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Seismic Risk Assessment of Existing Buildings Based on Architectural View in Dhaka City, Bangladesh

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Abstract: Dhaka, capital city of Bangladesh is one of the most crowded and merely planned megacities in the world, who faces water logging, fire hazard and flood in high frequent rate that sometimes we almost forget about seismic risk. Meanwhile, Dhaka has scrutinized as highly risky city in the world because of its geographic location close to seismically active zones on earth, unplanned urbanization, non-tecnichal construction practice, deficient knowledge on the seismic design of structural system, ignorance of building codes, horrendous construction monitoring by the relevant authorities and lack of coordination between different urban developing authorities. It is predicted by the scientists that a massive devastation in terms of casualities and property damage may be occured if a strong earthquake hits Dhaka. So, it is highly demanded to evaluate the vulnerability of existing buildings to understand the nature of emergency response and earthquake risk reduction strategies are required for Dhaka city in terms of urban planning and design. The aim of this paper is to appraise the earthquake risk of existing structures in different residential areas in Dhaka city. It is expected that citizens from the whole city are may not remain at the same risk. That is why Dhaka has divided into two part - Old and New Dhaka for study purpose. The areas covered under the survey are Mirpur and Lalbagh. Rapid Visual Screening (RVS) and Turkish Methods have been employed for the assessment of seismic risk in residential buildings based on recording various variables from the side way. Depending on the parameters, different performance scores has been assigned to individual building by which the buildings have been classified as safe, moderate and vulnerable. The survey results highlight that seismic vulnerability assessment recognized as 40.9% buildings are vulnerable, 19.3% moderately vulnerable and 39.8% safe. The end result of the study will be advantageous to strengthen the awarness of city authorities, engineers, planers, architects and local dwellers.

Keywords: Seismic Risk, Dhaka, R. V. S. System, Turkish Method, Vulnerability Score, Awareness

1. Introduction

A recent study published that Dhaka leaves in highly vulnerable situation for massive earthquake with the magnitude of 8 to 9 and the damage could be severe [1, 2]. The urban growth pattern of this city is staggeringly unplanned, contradicts with building code, decreased construction quality and no reflection of special treatment for seismic vulnerability in design put together the infrastructures in a fragile condition for future strong earthquake. After observing this situation, the Government of Bangladesh has published Guidebooks on City Earthquake Risk Atlas, Dhaka Risk-Sensitive Land Use Planning but practically stakeholders and authorities are far behind [3]. Lack of awareness causes an unplanned and unfit structural development here. If earthquake does not kill people these unsafe unplanned buildings do. Dhaka deserves special treatment because of its earthquake vulnerabilities. The first step should be identify the highly vulnerable structures and retreat them like retrofitting. If inevitable and proper measure can be taken against the shaky buildings the intensity of seismic vulnerability can be reduced [4]. Therefore at present it's highly demanded that an evaluation of existing buildings to seismic resistance. To address present scenario of Dhaka, this study conducts an assessment of existing buildings to

identify the sensitive structures and the components which can cause poor performance during future earthquake.

The prime concern of this research is the analysis of vulnerable situation of existing residential buildings in Dhaka City due to earthquake. Particularly, identify the seismic risk of existing buildings in selected area based on architectural view and enhance the awareness of city authorities, engineers, planers, architects and local dwellers by the outcome of the study are our goal too.

Timeline of Dhaka expansion clearly gives an image that, it has two dominant patterns in the evolution of urban: old Dhaka or the historic core and new Dhaka or northern expansion [5]. Number of high-rise building is increasing rapidly all over the city mostly in developed Dhaka. On the contrary, Old Dhaka is mostly unplanned and vulnerable part of Dhaka city. Hence, this study has attempted to identify and analyze the vulnerability factors with respect to buildings appearance in two different study areas named Pallabi and Lalbagh. Pallabi is in under Dhaka North City Corporation, which has been a growth of supermarkets, schools, commercial buildings, residence etc [6]. No studies or survey find for seismic risk in this area. If any hazard happens here, millions of people will be sufferer. On the other hand, old Dhaka has indigenous historical core e.g. Shankhari Bazaar, Tanti Bazaar, Sadarghat, Lalbagh. Which are very densely populated areas with inadequate and narrow lanes and by lanes [7]. Apart from that, any post disaster management will be worse here due to unofficial or haphazard dense community, buildings and shelters without engineering supervision, huge amount of poor constructed buildings, adjoining building pattern and shortcoming of open spaces which have created inaccessibility of movement at the building block and street level [8]. Lots of studies took part in Shankhari Bazaar, Tanti Bazaar, Sadarghat about vulnerability and redevelopment. Comparatively Lalbagh has a few numbers of studies. Figure 1 has shown the screened are with respect to Dhaka city.

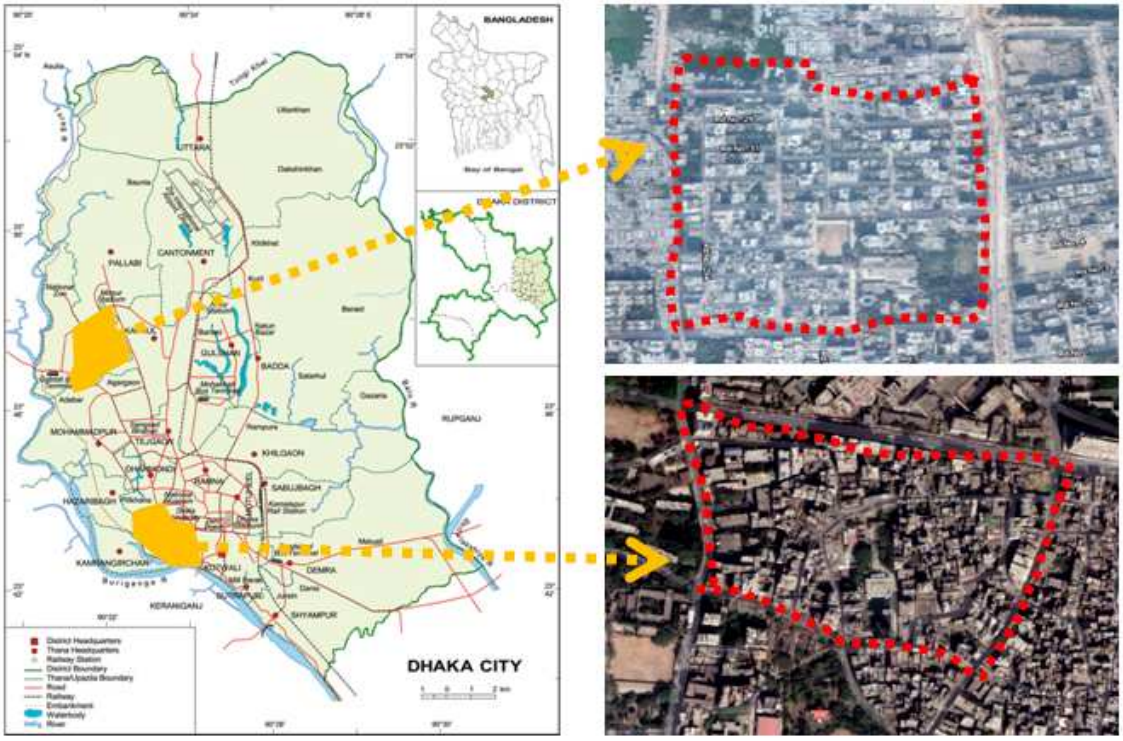


Figure 1. *Study Area Map (Courtesy Google Map).*

2. Materials and Method

In Bangladesh, there is no developed method to assess the vulnerability of existing buildings [9]. Researchers are trying to invent and develop scientific methods now a days. That's why to assess the buildings of study area two methodologies has followed named RVS (Rapid Visual Screening) from FEMA (Federal Emergency Management Agency), Turkish Method by Haluk Sucuoglu.

2.1. Turkish Method

In 2003, Professor Haluk Sucuoglu and Professor Ufuk Yazgan from Turkey developed a simple two-level building assessment procedure based on various building parameters to evaluate building performance during earthquake. Basically, this procedure was invented to generate a building database with ranking according to their calculated seismic performances under a defined ground excitation [10]. At first, a building assess from road which depends on six simple structural and geotechnical parameters. Those parameters for representing building vulnerability are the following [10]:

1. The number of stories above ground.
2. Presence of a soft story (Yes or No).
3. Presence of heavy overhangs, such as balconies with concrete parapets (Yes or No).

4. Apparent building quality (Good, Moderate or Poor).
5. Presence of short columns (Yes or No).
6. Pounding between adjacent buildings (Yes or No).

Each building is measured on a scale of vulnerability based on the presence or absence of these parameters. Parameter variation adds different dimension to the seismic performance score. Performance score is calculated by using this formula [10]

$$PS = (BS) - \Sigma [(VSM) \times (VS)]$$

$$PS<50 \rightarrow \text{Vulnerable Structure}$$

Where, PS = Performance Score, BS = Base Score, VS = Vulnerability Score, VSM = Vulnerability Score Modifier.

2.2. RVS (Rapid Visual Screening) Method

During 1988, Rapid Visual Screening (RVS) was first invented in USA and modified in 2002 to integrate with latest technology by FEMA. They published a report book named "*FEMA 154 report, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*". The most prominent feature of this method is assessing vulnerability without any structural analysis calculation and not entering inside the building. One can easily identify and rank potentially hazardous buildings by applying a scoring system [11, 12]. Indian Institute of Technology, Bombay revised this RVS method partially for Indian Subcontinent Zone because all features of RVS method like building type, damage to building are not suitable for this region [13]. It only takes 15-30 minutes for each building to inspect the building and collect all data on spot [12]. Based on five different scales (EMS - 98), a trained surveyor calculate the performance score of the building which indicate the seismic performance of the building.

2.3. Methodological Approach

In this research, we followed a three steps method which consists of a) data collection or compilation b) data integration and c) information output. This overall process is illustrated step by step in Figure 2.

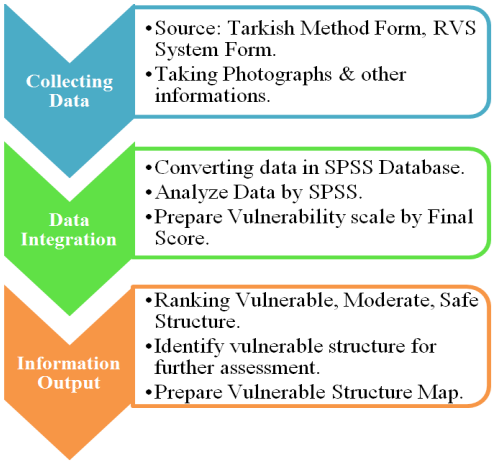


Figure 2. *Conceptual Process of Methodology.*

3. Result and Discussion

This investigation has scrutinized on 538 surveyed buildings in Pallabi and Lalbag. Among them, 310 buildings surveyed in Lalbagh and 228 buildings surveyed in Pallabi. General observations from the collected data of two areas give a clear portrait of probable destruction in case of future earthquake. Besides this, a relationship has enhance between different parameters and vulnerability factors to contend this assessment.

Source: Field Survey, 2019

Figure 3. *Existing Buildings in Study Area.*

3.1. Findings from Turkish Method

In the first place, Dhaka has considered in soil Zone-III from Turkish method as the PGA (Peak Ground Acceleration) value is equivalent to updated earthquake zoning map from BNBC. For Dhaka, the potential Peak Ground Velocity (PGV) 31.49-32.33 has taken as the parameter of seismic ground motion intensity [14]. Total number of structures in this area is almost residential, where most of them are moment resisting RC frame. Among 528 buildings, 214 buildings scored more than 90. If, the building score > 90 then it is considered as safe. Total 104 buildings scored from 50 to 90. When 50< Performance Score<90, building is consider as moderate. When the score is 0-50, those building might be took as censorious which must needed to further investigation. Amidst all buildings, the number of vulnerable is 220. Figure 4 has exhibited the percentage.

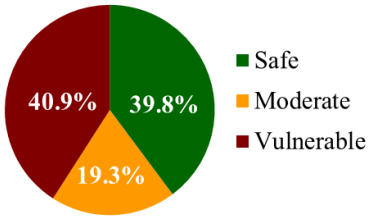


Figure 4. *Overall Building Performance by Turkish Method.*

Building story is an ancillary parameter here. Meanwhile, the building story and performance score is allied. If the building story put in opposition to building vulnerability score, it perceives that, 6 story building is in the highest position for vulnerability. Building vulnerability in two study area has calculated separately and has presented below.

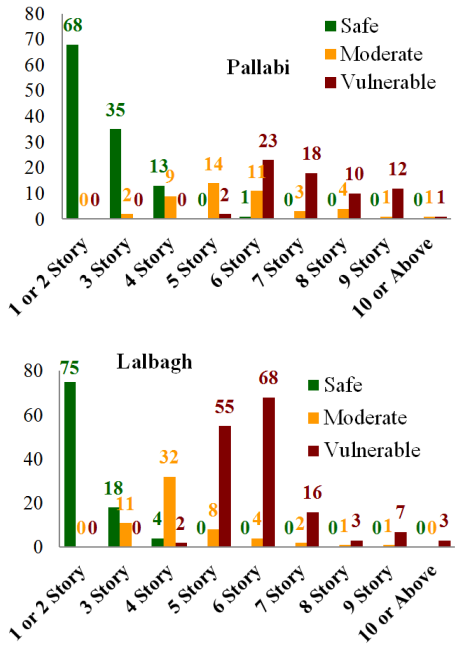


Figure 5. *Vulnerability with respect to Stories.*

Analyzing all data by Turkish Method it has found that, Lalbagh is in more risky position than Pallabi. In Lalbagh, buildings are mixed used in bulk, ground level are using for commercial purposes, almost 75% buildings here are in measurable condition. Comparatively Pallabi is a planned and developed area. But here also many buildings those are not followed RAJUK rules. Overall building performance score of assessed buildings has shown in Figure 6 in two groups. This figure depicts the comparison between Lalbagh and Pallabi clearly about Vulnerability and building story.

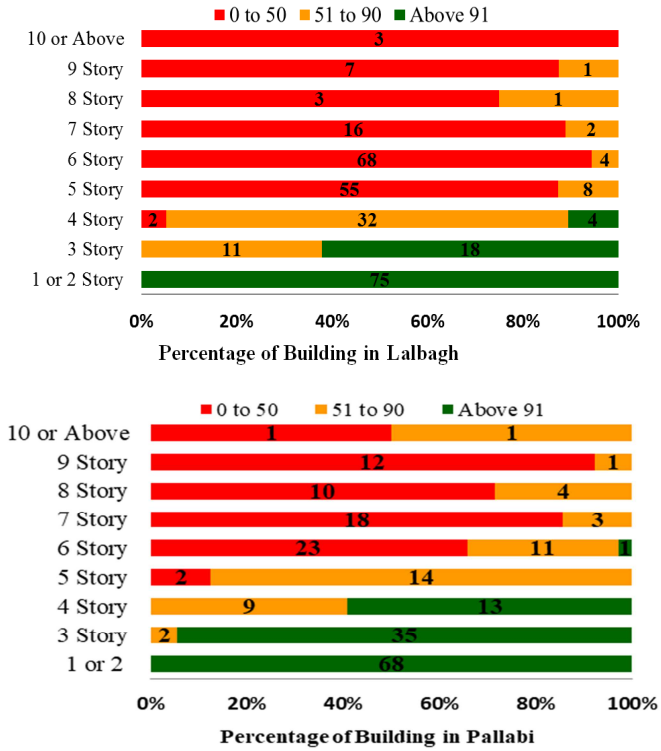


Figure 6. *Building performance score in detail.*

3.2. Findings from RVS System

In accordance with RVS method, this process works for four or above story buildings only [15]. That's why, among 538 Buildings only 329 was analyzed by RVS. The parameters contributing the scoring system are mainly, building height, irregular shape of the buildings and soil type [13]. Overall, Dhaka has soil type II which is in medium condition, so this variable remains constant [16]. For Dhaka, cut off value dictates as 3.0, which will be smaller when negative parameters will be revised [17]. The results shows that no building picked up at the cut off value which was determined by FEMA, in addition a great number of buildings demand additional analysis to measure the risk of actual level. The summary findings from RVS method from the study area has provided in Table 1. According to RVS method, if the score is S < 0.7, the building is highly vulnerable and need further evaluation and treatment. It is assumed that, if building score is S <0.3, the building has a great chance to collapse at ground level. Among 329 buildings, 162 buildings scored below 0.3 and 71 buildings scored 0.3 to 0.7. So, these 233 buildings need further evaluation and retrofitting.

Table 1. *RVS Score for Different Storied Buildings.*

Story	Score Range			
	S < 0.3	0.3 < S <0.7	0.7 < S < 2.0	2.0 < S < 3.0
	Number of Buildings			
4	2	11	11	36
5	47	12	0	20
6	79	10	1	17
7	29	5	1	4
8	2	11	1	4
≥ 9	3	22	0	1
Total	162	71	14	82
Percentage	49.2%	21.6%	4.3%	24.9%

For the both study area, performance score of assessed buildings by RVS method shows that Lalbagh is more vulnerable than Pallabi. Figure 7 has shown the building score in both study area.

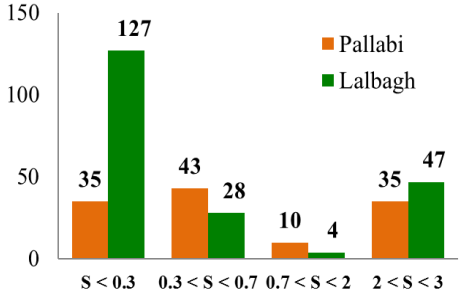


Figure 7. *Building Vulnerability Score.*

Analyzing all data by RVS System, it has found that, 6 story building is more vulnerable than other story type. Among study area, Lalbagh is comparatively vulnerable than Pallabi. In Lalbagh, 5, 6 & 7 story buildings are in most vulnerable. On the other hand, Pallabi has 6 & 7 story buildings in most vulnerable position has shown in Figure 8.

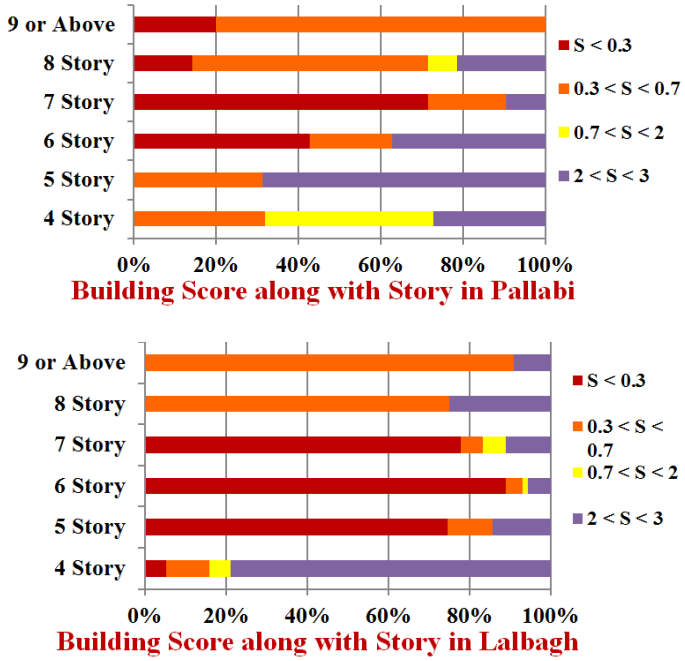
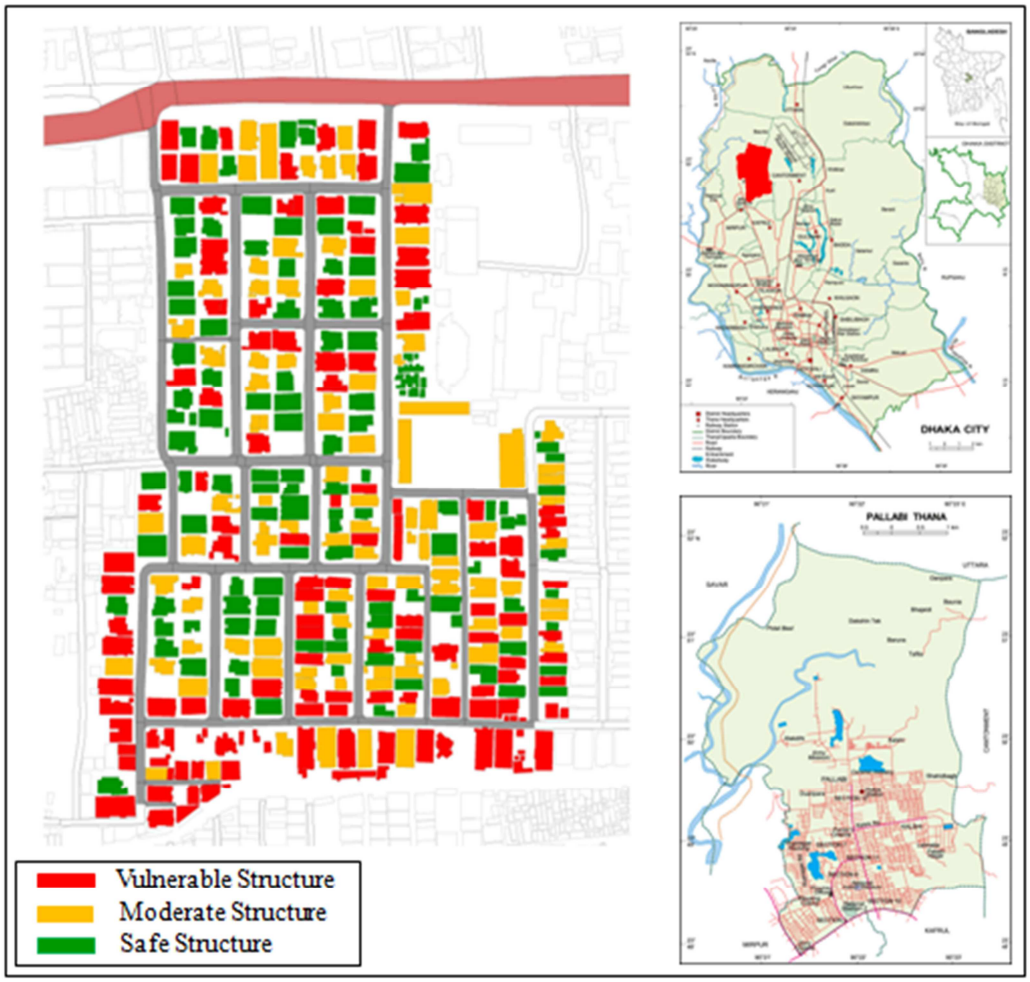
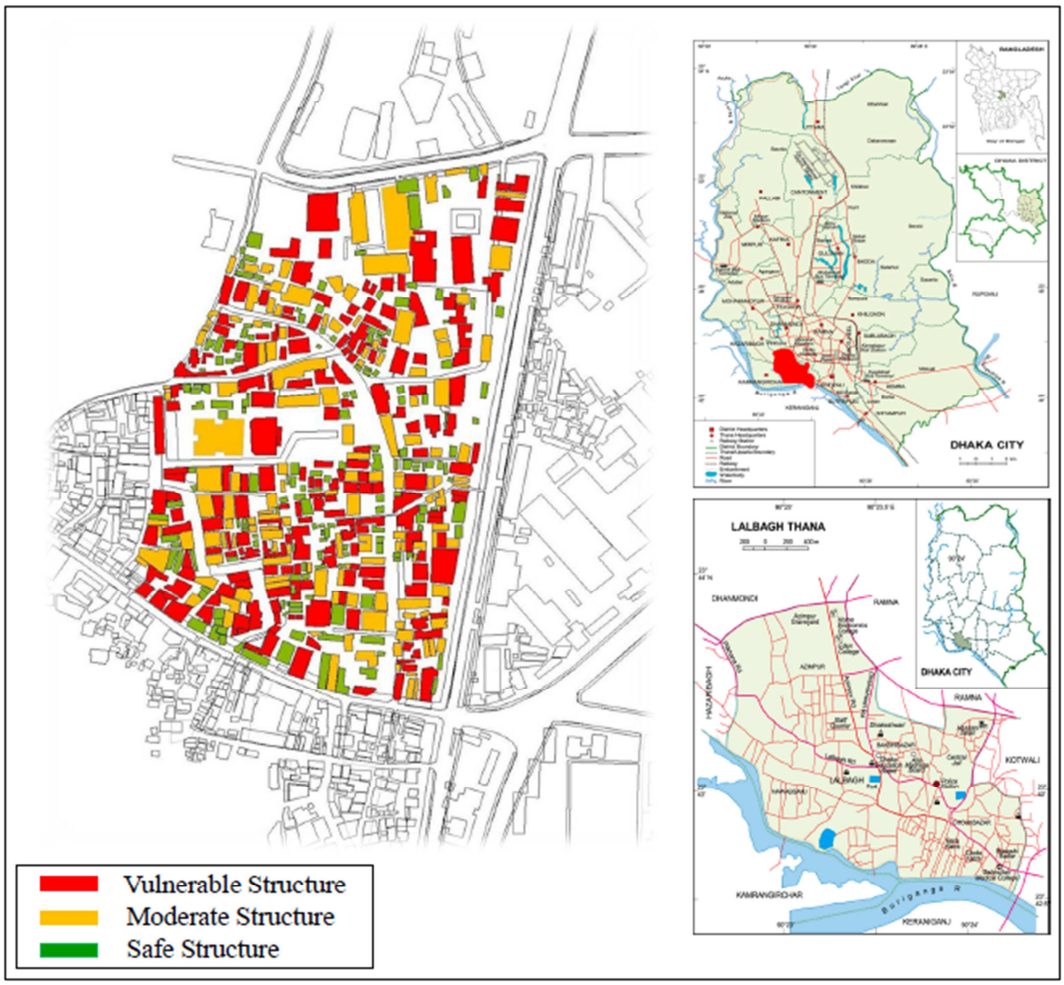


Figure 8. *Score Distribution in Building Height.*



Source: Field Study, 2019

Figure 9. *Vulnerability Map for Pallabi.*



Source: Field Study, 2019

Figure 10. *Vulnerability Map for Lalbagh.*

After compiling two methods, a map has prepared for both study areas (Figures 9-10). These maps are showing building vulnerability rank along with building story. Safe, moderate and vulnerable buildings have marked in three different colors. Hotspot zone for vulnerable buildings has marked in map.

3.3. Identify the Hotspot of Vulnerable Buildings

Between those two vulnerable maps, Pallabi has identified a hotspot zone whereas Lalbagh map is overall same at every corner. We have found that, hotspot is located at the edge of Pallabi residential area. Buildings located in this transition area didn't maintain the building code and proper construction rule. Limited space gap between buildings and maximum buildings are incomplete and not well planned as other part of Pallabi. Inside Pallabi a number of building owners violated the approved plan but most of them have maintain some gaps between buildings. There are peer pressure and community engagement to protect minimum spaces between buildings in Pallabi. This edge of Pallabi has more similarities with Lalbagh in terms of building structures. We have identified some reason by discussing with local people. A number of buildings have built in several steps and they have no approval at the beginning. Those building owners have taken approval from RAJUK later and some of them do not have any kind of permission yet. Those who have taken permission later haven't rebuild the whole building rather renovate some portion and expand vertically and horizontally. The permission helps them to get and/or continue utility connections and save them from regulatory authorities. Some of the buildings have made before building code established or came into practice. A number of the new building owner have violated the approved plan and don't even enclose minimum open spaces between buildings.

3.4. Comparison Among Vulnerability Factors Scenario

Soft story, short column, Pounding effect, heavy overhang, apparent quality, plan irregularity and vertical irregularity – these are the parameters from both Turkish method and RVS system. These parameters have evaluated separately to justify building performance score. During the survey, it has found that, short column and heavy overhang are 47.9% and 53.5% sequentially those two factors are striking in Dhaka. Another point worth noting is pounding effect, which has identified just above a half (56.2%) of all buildings. When it comes to irregularity in plan and vertical length, vertical irregularity is

21% higher than plan irregularity. Plan irregularity mainly causes asymmetrical geometric shape in building plan in the field area. Given figures below are showing the complete scenario.

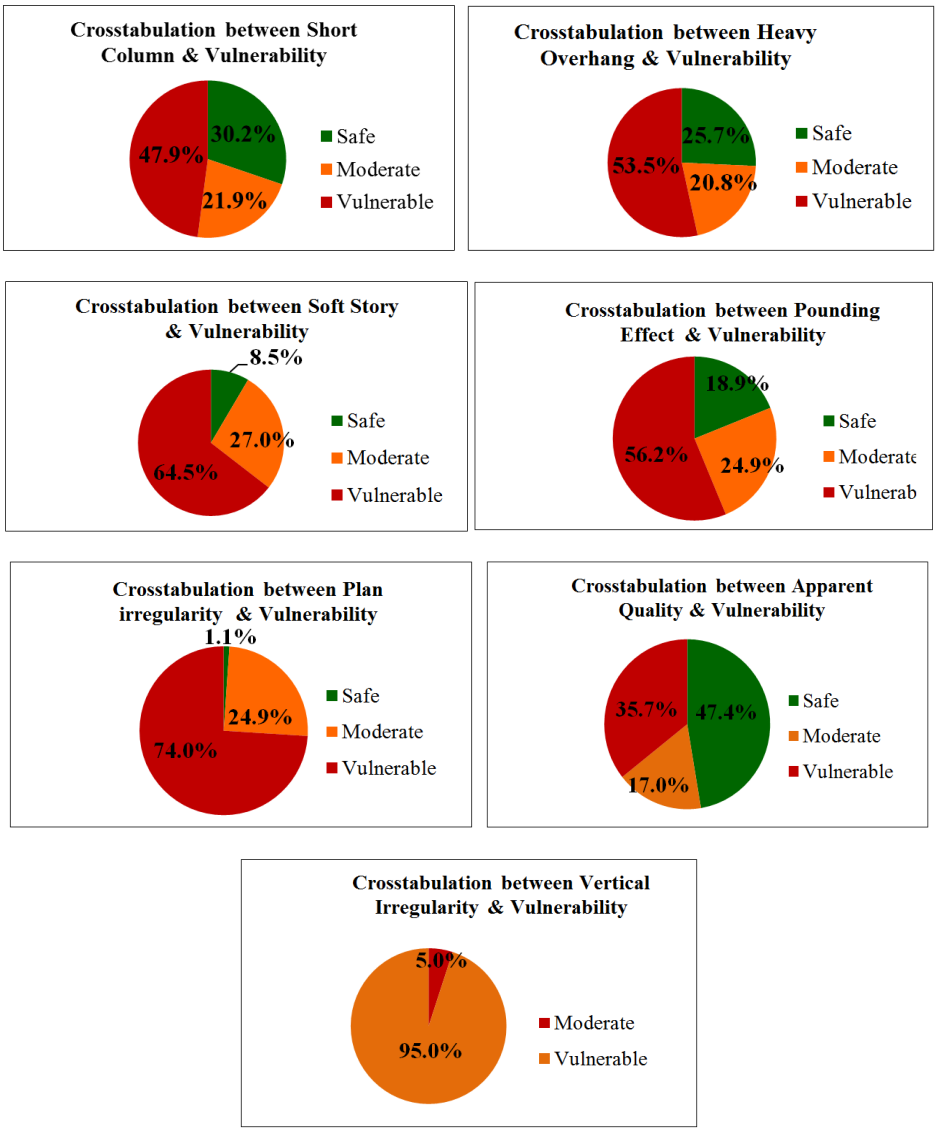


Figure 11. *Percentage of Vulnerability Factors Scenario.*

With regards to all vulnerability indicator, apparent quality and vertical irregularity are in the bottommost point. However, most of the vulnerable factors are available in significant number in both of the study area. An overall scenario of vulnerable factors of the observed buildings has given below for better understanding.

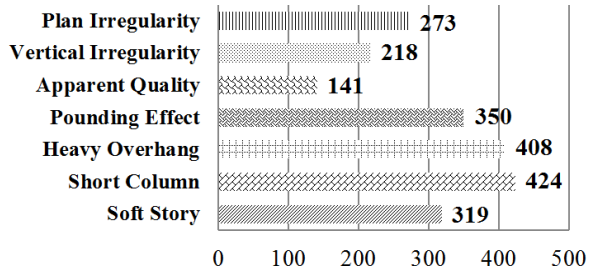


Figure 12. *Overall Scenario of Factors.*

3.5. Summary Findings

3.5.1. Turkish Method Findings

1) From this assessment, we found soft story in 61.3%, short column in 78.8%, Heavy overhang in 78.7%, pounding effect in 68.4% buildings among total 528 buildings in both study areas.
2) Among 538 buildings, from architectural view 26.5% buildings are in good apparent quality, 43.3% buildings are in moderate apparent quality and 30.2% buildings are in poor condition in survey.
3) By Turkish Method, among 538 buildings total 31.3% buildings are safe, 19% buildings are moderately vulnerable and 49.7% buildings are in vulnerable condition in terms of their performance score (PS) value after survey.

3.5.2. RVS Method Findings

1) Among 329 buildings 87.1% buildings have plan irregularity, 69.5% buildings have vertical irregularity from architectural view.
2) By RVS method, 49.24% buildings are vulnerable, 21.58% buildings are moderately vulnerable and 29.17% buildings are safe.

3.5.3. Findings in Pallabi

1) In Pallabi, among 228 buildings 117 buildings are safe, 45 buildings are moderately vulnerable and 66 buildings are vulnerable.
2) Among vulnerability parameter, pallabi has 118 soft story buildings, 159 short column buildings, for pounding effect Pallabi has 120. On the other hand, 149 buildings have heavy overhang buildings, 26 poor & 93 moderate apparent quality buildings, 85 plan irregular buildings and 67 vertical irregular buildings.

3.5.4. Findings in Lalbagh

1) Lalbagh has 259 heavy overhang buildings, 115 poor & 137 moderate apparent quality buildings, 188 plan irregular buildings and 151 vertical irregular buildings.
2) Among vulnerability parameters from architectural view, Lalbagh has 201 soft story buildings, 265 short column buildings and for pounding effect Lalbagh has 230 in numbers.
3) In Lalbagh, among 310 buildings 97 buildings are safe, 59 buildings are moderately vulnerable and 154 buildings are vulnerable.

3.5.5. Overall Findings

1) Total 329 buildings have screened by both two methods. Each building has scored same by both methods.
2) Among 538 buildings, 220 are vulnerable, 104 are moderately vulnerable and 214 buildings are safe.
3) Those 220 vulnerable buildings and 104 moderately vulnerable buildings should be taken under further assessment to identify their vulnerable structural component and retrofit thereafter as early as possible on priority basis.

3.6. Estimated Causalities

In surveyed area of Pallabi, among 228 buildings 66 buildings are in vulnerable condition. Each of them has two units per floor and they are soft storied buildings. Total 854 households live in those 66 vulnerable buildings. If any serious earthquake happens here, those 66 buildings will face most perilous situation. Roughly 3620 people will be affected seriously and have life threatened [18]. In spite of this, 47.96% people live in the soft story buildings, other surrounding buildings are also in risk as the buildings may fall on the side building and increase the casualty.

On the contrary, Lalbagh has 154 vulnerable buildings, which have diversified structural system. Meanwhile, all of them have one to four units per floor, serving total 1652 households. So, same magnitude earthquake will harm Lalbagh more than pallabi. Roughly 7005 people will be affected in Lalbagh [19]. Around 11592 people live in surveyed area of Lalbag, among them near about 60.43% people are directly vulnerable to the casualty and other surrounding areas are also indirectly vulnerable. We didn't find any data about property loss. People are not willing to give information about their personal property.

3.7. Perceptions of the Possessors

The findings from the survey have been analyzed and the perception of the building owners has been taken by interviewing them. Owners have marked Dhaka city as most vulnerable in terms of earthquake, whereas they marked their own building as somehow vulnerable. None of the respondents knew in which geographical area they are living in terms of soil condition and earthquake vulnerability. A very large proportion of buildings had constructed in between 1940 to 2012. Respondents from Pallabi reported their buildings were made in few years ago or once renovated, while Old Dhaka reported that their buildings have renovated several times including adding floors and changing internal layout. In terms of RAJUK guidelines, Pallabi has followed the rules roughly although the owners aren't familiar with the term "Bangladesh National Building Code" *(Imarat Nirman Bidhimala)*. None of the respondents are able to show the instruction chart with to do list in written or pictorial format on the time of earthquake. None of the buildings have written the phone number of fire service/ambulance. One of the respondents said he has the number, saved in his mobile and may call 999 for any kind of help. Respondent suggest having the emergency phone number with to do list stickers to be printed and put everywhere. They also suggest taking measures to the people who violating the law and build oversized structures without or beyond permission. One respondent raised the issue of billboard and mobile phone tower over the roof of the building may make the building and the surrounding building more vulnerable. Another respondent raised issue about the quality soil test and piling which may be compromised and can't be tested later. They also suggest taking measure by the government to have more research and fine tune the RAJUK permission procedure so the city can accommodate the large number of people with low vulnerability as other developed cities.

4. Recommendation

First and foremost, the prime intent of this study is to enumerate the current scenario of Dhaka in term of future earthquake by assessing vulnerability. Comparatively concrete moment resistant frame considers as hefty structural system, which is in demand in study area, Nevertheless, this structural system is also under threat on account of several vulnerability factors. Research shows that, if any tremor happens at night, it will be a dreadful incident. Depending on this work few selective to do list has prepared as follow:

1) People from every single group like architect, lanner,

engineer, general public, governing body all should come forward from there place to increase awareness and work hand in hand to mitigate the issue.

2) Identified vulnerable buildings should take under observation and immediate treatment like retrofitting or smash if require.
3) Bangladesh Government should arrange earthquake drill in every institute and spread the knowledge to root level.

5. Conclusion

It is beyond doubt that all types of natural disasters are part of mother nature. It is obvious, we are incapable to stop it but able to minimize the loses. For earthquake, most of the casualties happen for collapsing buildings. If it is possible to save infrastructure then the deterioration will be minimum. Regarding this, our study has made an effort to identify vulnerable structures in study area to assist responsive authority and personnel to take necessesary steps.

The immense outcome of the study has strengthened the awarness of the engineers, planers, architect, local dwellers. By the same token, this study result can be supportive to workout on earthquake risk resistance structural system.

By and large, scholars should come forward to develop our very own vulnerability assessment method for our country with considering all negative and positive features from field. Only then we will get the concrete result of casualty.

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