Assessment of Emergency Evacuation Preparedness for Seismic Hazard in an Urban Area

A. Chakrabarty [1], M. Rahman [2], M. Ubaura [3]

[1] *Master's Student, Jahangirnagar University, arnobanik2@gmail.com*
[2] *Assistant Professor, Jahangirnagar University, mizanurp@gmail.com*
[3] *Associate Professor, Tohoku University, ubaura@tohoku.ac.jp*

Abstract

Unplanned development in Dhaka city increases the potential impact of an earthquake. Evacuation preparedness is crucial for reducing the impact of an earthquake. This paper contributes to the existing knowledge of earthquake preparedness with representative data collected from people with different socio-economic background at ward 30 in Dhaka city and establishing its relationship with locational characteristics of available temporary evacuation shelters within the ward. Dhaka city has two city corporations- Dhaka North City Corporation and Dhaka South City Corporation. Ward 30 is one of the 36 wards in Dhaka North City Corporation, selected for study based on high number of households, mix of planned and unplanned area, availability of open space for temporary shelters and mixed land use. In this particular study, five sectors for evacuation preparedness in household level is selected which have five indicators each. Each sector has score range of 0 to 5, where 0 is the lowest and 5 is the highest score. The sampling method is purposive sampling method and the sample size is 383 individuals coming from various points of the socio-economic spectrum, based on age, gender, education and monthly income. Regression is used to analyze the factors for influencing evacuation preparedness through SPSS. The open spaces, educational facilities and religious facilities built after 1993, are selected in this study as temporary evacuation shelters, based on Bangladesh National Building Code of 1993, considering structures' age is less than 30 years and they were developed following the code. Service area analysis for temporary evacuation shelters is done using Network Analyst tool in ArcGIS, marking their locational coverage within the ward, showing if coverage shortage or overlap exists. The survey showed earthquake awareness score 2.36, emergency evacuation knowledge score 2.23, provision for elderly/disabled score 0.4, vulnerability of structures score 1.86 and self-protection ability score 1.95, portraying dismal condition especially in provision for elderly/disabled and emergency evacuation knowledge. The overall emergency evacuation preparedness is not satisfactory, according to the survey. Based on the final scores, analysis of the influencing factors for evacuation preparedness and temporary shelter characteristics, a guideline is provided for improving the emergency evacuation preparedness in the study area, contributing to the decision-making process and helping to achieve the goal of developing effective and efficient urban planning strategies for earthquake resiliency of urban areas.

Keywords: Emergency Evacuation; Earthquake Preparedness; Risk Awareness; Socio-Economic Vulnerability; Temporary Shelter

1. Introduction and Background

Earthquake is one of the most devastating natural disasters, because of its unpredictability and power of destructibility. The short- and long-term effects of an earthquake range from local level to national level, in many cases international level. For example, Tohoku earthquake in Japan has greatly affected the global supply chain of materials essential for manufacturing firms and companies. This created a supply shock, which affected the economy of Chinese Taipei, Thailand and Malaysia [1]. The socio-economic impact of a severe earthquake has also long-term socio-economic impact on countries. In recent history, earthquakes in Japan, Indonesia, Haiti, Mexico, Chile etc. caused enormous damage to physical properties, mass casualties and intense trauma and suffering to the survivors. According to Dickson E. et al. [2], cyclone and earthquake exposure in large cities is projected top, rising from 680 million in 2000 to 1.5 billion in 2050. East Asia is highly susceptible to exposure, 267 million in 2050, followed by Latin America and the Caribbean (150 million in 2050) and the countries which are members of the 'Organization for Economic Co-operation and Development.' South Asian cities will have exposure growth of 3.5 percent, followed by cities in Sub-Saharan Africa.

Geographically Bangladesh is located close to the boundary of two active Plates: the Indian Plate in the west and Eurasian Plate in the east and north. Omar M. [3] explains, "The earthquake record suggests that since 1900, more than 100 moderates to large earthquakes occurred in Bangladesh, out of which more than 65 events occurred after 1960. This brings to light an increased frequency of earthquakes in the last 30 years. This increase in earthquake activity is an indication of fresh tectonic activity or propagation of fractures from the adjacent seismic zones."

The development of Dhaka city has largely happened in an unplanned way. Dhaka is growing rapidly but urbanization is not planned properly. As urbanization is increasing, more people in cities face natural hazards. In Bangladesh, 36.63% of total population live in the cities. [4] In couple of decades, thousands of multi storied buildings have been built in Dhaka city, without required open spaces. They encroach on roadways, cover up waterbodies and natural water reservoirs. Garment factories and some other industries are located in the Dhaka city. Buildings without maintaining regulation have made the situation more complex. Poorly built buildings constructed with concrete, bamboo or tin along with slum areas having high density population have contributed to earthquake vulnerability [5]. 66 percent of buildings in the capital were constructed violating building code of Rajdhani Unnayan Kartripakkha (Rajuk) [6]. The Dhaka Structure Plan (2016-2035) [7] analyzes the scenario by the following points:

• Absence of critical public facilities (i.e. school, hospital, police station, sewerage system etc) and failure of their proper functioning may have serious impacts on the dwellers, after earthquake.

• City authorities are ill-prepared to face a high-intensity earthquake event because of little contemporary experience.

In case of an earthquake hitting Dhaka city, it will be difficult to provide emergency evacuation to the residents because of the unplanned development. The awareness level among the people will also play a big role determining the panic factor and overall preparation level. In case of emergency shelter, Omar M. [3] suggests primary schools, high schools, colleges, community centers and mosques can be used as temporary evacuation shelters.

This paper analyzes the earthquake evacuation preparedness of an urban area, Ward 30 of Dhaka North City Corporation. It has the population of 186639 and an area of 2.47 sq. km. Firstly, through a scoring system, which explains the human factor of preparedness, and secondly, presence of open spaces, educational and religious institutions and their suitability and carrying capacity for emergency evacuation shelters. The human factor is analyzed through 5 main variables which have 5 sub variables each. The paper proceeds as follows: Section 1 will provide introduction and background. Section 2 will discuss the variables used in scoring of earthquake evacuation preparedness and possibility of using open spaces, educational and religious institutions as temporary evacuation shelters. Section 3 will show the data analysis of the questionnaire survey and location and availability of open space, educational and religious institutions for temporary evacuation shelter. Section 4 will present the result of the study and Section 5 will provide the conclusion.

2. Earthquake Evacuation Preparedness Variables

The government of Bangladesh has taken steps to make the disaster preparedness system more holistic. In National Plan for Disaster Management 2016-2020 [8], importance is given to all stakeholders in the disaster management system and building efficient preparedness and resilient communities. Household preparedness is required to develop earthquake preparedness at local level and to build resiliency.

2.1 Variables for Measuring Earthquake Evacuation Preparedness

The household level earthquake evacuation preparedness depends of various factors. Chen C. Y. et al. [9] described factors for better earthquake preparedness by prior exposure to earthquake, emergency training, earthquake preparedness knowledge, education, self-reliance and fate reliance. Wu G. et al. [10] described specific material stockpile (Water, food, medicine, flashlight, and radio) at home, for material preparedness of earthquake. For preparedness related behaviors, "knowledge of nearby emergency shelter, having participated in emergency exercise/drills, the intention of purchasing earthquake insurance if available, knowing the difference between earthquake prediction and earthquake warning, having visited the China Earthquake Administration Bureau's website or social media public communication page" these variables were used. Pakjouei S. et al. [11] showed disabled person's needs during earthquake, including need of assistive devices, access to vehicles and household and workplace adaptation. Following the previous studies, 5 major variables affecting emergency evacuation preparedness are identified- Earthquake risk awareness, Emergency evacuation knowledge, Provision for elderly/disabled, Vulnerability of structures and Self-protection ability. The total indicators under variables are presented below:

Variable 1: Earthquake risk awareness. This variable includes the following indicators: awareness of earthquake probability, steps taken to increase earthquake knowledge, awareness of home safety for earthquake, earthquake safety plan and safety measures at home.

Variable 2: Emergency evacuation knowledge. It includes the following indicators: knowledge about quick route out of home, fixed post-earthquake meeting place, participation in earthquake drills, knowledge about the procedure for earthquake emergency evacuation and keeping the number of emergency services.

Variable 3: Provision for elderly/disabled. The following indicators are included in the variable: structural provision for evacuation of elderly/disabled at home, access to vehicles for evacuation, training for the elderly/disabled for emergency evacuation, assistive devices for elderly/ disabled, training of caregivers for elderly/ disabled for emergency evacuation.

Variable 4: Vulnerability of structures. This variable includes the following indicators: age of the living place, construction quality of living place, accessibility of the living place, construction material of the living place and building height of the living place.

Variable 5: Self-protection ability. This variable includes the following indicators: savings for emergencies, safety instruments at home, health Insurance, formal savings for general purposes the ability to shift residence.

2.2 Temporary Emergency Evacuation Shelter Criteria

Chen Z. et al [12] have classified evacuation shelters through temporal basis, describing as: Immediate shelter (for the first day), Short-term shelter (One day to a week) Long-term shelter (A week to a month) and Permanent shelter. In this study, short-term shelter is considered. The open spaces, the educational facilities and religious facilities in the study area are considered for the locations of temporary evacuation shelters. Schools are prime locations for temporary emergency evacuation shelters, as described by Anderson A. et al. [13] "…communities may simply go to the school for shelter without direction from disaster management authorities. Because of conscious efforts to protect children, in many communities, schools are designed and constructed to be the most disaster-resilient structures available."

Another criterion for choosing educational facilities for evacuation shelters is the Bangladesh National Building Code of 1993, which limits the structure age up to 27 years for selection and provides the basis for earthquake resistant buildings.

3. Analysis of the Data

3.1 Sampling and Measurements

The sampling size of the population is 383 persons. The data was collected through purposive sampling method. 25 preparedness indicators, under the 5 main variables were asked to the participants. Their response was collected as 'yes' or 'no' and were given the value of 1 and 0 respectively. Every 5 indicators under each variable creates a continuous score ranging from 0 to 5. The mean values of the indicators under each variable are summed and this shows the preparedness level at each variable.

In case of temporary shelters, there are several measurements for the selection of per person area size inside the temporary shelters. Chen Z. et al [12] estimates 2 m^2 of space per person, for the population density of 10000 people per sq. kilometer. Omar M. [3] describes the per person space is 1.65 m^2 according to 'Guideline of Management of Evacuation Shelter' prepared by the Tokyo metropolitan government. The study area of this research has the population density of 75562 person per sq. kilometer. Based on population density, per person area size inside the temporary shelters is 2 m^2.

3.2 Sampling Demographic

The sampling demographic consists of 6 variables – age, gender, education, occupation, family size and monthly income.

Table 1 – Demographic of the Surveyed Population

Surveyed Population		Demographic Percentage
Age	Under 20	19.6
	20 – 29	23.0
	30 – 39	29.5
	40 – 49	12.0
	50 – 64	9.4
	Over 65	6.5
Gender	Male	53.0
	Female	47.0
Education	H.S.C and Above	48.6
Occupation	Student	31.3
	Private Service Holder	16.4
	Public Service Holder	2.6
	Businessman	11.7
	Retired	3.7
	Other	14.6
	Housewife	19.6

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Family Size	4 members or More	59.7
Monthly Income (In Taka)	less than 10000	7.0
	11000-25000	23.5
	26000-40000	30.5
	41000-55000	29.5
	56000-70000	6.3
	more than 70000	3.1

3.3 Temporary Shelter Location

There are 18 locations for temporary shelters. 15 of them are educational facilities and 3 are open spaces. The religious structures of the study area also hosted some business activities, so they were not selected.
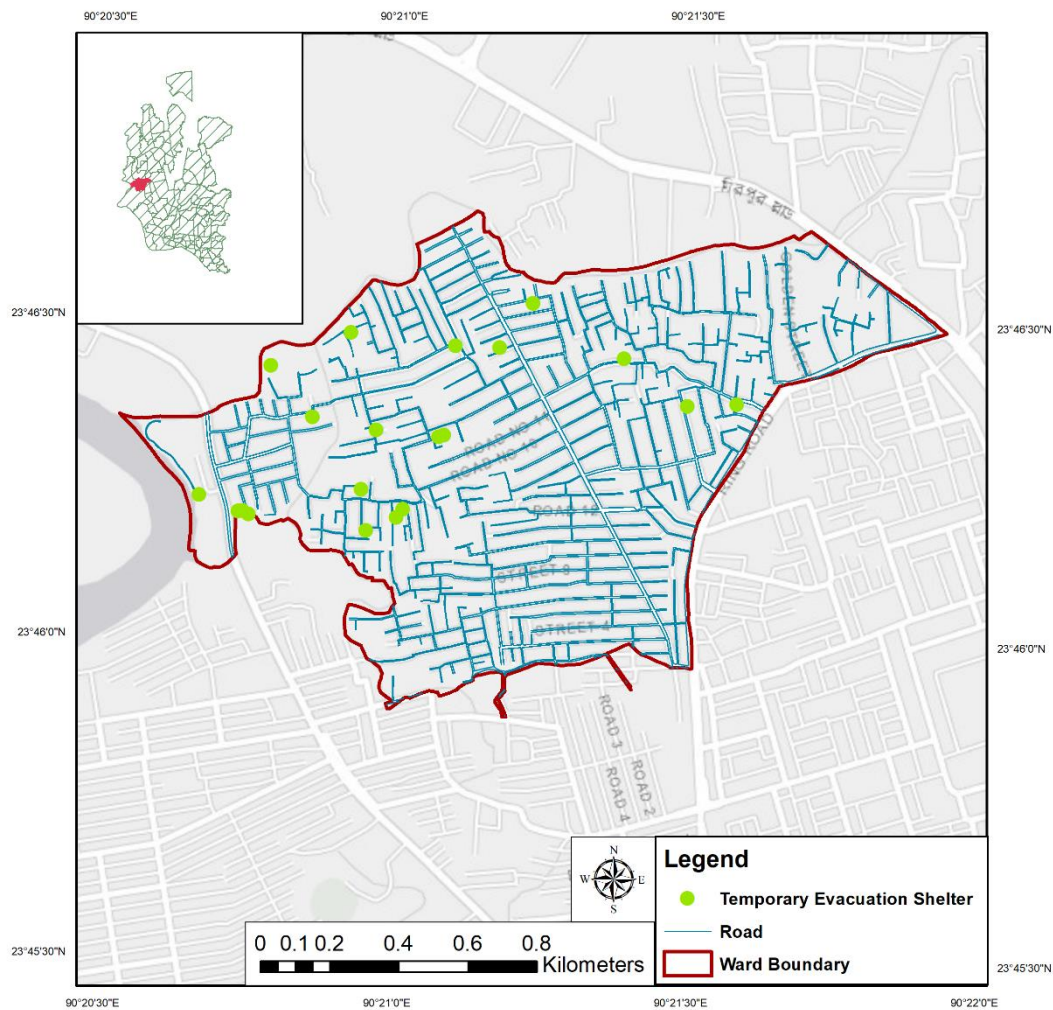

Fig. 1 – Temporary Evacuation Shelter Location in Study Area

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4. Results

4.1 Emergency Evacuation Preparedness Score

The Earthquake risk awareness score is 2.36, Emergency evacuation knowledge score is 2.23. Provision for elderly/disabled score is 0.4, Vulnerability of structures score is 1.95 and Self-protection ability score is 1.86. All scores are presented at the range of 0-5, 0 being the absence of the preparedness variable and 5 being the very best scenario of preparedness.

Table 2 - Emergency Evacuation Preparedness Score

Earthquake risk awareness	Mean	Total Score	Emergency evacuation knowledge	Mean	Total Score	Provision for elderly/disabled	Mean	Total Score
Earthquake probability	1	2.36	Quick route out of home	0.71	2.23	Structural provision	0.03	0.4
Taken steps to increase earthquake knowledge	0.42		Post-earthquake meeting place	0.42		Access to vehicles	0.13	
Home is unsafe for earthquake	0.52		Participation in earthquake drills	0.12		Training for the elderly/disabled	0.06	
Have earthquake safety plan	0.21		Know earthquake emergency evacuation procedure	0.17		Assistive devices	0.1	
Safety measures at home	0.21		Know the number of emergency services	0.71		Training of caregivers for elderly/ disabled	0.08	

Vulnerability of structures	Mean	Total Score	Self-protection ability	Mean	Total Score
Age of the house	0.2	1.95	Savings for emergencies	0.2	1.86
Construction quality of house	0.1		Bought safety instruments at home	0.01	
Accessibility of the house	0.08		Health Insurance	0.08	
Construction material	0.83		Formal savings for general purposes	0.83	
Building Height	0.74		Ability to shift residence	0.74	

4.2 Factors Influencing Evacuation Preparedness

The general linear regression model was run on the five variables of emergency evacuation preparedness. The monthly income was significant factor for self-protection ability and provision for elderly/disabled. The vulnerability of structures is inversely correlated to income. Effect of age and

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gender on emergency evacuation knowledge and earthquake risk awareness was not statistically significant.

4.3 Carrying Capacity of Temporary Evacuation Shelters

The temporary evacuation shelters are scattered all across the study area. They also vary in carrying capacity. Only 3560 persons out of 186639 persons living in Ward 30 can be served by the temporary evacuation shelters. It is derived from the area covered by each temporary evacuation shelter divided by area required per person.
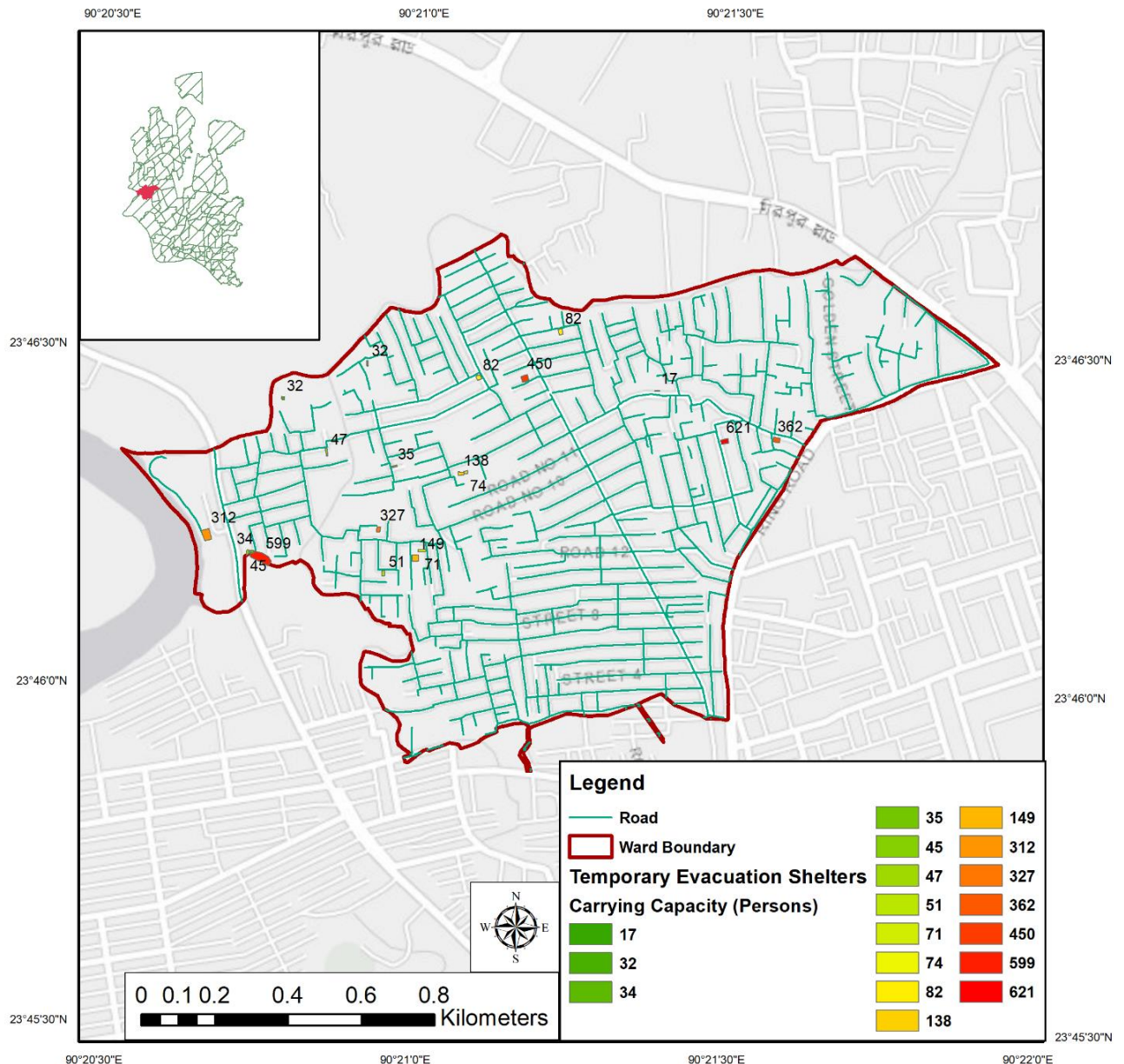

Fig 2 – Carrying Capacity of the Temporary Evacuation Shelters

4.4 Service Area Covered by Temporary Evacuation Shelters

The service area of the temporary shelters is considered based on the distance covered by foot in 5-minute walk, 400 meters. The Service area of the temporary evacuation shelters do not cover all of the study area. The

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north, west and some part of the east side of the study area is under the service area of the temporary evacuation shelters.
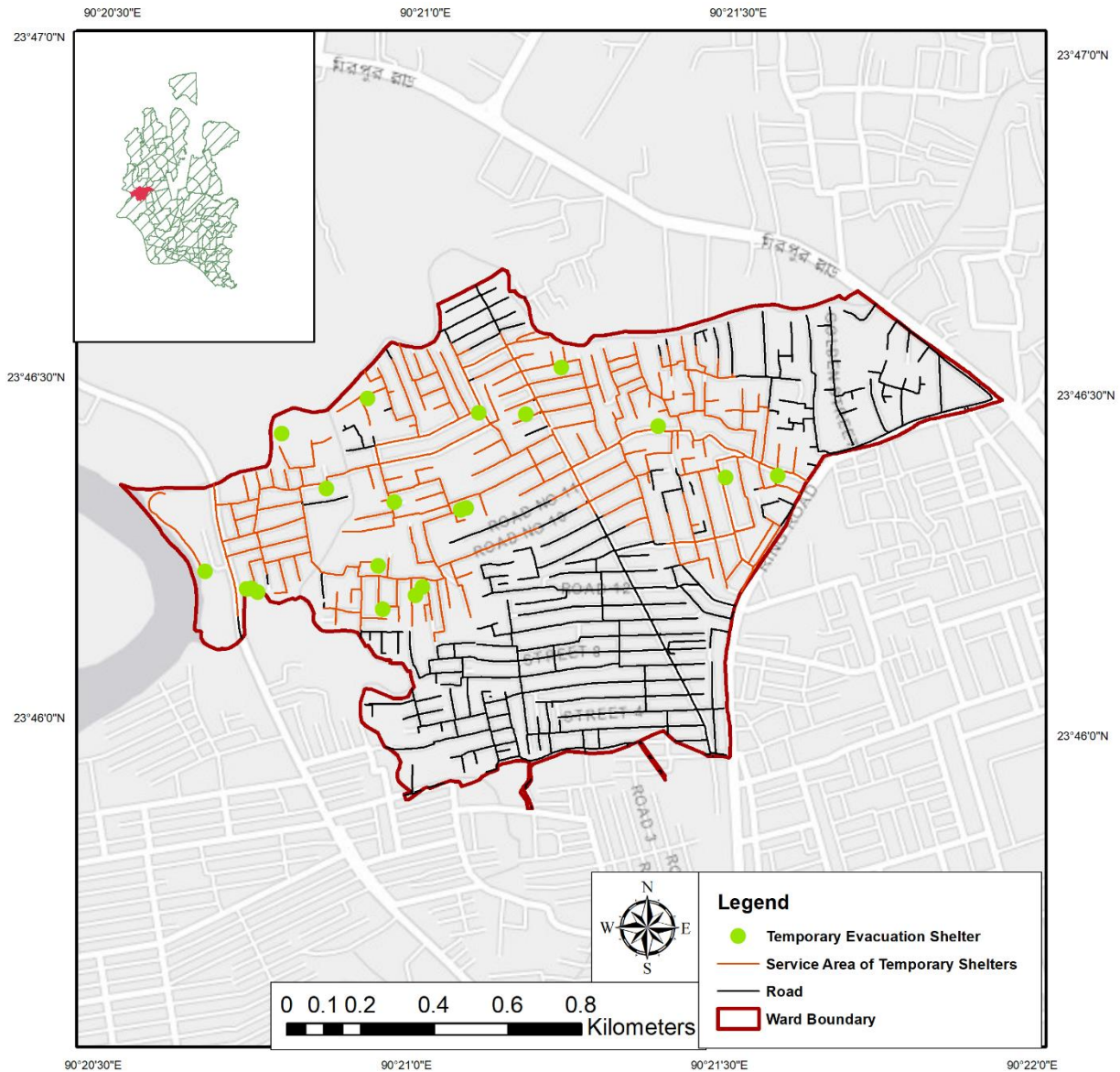

Fig 3 – Service Area of the Temporary Evacuation Shelters

5. Conclusion

It is evident from the results that the emergency evacuation preparedness for seismic hazard in the ward 30 of Dhaka North City Corporation is very poor. Elderly and disabled persons are some of the most vulnerable demographics of the society. The score of provision for elderly/disabled variable shows the worst preparedness of all of the variables. The indicators also show that most of the population did not have the opportunity to take part in earthquake drills and the knowledge of emergency evacuation procedure is also very low. Although, all of the population know that the area they live in has the risk of earthquake. Most of the population know the number of emergency services and has formal savings.

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The temporary shelter locations are sparse and the service area of them do not cover all of the study area. The carrying capacity of them is very low, only 1.9% of the total population can be served by them. There is no temporary evacuation shelter in the west part of the ward 30.

Several measures are to be taken to improve the current situation of emergency evacuation preparedness of the study area. There has to be earthquake evacuation drill organized to make people understand the procedure during earthquake evacuation. Awareness campaign can be arranged in educational facilities of the study area to disseminate earthquake preparedness knowledge. With the help of local governance body, ward-wide training program for earthquake preparedness can be organized. The structural provision in buildings for elderly/disabled persons has to be ensured, through policy instruments of the government. The carrying capacity of the temporary evacuation shelters can only be improved through new open space creation.

5. Acknowledgement

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