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Identification of inaccessible roads and vulnerable settlements in Dhaka city for search and rescue operation using ArcGIS tools

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Abstract

Dhaka is the most populated and congested city in Bangladesh. Indiscriminate and unplanned urbanization has made the city more vulnerable and risk-prone for rescue operation in any disasters. This study focuses on the inaccessible roads and vulnerable areas of Dhaka city during search and rescue operations. Four important locations of Dhaka city have been selected to analyze the accessibility of emergency rescue vehicle in the road network. The most vulnerable areas and houses for rescue activities of any kind of hazards depending on the narrow roads, networking system and road congestion has been identified using ArcGIS. Among four locations, maximum of 60% houses of old Dhaka has been found vulnerable for any types of hazards. In addition, the traffic volume analysis is performed for the most vulnerable area and thus vulnerable houses have been identified on the basis of maximum congestion. By considering all the findings, urban planners should make an initiative to develop a quick response as the city currently lacks sustainable and effective disaster management plans.

Keywords: Inaccessible road, ArcGIS, vulnerable house, search and rescue operation.

1. Introduction

Bangladesh is the eighth largest country by population (Rahman & Rabbani 2007). Dhaka is one of the most overcrowded cities in the world with a population of 162.9 million and only with rudimentary emergency service (Islam et al. 2017). Due to the concentration of job facilities and other investments, Dhaka city has been experiencing a population growth of 6.5% each year (Ferdous & Rahman 2013). The city is also identified as an earthquake risk prone city due to geological and geomorphological formation, indiscriminate and unplanned construction of buildings. Some buildings in older part of Dhaka city collapsed even without any earthquake, so it is beyond imagination what will happen during a moderate earthquake. In June 2004 a five storied building collapsed in Sakharibazaar which killed 19 people and injured several others among its 30 inhabitants.

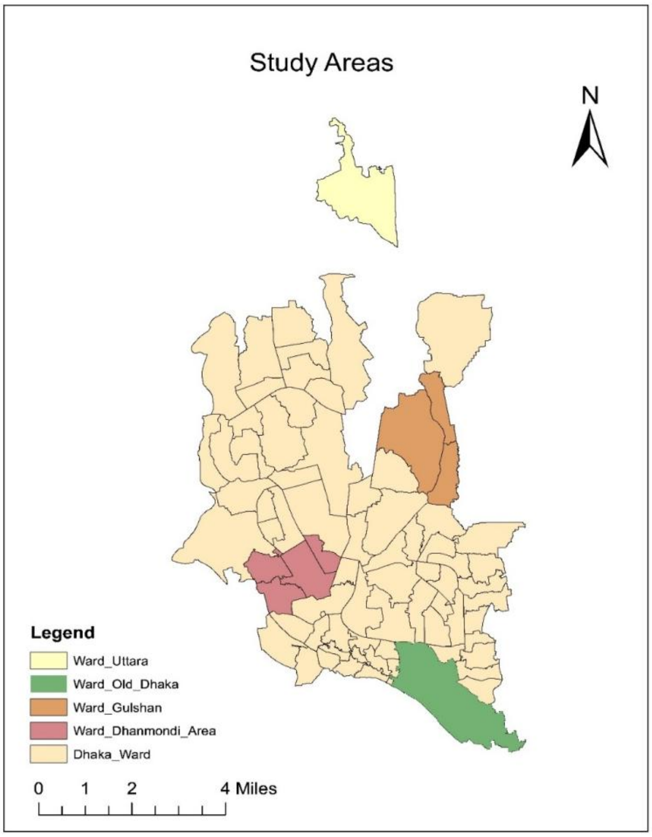


Fig. 1. Map of study area.

Due to poor construction quality of buildings, in April 2005 a nine storied factory building collapsed in Savar that killed 70 people and injuring around 200 others among its 300 workers and in February 2006, a five storied under construction building collapsed in Tejgaon that killed 18 and injured 40 workers. On 24 April 2013, a nine storied building ‘Rana Plaza’ collapsed in Savar is considered one of the worst man made hazard killing 1127 people (Barua and Ansary 2017). If a 6-magnitude earthquake shakes Dhaka originating from it’s beneath some 78,323 buildings will be destroyed completely with aneconomicloss of US $1075million (CDMP). So, if any disaster takes place like Nimtoli fire incident and Rana Plaza, the effect and damages will be terrific (Rahman et al. 2015).

The risk in urban center is complex due to unplanned urbanization and development in high risk zones. So their effects demand a prompt response from decision makers and the population, through the proper management of the emergency situations (Waugh & Streib 2006).In emergency situations, the key element is rapid accessibility to places where possible casualties may be located. Timely intervention within the first two hours is critical in saving the wounded and in determining the safest access routes for specific equipment proves essential. In general, natural disaster management includes actions that are particularly important for communities vulnerable to such events, which lead to the development of impact scenarios before the natural hazards occur (Blaikieet al. 2004). In this sense, GIS techniques may be particularly useful in developing decision-making scenarios for potential earthquake disasters. Urban vulnerability analysis using spatio-temporal information is increasingly used by urban planners and policy makers to anticipate and prevent catastrophic human disasters.

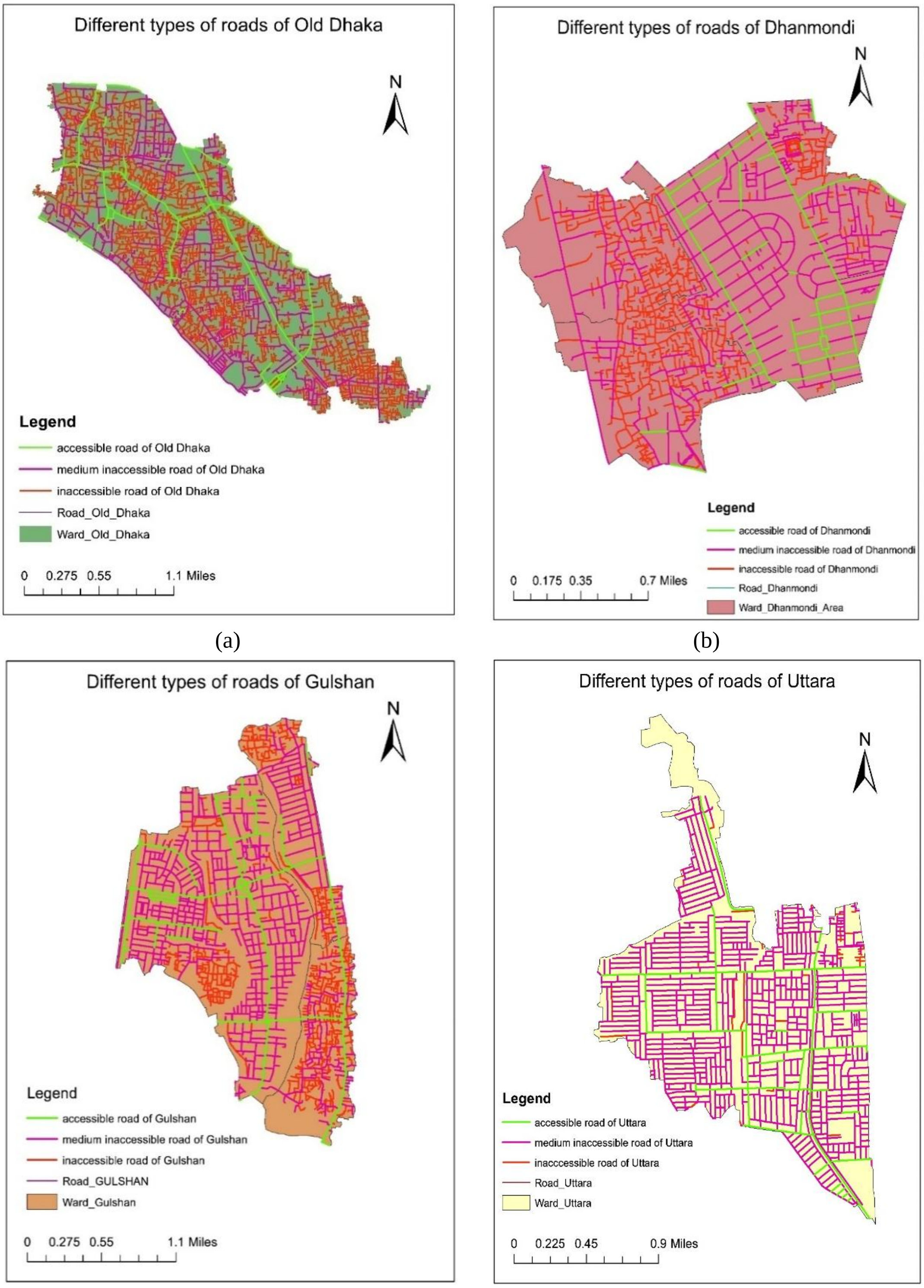


Fig. 2. Different types of roads in study areas (a) Old Dhaka (b) Dhanmondi (c) Gulshan (d) Uttara.

Over the past two and half decades, the integrated use of geographic information systems (GIS), global positioning systems (GPS), and remote sensing has become instrumental in addressing urban vulnerabilities at the local, national, and international levels (Alexander and Smith 1993; Rashed and Weeks 2002; Wu and Webster 2000 ; Zuo and Chen 2009). Using these tools to analyze the landscape, researchers have identified numerous urban vulnerabilities resulting from a lack of emergency vehicular accesses and open spaces. To help remedy this situation, this paper analyzes spatial arrangements and road types, road networks and vehicular densities for different study areas in Dhaka city.

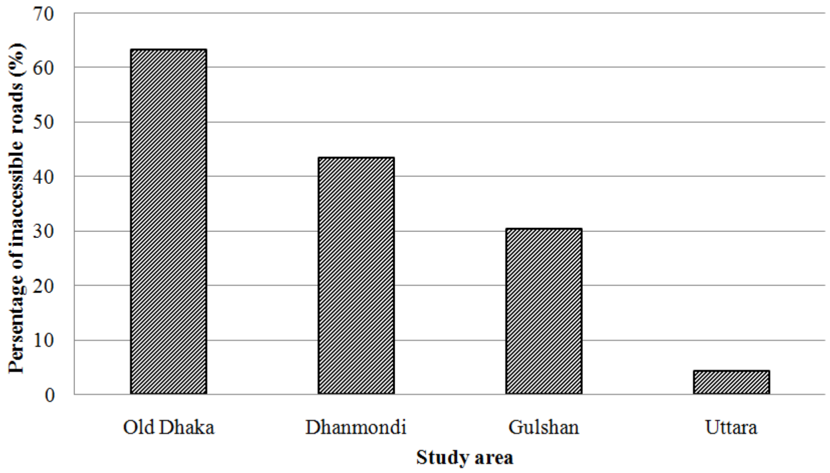


Fig. 3. Percentages of inaccessible rods of the different study areas.

Rigorous literature review is required for such a huge scale of disaster and the real road network. Although there is some related work that has been done on a smaller scale, extensive research is rare specially using GIS tool. Research has identified a mix of urban vulnerabilities (Kaplan 1996; Richardson 1994).Some researchers have used simulation methods to view the roles of these ensembles in urban amenities (Torrens2006) while other researchers have taken a theoretical approach to define vulnerability damage or injury because of biophysical factors. Rasheed and Week (2003) relate urban vulnerabilities to natural hazards such as earthquakes, and to human behavioral adaptations; and argue that urban vulnerabilities become intertwined with socioeconomic systems. Urban ensembles such as buildings, streets, bridges, public and industrial areas, roofs, facades, open and green spaces, are obviously highly interrelated, but they can be visualized using design plans, drawings, and video data records. Various layers such as houses, critical facilities, industrial sectors, and others can be overlaid together for visualization and subsequent spatial analysis. Researchers often apply spatial, multi-criteria approaches using spatial objects to examine the quality of life, urban conditions and aesthetic structures, because these “urban ensembles” represent dynamic phenomena involving people not only as users but also as victims, contributors, and modifiers (Alexander 2000; Burton et al. 1978; Allen 2003; Koeninger and Bartel 1998; Mileti 1999;Menoni, 2001). Remote sensing and GIS technologies have proved to be especially-helpful tools to identify vulnerable and/or non-vulnerable ensembles across urban landscapes. Alexander and Smith (1993) used GIS to locate areas within seismic zones and analyzed the degrees of urban vulnerability they posed. Rashed and Weeks (2002) explained how a society might be subjected to various hazards because of its own actions, such as construction of unaesthetic and congested structures such as substandard buildings and narrow roads.A disaster management cycle (Alexander, 2000) or an emergency management system includes four distinct phases: mitigation, preparedness, response and recovery. Geospatial techniques can be effectively used in any of these phases for the successful management of natural disasters (Ebert et al., 2009). Non-structural solutions such as evacuation planning are becoming an emerging issue due to their effectiveness in reducing disaster risk and vulnerability (Cova, 1999).

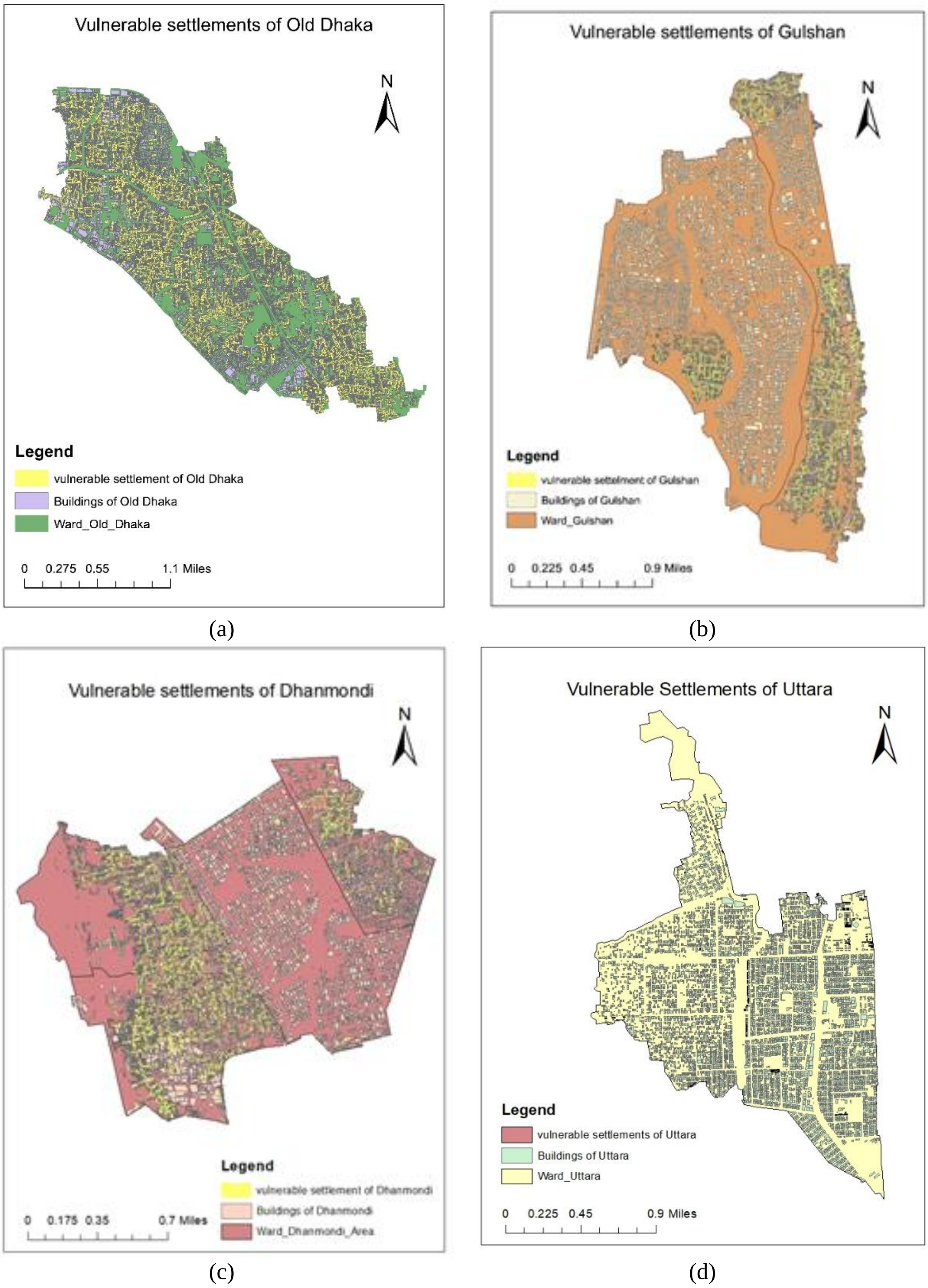


Fig. 4. Vulnerable settlements of study areas (a) Old Dhaka (b) Dhanmondi (c) Gulshan (d) Uttara.

Various methods, including macro-simulation, meso-simulation and micro-simulation models, have been applied to a range of hazards. For example, microscopic traffic simulation linked with a GIS was used to test the neighbourhood evacuation plan in the urban–rural interface in Salt Lake City, Utah (Cova and Johnso 2002). Dunn (1992) used network algorithms within a GIS to identify alternative evacuation routes in an emergency. Similarly, Cova and Church (1997) developed a method to examine potential evacuation difficulties in the transportation network during a simulated disaster in Santa Barbara, California. Chen and Zhan (2008) demonstrates am agent based simultaneous and staged evacuation strategies in the city of San Marcos, Texas. That study further remarks that, although certain staged evacuation strategies do help to reduce the total evacuation time, traffic congestion during a mass evacuation could be a serious issue. It should be noted that the majority of the micro-simulation work is based on a network data model, usually in a small area, to determine the total clearance time needed for evacuees to leave during an approaching disaster. Additionally, agent-based models could be difficult to implement in densely populated areas (Fang et al. 2003). Because Dhaka is densely populated and there is no up to date road network data, agent-based modeling is very difficult task to carry out.

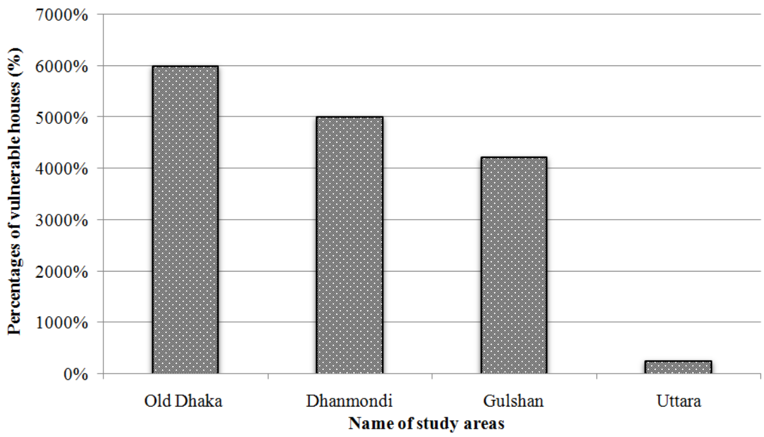


Fig. 5. Percentages of vulnerable houses in different study areas.

Very few researches have been found focusing on the inaccessible roads and vulnerable areas of Dhaka city during search and rescue operations. This study focused to look at the unplanned urban city context in old Dhaka, Dhanmondi, Gulshan and Uttara to analyze the accessibility of emergency rescue vehicle in the road network of selected study areas of Dhaka, to identify the most vulnerable areas and houses of Dhaka for rescue activities of any kind of hazards depending on the narrow roads, networking system and road congestion.

2. Profile of the study area

Researcher selected four study areas (Figure 1)) for the purpose of this research- Gulshan, Uttara, Old Dhaka and Dhanmondi. The cause of selecting these 4 areas is that all these areas can represent the all types of road condition in Bangladesh, especially the Dhaka city.

2.1 Gulshan

Gulshan is one of the most popular and developed area in Dhaka. Though it was a residential area but with the pace of time many commercial buildings are also established here. Gulshan is a commercial and residential area, originally meant for offices and embassies of diplomatic missions, as well as residences. The Gulshan Thana comprises an area of 53.59 km², consisting of three wards (72, 73 and 74), 37 mouzas and 20 villages, including Gulshan Model Town, consisting of Gulshan circle 1 and circle 2, Banani Model Town, Baridhara Diplomatic Zone, and Mohakhali. 50% of the area is residential, 20% commercial, and 12% is diplomatic area. 18% land in Gulshan consists of other areas, including slums, of which the biggest is the Karail slum and Gulshan Lake. This area is comparatively planned.

2.2 Dhanmondi

Dhanmondi is a planned residential area of Dhaka city. Initially, DIT (RAJUK from 1987) kept Dhanmondi plots exclusively residential and did not allow use of any plot or house for commercial purposes. But in response to tremendous pressure on city land after 1972, the rule was relaxed to the point of virtual non-application. At present, nearly half the plots of Dhanmondi Residential Area are used for non-residential purposes, which include shops and stores, government and semi-government offices, show rooms and warehouses of business firms, NGO offices and clinics, educational institutions and even manufacturing units. Consequently, the social character of the area has changed very drastically. Socially and economically, Dhanmondi has now become a multi-purpose area. Socially, the non-residential elements of Dhanmondi are now much larger and much more influential than the owner-occupiers and resident tenants. Thus the original plan of keeping Dhanmondi a purely residential area has now given way to free play of market forces.

2.3 Old Dhaka

The southern portion of Dhaka, located along the northern bank of the Buriganga river, is traditionally called "Old Dhaka" and the rest of the city forms what is termed New Dhaka. Old Dhaka is much smaller in size than New Dhaka. Old Dhaka consists of 8 Thanas which includes Hazaribagh, Lalbagh, Chowkbazar, Bangsal, Kotwali (Dhaka Sadar), Wari, Sutrapur and Gendaria. Old Dhaka is under the administration of Dhaka South City Corporation. Old Dhaka is bounded by the areas of Mohammadpur on the west, Dhanmondi, New Market, Shahbagh, Ramna, Motijheel and Sabujbagh on the north, Jatrabari and Shyampur on the east, adding also Kamrangir Char Thana and Keraniganj Upazila on the south. The old city covers an area of 284.3 acres with a population of 8,87,000. The area is home to 15% of the total population of urban Dhaka while occupying only 7% of its gross built-up area (DMDP, 1995–2015, Vol ll). Most parts of the old Dhaka are undergoing gradual physical deterioration with the pace of time. The scarcity of open spaces, coupled with the high plot coverage, limits the scope of recreational, and social gathering places for cultural activities. The socio-cultural characteristics of the old Dhaka have also undergone changes. Historic buildings and lands have been subdivided for multiple families, densities have risen exponentially, and new settlements are constructing without taking any special consideration of the historic settlements.

2.4 Uttara

Uttara is planned by RAJUK and divided into 14 sectors, starting from sector 1 to sector 14. The northern part of Dhaka. At the 2001 Bangladesh census, Uttara had a population of 345,097 with an area of 36.91 km^2.The total residential area is far from the congestion and pollution of Dhaka. Uttara is comparatively new area and well planned.

3. Data collection

Data collection is a vital part of the research which has been carried out from both primary and secondary sources. Primary data have been collected from observing through Google Maps and Google Earth whereas the secondary data have been collected in form of hard copies and shape files from different sources, like Bangladesh Fire Service and Civil Defense (BFSCD), Department of Disaster Management(DDM), Bangladesh.

3.1 Primary data collection

The research is mainly based on both primary and secondary data. The primary data were collected by manual process. By observing the Google maps for three different times of a day primary data were collected. And by Google earth locations of hospitals and fire stations are collected.

3.2 Secondary data collection

For this research shape files of area boundary of the study area, roads and building of the study areas were collected from DDM (Comprehensive Disaster Management Program, CDMP-2). Rescue vehicles size chart was collected from BFSCD.

4. Methodology

Vulnerable settlements of four different areas (Dhanmondi, Gulshan, Old Dhaka and Uttara) of Dhaka city were identified considering the road width criteria and after that most vulnerable area was further analyzed by the criteria of traffic volume and congestion of that area. In case of analysis considering road width, ArcGIS 10.1 is used to classify all of the roads of the study areas into different classes. Shape files of area boundary, roads and buildings are used for ArcGIS operation. Then from the inaccessible roads vulnerable areas were identified by buffering around it. Lastly, vulnerable houses were identified from the intersect operation between the buffering areas and buildings.

In case of analysis considering traffic volume, at first the most congested roads were identified from google map traffic update for three different peak hours (9-10 am, 1-2 pm and 6-7 pm) of a day. Hospital and fire station locations were also identified from google earth and point shape files were created using their co-ordinates. The road networks were converted into network dataset junctions and network dataset edges by creating a new data set for each of the four areas. Service areas for the hospitals and fire stations were exported as polygon shape files considering a length of one kilometer shortest distance from the facilities and the buildings lying within the service area boundary were identified. The congested roads were buffered to finally identify the vulnerable buildings within the service area boundary of the facilities for three different peak hours of traffic flow.

5. Result and discussion

5.1 Data analysis considering road width

In this research four study areas were selected and all the roads of these areas were analyzed. As we know from fire service and civil defense that minimum 4 meter wide roads can give access to the emergency rescue vehicles. So the roads whose width more than 4 meter are accessible for emergency vehicles. But all of these accessible roads are not risk free at all. Because we all know that in Bangladesh most of the roads don’t have enough footpaths for the pedestrians. Again, where the footpaths are available, almost these are used by the hawkers, beggars and street people. So, the moderate vulnerable roads’ width should be 4 meters to 10 meters. So more than 10 meter wide roads are completely risk free.

At first we only identify the accessible and inaccessible roads of four study areas. Here we actually calculate the road size and ignore the footpaths, pedestrians and opposite side vehicles. Here we only identify the inaccessible roads of each areas and compare them.

The roads of these areas are classified into three classes (Figure 2)

- Inaccessible roads (width < 4m)
- Medium accessible roads (4m < width < 10m)
- Accessible roads (width >10m)

Here we can see from Figure 3 that in old Dhaka about 63.3% roads are inaccessible, 43% roads are inaccessible in Dhanmondi, 30.5% roads are inaccessible in Gulshan and only 4.4%

roads are inaccessible inn Uttara for fire rescue vehicles. So the most vulnerable area among these selected areas is Old Dhaka and the least vulnerable area is Uttara.

5.2 Finding vulnerable houses

As we already find the most vulnerable or highly risky or inaccessible roads of each area, now we can easily find the vulnerable houses of each area. For that we considered to buffer 10 meter around the inaccessible roads as we obtain this concept from Dhaka city corporation office. In this selected area all the houses are highly vulnerable in context of accessibility for different rescue activities.

From the analysis (Figure 4 & Figure 5) we obtained that in Old Dhaka, 26505 houses are vulnerable among 44202 houses. So, 60% houses of old Dhaka are extremely vulnerable. In Uttara, 195 houses are vulnerable among 8182 houses. So here vulnerability becomes 2.4%. In Gulshan, 7361 houses are vulnerable among 17335 houses. Here the vulnerability is 42.4%. In Dhanmondi, 6871 houses are vulnerable among 13902 houses. So, in Dhanmondi 50% houses are vulnerable in context of rescue accessibility. From the analysis, it is found that highest amount of vulnerable houses exists in Old Dhaka and the lowest amount of vulnerable houses remain in Uttara.

5.3 Data analysis considering road congestion and traffic volume

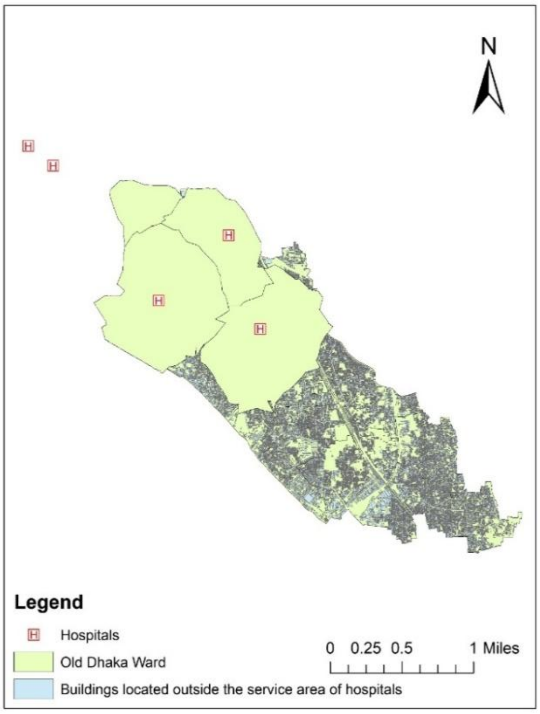
From the all above analysis we can say that Old Dhaka area is the most vulnerable area among the four study areas. Here the amount of accessible roads for rescue activities is very low, so people of this area is more vulnerable in context of search and rescue activities.

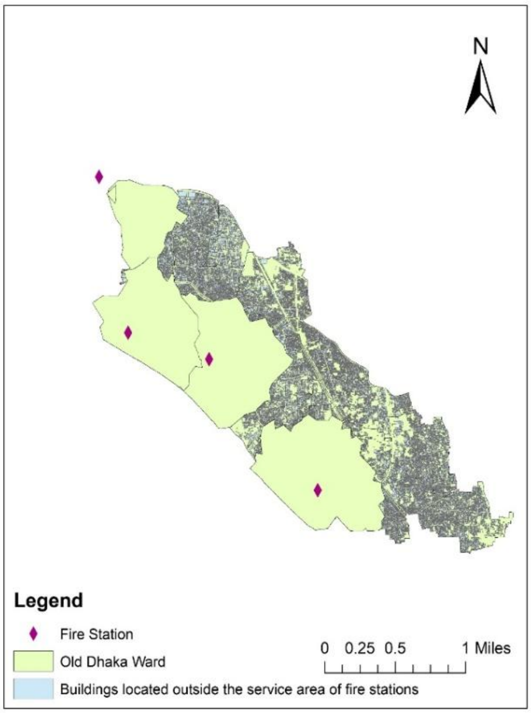
Most congested roads of Old Dhaka were extracted from traffic update of Google maps and processed in ArcGIS to identify the vulnerable houses to emergency services. Three different time periods were used in this context: 9-10 am, 1-2 pm and 6-7 pm. Locations which lacks quick access to sufficient emergency services were also identified considering one kilometer length of service area of the facilities. After the analysis, it is found that the inaccessible roads and vulnerable houses within the service area of hospitals and fire services for three different time of a day (Figure 6). Now it can be decided form Figure 6 that if any accident takes place which houses are in danger due to lack of quick rescue service because of the traffic congestion.

6. Conclusion

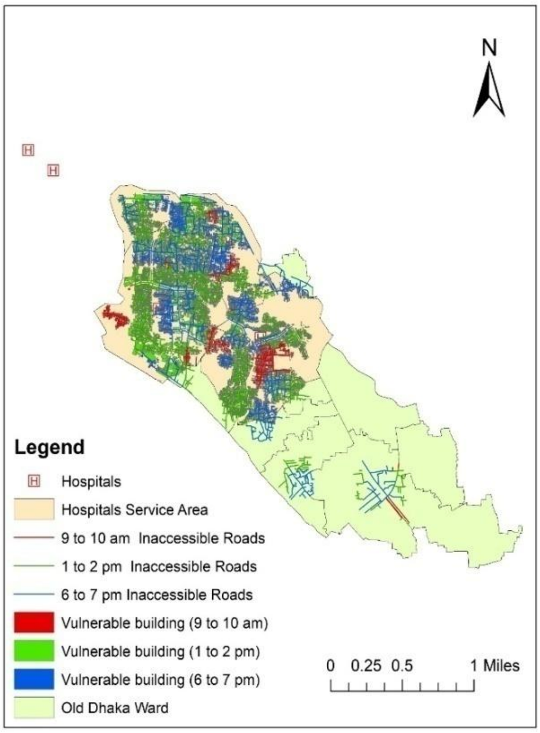
The existing situation of the study areas of Dhaka city is the matter of great concern now. Previous experiences say that if a disaster takes place the loss will be unmanageable like Nimtoli fire incident, Rana Plaza incident etc. Keeping this incident in mind that this study found out the accessible and inaccessible roads for rescue vehicles. Most of the effective rescue vehicles need a considerable space for movement and turning. From this study, it is found that the old Dhaka area is most vulnerable because of its unplanned settlements and narrow roads.

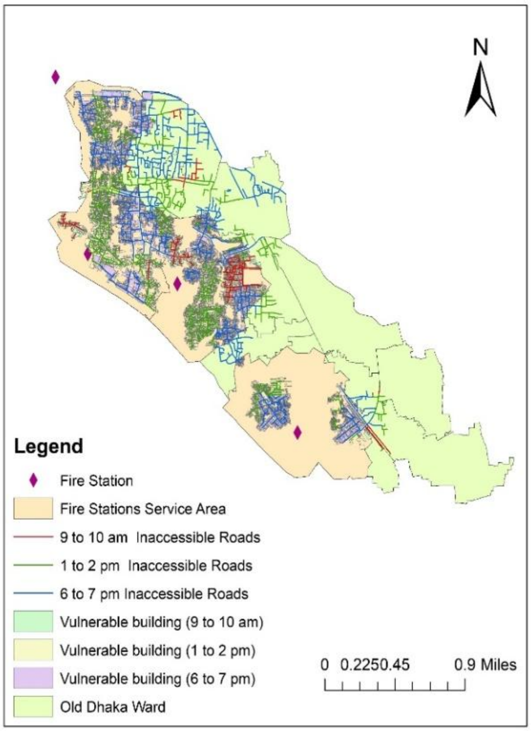
To have the main reason behind the rescue problem, it is necessary to observe the complete picture of exiting vulnerability of an area. One of the major reasons of vulnerability of the study area is poor road network which is practically impossible to improve at present. Design of new road network is strongly recommended as a long term measure. The vulnerable settlement map can be a tool for disaster management authorities for determining the mitigation measures for the buildings and the people can be relocated living in those vulnerable buildings.





(a) (b)





(c) (d)

Fig. 6. Map showing (a) buildings located outside the service area of hospitals (b) outside the service area of fire stations (c) vulnerable buildings within service area of hospitals (d) vulnerable building within service area of fire stations at Old Dhaka.

The study of finding inaccessible roads and vulnerable settlements has been carried out at four small areas of Dhaka City. And the traffic volume analysis is performed only for the most vulnerable area among them. Again this analysis is done to find the vulnerable houses within the service area produced by the researcher. If the methodology is applied for the entire Dhaka city, it will help the policy makers to prioritize special consideration area or hotspot for disaster management. Then it may be a great way to identify the inaccessible roads and vulnerable communities that can be a tool to devise essential steps to rescue people in time.

Despite the limitations listed above, this study could provide information for urban planners and emergency managers in a situation where unchecked urban growth sees thousands of people settling in dangerous locations.

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