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DELINEATING THE SERVICE AREA OF CYCLONE SHELTER AND VULNERABLE HOUSEHOLDS USING NETWORK ANALYST TOOL: A CASE STUDY ON SOUTHKHALI UNION OF BAGERHAT DISTRICT, BANGLADESH

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Abstract

In Southkhali Union of Bagerhat district in Bangladesh about 47% of the total population is living beyond the service area of cyclone shelters (CS) not only for the carrying capacity of CS but also for the accessibility. Location-allocation tool of Network Analyst tool in ArcGIS determined the service area of each CS in the study area based on its shelter capacity and accessibility. People residing outside the service area of cyclone shelter are highly vulnerable due to low elevation of land and poor housing structure. The location-allocation tool of Network Analyst provided the proper evacuation plan that would identify the shelter location for each household or cluster of population and the evacuation route also. It would also help to find the proper location to build new shelters for unserved community.

Key words: Accessibility, Network analysis, Service area, Vulnerable households, Location-allocation tool

Introduction

Bangladesh is the sixth most disaster prone countries of the world where 97.7% of the total population of 97.1% area are at risk of multiple natural calamities including cyclones (World Bank 2015). Cyclone and storm surge are the most devastating among all the disasters in Bangladesh which devastates lives and properties in coastal areas. Geographic location, the unique natural setting of the country and its tropical monsoon climate make the country more vulnerable to cyclones and storm surges (Paul 2009). Nearest position from equator, warm oceanic temperature, presence of high vertical wind, low pressure areas, easterly wind in the Bay of Bengal are the significant factors that causes to form cyclone. On the other hand, coastal zone is mainly low-lying with 62% of the land having an elevation less than 3 meters and 86% less than 5 meters from the mean sea level (MSL) (CDMP 2009). Since 1960 most of the coastal areas are protected by embankments and polders which protect the coastal communities from tidal surge.

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During the last 100 years, Bangladesh has experienced 53 major cyclones (Ahamed *et al.* 2012). Historically major cyclones hit the coastal areas of the country in 1970, 1991 and 2007. In cyclone SIDR [1](2007), the number of human death was 3,363 and in AILA[2] it was 190 (GoB 2008). It is to be mentioned that Government of Bangladesh (GoB) and NGOs have taken initiatives in coastal areas to reduce the risk of human life and properties. A large number of people who are living outside or near to embankments still are vulnerable to storm surge and cyclone. Frequent attack of cyclone in last 2 or 3 decades and disaster preparedness program of GoB and NGOs raise the awareness level of communities during the disaster period. Though the community people prepared to move, they do not know which cyclone shelter (CS) they should go. As part of disaster preparedness, people should be evacuated to the shelters or safe locations before the cyclone or storm surges stuck. So service area delineation of each CS and determination of the appropriate CS for each house would help to evacuate the people on time.

Accessibility is an attribute of people (and goods) rather than transport modes or service provision, and describes integrated systems from a user viewpoint (Halden *et al.* 2005). There are three primary components that make up accessibility. Accessibility means the easiest or shortest way to move from one place to another. It can be defined as the ease with which activities at one place may be reached from another via a particular travel mode (Liu and Zhu 2003). In the context of health care, accessibility is viewed together with a set of more specific areas of fit between the patient and the health care system-specifically availability, affordability, accommodation and acceptability (Penchansky and Thomas 1981). Measured straight-line distances, driving distances and time method used by Al-Taiar *et al.* (2010) for vaccination facilities development under Yemen and all three measures showed strong association with vaccination of children after adjusting for socio-economic status. Measured distance method used between patient and facility's zip codes in Michigan for patient management Lin *et al.* (2005) where similar differences observed between revealed and potential access in both rural and urban areas. In a word, accessibility can be determined by its route or path of origin to destination and mode of communication which usually better understand with network analysis. Network usually means a set of connected lines. It can represent the river, road, rail line or even telecommunication lines. Network analysis has a strong theoretical basis in the mathematical disciplines of graph theory (Curtin 2013). Network analysis consists of a set of techniques for modeling processes that occur on networks. The network analysis

[1]SIDR a severe tropical cyclone hit Bangladesh on 15 November, 2007.
[2] AILA a severe tropical cyclone hit Bangladesh on 27 May, 2009.

can be able to perform three tasks: locations on networks, routing across networks, and network flow analysis.

Along with the accessibility and communication status, readiness of community to receive a service is very important to determine the boundary of a service area. Parker and Campbell (1998) used calculated network distance for accident and emergency services phenomena and findings suggest that the majority of patients choose medical practices near their home which is geographically closest to their home address. Luo and Wang (2003) developed two-step floating catchment area and gravity based method for primary health care in Chicago. This method was simpler and easier to interpret and used for improving the designation of health professional shortage areas. Couple of studies on people's behavior on moving towards a CS in coastal area of Bangladesh have found that both physical and social barriers may impede their movement. During cyclone, most of the people who were within a range of 1 mile (1.6 km) took safer shelter and all of them have reached there on foot (Paul and Routray 2011). Paul and Routray (2013) found in their study that major causes of refuge in cyclone shelters were poor road communication and also the low capacity of cyclone shelters. Both of the study suggested that during the construction of new CS, maximum coverage should be considered to maximize the coverage of future CS. Eklund and Martensson (2012) used GIS application to analyze accessibility of health services where GIS and network analysis were used to generate different estimations of accessibility based on the existing road network and transport barriers. The study analyzed the service area in three scenarios - worst case, present situation and best case. In the study, worst case considered when all checkpoints, road gates and barriers closed; present situation considered as all checkpoints and some road gates open but barriers closed; best case considered when all checkpoints, road gates and barriers were removed.

Vulnerable households indicate the people living in houses that are exposed to cyclone or storm surge. In other it can be said that the houses which would be damaged in worse level due to weak design and closeness to river or sea. In coastal Bangladesh most of the houses are poorly constructed as the people are living with hardship. To understand the effectiveness of cyclone shelters Quader and Mahbub (2012) conducted a study. The study attempted to determine the appropriate location of cyclone shelter along with evacuation plan for existing CS in coastal area and finally formulate a policy guideline for managing cyclone shelters and locating future shelters. According to the study most of the population is out of shelter coverage.

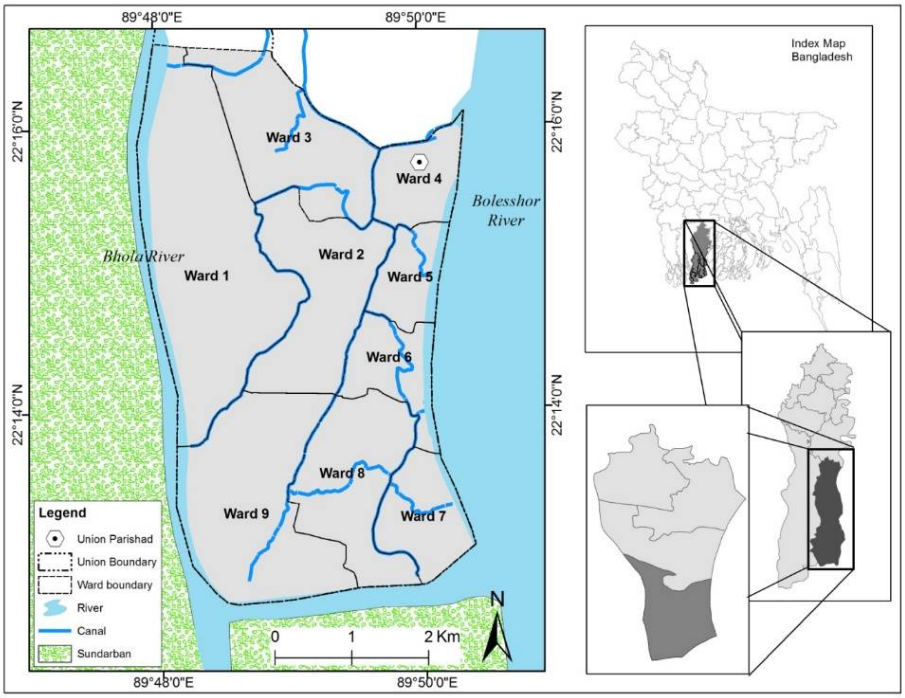
Reviewing cyclone shelter related articles and documents it can be said that very few attempts were made to determine the service area of cyclone shelter. Though CDMP determined the catchment area or service area considering population distribution uniformly in the ground and also not considering physical barriers i.e. canal, pond or crop land etc. This particular paper tries to delineate the boundary of each CS according to carrying capacity of each CS, household level population and detail road network data were analyzed. GIS techniques have the capability to determine the service area of cyclone shelter. The study demonstrated how network analysis of GIS resolves the service area of a CS in capacity constraints and physical barriers. GIS Networks are widely used for usually two kinds of modeling (transportation network and utility network). Network analyst can simply determine the quickest way to reach from one point to another. Location-allocation analysis, a tool in the ArcGIS Network Analyst extension, determines an optimal location for one or more facilities that will service demand from the surrounding population. The major objectives of this study were to:

- delineate the service area of each CS based on its accessibility and capacity,
- find out the nearest accessible CS from each settlement and
- identify the vulnerable households which are beyond the service area of CS.

Profiling study area

Southkhali Union is located in Sarankhola Upazila of Bagerhat District. The union is surrounded on the north by the Royenda Union, on the south by the Sundarbans, on the east by the Baleswar River and on the west by Bhola River and also the Sundarbans. The area is located between 89°48'01"E and 89°50'30"E longitude and 22°17'01"N and 22°13'30"N latitude. The total area of the union is 36.88 sq. km. There are many canals flowing over the villages. According to the Census 2011, the total population of the Union was 24,980 (BBS2011). The economy of Southkhali Union is predominantly agricultural. Its economy is also dependent on the Sundarbans, rivers and Bay of Bengal. The literacy rate in this Union is 54.75%. About 24% people live under the poverty line (BBS 2011). While only 7.26 % households are connected with electricity. The elevation of the Union varies from 1 - 3 m above the mean sea level (MSL). This Union experienced hazard in different times. Cyclone and flood are common hazards in the study area. People of this Union are affected severely by cyclone SIDR and AILA. There are 27 CSs in 23 locations. The total capacity of cyclone shelter is 11,050. Among the 27 CSs, LGED (Local Government Engineering Department) have made 13 CSs. A leading NGO Karitas has made five cyclone shelters and Ashroy Foundation constructed three cyclone shelters. Other cyclone shelters were constructed by World Bank, BRAC, Islamic

Relief, Prodipon, Shusilon and Bangladesh Army. Among the cyclone shelters, 22 shelters have management committees. Community and NGO are the members of the committee. In the study area, total length of road network is 89.36 kilometers. Most of the roads are *katcha*. The percentages of pucca, herringbone and *katcha* road are, respectively 9.3, 24.22 and 66.44%. Southkhali Union is one of the most vulnerable Union because of its low elevation, exposure to the mighty Boleswar River and poor communication with the Upazila headquarter. Sarankhola was worse victim of cyclone SIDR as the highest number of people killed in this Union among the Unions. Considering these issues, Southkhali Union was selected as our study area.



Source: LGED & Field Survey, 2014.

Fig. 1. Southkhali Union (Study area).

Methodology

In case of CS route only road network would be considered as because during a cyclone all other communication are not useable. Network analysis could measure the accessibility of a particular service or a point from another point. Locational barrier like

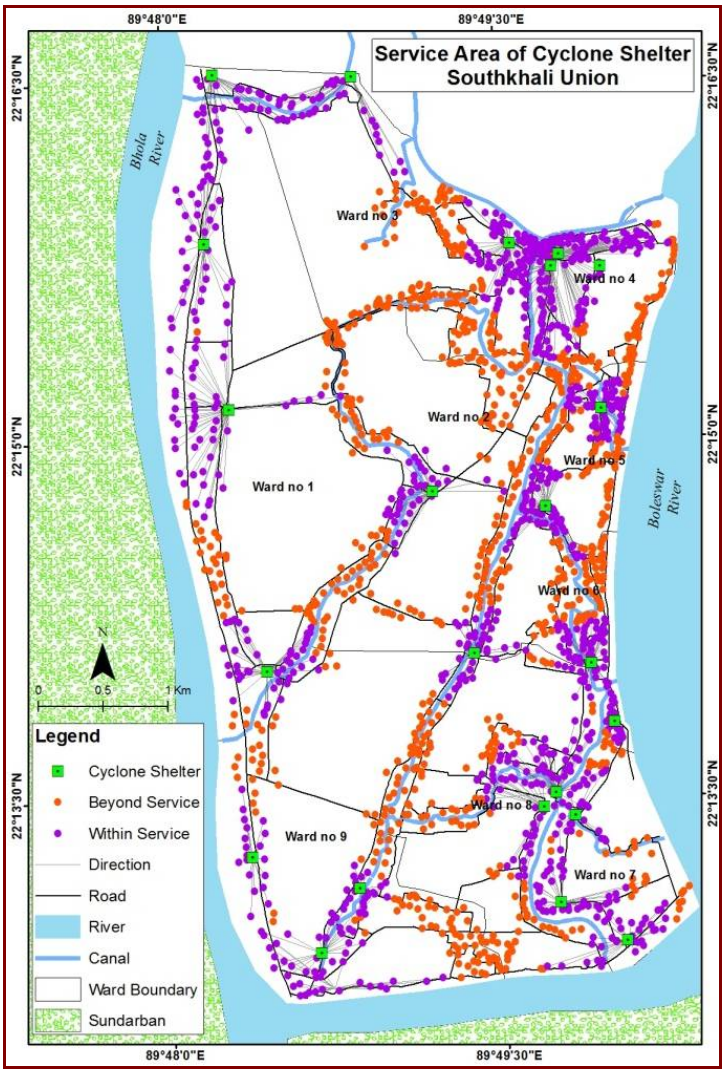
river is considered as a contributing factor towards dithering in response to cyclone warnings in the study.

Source: Field Survey, 2014.

Fig. 2. Settlement pattern of the study area.

Data collection: Data have been collected from both primary and secondary sources. Different tools and techniques were applied to collect data (primary data) from field survey. Location of cyclone shelter, household and other important structures were collected from GPS survey. Detail road network along with the physical condition (Pucca, herringbone or Katcha) recorded through GPS survey using tracking option. To identify the important features like pond, canal, bridge with its physical conditions

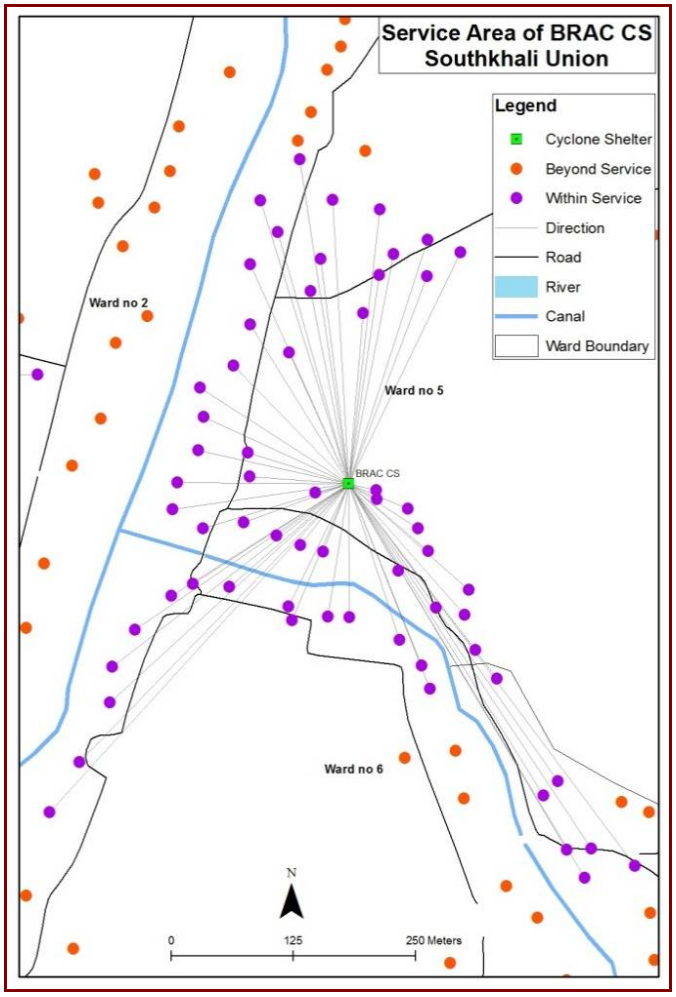
Google earth Image was used. Other qualitative information i.e. capacity of cyclone shelters, condition, water and sanitation facilities of cyclone shelters etc. were collected from secondary sources (i.e. NGOs, Red crescent, related government offices). Administrative boundary of the study area collected from Local Government Engineering Department (LGED). Information about house like owner name, number of family members, housing structure etc. was collected through field survey.



Source: Field Survey, 2014.

Fig. 3. Service area of all cyclone shelters in the study area.

Georeferencing (data preprocessing) and digitizing: To prepare a spatial database (shapefiles and geodatabase) GIS and statistical software were deployed. In the first step value from the GPS are downloaded to PC using DNRGPS software that convert the GPX file to shapefile format. To digitize the physical features of the area satellite image was downloaded in JPEG format from Google earth which was not geographically referenced. Those images were georeferenced using georeferencing tools of ArcGIS10.3.



Source: Field Survey, 2014.

Fig. 4. Service area of BRAC CS.

Information of images was captured through digitization process. The projected value is "WGS 1984 UTM Zone 45N". On the other hand, the information collected in checklist were input into PC using MS excel. Finally the tabular information joined with the shapefile based on location. After completion of data capture, all the shape files were converted to geodatabase. The primary purpose for organizing related feature classes into a common dataset was for building a topology and a network dataset.

Data analysis: The data analysis was integrated with network analysis and statistical analysis for delineating service area through various datasets. Location-allocation tool of network analyst was used to resolve the service area. Location-allocation helps to choose which facilities from a set of facilities to operate based on their potential interaction with demand points. To identify the vulnerable population in case of extreme cyclone event only CS were considered as safe location.

Results and Discussion

The settlement pattern of the study area is linear. Linear settlement patterns are generally associated with linear feature, either natural or constructed. Roads and rivers have influenced on settlement pattern. Fig. 2 shows that in the study area, Settlements are growing along the roads or the river/canal to avail better communication and availability of water. Most of the fishermen are living in just beside the eastern embankment, and along the western embankment, most of the people collect resources from Sundarbans.

In the study area, population concentration is increased from southern to northern direction. The highest density of population is found in Ward nos. 4 and 6.

Service area: When signal no. 6 is given, people must take safe shelter. In this worse scenario, any kind of transport cannot be used without walking. Several studies reveal that in extreme situation usually people are notable to or willing to walk more than 30 minutes. In this study, more than 80% inhabitants opined that more than 30 minutes is not possible for them to walk during cyclone. It is calculated that in 30 minutes they are able to cover 1 km. So the travel time is considered as 2 km per hour in an average. Capacity of CS is also an important factor in this analysis. Because all the people in 1 kilometer distance may not take shelter in cyclone shelter due to low capacity. After analyzing the data, it was found that 52.73% of total people can be evacuated during an emergency in cyclone shelter.

Vulnerable households: In the study area, most of the houses are Katcha. But the number of tinshed and Jhupri is also high. About 59.12 per cent of total settlement is Katcha. The

percentage of Jhupri, tinshed, semi-Pucca and Pucca are 2.84, 28.67, 4.27 and 5.08, respectively. In this study, vulnerable households are those which are beyond the service area where nearly 10,000 people resided. Housing structure is an important factor to analyze vulnerability. Figs. 3 and 4 showed the location of vulnerable households. The study finds that overwhelming majority (93%) of vulnerable households are living in Katcha, tin shed or Jhupri houses. From the previous experience of cyclone, the southern population of the union are the most vulnerable. The study found that insufficient and poor communication system make the situation worse. A cluster of people in western part are living outside the embankment are living dangerously. From the experience of SIDR most vulnerable households are located just beside the embankment of Boleswar River. Analysis showed that a large portion of vulnerable households are located inside the embankment area.

Conclusion and recommendation: In this study, the assessment of CS's service area was based on allocation of population in different shelters for evacuation and people's accessibility based on communication network. Using GIS and RS techniques, the distribution of households, location of CSs and communication networks were recorded. Unique ID was developed for each household and also for the CS. The location-allocation tool of ArcGIS determined the service area of CSs. Designated household with unique ID was assigned for particular CS. According to the study, about 47% of the total population is living beyond the service area of cyclone shelters (CS) not only for the carrying capacity of CS but also for the accessibility. So it can be said that nearly half of the total population is vulnerable to cyclone and storm surge. From field survey it is found that most of the people do not know which particular shelter would be more accessible or suitable for them. On the other hand, volunteers do not have appropriate emergency evacuation plan.

Using GIS for evacuation plan and establishment of new cyclone shelter would reduce the risk of coastal communities. Location-allocation tool of ArcGIS would provide the appropriate location for new shelters. Proper evacuation plan is essential during an emergency which needs a detailed database of population, household location, infrastructures including road network and other important utilities. During Household Census GPS location of each household can be recorded which will be linked with population afterward. The system has been organized in such a way that, any changes, addition, removal or increasing of shelter capacity could be done very easily at Upazila level by Upazila statistics office. Local Government Engineering Department (LGED) collects infrastructural information at regular basis. The Disaster Management Information Centre (DMIC) under the Ministry of Disaster Management (MoDM) can

compile both databases in GIS format. From the database it is possible to determine the service area of CSs is essential for evacuation planning and shelter management practices. According to the service area generated by location allocation tool of ArcGIS, DMIC would prepare the evacuation plan for emergencies and circulate the plan at Upazila level. Upazila office will implement the plan at local level. Thus the GIS would be the best practiced tool for saving life from cyclone and storm surge.

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