The Jahangirnagar Review: Part II: Social Science, Vol. XLV, 2021
Printed in December 2021, ISSN 1682-7422 © Jahangirnagar University

Seismic Risk Assessment and Evacuation Preparedness: Approach of Resilient City with Evacuation Knowledge

Mohammad Mizanur Rahman*

Abstract: Bangladesh is in a high-risk zone of seismic danger, based on historical records, geological evidence, and contemporary earthquake patterns. Earthquake is one of those natural catastrophes that has a direct and immediate impact on people's lives and communities. The procedure of the execution of the study is in three terms and they are social vulnerability/social aspects, physical vulnerability aspects and emergency response. In the social aspects some index were calculated for 5 indexes by 0 to 1 range scoring method and 380 samples were collected for that. The effectiveness of emergency evacuation level of service or virtual effectiveness analysis also conducted by consumer's contentment index and public stuffs index. The vulnerability of the buildings in the study area has been calculated with the Visual Rating (VR) method. In the result of the study total score of social awareness and emergency evacuation preparedness factors is 8.91 out of 25 which represents the poor condition of social awareness. The consumers contentment index is 47.1 and the public stuffs index is 38.89 out of 100 score in savar study area which also represent the poor condition of satisfaction level regarding earthquake preparedness. About 43% building have no damage condition and 10% buildings have lightly damaged possibility and 28% buildings have the less possibility of collapse following by the 15% buildings of moderate possibility of collapse and about 4% building have high possibility of collapse. These result is found by 100 buildings surveyed in different ward of study area. However, due to a lack of knowledge and financial support, more participants may be unable to participate in the study. This research will help with community planning and development, as well as developers' utilization of underutilized rebuilding approaches. The model employed in this study will directly contribute to the evaluation of vulnerability and will also aid in the earthquake mitigation activities of the Savar Municipality.

Keywords: Seismic risk, Evacuation preparedness, Rehabilitation Strategies, Physical Vulnerability, Visual Rating (VR) method, earthquake mitigation.

Introduction

Bangladesh is one of the most earthquake-prone countries on earth (Tuzzohora, Parvez and Rahman, 2015). Bangladesh is seismically active due to the existence of several fault lines and tectonic plate boundaries. Seismic risk is increased by previous earthquake experience, rapid urbanization, high population growth rates, high density, and the development of economic infrastructure (CDMP, 2014). Earthquakes have both direct and indirect harmful consequences for human lives and a country's socioeconomic growth (Tuzzohora, Parvez and Rahman, 2015).

As the population of cities grows, more people are exposed to natural dangers. In Bangladesh, 35.86% of total population live in the cities (Statista, 2019). Major earthquakes may occur in the Sub-Himalayan area, including Bangladesh, according to Bilham (2004). According to earthquake hazard, Bangladesh has been divided into four seismic zones on the zoning map:

* Assistant Professor, Department of Urban and Regional Planning, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh. Email: mizanurp@gmail.com, mizanurp@juniv.edu

Zone-I, Zone-II, Zone-III and Zone-IV are the four zones in which Savar is located in Zone – II (BNBC, 2020). The Savar is moderate seismic intensity area with 0.20 seismic coefficient values (BNBC, 2020). The risk in Savar, like in Dhaka, is compounded by uncontrolled urbanization and growth in high-risk zones. Dhaka and Tehran are the cities with the highest danger of a seismic disaster (Rahman, 2004). Despite the fact that no moderate to major earthquakes have struck Dhaka in the past, the city suffers small tremors practically all year, indicating that the region is seismically active (Khan, 2004). So the near Dhaka city the savar urban area is very much seismically active with its unplanned building structure. The Savar municipality appeared highly vulnerable to earthquakes due to the region's physical characteristics and road conditions (Akter, Shawon and Rahman, 2021).

Many new challenges are arising as a result of rapid and unplanned urban growth and development (Briassoulis, 2009; Mahmud, Rahman and Sharmin, 2020). Every uncontrolled development has several severe social, catastrophic, and environmental consequences (Rahman, 2012; Rahman, Hossain and Miti, 2019; Ahmed and Rahman, 2020). Due to insufficient organization, preventive, and evacuation systems and/or preparedness plans, risk in urban areas is quickly growing, particularly in developing countries (Biswas, Rahman and Akther, 2016; Hasan and Rahman, 2014; Chakrabarty, Rahman and Ubaura, 2020). The urban area, Savar are growing in an unplanned manner in order to meet the population's housing needs (Rahman, et al., 2020; Rahman, Hossain and Miti, 2019). The newly constructed houses are not up to code (Rahman and Akther, 2015), while the existing houses' repair and maintenance are inadequate, resulting in disastrous outcomes in the event of a calamity such as an earthquake (Akther and Rahman, 2017; Shawon et al., 2021). Open spaces/playgrounds and wetlands are being converted to buildup areas (Rahman et al., 2020) in the form of development (Rahman, Saha and Tanvin, 2021), and the loss of open spaces and water bodies is increasing risk vulnerability such as earthquakes (Rahman, Tariq and Sharmin, 2020, 2021; Shawon et al., 2021).

Dhaka's earthquake danger is fueled by the city's vulnerability, exposure, and poor emergency response and recovery capabilities (Davidson et al., 2000). CDMP (2009a, 2009b, 2009c) estimated Dhaka's seismic risk in the event of a 7.5 Mw earthquake generated by the Madhupur fault. According to the estimate, about 270,604 structures out of a total of 3,26,000 will be moderately damaged, accounting for almost 89 percent of the entire building stock.

On 24 April, 2013, Rana Plaza collapsed in Savar (Wikipedia, 2020). Up to 13 may, total 1,134 people died (Tansy, 2015). Approximately 2,500 injured people were rescued from the building alive (Alam and Hossain, 2013). This example shows how deadly building collapse are. In April 12, 2005, a nine-story industrial building in Savar collapsed, killing 60 people and injuring about 100 workers due to poor building construction quality (The Daily Star, 2005).

The danger in urban areas is complex due to uncontrolled urbanization and development in high-risk zones. Savar, is located near Dhaka the capital of Bangladesh, is a special category pourashava with a population of 2,86,007 and the population density is 20,313 (BBS, 2011) which is very high. Because of the high population density, the ward number 3, 5 and ward 2 is more sensitive to earthquakes. The high density municipality proves the how poor condition of the emergency preparedness during and after any disaster in this place. Apart from the main city of Dhaka, the unique category of Municipality was not previously considered for earthquake susceptibility. As a result, assessing the susceptibility to seismic hazard in this highly populated town is critical. Furthermore, the study region, Savar Municipality, is linked to several businesses, including textile manufacturers.

This research helps to find out the level of earthquake vulnerability according to disaster risk index. Furthermore, it also give the level of earthquake risk awareness and earthquake evacuation knowledge by different socio-economic background people and finally To improve the resilient plan in the perspective of emergency evacuation management for earthquake and other secondary hazard e.g. building collapse. These should optimize the time of intervention (evacuation, rescue, hospital treatment, etc.) in the most efficient way to minimize the suffering of the populations (Omar, 2018).

Considering the realities, the objectives of this study were: (1) to evaluate the level of earthquake vulnerability according to disaster risk index; (2) to determine the earthquake risk awareness and earthquake evacuation knowledge in the study area; (3) to find out the resilient plan related peoples opinion in the perspective of emergency evacuation management for earthquake.

Methodology of the Study

The procedure to execute of the study is in three terms and they are social vulnerability/social aspects, physical vulnerability and emergency response. The ***social vulnerability*** is measured by analyzing five indexes. To assess the social vulnerability aspects some variables is selected. These is demography, earthquake risk awareness, emergency evacuation knowledge, provision for elderly/disabled, self-protection ability and temporary emergency evacuation shelters. To give the final weight and rank of the above stated factors, a questionnaire survey has been conducted to quantify the relative priority of the given set according to the appropriate value scale.

Sample design

In this research survey, an "individual" has been chosen as a sampling unit. There are about 286008 people in Savar Municipality Area (BBS, 2011)

Formula:

The sample size (n) is calculated according to the formula: $n = [z^2 * p * (1 - p) / e^2] / [1 + (z^2 * p * (1 - p) / (e^2 * N))]$
Where: z = 1.96 for a confidence level (α) of 95%, p = proportion (expressed as a decimal), N = population size, e = margin of error.
$z = 1.96, p = 0.5, N = 286008, e = 0.05$
$n = [1.96^2 * 0.5 * (1 - 0.5) / 0.05^2] / [1 + (1.96^2 * 0.5 * (1 - 0.5) / (0.05^2 * 286008))]$
$n = 384.16 / 1.001343 = 383.64$
$n \approx 380$
The sample size (with finite population correction) is equal to 380

Method for Emergency Evacuation Level of Service/Virtual Effectiveness Analysts: Emergency Evacuation Level of Service has been assessed. It is develop a number of measures or issues for a sustainable and efficient evacuation system on the basis of the shortcomings of present system. Investigation is done through Michael Patton's Utilization Focused Evaluation Model (Patton, 2014 and 1997). Consumer satisfaction index and public stuffs index are two dimensional studies that are used here to quantify and analyze the success of such efforts. ***Consumers Contentment Index:*** Direct questioning of a representative sample of the user community is used to assess stakeholders' views of and satisfaction with the quality of emergency evacuation service. A Consumers contentment index (C.C.I.) is thus defined as:

$$\mathrm{C.C.I} = \sum_{\mathrm{i}}^{\mathrm{q}}(\mathrm{Ri})$$

In which, R_i = question i, value, and q = questions number. When all of the replies are given maximum values, the customer satisfaction index assumes maximum value (100 in this example), showing total contentment with all of the Components that make up the overall quality of service.

Public Stuffs Index: Within Study Area Overall, buildup area has been measured through visual inspection. It is based on rating of building block on a scale of 1 to 4. A Public Stuffs Index (P.S.I.) may be calculated by adding the aggregate impact of all block facts in the area and normalizing the results so that an entirely trustworthy neighborhood gets a score of 100 (this condition is all but impossible to obtain). To calculate the Public stuffs index, use:

$$\mathrm{PSI} = 100 - \frac{100}{s}\ X\ \frac{\sum_{1}^{b}(si-1)}{b}$$

In which S_i = buildup rating of i^{th} block, b= number of block.

Physical Vulnerability Aspects/Building assessment: The Visual Rating (VR) Method was used to determine the vulnerability of the structures in the research area. For this it is calculated with an established Visual Rating (VR) Method. In this stage the simplified seismic capacity index has been calculated considering column area ratio, RC wall area ratio, masonry wall area ratio and their average shear strength. This VR method is developed specially for Bangladesh by Tohuku University - Japan, PWD and HBRI.

$$I_{VR} = \frac{1}{n.w}\left[\tau_c\left(\frac{b_c^2}{l_s^2}\right) + \tau_{inf}\left(\frac{t_{inf}}{l_s}.R_{inf}\right) + \tau_{cw}\left(\frac{t_{cw}}{l_s}.R_{cw}\right)\right] F_{IV}.\ F_{IH}.\ F_D.\ F_Y$$

Where, τ_c = The average shear strength of column, τ_{cw} =The average shear strength of shear wall, τ_{inf} = the average shear strength masonry infill, n= Number of story, w = Unit weight of buildings, t_{inf} = Thickness of masonry infill, t_{cw}= Thickness of concrete wall, Visual Rating Parameters: b_c=Average column size, l_s=Average span length, R_{inf} =Masonry infill ratio, R_{cw} =Concrete wall ratio, The reduction factors are as follows: F_{IV}=The modification factors for vertical irregularity, F_{IH} = The modification factors for horizontal irregularity, F_D = The modification factors deterioration of concrete, F_Y = The modification factors for year of construction.

The decision criteria and ranges has been obtained according to the Visual Rating Index (I_{VR}) as shown in Table 1. Market places and industries has been categorized into 5 (five) classes such as A, B, C, D, and E describing the different levels of seismic vulnerability depending on Visual Rating Index (I_{VR}).

Table 1: Categories for Visual Rating Method

Range of Each Categories	Categories	Description
$0.26 \leq I_{VR}$	A	No Damage
$0.24 \leq I_{VR} < 0.26$	B	Light Damage
$0.16 \leq I_{VR} < 0.24$	C	Less Possibility of Collapse
$0.10 \leq I_{VR} < 0.16$	D	Moderate Possibility of Collapse
$I_{VR} < 0.10$	E	High Possibility of Collapse

The first step in determining the stage's vulnerability will be to categorize the building inventory into different construction classes. Each of the construction classes for buildings in the study region will subsequently be given fragility curves. For any given damage condition, a fragility curve will offer a cumulative frequency or likelihood of reaching a specific displacement threshold (BUERP, 2014). The damage condition has been categorized into the five categories listed above. Estimates of buildings in each damage condition have been derived from the construction of the fragility curves.

Emergency Response/ Accessibility vulnerability

Emergency response/accessibility is one of the most important components of earthquake preparedness because a few minutes of delay by emergency response team may mean loss of human life. By GIS software and from the GIS database the narrow road were selected here in which there is no accessibility of fire brigade car and ambulance for the emergency rescue.

In this research the access road is identified which width is more than or equal to 10 feet. The percentage of structure that is inaccessible by each road was determined, and the results were utilized as indicators as no access of rescue facilities.

Integrating the above stated three aspects the vulnerability result in the study area is accumulated by merging this three layers.

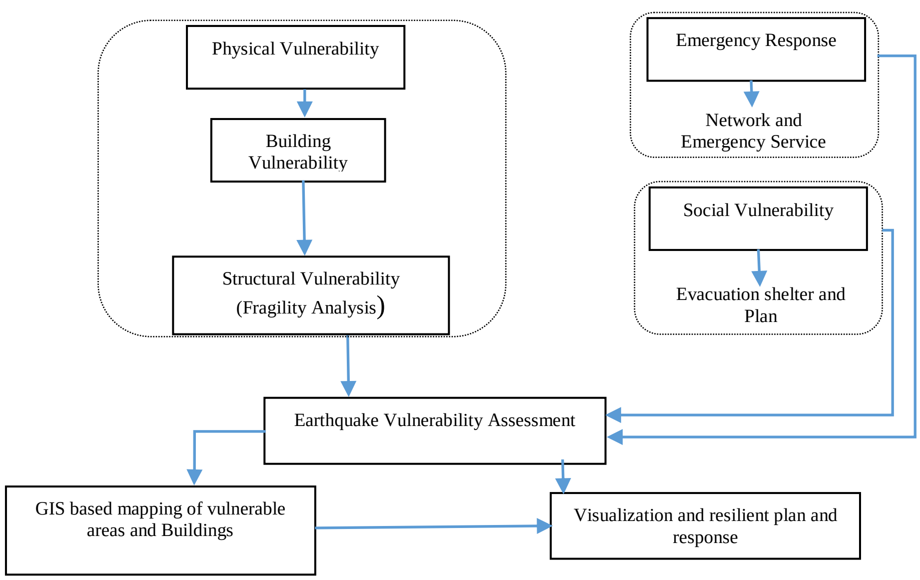

Fig 1: Methodological flow chart of the study

Resilient Cities and Seismic Risk

Tilio et al., (2011) define a resilient city as adopting an approach implies defining what aspects of a city can reflect the bare minimum necessary to ensure functionality. Paton et al., (2001) define a resilient city as a short or medium network of physical systems and human communities, the first of which includes all types of structures and infrastructures, "acting as the city's body, its bones, arteries, and muscles," and the second of which includes all types of associations and organizations, "acting as the city's brain, directing its activities, and responding to its nefarious activities."

Community seismic resilience is described as the ability of social units to avoid risks, contain the consequences of earthquakes when they occur, and carry out recovery activities in ways that minimize social disturbance and decrease the effects of future earthquakes (Bruneau et al., 2003). This may be accomplished by focusing on structural issues as well as emergency response and strategies, including institutions and organizations, especially those that conduct critical roles for community well-being, such as health care facilities (Tilio et al., 2011).

It is defined as a function of danger, exposure, and vulnerability (CDMP, 2009c) when cities are considered complex systems (Fransen, van Dijk, & Edelenbos, 2021). However, the idea of urban seismic vulnerability (CDMP, 2009c; Rahman, Ansary and Islam, 2015; Akhter, 2010 and Roy, 2014) and capacity for disaster resilience (Warrick et al., 2017; Miles et al. 2012 and Chen et al. 2008, 2009) has previously been utilized in different literature. The impacts of earthquakes are not confined to physical destruction; they also have consequences in economic, social, and political activity, and they have a significant impact on a city's ability to respond (Manyena, 2006). A strategy for reducing urban seismic risk that maximizes system resilience (Comfort, 2007). This resilience system can be used to develop strategies (Bruneau, 2003) and might improve the capacity against earthquake (Barnett, 2001).

Result and Discussion

Preparedness for an emergency evacuation and social awareness

A grading system is used to assess the level of awareness among building users and. Under the emergency evacuation readiness and awareness state in the research region, there are five factors. They are as follows:

- Awareness of Earthquake Risk
- Knowledge of Emergency Evacuation
- Provision for the Elderly/Disabled
- Vulnerability of Residential Structure
- Self-Defense Ability

Each variable is subdivided into five subvariables. The sub variables' negative and positive answers are coded from 0 to 1. The condition of each sub-variable is described by the mean values of each sub-variable. The condition of each variable is represented by the sum of sub-variable mean scores.

Earthquake risk awareness

There are five sub-variables in the earthquake risk awareness variable. The sub-variable earthquake likelihood in the area has the highest score of 0.86. The lowest score is 0.19 for having an earthquake protection strategy. The overall rating is 2.11 out of 5.

Table 2: Earthquake Risk Awareness at Home

Earthquake Risk Awareness of the Hospital Users	Frequency (N)	Minimum	Maximum	Mean	Total Score (Out of 5)
The likelihood of an earthquake in the area is high.	380	0	1	0.86	2.11
Steps have been taken to enhance seismic awareness.	380	0	1	0.17	
The building is earthquake-safe.	380	0	1	0.53	
Have an earthquake protection strategy in place.	380	0	1	0.19	
Home has taken safety precautions.	380	0	1	0.36	

Source: Field Survey, 2020

The four indexes (Emergency evacuation knowledge, Provision for the elderly/disabled, vulnerability of Residential Structure, and Self-protection capacity) were computed in the same way as in the previous example, and the total score of these four indexes is displayed in the table below.

Scores for total social awareness and emergency evacuation preparedness

The continuous values generated from the sub-variables under five variables of emergency evacuation readiness elements are added together to provide a total score with a range of 25. The total score of 8.91 out of a possible 25 indicates that inhabitants have a poor degree of social knowledge of earthquake preparation.

Table 3: Total Score of Social Awareness and Emergency Evacuation Preparedness Factors

Emergency Evacuation Preparedness Factors	Score
Earthquake Risk Awareness at Home	2.11
Emergency evacuation knowledge	2.45
Provision for elderly/disabled	0.84
Vulnerability of Structures	1.82
Self-protection ability	1.69
	Total: 8.91 (out of 25)

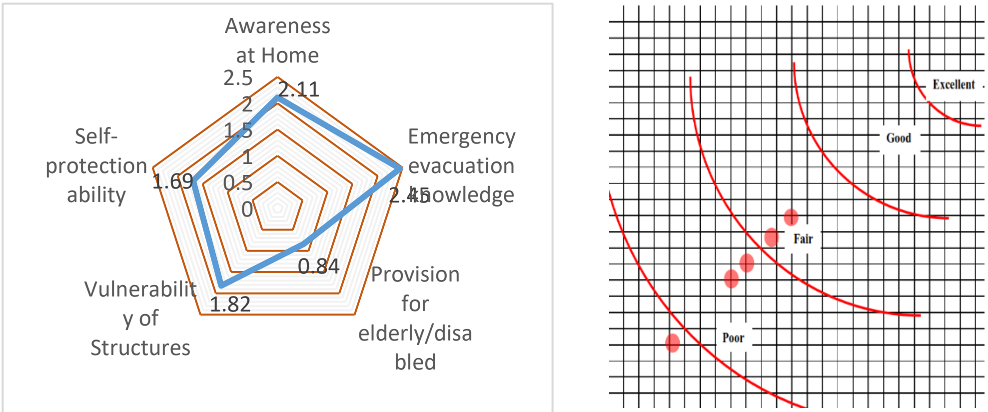

Fig 2: (a) Social Awareness Score and (b) graphical presentation of emergency evacuation preparedness factors

Emergency Evacuation Level of Service/Virtual Effectiveness Analysts

Calculation of the consumer's contentment index for households Units (HH)

The following table shows the average value of ten question related to different emergency evacuation management issues that get from the field survey.

Table 4: Average Value of Parameters for Calculating Consumers contentment Index

Primary Parameters	Secondary Parameter	Value	Frequency	Weight = Value X frequency	Total weight	Average weight, R_i
Evacuation Point	Nearby Play field	10	29	290	2272	6.0
	Out of Locality	8	57	456		
	Nearby void place	6	213	1278		
	Riverbank side	4	43	172		
	Road side	2	38	76		
Distance of Migrant Place	Below 50 m	10	46	460	1624	4.3
	50 m to 100 m	8	28	224		
	101 m to 200 m	6	41	246		
	201 m to 300 m	4	82	328		
	Above 300 m	2	183	366		
Manage	Well managed	10	12	120	1600	4.2
	Good	8	34	272		
	Medium or ok	6	58	348		
	Worse system	4	154	616		
	No system	2	122	244		

Primary Parameters	Secondary Parameter	Value	Frequency	Weight = Value X frequency	Total weight	Average weight, R_i
	available					
In this way the other parameters score are as bellow						
Management system of emergency situation					1782	4.7
Awareness Rising system					2414	6.4
Evacuation Point					1254	3.3
Distance of Migrant Place					1558	4.1
Management					1842	4.8
Management system of emergency situation					1848	4.9
Awareness Rising system					1704	4.5

Source: Field Survey, 2020

So, Consumers contentment index for Households Unit (HH) (using equation),

$$C.C.I = \sum R_i$$
$$= 47.1$$

Calculation of Public Stuffs: Table 5 shows the overall observation view of the different residential areas. The weight of buildup is given on a scale range from 1 to 4, where the lower value shows the best condition. The buildup rate of each block of the residential area is given based on the observation survey.

The overall street cleanliness for Households Units (HH)

Table 5: The Overall observation view of households Units (HH)

Area Building	Visual cleanliness rate, S_i	Area Building	Visual cleanliness rate, S_i
One Storied Building	1	Building more than 30 years old	3
Two Storied Building	2	Building For rental	2
Three Storied Building	2	Renewed single storied building	1
Four Storied Building	2	Temporary house	1
Five Storied Building	3	Building with open space	1
Six Storied Building	4	New planned Building	1

Source: Field Survey, 2020

So, Public Stuffs Index

P.S.I = 100-100/4 X (23-1)/9

= 100-61.11

= 38.89

Calculation of Consumers contentment index and Public Stuffs Index of residential buildings are calculated and shown in following graph.

Using the value of Consumers contentment index and Public Stuffs Index of the study area, the assessment of level of service is done here.

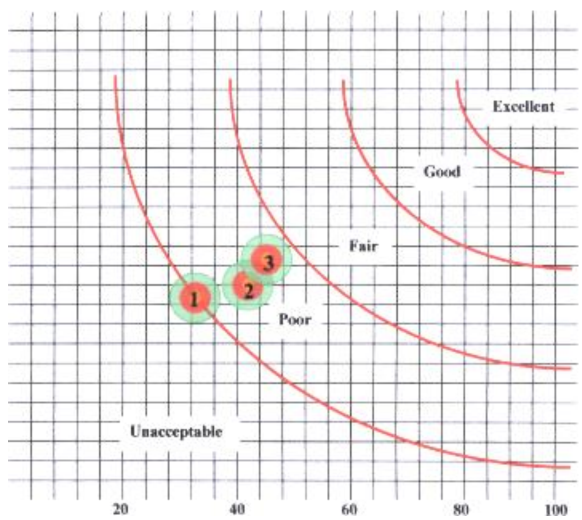

Fig 3: Emergency Evacuation Level of Service of Study area Sasvar Municipality

Source: Field Survey, 2020

Figure 3 shows a visual representation of the study area's degree of service. Each of the numbered circles on the graph reflects the average of the Consumers satisfaction and community impact indices in three distinct research units: Households are classified as having a combination of characteristics that result in an unsatisfactory quality of service. It demonstrates a low degree of service. It emphasizes the need of a well-executed Evacuation Plan for the research area.

Physical Vulnerability Aspects

Building assessment

According to the five categories listed in the methodology section, the damage condition has been categorized. Estimates of buildings in each damage condition have been derived from the construction of the fragility curves. Although just ten columns are depicted here, a total of 100 structures were examined to determine the study area's physical vulnerability.

Table 6: Damage Scenario of Buildings by Visual Rating Method

Sl. No	No of Stories	Column Size	Average span length	Concrete wall ratio	I_{VR}	Description
1	2	305	3400	0	0.278	No Damage
2	6	610	5400	0.0625	0.130	Moderate Possibility of Collapse
7	6	458	3658	0	0.226	Less Possibility of Collapse
31	5	458	3658	0	0.271	No Damage
35	6	458	4268	0	0.166	Less Possibility of Collapse
47	6	305	3658	0	0.100	Moderate Possibility of Collapse
54	5	458	4268	0.0625	0.249	Light Damage
69	5	258	3658	0	0.086	High Possibility of Collapse
76	3	258	3658	0	0.143	Moderate Possibility of Collapse
95	5	458	4268	0.0625	0.249	Light Damage

Source: Field Survey, 2020

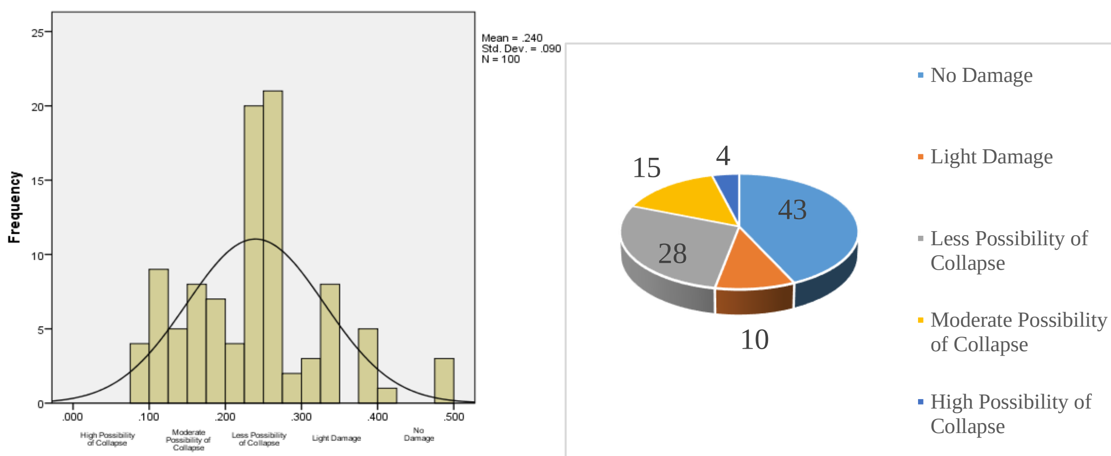

Fig 4: Damage distribution curve and percentage of damage situation by VR Method

From the above figure it is seen that about 43% building have no damage condition because these are newly developed building approving from pourashava authority and all of these are constructed following the building code. 10% building is lightly damaged if there occur any earthquake and 28% buildings have the less possibility of Collapse following by the 15% buildings of moderate possibility of collapse. In the study area about 4% building have high possibility of collapse.

Emergency Response/ Accessibility vulnerability

Rescue and evacuation are possible if the area is accessible.

A few studies have been done on the accessibility of rescue and evacuation. Hajibabaee et al. (2014) developed accessibility indicators as part of their complete seismic risk evaluation of urban structures. The accessibility indicator is created by combining the road width with the anticipated physical damage (Hajibabaee et al., 2014).

In accessible places are defined in the report (Tokyo Metropolitan Government, 2013) by the Tokyo Metropolitan Government as areas where rescuers are unable to reach people and citizens are unable to flee due to restricted roadways. The buffer area was developed for different road widths to identify those regions and GIS tools is used here (Rahman and Hosen, 2018). But in my research the access road is identified which width is more than or equal to 10 feet. The percentage of structure that is inaccessible by each road was determined, and the results were utilized as indicators as no access of rescue facilities.

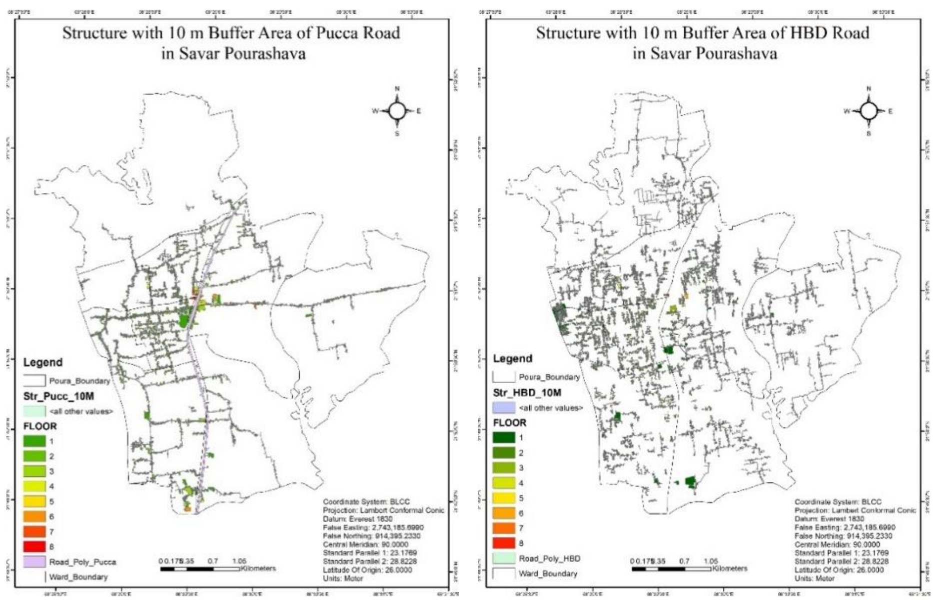

Fig 5: Structures with road access in any emergency evacuation in Savar Pourashava

Physical harm cannot be predicted in Savar because to a lack of seismic experience and study.

The buffer used in the Tokyo Metropolitan Government's report (Tokyo Metropolitan Government, 2013) is used in this study to define the inaccessible structure since there has been no assessment of physical damage at a small scale in Savar. The research excludes katcha roads. For this study, only pucca and HBD road having a width of more than 8 feet or 10 feet were chosen.

Table 7: Ward wise building number which have no emergency evacuation access/road access (road width 10 feet)

Ward No	Building No with no Road Access	Percentage %	Ranking
Ward 1	177	8.86	5
Ward 2	73	3.66	9
Ward 3	146	7.31	6
Ward 4	128	6.41	8
Ward 5	141	7.06	7
Ward 6	396	19.83	1
Ward 7	240	12.02	4
Ward 8	380	19.03	2
Ward 9	264	13.22	3
Total	1997	100.00	

Out of 1997 building more or equal to 4 stories building is about 92 and most of them are in the ward 5, ward 6, ward 8 and in ward 9.

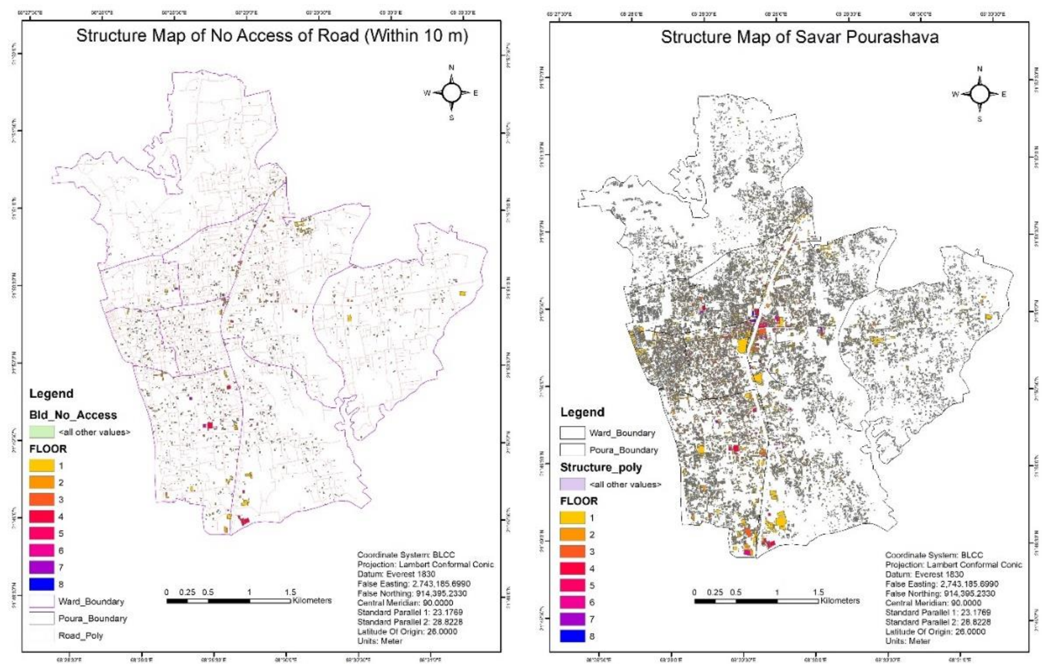

Fig 6: Map of buildings have no access from road (10 m buffer) in any emergency rescue

Table 8: Ward wise HH and density data

Ward No	Total HH/Structure	Percentage %	Population	Area_sqkm	Dens_sqkm
Ward 1	4774	14.36	34926	3.63	9625.91
Ward 2	2195	6.60	20255	0.58	34732.64
Ward 3	2168	6.52	30204	0.49	62111.67
Ward 4	2519	7.58	14628	0.79	18559.42
Ward 5	2057	6.19	28373	0.65	43978.33
Ward 6	4567	13.73	43545	2.00	21789.88
Ward 7	5090	15.31	50053	3.16	15821.54
Ward 8	5747	17.28	30904	2.67	11589.58
Ward 9	3601	10.83	33120	2.55	12993.07
Total	33254	100.00	286008	16.51	17324.68

Availability of Emergency Medical Facilities

In the study area the road is narrow and if there occur any disaster as like as earthquake then it will be difficult to reach the health services. There are some health service facilities savar pourashava but they are not well distributed to all the wards. Most of the health centers are located in ward 5, ward 6 and ward 8.

Assessment of Earthquake Risk Vulnerability

Table 9: Weighting factor of earthquake risk vulnerability

Ward No	Population	Den/sqkm	Total Empl	Residen.	Commer.	Industry	Total Weight	Ranking
1	34926	9626	4292	4669	126	6	536450	6
2	20255	34733	2569	2149	90	12	598080	5
3	30204	62112	1716	1897	333	0	962620	1
4	14628	18559	1217	2435	127	0	369660	9
5	28373	43978	1662	1887	176	4	760800	2
6	43545	21790	3824	4131	275	75	736400	4
7	50053	15822	4213	4630	326	41	750850	3
8	30904	11590	2744	5247	370	17	508720	8
9	33120	12993	2841	3391	169	41	525550	7

From the above table it is seen that ward number 3 and ward number 5 is high risk area in the study area because of their population and density. The normal weightage factor is added here to identify the vulnerability rank of the earthquake risk (Sarkar and Rahman, 2018). In the above table all the factors is multiply by 10 and total weight is obtained by 6 factors. The highest weight got the highest ranking.

Risk Reduction Strategies and Conclusion

School Orientation Program

Some non-governmental organizations (NGOs) in the study area, like as BRAC, Proshika, and Oporajeo-Bangladesh, are now doing awareness-raising efforts at a few selected schools.

They, on the other hand, have no contact with local authorities like the Ward Commissioner's Office. As a result, many community efforts are unsuccessful.

Local Residents' Opinions on Risk Reduction Strategies

It's critical to understand a community's perspectives on risk reduction before establishing a plan. Many of the ideal metrics may or may not be appropriate for the research topic. As a result, their views on their existing institutional linkages, capability and drawbacks in risky situations, and key reasons of vulnerability have been gathered using various Participatory Rural Appraisal (PRA) methodologies. Finally, they were questioned about risk-reduction techniques they would want to employ.

The Study Area's Capacity and Drawbacks

Strengths, weaknesses, opportunities, and threats of the research region have been identified through focus group discussions with local people in order to build a successful risk reduction plan using SWOT analysis. The study area's major strength is the sense of community among the locals. There have been no earthquakes in the study region. Before the fire department arrived, the majority of the flames had been put out by locals. Some female members of the world level committee focus on problems in the research field that impact women and children.

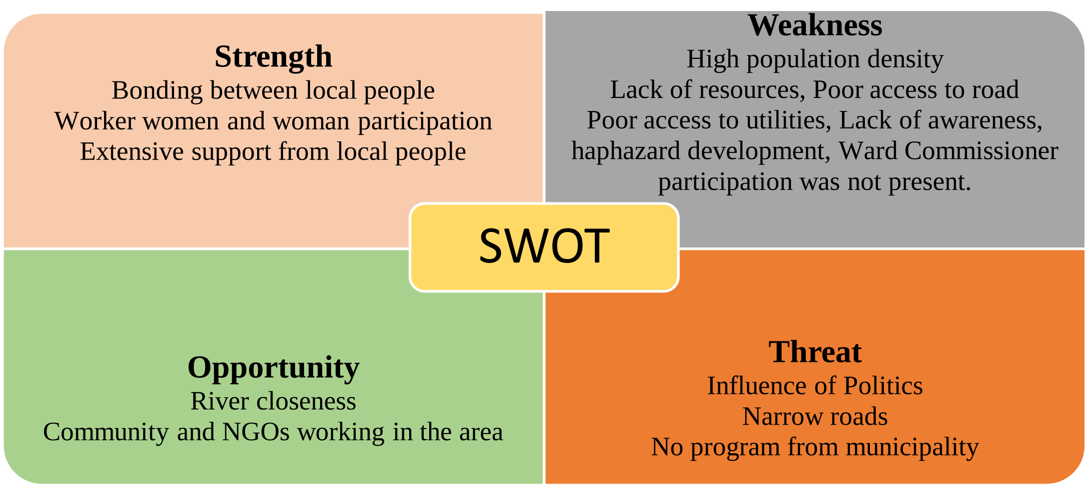

Figure 7: SWOT analysis of the study area

Source: Focus Group Discussion, 2020

According to the BBS 2011 census, savar pourashava has a total population of 2,86,007 people and 74,515 households. The population density is 20,313 which is comparatively very high to the national density of 972 per sq. km. In the event of a disaster, managing such a large population will be extremely difficult. Aside from that, most municipal amenities such as water, electricity, and gas supply are unavailable to the locals.

After examining the community's external variables, it was discovered that the study area's river accessibility provides an opportunity for earthquake or any fire hazard. Some NGOs operating in the area may be able to assist with disaster risk reduction. Aside from opportunity, several external unfavorable factors in the research region may stymie risk reduction efforts.

Vulnerability's Major Causes

Local residents believe that the study area has several issues that make it vulnerable to earthquake in the area. These include a lack of understanding of earthquake hazards, limited road access, inadequate utility access and high population density. The study area's greatest concern, according to the pair-wise ranking matrix technique, is a lack of earthquake risk awareness, followed by high population density and limited roads. The FGD identifies the major issues, which include the following:

Problem 1: Lack of earthquake risk awareness; Prob 2: Narrow Road/Poor access; Prob 3: High population density; Prob 4: Emergency evacuation knowledge; Prob 5: Self-protection ability and Prob 6: Poor access to utilities.

Table 10: Pair-wise ranking of existing problems matrix

	Prob 1	Prob 2	Prob 3	Prob 4	Prob 5	Prob 6	Score	Rank
Prob 1	√		√	√	√	√	5	1
Prob 2		√	√	√		√	4	2 (1)
Prob 3	√	√	√			√	4	2 (2)
Prob 4	√	√		√	√		4	2 (4)
Prob 5	√			√	√		3	3
Prob 6	√	√	√			√	4	2(3)

Source: Focus Group Discussion, 2020

From the above table it is seen that the problem 1: Lack of earthquake risk awareness is the ranked one problem.

People in the area desire to adapt risk-reduction strategies

Based on the input of local inhabitants, a risk reduction strategy was established after analyzing the present level of vulnerability. Based on the assessment of those stages, a checklist has been established for the study area in order to reduce the risk of earthquake risk mitigation measures. The people, according to focus group discussions, do not currently practice any of these measures. In addition, they were asked which of these projects they would be prepared to adapt in the future. Due to financial incapacity and a lack of risk perception, the majority of these are unsuitable for them.

Table 11: Risk-reduction measures are ranked in pairs-wise matrix

	Training	Road Access/Wide	Emergency evacuation	Awareness	Structural measures	Score	Rank
Training	√		√	√		3	3
Road Access/Wide		√	√			2	4
Emergency evacuation	√	√	√	√		4	1
Awareness	√		√	√	√	4	2
Structural measures				√	√	2	5

Source: Focus Group Discussion, 2020

Besides again from five risk-reduction measures listed above, there are a few additional options. Due to a lack of resources to design risk-reduction measures for each home, all of these are inapplicable in the study area. Short-term, intermediate-term, and long-term measurements are all options for lowering the local community's risk perception.

Structural and Non-Structural Measures

- Access roads should be expanded in the short term by covering exposed drainage. Construction materials and industrial items should be stored off the road in the near future.
- The most vulnerable buildings of the study area should be retrofitted if possible. The new building should be constructed by the regulatory authority permission and by following BNBC code.
- An evacuation plan should be established and disseminated at the local level so that residents are aware of the location of evacuation shelters and the safest path to those shelters in the event of a crisis.
- When selecting evacuation centers, structural stability and road accessibility should be considered.
- Regular community group talks and meetings on earthquake and fire hazard awareness should be held with local people in schools, social clubs, and the ward office
- Volunteer teams made up of local students may be formed by social clubs.
- Educational institutions such as schools and madrashas are respected by the community, and they are thought to be in a position to lead disaster risk management in the study area.
- Religious institutions have a significant role in reducing community catastrophe risk because they affect a wide range of individuals.

Conclusion

Earthquakes may have significant loss of city’s urban features as like as physical and social damage of the communities. Some unplanned urbanization issues as like as fast population increase and density, poor building structures, and other factors may result in an uncontrolled situation to make the municipality more vulnerable to earthquake. Besides these the poor condition of social awareness and emergency evacuation preparedness factors (8.91 out of 25) which is very low in savar municipality may increase the earthquake risk and vulnerability. Besides these in this study there have high possibility of 4% buildings to collapse in terms of their vulnerability assessment. This study is was conducted by physical vulnerability study of 100 buildings in determining the amount of damage risk. The significant issues of this study is the concept of social awareness regarding earthquake vulnerability and measuring it will help communities and people in recovering from and responding to earthquakes. This study will benefit in community planning and development, as well as in building construction with some social awareness and emergency evacuation knowledge. The model utilized in this study will directly contribute to the evaluation of vulnerability and will also support in the earthquake mitigation activities of the Savar Municipality.

References

Ahmed, M. and Rahman, M. M. (2020). "Local Climate Change Governance and Making Climate Resilient Town: The Role of Local Authorities." *Research and Reviews: Journal of Architectural Designing,* 2(1), 1–13. http://doi.org/10.5281/zenodo.3901378.

Akter, J., Shawon, M. T. A. and Rahman, M. M. (2021). Urban Density Influence on Travel and Mode choice Behavior of Savar Municipality: Household Survey Study. *Journal of Transportation Engineering and Traffic Management*, 2(2), 1–20. http://doi.org/10.5281/zenodo.5082057

Akther, F. and Rahman, M. M. (2017). "Consequences of commercial use in National Highway: A Case Study on Section of Dhaka Aricha Highway in Savar Municipality," *The Jahangirnagar Review, Part II: Social Sciences*, Vol. XXXVIII, 2014, pp. 191 – 206.

Akhter, S. H. (2010). Earthquakes of Dhaka. Environment of Capital Dhaka—Plants wildlife gardens parks air water and earthquake. *Asiatic Society of Bangladesh, Dhaka*, pp. 401-426.

Alam, J. and Hossain, F. (13 May, 2013). "Bangladesh collapse search over; death toll 1,127". Yahoo News. Associated Press. Retrieved 13 October, 2020.

Barnett, J. (2001). Adapting to climate change in Pacific Island countries: the problem of uncertainty. *World development*, 29(6), 977-993. https://doi.org/10.1016/S0305-750X(01)00022-5

BBS. (2011). Population Census-2001, Community Series, Zila: Dhaka. Bangladesh Bureau of Statistic, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. Retrieved from www.bbs.gob.bd/webtestapplication/userfiles/image/census 2011.

Bilham, R. (2004). Earthquakes in India and the Himalaya: tectonics, geodesy and history. *Annals of Geophysics*, Vol. 47, N. 2/3. http://hdl.handle.net/2122/798

BNBC. (2020). Bangladesh National Building Code, 2020. Ministry of Housing and Public Works, Government of the People's Republic of Bangladesh.

Biswas, M. R. U. I., Rahman, M. M. and Akther, F. (2016). "An Aproch to Implement Master Plan in the Urban Local Government of Bangladesh: A Case Study on Phulpur Municipality," *Jahangirnagar University Planning Review*, ISSN 1728-4198, Vol. 14, June 2016, pp. 97 - 112.

Briassoulis, H. (2009). Factors influencing land-use and land-cover change. *Land cover, land use and the global change,* UNESCO *encyclopaedia of life support systems (EOLSS),* 1, 126-146.

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., Shinozuka, M., Tierney, K., Wallace, W. A., & von Winterfeldt, D. (2003). A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities. *Earthquake Spectra*, 19(4), 733–752. https://doi.org/10.1193/1.1623497

BUERP. (2014). Bangladesh Urban Earthquake Resilience Project. Dhaka Profile and Earthquake Risk Atlas. *World Bank, Earthquake and Megacities Initiatives (EMI).* Retrieved on 25 July, 2020 from https://emi-megacities.org/wp-content/uploads/2015/01/Dhaka-City-EQ-Risk_ProfileandAtlas_FINAL.pdf.

CDMP. (2009a). Earthquake Contingency Plan for Dhaka City. Dhaka: Comprehensive Disaster Management Program (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh, Phase 1.

CDMP. (2009b). Risk Assessment of Dhaka, Chittagong and Sylhet City Corporation Area. Dhaka: Comprehensive Disaster Management Program (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh, Phase 1.

CDMP. (2009c). Seismic hazard map for seismic hazard and vulnerability assessment of Dhaka, Chittagong and Sylhet City corporation areas. Comprehensive Disaster Management Programme (CDMP), Ministry of Food and Disaster Management, Dhaka, Bangladesh.

CDMP. (2014). Scenario Based Earthquake Contingency Plan of Mymensingh Municipality Area. Comprehensive Disaster Management Programme (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh.

Chakrabarty, A., Rahman, M. M. and Ubaura, M. (2020). "Assessment of Emergency Evacuation Preparedness for Seismic Hazard in an Urban Area" in the *17th World Conference on Earthquake Engineering*, 17WCEE, Sendai, Japan - September 13th to 18th 2020, pp. 6h-0004, 1-9. Sendai, Japan.

Chen, S. C., Ferng, J. W., Wang, Y. T., Wu, T. Y., & Wang, J. J. (2008). Assessment of disaster resilience capacity of hillslope communities with high risk for geological hazards. *Engineering geology*, 98(3-4), 86-101. https://doi.org/10.1016/j.enggeo.2008.01.008

Chen, S. C., Wu, C. Y., & Wu, T. Y. (2009). Resilient capacity assessment for geological failure areas: examples from communities affected by debris flow disaster. *Environmental geology*, 56(8), 1523-1532. https://doi.org/10.1007/s00254-008-1251-y

Comfort, L. K. (2007). *Shared risk: Complex systems in seismic response*. Emerald Group Publishing.

Davidson, R. A., Villacis, C., Cardona, C., & Tucker, B. (2000). A project to Study Urban Earthquake Risk Worldwide (Article no. 0791). Paper presented at the 12th World *Conference on the Earthquake Engineering (12 WCEE*). https://www.iitk.ac.in/nicee/wcee/article/0791.pdf

Fransen, J., van Dijk, M. P., & Edelenbos, J. (2021). Urban paradigm shifts in emerging economies. *In Urban Planning, Management and Governance in Emerging Economies*. Edward Elgar Publishing.

Hajibabaee, M., Amini-Hosseini, K., & Ghayamghamian, M. R. (2014). Earthquake risk assessment in urban fabrics based on physical, socioeconomic and response capacity parameters (a case study: Tehran city). *Natural hazards*, 74(3), 2229-2250. https://link.springer.com/content/pdf/10.1007/s11069-014-1300-7.pdf

Hasan, M. M. and Rahman, M. M. (2014). "The Best Practices of Coping Strategies during Hazards: A Lesson from Local Charland Women," The *Jahangirnagar Review, Part II: Social Sciences*, Vol. XXXIV, 2010, pp. 81 – 91.

Khan, A.A. (2004) "Earthquake hazard: Dhaka city perspective", The Daily Star, Vol. 5 No. 40.

Mahmud, H., Rahman, M. M. and Sharmin, S. (2020). "Urbanization Impact on Wetlands: A Case Study on Dhamrai Paurashava." *The Jahangirnagar Review, Part II: Social Sciences*, Vol. XLI, 2017, ISSN 1682-7422, pp. 277-291.

Manyena, S. B. (2006). The concept of resilience revisited. *Disasters*, 30(4), 434-450. https://doi.org/10.1111/j.0361-3666.2006.00331.x

Miles, S. B., Green, R. A., & Svekla, W. (2012). Disaster risk reduction capacity assessment for precarious settlements in Guatemala City. *Disasters*, 36(3), 365-381. https://doi.org/10.1111/j.1467-7717.2011.01267.x

Omar, M. A. I. (2018). Seismic Risk Assessment Considering Emergency Response Difficulties in Dhaka City Corporation Area, Bangladesh (Masters Thesis). Yokohama National University.

Paton, D., Millar, M. & Johnston, D. Community Resilience to Volcanic Hazard Consequences. *Natural Hazard*s 24, 157–169 (2001). https://doi.org/10.1023/A:1011882106373

Patton, M. Q. (2014). Utilization Focused Evaluation. 4th Edition. Sage Publications.

Rahman, M. M. and Akther, F. (2015). Provisions and Violations of Setback Rules in Building Constructions: A Case Study of Savar Pourashava. *Jahangirnagar Review Part II Social Sciences*, Vol. XXXV, ISSN 1682-422, pp. 179-191

Rahman, M. G. F. (2004) "Seismic Damage Scenario for Dhaka City", M.Sc. Engg. Project thesis, Department of Civil Engineering, BUET, Dhaka.

Rahman, M. M. (2012). "An Investigation into Urban Water Quality: A Focus on Savar Pourashava," Ja*hangirnagar University Planning Review*, ISSN 1728-4198, Vol. 10, June 2012, pp. 127-138.

Rahman, M. M. and Akther, F. (2015). "Provisions and Violations of Setback Rules in Building Constructions: A Case Study of Savar Pourashava," *The Jahangirnagar Review, Part II: Social Sciences*, Vol. XXXV, 2011, pp. 179 – 191.

Rahman, M. M., Saha, R. and Tanvin, F. (2021). "Regional Economic Development of Pabna District in Bangladesh: A Shift Share Approach." *Journal of Engineering Analysis and Design*, 3 (1), pp. 1–9. http://doi.org/10.5281/zenodo.4700533

Rahman, M. M., Tariq, A. A. and Sharmin. S. (2020). "Planning Intervention in Emergency Evacuation to Minimize Hazard Impact: A Case Study of Old Dhaka and Dhaka Export Processing Zone." *Journal of Earthquake Science and Soil Dynamics Engineering*, 3(3), 1–16. http://doi.org/10.5281/zenodo.4305837.

Rahman, M. M., Rahman, A., Satu, S. A., and Sharmin. S. (2020). "Locational Attributes of Playgrounds in a City: Need Assessment Approach on Zone 2 in DNCC, Bangladesh." *Journal of Research in Infrastructure Designing*, 3(1), 1–15. http://doi.org/10.5281/zenodo.3877989.

Rahman, M. M., Hossain, S. M. and Miti, S. S. (2019). "The Deterioration of Water Bodies in Savar Municipality & Impact upon the Natural Drainage and Flow Routes." *International Journal of Advanced Research in Innovative Discoveries in Engineering and Applications [IJARIDEA]*, Vol.4, Issue 3, 27 June 2019, pg. 7-13.

Rahman, M. M. and Hosen, M. M. (2018). "Land use - Temporal Pattern Analysis of Urban Heat Island by Using Remote Sensing: A Case Study on Pabna Municipality," *Pabna University of Science and Technology Studies*, Volume 03, 2018, pp. 1-7.

Rahman, M. M., Tariq, A. A. and Sharmin, S. (2021). "Earthquake Resilience at District Level Hospital in Bangladesh: Tactic of Non- Structural Elements and Social Awareness" in the *1st Croatian Conference on Earthquake Engineering, 1CroCEE, Zagreb, Croatia*, 22 - 24 March 2021, pp. 187 - 198, Zagreb, Croatia.

Rahman, M. M., Akther, F., Satu, S. A. and Sharmin, S. (2020). “Geographic Information System (GIS) based Approach in Delineation of Efficient Natural Flow Routes for Drainage Plan of a Municipality”. *International Journal of Research Publications*. Volume-50, Issue-1, April, 2020. DOI: 100501420201045. http://ijrp.org/paper-detail/1046

Sarker, S., and Rahman, M. M. (2018). “Trend Analysis of Bank Erossion of Jamuna River and Migration Impact: A Case Study on Teota Union of Shibalaya Upazila,” *Journal of Bangladesh Institute of Planners*, ISSN 2075-9363, Vol. 9, 2016, April 2018, pp. 81-93.

Rahman, N., Ansary, M. A., & Islam, I. (2015). GIS based mapping of vulnerability to earthquake and fire hazard in Dhaka city, Bangladesh. *International journal of disaster risk reduction*, 13, 291-300.

Roy, S. (2014). Probabilistic prediction for earthquake in Bangladesh: Just how big does the earthquake have to be next years?. *Open Journal of Earthquake Research*, 2014. DOI:10.4236/ojer.2014.32011

Shawon, M. T. A., Rahman, M. M. and Ahmmed, M. Z. (2021). Municipal Solid Waste Management and Environmental Awareness: Household Survey Study on Dhamrai Municipality. *Research and Reviews: Journal of Environmental Sciences*, 3(2), 1–15. http://doi.org/10.5281/zenodo.4911432

Shawon, M. T. A., Mahmud, M. A., Rahman, M. M., Ubaura, M. and Rashied, M. (2021). “Evaluating Earthquake Vulnerability Using Analytical Hierarchy Process (AHP) and Social Appraisal of Retrofitting in Lalmatia, Dhaka” in the *1st Croatian Conference on Earthquake Engineering, 1CroCEE, Zagreb, Croatia*, 22 - 24 March 2021, pp. 145 - 156, Zagreb, Croatia.

Statista. (2019, December 9): Bangladesh: Urbanization from 2008 to 2018. Statista; Statista https://www.statista.com/statistics/455782/urbanization-in-bangladesh.

Tansy, H. (23 April, 2015). "Reliving the Rana Plaza factory collapse: a history of cities in 50 buildings, day 22". The Observer. London: The Guardian. Retrieved 22 June 2017

The Daily Star. (2007). The Daily English newspaper in Bangladesh. Published on Friday, Oct 5, 2007. Retrieved from https://www.thedailystar.net/news-detail-6625

Tilio L., Murgante B., Di Trani F., Vona M., Masi A. (2011) Resilient City and Seismic Risk: A Spatial Multicriteria Approach. In: Murgante B., Gervasi O., Iglesias A., Taniar D., Apduhan B.O. (eds) Computational Science and Its Applications - ICCSA 2011. ICCSA 2011. *Lecture Notes in Computer Science*, vol 6782. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-21928-3_29

Tokyo Metropolitan Government. (2013). Your community’s earthquake risk: The seventh community earthquake risk study; 2013 (in Japanese).

Tuzzohora, F., Parvez, S. and Rahman, S. (2015). Effective Evacuation Management and Mitigation Plan for Earthquake: A case Study on Lalbagh Area of Dhaka City. *International Journal of Earthquake Engineering and Geological Science (IJEEGS).* Vol. 5, Issue 2, Jun 2015, 1-16.

Warrick, O., Aalbersberg, W., Dumaru, P., McNaught, R., & Teperman, K. (2017). The ‘Pacific Adaptive Capacity Analysis Framework’: guiding the assessment of adaptive capacity in Pacific island communities. *Regional Environmental Change*, 17(4), 1039-1051. doi:10.1007/s10113-016-1036-x

Wikipedia. (2020). 2013, Dhaka garment factory collapse. Retrieved on 15th October, 2020 from https://en.wikipedia.org/wiki/2013_Dhaka_garment_factory_collapse.