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Spatial Accessibility Analysis of The Cyclone Shelters in The Southern Part of Bangladesh

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Abstract

Approximately 50% of Bangladesh is 7 m or less above and faces the Bay of Bengal. The coastal zone covers an area of about 33% of the country, representing 19 districts and 29% of the population. Accordingly, the local geography produces not only the life-giving monsoon but also the catastrophic revenge of cyclone and so on. Hence Cyclone Shelters(CS) are the important infrastructures during cyclones which should be available in the vulnerable areas in sufficient numbers with sufficient facilities for the large number of communities.The main goal of this study is to determine the areas deprived of Cyclone Shelter facilities by creating upazila-wise accessibility index depending on GIS based analysis, attempted to link cyclone risk area to socio-economic, demographic aspects and housing conditions based on secondary data. A total of 109 upazilas of 16 coastal districts have been considered. The 2SFCA method is used to determine the accessibility index considering threshold distance. The accessibility index is found quite lower in 61 upazilas, higher in 05 upazilas and zero in 43 upazilas. Therefore, some recommendations are proposed which might help the corresponding authorities to find out the locations need to build new CS and ensure proper facilities at the existing shelters.

Keywords: *Cyclone shelters; spatial data; accessibility index; threshold distance; two-step floating catchment area (2SFCA) method.*

1 Introduction

1.1 Background of the Study

Bangladesh is the 6th most disaster-prone country in the world where 96.0% of its total population and 96.5% area are at risk of multiple natural calamities including cyclones. Geographic location, the unique natural conditions of the country and its regular monsoon climate make the country more vulnerable to cyclones and storm surges. Major cyclones that hit the coastal areas after 2000 are in 2007, 2009, 2011, 2016, 2019, 2020 and 2021. In cyclone SIDR (2007), the number of human deaths was 3,363, that was in AILA 190 (GoB, 2010), Mohasen (107), Mora (135), Amphan (118).

The Bangladesh government and international cooperation agencies have worked together to mitigate cyclones, primarily through developing early warning systems and building cyclone shelters since achieving independence in 1971. Before the destructive cyclone of 2007, Bangladesh had only 1,500 cyclone shelters in the coastal districts and after Sidr Govt. constructed around 2,000 shelters. It was estimated that around 1.5 million people took refuge in Multi-Purpose Cyclone Shelters (MPCS) when Cyclone Sidr hit the coastal districts in 2007. The capacity of MPCS can accommodate only about 9% of the total coastal population. The World Bank (2010)

estimated that there need to be more than 5,500 cyclone shelters as an integral part of disaster management strategy. Although the number of deaths has decreased significantly with the increased construction of cyclone shelters, some aspects have still existed in cyclone countermeasures: the inequality of shelter distribution and its capacity and frequency, lack of proper accessibility for the women, physically challenged people as evacuation centers in emergencies owing to inadequate maintenance.

Cyclone shelters in Bangladesh are not designed by assessing the demand of the catchment area. There was always a gap between demand and supply of cyclone shelters in the coastal areas of Bangladesh. There are a large number of Upazilas and Unions not having cyclone shelters. According to the policy of the Bangladesh Government, the location of the shelters must be close to the vulnerable communities within a distance of 1.5 km with a good road network. Cyclone shelters should be accessible for use by all the communities including women, children, the aged and the disabled (CDMP, 2011). According to Paul and Routray (2013), 1 mile (1.6km) is the accessible distance to reach the CS on foot during cyclone. That means people can go to the cyclone shelter within a 1.6 km radius zone.

1.2 Objectives of the Study

The study has been outlined the following specific objectives for exploring the reality from the field.

i. Analyzing the spatial accessibility to cyclone shelters for normal condition (d= 1.5 km) and for disabled and aged people (d = 0.75 km).
ii. Finding out the locations lacking of cyclone shelters considering population density, accessibility and available amenities as future recommendation.
iii. Studying the location of existing cyclone shelters in relation to geographic and socio-demographic context.
iv. Analyzing existing healthy facilities (drinking water, sanitation, utilities, ventilation etc.), gender separation facilities (separate room, toilet etc.) and facilities for the disabled.

2 Methodology

2.1 Study Framework

The whole process is conducted with the help of spatial analysis through ArcGIS and QGIS software. GCS WGS 1984 is the coordinate system supported for the output scene layer package.

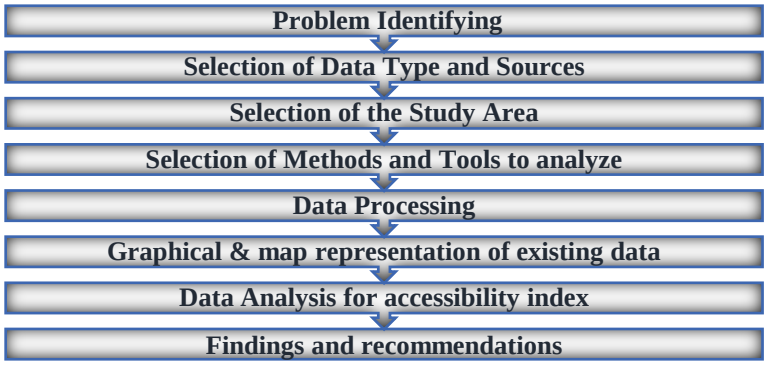


Figure 1. Methodological Framework of the study

2.2 Selection of Data and Data Source

The study is purely based on secondary data. A list of variables (demographic, socio-economic, cyclone shelter-related data) have been prepared based on a review.

Table 1. Basic collected data and their sources.

Data Type	Data	Data Source
Temporal	Demographic and Socio-economic	Bangladesh Bureau of Statistics (BBS)
	Flood and cyclone	Bangladesh Meteorological Department (BMD) & Water Development Board (BWDB)
Spatial	Cyclone Shelter	Local Government Engineering Department (LGED) & Ministry of Disaster Management and Relief
	Administrative	Bangladesh Bureau of Statistics (BBS)
	Local Road	Local Government Engineering Department (LGED)

An extensive online search has been done to find the most complete and latest data of the variable listed earlier. Some of data has been collected from the distinguished authorities directly. Necessary tools or software to analyze data for whole through the study are: ArcGIS 10.8, QGIS 3.26, Microsoft Excel and Google earth.

2.3 Study Area

Among the total 64 districts, there are 19 coastal districts in Bangladesh. Among those, 16 districts have been selected for the study as southern and coastal part of Bangladesh. These districts are selected because these are the most vulnerable to cyclones according to Emergency Response Preparedness Plan-2014. The study area has been divided into 03 parts to analyze GIS based accessibility. It's divided basically considering as cluster system as follows-

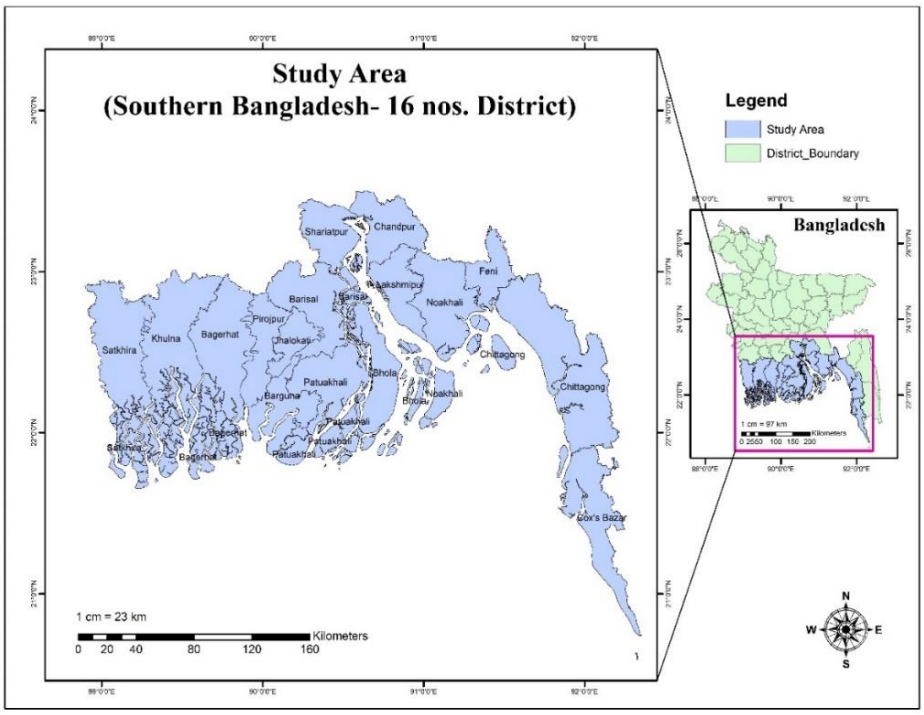


Figure 2. Study Area (Data Source: BBS, 2020)

(a) Study area i: Chattogram, Cox's Bazar, Feni, Lakshimpur, Noakhali (b) Study area ii: Barisal, Barguna, Jhalokathi, Patuakhali, Pirojpur, Bhola and (c) Study area iii: Khulna, Satkhira, Sariatpur, Chandpur, Bagerhat

2.4 Data Processing and analysis

a) Two-step Floating Catchment Area (2SFCA) Method

It rehearses the process of 'floating catchment' twice (once on supply locations and once on demand locations) and is therefore intimated to as the two-step floating catchment area (2SFCA) method. The 2SFCA method was developed by Luo and Wang (2003). It measures spatial accessibility as a ratio of provider to population, combining two steps:

Step 1 (CS catchment): For each cyclone shelter, sum all populations that lay within a threshold distance (d_{max} = 1.5 km) and calculate the population-to-provider ratio, which represents in the following eq. (1)

$$R_j = \frac{S_j}{\Sigma_{k\in\{d_{kj}\le d_0\}} P_k} \qquad (1)$$

Where, P_k is the population at location k whose centroid falls within catchment j ($d_{kj} \le d_0$), S_j is the no. of shelters at location j and d_{kj} is the travel distance between k and j.

Step 2 (population catchment): For each population catchment (unions in this study), find all services that fall within a threshold distance (d_{max}) and sum the population-to-provider ratios from step 1 showing in the eq. (2)

$$A_i^F = \sum_{j\in\{d_{ij}\le d_0\}} R_j = \sum_{j\in\{d_{ij}\le d_0\}} \frac{S_j}{\Sigma_{k\in\{d_{ij}\le d_0\}} P_k} \qquad (2)$$

Where, A_i^F represents the accessibility of population at location i, R_j is the CS-to-population ratio at CS location j whose centroid falls within the catchment centered at population location i ($d_{ij} \le d_0$) and d_{ij} is the travel time

between i and j. A larger value of A^F_i indicates better access to cyclone shelters at that population location.

b) Steps for GIS analysis are as follows-

i) Making Distance dataset in ARCGIS Network Analyst Tool.

ii) Calculating Shortest distance from upazila centroid to CS and determining Composite Accessibility Index (CAI) by 2SFCA.

iii) Creating a Choropleth Map showing upazila accessibility to CS.

iv) Natural Breaks has been used for data classification.

In the 2SFCA method, accessibility within a threshold distance is the same and out of this catchment accessibility is zero. A sample calculation for a circle of threshold radius is given below:

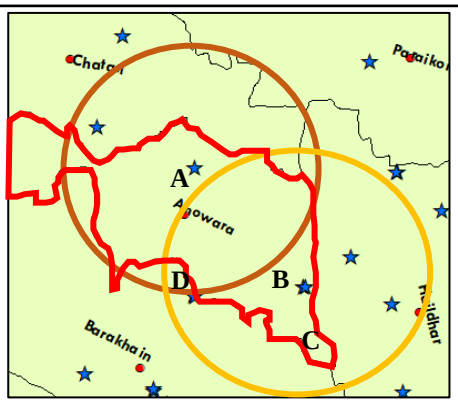


Figure 3. Sample calculation of 2SFCA

Step 01:

R_A = (1600/14060) = 0.113

R_B = (1200/14060+ 22,000) = 0.033

R_C = 450/(14,060+ 22,690) = 0.0122

R_D = 1,500/ (14,060+18,000) = 0.046

Step 02:

Ai^F = (0.113+ 0.033+ 0.0122+ 0.046) * 100 = 20.42

$$Step\ 01:\ R_j = \frac{S_j}{\Sigma_{k\in\{d_{kj}\le d_0\}}P_k}$$

$$Step\ 02:\ A_i^F = \sum_{j\in\{d_{ij}\le d_0\}} R_j = \sum_{j\in\{d_{ij}\le d_0\}} \frac{S_j}{\Sigma_{k\in\{d_{ij}\le d_0\}}P_k}$$

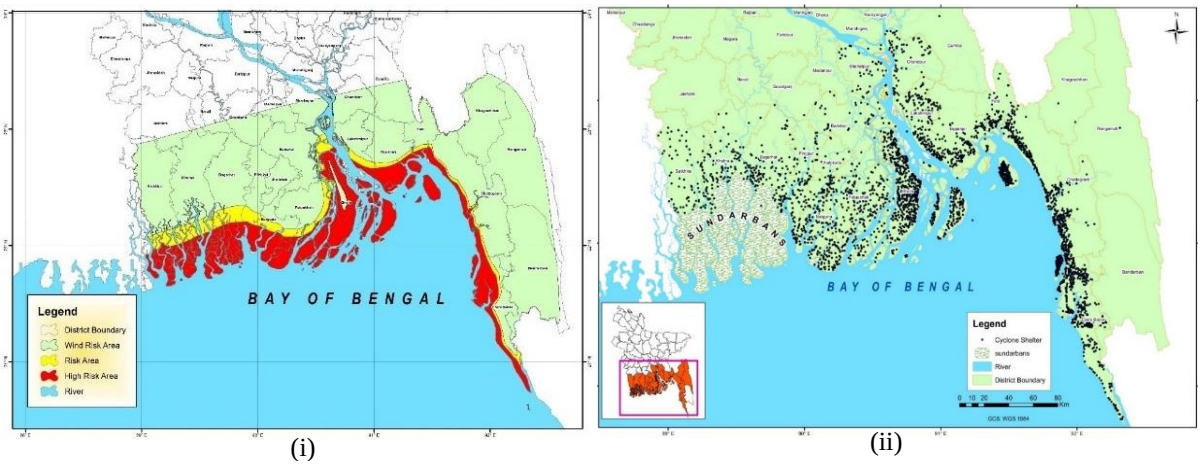
R_j is the accessibility index of specific cyclone shelter.

A^F_i is the composite accessibility index of an Upazila

3 Results and Discussions

From the analysis, it can be summarized as follows:

a) Wind risk (75%), medium risk (8%) and high risk (17%) cyclone prone areas are shown through GIS mapping. Adjacent to coast are most vulnerable. But comparative remote areas are also vulnerable during cyclone as availability of CS is not sufficient. The cyclone shelters are clustered towards the coast (more than 80% of total nos. of CS)

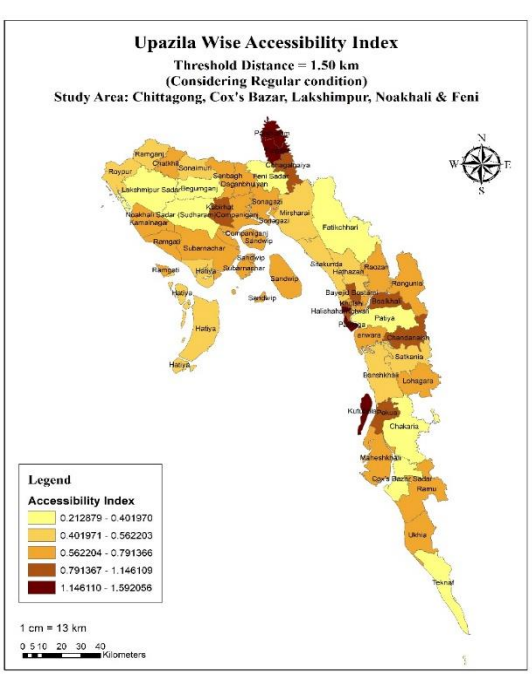


(i) (ii)

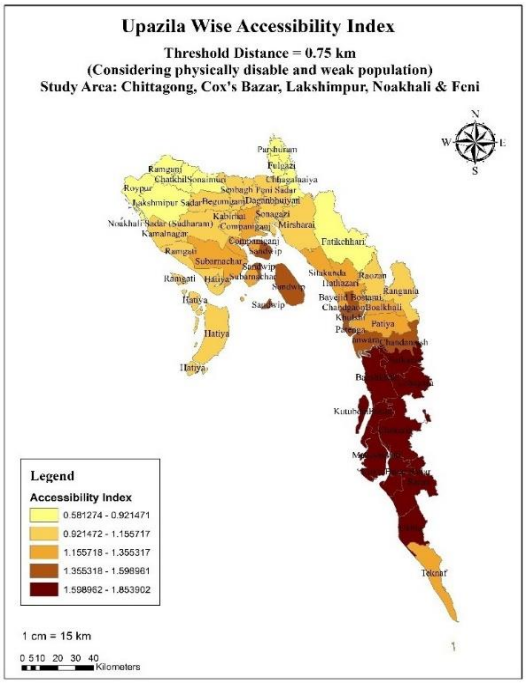
Figure 4. (i) Cyclone prone area (ii) Cyclone shelter location map

b) After GIS based accessibility analysis, it shows from the illustrated map (Figure 5) given below. A few nos. of upazilas (only 05 nos: Halishahar, Pahartali, Patenga,Kutubdia, Parshuram) have higher

accessibility to cyclone shelters. 61 nos. of upazilas have lower accessibility to cyclone shelters for regular case, where only 15 nos. of upazilla for disabled community. Considering for regular case, the population of these upazilas is almost 17,051,817. Another 43 nos. of upazilas have zero accessibility which consist of almost 9,743,890 populations.



i(a)



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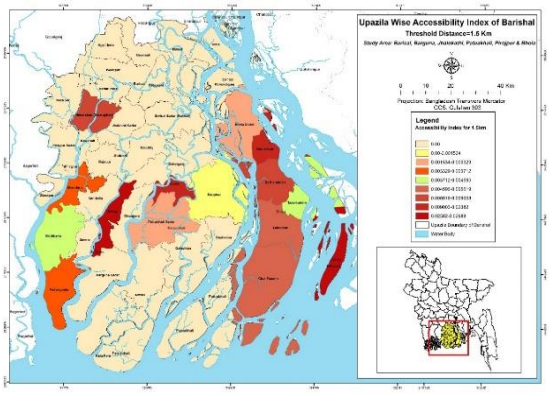
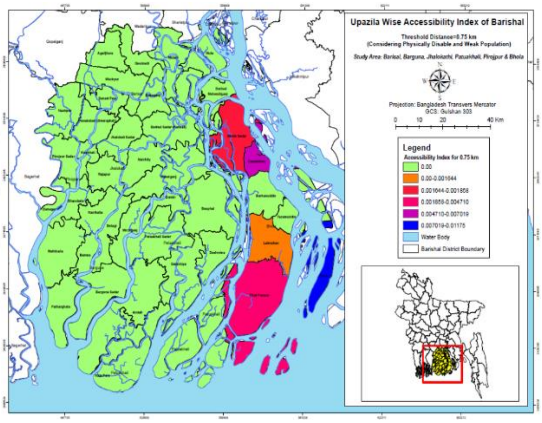
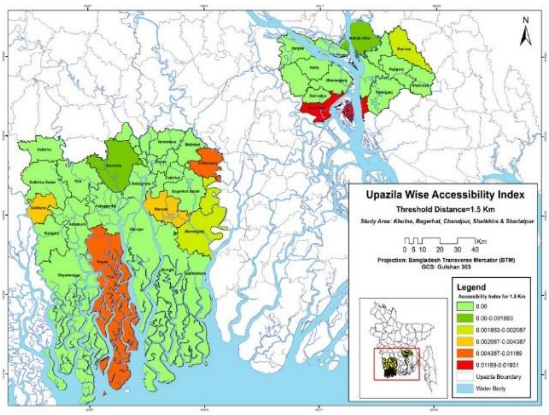


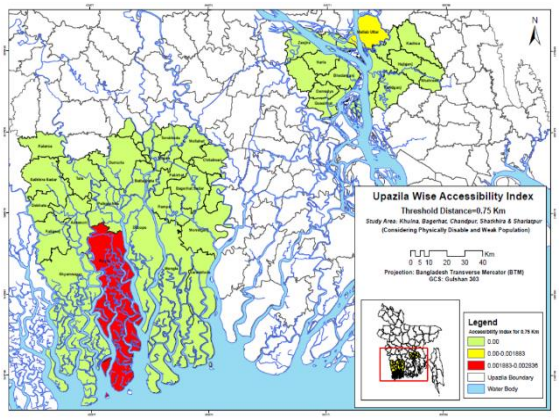
ii(b)



ii(e)



iii(c)



iii(f)

Figure 5. Accessibility Index of Study Area for 1.5km (a, b & c) and 0.75 km (d, e & f)

This community faces a serious destruction during cyclone event. As for disabled community zero accessibility cover almost 65% area, which is more and huge number of disabled community is suffering during cyclone. From BBS data, around 65% of people live either in Kutcha house or in Jhupri house in most coastal area. These people are severely vulnerable to cyclones and adequate cyclone shelters need to be provided in these areas where upazilas are stated and cyclone shelters should be constructed in those areas.

Table 2. Three types of accessibility (Higher, Lower, Zero) of the study areas

Accessibility Index	d = 1.5 km distance for regular case		d = 0.75 km distance for disabled community	
	Nos. of Upazilla	Population	Nos. of Upazila	Area covered
Zero (= 0)	43	36%	62	64.8%
Lower (≤ 1)	61	63%	15	19%
Higher (≥ 1)	5	1%	32	16.2%

4 Conclusion

About sixty-five percent of people in the study area live in either Jhupri house or Kutcha house. These houses are very vulnerable to the cyclone. But the cyclone shelters are not evenly distributed. Some areas are clustered in coastal areas and the remote areas have a fewer number of cyclone shelters. Even, the population density is higher in remote areas where cyclone shelters are very few.

As an emergency facility, cyclone shelters were provided by different agencies in the study areas at different times. Previously, the adjacent areas were given priority to construct the new cyclone shelters. Now from this study, it is clear that about 43 upazilas have zero accessibility to the cyclone shelter. A large number of upazilas have a lower accessibility index and fewer upazilas have the higher accessibility. All these upazilas which have the zero-accessibility index should be given priority to construct new cyclone shelters to protect the vulnerable people from the devastating cyclone. Analysis the lower accessibility, around 37 upazilas accessibility is near about zero, which should be under consideration to build new cyclone shelter.

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