmarks etc that is used to render sector data more meaningful. In order to prepare building inventory data base, base map should contain buildings [3]. In this study first the satellite image obtained is georeferenced using control points.

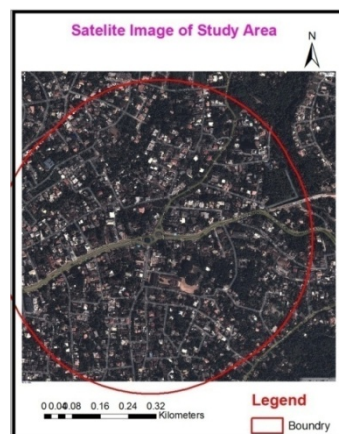


Figure 3: Satellite image of study area

Figure 3 shows the satellite image of the study area after preprocessing. From the preprocessed image buildings of study area is digitized in Arc Map.

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Figure 4: Base map

Figure 4 shows the the preprocessed image buildings of study area is digitized in Arc Map.

## VII. DATA BASE GENERATION

A database is an organized collection of data. The data is typically organized to model relevant aspects of reality [3]. In this project building inventory data and population data is used to create Data base. Building inventory data contains the information such as Building name, Number of storeys, Age of building, and Building structure. Population data contains information such as Population during daytime about 8 am to 6 pm and Population during night time about 6pm to 8 am.

## VIII. WEIGHTAGE ESTIMATION FOR BUILDING PARAMETERS

In this work in order to find out the building vulnerability certain parameters such as building materials, type of structure and number of stories etc are considered. Building materials have an important role during the assessment of vulnerability. The building constructed by mud or adobe is highly vulnerable, but that constructed with steel is less vulnerable. The buildings constructed with concrete and bricks are moderately less vulnerable than that of mud and mixed materials. The type of structure has also an important role during the assessment of building vulnerability. Studies shows that framed structures are less vulnerable than that of load bearing structures. Number of stories also has a vital role in vulnerability assessment. In the case of high frequency earthquake most of the damages occur in short buildings than that of tall buildings. But in the case of low frequency earthquakes tall buildings undergo major damage than that of short buildings.

In this work in order to find out the vulnerability index of buildings the weight of each parameter is calculated by Analytic hierarchy process (AHP).According to field survey the buildings in study area is constructed by materials such as concrete blocks, bricks, mud and mixed materials. Using AHP weightage of each material is found out. Relative weights to each criterion are assigned on its importance within the node to which it belongs. The sum of all the criteria belonging to a common direct parent criterion in the same hierarchy level must be equal to 100% or 1[4].

A decision matrix is constructed by using Saaty's scale and factor attributes are compared pair-wise in terms of importance of each criterion/ decision element to that of the next level. Once the pair-wise matrix is made, Saaty's method of eigenvectors/relative weights is calculated. Similarly in the case of type of structure weight age of framed and load bearing structures are found out. Then weightage of single, double, triple to five storey and multi storey buildings are found out using AHP.

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Table 1: scale for pair-wise comparison [3]

Intensity of importance	Definitions	Explanations
1	Equal importance	Two criteria contribute equally to objective
3	Moderate importance of one over another	Experience and judgment strangely favor one criterion over another
5	Essential or strong importance	Experience and judgment strangely favor one criterion over another
7	Very strong or demonstrated importance	A criterion is favored very strongly over another
9	Extreme importance	The evidence favouring one criterion over another is of the highest possible order of affirmation
2,4,6,8		Intermediate values between the adjacent scale values
Reciprocal		If criteria I has one of the above numbers assigned to it when compared with criteria j, then j has the reciprocal value when compared with i.

First the weightage of building materials were found by developing a decision matrix. During seismicity mud materials are most vulnerable than that of mixed, bricks and concrete blocks. Hence more importance is given for mud materials in decision matrix development. Similarly the weights of framed and load bearing structures are found. In case of seismicity load bearing structures are more vulnerable than that of framed structures hence more importance is given for it. Then weightage of buildings for different storey heights are estimated. Two cases were considered such as low frequency earthquakes and high frequency earthquakes. In the case of low frequency earthquakes more damage will occur for multistory building. Hence more weight is assigned for multistorey buildings. But in the case of high frequency earthquakes more importance is given for low rise buildings because at high frequency more damage will occur for low rise buildings than that of high rise buildings.

Table 2 shows the Decision matrices and weights obtained for various building parameters. If the consistency ratio of each parameter exceeds 0.1 then decision matrix should be revised. But in this study consistency ratio of building materials, building types and number of storey for both high and low frequency earthquakes are 0.0965,0.0623,0.0536 and 0.0495 respectively, which is less than 0.1 hence no need for revision.

## IX. VULNERABILITY INDEX ESTIMATION

After finding the weightage of each building parameters vulnerability index for different combinations of these parameters is determined. Calculation of vulnerability index for different combination of parameters by manually is very difficult and tedious. Hence a programme was developed in C++ platform. The input for this programme is the output obtained from AHP and the output of this programme is the vulnerability index for each combinations.

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Table 2: Decision matrix and weight obtained for building parameters

Building parameter	Decision Matrix				Weight obtained	
Building materials	Mud	Mixed	Bricks	Concrete		
Mud	1	5	7	7	Mud	0.625
Mixed	0.2	1	5	5	Mixed	0.2656
Bricks	0.1429	0.2	1	1	Bricks	0.0544
Concrete	0.1429	0.2	1	1	Concrete blocks	0.0544
<b>Building Type</b>						
	Framed	Load bearing				
Framed	1	0.125			Framed	0.125
Load bearing	8	1			Load bearing	0.875
<b>Number of storeys</b>						
<b>1.High frequency earthquakes</b>						
	Single	Double	3 to 5 storey	Multi storey		
Single	1	3	5	7	Single	0.5066
Double	0.3333	1	4	6	Double	0.3062
3 to 5 storey	0.2	0.25	1	6	3 to 5 storey	0.1432
Multi storey	0.1429	0.1667	0.1667	1	Multi storey	0.0434
<b>1.Low frequency earthquakes</b>						
	Single	Double	3 to 5 storey	Multi storey		
Single	1	0.3333	0.1667	0.125	Single	0.0437
Double	3	1	0.25	0.1429	Double	0.0835
3 to 5 storey	6	4	1	0.1667	3 to 5 storey	0.2218
Multi storey	8	7	6	1	Multi storey	0.661

Vulnerability index thus obtained from C++ programme is assigned to each building in data base. Then vulnerability is classified into four classes such as less vulnerable, Moderate vulnerable, high vulnerable and very high vulnerable. The combinations which have high vulnerability index come under very high vulnerability class and low vulnerability index come under less vulnerable class. Then using queries in GIS buildings in each vulnerability class is identified

## X. RESULTS AND DISCUSSION

According to the vulnerability index obtained from C++ programme the entire possible building combinations of study area is classified into four vulnerable classes such as less vulnerable, Moderate vulnerable, high vulnerable and very high vulnerable.

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Table 3: Vulnerability class and combinations for low frequency earthquakes

Vulnerability class	Combinations
Very High Vulnerable	Mud-Load bearing-Multi storey
	Mixed-Load bearing-Multi storey
	Mud-Load bearing-3 to 5 storey
	Mixed-Load bearing-Double storey
	Mud-Framed-Multi storey
High Vulnerable	Mud- Framed-Single storey
	Mixed- Framed-3 to 5 Storey
	Mud-Load bearing- Double storey
	Brick- load bearing –Double storey
	Brick-Load Bearing- Multi Storey
	Concrete Block-Load Bearing- Multi Storey
	Mud-Load Bearing-Single storey
Moderate Vulnerable	Mixed-Load Bearing-Double storey
	Mud-Framed-3 To 5 Storey
	Mixed-Load Bearing-Single storey
	Concrete Block-Load Bearing- 3 To 5 Storey
	Brick-Load Bearing- 3 To 5 Storey
Less Vulnerable	Mixed-Framed-3 To 5 Storey
	Mud- Framed -Double storey
	Brick- Framed -Single storey
	Brick- Framed -Double storey
	Brick- Framed -3 To 5 Storey
	Brick-Load Bearing- Single storey
	Brick-Load Bearing- Double storey
	Concrete Block -Framed - Double storey
	Concrete Block- Framed - 3 To 5 Storey
	Concrete Block- Load Bearing -Single storey
	Concrete Block- Load Bearing - Double storey
	Concrete Block- Framed - Multi Storey
	Concrete Block- Framed -Single storey

Table 3; shows the four vulnerability classes and their corresponding combinations for low frequency earthquakes. Based on this a vulnerability map at low frequency earthquake has been prepared using Arc map.



Figure 5: Vulnerability map at low frequency earthquake



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Figure 5 shows the building vulnerability map for low frequency earthquake. Most of the buildings in study area come under less vulnerable class and there are no buildings in very high vulnerable class.

Table 4: Vulnerability class and combinations for high frequency earthquakes

Vulnerability class	Combinations
Very High Vulnerable	Mud-Load bearing-Single storey
	Mixed-Load bearing-Double storey
	Mixed-Load bearing-Single storey
	Mixed-Load bearing-Double storey
	Mud-Load bearing-3 to 5 storey
High Vulnerable	Mud- Framed-Single storey
	Mixed- Framed-3 to 5 Storey
	Brick- load bearing –Single storey
	Concrete Block-Load Bearing-Single Storey
	Brick-Load Bearing- Multi Storey
	Mud-Framed-Double Storey
	Mud-Load Bearing-Single storey
	Mixed- Load Bearing- Multi Storey
Moderate Vulnerable	Mixed-Framed-Single storey
	Brick-load bearing-Double storey
	Concrete Block-Load Bearing-Double Storey
	Mud- Framed-3 to 5 storey
	Mixed-framed-Double
Less Vulnerable	Brick- load bearing –3 to 5 Storey
	Concrete Block-Load Bearing-3 to5 Storey
	Mixed- Framed-3 to 5 Storey
	Concrete Block-Framed-Single Storey
	Brick- Framed –Single Storey
	Brick- Load bearing –Single Storey
	Brick- Load bearing –Double Storey
	Concrete Block- Framed - Single Storey
	Mud-Framed-Double
	Mud-Framed-Multi storey
	Concrete Block- Framed - Double Storey
	Brick-Framed-Double storey
	Brick-Framed-3 to 5 storey
	Concrete Block- Framed - 3 to 5 storey
	Brick-Framed- Multi Storey
	Concrete Block- Framed - Multi storey

Table 4 shows the four vulnerability classes and their corresponding combinations for high frequency earthquakes. The vulnerability map for high frequency earthquake has also been prepared based on table 4. Vulnerability classes obtained for both low and high frequency earthquake are added to the data base for the preparation of vulnerability maps using Arc map.

Figure 6 shows the building vulnerability map for high frequency earthquake. During high frequency earthquake most of the buildings of study area come under high vulnerable class and number of buildings in very high vulnerable class is comparatively less than that of other classes.

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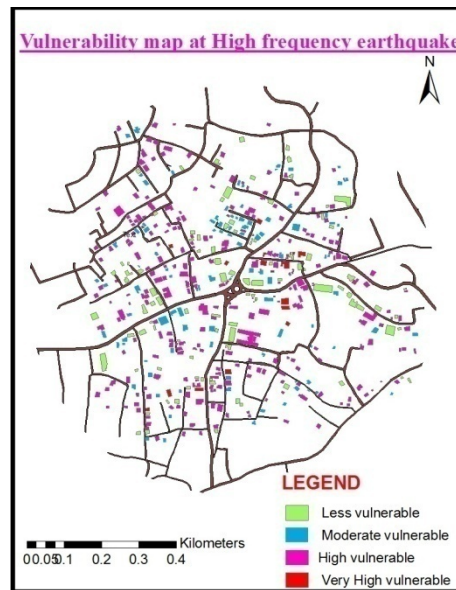


Figure 6: Vulnerability map at high frequency earthquake

## XI. CONCLUSION

A new approach is introduced in this study to find the seismic vulnerability of buildings. The use of geo-data base and analysis in GIS using attribute data provided an easy platform for the spatially distributed assessment of building vulnerability. In the vulnerability map of high frequency earthquake 3% buildings fall under very high vulnerable class, which is due to the presence of mud buildings, and 56% fall under high vulnerable class due to the large percentage of low rise buildings in the area. The vulnerability map of low frequency earthquake shows that 95% buildings fall under less vulnerable class, and 4% fall under moderate vulnerable class. This shows the absence of high rise load bearing buildings in the study area.

## REFERENCES

- [1] F. Lazzali, M. Farsi, "Seismic vulnerability assessment of buildings in Algiers area", World Academy of Science, Engineering and Technology, pp.61, (2012)
- [2] Dr. Ling Xu, Dr. Jian "Introduction to multi-criteria decision making and the evidential reasoning approach", working paper no. 0106, (2001)
- [3] Rajiv Awasyojana, "Guidelines for GIS mapping, MIS development and integration of GIS with MIS", report on subcommittee 1 (2005)
- [4] Ghamgosar, haghhyghy " Multicriteria decision making based on Analytical Hierarchy process in GIS for tourism", Middle east journal of scientific research.,vol 4, pp.501-507, (2011)
- [5] IS 1893(Part 1):2002
- [6] Jose badal, and Alvaro Gonzalez "Preliminary quantitative assessment of earthquake casualties and damages", Natural Hazards 34, pp.353-374,(2005)
- [7] Jovel, and Roberto "Natural Disasters and Their Economic and Social Impact", Economic Commission for Latin America and the Caribbean Review, No. 38, (1989)
- [8] M. Wieland, and M. Pittore, "Estimating building inventory for rapid seismic vulnerability assessment: Towards an integrated approach based on multi-source imaging", Soil Dynamics and Earthquake Engineering 36. (2011)
- [9] Mahdi Hashemi, and Ali Asgar, "A GIS based earthquake assessment and settlement methodology" Soil Dynamics and Earthquake Engineering 31. pp.1607-1617, (2011),
- [10] Sandeep Maithani, "Urban seismic risk assessment in Dehradun city using remote sensing and geoinformation Techniques", Project. (2007)
- [11] Stavros Anagnostopoulos, and Costas Providakis, Paolo Salvaneschi, and George "Seismocare: An efficient GIS tool for scenario-type investigations of seismic risk of existing cities", Soil Dynamics and Earthquake Engineering 28. (2007)
- [12] Agarwal, and Ajay Chourasia "Methodology for Seismic Vulnerability assessment of building stock in Mega cities", Workshop on Microzonation. (2004)