ACCESSIBILITY OF MOVEMENT CHALLENGED PERSONS AND THEIR EARTHQUAKE RISK PERCEPTION

by

MD MUSFIQUR RAHMAN BHUIYA

WANYUN SHAO, COMMITTEE CHAIR
JOE WEBER
STEVEN JONES

A THESIS

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ABSTRACT

This study aims to evaluate the accessibility during earthquake evacuation for movement challenged persons (MCPs), a disable group highly vulnerable to earthquake, and explores their risk perception in the context of megacity Dhaka, Bangladesh. As there is no accessibility measure to determine accessibility of a network of MCPs integrating physical impedance faced by them in their movement, this study has modified Link to Node Ratio calculate the accessibility of MCPs with consideration of physical impedance and applied it determine the accessibility of MCPs to evacuation routes of 13 wards of Dhaka. Study of accessibility of MCPs during evacuation reveals that 6 wards have poor overall accessibilities while 3 wards have relatively satisfactory conditions of overall accessibility and 4 wards have relatively good accessibilities but fall short of satisfactory conditions. The study reveals that MCPs who are more aged and have more severe level of disability perceive accessibilities of evacuation network, indoor floor surface and entrance gate to be lower. Moreover, male and better educated MCPs is found to perceive accessibilities of indoor floor surface and entrance gate to be higher. Age, income, structure, having experienced an earthquake earlier, mass media as a source of information on earthquake training is found to contribute to perceiving higher level of earthquake risk (as a whole). MCPs who have participated in the training program is found to know what they should do in the advent of an earthquake irrespective of being outside or inside of the home. The study reveals lack of accessibility in training centers and lack of distribution of information of training programs as key reasons behind MCPs not participating in the training.

DEDICATION

This thesis is dedicated to my beloved parents Rawshanara Begum and Md Abul Hossain Bhuiya and my maternal uncle ABM Fazlul Bari.

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1. INTRODUCTION

1.1 Background of the Study

Persons with disabilities (PWDs) are the largest minority group in the world(United Nations, n.d.). There are more than 1 billion persons with disability and around 15% of the world population have some form of disability (World Health Organization, 2018). Because of this enormous number of people with disabilities across the world, rights of persons with disability (PWDs) have become a global concern. The international community is working actively to ensure the rights of the PWDs. International agenda such as New Urban Agenda declared in UN-HABITAT III, Sustainable Development Goals (SDGs) and Convention on the Rights of Persons with Disabilities (CRPD) of the United Nations (UN)have urged to ensure accessibility and other rights of PWDs (UN HABITAT, 2016; United Nations, 2006). Particularly, Goal 11 of SDGs pledges to develop inclusive, safe, resilient and sustainable cities and human settlements with a special focus on the rights of the mobility of PWDs to encourage inclusive and sustainable development (Pakjouei, Aryankhesal, Kamali, & Seyedin, 2018; United Nations, 2006).

In order to achieve Goal 11 of SDG, it is necessary to build sustainable and resilient cities that will be inclusive of PWDs. Inclusiveness is an integral part of resilience and capacity building. PWDs are people who are most vulnerable to disasters (Alexandar, 2011; Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011; Hemingway & Priestley, 2014; Pakjouei et al., 2018). Without developing resilience of PWDs in a city, it is impossible to develop a resilient and sustainable city (Alexandar, 2011; Hemingway & Priestley, 2014; Pakjouei et al., 2018). As persons with disabilities are one of the most vulnerable groups to disasters, it is necessary for them to be well aware of disaster risks and to be well prepared to withstand a disaster and during an emergency(Pakjouei et al., 2018; UN HABITAT, 2016; United Nations, 2006). If PWDs are not aware of the risk, they are unlikely to take sufficient precautionary measures to be safe at in the advent of a disaster. In order to raise awareness of disaster risks and take the necessary steps to develop a lucid risk perception, it is imperative to gauge the existing risk perception of vulnerable people.

Another important aspect of developing resilience for the PWDs is to ensure that they can reach a safe location at the time of emergencies (Comfort et al., 1999; NACCHO, n.d.; Stuntzner & Hartley, n.d.). In order to develop the resilience of PWDs at the community level, they should have the capacity to reach shelters by evacuating quickly during the time of emergency (Hemingway & Priestley, 2014; Landry et al., 2016; Zandt et al., 2012). For this, PWDs should have adequate accessibility using a convenient road network to access to shelters (Bennet, Kirby, & MacDonald, 2009; Hemingway & Priestley, 2014; Landry et al., 2016; Tauhid, 2007; Zandt et al., 2012). But, unfortunately, many studies have revealed a grim situation of accessibility of PWDs (Bhuiya, 2018; Hashim et al., 2012; Hayati & Faqih, 2013; Keerthirathna, Karunasena, & Rodrigo, 2018; Newton, Ormerod, & Thomas, 2007; Nischit, Bharghava, & Akshay, 2018). Studies reveal that poor surface condition of road and footpath, unavailability of curbs in footpath among other factors greatly hinders the mobility of PWDs (Clarke, Ailshire, Bader, Morenoff, & House, 2008; Frye, 2013; Hayati & Faqih, 2013; Rosenberg, Huang, Simonovich, & Belza, 2012; Sharma, Kumar, & Singh, 2015). Such a situation imposes a substantial barrier for PWDs to reach the shelter during a disaster using the evacuation route (Pakjouei et al., 2018; UN HABITAT, 2016; United Nations, 2006, n.d.).

In order to develop policy measures to raise resilience for PWDs by improving accessibility to evacuation routes, the first step should be to evaluate the current condition of accessibility(Landry et al., 2016; Littman, 2019; Unal & Uslu, 2016). Accessibility can be determined using impedance including time, cost, distance (Litman,2019). Integrating qualitative factors like physical impedance faced by PWDS in measuring accessibility requires applying an index-based approach (Foda & Osman, 2010; Littman, 2019; Tal & Handy, 2011). Researchers have developed and applied different accessibility index to determine accessibility to built environment features (Dai & Wang, 2011; Ferrari, Berlingerio, Calabresen, & Reades, 2013; Foda & Osman, 2010; Kim & Wang, 2019; Luo & Wang, 2003; Tal & Handy, 2011; Witten, Pearce, & Day, 2011). To date, no comprehensive studies have yet developed an accessibility index for PWDs to evaluate their accessibility situation by considering the impedance they face in their movement. This study fills the gap by considering perceived accessibility and physical impedance of road by MCP to calculate accessibility. Specifically, physical impedance insofar as related to the perception of the PWDs entails how much they feel an evacuation route accessible to them. The perceived level of accessibility and physical impedance are linked with risk perception. The accessibility of PWDs can be measured by integrating perceived physical impedance faced by PWDs (Girão, Pereira, & Fernandes, 2017a; Littman, 2019). Quantification of perceived impedance using an index would be helpful for urban planners, policymakers, architects, civil engineers to realize the gravity of the movement challenges faced by PWDs and accordingly adopt proper policies and field-level measures to deal with the problems (GIRÃO, PEREIRA, & FERNANDES, 2017b; Yoshida & Uwe, 2009).

This study explores above mentioned two important aspects of resilience building of PWDs which would be helpful for policymakers to take pragmatic measures for capacity building of PWDs. As movement challenged persons (MCPs) suffers more than any other groups of PWDs, they have been selected as target study group for this research. To conduct the study, Dhaka is selected as study area. Dhaka is the capital of Bangladesh and sixth megacity in the world with 21 million population and total area of 300 square kilometers, where more than 23,000 persons live per sq. km (World Population Review, 2021). Total number of PWDs in Dhaka is 604,771 and among them, 221258 is movement challenged or other physically disabled persons, which is higher than other cities of Bangladesh. High level of earthquake risk with significant number of PWDs including MCPs makes Dhaka an ideal study area. On the other hand, close proximity to Madhupur fault line, unplanned development, poor building structures, high population density, a lack of awareness among people regarding response and recovery processes make people of Dhaka highly vulnerable to earthquakes (Comprehensive Disaster Management Programme (CDMP), 2009). The study evaluates the accessibility of MCPs to evacuation route integrating perceived accessibility and physical impedance (Bangladesh Bureau of Statistic, November 2015). Further, the study explores the relation of socio-economic situation, exposure to disaster, perception of the people about the vulnerability of their own life and property with risk perception. Findings from the analysis of risk perception are useful to identify the factors of risk perception and help policy makers take measures to raise risk awareness and develop appropriate risk perceptions (GIRÃO et al., 2017b; Yoshida & Uwe, 2009).

1.2 The Objective of the Study

The study has gone through a comprehensive analysis of the existing accessibility index. This research aims to develop an accessibility index to measure the accessibility of MCPs to the built environment.

The study has two objectives:

1.This project evaluates the accessibility of evacuation routes for movement challenged persons (MCP) of selected areas in Dhaka using the newly developed accessibility index.

2.The study conducts an analysis of risk perception of earthquakes among MCPs

1.3 Intellectual Merit of the Study

Given that no study exists to measure the accessibility of MCPs to evacuation routes using a physical impedance-based index and their risk perception, this project fills this gap in the scientific literature. The study determines physical impedance based on perceptions and experience of MCPs instead of using proxy physical parameters which is a uniqueness of the study. Besides, there is no comprehensive study on risk perceptions of persons with mobility impairment. This study addresses that gap of literature as well.

1.4 Significance and Broader Impact of the Study

The study aims to evaluate accessibility of MCPs of Dhaka and their risk perception. At a local scale, this study helps develop effective policy and planning measures to develop resilience of MCPs of Dhaka to earthquake.

This study not only has a local impact but also provides insights directly applicable to the U.S. and other developed and developing countries of the world. Situated in a city with high population density and acute environmental hazards, the method developed in this project can be applied to other large cities in the world. In U.S., 13.7% of adults with disabilities have mobility challenges. These movement challenged persons are greatly vulnerable during a disaster. The lessons learned in this project can be transferred to the context of U.S and other countries of the world.

2. LITERATURE REVIEW

The aim of conducting research is to review and develop insights to find out the possible answers to any question. Researchers group together relevant thoughts to formulate a theory. Researchers build up the theoretical framework from the perspective of relevant studies. To conduct this research a wide range of literature is studied to develop a solid concept about accessibility, accessibility measures, risk perception. In this chapter, a review of the study conducted for this thesis is described, and later how these studies have influenced this thesis is explained.

2.1 Accessibility and Accessibility Measures

Accessibility is a term often used in transportation planning. Accessibility is generally understood to mean "ease of reaching" and "effort of a person to reach a destination (Geurs & Eck, 2001). Accessibility is always linked with a destination or land uses. It is the combined outcome of the transportation system and land use (Bhatt et al., 2000). Travel distance, travel time and travel cost are the most common parameters used to measure accessibility (Geurs & Eck, 2001). But, many studies explains the concept of accessibility. Geurs and Eck (2001) suggested that individual components such as needs, abilities, and opportunities of individuals be used to define accessibility. According to Miller (2018), accessibility combines the factor of travel impedance to reach or interact with different points in space with travel distance, travel cost and travel time (Miller, 2018). Higgs (2005) defined accessibility as the ability of a person to reach a land use or facility and the level of suitability between the people and the system. Higgs further suggests barriers to accessibility be used to define accessibility (Higgs, 2005). Perceptions of these impedances and barriers vary from person to person and depend on cognitive abilities, personal experiences and constrain, tastes, and preferences (Miller, 2018). The ability of a person to exploit a physical context of access varies depending on their cognitive, physical, and financial capabilities. Persons with disabilities are not equally competent as physically persons when exploring space. They have special accessibility needs. In order to ensure convenient movement for persons with disability footpaths must have kerbs, buildings should have ramps, floor surface will have to be smooth (New Zealand Transport Agency, 2008)

Accessibility measures are increasingly considered in planning and management. They are used to measure levels of accessibility of transportation networks, land use or mode, and services. If accessibility is measured based on an indexed value of relevant parameters, it is called the accessibility index (Bhatt et al., 2000). Weibull (1976) developed a number of axioms for an accessibility measure. These are: the order of opportunities should not influence the value of the accessibility measure and the structure of the data should not affect the outcomes; the value of the measure should not increase with the increase in distance or dwindle with increasing attractions ; opportunities with zero value should not have contributions to the measure(Weibull, 1976). Morris et al. (1979) has proposed several other criteria pertaining to the parameters and performance of an accessibility measure. The criteria include technical feasibility, the inclusion of a behavioral basis, and easy interpretability (Morris, Dumple, & Wigan, 1979). Easy interpretability of the accessibility measure facilitates policymaking and public involvement (Geurs & Eck, 2001).

On the other hand, Bhat et al. (2001) suggests that an accessibility measure should take into consideration the ease of aggregation over time, space, activities, modes, individuals; the availability of data needed for estimation and application; and performance of accessibility measures (Bhatt et al., 2001). Geurs and Eck (2001) demonstrates that there is a trade-off between interpretability and methodological soundness of the accessibility measures. Wilson (1971) proposed accessibility measures should answer a number of questions: What is the degree and type of disaggregation, how origins and destinations will be integrated, what is the procedure of measuring attraction, and how impedance will be measured?. Wilson (1971) also argues that impedance factors need to be weighted to reflect individuals' perceptions. Following this suggestion, Davidson (1980) has regarded perceived distances as the most accurate way to measure accessibility (Davidson, 1980). The construction of perceived accessibility measures depends on subjective data and are more difficult to obtain in comparison to using objective parameters in the accessibility measure (Lättman, Olssona, & Friman, 2018).

Morris et al. (1979) distinguishes objective from perceived measures of accessibility. However, the concept of accessibility and how it is measured rely mostly on objective indicators of accessibility, such as travel time, distance, and travel cost (Lättman et al., 2018). As a consequence, social dimensions of accessibility such as levels of accessibility of specific population groups such as the elderly or persons with disabilities are not comprehensively captured by traditional accessibility measures (Lucas, Wee, & Maat, 2016). Budd and Mumford (2006) revealed that there are indeed gaps between conventionally measured accessibility and how accessibility is perceived by individuals (Budd & Mumford, 2006). As opportunities and abilities to travel are likely to be perceived differently among individuals, to understand the distinction between objective and perceived accessibility is highly relevant (Lättman et al., 2018).

Perceived accessibility is how people rate the condition of the transportation system concerning opportunities available to them. Perceived accessibility consists of perceptions of the level of ease of access to the built-environment and transportation system. Perceived accessibility is important as it reflects an individual's ability to reach destinations. (Lättman et al., 2018). Although a number of studies have made a comparative analysis of perceived accessibility and objective accessibility in terms of travel time, travel distance, travel cost, travel mode choice, there is rarely any study which incorporates the impacts of physical impedance in the study of perceived accessibility (Cheng & Chen, 2015; Curl, 2018; Ryan, Lin, Xia, & Robinson, 2016). Studies show that the physical impedance faced by people with disability, elderly people, pregnant women negatively influences their accessibility (Lättman, Olsson, Friman, & Fujii, 2019; Sanchez et al., 2000).

2.2 Different Accessibility Measures

2.2.1 Network Characteristics Based Accessibility Measures

Total Accessibility Measure: Total accessibility based on connectivity of network and accounts for the total number of paths in a network. A total accessibility measure considers both direct and indirect paths between origin and destination. Variability of accessibility of connecting links (direct and indirect) can be compared using the total accessibility index(Rodrigue, Cosmtoius, & Slack, 2006).

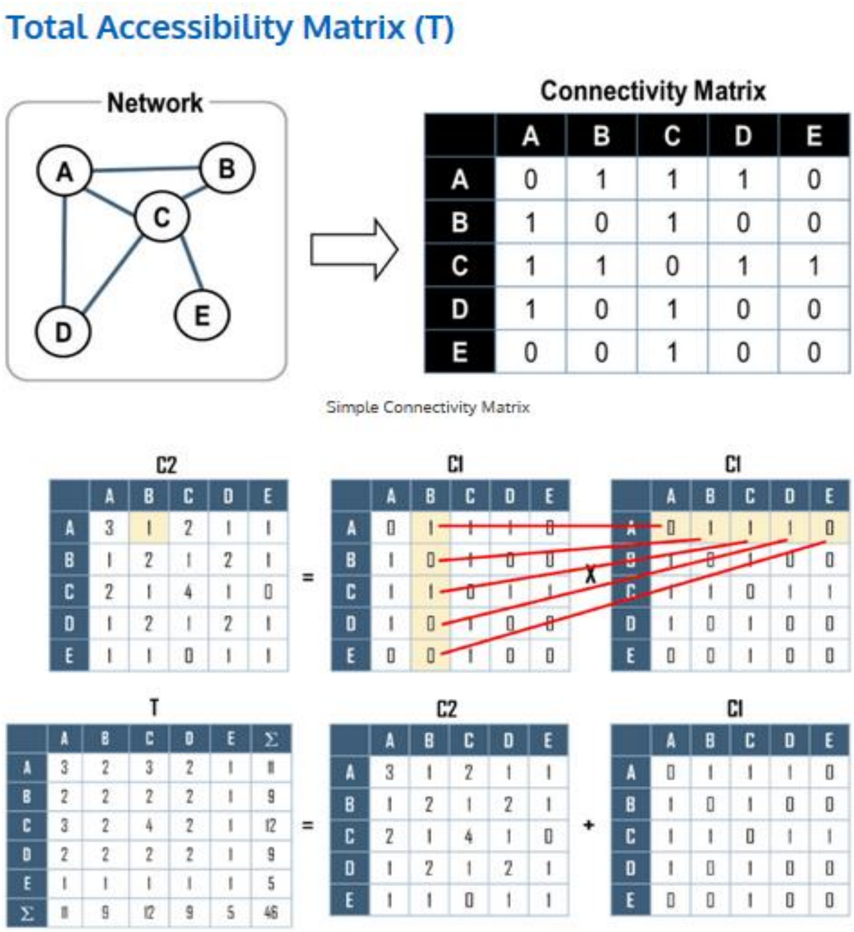


Fig 2.1: Total Accessibility Matrix (The Geography of Transportation Systems, 2020)

The total accessibility matrix (T) can be obtained from the following procedures:

- A connectivity matrix (C1) is constructed. In C1 matrix,1 or 0 is used to denote whether a connection exists between two nodes.1 is used if a direct connection exists between two and 0 indicates no direct connections between two nodes In Fig 2.1, node C is having the highest degree, which is the sum of all the connections this node has.

- Then, the second-order (two-linkages paths) connectivity matrix (C2) is constructed. The total number of two-linkages paths (matrix C2) will equal to (C1xC1) matrix. Each cell in the C2 matrix is determined from the result of the summation of the product of each corresponding row and column from the C1 matrix. For example, cell A-B in matrix C2 is constructed from the following: 0*1 + 1*0 + 1*1 + 1*0 + 0*0. It denotes that there is only one possible two-paths link between nodes A and B (A-C-B). C2 matrix reveals that there are two possible two-linkages paths between nodes C and A (C-B-A and C-D-A).

- Then, the construction of the Nth (N=1, 2,3,…..n) order connectivity matrices is repeated until the number of Nth-linkages paths is equivalent to the diameter (the path between most distant nodes) of the network. A 3rd order connectivity matrix (C3) will equal to C1XC2. A network with a diameter of n will require the construction of n matrices (C1 to Cn). Since the above network has a diameter of 2, only two matrices, C1 (1st order connectivity) and C2 (2nd order connectivity) is constructed.
- In order to construct the total accessibility matrix (T), matrix C2 (two-linkages paths) is added to matrix C1 (single paths; connectivity matrix). The summation represents the total number of paths from a node. For this network, there are thus 46 possible paths in total, with node C having the largest number (12); either originating from it or having it as a destination(The Geography of Transportation Systems, 2020).

Network Characteristics based Accessibility Index for Non-motorized transport

Tal and Handy (2011) suggests an approach to measure the accessibility of pedestrian networks using road network characteristics as well. Their study considers accessibility as a function of connectivity and proximity. Proximity is linked to land use pattern-location and proximity between land uses. Connectivity is represented as the number of connections in a network. Three approaches has been applied in this study to determine pedestrian accessibility. The Link to Node ratio is determined by dividing the total number of links in a network by the total number of nodes. This method can be used to determine the accessibility of the road network where roads have crossed each other. LNR has no distance component and does not measure connectivity with respect to fixed origin-destination (Tal & Handy, 2011). In transport geography, the Link to Node ratio is represented β and called Beta index(Shashank, 2015; Tressider, 2005).

$\beta = L/N$

Where β=Link to Node ratio,

L=Number of links in a network

N=Number of Nodes in a network

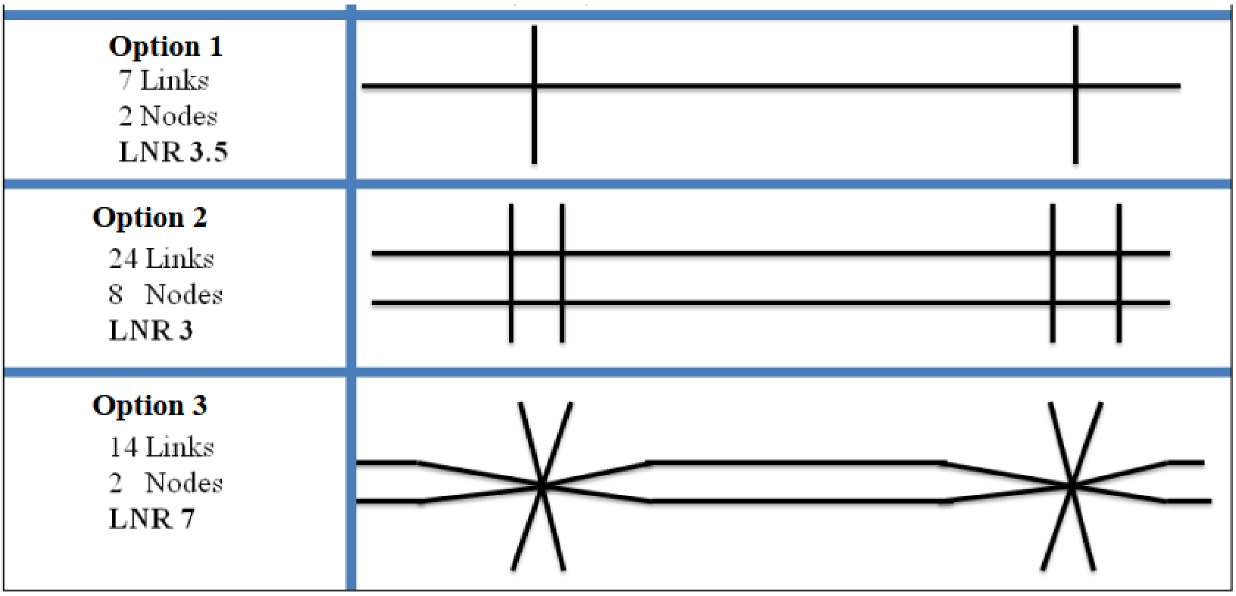


Fig 2.2: Link to Node Ratio (Tal & Handy, 2011)

The second approach is Pedshed where the total area that can be reached by a road network within a certain radius is used as measured accessibility. Pedshed is expressed as a percentage of the total accessible area to the total area of circular coverage area. Pedshed is calculated accounting for a single origin without a fixed destination (Dill, 2004; Tal & Handy, 2011).

The third measure is Household within PedShed. It is derived from Pedshed where instead of land area, the number of household is used as a parameter. Household is considered as the origin point of a trip to reach a fixed destination. These two measures help reveal changes in accessibility with the change in spatial location of origin or destination. Pedshed and Household withing PedShed are location-specific measures. Pedshed measures accessible destination in respect of specific origin and Household withing PedShed measures accessibility specific origin and destination (Dill, 2004; Tal & Handy, 2011).

All these three methods are GIS-based. It is very common for GIS databases only to consider an arbitrary point of access to land use in spite of having multiple access points. Under these circumstances, accessibility will be under-evaluated by the above-mentioned indices.

2.2.2 Shortest Path Based Accessibility Measures

Shimbel Index: Shimbel index determines the minimum number of paths necessary to connect one node with all the other nodes in a network by developing a Shimbel matrix (Rodrigue et al., 2006). Thus, the Shimbel index avoids redundancy by not considering unnecessarily long routes. For this, it can be considered as an updated version of Total Accessibility(Webspace, n.d.). To calculate Shimbel index, the number of indirect connections or paths that link nodal pairs is obtained by matrix multiplication (Otten & Bellafiore, 2018).

Shimbel Distance Matrix (D-Matrix)

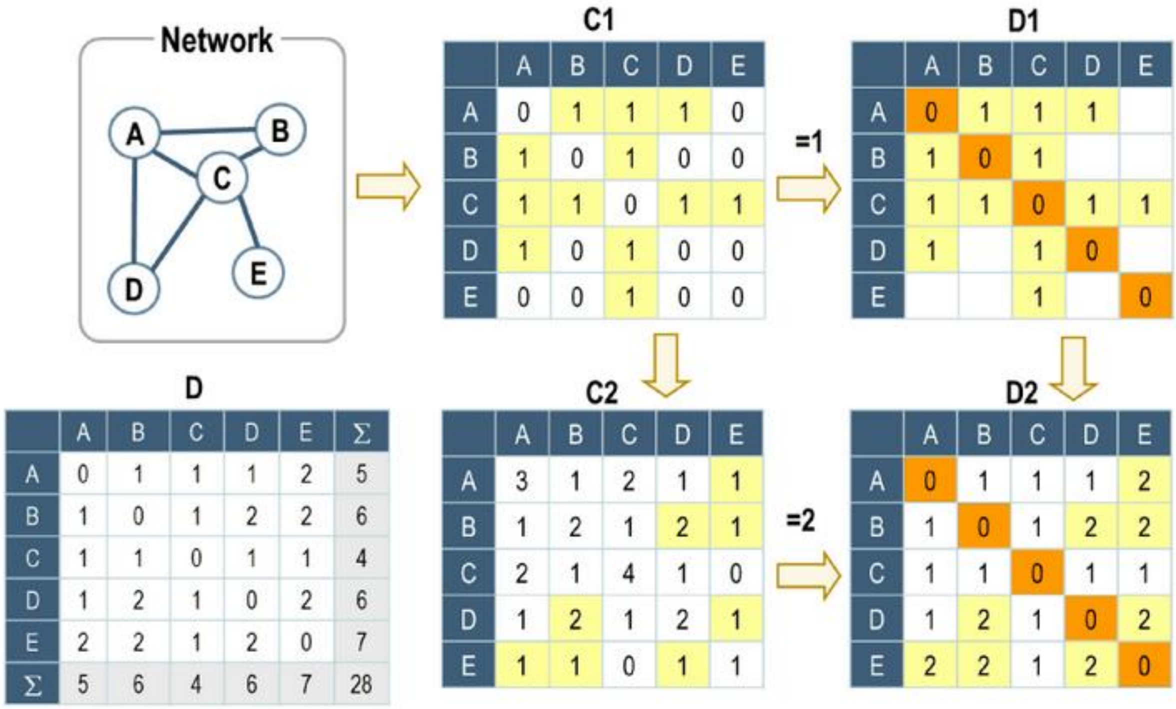


Fig 2.3:Shimbel Distance Matrix(D-Matrix)

The Shimbel Distance Matrix (or D-Matrix) represents the shortest paths between the nodes within a network. These shortest paths are always equal or lesser to the diameter (Diameter of a network is the number of links required to connect the two most remote nodes in a road network following the shortest path between those two-point. Diameter is referred to as the longest, shortest path of the network. For constructing the D matrix, C matrices of Nth order are built until it reaches the diameter of the network. Then, each C matrix is converted into a corresponding D matrix. In Fig 2.3 two C matrices, C1(connectivity matrix) and C2 (two-linkages paths; C1*C1) have been built since the diameter is 2.

- The first order Shimbel Matrix (D1 in Fig 2.3) is a simple adaptation of the C1 matrix. In C1, all the direct links have been kept. A value of 0 is assigned for all the C_{ii} cells since the shortest path between a node and itself will be always 0. Cells with a value of 0 in the C1 matrix is kept unfilled on the D1 matrix.

- The second-order Shimbel Matrix (D2 in Fig 2.3) has been built from the first-order matrix D1 but only contains unfilled cells. A value of 2 is assigned for each cell on the D2 matrix that has a value greater than 0 on the C2 matrix, but if a value of 1 already exists (D1 matrix), this value is kept. This implies that on the D2 matrix of the figure 2.3, only the values of the yellow-colored cells is changed to 2. Since the diameter of this network is 2, the D2 matrix is the Shimbel distance matrix.

- To build an N th order Shimbel Matrix (DN), for a network having a diameter of 3, a D3 matrix is to be built from a C3 matrix (C1xC2) as at least 1 cell remains empty in the D2 matrix. Construction of Nth (N=1,2,3,4,…….n) order Shimbel matrices is repeated until the diameter is reached.

- In The Shimbel Matrix (D), the order of the Shimbel distance matrix that corresponds to the diameter is referred to as the D matrix. The summation of rows or columns is the Shimbel distance for each node. In the D matrix of the Fig 2.3, node C has the least summation of shortest paths of 4 and is thus the most accessible, followed by node A of 5, nodes B and D of 6, and node E of 7. The total summation of minimal paths is found to be 28(Rodrigue et al., 2006).

Although the Shimbel matrix fails to take into account distance between nodes, Value Added Graph can be used as a proxy for Shimbel matrix in order to consider the minimal distance between nodes to calculate accessibility and connectivity (Otten & Bellafiore, 2018; Rodrigue et al., 2006).

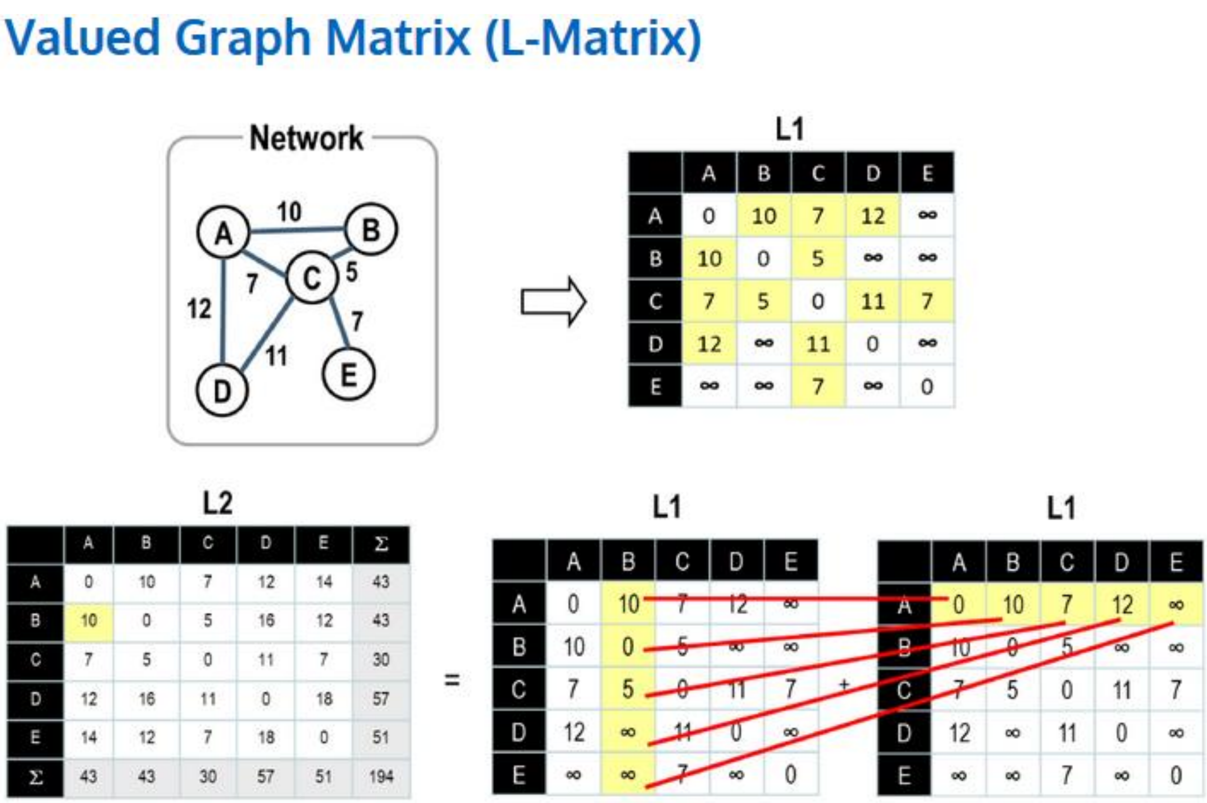


Fig 2.4: Value-added graph for (D-Matrix) (Rodrigue et al., 2006)

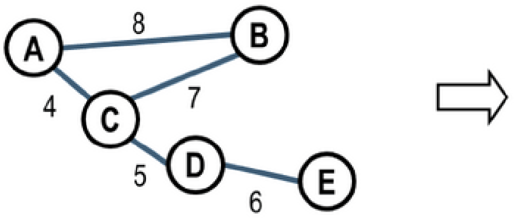
The construction of the valued graph matrix (L-matrix) follows the following steps:

- The distances in the network are transcribed in matrix L1 (direct connectivity distance) shows for each pair directly connected. Infinite value is given for pairs of nodes that are not directly connected.

- The calculation of the Nth order L matrix is similar to the creation of the Shimbel Matrix. But, in this case, the minimal distance is used on the matrix. The shortest path between nodes A and B is the A-B link. However, there is also an A-C-B link, for which the summation of distances could be smaller (actually it is not). The calculation of the L2 matrix requires the cross-summation of the L1 matrix. In L1, each cell in a column is added with each cell in a row. The B-A cell on matrix L2 has been calculated by the cross summation of column B and row A. Only the smallest value of the five operations is kept, which is 10 in this case. Since the above network has a diameter of 2, only two steps are necessary and the L2 matrix becomes the L-Matrix. The summation of each row on the L2 matrix represents the minimal distance required to travel to reach all the other nodes in the network. For node B, it is found to be 43.

Geographic Accessibility Index: Geographic accessibility considers that the accessibility of a location is the sum of all distances between other locations divided by the total number of locations. In order to calculate geographic accessibility index, a matrix is developed with shortest distances between nodes/locations and then, dividing the total distance between nodes by number of locations. In order to reach a node from the origin, one might need to cross a number of nodes in between. For example, in order to go to C from A, one might need to go to B, then he will reach C from B. To calculate the geographic accessibility index, the shortest distance between A and B and B and C will be considered as distance. The lower its value, the more a location is accessible. Geographic Accessibility index uses distances as an impedance value. This method is simple to use and can be easily applied to a network in GIS, but does not consider the relative weight of different locations in terms of attraction and emissiveness of land uses (Rodrigue et al., 2006).

Geographic Accessibility



L

	A	B	C	D	E
A	0	8	4	9	15
B	8	0	7	12	18
C	4	7	0	5	11
D	9	12	5	0	6
E	15	18	11	6	0

A(G)

	A	B	C	D	E	∑/n
A	0	8	4	9	15	7.2
B	8	0	7	12	18	9.0
C	4	7	0	5	11	5.4
D	9	12	5	0	6	6.4
E	15	18	11	6	0	10.0
∑/n	7.2	9.0	5.4	6.4	10.0	38.0

Fig 2.5: Geographic Accessibility Measure (Rodrigue et al., 2006)

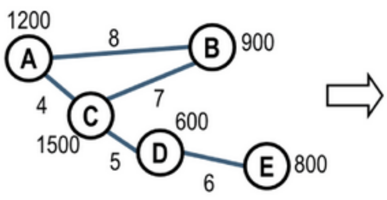
According Fig 2.5, the construction of a geographic accessibility matrix, A(G) involves the following steps:

- At first, a matrix (L) with the shortest distance between five nodes (Node A to Node E) is constructed

- Then, the geographic accessibility matrix A(G) is built. The A(G) matrix is akin to the L-matrix except that the summation of rows and columns is divided by the number of locations in the considered network. The summation values are the same for columns and rows of A(G) matrix. The most accessible place is Node C as it has the lowest summation of distances.

Potential Accessibility Index: Potential accessibility considers accessibility as the potential of opportunities to interact(Geurs & Eck, 2001). Potential Accessibility is based on the concept of distance weighted by attributes of a location. All locations are not equally significant as they have different attributes and weights. A non-transposable potential accessibility matrix with the shortest distance between location is developed to calculate this index. Potential accessibility matrix can be used to calculate emissiveness (the desirability to leave a location) and attractiveness (the desirability to reach a location) (Rodrigue et al., 2006; The Geography of Transportation Systems, 2020). Distance decay function can be used to determine differential accessibility with the change in distance to travel (Hansen, 1959). Potential accessibility can be analyzed for a multi-modal transportation system and different socio-economic groups (Black & Conroy, 1977). The Potential Accessibility Index has certain limitations. This index might result in higher accessibility because of greater mass (total floor area, number of employers/people residing etc) of a land use i.e. origin or destination(Geurs & Eck, 2001). This approach does not consider the individual impedance while evaluating accessibility (Ben-Akiva & Larmen, 1985). This measure also does not take into consideration spatial distribution of demand of opportunities (e.g. inhabitants) (Q. Shen, 1998) .

Potential Accessibility



L

	A	B	C	D	E
A	0	8	4	9	15
B	8	0	7	12	18
C	4	7	0	5	11
D	9	12	5	0	6
E	15	18	11	6	0

P

A	1200
B	900
C	1500
D	600
E	800

P(G)

i\j	A	B	C	D	E	∑i
A	1200.0	150.0	300.0	133.3	80.0	1863.3
B	112.5	900.0	128.6	75.0	50.0	1266.1
C	375.0	214.3	1500.0	300.0	136.4	2525.7
D	66.6	50.0	120.0	600.0	100.0	936.6
E	53.3	44.4	72.7	133.3	800.0	1103.7
∑j	1807.4	1358.7	2121.3	1241.6	1166.4	7695.4

Fig 2.6: Potential Accessibility Measure(Rodrigue et al., 2006)

By considering the same valued graph matrix (L) from Fig 2.6 and the population matrix P, the potential accessibility matrix, P(G), can be developed:

- The value of all corresponding cells will equal the value of their respective attributes of the population (P).
- The value of all non-corresponding cell will equal their attribute of the population divided by the corresponding cell in the L-matrix.

The higher the value, the more a location is accessible. In Fig 2.6 , node C is the most accessible node. The matrix being non-transposable, the summation of rows is different from the summation of columns which represents their respective attractiveness and emissiveness. Node C has more emissiveness than attractiveness (2525.7 versus 2121.3).On the contrary, Node B has more attractiveness than emissiveness (1358.7 versus 1266.1).

2.2.3 Travel Time, Travel Distance-based Accessibility Measures

Contour Based Measure Accessibility Measure: A contour measure is also called “an isochronic measure”, “cumulative opportunities”, “proximity distance”, or “proximity count”. It is considered to be one of the simplest accessibility measures which considers travel time or distance threshold as well as the existence of a number of potential lands uses or activities with the considered threshold as the accessibility for a spatial unit (Bhatt et al., 2000). Contour-based accessibility is often used as accumulative measures, counting the number of total services or the number of different services within a threshold value for a mode of travel. Therefore, from a methodological point of view, contour-based measures could also be defined as measures accounting for the transport and land use component without having a continuous decay function(Albacete, 2016).

Albacete(2016) mentioned that contour-based accessibility measure consists of four elements: trip origin (land use component), trip destination (land use component), travel distance or travel cost or travel time of connecting links and mathematical relation depicting how accessibility changes with travel time, distance or cost.

The origins of the contour measure refer to the reference point where the physical travel starts. On this subject, several authors have pointed out two main aspects for consideration about the origins of contour-based measures: spatial resolution and trip chains. The importance of the spatial resolution of land use throughout the accessibility calculation represents a limitation. A land-use data with higher spatial resolution must have land use locations highly disaggregated spatially (for example, any particular land use might have a number of buildings under its jurisdiction and a land-use data with higher spatial resolution will indicate the location of all the buildings separately instead of all the buildings as a single entity in map or land use data) which is not always easily available (Silva, 2008). Based on the spatial resolution of the original data, results may differ even if using the same calculation method. But, the problem associated with this approach is that too fine a resolution may increase the computational and data requirements. Destinations or opportunities refer to the set of services considered reachable (and therefore included in the accessibility calculation).

Links can be used to illustrate how origin and destination points are connected in a network by using a cost matrix. Travel time is the most widely used unit, but in other instances travel distance, economic costs, or a combination of these three units (for example translating travel time into monetary cost and adding it to the transportation cost) have been used. There are three aspects of the link that may strongly affect the outcome. Firstly, the unit (distance/cost/time) has to be carefully selected based on the requirement of the study. Secondly, the transformation between units (for example time to money, money to space, or space to time) has to be carefully done since its transformation indirectly includes information about the existing transport network, urban fabric, and monetary value for the population. And thirdly, the level of detail of the available data will deliver more feasible results without adding any computational costs to the calculations. Therefore, it is important to obtain as defined original data about the links as possible.

Finally, the mathematical relation of attractiveness and/or repulsion between the origins and the destinations (opportunities) is a fourth element that is a concern of the debate. The debate around this relation is focused on the threshold value. Although the principle assumes that all services within the threshold value are labeled with the same accessibility index, several authors have proposed a final composed accessibility index based on different threshold values (Bhatt et al., 2001; Mavoa, Witten, McCreanor, & O'Sullivan, 2011).

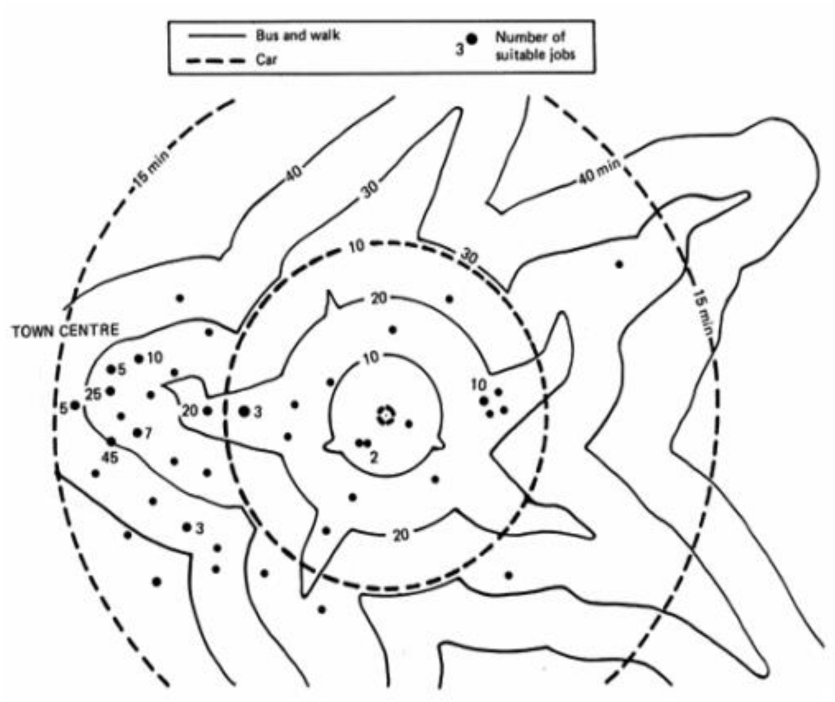


Fig 2.7: Contour based accessibility for different transport mode

The threshold value is controversial since it is based on subjective perceptions. Its evaluation and improvements for contour-based accessibility measures are decided based on the subjective perceptions of the researcher. Several authors have pointed out that all the services or opportunities are treated equally if they are within the threshold value and this might not correspond to the actual relevance of the opportunities for individuals (Voges &

Naudé, 1983). In those cases where the measure is based on relative values among citizens or sub-areas of the region, the effect is stronger (Baradaran & Ramjerdi, 2001). In the cases where the study area is big, the relative results of accessibility will tend to overestimate the accessibility level since areas with very low accessibility have been included in the calculation. The opposite may occur when the study area is small with a high density of optimal transportation services. Geurs and van Eck (2001), Silva (2008) and van Wee et al. (2012) have pointed out that the lack of temporal components represents a major limitation for contour-based measures. The individual component of accessibility is not included. All individuals of a certain group are assumed to have the same travel behavior and use the same set of opportunities. Contour-based measures are not able to make individual differentiation among citizens (Baradaran & Ramjerdi, 2001). The contour-based accessibility measure does not necessarily correspond to individual travel behavior. Many authors have calculated the spatial and individual characteristics that seem to affect travel behavior (Voges & Naudé, 1983)and the choice of transport mode. Therefore, the assumption of travel behavior based only on a travel cost matrix can be misleading if those other components are not taken into account. The exclusion of competition effects between origins and destinations decreases the reliability of the measure. The spatial definition of the area of analysis strongly affects the final result.

The Structural Accessibility Layer: Structural Accessibility Layer (SAL) is an accessibility measure that has been developed by Silva et al. (2008) based on the concept of the contour-based accessibility measurement technique. It assesses how urban structure constrains the travel choice of people. Although it includes land use and transport components, it does not consider individual and temporal factors. It includes two accessibility measures: Diversity of Activity Index (DivAct) index and a comparative accessibility measure (accessibility cluster) for categorization. DivAct measures the number of activity types reachable within a given threshold time.

$$\text{DivAct}=(\sum_i Act_i \times f_i) / \sum_i f_i$$

where i is the type of activity, Act_i is a binary variable indicating whether the activity i is accessible within the threshold time or otherwise, and f_i their potential frequency of use.

The value of DivAct ranges from zero (no accessible activities within the set boundaries) to 1 (all activities accessible within the threshold) and shows how close residences are to a variety of activities considering a certain travel mode or combination of modes. Likewise, contour measures, to determine the activity types which are reachable from an origin point accessibility are defined based on a cut-off value of time and cost. The selection of cut-off value is likely to vary based on transport modes.

DivAct takes into consideration the frequency of activity. The access to activity with a higher frequency of use provides higher values of the diversity of activities in comparison to activities with a lower frequency of use. Thus, SAL can be considered as a contour measure weighted by frequency. Accessibility for each transport mode can also be disaggregated by weighing DivAct value based on population to find regional diversity of accessibility (Silva et al,2008). Silva et al (2008) all suggested that disaggregation of accessibility can also be made according to the land use category using the SAL framework.

The results of the DivAct are used to derive a comparative accessibility measure by travel modes (private car, public transport [PT], and non-motorized transport [NM]). Comparative accessibility measure is generally referred to as the Sustainability Measure.

To evaluate the sustainability of potential mobility patterns, all potential combinations of accessibility are represented in a benchmark cube. This benchmark cube is the central feature of SAL. Each axis is divided into three categories in the cube, creating 27 classes, then amassed into nine accessibility clusters from 1 to IX represented in 9 different colors in the benchmark cube. The clusters define the availability of transport modes for reaching desired activities. Each of the classes represent different accessibility condition in respect of land use and transportation mode. The classification of sustainability of mobility pattern represented by the comparative accessibility index is used for aggregation of accessibility measures of all transport mode types, producing final aggregate value of comparative accessibility (Fig 2.8 and Fig 2.9).

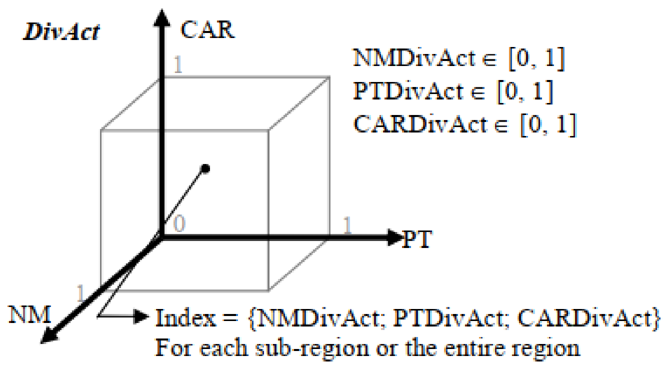


Fig 2.8: Potential combination of accessibility by three transport modes (NM=Non-mototized, PT=Public Transport, Car) (Silva, 2012)

A transport mode is considered to be favored by land use and transportation situation when it provides high level of accessibility. Land use and transport condition unable to provide to high level of accessibility for any considered mode of transport is categorized to cluster VIII and Xi as they does not represent favorable condition for use of any transport concerning potential choice of transport mode and potential travel distance (Fig 2.9).

The main advantages of the SAL are ease of use in understanding and communicating of the tool and the coherence of the measures. The soundness of the basic contour measure has been enhanced by using disaggregated spatial analysis (at the census tract level, or grid-based of at most 1 sqm) of accessibility levels by different transport modes and several types of activities. Although SAL can overcome the problem of providing equal weight to each of the land uses and destinations, it does not take into consideration the distance decay. Distance decay can be integrated with SAL by high disaggregation level of analysis (based on spatial scale, transport modes, and activity types) which enhances the understanding of the urban structure conditions, but, at the same time, it will make the tool complex. The regional scale of analysis limits its application at a micro-scale. the SAL is data-intensive and time-consuming and therefore, it is expensive, being out of reach of average local authorities(Silva, 2012).

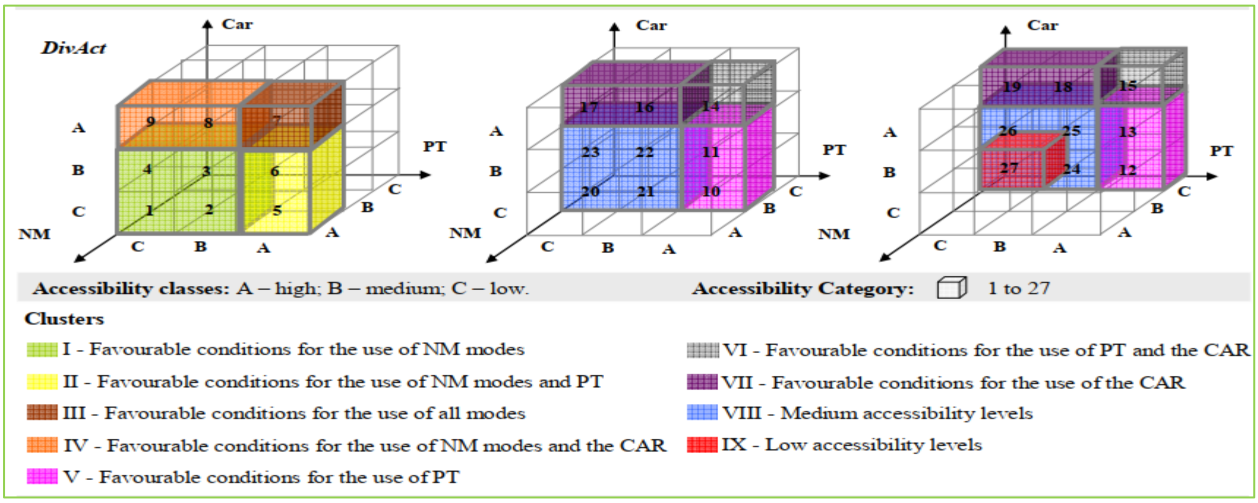


Fig 2.9: The benchmarking cube and accessibility clusters for Structural Accessibility Layer for three transport modes (NM=Non-motorized, PT=Public Transport, Car) (Silva,2008)

Public Transport and Walking Accessibility Index (PTWAI): Mavoa (2011) proposed Public Transport and Walkability Accessibility Index (PWTAI) and applied it for a multi-modal network of Auckland, New Zealand using ArcGIS. This method is based on the concept of contour-based accessibility measure as accessibility is determined based on travel time required to reach destination land uses. With an increase in the amount of travel time required to reach a land use, it’s accessibility is considered to be deduced. The travel time includes access time required to reach the transit by walking, waiting time for the bus at a transit stop, and travel time on public transit. Total travel time is categorized into number groups and each category is assigned an ordinal score denoting different levels of accessibility. This ordinal score is called accessibility score. PTWAI is a multi-contour measure as contours are considered for different threshold values of the time. While calculating the access time to the transit stop, GIS data is used. The distance between the length of the road segment to be walked to reach transit stop is divided by a fixed walking speed (78 meters/min) to determine the time required to reach transit stop (Albacete, 2016; Mavoa et al., 2011). In this method, destination land uses are categorized into a number of domains based on the similarity of characteristics. Accessibility score of land uses determined based on the total travel time required to reach the destination. Accessibility scores of land use belonging to each domain is summed up and averaged for each domain. The final accessibility score is determined by summing up average accessibility score for each domain considering equal weight for each domain of land uses (Mavoa et al., 2011).

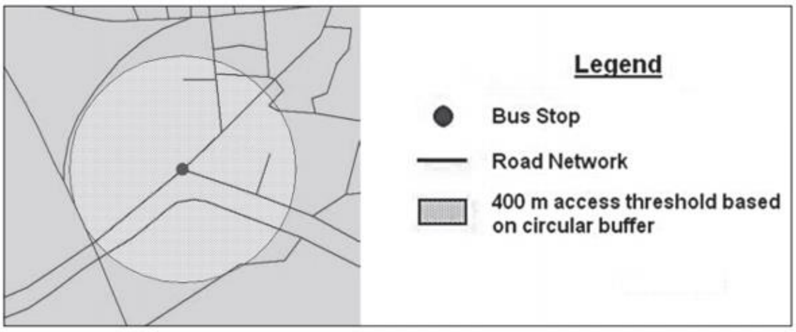
Unlike Structural Accessibility Layer, PTWAI does not take into consideration the diversity of land uses. PTWAI does not consider individual travel behavior and considers equal accessibility for each individual in terms of speed and travel time (Albacete, 2016). PTWAI stratifies travel time in an ordinal (integer) scale but does not consider the distance decay function(Silva, 2008).

2.2.4 Network Characteristics and Coverage Area-based Accessibility Measures

Foda and Osman (2010) has developed three indexes based on road network characteristics and coverage area to determine accessibility to bus stops. In each of the methods, it is considered that all transit users will travel for 5 minutes at a speed of 1.3 m/s to reach the bus stop as a basis for calculating coverage area for bus stops (Foda & Osman, 2010).

Foda and Osman (2010) suggests three methods: Ideal Stop Accessibility Index (ISAI), Actual Stop Accessibility Index (ASAI), and Stop Coverage Ratio Index (SCRI) to determine pedestrian accessibility to bus stop using GIS following road network characteristics and compared pros and cons of three methods.

Ideal Bus Stop Coverage Index is obtained by dividing the total length of the pedestrian road network links lying within a walking distance by circular catchment area covered by walking distance (Fig 2.10).



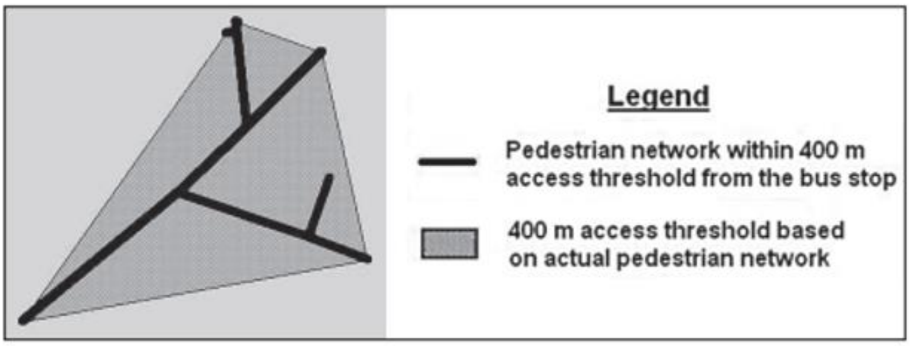
ISAI= L_i / C_i

L_i=Length of road network within ideal coverage area (400 m buffer)

C_i= Area of ideal coverage area

Fig 2.10: Ideal Stop Accessibility Index (Foda & Osman, 2010)

To determine the Actual Bus Stop Access Coverage, all the pedestrian road network links that lie within the specified maximum walking distance are identified. Joining the ends of those links creates a polygonal area, which is referred to as the “Actual Bus Stop Access Coverage” for the bus stop (Fig 2.11). ASCI is determined by dividing sum of lengths of links within Actual Bus Stop Coverage by the area covered by within Actual Bus Stop Coverage.



ASAI= L_a /A_a

L_i=Length of road network within Actual Coverage Area

A_a= Actual Bus Stop Coverage

Figure 2.11: Actual Bus Stop Coverage Index (Foda & Osman, 2010)

SCRI is the ratio of the actual coverage area of the bus stop to the ideal coverage area of the bus stop as shown in Fig 2.12 (Foda & Osman, 2010).

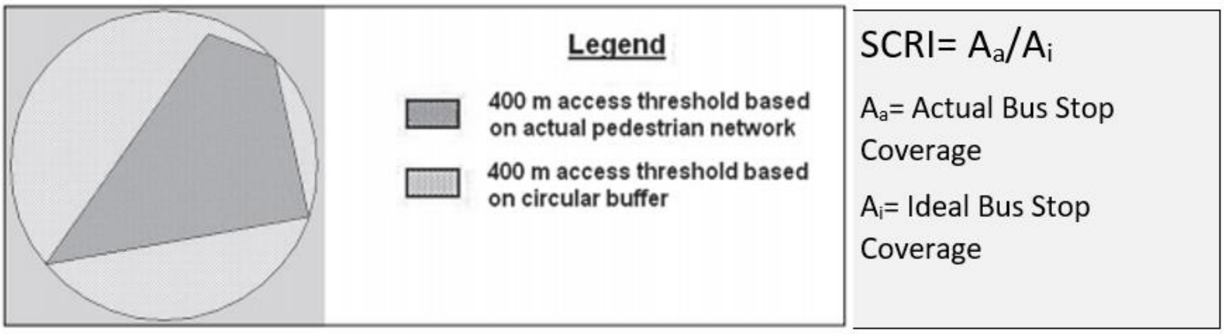


Fig 2.12: Stop Coverage Ratio Index (Foda & Osman, 2010)

2.2.5 Relative Impedance Based Accessibility Index

Chruch and Martson (2002) suggested the concept of relative accessibility to quantify challenges faced by persons with disability. Generally, a physically fit person will follow the shortest path whereas it is not possible for persons with disability to follow the shortest path because existence of hindrance like stairs, undulated or cracked floor surface as. Fig 2.13 describes such a situation (Church & Mattson, 2002; Tauhid, 2007). Relative accessibility is measured by ratio travel distance, cost or time incurred by a disable persons to reach a place avoiding a path with obstacles to ratio travel distance, cost or time incurred by a physical person to reach same destination. Trip frequency, multiple trip destinations can also be integrated in this index. Relative accessibility is an important measure because it helps to realize impact of obstacles on the movement of persons with disability (Church & Mattson, 2002) .

Relative Accessibility= A_d/A_p

Where A_d=Travel distance/time/cost of a person with disability to travel between certain origin and destination and A_p= Travel distance/time/cost of a physically fit person to travel between the same origin and destination

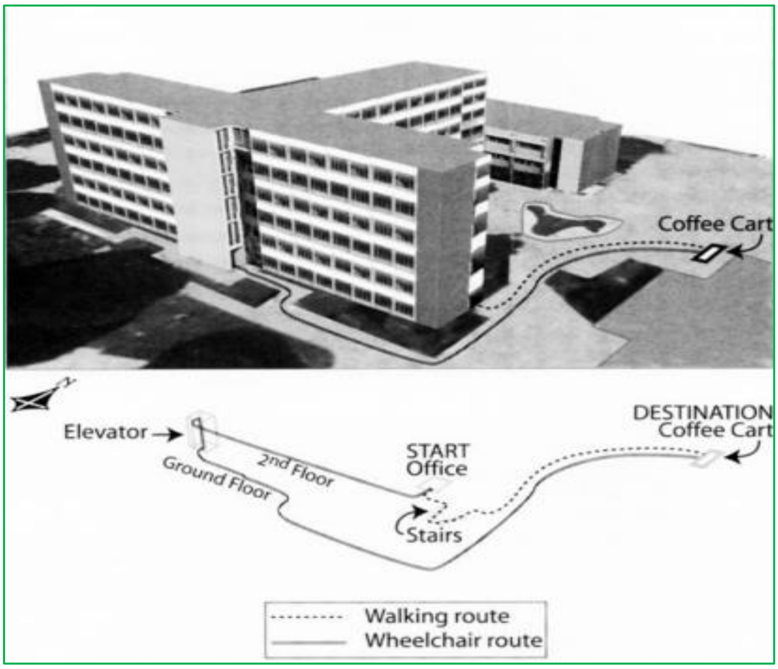


Fig 2.13: Relative Accessibility (Church & Mattson, 2002)

2.2.6 Floating Catchment Method and Gravity Model Based Accessibility Index

A floating catchment area (FCA) is defined as a catchment area which placed at the centroid of a sub-region (point of demand) to identify supply/availability of particular facilities within the catchment area. Then, the catchment is moved to another sub-region to determine the supply of facility for that individual. As this catchment floats among individuals within a region, it is called floating catchment and this method of determining facility supply and facility demand ratio is well known as simple floating catchment method. According to Peng (1997), a catchment area can be defined as a square around each location of residents, and the used jobs–residents ratio within the catchment area to measure the job accessibility for that location (Peng, 1997). The catchment area may also be defined as a circle or a fixed travel time range (Wang, 2000; Wang & Minor, 2002).

Fig 2.14 represents an example to illustrate the method graphically. For simplicity, assume that each demand location (e.g., tract) has only one resident at its centroid and the capacity of each supply location is also 1. A circle drawn around the centroid of a residential location defines its catchment area. Accessibility in a tract is defined as the supply-to-demand ratio within its defined catchment area. For instance, within the catchment area of tract 2, total supply is 1 (i.e., only *a*) and total demand is 7. Therefore, accessibility at the tract 2 is the supply-demand ratio, i.e., 1/7. The catchment area of tract 11 has a total supply of 3 (i.e., *a*, *b*, and *c*) and total demand of 7. So, the accessibility at tract 11 is 3/7.

The above example can also be used to explain the limitation of the simple FCA method. It assumes that services within the catchment area are completely available to residents located within the catchment area. But, the distance between a supply and a demand within the catchment area may exceed the threshold distance of the radius of the catchment area. From Fig 2.13, the distance between tract 13 and *a* is greater than the radius of the catchment area of tract 11. In tract 2, the supply at *a* is within the catchment of tract 2, but may not be fully able to serve demands within the catchment, as it also serves tract 11. This indicates the need to discount the availability of a supplier by the intensity of competition for its service of surrounding demands.

A method developed by Radke and Mu (2000) overcomes the above limitations. It repeats the process of floating catchment twice: once on supply locations and once on-demand locations. It is therefore referred to as the two-step floating catchment area (2SFCA) method (Luo & Wang, 2003; Radke & Mu, 2000). For overlapping areas (spatially decomposed area) supply to demand, ratios are summed up. This method accounts for both proximity and availability of service providers.

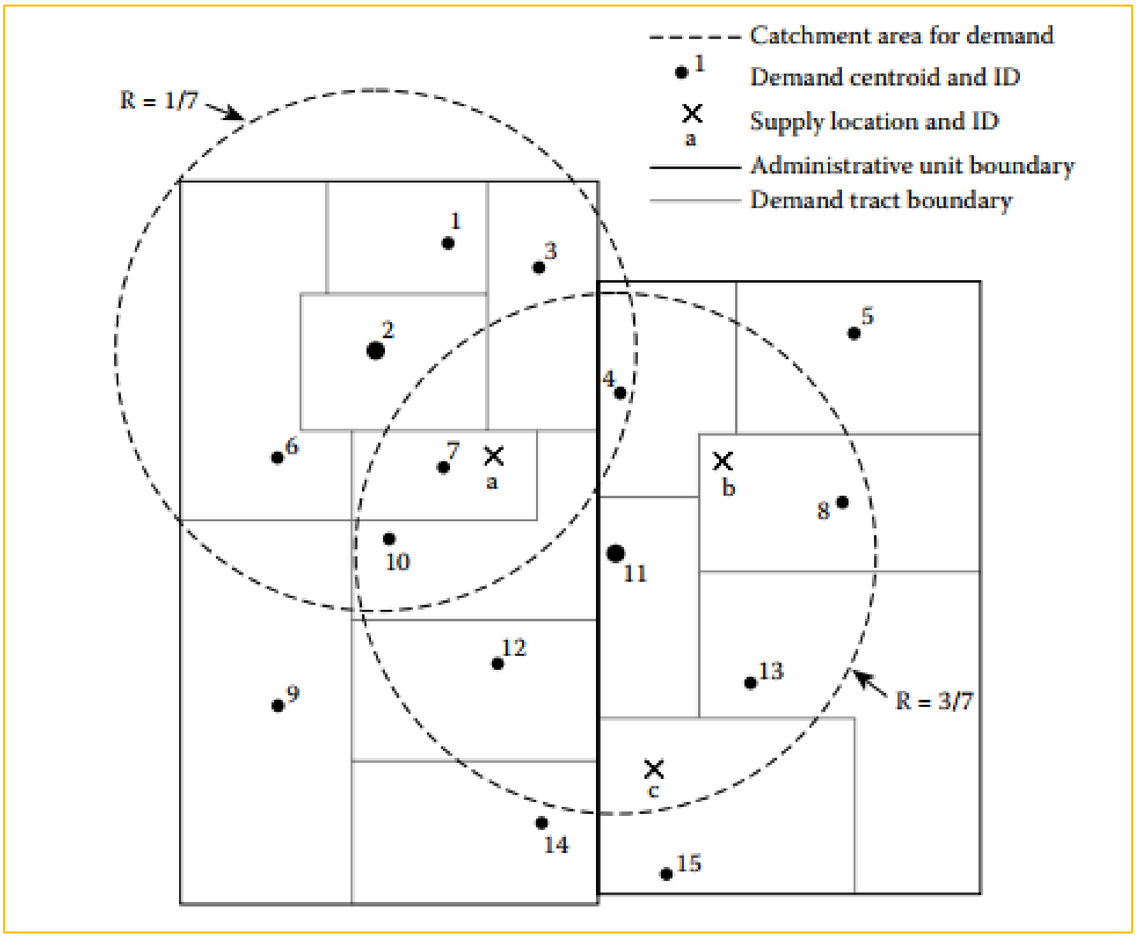


Fig 2.14: Earlier version of the FCA method (Luo & Wang, 2003)

Two steps of 2SFC method is discussed below:

Step 1. For each physician location at j, all population locations (k) that are within a threshold travel time (d_o) from location j (catchment area j) are identified and the physician-to-population ratio, Rj, within the catchment area is determined.

$$R_j = \frac{S_j}{\sum_{k=1}^{k=m} P_k}$$

where P_k is the population of tract k whose centroid falls within the catchment (that is $d_{kj} \leq d_o$), S_j the number of physicians at location j, and d_{kj} is the travel time between k and j, m is the total number of tracts which centroid falls within catchment.

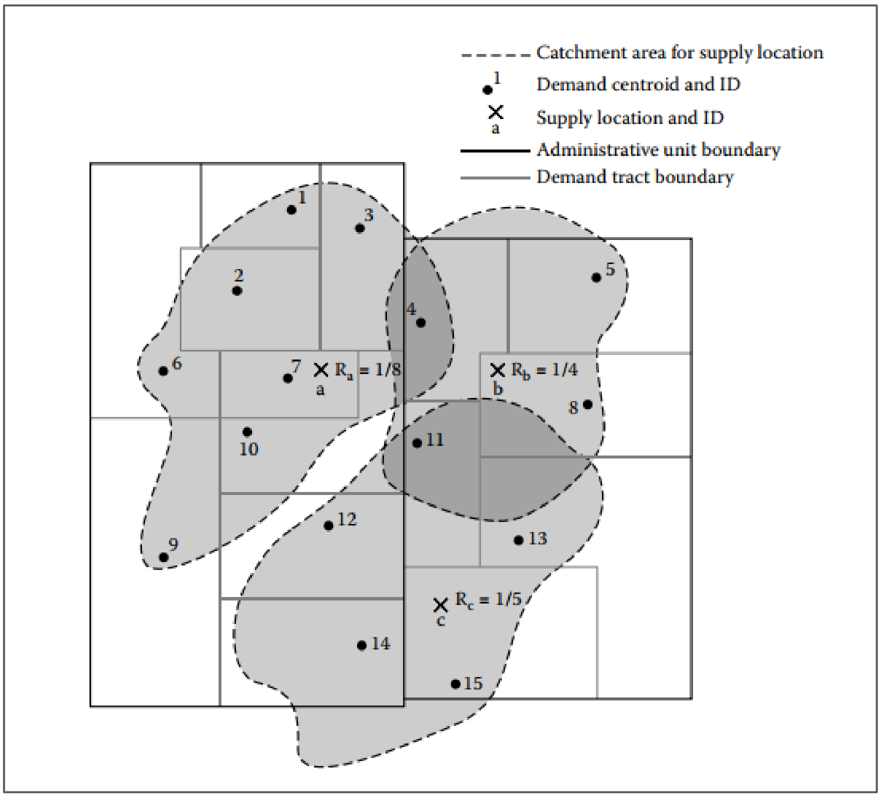


Fig 2.15: The Two Step Floating Catchment Method

Step 2. For each population location i, search all physician locations (j) that are within the threshold travel time (d_o) from location i (catchment area i), and sum up the physician-to-population ratios, R_j, at these locations:

$$A_i^F=\sum_{j=1}^{n} R_j=\sum_{j=1}^{n} \frac{S_j}{\sum_k P_k}$$

where A_i^F represents the accessibility at resident location i based on the two-step FCA method, R_j is the physician-to-population ratio at physician location j whose centroid falls within the catchment centered at i ($d_{ij} \leq d_o$), and d_{ij} is the travel time between i and j, n is the total number of physician location) that are within the threshold travel time (d_o) from location i (catchment area i) . A larger value of A_i^F indicates a better accessibility at a location.

Fig 2.15 uses the same example to illustrate the 2SFCA method. But, in this instance, travel time has been used to define catchment area instead of straight-line distance. The catchment area for supply location of *a* has one supply and eight residents, and thus carries a supply-to-demand ratio of 1/8. The resident at 4 can reach both supplies *a* and *b* (shown in an area overlapped by catchment areas *a* and *b*) within threshold time and therefore enjoys a better accessibility (i.e., $R_a + R_b = 0.375$).

2SFCA considers all facilities within threshold travel time are considered equally accessible regardless of difference in travel time to reach facilities at different location. The 2SFCA method treats distance (time) impedance as a dichotomous measure; i.e., any distance or time within a threshold is equally accessible and any distance or time beyond the threshold value is equally inaccessible. This can be codes as follow with 0 as inaccessible and 1 as accessible:

a. d_{ij} or $d_{kj}=\infty$ if $d_{ij} > d_o$

b. d_{ij} or $d_{kj}=1$ if d_{ij} or $d_{kj} \leq d_o$

This dichotomy can be overcome by integrating gravity model with in the concept of 2SFCA. The gravity model considers a nearby supply more accessibly than a remote one and depicts a continuous decay of access with increase in distance (Q. Shen, 1998; Wang & Minor, 2002) . The gravity-based accessibility measure at location *i* can be written as

$$A_i^G=\sum_{j=1}^{n}\frac{S_j\, d_{ij}^{-\beta}}{V_j} \qquad \text{where } V_j=\sum_{k=1}^{m} P_k\ d_{kj}^{-\beta}$$

A_i^G is the gravity-based index of accessibility, where n and m are the total numbers of physician. A_i^G discounts the availability of a physician by the service-competition intensity at that location, Vj, measured by its population potential. β is a travel distance friction coefficient.

2.4 Limitations of Existing Accessibility Measures to Evaluate Accessibility for PWDs

Relative accessibility measures the impedance faced by PWDs due to the presence of stairs and other obstacles. The best way to calculate relative accessibility will be to observe PWDs and physically fit persons traveling between two points and determine travel distance or cost or time. This is nevertheless time-consuming. Using self-reported data of travel time or travel distance by PWDs can be an alternative approach but cannot be always reliable (Brenner & DeLamater, 2016; Rosenmen, Tennekoon, & Hill, 2011). In addition, this index is not comprehensive enough to evaluate the accessibility of PWDs as a whole. This index does not consider certain aspects of accessibility such as convenience in using elevators or ramps or entrance gate. Accessibility of ramps can be measured based on the deviation of slope from the standard value of slope amount of space lacking to ensure enough space for maneuvering. Similarly, accessibility of the entrance gate can be measured based on the deviation of its width, the width of the unobstructed wall, from the required width to ensure universal accessibility. An elevator must have a standard width to ensure universal accessibility and its deviation from the standard value of the width of the elevator can be used to evaluate the accessibility of elevators. Characteristics of the floor is a qualitative parameter, so the accessibility of floor material can be determined based on the perceived value of accessibility provided by PWDs. The value of relative accessibility (ratio), accessibility of slope, and an elevator (percentage of deviation), floor material (ordinal) will be in a different unit. The values of these parameters need be normalized and be combined to evaluate the accessibility of PWDs in a comprehensive manner (Advi, 2010; Patro & Sahu, 2015).

Generally, a physically fit person will follow the shortest path whereas it might not be possible for persons with disability to follow the shortest path because of hindrance like stairs, undulated or cracked floor surfaces (Church & Mattson, 2002; Tauhid, 2007). Shimbel

Index, Potential Accessibility Index, and Geographic Accessibility index uses the shortest path between nodes to calculate accessibility. It does not however give any special consideration to which might be the shortest path for PWDs. These indexes might be modified by gathering information on the perceived level of accessibility of different roads connecting two nodes in a network and identifying the roads with the lowest level of impedance as the alternative shortest path. Then using the length of different links of the actual shortest path for PWDs in the connectivity matrix to calculate accessibility.

Contour based measures, Coverage area-based measures, PedShed, and Households within PedShed consider a threshold value of travel time or travel distance considering equal speed of individuals. But, the walking speed of PWDs are likely to be slower in comparison to physically fit persons. The threshold value of travel distance will be smaller for PWDs for a given period. Except coverage based measures, the other three indices consider travel distance along the road network to create service area. The perceived physical impedance of PWDs to walk over different segments and how it will negatively impact travel speed and distance of PWDs should be considered while determining service area for Contour based measures, PedShed, and Households within PedShed. On the contrary, the catchment area for Coverage Area-based Accessibility Measures is likely to be smaller as PWDs will not be able to walk the equal distance of physically fit person in a fixed time. The best way to determine catchment for PWDs will be to calculate their walking speed through physical surveys and multiply the walking speed with a given time to determine the catchment area. But, this approach can be physically demanding for PWDs as well as time-consuming.Self-reported travel speed can be used as a proxy.

Likewise, 2SFCA and Gravity Based Accessibility Measures assume equal accessibility for everyone. PWDs would need more time to travel the same distance compared to a physically fit person. For this, either the threshold of travel time will have to be increased or the threshold of travel distance will need to be decreased while applying 2SFCA and Gravity based Accessibility Measure for PWDs. Lou and Wang (2003) revealed in their study that travel distance friction of distance decay function is sensitive to travel time or travel distance threshold. So, the value of travel distance friction is likely to fluctuate if travel time or travel distance threshold is changed in Gravity Based Accessibility Measures(Luo & Wang, 2003). The concept of distance decay can be merged with distance function by using the value of relative accessibility multiplied by threshold travel distance or time instead of only threshold value of travel distance or travel time. Relative accessibility will integrate the impact of physical impedance on accessibility of PWDs in Gravity Based Accessibility Measure.

If the perceived threshold value for PWDs is d_{pij} ; then,

$$r = \frac{d_{pij}}{d_{ij}}$$

so, $d_{ij} = r\, d_{pij}$

Then formula of Gravity based Accessibility Index in equation (b) can be modified as follow using relative accessibility index "r" :

$$A_i^G = \sum_{j=1}^{n} \frac{S\,(d_{ij})^{-\beta}}{V_j}$$

$$A_i^G = \sum_{j=1}^{n} \frac{S\,(rd_{pij})^{-\beta}}{V_j}$$

where $V_j = \sum_{k=1}^{m} P_k\ (rd_{pkj})^{-\beta}$

Likewise, Link to Node Ratio (LNR) assumes equal accessibility for each link in a road network for all persons. However, in a link with the poor surface condition, accessibility of PWDs cannot be equal to physically fit persons. Perception of PWDs about physical impedance can be measured in ordinal scale (e.g. high impedance, moderate impedance, low impedance as 3,2,1) and used as a value of impedance. As physical impedance reduces the level of accessibility, LNR can be divided by ordinal physical impedance value to determine modified LNR for PWDs to reveal how the physical impedance of link is retarding accessibility of PWDs. If B_d represents LNR for PWDs and i is the impedance value in ordinal scale, LNR can be modified to determine the accessibility of PWDs in the following ways:

$$\beta_d = \frac{L}{iN}$$

Alternatively, integrating the physical impedance value of links ratio can be integrated with Link to Node through dividing LNR by relative accessibility value.Relative Accessibility is the ratio of accessibility of PWDs and physically fit persons and an indication of impedance. If r is the relative accessibility value, substituting impedance with relative accessibility i=r and β_d will be as follows.

$$\beta_d = \frac{L}{rN}$$

For analyzing the accessibility of PWDs using relative accessibility will require data of travel distance or time for both PWDs and physically fit persons. It is data intensive and will require significant amounts of time and financial resources to collect data. On the contrary, (self-reported) physical impedance is less data-intensive as it requires the collection of data from PWDs only. This formula is particularly useful to evaluate accessibility when the researcher has time and financial constraints.

It has been found that except for Relative Accessibility Measure, the other considered accessibility measures assume equal mobility of all individuals and ignore the impact of mobility constraints on accessibility of PWDs. The major limitation that has been found in most of the considered accessibility measures is the use of the same threshold value of travel time or distance assuming PWDs have the same walking speed as physically fit persons. The measures which are based on the shortest distance do not take into account the fact that the shortest path for a PWD can be different than that of a physically fit person because of the existing physical impedances on the shortest path. Although Relative Accessibility Measure attempts to determine the accessibility condition for PWDs, it is not comprehensive enough as it does not consider accessibility of ramps, elevators, floor surface of circulation space. In Table1, we provide detailed limitations and possible approaches to modify these measures to better measure accessibility for PWDs. Table 2.1 suggests some possible approaches of number of existing accessibility measures.

Table 2.1: Limitations and possible approach of modification of accessibility measures

Accessibility Measure	Limitations to evaluate accessibility of persons with disability	Possible approach to modify the accessibility measures
Relative Accessibility	Not comprehensive to include accessibility of PWDs to elevators, entrance gate, circulation floor, ramps	Measure deviation of standard dimensions of universal accessibility for relevant features of ramps, elevators, entrance gate etc. Measure the accessibility of the floor surface for PWD based on their perceived accessibility
Contour measures, Pedshed, Households within PedShed	Does not differentiate of travel time/ distance/speed between PWDs and physically fit persons. Considers the service area for PWDs and physically fit persons will be identical in a given time, ignoring mobility issues related impedance faced by PWDs	Consider the impact of physical impedance faced by PWDs to restrain their service area in terms of travel distance

Accessibility Measure	Limitations to evaluate accessibility of persons with disability	Possible approach to modify the accessibility measures
Coverage Area based measures	Does not differentiate walking speeds between PWDs and physically fit persons	Determine walking speed of PWDs through physical surveys or the use of perceived travel distance
2SFCA Method, Gravity Based Accessibility Measures	Consider the same threshold of travel distance for everyone during a given time	Use perceived travel distance to determine the threshold of travel distance Integrate Relative Accessibility with distance decay function of 2SFCA and Gravity Based Accessibility measures.
Link to Node ratio (LNR)	Considers each link of road of network is equally accessibility for everyone	Consider perceived impedance for each link or integrate LNR with Relative Accessibility

2.4 Risk and Risk Perception

Risk (or more specifically, disaster risk) is the potential losses in terms of lives, health livelihoods, status, assets, and services which could occur to a particular community or society or region over some specified period in the future in the advent of a disaster. The probability of harmful consequences, or expected losses: deaths, injuries, property loss, disruption to livelihood or economic activity getting disrupted or environmental damage resulting from interactions between natural or human-induced hazards and vulnerable conditions are considered as Risk in disaster management (United Nations Office for Disaster Risk Reduction (UNDRR), 2015).

Risk perception implies how people perceive their level of risk to a disaster. Risk perception is pivotal to identify how people will respond to hazards and to determine whether hazards turn into disasters with a catastrophic effect on communities. Understanding how people perceive risk in the context of natural hazards is significant to ameliorate risk communication activities and disaster preparedness. (Karanchi, Kalaycıoğlu, Erkan, & Doğulu, 2020).

2.4.1 Socio-demographic Factors, Socioeconomic Factors and Risk Perception

The effect of socio-economic and socio-demographic factors on disaster risk perception has been explored in a number of studies. Age, gender, household structure, level of education, household income has been found to influence the risk perception of people.

Age is an important demographic factor influencing the perception of natural hazards positively (Grothman & Ruesswig, 2006; Shao, Keim, Xian, & O'Connor, 2019; Tian, Yao, & Jiang, 2009). Armas (2006) studied the risk perception of inhabitants of regions with high earthquake risk in Bucharest and suggested that elderly people are more fearful about earthquakes. Tian, Yao, & Jiang (2009) explored the risk perception of the people of China and found that elderly people are more aware of earthquake risk. Fear of elderly people of the earthquake can be ascribed to their higher level of vulnerability to it (Armas, 2006). On the contrary, Boltzen and Bergh (2009) found that risk aversion decreases with age. Edward (2010) tried to explain the positive relationship between age and risk aversion in terms of portfolio risk aversion theory. Edward (2010) explained that people become less aware of the risk as they age and shift to safer places or houses to live in after retirement or when they are close to retirement (Botzen & Bergh, 2009; Edward, 2010). Gender is another important factor influencing the risk perception of people (Armas, 2006). In general, women demonstrate a higher risk perception(Grothman & Ruesswig, 2006; Plapp, 2001; Shao et al., 2019). Kung and Chen (2012) studied the earthquake risk perception of the people living in Taiwan. The study of Kung and Chen (2012) also revealed that female may tend to have a higher sense of life threat caused by an earthquake or worry about reoccurrence of an earthquake (Khan, Qureshi, Rana, & Maqsoom, 2019; Kung & Chen, 2012).

The level of education and income has been found linked with risk perception in several studies (Armas, 2006; Kung & Chen, 2012; Tian et al., 2009). High-income people are sanguine that their lives and properties are less vulnerable to earthquakes. On the other hand, people with higher levels of education are less concerned about earthquake risk(Armas, 2006; Tian et al., 2009). A potential explanation for this may be that people with higher education or income may have better mitigation ability as well as preparedness to withstand earthquakes. For this, they might feel a higher degree of control over a disaster(S. S. Shen, 2006).

The household structure has been found to have nexus with risk perception (Tian et al., 2009). Tian, Yao, and Jiang (2009) found that risk perception will decrease as the building condition improves. Risk perception is significantly reduced when people move into a brick concrete structure house that is made up of rubble foundation, brick wall, and concrete beam from a house with a poor structural foundation. People living in buildings with a strong foundation felt safer to withstand a disaster which negatively impacts their risk perception.

2.4.2 Risk Perception and Previous Experience of a Disaster

Literature reveals that the role of previous experience on risk perception in the face of natural hazards is positive. Experiencing a disaster makes people aware of vulnerabilities to disasters and increase their perception of risk(Bronfman, Cisternas, Repetto, Castaneda, & Guic, 2020; Kung & Chen, 2012; Terpstra, 2011; Wachinger, Renn, Begg, & Kuhlicke, 2012). However, the characteristics and frequency of the event and the experience of the people of the disaster greatly influence risk perception. Some researchers suggest that if the consequences of the events are not significant, it does not influence risk perception (Burningham, Fielding, & Thrush, 2008; Hung, Shaw, & Kobayashi, 2007). According to

Bubeck, Boltzen, and Aerts (2012), severity and negative consequence of disaster positively affect risk perception (Bubeck, Botzen, & Aerts, 2012). The time elapsed after experiencing a disaster can also affect the relationship between experience and risk perception. Earlier research suggests that the influence of past experience fades away few years after the occurrence of the event, especially if the negative consequences of the past disaster are meager (Bubeck et al., 2012; Burningham et al., 2008). Wachinger et al (2012) argued that direct experience with a disaster leads to higher risk perception. Direct experience can be physically experiencing the disaster, suffering physical damage or loss of property (Becker, Patonb, Johnstona, Ronand, & McClure, 2017). Becker et al (2017) investigated the nexus between the previous experience of earthquake and risk perception of people of Napier, Timaru, and Wanganui of New Zealand and concluded that direct experience is the one that influences risk perception most. A more robust and vivid experience of a disaster allows people to better realize the possible devasting impacts of a future disaster (Becker et al., 2017).

2.4.3 Risk Perception and Participation in Awareness-raising activities

Disaster preparedness is of paramount importance in the context of disaster management as it assists to reduce the loss of life and assets in the wake of the disaster. Risk perception has been linked with disaster preparedness in a number of studies. If people have a high level of risk perception, they will be more aware in taking mitigation or adaptation measure to withstand measure (Becker et al., 2017; Cerase, Crescimbene, Longa, & Amato, 2019; Miceli & Settanni, 2006; Paton et al., 2016; Wachinger et al., 2012). Awareness of people about their vulnerability to the disaster has been pivotal to assist people to perceive disaster risk.

Literature reveals that awareness about disaster risk can be raised by organizing disaster awareness activities. These awareness-raising activities can include training programs, workshops (Mañez, Carmona, Haro, & Hanger, n.d.). The awareness-raising programs aim to develop risk perception of people by informing them about their vulnerability to disasters and sources of vulnerability. It is very common to organize training programs and workshops to inform how to evacuate safely at the advent of a disaster, which route to follow to go take shelters, and where are the locations of safe shelters. Informing people about the safe shelters and evacuation route is very important for the evacuation of community people at the time of occurrence of rapid on-set disasters like earthquakes, tornadoes so that people can immediately seek refuge in safe places without getting harm. Along with that, it is very common in many countries to organize training programs at the community level to educate them on what they will have to do on a priority basis to be safe during an emergency. In case of earthquake training, people should be informed of what to do at the advent of an earthquake depending on their location (in-home/outside/ in-car) with practical demonstration and active participation of community people. Earthquake training and workshops organized by the Community Emergency Response Team (CERT) of USA, National Society for Earthquake Technology (NSET) of Nepal, Philippine National Red Cross (PNRS), Jisyobo and Jichikai of Japan can be the ideal examples of community-based disaster preparedness and awareness-raising programs. (Community Emergency Response Team, 2019; National Society for Earthquake Technology NSET, 2012a, 2012b; Phillipine National Red Cross PNRC, 2019; Shaw, Ishiwatari, & Arnold, n.d.).

Along with workshops and training programs, mass media and social networks can play an important role to develop risk perception. According to Xu et al (2020) media exposure has several functions in the formation of disaster risk perception, for example, communicating information before, during, and after the disaster; encouraging people to learn disaster knowledge and skills and establishing public responsibility and safety culture. People are likely to know about the occurrence of a disaster and devastation caused by it from newspapers, television (Xu, Zhuang, Deng, Qing, & Yong, 2020). Besides, Facebook posts and tweets from friends, family members, relatives can also help to get informed about the occurrence of a disaster and make people aware of the vulnerability. Lambert (2020) investigated a Facebook discussion group for earthquake risk communication in Alaska, USA, comparing patterns of use during periods of low magnitude activity and during the January 2018 M7.9 Gulf of Alaska earthquake. Findings illuminate the roles the group plays for different users, with public members and staff using it for both informational and social/emotional reasons, such as seeking/providing reassurance, building trust. Lambert (2020) found that key functions vary throughout the earthquake cycle, with a focus on building relationships and two-way communication during the intervention period and on controlling quality and accessibility after the major events. This study provided practical insights for organizations using social media for risk communication (Lambert, 2020). Similarly, Twitter, Instagram can be a great source of information observations and experiences posted by users about earthquakes, floods, cyclones (Hernandez-Suarez et al., 2019). Besides, there are many documents, blogs, search engines, and statistical data available on the internet that can provide information to people to perceive disaster risk(Earthquake Track n.d.; Pacific Northwest Seismic Network n.d).

2.5 Conclusion

This chapter has undergone a comprehensive review of literatures pertaining to study topic. Literature review of accessibility measures is found helpful to determine an accessibility index to be used for evaluating the accessibility of movement-challenged persons to evacuation routes. The literatures on risk perception has been helpful to find variables influencing earthquake risk perception and design a questionnaire for this research incorporating those variables.

3. THE METHODOLOGY OF THE STUDY

This chapter will describe the methodology of the study. This chapter will describe the selection procedure of movement challenged persons, justification of the study area, data collection and data analysis process.

3.1 Selection of Movement Challenged Persons

Movement Challenged Persons (MCPs) have been selected as the target group of the study. In this study, people with physical disabilities who need support from others or equipment such as wheelchairs, crutches, for their movement due to impairment in legs are considered as Movement Challenged Persons (Asia-Pacific Development Center on Disability (APCD) and South Asian Disability Forum (SADF), 2013). Persons who are facing mobility challenges for more than one year are considered as objects for the study.

Although there are statistics about physically disabled persons living in Dhaka, there are no specific statistics for MCPs. For this, the total size of the population is determined as unknown. It is required to survey 384 MCPs at a 95% confidence interval and a 5% significant level (Qualtrics, 2019). Following this rule, a total number of 455 MCPs are surveyed.

3.2 The Study Area

Dhaka, the capital city of Bangladesh is selected as the study area. The total number of physically disabled persons in Dhaka is 221258, which is higher than in other cities of Bangladesh (Bangladesh Bureau of Statistic, November 2015).

Dhaka is highly vulnerable to earthquakes and other seismic hazards because of its proximity of 60 kilometers to the Madhupur fault line. Micro-seismicity data supports the existence of at least four earthquake source points in and around Dhaka. Dhaka is one of the five cities of South Asia which are at a very high risk of earthquakes (Comprehensive Disaster Management Programme (CDMP), 2009a). Along with that, unplanned development, poor building structures, high population density, a lack of awareness among people regarding response and recovery processes make people of Dhaka more vulnerable to earthquakes (Asian Disaster Preparedness Centre (ADPC), 2005; Comprehensive Disaster Management Programme (CDMP), 2009b; Sameen & Razzaque, 2016).

Worse still, persons with disabilities including MCPs in Dhaka suffer from not having adequate access to features of the built environment greatly due to poor accessibility conditions in buildings (Abir & Haque, 2011; Bhuiya, 2018; Tauhid, 2007) (Fig 3.1 and 3.2). Dhaka has poor accessibility for MCPs in comparison to cities in the U.S.(Bhuiya, 2018; Okhlahama Ramp Project, n.d.; Owens, 2019; Tauhid, 2007). Considering the existence of a significant number of persons with physical disabilities, poor accessibility conditions for MCPs and the high earthquake risk of Dhaka city, this city is selected as the study area to evaluate the accessibility of MCPs to critical features. Methods developed by and insights are drawn from this study can be used for other cities vulnerable to natural disasters in the world.

Fig 3.1: Poor condition of footpaths of Dhaka City

Fig 3.2: Poor condition of footpaths of Dhaka City

Ward is the finest administrative unit in Bangladesh (Bangladesh Bureau of Statistics (BBS), 2011). In the Comprehensive Disaster Management Project (CDPM), the evacuation paths have been determined for the number of wards of Dhaka. The author has access to evacuation routes of 13 wards of Dhaka. These wards are selected in the study and MCPs living in these wards are considered as the target group for the study (Comprehensive Disaster Management Plan, 2014). Among the selected wards, eight are from Dhaka North City Corporation (DNCC) and five are from Dhaka South City Corporation (DSCC). The following wards have been selected for the research:

- DNCC Ward 01
- DNCC Ward 02
- DNCC Ward 11
- DNCC Ward 12
- DNCC Ward 20

- DNCC Ward 29
- DNCC Ward 31
- DNCC Ward 32
- DSCC Ward 04
- DSCC Ward 15
- DSCC Ward 32
- DSCC Ward 45
- DSCC Ward 51

Henceforth, these wards are referred to by their city corporation names and ward number and the word “ward” is omitted(For example DNCC 01).

3.3 Data Collection

Questionnaire Survey and Participatory GIS Approach: The questionnaire survey is conducted at the orthopedic departments of selected hospitals or rehabilitation centers after securing permission from hospital authorities. Information on perceived impedance with respect to road characteristics of the evacuation path of temporary shelters of the ward where MCPs are living is collected through a participatory GIS approach at the time of conducting the questionnaire survey. Data on perceived impedance is integrated into GIS Shapefile created for Detail Area Plan (DAP) (Rajdhani Unnayan Kartipakkha(RAJUK), 2016). The MCPs are asked which roads in the network they choose to reach the evacuation route from home, i.e. egress route to evacuation route, and which roads in the network they choose to arrive at temporary shelters from the evacuation route, i.e. access routes from evacuation route. Subsequently, they are asked to provide scores of perceived impedance and accessibility for the connecting links. Egress route, the evacuation route, and access route are combinedly referred a as evacuation network for an MCP. For example, a link connects land use A and land use B. MCPs are asked how much impedance will they face crossing the link connecting land use A and B. During the participatory GIS activity, google earth and google map are used as assistance tools. The GIS shapefile of the evacuation route is converted into KML and exported to google earth so that the evacuation route can easily be identified in Google Earth. Using Google Street View, survey respondents are shown the condition of the surface of links to evacuation routes and evacuation routes themselves. The surveyed MCPs are asked to rank physical impedance of evacuation routes and connecting paths on a scale of 1-5. Based on the rank provided by MCPs, the impedance values of each link are stored in the GIS shapefile of the evacuation route.

While conducting the survey, MCPs are asked to rank the accessibility based on physical impedance they face while walking/moving over the floor surface i.e circulation space of their residential buildings (space connecting the entrance gate of apartments of MCPs and the entrance of residential buildings) and crossing the entrance gates. accessibility of circular space and entrance of residence are not calculated using any accessibility measures. So, MCPs are asked to report their perceived accessibility directly for circular space i.e floor surface and entrance gate on an ordinal scale directly (as per Table 3.1). This study aims to integrate physical impedance with current an accessibility measure to determine the accessibility of evacuation routes. So, MCPs are asked to mention the level of impedance as per Table 3.2, they face to cross a link that is integrated with an existing accessibility index (Table 3.2). As there is a possibility of MCPs not visiting the temporary shelter before, they might not have experience of using the entrance gate of the temporary shelter. For these MCPs, they are not asked about their perception of physical impedance or accessibility condition of the entrance gate in the shelter.

Table 3.1: Likert Scale for perceived accessibility

1	2	3	4	5
Very poor accessibility	Poor accessibility	Moderate accessibility	Good Accessibility	Very Good Accessibility

Table 3.2: Likert Scale for perceived impedance

1	2	3	4	5
Very Low impedance	Low impedance	Moderate impedance	High Impedance	Very High Impedance

Physical Feature Survey: Physical features survey is conducted at temporary shelters to create an inventory of accessibility situation of entrance gates of temporary shelters that are directly accessible through the evacuation route. It is checked whether the entrance gates of the temporary shelters is constructed by following rules of universal accessibility of Bangladesh Building Construction Rules (BCR) 2008. As there is no standard in the BCR about the surface condition of a facility, the surface condition of temporary shelters is not considered as an accessibility parameter when conducting the physical survey. Table 3.3 shows the features that are considered as part of the inventory-based guidelines of BCR. While conducting the physical survey, the ruler is used to measure relevant parameters. A check list is produced to take on whether the conditions provided in Table 3.3 is fulfilled by entrance gate of a critical facility.

Development of Accessibility Index for Movement Challenged Persons: An extensive literature review is conducted on the current research on the accessibility index. Current accessibility indices are critically reviewed to identify their strengths and weaknesses. Based on the literature review, the weakness of the existing indices are addressed by integrate perceived impedance faced by MCPs into the objective measures. Data collected on perceived impedance faced by MCPs to move along evacuation routes are used to develop the index.

Based on the literature review, the Link to Node ratio (LNR) is identified as a suitable index which can be modified to determine the accessibility of MCPs to evacuation routes incorporating physical impedance value. The Link to Node ratio is determined by dividing the total number of links in a network by the total number of nodes using ArcGIS software (Tal & Handy, 2011).

LNR=L/N

Where L=Number of links in a network; N=No of Nodes in a network

The reason of selecting LNR is that it reflects the level of connectivity of a road network. Connectivity of evacuation routes is important for earthquake evacuation. A road is likely completely blocked at the time of an earthquake due to the collapse of buildings. If the road network is more connected with multiple routes, people will have more options to select an alternate route to go to a safe location if one link of the evacuation route is blocked.

Table 3.3: Features of Universal Accessibility based on BCR 2008

Feature	Universally Accessibility	Not Universally Accessible
Width of the entrance gate	>=800 mm	<=800 mm
Turnstile door	No	Yes
Height of Lockset from ground	800-900 mm	>900 mm or <800 mm

Feature	Universally Accessibility	Not Universally Accessible
Maneuvering Space without obstruction on the side road when you are pushed from outside	1200mmx1200mm	less 1200 mm on both sides
Length of the unobstructed wall on the side road when you are pushed from outside	>=300 mm	<300 mm
Maneuvering Space without obstruction on the side road when you are pushed from inside	1500 mm x 1500 mm	less 1500 mm on both sides
Length of the unobstructed wall on the side road when you are pushed from inside	>=600 mm	<600 mm

In order to integrate perceived physical impedance value with LNR, LNR will be divided by impedance value given by MCPs based on their perceptions of the accessibility condition of the links of the evacuation network. The average physical impedance value for the evacuation network will be calculated by dividing the summation of impedance for the evacuation network by the total number of links. LNR will be divided by the average physical impedance value given by MCP and modified LNR (MLNR) will be determined for each surveyed from the ward and MLNR from each responded will be averaged to determine the accessibility of the evacuation network for that ward.

$I_k=(\sum_{x=1}^{L} i_{xk})\ /L$ ……………………………………………………………….(1)

Modified LNR (MLNR) for an MCP $MLNR_k=L/\ (NI_k)$ …….……………………….(2)

MLNR for the ward= $(\sum_{k=1}^{N} MLNR_k)/P$ ……..…………………………………….(3)

Where i_{xk} is the perceived accessibility of a particular link of the network by a particular responded living in a particular ward, x indicates a particular link of the network of the ward, k indicates a particular respondent living in the ward, L is the total number of links in the network of the ward, I_k is the average of physical impedance for the network of the ward for a particular respondent living in the ward, N is the total number of nodes in the network of the ward, P is the total number of samples from the particular ward.

3.4 Data Analysis

Accessibility of MCPs During Evacuation : Before standardizing the universal accessibility condition of the entrance gates of temporary shelters, it is identified how many criteria of universal accessibility are fulfilled by entrance gates of temporary shelters and the number of fulfilled criteria will be converted in percentage. This process is carried for the entrance gates of all temporary shelters accessible via the evacuation route of the ward. Then this percentage value of all entrance gates will be averaged to determine the overall condition of universal accessibility for a ward To illustrate, a ward (DSCC 52) has two temporary shelters accessible through evacuation routes.If the entrance gate of one temporary shelter meets 2 out 7 criteria, it is determined that the universal accessibility of this shelter is 28.5% (0.2857). The other temporary shelter meets 1 out 7 criteria. It is thus determined that the universal accessibility of this shelter is 14.14%(0.1414). The average value of universal accessibility of critical facilities for this ward is therefore 0.2142.

Accessibility of surface and entrance gate of each residential buildings where MCPs live measured on a scale of from 1-5. The average values for accessibility of surfaces and entrance gates of residential buildings are determined and assigned as the value for overall accessibility surface and entrance gate of the ward.

The values of different accessibility indicators are standardized using z score

$$Z=(X-X_{avg})/SD \quad (4)$$

In equation (4), X represents the value of an indicator for the ward, X_{avg} represents the average of that particular indicator for all considered wards and SD is the standard deviation of that particular indicator for all considered wards.

All these four z values are added to determine the composite accessibility index. This approach to determine the overall accessibility is based on the consideration that MCPs have to cross the circulation space of the residence, followed by the entrance gate of the residential building, then get on the evacuation route, and finally reach the entrance gate of the temporary shelter. As there is no theoretical consideration of which feature should be assigned heavier weight, the accessibility of each feature is considered equally important when computing the overall accessibility index.

$$Ac=Z_{AE}+Z_{CR}+Z_{GR}+Z_{GS}$$

In the above equation, Ac= Value of Overall Accessibility

Z_{AE}=Standardized Modified LNR i.e. accessibility of evacuation route

Z_{CR} =Standardized Accessibility of Circulation space of Residence

Z_{GR}= Standardized Accessibility of Entrance Gate of Residence

Z_{GS}= Standardized Universal Accessibility of Entrance gate of temporary Shelter

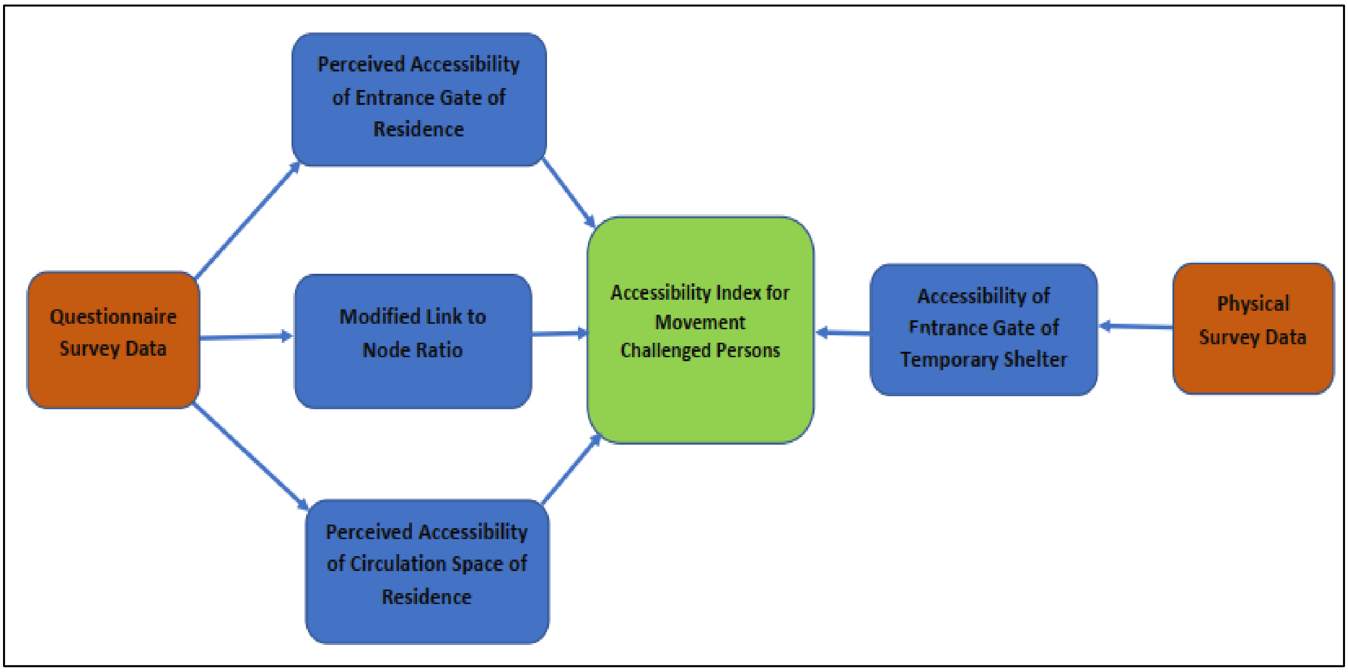


Fig 3.3: Components of accessibility measurement

Risk Perception of MCPs: Drawing from the existing literature, the analysis of risk perceptions of earthquakes among MCPs specifically examine the effects of multiple factors on risk perceptions of earthquakes. These factors consist of several clusters including socio-economic background, prior experience with earthquakes or ground shaking, perceived social vulnerability to earthquake, knowledge about earthquake training programs. Depending on the nature of the dependent variable, binary, logistic regression, ordinal logistic regression, multi-nominal regression are applied to explain variations of risk perceptions of MCPs.

Respondents are asked to rank perceived possibility of earthquake, perceived fear of earthquake, perceived potential damage to property, perceived potential threat to earthquake, impact of last experienced earthquake / ground shaking on a scale of 1-5 where 1 stands for lowest intensity and 5 stands for highest intensity. Before developing the statistic models, the nominal variables is coded in ordinal scale. Table 3.4. provides details of conversion of nominal variables into ordinal scale. The severity of disability depends on the incapability of the MCPs to transfer the load to the lower limbs. The wheelchair should be used by the person who can put minimum weight on lower limbs and is unable to use leg(s) to walk.

Walking sticks (Canes) are suggested to be used by MCPs whose lower limbs can hold some amounts of weight and are less dependent on movement supporting instruments compared to those using wheelchairs. Walking frame and crutches are recommended to MCPs who can use their lower limbs to walk but hold smaller amounts of weight compared to those using canes. Their dependency on movement supporting instruments is thus between wheelchair and cane users(Bradley & Hernandez, 2011; Cunha, 2020). Three dichotomous variables are considered: previous experience of the earthquake (Yes/ No), participation in earthquake training (Yes/No) and gender (Male/Female). The structure type is coded based on the existence of column, construction material, soft storied characteristics of the residential building. Age, education (years of schooling), income are also converted into ordinal scale.

Table 3.4: Coding of nominal variables into ordinal variables

Variable	Coding
Supporting Instrument	1= Walking stick/cane
	2= Walking frame / crutch
	3 = Wheelchair
Gender	0= Female
	1=Male
Age	1=0-20 years
	2=20-30 years
	3= 30-40 years
	4= 40 -50 years
	5= greater than 50 years
Education	1=Below secondary school (less than 10 years schooling)
	2= Secondary School Certificate (10 years schooling)
	3= Higher Secondary School Certificate (12 years schooling)

Variable	Coding
	4= Bachelor(16 years of schooling)
	5= Masters or above (more than 16 years of schooling)
Income	1=less than 10000 Taka
	2= 10000 – 20000 Taka
	3= 20000- 30000 Taka
	4= 30000 – 40000 Taka
	5 = 40000-50000 Taka
	6=greater than 500000 Taka
Structure	1= Tinshed two storied buildings without columns
	2= Tinshed two storied building with column
	3= Brick walls; concrete beams; concrete columns, soft storied
	4= Brick walls; concrete beams; concrete columns, not soft storied
Previous experience of earthquake	0=No
	1= Yes
Impact of last Earthquake experienced	0= No impact
	1= Very low
	2= Low
	3=Moderate
	4= Severe
	5=Extremely severe
Time gap from last earthquake experienced	1= within 1 year
	2= 2-3 years
	3= 4-5 years
	4=6-7 years
	5=more than 7 years

Variable	Coding
	6=Never
Earlier participation in earthquake training	0=No 1=Yes
Time gap from last participation in earthquake training	1= within 1 year 2= 2-3 years 3= 4-5 years 4=6-7 years 5=more than 7 years 6=Never

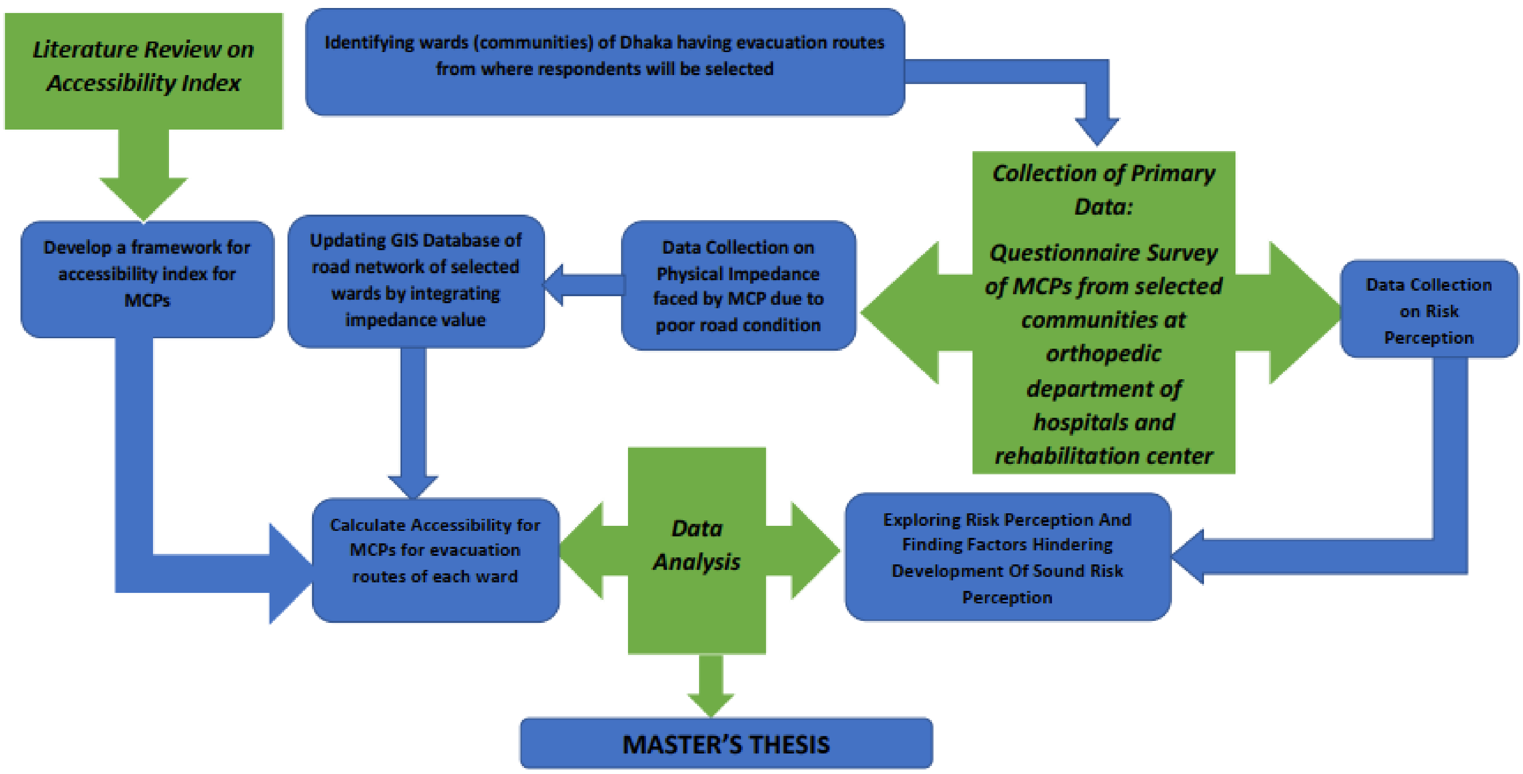


Fig 3.4: Framework of the study

4. ACCESSIBILITY OF MOVEMENT CHALLENGED PERSON FOR EARTHQUAKE EVACUATION

This chapter is focused on the assessment of accessibility of mobility challenged persons(MCPs) to the evacuation network. According to the proposed methodology in Chapter 3, the accessibility of MCPs to the evacuation network is calculated for each ward. Along with determining the accessibility of the evacuation network, accessibility of MCPs to the floor surface of their residence and entrance gate, as well as entrance gate of temporary shelter, have been considered to evaluate accessibility situation of MCPs. The relation of the accessibility of MCPs with socioeconomic factors is also explored in this chapter.

Modified Link to Node Ratio (MLNR) is used to determine the accessibility of evacuation network. The evacuation network connects the residence of MCPs and temporary shelters. MCPs must be able to cross connecting space between the evacuation network and their homes and entrance gates conveniently to reach the starting point of evacuation network. MCPs must be able to cross the entrance gate conveniently to overcome their disabilities to reach the temporary shelter. Otherwise, despite having good accessibility of evacuation network it is difficult for MCPs to reach the temporary shelter with hard to enter gates. For this, along with accessibility of the evacuation network, the floor surfaces and the entrances of residence buildings of MCPs and the entrance gates of critical facilities have been considered to evaluate the accessibility of MCPs to the evacuation network comprehensively.

4.1 Accessibility of the Evacuation Network

Table 4.1 reveals the accessibility of evacuation network based on Modified Link to Node Ratio (MLNR). It can be interpreted that five wards have higher value of accessibility (greater than 0.0035) of evacuation network and these wards are DNCC 02, DNCC 11, DNCC 29, DSCC 45, DSCC 51. DNCC 01, DNCC 20, DSCC 32 have a relatively lower level of accessibility (less than 0.0023) than other wards. Among the considered wards, DNCC 29 has the highest value of MLNR and DNCC 01 has the lowest value of MLNR. Among the wards in the DNCC, DNCC 29 has the highest value of MLNR and DNCC 01 has the lowest value of MLNR while among the wards in the DSCC, DSCC 32 has the lowest value of MLNR and DSCC 45 has the highest value of MLNR. The z value of MLNR reveals that six wards (46.51%): DNCC 01, DNCC 20, DNCC 31,DSCC 04, DSCC 15, DSCC 32 have MLNR greater than average and other seven wards (53.49%) have MLNR greater than average. Fig 4.1 shows the map of the accessibility of evacuation network of wards.

Table 4.1: Accessibility of evacuation network

Ward	MLNR	Z value
DNCC 01	0.00193	-1.71982771
DNCC 02	0.00387	1.064844533
DNCC 11	0.00398	1.22273832
DNCC 12	0.00325	0.174897733
DNCC 20	0.00226	-1.238969359
DNCC 29	0.00391	1.122260455
DNCC 31	0.00295	-0.255721686
DNCC 32	0.00333	0.246667636
DSCC 04	0.00248	-0.930358776
DSCC 15	0.00299	-0.186822579
DSCC 32	0.00219	-1.346624214
DSCC 45	0.00387	1.069150727

Ward	MLNR	Z value
DSCC 51	0.00367	0.77776492
Average	0.00312	
Standard Deviation	0.00069	

4.2 Accessibility of the Circulation Space of Residence

Table 4.2 reveals the average perceived accessibility of the indoor surface of the residence of MCPs. Among the considered wards, 4 wards have indoor surface accessibility below 2 and these wards have poor accessibility of indoor surface. On the other hand, 9 wards have indoor surface accessibility between 2 and 3and these wards have a moderate level of accessibility of indoor surface. It is noticeable that there is no ward that has perceived accessibility greater than 3, implying that there is no ward with good perceived accessibility of indoor surface. It has been found that 7 wards including DNCC 01, DNCC 02, DNCC 11, DNCC 12, DNCC 20, DNCC 29, DNCC 31 have negative z value and 6 wards including DNCC 32, DSCC 04, DSCC 15, DSCC 32, DSCC 45, DSCC 51 have positive z value. The wards with negative z values have relatively poor perceived accessibility of indoor surface and the wards with positive z values have better conditions in terms of perceived accessibility of indoor surface.

Among 13 wards, DSCC 51 has the highest perceived accessibility of indoor surface and DNCC 01 has the lowest perceived accessibility of indoor surface. The overall average perceived accessibility of indoor surface is 2.19 (which is a little greater than 2, the threshold of poor accessibility) and indicates that the study area generally does not have good accessibility of indoor surface of the residence. Fig 4.2 shows the map of the accessibility of indoor circulation surface of MCPs' residency for considered wards.

Table 4.2: Average perceived accessibility of indoor surface of residence of MCPs

Ward	Average perceived accessibility of indoor surface	z value
DNCC 01	1.63	-1.589
DNCC 02	1.91	-0.779
DNCC 11	1.74	-1.265
DNCC 12	2.03	-0.455
DNCC 20	1.97	-0.617
DNCC 29	2.00	-0.536
DNCC 31	2.11	-0.212
DNCC 32	2.23	0.112
DSCC 04	2.74	1.570
DSCC 15	2.66	1.327
DSCC 32	2.57	1.084
DSCC 45	2.40	0.598
DSCC 51	2.46	0.760
Average	2.19	
Standard Deviation	0.352742	

4.3 Accessibility of the Entrance Gate of the Residence

Table 4.3 reveals the average perceived accessibility of the entrance gate of the building of residence of MCPs for different wards. Among the considered wards, 5 wards have the accessibility of entrance gate of the residential building below 2 and these wards have poor accessibility of entrance gate of the residential building. On the other hand, 8 wards have the accessibility of entrance gate between 2and 3 and these wards have a moderate level of accessibility. It is noticeable that there is no ward that has perceived accessibility greater than 3, implying that there is no ward with good perceived accessibility of entrance gate. It has been found that 7 wards: DNCC 01,DNCC 02, DNCC 11, DNCC 20, DNCC 29,DNCC 32 have negative z value and 6 wards: DNCC 12, DNCC 31, DSCC 04, DSCC 15, DSCC 32, DSCC 45, DSCC 51 have positive z value. The wards with negative z values have relatively poor perceived accessibility of the entrance gate and the wards with positive z values have better conditions in terms of perceived accessibility of the entrance gate. Among 13 wards, DSCC 15 has the highest perceived accessibility of entrance gate of the building of residence and DNCC 11 has the lowest perceived accessibility of entrance gate of the building of residence. The overall average perceived accessibility of the entrance gate of residence is 2.18 (which is a little greater than 2, the threshold of poor accessibility) and indicates that the considered wards generally have poor accessibility of entrance gate of the residence. Fig 4.3 shows the map of the accessibility of entrance gate of MCPs' residency for considered wards.

Table 4.3: Average perceived accessibility of entrance gate of the residential building of MCPs

Ward	Average perceived accessibility of entrance gate	z value
DNCC 01	1.86	-0.95229
DNCC 02	1.80	-1.11958
DNCC 11	1.63	-1.62146
DNCC 12	2.29	0.302415
DNCC 20	1.97	-0.6177
DNCC 29	1.91	-0.78499
DNCC 31	2.60	1.222529
DNCC 32	2.09	-0.28311

Ward	Average perceived accessibility of entrance gate	z value
DSCC 04	2.29	0.302415
DSCC 15	2.74	1.640762
DSCC 32	2.46	0.804295
DSCC 45	2.20	0.051475
DSCC 51	2.54	1.055235
Average	2.18	
Standard Deviation	0.341573	

4.4 Regression Models Explaining Perceived Accessibility

Table 4.4 reveals the relationship of accessibility of evacuation network, indoor floor surface and entrance gate on one hand, and sociodemographic factors on the other.. As MLNR is a continuous variable, it has been modelled using Ordinal Least Square (OLS) regression. The accessibility of indoor floor surface and entrance are ordinal variables and Ordinal Logistic Regression has been used to model those. Statistical models reveal that supporting instrument and age has significant negative relationships with the accessibility of evacuation network, indoor floor surface and entrance gate. Intuitively, people who have higher levels of disability and are more dependent on supporting instruments have less perceived accessibility as they experience more mobility challenges. To illustrate, if there are ditches in the evacuation network, then there is a higher possibility for wheelchair users to get stuck in a ditch and experience more mobility challenges than walking frame/crutch users and cane users. Further, if indoor surface connecting entrance gate and apartment of residence have stairs, wheelchair users are likely to face more difficulties to cross stairs than other instrument users. Wheelchair users might have undergone more challenges to open an entrance gate than walking frame/crutch and cane users. Cane and walking frame/ crutch users can try to open the entrance gate standing on their own feet but wheelchair users cannot. For this, wheelchair users might have reported less accessibility of entrance gate in general. The same logic can be extended to other instrument users. As the level of dependence on instruments increases, the more impedance users are facing.

The negative relation between accessibility and age can be explained by the fact that people's physical strength declines with progression in age. Constrained by less physical strength, MCPs who are older may have experienced more impedance and difficulty to cross evacuation network, indoor floor surface and to open entrance gate and have reported lower values of accessibility. Gender and education have been found to have significant positive relations with the perceived accessibilities of the indoor floor surface and entrance gate. Men generally are physically stronger than women and from this perspective, male MCPs have provided higher accessibility value as they undergo less physical challenge to cross indoor floor surface and open the entrance gate. People who are highly educated tend to be more self-confident to overcome their mobility constraints and have less negative perception of their disabilities, which leads them to perceive higher accessibility for indoor floor surface and entrance gate (Essex, 2016; Oxbridge Academy, 2017; Turiano, 2017).

Table 4.4: Estimation results of statistical models

Variables	Accessibility of Evacuation network	Accessibility of Indoor floor surface	Accessibility of Entrance gate
Supporting instrument	-.006*	-.646***	-.903***
Gender (Male)	.009	.864***	.385*
Age	-.006**	-.265***	-.186**
Income	.002	.044	-.062
Education	.001	.272***	.192**
Structure type	.002	-.134	-.056
Samples	455	455	455
R^2	0.061		

Variables	Accessibility of Evacuation network	Accessibility of Indoor floor surface	Accessibility of Entrance gate
McFadden PseudoR^2		0.071	0.062

*p<0.05, **p<0.01, ***p<0.0001

4.5 Accessibility of the Entrance Gate of the Critical Facilities

Table 4.5 reveals the situation of universal accessibility of critical facilities of selected wards of Dhaka city. As mentioned in the methodology section, Table 4.5 depicts the percentage of criteria of universal accessibility of the entrance gate of Building Construction Rules 2008, Bangladesh maintained by the critical facilities on average. Among the considered wards, DNCC 31 has maintained the highest 85.71% of universal accessibility and DNCC 29 has the lowest 14.28% of universal accessibility of the entrance gate. It has been found that 5 wards including DNCC 02, DNCC 11, DNCC 12, DNCC 20, DSCC 32, DSCC 51 have negative z values indicating relatively poor accessibilities of entrance gate. On the other hand, 8 wards including DNCC 01, DNCC 31, DSCC 04, DSCC 15, DSCC 45 have positive z values and can be considered to have better accessibilities of entrance gate. Notably, only 2 wards'universal accessibilities are greater than 70% and the other 11 wards' accessibilities of entrance gate are below 40%.. It is also noticeable that the overall universal accessibility is 25.61% for all wards and it indicates general poor universal accessibility of the considered wards as a whole. Fig 4.4 shows the accessibility of entrance gate of critical facilities for wards.

Table 4.5: Universal Accessibility of the entrance gate of critical facilities

Ward No	Universal accessibility of entrance gate (percentage)	z value
DNCC 01	25.714286	0.004446
DNCC 02	19.642857	-0.269542
DNCC 11	17.142857	-0.382360

Ward No	Universal accessibility of entrance gate (percentage)	z value
DNCC 12	23.809524	-0.081511
DNCC 20	19.047619	-0.296403
DNCC 29	14.285714	-0.511296
DNCC 31	85.714286	2.712090
DNCC 32	24.761905	-0.038532
DSCC 04	35.714286	0.455720
DSCC 15	34.285714	0.391252
DSCC 32	14.285714	-0.511296
DSCC 45	71.428571	2.067413
DSCC 51	21.428571	-0.188957
Average	25.615764	
Standard Deviation	22.15948376	

4.6 Overall Accessibility of the Evacuation Scenario

Table 4.6 shows the overall accessibility for evacuation scenario of MCPs for considered wards. Among the considered wards, DNCC 01 has the lowest z value for overall accessibility while the DSCC 45 has the highest level of overall accessibility. According to Table 4.6, 6 wards have negative values of z score and these wards have relatively poor conditions for overall accessibility for evacuation of MCPs. These wards are: DNCC 01, DNCC 02, DNCC 11, DNCC 12, DNCC 20, DNCC 29. On the other hand, 7 wards including DNCC 31, DNCC 32, DSCC 04, DSCC 15, DSCC 32, DSCC 45, DSCC 51 have positive values for z scores and can be considered to have better conditions of accessibility for evacuation. Among these wards, DNCC 32 and DSCC 32 have z values of 0.031 and 0.034, both of which are close to zero. These low scores indicate low accessibilities for evacuation for MCPs in these wards. Three wards including DNCC 31, DSCC 15 and DSCC 51 have z values that are greater than 3 and can be considered to have relatively satisfactory conditions of accessibility of evacuation for MCPs. Fig 4.5 shows the overall accessibility of evacuation situation for wards.

Table 4.6: Overall accessibility condition of evacuation scenario based on z score

Ward	Z Value of Accessibility				
	Evacuation network	The indoor floor surface of residential building	Entrance gate of residential building	Entrance gate of critical facilities	Overall z value
DNCC 01	-1.72	-1.589	-0.952	0.004	-4.256
DNCC 02	1.065	-0.779	-1.12	-0.27	-1.103
DNCC 11	1.223	-1.265	-1.621	-0.382	-2.046
DNCC 12	0.175	-0.455	0.302	-0.082	-0.059
DNCC 20	-1.239	-0.617	-0.618	-0.296	-2.77
DNCC 29	1.122	-0.536	-0.785	-0.511	-0.71
DNCC 31	-0.256	-0.212	1.223	2.712	3.467
DNCC 32	0.247	0.112	-0.283	-0.039	0.037
DSCC 04	-0.93	1.57	0.302	0.456	1.398
DSCC 15	-0.187	1.327	1.641	0.391	3.172
DSCC 32	-1.347	1.084	0.804	-0.511	0.031
DSCC 45	1.069	0.598	0.051	2.067	3.786
DSCC 51	0.778	0.76	1.055	-0.189	2.404

4.7 Conclusion

This chapter has explored the accessibility situation by considering four components of accessibility for evacuation: indoor floor surface, entrance gate of the residential building, evacuation network, and f entrance gate of temporary shelter / critical facilities. Accessibilities of the first three components have been evaluated based on the perceptions of MCPs while the last component has been evaluated based on a physical survey. As the accessibility components differ in nature as well as in measurement, each has been standardized before being summed up to create an additive scale evaluating an overall accessibility situation. 6 wards have been found to have poor overall accessibilities (negative z value) while 3 wards have relatively satisfactory ($z>3$) conditions of overall accessibility. Overall accessibility situation of the rest 4 wards have relatively good accessibilities but fall short of satisfactory conditions (positive z value is not very high).

This chapter also inspects the relationship between sociodemographic factors and perceived accessibilities for evacuation which include indoor floor surface, entrance gate of the residential building, evacuation network. Statistical models reveal that supporting instrument and age have significant negative relationships with the perceived accessibilities of evacuation network, indoor floor surface and entrance gate. Moreover, gender and education have been found to have significant positive relations with the perceived accessibilities of indoor floor surface and entrance gate.

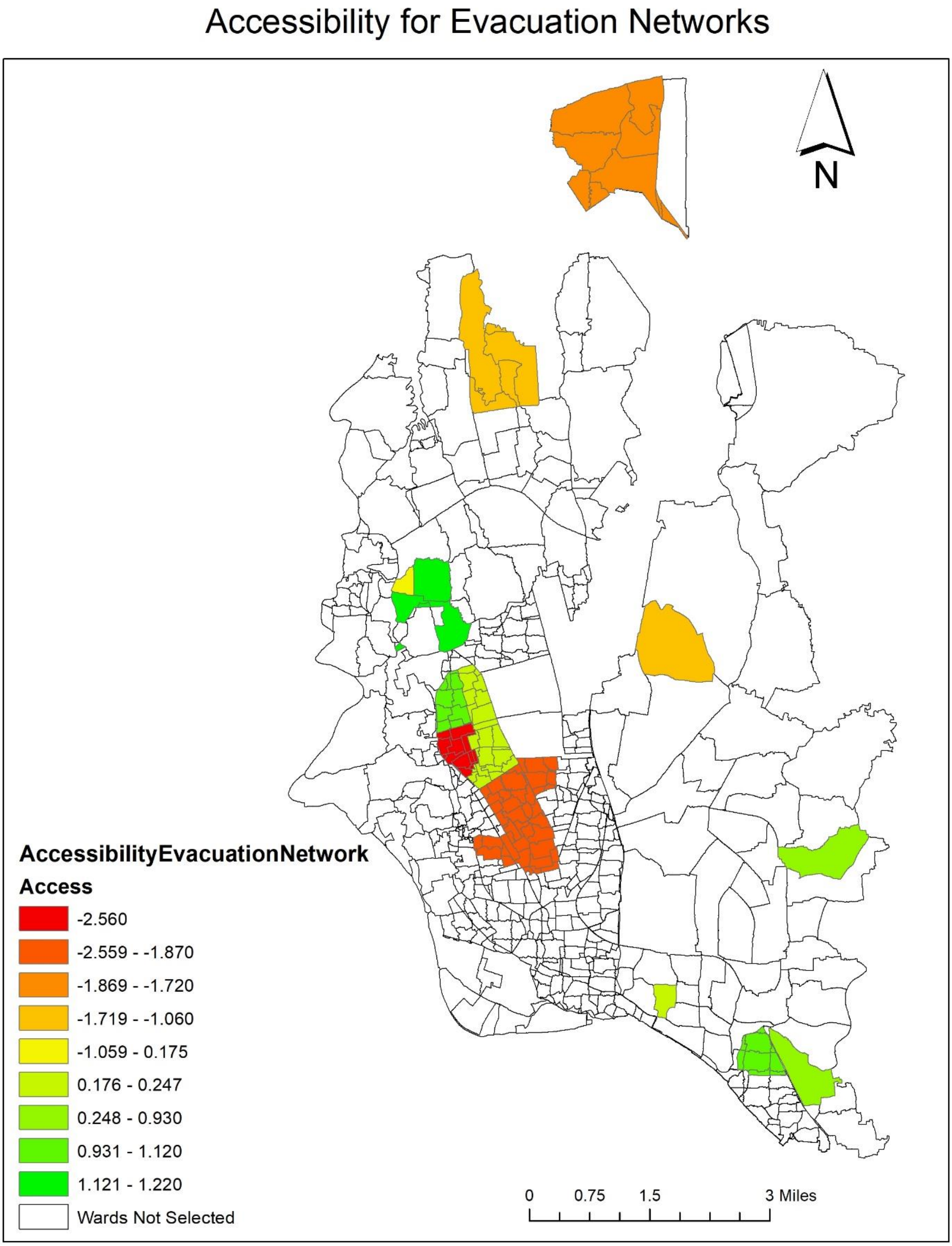


Fig 4.1: Accessibility of evacuation networks

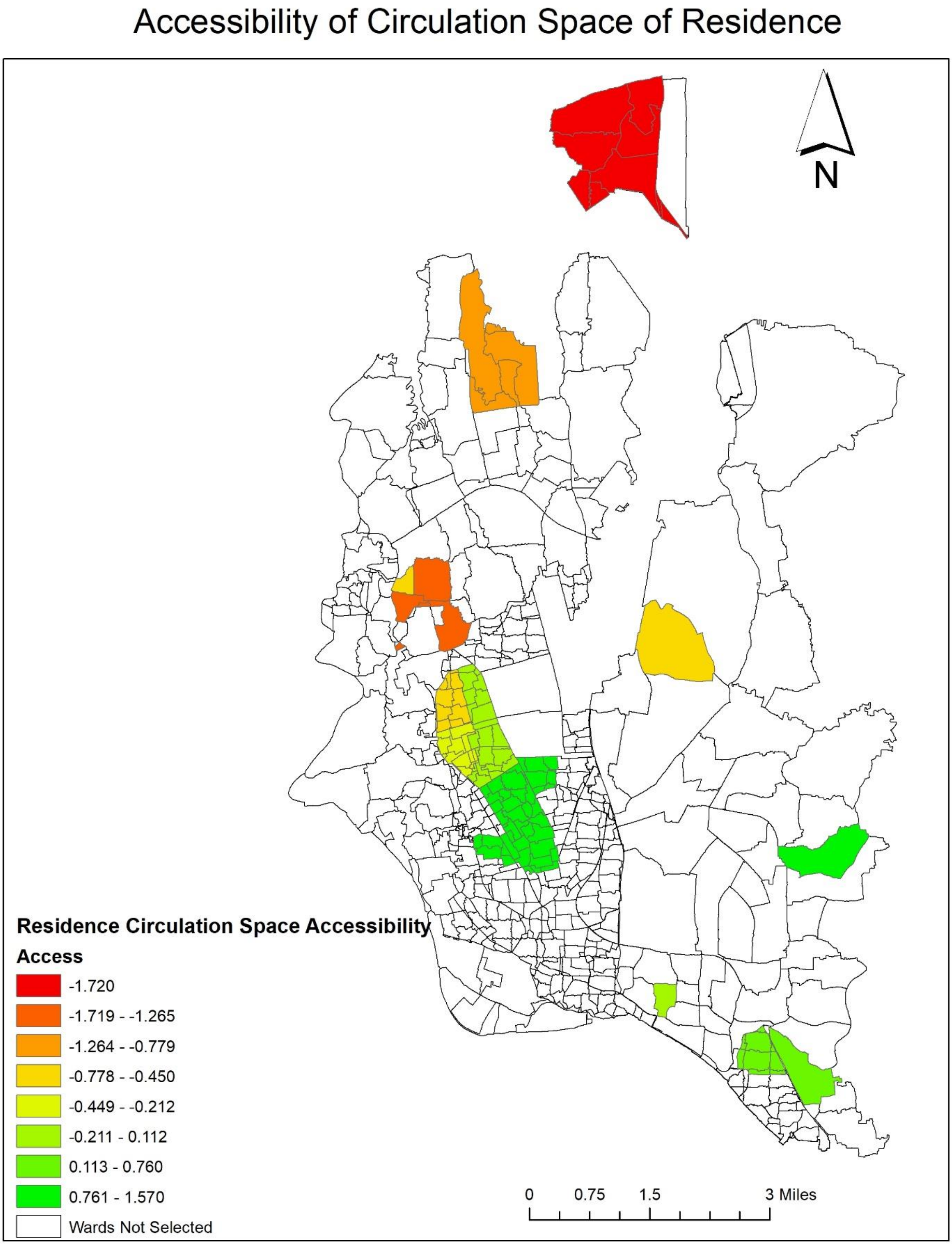


Fig 4.2: Perceived accessibility of circulation space of residence

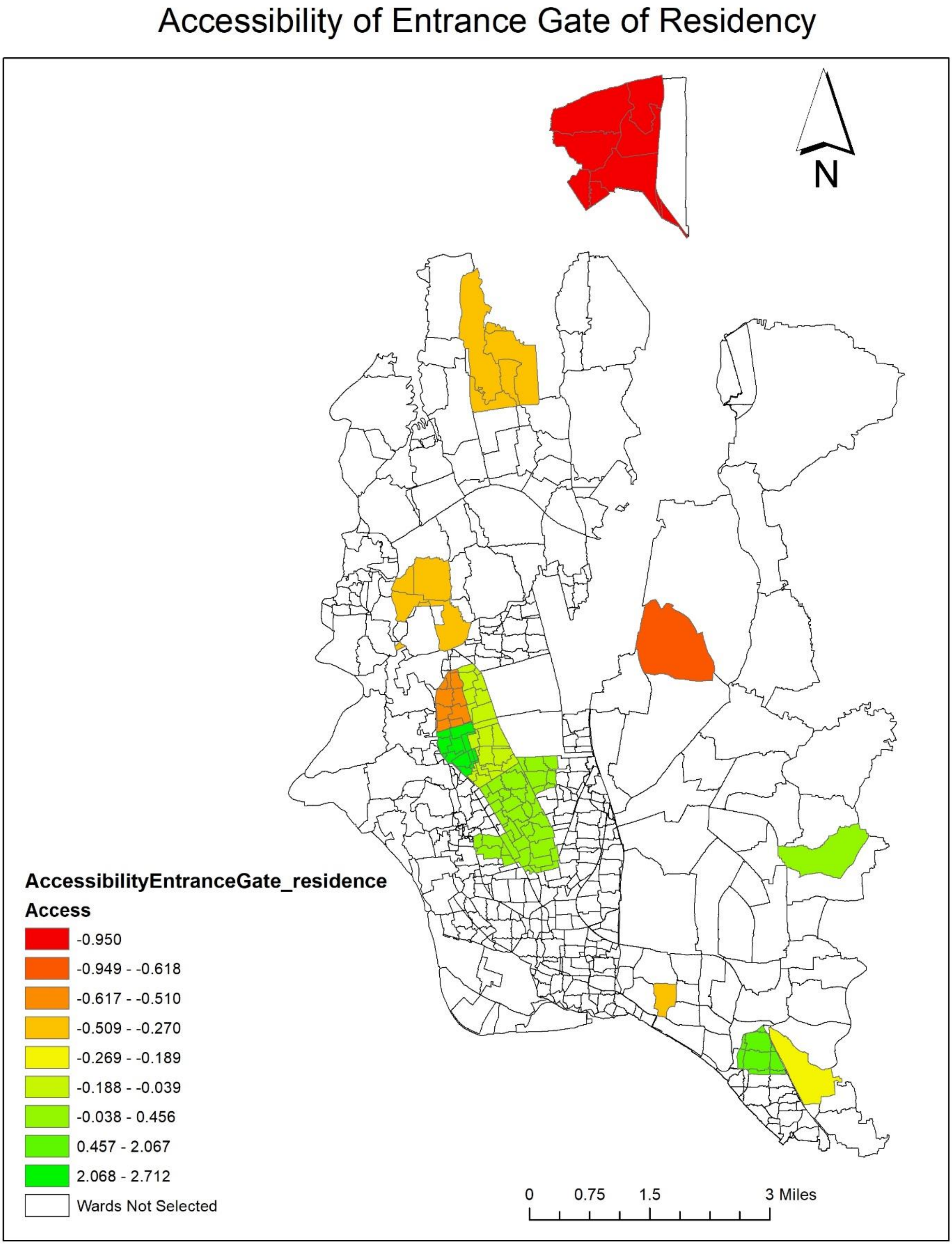


Fig 4.3 : Perceived accessibility of entrance gate of residence

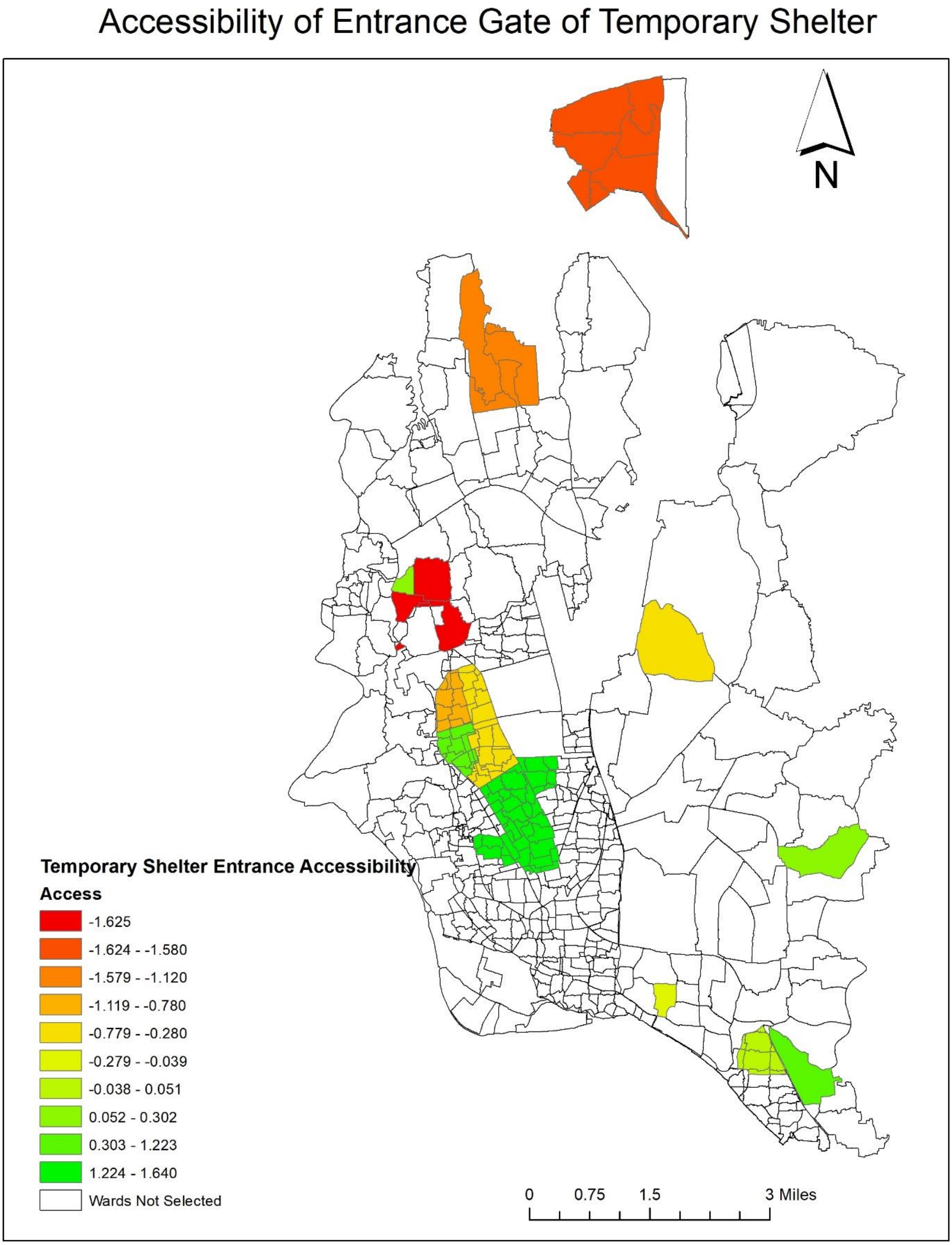


Fig 4.4: Accessibility of entrance gate of critical facilities

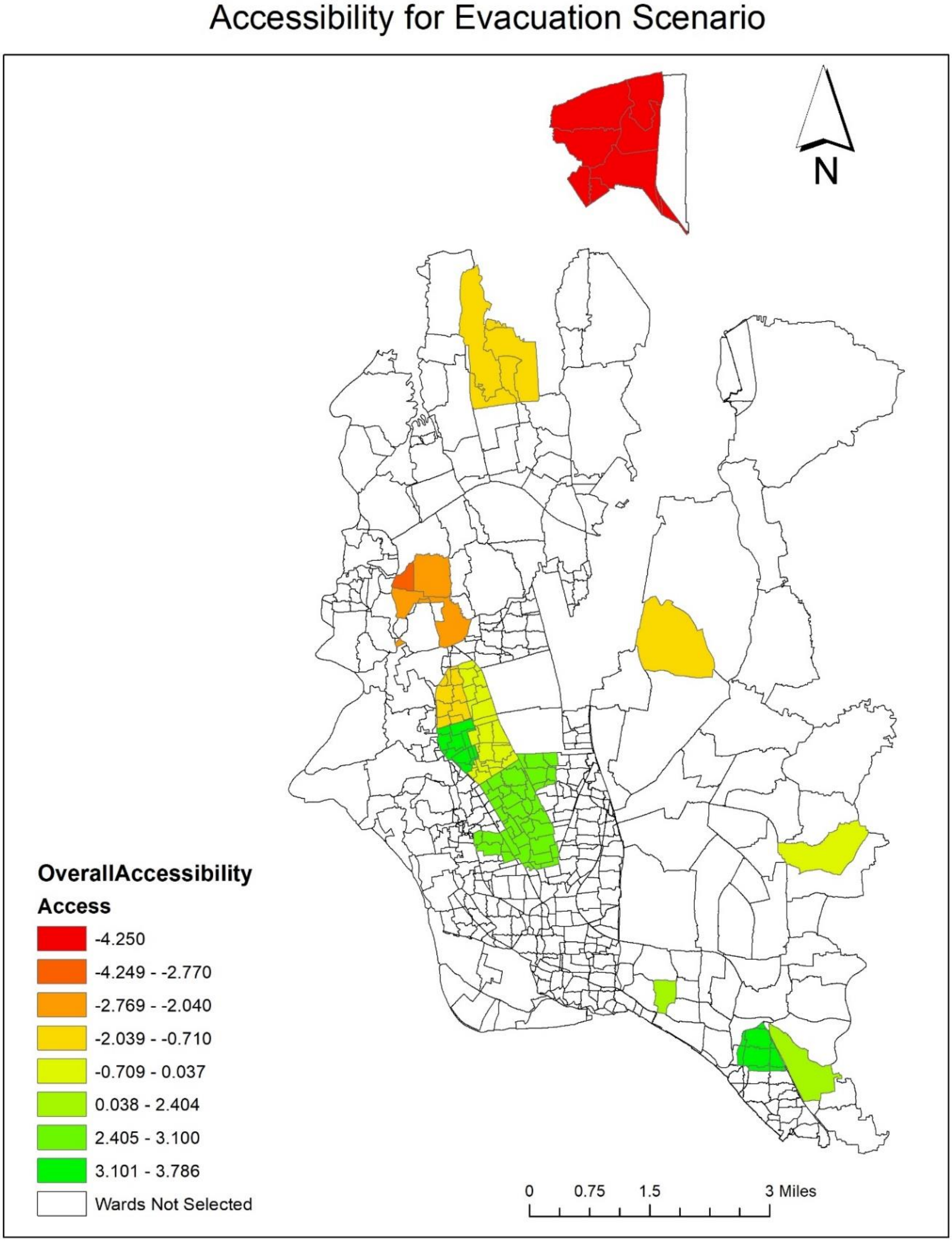


Fig 4.5: Overall accessibility of evacuation of movement challenged persons

5. EARTHQUAKE RISK PERCEPTION OF MOVEMENT CHALLENGED PERSONS OF DHAKA CITY

This chapter explores the risk perception of movement challenged persons (MCPs) of Dhaka city. This chapter focuses on risk perception based on the perceived level of fear, threat, damage from an earthquake as well as the probability of occurrence of an earthquake in Dhaka city. Along with these factors, the relations of risk perception with the previous earthquake, participation in earthquake preparedness training, information source of earthquake risk and training are explored. In addition, the MCPs knowledge on earthquake response, natural disaster management plan, the existence of fault lines in Bangladesh are explored.

5.1 Risk Perceptions

In this study, four dimensions of risk perceptions about earthquake are considered: the perceived probability of occurrence of an earthquake, the perceived probability of occurrence of an earthquake; perceived fear, perceived threat to life and perceived damage to property from an earthquake.

To examine if all the risk perception dimensions can be combined into a single variable, factor analysis is conducted. The varimax rotation is used and an eigenvalue greater than 1 has been used to determine the number of factors. The result of Kaiser-Meyer-Olkin Measure of Sampling Adequacy is 0.753 and a significance level of 0.00 for Bartlett's Test of Sphericity implies that factor analysis can be useful for dimension reduction (Table 5.1).

Scree plot in Fig 5.1 reveals that considered four factors can be loaded into a single factor as only one factor has been found to have eigenvalues greater than 1. Table 5.2 reveals that 61.044% of the variance is explained by the loaded factor. This single factor will be mentioned as RISK PERCEPTION. To conduct the regression analysis, risk perception has been loaded into the new variable risk perception.

Table 5.1**:** Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity

Test		**Result**
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.753
	Approx. Chi-Square	585.784
Bartlett's Test of Sphericity	df	6
	Sig.	.000

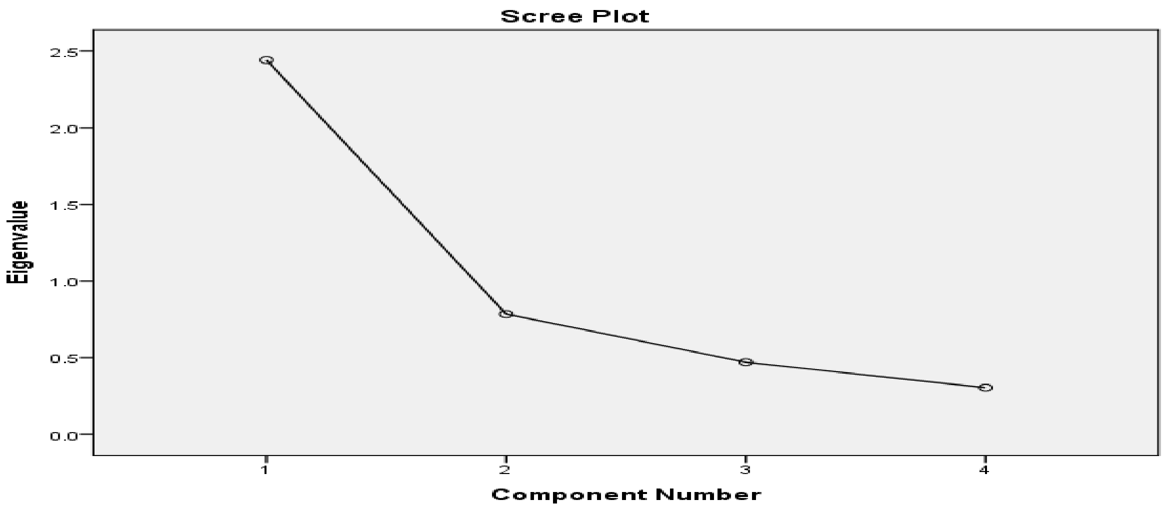


Fig 5.1: Scree plot from factor analysis

Before developing the models, the information source for earthquake training and risk for MCPs have also loaded into factors for the convenience of data analysis. There are five different information sources: mass media, newspaper, family members and friends, internet, social media. Two factors have been found through factor analysis for both information source of earthquake training and risk. Mass media and newspaper loaded into single factor named mass media while internet, social media, family and friends loading into another factor named internet and family.

Table 5.2: Variance explained by the factors

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.442	61.044	61.044	2.442	61.044	61.044
2	.784	19.609	80.653			
3	.470	11.754	92.407			
4	.304	7.593	100.000			

Each dimension of risk perception is modeled using ordinal logistic regression and the composite risk perception is modeled using the ordinary least square regression method. Table 5.3 reveals the results from statistical modeling.

It has been found age and structure type are significantly correlated with each dimension of the four risk perception as well as the composite risk perception. Age is positively correlated with all risk perception dimensions. It can be explained by the fact that people who are advanced in age are more concerned about earthquake risk leading to providing higher value for risk perception. On the other hand, structure type is negatively correlated with risk perception which implies that MCPs who are living in better-structured houses perceive less risk perception and are thus less concerned about earthquake risks. MCPs living in well-structured houses feel safer from the earthquake and hence, they therefore have lower risk perception. It has been found that supporting instrument i.e. level of disability is significantly positively correlated with the perceived threat to life and property from the earthquake as well as the composite risk perception. People who have a higher level of disability are more concerned that they will not be able to save their lives or property in the event of a disaster constrained by their disabilities.

Experiencing earthquake/ground shaking and number of earthquake experienced in the past have positive significant effects on the perceived threat to life and property and the composite risk perception which commensurate with findings from other literature revealing previous experience of an earthquake makes people more concerned about earthquake risk.

Information of earthquake training received from the mass media i.e. newspaper, radio, television might have highlighted information on damage caused by previous earthquakes/ground shakings to encourage people to participate in training and significantly contributed to the overall risk perception, perceived damage of life and property from an earthquake. Similarly, news available on the internet and family has been found significantly related to the overall risk perception and perceived probability of earthquake and damage to life and property positively. It is interesting to notice that the internet and family as a source of training information have been found positively related to perceived fear but negatively related to the probability of occurrence of an earthquake in a significant way. Training program information received from the internet or family might have contained information on possible damage that can be caused by an earthquake to encourage people to participate in training. But, information on the possibility of occurrence of the earthquake (like information on the existence of fault line in Bangladesh) might be missing in training information received from the internet or family leading to a negative relation between the probability of earthquake and this information source. Mass media as an information source for earthquake risk has a significant negative relation with the perceived threat to life and property. It can be attributed to information on damaged caused by earthquake/ ground shaking that might not have been disseminated in the news of mass media. Alternatively, people who rely on mass media as information source may be put under the assumption that they are well informed and therefore feel less insecure about future risks.Gender, number of earthquakes experienced, the impact of the last earthquake, participation in training, internet and family as a source of the earthquake has not been found significantly related with any of the risk perception parameters and risk perception.

Table 5.3: Risk perception of movement challenged persons

Variables	Probability of earthquake	Perceived fear	Perceived threat to life	Perceived threat to property	Risk perception
Supporting Instrument	.056	.155	.243*	.416***	.131**
Gender	-.143	.019	.011	.134	.016
Age	.159**	.417***	.291***	.323***	.182***
Income	.108	-.205**	-.386***	-.373***	-.159***
Education	-.073	-.025	.074	.241*	.037
Structure Type	-.267***	-.322***	-.303***	-.288***	-.171***
Previous experience of earthquake	2.342***	.277	1.467**	1.460**	.754***
Number of earthquake experienced	.167**	.057	.023	.001	.030
Time gap from last earthquake experienced	.074	-.229**	-.131	-.057	-.055
Impact of last earthquake experienced	.105	.076	-.064	.062	.030
Participation in training	-.039	-.101	.104	.345	.064
Information source for training: mass media	.033	.656	1.811**	1.584*	.557*

Variables	Probability of earthquake	Perceived fear	Perceived threat to life	Perceived threat to property	Risk perception
Information source for training: internet and family	-.430***	.202*	.130	.139	.027
Information source for risk: mass media	-.189	-.608	-1.692**	-1.388*	-.526
Information source for risk: internet and family	.659***	.103	.261**	.190*	.156***
Sample	455	455	455	455	455
R square					0.39
MacFadden pseudo R square	0.139	0.093	0.11	0.116	

*p<0.05 , **p<0.01, ***p<0.001

Table 5.4 shows the modeling of risk perception of movement challenged persons participating in earthquake preparedness. It has been found that training duration, training effectiveness, time gap from last participation in training is not significantly related to risk perception.

Table 5.4: Risk perception of movement challenged persons participating in earthquake training

Variable	Probability of earthquake	Perceived fear	Perceived threat to life	Perceived threat to property	Risk perception
Supporting Instrument	.118	.380	.527*	.803***	.232**
Gender	.076	-.327	-.020	.313	.026
Age	.262*	.378*	.313**	.387**	.185***
Income	.153	-.423*	-.345*	-.444**	-.187**
Education	.117	-.060	-.131	.428	.054
Structure Type	-.308*	-.324*	-.190	-.106	-.120
Previous experience of earthquake	1.680	-1.021	1.750*	1.650	.543
Number of earthquake experienced	.300**	.148	.106	.026	.063
Time gap from last earthquake experienced	.202	-.337*	-.075	-.014	-.024
Impact of last earthquake experienced	.204	.171	-.245	.016	.025
Training duration	.101	.064	.129	.034	.044
Training effectiveness	-.268	-.314	-.532	-.309	-.165
Time gap from last training	.006	-.027	.034	.079	.034
Information source for training: mass media	-.236	.890	2.158*	3.525**	.748*
Information source for training: internet and family	-.632	.272	.031*	-.068	-.040
Information source for risk: mass media	.009	-.527	-2.135*	-3.168**	-.681

Variable	Probability of earthquake	Perceived fear	Perceived threat to life	Perceived threat to property	Risk perception
Information source for risk: internet and family	.654*	.119	.167	.103	0.121
Samples	455	455	455	455	455
R square					0.345
MacFadden Pseudo R square	0.162	0.117	0.109	0.148	

*p<0.05 , **p<0.01, ***p<0.001

5.2 Knowledge of Earthquake Response

Table 5.4 shows the results of statistical modeling of variables related to knowledge of earthquake response. In relation to investigating knowledge of the MCPs about earthquake response following questions have been asked:

a.Where they will seek shelter if they are inside their home at the time of an earthquake

b. Where they will seek shelter if they are outside at the time of an earthquake

c. If they know the location of critical facilities/temporal shelter location in their ward (Yes/No)

d. If they know about the evacuation route of their ward (Yes/No question)

Binary logistic regression has been applied to statistically model the knowledge of MCPs about earthquake response. If the answer to question a is they will stay inside the building, cover head under a desk or table or other types of the shield, it has been regarded as

Yes and if the answer is I do not know, it is considered as No. If the answer to question b is, take shelter in an open space, it is considered as Yes and if the answer is I do not know, it is considered as No. Question c and d have been answered by respondents in Yes/No form. Yes has been coded into 1 and No has been coded into 0. All the four variables: knowledge of how to respond on the occurrence of an earthquake in the advent of an earthquake while being inside home and outside, location of the temporary shelters at the ward, knowledge of the existence of evacuation route of the wards have been combined into a single variable overall KNOWLEDGE OF EARTHQUAKE RESPONSE. The value of knowledge of earthquake response has been determined by adding up values of four considered variables (0/1) in an ordinal scale. Ordinal logistic regression has been applied to develop a statistical model for knowledge of earthquake response.

192 MCPs (42.2%) and 242 MCPs (52.7%) knows where to seek shelter while being inside and outside of home respectively at the time of earthquake.Participation in training is significantly linked to MCPs knowledge on how to respond in the advent of the earthquake while being inside as well as outside as well as knowledge of response. Internet and family member as a source disseminating information on earthquake risk might have provided information on earthquake vulnerability of MCPs and hence, encouraged them to know where to seek shelter while being inside home leading to the significant relationship between mass media as a source of earthquake risk and knowledge of what to do at the advent of an earthquake while being at home. People who have experienced an earthquake before, they might have felt an urge to know where to seek shelter when outside in the occurrence of an earthquake leading to a significant positive relationship between knowledge on where to seek shelter while being outside with previous experience of the earthquake. MCPs knowledge of evacuation route has been significantly related to mass media as training information negatively. This can be explained by the fact training related information should contain

information like venue, time of training or why people should participate in training. Information on the evacuation route should have been provided to the participants. For this, MCPs who depend on training information sources to know about the evacuation route might not know about it. Only 9 MCPs (1.9%) and 10 MCPs (2.1%)have been found to know the location temporary shelters and evacuation routes in wards which is very low. No variables have been found to have significant relationships with knowledge of the location of temporary shelter and the existence of evacuation routes at the ward. Supporting instrument, gender, age, income, education, structure type, previous experience of the earthquake, number of earthquakes experienced., time gap from the last earthquake experienced, the impact of the last earthquake, mass media as an information source of earthquake risk has not been found significantly correlated with any of earthquake response parameters. As no significant relation has been found between knowledge of evacuation route and shelter location with participation in training, it can be interpretated training programs have not been successful to provide MCPs on information about location of temporary shelter and evacuation route.

Table 5.5: Knowledge of earthquake response of movement challenged persons

Variables	Place of taking shelter		Shelter	Evacuation	
	when inside	when outside	location in ward	route in ward	Earthquake response
Supporting Instrument	-.086	-.176	-.736	.881	-.076
Gender	.021	-.108	1.164	.113	.060
Age	.031*	.007	-.099	.178	.057
Income	.212	-.104	.103	.001	-.019
Education	.025	.202	-.924	.217	.125

Variables	Place of taking shelter when inside	when outside	Shelter location in ward	Evacuation route in ward	Earthquake response
Structure Type	-.018	-.151	.216	-.124	-.098
Previous experience of earthquake	.985	1.391*	-2.071	-3.222	.787
Number of earthquake experienced	.162	-.108	.179	-.149	-.107
Time gap from last earthquake experienced	-.013	.200	-.101	-.259	.104
Impact of last earthquake experienced	.392	-.061	-.456	.906	-.158
Participation in training	4.42***	3.64***	-.553	-.446	5.15***
Information source for training: mass media	-.172	.079	-.138	-.850*	-.138
Information source for training: internet and family	.079	.318*	-.462	.025	.137
Information source for risk: mass media	.076	.088	.016	.104	.112
Information source for risk: internet and family	.343**	-.015	-.188	.917	.102
Samples	455	455	455	455	455
MacFadden Pseudo R square					0.27

*p<0.05 , **p<0.01, ***p<0.001

Table 5.6 reveals knowledge of earthquake response of movement challenged persons participating in earthquake training. It has been found that people who have participated in training program longer period knows where to seek shelter when being outside and inside home. This relationship has been found significant.

Table 5.6: Knowledge of earthquake response of movement challenged persons participating in earthquake training

Variables	Place of Taking Shelter when inside	when outside	Shelter location in ward	Evacuation route in ward	Earthquake response
Supporting Instrument	-.183	-.239	-.751	148.251	-.552
Gender	.244	-.035	1.242	6.332	-.434
Age	.032	-.001	-.113	1.702	-.295
Income	.257	-.093	.082	-29.772	.229
Education	.086	.195	-.541	-89.233	-.076
Structure Type	-.015	-.167	.274	-41.114	-.044
Previous experience of earthquake	1.286	1.272	-1.895	193.023	1.202
Number of earthquake experienced	.158	-.108	.179	-33.919	.064
Time gap from last earthquake experienced	-.052	.176	-.085	-8.678	.009
Impact of last earthquake experienced	.508*	.035	-.586	-60.925	-.201

Variables	Place of Taking Shelter when inside	when outside	Shelter location in ward	Evacuation route in ward	Earthquake response
Training duration	1.24***	1.02***	-.268	-70.583	.493
Training effectiveness	-.303	-.240	.390	-15.630	.297
Time gap from last participation in workshop	.329	.274	-.110	45.596	.076
Information source for training: mass media	-.094	.104	-.167	67.386	-.150
Information source for training: internet and family	.073	.328*	-.454	-5.739	.281
Information source for risk: mass media	.094	.102	.031	-60.260	.257
Information source for risk: internet and family	.384*	-.011	-.138	148.248	.385
Samples	455	455	455	455	455
MacFadden Pseudo R square					0.38

*p<0.05 , **p<0.01, ***p<0.001

5.3 Knowledge of NDMP and Fault-line Existence

MCPs were asked if they know about the Natural Disaster Management Plan (NDMP), Bangladesh and the existence of fault lines in Bangladesh. Table 5.7 shows the results of binary logistic regression modeling of knowledge of MCPs on the existence of NDMP and fault line. 165 MCPs(36.2%) have been found to know about NDMP.It has been found that education is significantly positively related to these variables. MCPs who are more educated are likely to be aware of information from the government and have more venues to learn about the existence of NDMP and fault lines. On the other hand, 191 respondents (41.9%) have been found know the existence (along exacy name) of fault line in Bangladesh. MCPs might have provided information about the existence of fault lines in Bangladesh which lead to significant relationship participation in earthquake training and knowledge of the existence of fault lines. Gender has been found to have a negative significant relationship with the knowledge of NDMP which implies female MCPs are likely to have to know more about the existence of NDMP. Females are considered to be more sensitive and aversive to disasters and correspondingly to be more cautious about disaster management which can contribute to their knowledge about the existence of NDMP. Supporting instrument, age, income, structure type, previous experience of the earthquake, number of earthquakes experienced., time gap from the last earthquake experienced, the impact of the last earthquake, information sources of earthquake risk and training has not been found significantly related with knowledge of MCPs about NDMP and fault line existence.

Table 5.7: Knowledge of movement challenged of NDMP and fault line existence in Bangladesh

Variables	NDMP	Faultline existence
Supporting Instrument	-.120	-.165
Gender (Male)	-.425*	-.493

Variables	NDMP	Faultline existence
Age	-.071	-.031
Income	-.001	-.137
Education	.456***	1.596***
Structure Type	-.008	.017
Previous experience of the earthquake	.371	-.165
Number of earthquakes experienced	-.175	.129
Time gap from the last earthquake experienced	-.041	-.017
Impact of the last earthquake experienced	-.169	.126
Participation in training	.406	1.243***
Information source for training: mass media	.655	-.070
Information source for training: internet and family	.060	.182
Information source for risk: mass media	-.405	.053
Information source for risk: internet and family	-.053	.032
Samples	455	455

*p<0.05 , **p<0.01, ***p<0.001

Table 5.8 shows results of binary logistic modeling of knowledge of NDMP and fault line existence in Bangladesh movement challenged persons participating in the training program. Gender and education have been found significantly related to knowledge of NDMP positively. No variables has been found significantly related to knowledge of the existence of fault line in Bangladesh.

Table 5.8: Knowledge of NDMP and fault line existence in Bangladesh movement challenged persons participating in the training program

Variables	Knowledge of NDMP	Faultline existence in Bangladesh
Supporting Instrument	-.315	-.230
Gender	-.872*	.318
Age	-.060	-.130
Income	-.063	-.208
Education	1.666**	.903
Structure Type	-.014	.275
Previous experience of the earthquake	.451	.831
Number of earthquakes experienced	-.169	.084
Time gap from the last earthquake experienced	-.267	.008
Impact of the last earthquake experienced	-.347	.142
Training duration	-.274	.193
Training effectiveness	.572	-.474
Time gap from last participation in the workshop	.234	1.122
Information source for training: mass media	2.391	.378
Information source for training: internet and family	.177	-1.378
Information source for risk: mass media	-1.815	-.296
Information source for risk: internet and family	-.092	-.230
Samples	455	455

*p<0.05 , **p<0.01, ***p<0.001

5.4 Reasons for not Participating in Earthquake Preparedness Training

Fig 5.1 shows the causes of not participating in the training. It has been found that the most common reason for MCPs to lack of accessibility to training centers. The second most common reason for MCPs not participating in training is that people are not provided with information about training programs. The third most common reason behind MCPs not participating in training program is that they consider the training programs physically demanding.

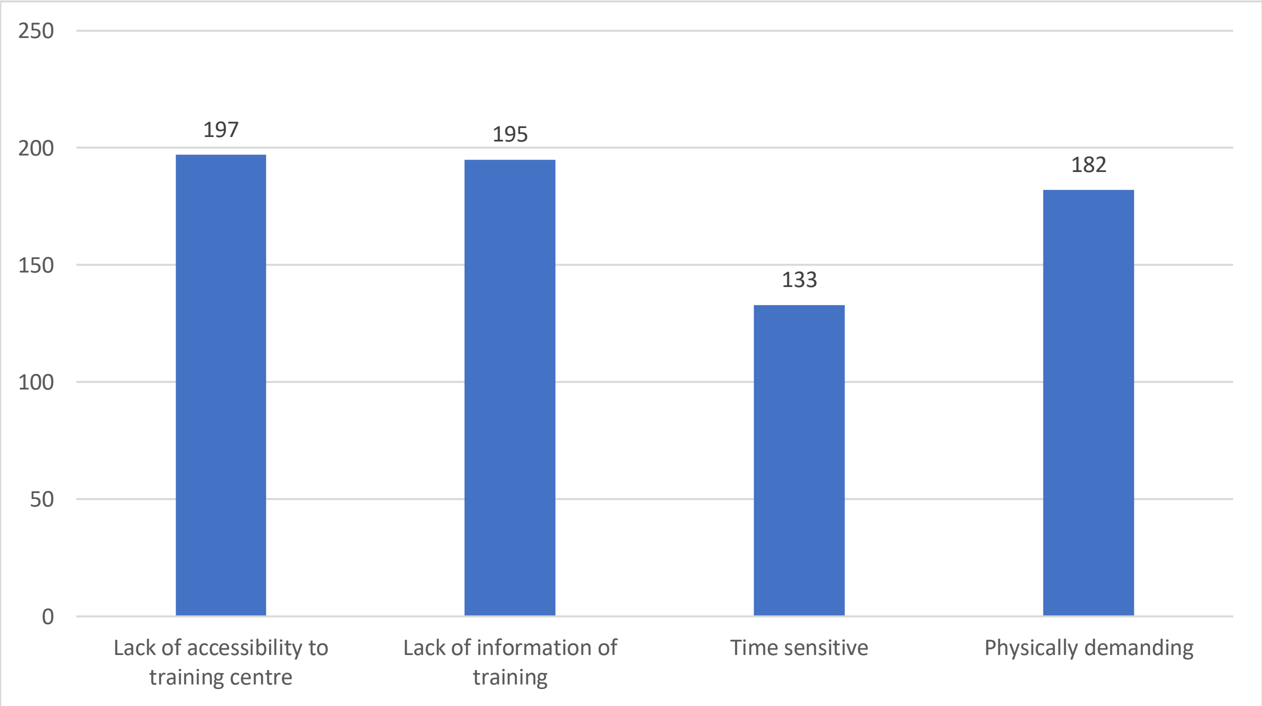


Fig 5.2: Causes of not participating in training

5.5 Conclusion

This chapter has explored the risk perception of movement-challenged persons. Four different dimensions as well as the overall risk perception , knowledge of earthquake response, knowledge of disaster management plan and existence of fault line of MCPs. Relations of variables of interest with socio-demographic factors, the severity of the disability, previous experience of the earthquake, source of information of earthquake risk and training, participation in training have been explored.

Age, income, structure, having experienced an earthquake earlier, mass media as a source of information on earthquake training have been found significantly related to the overall risk perception. MCPs who have participated in the training program have been found to know what they should do in the advent of an earthquake irrespective of being outside or inside of the home. MCPs who are more educated have a higher likelihood to know about NDMP and the existence of fault lines in Bangladesh. Lack of accessibility in training centers and lack of distribution of information of training programs have been found as key reasons behind MCPs not participating in the training.

6. CONCLUSION

The study addresses the issue of resilience to earthquakes among movement challenged persons (MCP), a highly vulnerable group. The study is divided into two main parts: analysis the accessibility of MCPs to evacuation routes and analysis of the risk perception of MCPs. 13 wards (communities) of Dhaka, the capital of Bangladesh, a city highly vulnerable to earthquakes with a significant number of persons with disabilities including MCPs, is elected as the study area.

As there is no exclusive accessibility measure / index available to determine the accessibility of MCPs, this study has developed an accessibility index comprising of four components and it has been applied to evacuation routes of wards of Dhaka city. The four components of the accessibility index are accessibility of circulation space and entrance gate of the residence of MCPs, accessibility of evacuation route and accessibility of entrance gate of temporary shelter. Required data to carry out the study is collected through questionnaire survey and physical survey. Perceived impedance value reported by MCPs is integrated with Link to Node Ratio to determine the accessibility of evacuation routes.

Accessibility of MCPs at the time of earthquake evacuation is assessed using developed accessibility measures. Findings of the data analysis reveal that 6 wards is found to have overall accessibility situation at a poor level while 3 wards have a relatively satisfactory condition of overall accessibility for evacuation. Overall accessibility situation of the other 4 wards might have relatively good accessibility for evacuation but it cannot be claimed to be satisfactory. The relation of four components of accessibility with socio-economic factors has been explored as well. Statistical models show that age and severity of disability (or mobility challenges) of MCPs have a significant negative relationship with the accessibility of evacuation network, indoor floor surface and entrance gate. Besides, Gender and level of education is found to have a significant positive relation with the accessibility of indoor floor surfaces and entrance gates.

Risk perception of MCPs has been explored using statistical models. Four different dimensions: risk perception, knowledge of earthquake response, knowledge of disaster management plan and existence of fault line of MCPs have been considered. Risk perception parameters include perceived probability of occurrence of the earthquake, perceived fear, threat to life and property as well as overall risk perception. Knowledge of earthquake response included four parameters: knowledge of where to seek shelter while being at home or outside at the time of the earthquake, temporary shelter location in the ward, evacuation route in the ward. Relations of variables of interest with socio-demographic factors, the severity of the movement challenges, previous experience of the earthquake, sources of information of earthquake risk and training, participation in training is explored. Age, income, structure, experiencing an earthquake earlier, mass media as a source of information on earthquake training is found significantly related to the overall risk perception. MCPs who have participated in the training program is found to know what they should do while being outside or inside of the home in the advent of an earthquake. MCPs who have a higher level of education have a higher likelihood to know about NDMP and the existence of fault lines in Bangladesh. Lack of accessibility in training centers and lack of distribution of information of training programs is found as key reasons behind MCPs not participating in the training.

As MCPs have complaint that they have not participated in training because of lack of accessibility in training centers, training should be arranged in buildings accessible for MCPs or existing training centers should be made accessible by the provision of ramps, smooth floor surface etc. Online training on earthquake response can also be arranged for MCPs so they do not need to go to training centers. MCPs also mentioned they have not participated in the training center because they have not been provided about it. So, the distribution of information on a training program is also important to encourage MCPs to participate in the training program. It has been found that knowledge of earthquake response is not satisfactory. To be specific, only a handful number of MCPs (around 2%) know about the temporary shelter and evacuation route of the ward. As having knowledge of temporary shelters and evacuation route is one of the most important parts of earthquake evacuation, training programs must be designed to impart this information to the public in general and MCPs in particular. As stated in the literature review, there are many ideal examples of community-based disaster management in the developed and developing countries that can be studied and adopted to make MCPs and other people well trained in earthquake response at the community level in the context of Dhaka and Bangladesh. Besides, mass media and social media should be encouraged to raise the awareness of earthquake risks and mitigation measures among MCPs by disseminating information. The information should include but is not limited to: the existence of fault line in Bangladesh, the relationship between unplanned development of Dhaka and its earthquake vulnerability, appropriate response measures in the occurrence of an earthquake, and the importance of participating in the training program.

This study can provide a guideline for future studies. The methodology utilized in this study can also be applied to accessibility to other networks. This study has not considered accessibility of circulation space of temporary shelter to develop the accessibility measure as temporary shelter may not have been visited by MCPs and they may not be fully aware of it's accessibility. Besides, there were time and human resource constrain to collect the data and it was not possible to take MCPs to temporary shelters to record their perceived accessibility and physical impedance of circular space of temporary shelters. So, future studies can be undertaken by taking MCPs to the temporary shelters and incorporate the perceived accessibility of circular space of temporary shelter based on their experience. Further, future studies can be undertaken to learn the scope of other accessibility index discussed in the literature review section to determine the accessibility of a network for MCPs. As the study has found training programs have not been able to impart MCPs knowledge of earthquake response and earthquake risk, research should be conducted on the effectiveness of the training programs., The opinion of MCPs can be taken on how to make the training program more effective through questionnaire survey and the survey data should be analyzed to gain insights into how to improve the contents of the training program.

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THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

April 23, 2020

Md Bhuiya
Department of Geography
College of Arts & Sciences
Box 870322

Re: IRB # 20-01-3185 : "Accessibility of Movement Challenged Persons to Evacuation Routes and their earthquake risk perception"

Dear Md Bhuiya:

The University of Alabama Institutional Review Board has granted approval for your proposed research. Your application has been given exempt approval according to 45 CFR part 46. Approval has been given under exempt review category 2 as outlined below:

(2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

(iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by §46.111(a)(7).

The approval for your application will lapse on April 22, 2021. If your research will continue beyond this date, please submit the annual report to the IRB as required by University policy before the lapse. Please note, any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

Please use reproductions of the IRB approved informed consent form to obtain consent from your participants.

Sincerely,

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer

Jessup Building Box 870127 Tuscaloosa, AL 35487-0127
205-348-8461 Fax 205-348-7189 Toll Free 1-877-820-3066