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Building Vulnerability Assessment and Social Appraisal of Retrofit in Lalmatia, Dhaka

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Abstract: Bangladesh is one of the earthquake vulnerable countries in the world. Since Bangladesh is close to the boarder of two active plates (in the west side the Indian plate and in the east and north and east side the Eurasian plate), the country is invariably at risk of an earthquake that may be harmful and could kill people in an instant. With the increasing rate of earthquake, people's natural tendency to be afraid because experts consider them what is going to be occurred to them as warning. In this study the AHP- Analytical Hierarchy process and Multi Criterion Analysis process is used to identify the earthquake vulnerability for Lalmatia study area. The AHP method is used here to assign the weight of vulnerability factors from the expert's opinion. In our study the weigh for six earthquake vulnerable factors were fixed and by this AHP method and the priority of vulnerable aspects were also identified by this method. This research reveals that 5 buildings are very high vulnerable to retrofit in the first step plan and 13 buildings are high vulnerable to retrofit in the second step plan. About 298 buildings are less vulnerable to retrofit. The retrofitting of structural components shouldn't be conducted for only an individual component or groups of components. The good performance of the entire structural system must be ensured. Retrofitting strategy was determined based on the results of technical assessment. The result and method of this study may be used to recognize the earthquake vulnerability in Lalmatia and also to take planning and mitigation measures against earthquake in Dhaka City.

Keywords: Analytical Hierarchy Process, Retrofit, Social Appraisal, Vulnerability, Priority for Retrofit.

Introduction

Bangladesh is vulnerable to earthquake because of the existence of several fault lines and tectonic plate boundaries (CDMP, 2014). Previous experience of earthquake and rapid urbanization, high population growth rate, high density and development of economic arrangements increasing the vulnerability for earthquake (CDMP, 2014). The capital city Dhaka with estimated population in 2020 is roughly 2.1 million (UN, 2020) and density of population is 44,500 per sq.km. (UN Habitat, 2020) which puts heavy pressure in the city. With high density this megacity continues to expand with extremely ill planned and increasing earthquake vulnerability. The earthquake risk and infrastructure protection in

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Dhaka is now a main concern as the earthquake disaster risk index ranks Dhaka as one of the 20 most risky cities in the world (Ahmed and Ahmed, 2010).

Without appropriate planning Dhaka is developing very fast and as a result we can see more incidents like the collapse of the Begunbari building on June 1, 2010. The buildings were built on wet land and in earthquake the soil liquefaction may happened on this building (Rahman, 2010). The Meteorological Department and BUET has identified about 90 earthquakes were occurred in Bangladesh through May 2007 to July 2008. Among the identified history of earthquakes, nine of which are above five on the Richter scale and 95 % of which were within a radius of 600 km of Dhaka city (Ferdousi and Rahman, 2010. CDMP (2009a, 2009b, 2009c) assessed that the Madhupur fault generates 7.5 Mw magnitude for Dhaka city. According to this assessment, out of total 3,26,000 buildings, approximately 270,604 buildings will be at least moderately damaged which comprises over 89% of total building stock. Besides 238,164 buildings will be damaged beyond repair. Around 260,788 and 182,450 people will die respectively for an earthquake taking place at 2:00 AM and 2:00 PM. Around 1,527,668 people will be displaced aftermaths an earthquake (CDMP, 2009a, 2009b, 2009c).

An assessment was piloted by ADPC from February 2008 to August 2009 in Bangladesh Government initiatives titled on Comprehensive Disaster Management Program (CDMP). According to this study, a 7.5 magnitude earthquake originated from the Madhupur fault could have killed at least 1,30,000 people if the earthquake had been attacked in daytime in Dhaka. An earthquake of 8 Richter scale created close to the Chittagong of plate boundary fault 2 may kill about 69,900 people living in the capital if the earthquake had been attacked in daytime. There may 13,600 people need to be hospitalized and 61,288 people may need first aid treatment (CDMP), 2010. Thus, the capital city Dhaka and Bangladesh both are extremely vulnerable to earthquake and considering these aspects the earthquake vulnerability in Lalmatia study was conducted. The Study was also conducted to find out the public's perception about the willingness of building owners to retrofit the existing building against earthquake vulnerability.

Literature Review

Dhaka is a fast growing and densely populated (21 million as of 2020, Dhaka population 2021) mega city, with a population density 48,000 per sq.km (Amin, 2018) and a large number of high-risk apartments (Akhter, 2010). Northeastern cities in Bangladesh have a higher risk of earthquake than other part (Hossain, 1998). According to CDMP, if an earthquake occurs on a Richter scale 6 magnitude then near about 78,323 buildings will be fully destroyed with an economic loss of US$ 1,075 million (CDMP, 2010). The other probabilistic thinking is that if the Madhupur fault generates 7.5 Mw magnitude earthquake then about 72,316 buildings in the city will be totally damaged and 53,166 partially with an economic loss about US$32948. This earthquake may also kill about 131,029 people instantaneously with an injury of 32,948 people (CDMP, 2010). United Nations published reports said that Dhaka and Tehran are very high-risk city (Rahman, 2004) although large earthquake has not been occurred yet historically (Khan, 2004). The large earthquake not occurred yet but some planning intervention may reduce the earthquake vulnerability in Dhaka city (Rahman, Tariq and Sharmin, 2020). To reduce the vulnerability the seismic retrofitting is one of the strong mitigation measures for the pre disaster (Solberg et al. 2010). In Japan the seismic retrofitting is applied in buildings to bring the seismic code revision of 1981 (Fukuyama, 2006). To take the retrofitting measures (Solberg et al. 2010), leading to ground use rules and community relocation (Erdick, 2008) and emergency evacuation preparedness and awareness (Chakrabarty, Rahman and Ubaura, 2020) can help to mitigate earthquake vulnerability. A parallel study in Lalmatia carried out and six affecting factors against earthquake vulnerability in five subcategories has been considered as like as construction year, population, road width, building use, area of parcel and building vulnerability (Shawon et al. 2021). Vulnerability assessment for both structural and non-structural elements are very important during and after earthquake event (Rahman, Tariq and Sharmin, 2021). All the literature above mentioned are discussed about the vulnerability loss and some methods to identify the vulnerability. But there was the research gap to find out the people's perception about the willingness of building owner to retrofit the existing buildings in response to building vulnerability. So, considering some vulnerability issues this research study was carried out to display the existing building's vulnerability in Lalmatia area in Dhaka City and also to identify the building owner's attitude about the willingness to retrofit the existing buildings.

Purpose and Objectives of the Research

The main aim of this research is to measure the earthquake vulnerability in Lalmatia, and the willingness to pay by the landowner to retrofit the existing buildings of Lalmatia area, Dhaka city. The following objectives have been taken to implement this aim:

- Assessing the earthquake vulnerability in the existing buildings in Lalmatia area, Dhaka.
- To investigate the willingness of building owner to retrofit the existing buildings.

Conceptualization and Theoretical Framework

Turkish Method

The Turkish government and the Japan International Cooperation Agency (JICA) came forward to implement a regional earthquake assessment and rehabilitation program after the 1999 earthquake in Kocaeli and Duzce. The Turkish method Level-1 is used in this work. The first phase of the survey from the sidewalk was conducted by observers through a walkdown visit.

Survey Parameters

The parameters selected in the Level-1 survey to indicate building vulnerabilities are as follows:

- *General Information**:*** Type of existing building, Number of building stories, Year of construction, Number of occupants, Maintenance record.
- *Appearance of a Soft Story**:*** Yes or No
- *Appearance of Heavy Overhangs**:*** Yes or No
- *Discernible Building Quality**:*** Good, Moderate or Poor
- *Pounding possibility Between Adjacent Buildings**:*** Yes or No
- *Appearance of a Short Columns**:*** Yes or No

The intensity of ground motion at a particular location depends mainly on the efficiency of the distance and the local soil conditions. There is a strong relationship between PGV (Peak Ground Velocity) and local soil shear wave velocity (Chowdhury, 1993). So PGV was selected to represent the intensity of ground motion in the study. Peak ground velocity (PGV) can be taken between 40 cm /sec to 50 cm /sec (Wu *et al.*, 2003). Thus, Zone II (40 <PGV<60) is considered for calculating performance scores because our study area matched the same characteristics with Zone II. The different base scores described in Table 1 which were determined based on the number of stories and the earthquake risk level in the site building.

Table 1: Base Score (BS) and Vulnerability Score (VS) for Concrete Buildings

Number of Stories	Base Scores (BS)	Vulnerability Scores (VS)				
	Zone II	Soft Story	Heavy Overhang	Apparent Quality	Short Column	Pounding
1 or 2	130	0	-5	-5	-5	0
3	120	-15	-10	-10	-5	-2
4	100	-20	-10	-10	-5	-3
5	85	-25	-15	-15	-5	-3
6 or 7	80	-30	-15	-15	-5	-3

Source: Sucuoglu and Yazgan, 2003

Building Seismic Performance

At first the vulnerability factors are fixed by the walk down survey and then the location of the building is determined by its location (by GPS survey), the seismic Performance Score (PS) can be finding out by using Eq. 1. The base score (BS), the Vulnerability Scores Multiplies (VSM) and the vulnerability scores (VS) to be used in Eq. 1 and the corresponding values are represented in tables 1 and 2.

$$PS = (BS) - \sum (VSM) \times (VS) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Table 2: Scale for the Vulnerability Scores Multiplies (VSM) and Parameters

Soft story	Exists = 1; Does not exist = 0
Heavy Overhang	Exists = 1; Does not exist = 0
Discernible Quality	Good = 0; Moderate = 1; Poor = 2
Pounding possibility	Exists = 1; Does not exist = 0
Short columns	Exists = 1; Does not exist = 0

Source: Sucuoglu and Yazgan, 2003

Then, the vulnerability value is found which is equal to the PS divided by BS. If this computed value is low, the vulnerability of the building will be high. Decide the range of vulnerability levels (Table 3) in the study (very low, low, medium, high and very high) and develop a map of vulnerability of concrete buildings.

Table 3: Vulnerability Score

Score	Vulnerability Level
0.1 to 0.2	Very High
0.21 to 0.4	High
0.41 to 0.6	Moderate
0.61 to 0.8	Low
0.81 to 1	Very Low

Source: Sucuoglu and Yazgan, 2003

This assessment process of building vulnerability is only applicable for RCC (pucca) building. In this process tin shed and semi pucca buildings are not evaluate for the vulnerability assessment of the study area.

Multi Criteria Decision Making (MCDM)

To evaluate the impacting factor and to identify their weight the Multiple-criteria decision-making (MCDM) is very popular term in our study. The MCDM is divided into two terms and they are Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM), (Zimmermann, 1991). These two methods give a clear statement for the decision maker as like as to make various quantities and weight to assess the study. By analyzing the limitations, weight, characteristics of the factors and the alternatives these systems are very essential to give a formal analysis in any research study. The MCDM method used here for the solution of our study problem. They also accept some parameters such as homogeneity in the problem solution (Malczewski, 1999). They can discuss thematic parameters such as the weight and the common set of values if there arises conflict among various actors. The optimal field suitability and the specific range of a particular indicator can be mapped by the results of MCDM. The researcher can then discuss and relate the results by overlaying their maps one by one to get the overall situation wich are actually geographically representation of their results.

Spatial Multi-Criteria Decision Making (MCDM)

This spatial multi criteria decision involves a set of alternatives. With respect to the given set of evaluation criteria, a choice of one or more alternatives is made (Jankowski, 1995 and Malczewski, 1996). It is extremely different from traditional MCDM techniques. Spatial multi criteria requires criterion value information, alternatives location in adjunct to the decision makers preferences. That means analysis results also depend on the value of judgements engaged in the decision-making process. Two considerations are pre-eminent importance for this analysis: (1) GIS component like data storage, acquisition, retrieval, manipulation and capability of analysis and (2) MCDM analysis component like aggregation of spatial data and preference of decision makers diverse decision alternatives (Carver, 1991; Jankowski, 1995 as sited in Siddayao 2014).

The Analytical Hierarchy Process

The AHP approve the decision maker to create a model consisting complex problem in hierarchical way indicating the relevance of the goal, criteria, sub criteria and alternatives. It additionally permits the decision maker to incorporate each subjective and objective concerns during this method (saaty, 1980). The AHP method involves the following basic steps:

- Construction of the hierarchy
- Comparative judgements or executing data collection to achieve pair wise comparison data of the hierarchical structure on elements.
- Overall priority rating construction (Harker & Vargas, 1987)

At the first stage, decision makers necessity to break down the complex multiple criteria decisions into its component. At each level of hierarchy, the criteria and sub criteria are not equally important to taking decision. In the decision-making task, AHP is able to consolidate and combine the evaluations of the criteria and alternatives by group or individual (Eastman *et al*., 1993). AHP and Multi criterion analysis is using in this study to explore the vulnerability of Lalmatia against earthquake torment. Table 4 explore that six parameters were selected to vulnerability appraisement and then six factors are further categorized into five sub criteria. Factors affecting the vulnerability against earthquake is shown in table 4.

Table 4: Vulnerability Measuring Factors and Weight

Major Criteria	Sub Criteria	Vulnerability				
		Very High	High	Medium	Low	Very Low
Building Vulnerability by Turkish Method	Weight	9	7	5	3	2
	0.1-0.2	•				
	0.21-0.40		•			
	0.41-0.60			•		
	0.61-0.80				•	
	0.81-1					•
Construction Year of Building	Before 1970	•				
	1970-1980		•			
	1981-1990			•		
	1991-2000				•	
	2001-2010					•
Population per Building	91 and more	•				
	90-71		•			
	70-40			•		
	40-21				•	
	20-0					•
Area of Parcel	Less than 100 m^2	•				
	101-250 m^2		•			
	251-500 m^2			•		
	501-1000 m^2				•	

Major Criteria	Sub Criteria	Vulnerability				
		Very High	High	Medium	Low	Very Low
	More than 1000 m^2					•
Road Width	Less than 10'	•				
	10'-20'		•			
	21'-30'			•		
	More than 30'				•	
Building Use	Residential		•			
	Educational			•		
	Commercial				•	
	Service Facilities					•
	Official					•

Source: Developed by authors, 2019

Pair-wise Comparison

Saaty (1980) developed the pair wise comparison method in the context of AHP (Analytical Hierarchy Process). Comparisons create a ratio matrix, as it takes the parameter in pair wise to produce the relative weights. Personal and subjective judgements can be taken in comparison (Chen, 2016). At a given time, two elements compared of this analysis can reduces the conceptual complexity (Muralidhar *et al*., 1990; Parvoti, 1992; Saaty, 1980). Three task involves in this analysis:

- A comparison matrix development at each level of hierarchy
- Relative weights calculation for each element of hierarchy
- Consistency ratio estimating to check the judgment consistency (Li *et al*., 2006)

Table: 5: Relative Important Scale of Point Intensity

Importance Ranking	Meaning	Description
1	Equal rank	Two events give equal judgment
3	Weak position of one over another	Results are marginally favor one action over another
5	strong importance	Result strongly favor one activity over another
7	Confirmed importance	Strongly favored an activity and its control is validated in practice
9	Entire importance	Strongly favored an activity and is the maximum potential order of confirmation
2, 4, 6, 8	Middle values between the two-neighboring decision	Negotiation is required
Reciprocals of Above Nonzero	If i shows the above nonzero numbers in the activity when comparing to activity j, then j will be common values in relating with i	

Source: Saaty, 1980

Analytical hierarchy used the **9-**point Scale for ranging from **1** to **9** (indifference or equal importance to extreme preference or absolute importance) which is shown in table 5. In this comparison matrix elements are compared in pairs in each level with respect to importance. The decision maker evaluates the contribution of each factor in this pair wise comparison matrix. In the comparison matrix at a given level will be reduced to a number of square matrices M= $[a_{ij}]_{n\times n}$ as in the following:

$$\begin{bmatrix} a_{11} & a_{12} \cdots & a_{1n} \\ a_{21} & a_{22} \cdots & a_{2n} \\ \cdots & \cdots\ \cdots & \cdots \\ a_{n1} & a_{n2} \cdots & a_{nn} \end{bmatrix}$$

Vector of weights, $[W=W_{1,}\ W_{2,}\ ......W_n]$ is calculated after formed the pair wise comparison matrix. The matrix M= $[a_{ij}]_{n\times n}$ is normalized by Equation 2.

$$a_{ij} = \frac{a_{ij}}{\sum M} \quad .... \quad (2)$$

For all j=1, 2, ... n.

To calculate the CR, the CI (Consistency Index) and RI (Random Index) for each level of matrix of order "n" can be obtained from Equation 3 and Equation 4.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad .... \quad (3)$$

$$RI = \frac{1.98(n-2)}{n} \quad .... \quad (4)$$

Then CR is computed using Equation 5

$$CR = \frac{CI}{RI} \quad .... \quad (5)$$

Here, RI is Random Consistency Index shown in table 6 which is obtained from randomly generated pair wise comparison matric. The comparisons are acceptable if CR<0.1 and the comparisons are not acceptable if CR>0.1 which is inconsistent judgements. One should revise and reconsider in such cases with their original values in this matrix A

Table 6: Random Index

N(number)	2	3	4	5	6	7	8	9	10	11	12	13	14
Random Index (RI)	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57

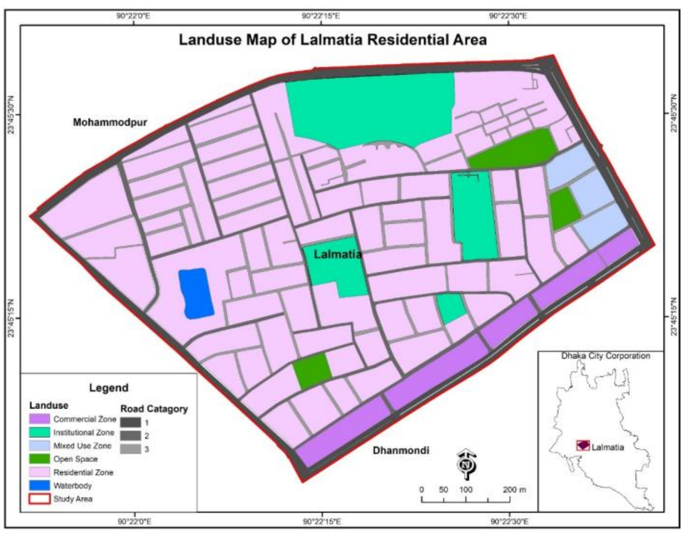
Source: Saaty, 1980

Methods

Physical observation and checklist survey has been comprised the survey of residential building to collect information regarding building number of stories, construction year of building, population per building, road width, Appearance of soft story, heavy overhangs, Discernible building quality, Appearance of short columns, pounding possibility between adjacent building, area of parcel, building use etc. For the study, sample size is calculated through the following procedure: Total population (building) size (N) = 1647, Error level (e) = 5%, Confidence level 95% and sample size was determined as 316. The sample was collected randomly in Lalmatia study area. Secondary data were collected from thesis papers, earthquake management related books, seminar papers, articles, journals, etc.

Objective Variable Matrix

Objectives	Variables	Data	Techniques
Assessing earthquake vulnerability in the existing buildings.	✓ Num. of stories ✓ Num. of residents ✓ Construction year of the building ✓ Road width ✓ Appearance of soft story ✓ Presence of Heavy overhangs ✓ Discernible building quality ✓ Appearance of short columns ✓ Land parcel ✓ Possibility of Pounding ✓ Building use	Primary sources (Field observation, checklist survey)	Measurement Technique: Turkish Method Spatial Distribution: GIS & RS
Investigating the willingness of building owner to retrofit the existing buildings.	✓ Willingness to pay ✓ Reduction level of Vulnerability ✓ Retrofit Cost	Primary sources (In-Depth interview/ Focus Group Discussion (FGD) Secondary sources (Related Organization: RAJUK, DCC, ADPC)	Technique: Analytical Hierarchy Process Spatial Distribution: GIS



Map 1: Land use Map of Lalmatia

Source: Developed by authors, 2019

Existing Conditions

There are different types of buildings structure in Lalmatia area like RCC, masonry and semi-pucca building. The masonry structures are more vulnerable during earthquake. There are different building stories in Lalmatia area. Five to six stories buildings are more (31.3%) than other stories in the study area. It is found that, there are few buildings aged more than 30 years. In Lalmatia area, the highest number of buildings constructed around 1985 to 1995 (almost 957 buildings constructed). Figure 1 shows that after 2005, construction and reconstruction of buildings is increasing most. Between 2005 to 2014, almost 47.8% buildings are constructed. Before 2005 building construction was more in 1985 to 1995. Again, construction of structures is increasing in last ten years. The use of the buildings is divided into some exact ranges that define the actual utilize of the building. In Lalmatia area most of the building is used as residential purpose. Some other type of building uses a like commercial, community services and mixed use also founds.

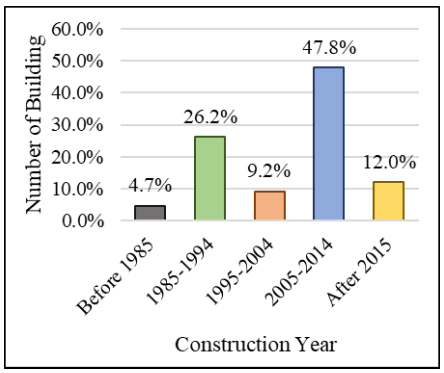


Figure 1: Construction Year of Building

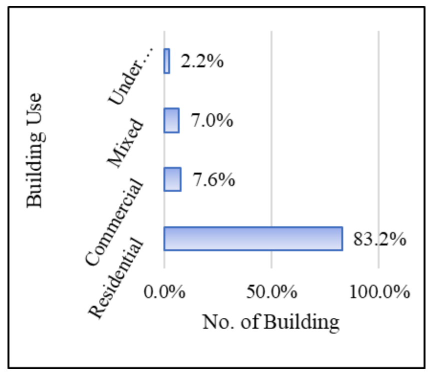


Figure 2: Percentage of Building Use

Source: Field survey, 2019

Amid the surveyed buildings, about 38% of buildings with heavy overhangs in Lalmatia area were found (Photograph 1). It was found that in most of the upper floor from two to three feet consist of heavy overhang. 4% building with short column was found in the study area (Photograph 2). Buildings with short columns typically convey serious damage throughout severe earthquake. Nowadays the ground story (Photograph 3) is left open for parking in large number i.e., without having any partition walls (RCC) between columns in the ground. The percentage of soft story buildings is less than the buildings without soft story. Almost 38% buildings having soft story. It is found that, majority of the apparent building quality is good in Lalmatia area, and it is almost 59.2%. It is found from field survey that the majority of the buildings has pounding possibility (59.8%) (Photograph 4).

Photograph 1: Appearance of Heavy Overhang Photograph 2: Appearance of Short Column

Source: Field survey, 2019

Photograph 3: Appearance of Soft Story Photograph 4: Pounding between Adjacent Building

Source: Field survey, 2019

Overall Vulnerability Scoring by AHP

AHP (Analytical Hierarchy Process) is a flexible, effective, and simple method to decision-making process. Saaty proposed the AHP method in 1980. It is a familiar method that decomposes several level decision-making problems through creating hierarchical relationship between different levels. This method uses comparison as a pair to distribute weights of different factors that helps to measuring the relative importance through the suing Saaty's 1 to 9 level scales. Consistency ratio (CR) is also calculating to verify the judgmental coherence. The accepted consistency ratio must be about 0.1 or less. This method includes following three steps-

- Two comparison matrices generation
- Calculation of weights for different factors

- Calculation of agreement ratio

Generating of a Binary Comparison Matrix

According to Saaty, a pair wise comparison matrix is a numerical relationship between two elements that appreciate more important element. In the numerical representation the weight of each factor compared together. Matric n×n (in this case 6×6) record the results that also called binary comparison matric Aij = [a n×n]. In Analytical Hierarchy Process, all elements of the metric are positive and concerning the “reverse condition” (the weight of j in regard to i will equal to 1/k, if the weight of i in regard to j equals to k). In every binary comparison matric, we will have two numerical quantity of Aij and 1/Aij.

Calculation Step for Different Factors

To determine the weight of each factor, a comparison matrix (table 8) has been developed. Calculation step includes the following:

Step 1: Calculating the Weighted Sum Vector (WSV) (table 8)

Table 8: Vulnerability Factors Comparison in Pair

Pair-wise comparison matrix (A1)						
Criteria	BV	CY	Pop^n	AoP	RW	LU
Building Vulnerability by Turkish Method (BV)	1	7	7	7	7	7
Construction Year of Building (CY)	0.143	1	2	4	6	7
Population per Building (Pop^n)	0.143	0.5	1	2	4	5
Area of Parcel (AoP)	0.143	0.25	0.5	1	2	3
Road Width (RW)	0.143	0.167	0.25	0.5	1	2
Land Use (LU)	0.143	0.143	0.2	0.333	0.5	1
Sum	**1.71471**	**9.06**	**10.95**	**14.833**	**20.5**	**25**

Source: Developed by authors, 2019

Step 2: Calculating the Inconsistency Vector (IV) (table 9).

Step 3: Obtaining λ_{max} (table 9).

Table 9: Criteria Weight Calculation

Normalized Pair-wise comparison matrix							**A2**	**A3 = ∑A1× A2**	**A3 ÷ A2**
Criteria	BV	CY	Pop^n	AoP	RW	LU	**Criteria Weight**		
BV	0.583	0.773	0.639	0.472	0.342	0.28	0.515	3.912	7.599
CY	0.083	0.110	0.183	0.270	0.293	0.28	0.203	1.350	6.645
Pop^n	0.083	0.055	0.091	0.135	0.195	0.20	0.127	0.810	6.401
AoP	0.083	0.028	0.046	0.067	0.098	0.12	0.074	0.459	6.238
RW	0.083	0.018	0.023	0.034	0.049	0.08	0.048	0.292	6.100
LU	0.083	0.016	0.018	0.022	0.024	0.04	0.034	0.210	6.181
Average									**6.527**

Source: Developed by authors, 2019

Step 4: Calculating the inconsistency index: defined by equation (6).

$CI = \frac{\lambda_{max} - n}{n-1} = \frac{0.527}{5} = 0.105$ ………… (6)

Step 5: Calculation of Inconsistency Ratio (CR): defined by equation (7). If this ratio is less or equal to 0.1, the consistency will be acceptable.

$CR = \frac{CI}{RI} = \frac{0.105}{1.24} = 0.085$ ………… (7)

Here,

CI= Consistency Index,

RI= Random Consistency Index,

n= Number of Attributes

and λ_{max}= Weighted Matrix

RI is derived from the table 6.

In our result the CR is estimated 0.085 which means there is a consent in result because we know that if CR is greater than 0.1 then the result should be reassessed and if CR ≤ 0.1 then it should be agreement in the result.

Overall Vulnerability Evaluation

The weights for the criteria are computed to evaluate the overall vulnerability using AHP method and afterwards vulnerability map of Lalmatia is prepared based on vulnerability level.

Findings

With the value of Turkish Method at the time of AHP model the range of vulnerability levels are depended on huge population, very high construction age, narrow road and building use is residential. AHP consider all multiple aspects that can affect any building vulnerability and weighted with seismic buildings related factors and present the vulnerability category.

Example

Table 10: Vulnerability Score of Very High Vulnerable Building by AHP Method

Uniq_id	No of stories	Vulnerability Score by Turkish Method	CY	Pop^n	AoP	RW	LU	Score
761	6	0.19	1990	55	46.87	22	R	42
1571	6	0.20	1998	52	322.13	22	R	36
1406	10	0.20	1990	76	118.97	22	R	42
1532	6	0.19	1990	54	283.68	26	R	40
970	5	0.18	1990	37	106.43	22	R	38

Source: Developed by authors, 2019

According to AHP method, by giving a priority on very high vulnerable and high vulnerable building (Turkish method) represents the three priority ranking. In case of very high vulnerable buildings (total buildings 5), 2 buildings get first priority (Uniq_id 761 and 1406), 1 get second and 2 gets third priority (Uniq_id 1571 and 970). In case of high vulnerable building (total buildings 21), 13 buildings get first priority, 5 gets second and 3 gets third priority. This priority list represents priority-based retrofitting. Figure 4 represent the priority list of high vulnerable building.

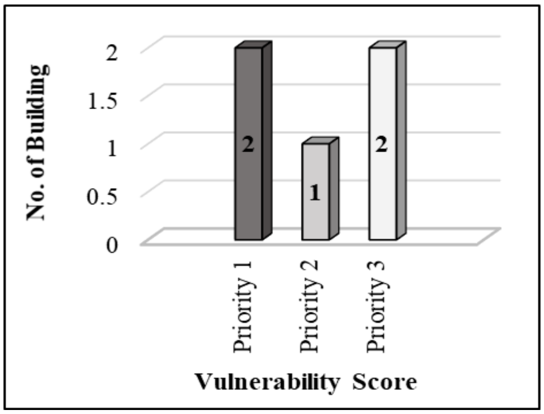


Fig 3: Priority of Very High Vulnerable Building

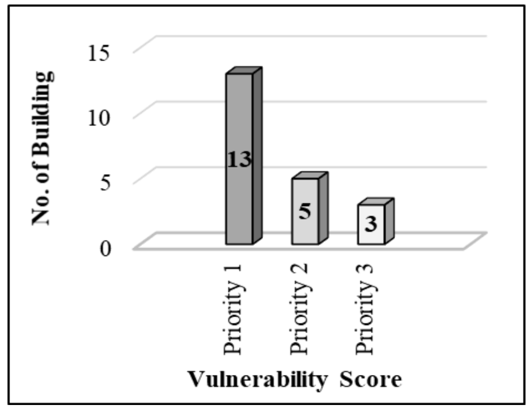
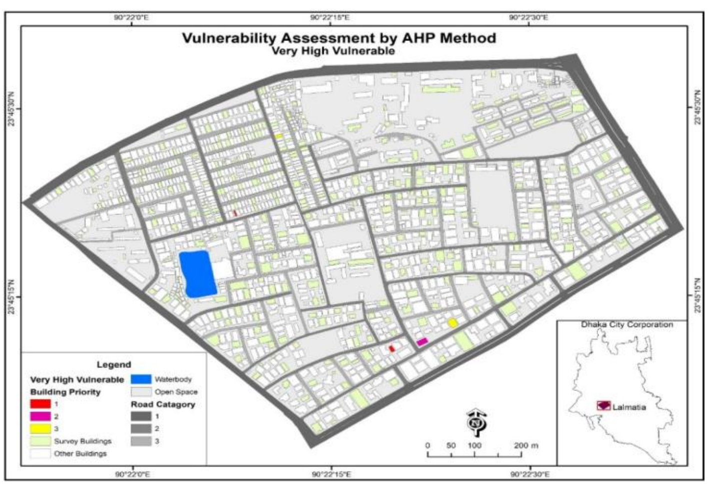


Fig 4: Priority of High Vulnerable Building

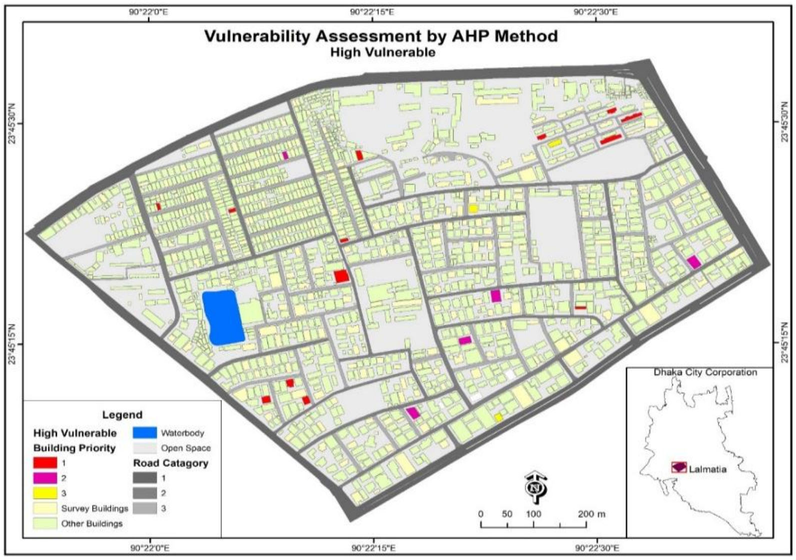
Source: Field survey, 2019

AHP method is used only for very high vulnerable building and a high vulnerable building in Lalmatia area. Map 2 represent the very high vulnerable building priority and map 3 represent the high vulnerable building priority. It was concluded that (based on AHP results), 5 building of very high vulnerable get most priority for retrofitting. And then 21 buildings get priority for retrofitting.



Map 2: Vulnerability Assessment Map (1) by AHP Method

Source: Developed by authors, 2019



Map 3: Vulnerability Assessment Map (2) by AHP Method

Source: Developed by authors, 2019

Willingness to Pay for Retrofit

Some people want to retrofit by thyself in Lalmatia area. Some people have already started to retrofit. Several people believe that developer can’t work properly. That’s why small size of respondent is agreed to retrofitting by developer. Responses show that awareness but that willingness to participate in a retrofit project is modest and is limited. Survey result shows that (Table 11), majority of the respondent are not agreed to retrofit for above mentioned prioritized 26 buildings. About 92% respondent are not agreed to pay for retrofit. Only 8% respondent are agreed to retrofitting.

Table 11: Willingness to Pay for Retrofit

	Yes	No
Willingness to Pay (Percentage)	2	24
Percentage	8%	92%

Source: Field Survey, 2019

The major barrier to building retrofit is the direct economic loss to the building owner. Findings stated that if the initial cost of implementation can be reduced then more building owners will adopt adequate mitigation measures. That can be through the provision of financial and market-based incentives such as low interest loans and tax deductibles. These incentives would be strengthening their ability to adopt appropriate seismic mitigation measures through reduce the owners initial retrofit and building maintenance costs.

Retrofit Plan Based on Vulnerability

Based on findings by applying AHP method, can make short term and medium-term plan (table 12) for retrofit. Short term plan for very high vulnerable building and medium term plan for high vulnerable building can be taken. It can be taken to year wise retrofit plan based on priority. For short term plan, Priority-1 building can be taken emergency retrofit within first year. Priority-2 building can be retrofitted within second year and Priority-3 building within third year.

Table 12: Short Term and Medium-Term Plan for Retrofit

Short term: 1-3 year (very high vulnerable building)			Medium term: 4-6 year (high vulnerable building)		
Year for Retrofit	Priority	Number of Building	Year for Retrofit	Priority	Number of Building
1st Year	1	2	4th Year	1	13
2nd Year	2	1	5th Year	2	5
3rd Year	3	2	6th Year	3	3

Source: Developed by authors, 2019

In case of medium-term plan, Priority-1 building can be taken emergency retrofitted within fourth year. Priority-2 building can be retrofit within fifth year and Priority-3 building within sixth year. This short term and medium-term plan will be applied only for very high vulnerable and high vulnerable buildings.

Conclusion

Earthquakes is the tremendous threat for the economy, and well-being of the cities, and communities. Thousands of buildings may collapse because of strong earthquake. These strong earthquakes create serious loss of a city that imposed to urban elements. Due to scarcity of digital technology and data, risk zoning map have not been prepared yet for Dhaka city against earthquake stress. The proper analysis of the vulnerable element against earthquake helps to identify risk level of damage. The present study, AHP method has been applied for weighting major building components and the results are also drawn up using GIS with several factors to stimulate earthquakes. Retrofit is one of the important techniques to reduce damage against earthquake hazard. But in the study more people can't be interested as because lacking of information and financial support. The concept of social retrofitting helps to individuals and communities that enable them to recover and react against earthquake hazards. This study will support the planning and development community as well as developers to exercised reconstruction techniques that was not properly exercised yet. The model that applying in this study will expressly contribute in the vulnerability appraisement and also helps to take mitigation attempts of Dhaka city against earthquake.

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