International Journal of Science Academic Research
Vol. 02, Issue 05, pp.1394-1400, May, 2021
Available online at http://www.scienceijsar.com
ISSN: 2582-6425

Research Article

EARTHQUAKE AND SOCIO-ECONOMIC VULNERABILITY ASSESSMENT IN DHAKA CITY

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Received 16th March 2021; **Accepted** 19th April 2021; **Published online** 11th May 2021

Abstract

Earthquake is one of the most extreme hazards that cannot be measured out of all the natural hazard reported. It has a major ability to degrade an urban socio-economic structure with geological components. For this reason, the main objective of this thesis is to assess the seismic vulnerability with socioeconomic aspects in terms of minimal loss of life and damage. In this research, a strategy for vulnerability evaluation has been developed for earthquake-prone areas in Dhaka District of Bangladesh. 240 different residential buildings within three selected wards of Dhaka city were selected to take an interview of building's owner for statistical studies which is a simple coding system to collect the data provided in the questionnaires. After that, calculated the proportion of respondents answering for each category of each question by SPSS software. This data was then utilized in a simple additive weighting (SAW) method to find out the most fragile area within the selected territory based on the social and economic status. The results revealed that ward no. 51 was the most vulnerable area against earthquakes according to social vulnerability, whereas ward no. 46 was more susceptible to earthquake due to economic vulnerability. The assessment outcome can be used to prepare urban emergency response to protect human life, economy.

Keywords: Earthquake, Dhaka, Socio-economic Vulnerability, Assessment, SAW.

INTRODUCTION

Earthquake is a form of energy of wave motion that comes from a limited region and extends from the source of disruption in every direction. It normally takes a couple of seconds to a minute. The point within the earth where earthquake waves originate is called the focus, from where spreads the vibrations all the way. The majority of earthquakes are minor tremors, while bigger earthquakes typically start with mild tremors, take the form of one or more violent shocks and gradually decreasing vibrations called aftershocks. An earthquake struck the city of Fokoshima, Japan, in March 2011. The earthquake lasted only a couple of seconds, but more than 15,000 people died (Albayrak et al. 2015). This example demonstrates how fatal earthquakes are. During the period from 1900 to 1976, earthquakes killed 2.7 million people (Roy, 2014). Earthquake impacts are one of the most devastating disasters, claiming large numbers of casualties, social trauma and physical property damage. Cutter *et al.* (2003) describes the biophysical vulnerability and vulnerability of the built environment and highlights the social aspects of vulnerability. They state that socially created vulnerabilities are largely ignored, mainly because of the difficulty in quantifying them, which also explains why social losses are normally absent in cost / loss estimation reports after a disaster. The socio-economic status plays an important role in increasing the risk-related social vulnerability. People with low socio-economic status have difficulty in restoring their living conditions, which have been disrupted by the disaster (Mileti, 1999). In this study, a vulnerability assessment process has been categorized for earthquake hazard in densely populated residential areas. The proposed model of assessment focused primarily on the social and economic status of the occupants of buildings. The proposed methodology has been implemented for Dhaka, which is one of the metropolitans of Bangladesh.

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Aim of the study

The aim of this research is to define the socio-economic vulnerabilities of an urban area to create significant contributions into disaster preparedness programs in order to determine and standardize effective earthquake disaster parameters with the accessible information.

Objectives

1. To identify the earthquake probability in densely distributed areas of Dhaka city.
2. To find out the specific factors of seismic vulnerability assessment with apposite techniques for earthquake prone area.

Background of this study

Earthquakes Vulnerability in Densely Populated Residential Areas (Bangladesh): Bangladesh is tectonically located on the north-eastern Indian plate near the edge of the Indian pack and at the junction of three tectonic plates-the Indian plate, the Eurasian plate and the Burmese micro plate (Sarraz et al. 2015). The Indian plate moves 6 cm / year in the north-east direction and sub ducting under the Eurasian plate (45 mm / year) and the Burmese plate (35 mm / year) in the north and east respectively (Akhter, 2010). Figure 1 shows different earthquake epicenter locations with their magnitude in and around Bangladesh. Due to the geotechnical setup, major cities including Chittagong, Sylhet, Dhaka, Rangpur, Bogra, Mymenshing, Comilla, Rajshahi are very much vulnerable to earthquake disaster. The occurrence and damage caused by several earthquakes (magnitude between 4 and 6) in the country or near the country's border in the last two decades has raised awareness among general population and the government in Bangladesh. The damage was primarily limited to rural areas near the epicenter, but destructive damage occurred in urban areas 50 to 100 km away from the epicenter.

Due to the magnitude 6.0 earthquake on the border between Bangladesh and Myanmar on 21 November 1997, a reinforced concrete frame building collapsed and killed several people in the port city of Chittagong (Al-Hussaini *et al.,* 2015). A study carried out by the Comprehensive Disaster Management Program (CDMP, 2010) shows that Dhaka city is in danger of massive destruction. The study states that some 78,323 buildings will be completely destroyed if a 6-magnitude earthquake shakes Dhaka from below. In the event of a 7.5-magnitude earthquake, there will be an economic loss of about US $1,112 million for only structural damage (Islam, 2010).Also, Dhaka is the most susceptible city of the world in earthquake, followed by Tehran according to a research of the United Nation in 1999 (Rahman, 2015).So, according to literature review, the possibility of a dangerous strike in and around Bangladeshis risingin the near future.

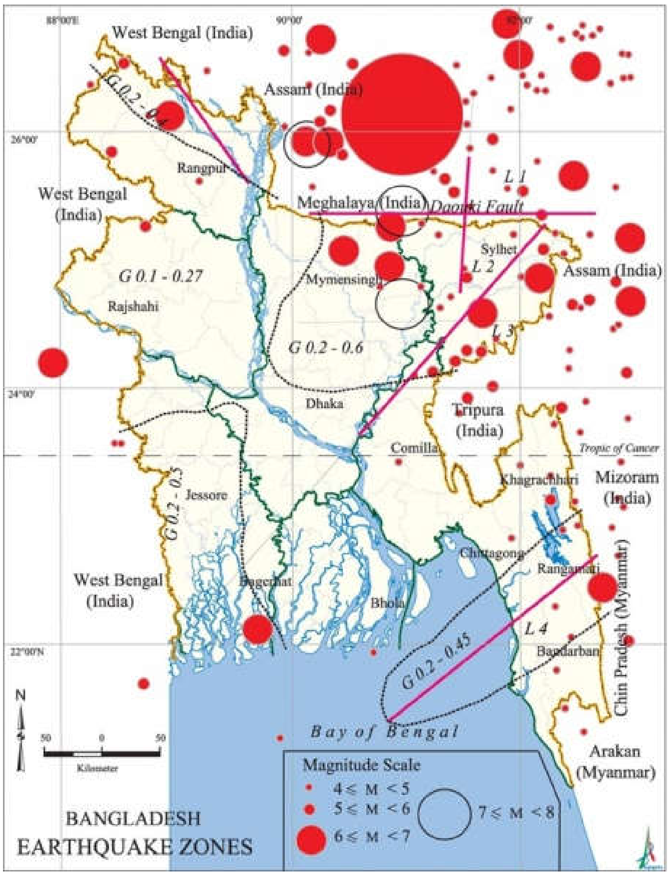

Fig. 1. Different Earthquake Zone with their Magnitude In and Around Bangladesh ("Earthquake," 2015)

Social and Economic Vulnerability: Vulnerability, as its most general meaning, is "the entity of conditions, which are defined by physical, social, economic and environmental factors and processes, that increases the sensitivity of the societies against the impact of the hazards" (UNDP, 2004). Social vulnerability is a measure of a population's sensitivity to natural hazards, its ability to respond to the impacts of hazards and to recover from them (Cutter et al, 2008). Race / ethnicity, socioeconomic class and gender are among the most common characteristics that define vulnerable populations, together with age (elderly and children), housing tenure (renter or owner), lack of access to resources (including information, knowledge and technology), social capital, social networks and connections, beliefs and customs, building stocks, etc (Güzey *et al.,* 2013). Economic vulnerability is most often described in individual economic circumstances such as income, employment, savings, etc. On the other hand, the vulnerabilities of these risk groups can vary from country to country. Thus, it is important to develop risk evaluation studies specifically for a country or region.

Study area

Dhaka, capital of Bangladesh, was chosen as the study location for the research. The city has become the world's 11th most populous city and considered as the most densely mega-city in the world. 91 wards are subdivided into 552 clusters for the Dhaka City Corporation area (CDMP and MoFDM, 2009). Three wards were chosen for study area showing in Figure 2.

- Ward no. 46 (Mohammadpur)
- Ward no. 51 (Kalabagan)
- Ward no. 60 (Old town)

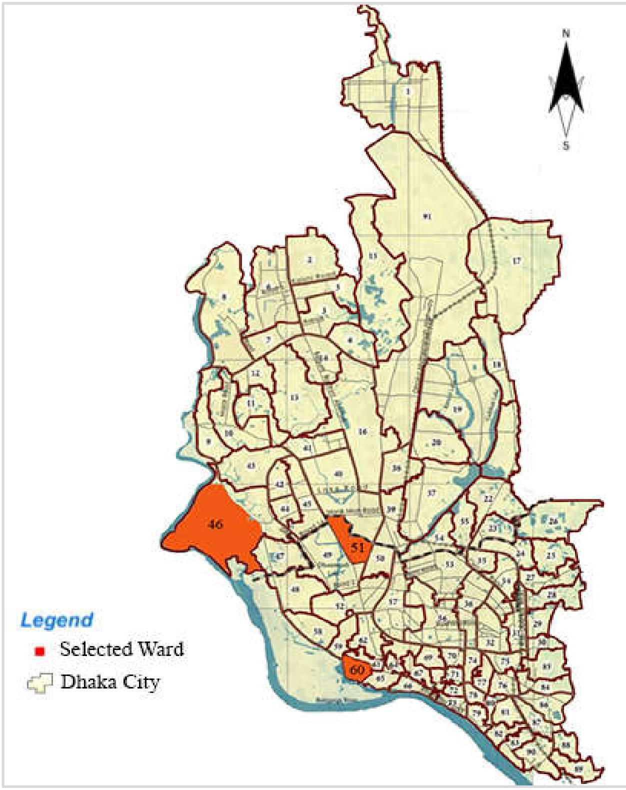

Fig. 2. Location Map of Study Area in Dhaka City

METHODOLOGY

Cluster and Indicator Development: In this study, the main sociological dimensions of socio-economic vulnerability are defined by reference to the characteristics of persons such as population profile, age distribution, gender, family type, marital conditions, size of the household, level of education, car ownership, number of dependents in the household, income levels, employment status, access to welfare benefits, social networks and housing conditions, house ownership status etc. The evaluation of social vulnerability parameters is based on the NOAA project (1999) with some changes. After analysing previous literature, 7 clusters and 15 indicators of social and economic vulnerability were decided to be used in the vulnerability assessment questionnaire. The Table 1 below displays the contents of the seven clusters accompanied by relevant indicators that increase social and economic vulnerability.

Table 1. Indicators of Social and Economic Vulnerability

Cluster Type	Indicator/Variables	Condition of Being Vulnerable
Demography	Age	Population Over Age 60, Under Age 18
	Household type	Single Parent with Child Families
	Gender of Household Head	Female Household Head
	Household size	If 6 or More
Education	Education level of household head	If Lower than Secondary
Security	Social security	If No Social Security Policy
	House insurance	Renting, No Insurance Policy for the Building
Disaster Related Attitude	Risk perception	If No Perception about Building Damage
	Knowledge of earthquake	If No Knowledge
	Citizen responsibility	If Not Accepted
Income	Monthly household income	If Less Than 10,733 BDT (per capita)
	Savings	If No Savings
Employment	Job of household head	If Unemployed
Ownership	Owner of the house	Rent
	Car ownership	No Car

Survey data collection and analysis: Samples buildings from three selected wards were chosen through the convenience sampling (data collection from building's occupants who are conveniently available to participate in study) for questionnaire survey to collect all the information needed for analysis and results. A total of 240 occupants of sample houses in Dhaka town were interviewed for the risk assessment process. Necessary secondary data were collected from Dhaka city corporation. Once the required data collected, the existing dataset was tabulated for analysis in SPSS and Microsoft Excel to formulate the input.

Data Calculation Process: Then, Type II vulnerability indicators are calculated to determine a general urban vulnerability index using simple additive weighting method (SAW) (Güzey *et al.,* 2013). Note that all the vulnerability indicators are given equal weights because of particular weight for the indicators was not found in any literature according to their importance. First of fall, total vulnerability numbers of all indicators according to the clusters was calculated. Then, overall the social and economic vulnerability was computed using Equation 1:

$$E(E_1, E_2, ..., E_n,) = \begin{bmatrix} b_{11} & b_{12} & ... & b_{1n} \\ b_{21} & b_{22} & ... & b_{2n} \\ ... & ... & ... & ... \\ b_{n1} & b_{n2} & ... & b_{nn} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ ... \\ E_n \end{bmatrix}$$

Where $b_{11},\ldots b_{nn}$ are the significance parameters of the essential indicators' E_1, ...,En influence on the compound variable E (Buracas and Zvirblis, n.d.).

Total Weighted Score = Requirement Score of Indicators X Weight of Indicators…….. Eq.1

Vulnerability Map Development: The mathematical values of the result, vulnerability indicators are formulated in the form of maps using Google maps and Photoshop to show which area is more vulnerable than others within the three selected neighbourhoods of Dhaka city.

RESULTS AND DISCUSSION

Social Vulnerability Cluster

Demographic Cluster: Based on condition of being vulnerable, the respondent was classified into two categories likely, Population over age 60 and population under age 18 as shown in Figure 3.

The highest proportion (52.29%) of the vulnerable respondent was found at ward no. 51, compared to ward no. 60 (43.46%) and 46 (46.64%). The family structure may also be determinant of the disaster vulnerability. Single parent with child are the most affected families in this category (Yücel and Arun, 1999). In this study, it was found that ward no. 60 (21.25%) placed the high vulnerable position compare to others. The earlier study (Duzgun *et al.,* 2011) by the Turkish Statistical Office shows that families with 6 or more members are demographically susceptible. Statistics presented in Figure 3 shown that the maximum vulnerable proportion (42.5%) of respondent belonged to ward no. 60 followed by ward no. 51 (40%) and ward no. 46 (32.5%). Above one-third of the total surveyed families is identified as vulnerable family which makes those areas more exposed to earthquake. On the other hand, ward no. 46 (17.5 %) is found to be more vulnerable than others, the percentage of female household heads is very low makes those areas less vulnerable in this category.

Figure 3 presents the overall results for the selected areas from various demographic cluster indicators of social vulnerability. It is clear that respondents ' vulnerability varies from zone to zone by different indicators.

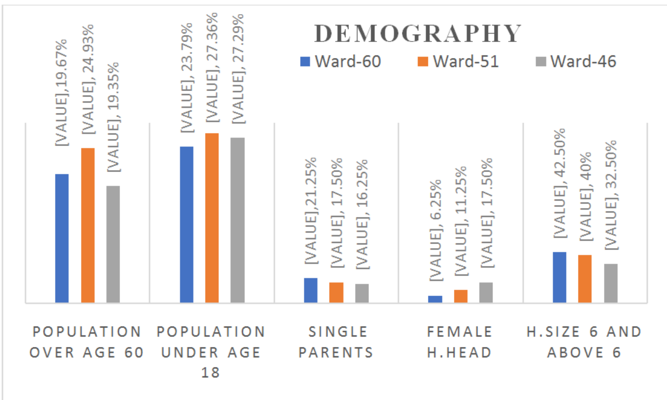

Fig. 3. Distribution of the Respondents by Age, Household Type, Gender and Household Size

Education Cluster: The respondents were classified into four categories based on their educational classes, namely "no education," "primary," "secondary" and "higher secondary." No education of household head or primary education was considered as a vulnerable range in this study. Data of Figure 4 revealed that approximately 27.5% of respondents do not have primary education in ward no. 51 compared to the respondents who have upper secondary education. Most of the educated respondents has a positive aspect of earthquake awareness. Education helps to gain respondent knowledge about the earthquake.

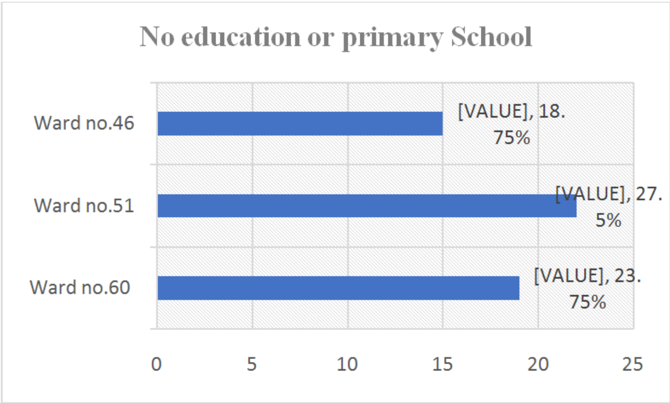

Fig. 4. Distribution of the Respondents by Education Level of the Household Head

Security Cluster: Social security policy ensures that during times of crisis, financial resources are available to everyone. However, if a person does not have social security, medical treatment or necessary living elements may be at risk during disaster. Data presented in Figure 5 indicated that ward no. 51 (22.5 %) was more vulnerable during the earthquake due to the lack of respondents ' social security policies than ward no. 60 (16.25 %) and ward no. 46 (12.5 %). House Insurance becomes an important factor to finance the repairs or rebuild process after an impact of natural hazard (Dwyer *et al.,* 2014). There is no insurance for a single house in the selected areas of Dhaka, according to the study. It makes those areas highly vulnerable to natural hazard (Figure 5).

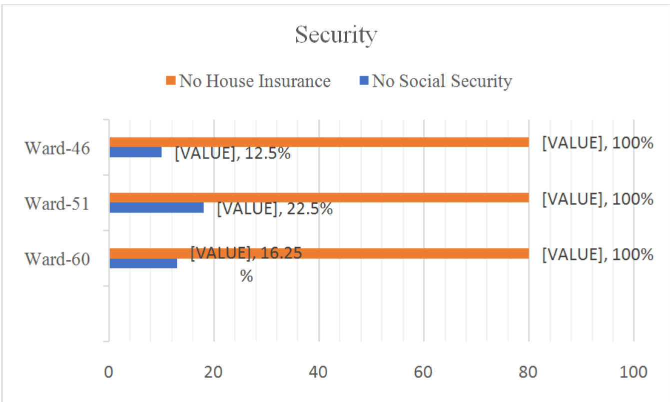

Fig. 5. Distribution of the Respondents by Social Security and House Insurance

Disaster Related Attitude Cluster: Figure 6 presents overall disaster related attitude material of the respondents acquired within field survey such as knowledge about earthquake, citizen responsibility and risk perception of the buildings etc. The respondents were classified into the following three categories based on the observed awareness of earthquake; 'no knowledge of the earthquake', 'somewhat' and 'an expert'. Data presented in the Figure 6 indicates ward no. 46 is more vulnerable where 28.75% of the respondents has no knowledge compared to others. If anyone has no sufficient knowledge about earthquake, it is difficult for him to take proper precaution during crises. Furthermore, ward no. 46 (41.25%) is more vulnerable than others, but the ratio of taking responsibility to build earthquake resistant house is high in every zone which makes the society less vulnerable in this category. One of the main indicators of social vulnerability is the risk perception of respondents about building damage. If people have no idea how significantly their building can be accomplished during the earthquake, they will not use the proper retrofitting system to secure the buildings. According to the data presented in Figure 6, 46.25% of respondents in ward no. 46 had poor perception of building damage compared to ward no. 60 (41.25%) and ward no. 51 (35%).

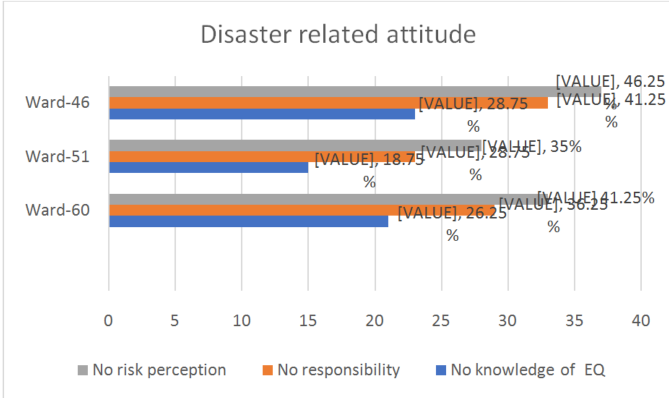

Fig. 6. Distribution of the Respondents by Disaster Related Attitude

Assessment of Social Vulnerability: As previously stated, social vulnerability indexes are calculated using a simple additive weighting method (SAW) to determine the highest vulnerable region among the selected areas (Güzey *et al.,* 2013). Note that all vulnerability indicators are given equal weights because, according to their importance, no particular weight was found in the literature review. Initially, for each indicator, total vulnerable respondents were calculated. Using Equation 2 the overall social vulnerability was calculated after that. Table 2 shows the calculation process.

Total Weighted Score = Requirement Score of Indicators X Weight of Indicators………Eq.2

A map presented in Figure 7 shows the risk level of social vulnerability for the selected areas. The result shows that Kalabagan (ward no. 51-45.7%) is highly vulnerable to earthquakes, while Old Town (ward no. 60- 44.1%) and Mohammadpur (ward no. 46- 43.9%) are the less susceptible ones.

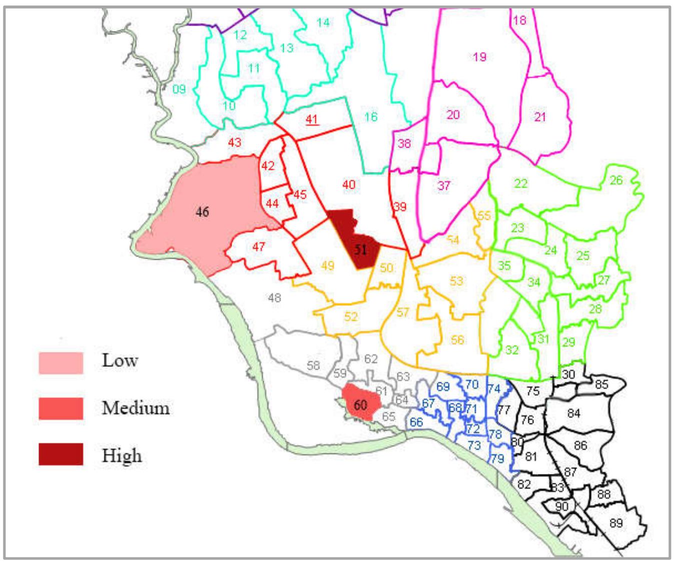

Fig. 7. Social vulnerability level for the selected areas of Dhaka city

Table 2. Social Vulnerability Assessment Procedure

Cluster Type	Indicator/Variables	Weight	Vulnerable Respondents		
			Ward No. 60	Ward No. 51	Ward No. 46
Demography	Age	10%	190	216	188
	Household type	10%	17	14	13
	Gender	10%	5	9	14
	Household size	10%	34	32	26
Education	Education level of household head	10%	19	22	15
Security	Social security	10%	13	18	10
	House insurance	10%	80	80	80
Attitude	Risk perception	10%	33	28	37
	Knowledge of earthquake	10%	21	15	23
	Citizen responsibility	10%	29	23	33
Total		100%	44.1%	45.7%	43.9%

Economic Vulnerability Cluster

Income Cluster: Family income status is important to compensate for the disaster-related losses. As the level of income decreases, the vulnerability increases. To achieve a better and safer shelter, income is a positive factor (Yücel and Arun, 1999). Income cluster includes 'monthly household income below BDT 11,000 (about US$ 130)' and 'household can save nothing from monthly income'. These are considered to be a vulnerable situation of a family. It has been found from this Figure 8, nearly one-third of selected residents (33.75%) from ward no. 51 have low income of USD 130 per month. Less savings than others, on the other hand, make ward no. 60 (31.25 %) more vulnerable to natural hazard.

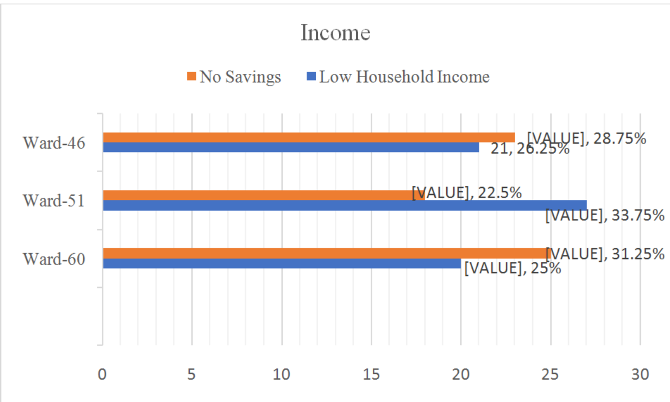

Fig. 8. Distribution of the Respondents by Household Income and Savings

Figure 8 shows the complete outcome of the income cluster's indicators (income level and savings condition) that were assessed for each of surveyed respondents in the selected areas.

Employment Cluster: Employment status indicates that a person has the ability to earn money to pay for services and resources that are not available in the event of a natural hazard, such as accommodation, cars, clothing (Dwyer *et al.,* 2014) etc. Consequently, the findings from Figure 9 indicate that the rate of unemployment in Dhaka city is not high, which could be a positive response to the earthquake. Otherwise, there is a high unemployed household head in ward no. 51 (22.5%) compared to others.

The Ownership Cluster: The field survey (Figure 10) reveals that nearly half of the residents are tenants in ward no. 51 (41.25 %) and ward no. 46 (55%). Because most of the inhabitants are tenants, the safety of the construction is not very considered. It makes them more vulnerable than ward no. 60 (36.25%) to earthquake. The extended structure, with various income inhabitants, shows a complicated ownership and a merged financial relationship that can interrupt the reconstruction method in the event of a significant earthquake. On the other hand, 35% of respondents in ward no. 46, 38.75% of respondents in ward no. 51 and 28.75% of respondents in ward no. 60 do not own a car. In both mitigation and natural hazard recovery processes, transportation is important.

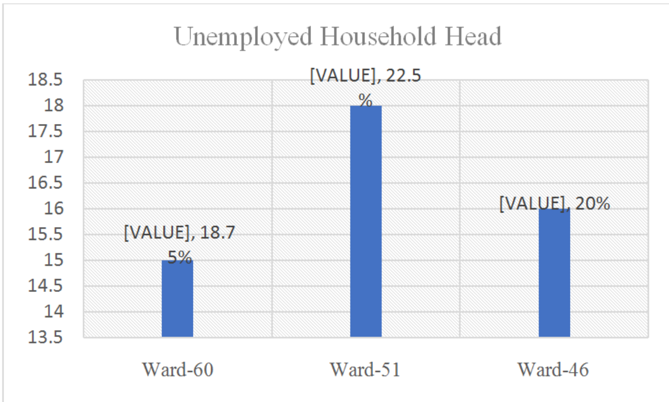

Fig. 9. Distribution of the Respondents by Household Income and Savings

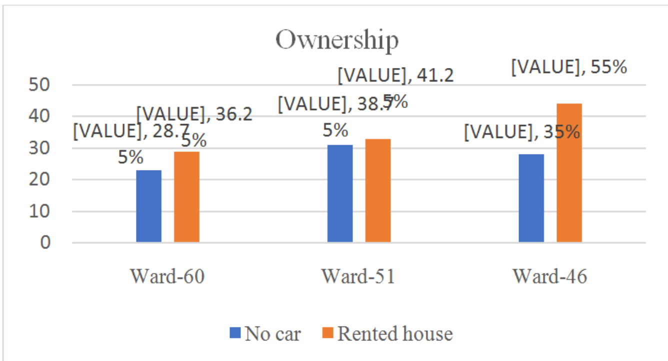

Fig.10. Distribution of the Respondents by House and Car Ownership

Assessment of Economic Vulnerability: The previously applied procedure (SAW) is also used for parameters of economic vulnerability in order to easily determine the highest vulnerable zone (Güzey *et al.,* 2013). Initially, for each indicator, total vulnerable respondents were calculated. Note that all vulnerability indicators are given equal weights because, according to their importance, no particular weight was found in the literature review. The result was expended on equation 3 after that. Table 3 shows the calculation process.

Table 3. Economic Vulnerability Assessment Procedure

Cluster Type	Indicator/Variables	Weight	Vulnerable Respondents		
			Ward no. 60	Ward no. 51	Ward no. 46
Income	Monthly Household income	20%	20	27	21
	Savings	20%	25	18	23
Employment	Job of household head	20%	15	18	16
Ownership	Owner of the house	20%	29	33	44
	Car	20%	23	31	28
Total		100%	22.4%	25.4%	26.4%

Total Weighted Score = Requirement Score of Indicators X Weight of Indicators………Eq.3

Economic vulnerability score is shown in a map in Figure 11 for each territory. The highly vulnerable territory is ward no. 46 (26.4%) whereas the lowest score belongs to ward no. 60 (22.4%).

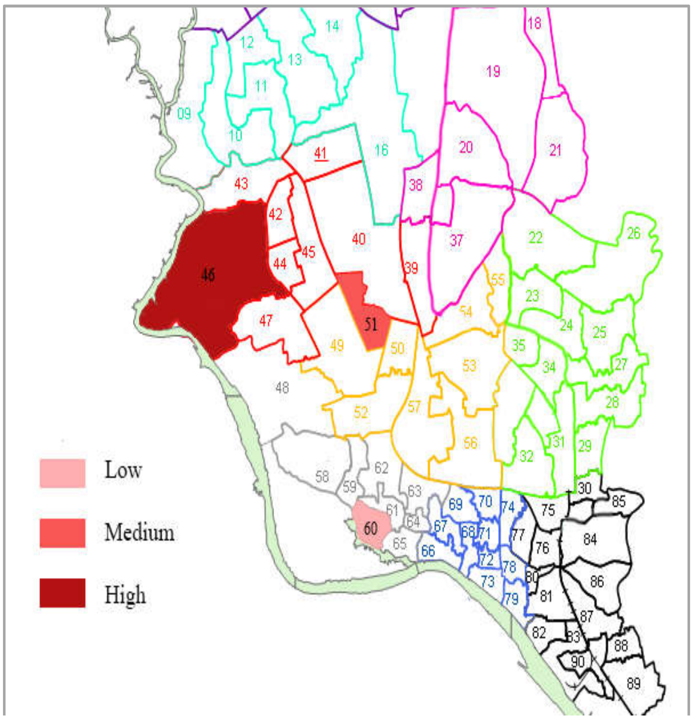

Fig.11. Economic Vulnerability Level for the Selected Areas of Dhaka City

CONCLUSIONS

To fulfil the objective of this research, it is concluded by formulating seismic hazard map according to the vulnerability ranking such as ward no. 51 is under high seismic hazard zone in social vulnerability while ward no. 46 lie under most hazard zone due to economic vulnerability. The proposed structure for vulnerability evaluation is versatile and can be easily extended with various mapping units to urban environments. As the vulnerability maps prepared for the communities of the considered case study provide the decision-makers a guidance in developing strategies for vulnerability reduction. For example, the vulnerable neighborhoods due to their lack of knowledge about earthquake can be improved by providing more information and global/regional news regarding earthquake through social medias. Additionally, the established structure helps decision-makers to track chronological changes in the urban environment due to risk management measures being implemented.

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