Accessibility of emergency rescue vehicle in the road network of Old Dhaka, Bangladesh

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Abstract

A suitable access routes for Bangladesh Fire Service and Civil Defense (BFSCD) vehicles not only significantly contributes to the response immediately aftermath of any disasters, but also has the latent capacity to facilitate recovery in disaster-prone environments. This study attempted to find out a suitable accessibility street network for BFSCD vehicles to ensure a safe and rapid evacuation as part of post disaster management strategy in unplanned urban areas like old Dhaka. This research identifies the narrow road with a average width less than 10 feet and does not have the provision to access the modern fire fighting vehicle. Accessible networks with alternatives were identified from the Geographic Information System (GIS) plotting from each origin to destination. It is seen that the secondary roads that were shown accessible are not at all suitable to use during emergency due to dead traffic (stagnant traffic due to high traffic congestion) and mixture of motorized and non-motorized vehicle. All the roads have poor above head clearance due to unveiled electric wire.

Keywords: Accessibility, emergency management, Evacuation, Shortest path

1. Introduction

Dhaka is one of the most overcrowded cities in the world with a population of 162.9million and only with rudimentary emergency service (World Bank, 2017). Bangladesh is the eighth largest country by population (Rahman &Rabbani, 2007). So, one can imagine the density of population in Bangladesh and its effect if any disaster takes place like Nimtoli fire incident and Rana Plaza (Rahman et al.). Moreover, density of population is more in old Dhaka and the streets are very narrow and congested. Rescue operations are severally affected due to unplanned urbanization and narrow road width in most part of Dhaka. Despite being ill-equipped with fire-fighting tools and with a low workforce to cover the rapidly increasing population in Dhaka, efforts of the fire department of the country during man-made or natural disaster needs to be lauded. Authority of the BFSCD informs that overpopulated areas of the city which has been expanding in unplanned ways are identified as the most inaccessible site. One of the aims of this type of research is to facilitate effective rescue planning for hazard prone urban areas (MoFDM, 2005). These refer to the measures necessary to address the immediate and short-term effects of a disaster, which focus primarily on the actions necessary to save lives and property. However, recovery refers to immediate and long-term holistic regeneration of a community following a disaster. Providing safety of urban environments, theories of rescue planning and urban design share a common interest. The circumstances of the city including its landscape, its buildings and its infrastructure– the components of the urban system could assist responding after a disaster. Anything related to the urban environment as a place for response is either quantitative and extremely specific or so general that it can be of much use (Moehle, 2009). For instance, according to a recent study, how road width is required for egress (Geis, 2000). But, there is very little discussion about the geographic arrangement of road width and shelter locations that might boost adaptation governments to facilitate rescue.

According to the BFSCD, several areas including Shakharibazar, Babubazar, Islampur, Tantibazar, Najirabazar area are most vulnerable to accessibility of fire fighters due to unplanned congested buildings and poor road width with other related attributes. Most effective fire fighting vehicle in BFSCD is near about 12 meter long and 2.5 meter in width. Most of the areas in old Dhaka are too congested and narrow road provision that make its condition worse. Roads of Shakharibazar, Islampur, Nazirabazar of old Dhaka area are too narrow to protect its site from any unusual events occurred because in such cases fire fighting vehicle cannot enter due to lack of width of the roads, overhead clearance, winding nature of the street etc. If any accident occurs in that area trapped people cannot be rescued. In the old Dhaka city, firefighting stations

are located at Palashi, Lalbag, Shadarghat and Siddikbazar (headquarters). However, peoples are now thinking that government or the related authorities of city affairs should immediately take the necessary steps to rapid usurping of city spaces, to curb unimaginable hazards and uncounted causalities in case of any disaster in the near future.

This study focused to look at the unplanned urban city context in old Dhaka. In view of disaster risk index, Dhaka, a rapidly urbanizing south Asian city is placed among the twenty most vulnerable cities of the world. In an unplanned city like Dhaka, an overwhelming demand for building able land continues to surpass needs for urban road networks. Such a pattern of development resulted in a dense urban fabric. However, most vulnerable to disasters remain particularly the old part of Dhaka city due to its unplanned settlements, high population and building density, vulnerable structures due to age of buildings, non-engineered constructions, contiguous layout, and lack of open spaces add up to the problem (Ansary, 2005) (Reja, 2008) (Jahan et al., 2008) (Kamal, 2009).

2. Objectives

- To analyze the accessibility of emergency rescue vehicle in the road network of old Dhaka city
- Find out the shortest path for emergency rescue vehicle.

3. Literature Review

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. The previous papers in the writing on unique vehicle steering and dispatching were displayed in the seventies and were either application-arranged (Wilson and Colvin, 1977) or analytical (Daganzo, 1978; Stein, 1978).

Before the end of the eighties, dynamic vehicle directing increased expanding consideration. Two main considerations clarify this inclination: new improvements in data innovation and the requirement for choice frameworks that could misuse this data to better speak to this present reality. Fascinating review article on unique vehicle steering can be found in Psaraftis (1988), Powell et al. (1995) and Lund et al. (1996).

Since continuous vehicle directing issues are NP hard and fast reaction times are required, correct calculations are not yet fit for taking care of issues of practical sizes (Psaraftis, 1980, 1983; Dial, 1996).This legitimizes the utilization of recreation models continuously situations. Savas (1969) utilized recreation as a device to play out a cost-viability examination of New York's crisis rescue vehicle administrations. He demonstrated that scattering of ambulances enhances the effectiveness of the EMS framework. Larson (1974) utilized the hypercube lining model, which consolidates hypothetical lining hypothesis results and reproduction as an apparatus in dispatching of police watch autos. Brandeau and Larson (1986) developed the utilization of the hypercube model to arrangement of crisis ambulances.

Ignall et al. (1978) utilized reproduction to propose inexact explanatory models to be utilized for police watch and fire operations in New York City. The connection amongst reenactment and systematic models has been additionally examined and assessed in a paper by Shantikumar also, Sargent (1983), in which a few employments of these half and half models are recommended. Zografos et al. (1993) built up a reenactment demonstrate for concentrate the exchange off between turnpike mischance delay and the measure of road crisis reaction armada, and for concentrate the impact of option dispatching systems on the execution of the expressway crisis reaction armada. Goldberg et al. (1990) built up a reproduction show for assessing elective base areas for a crisis reaction armada in Tucson, Arizona.

Kim et al. (2002) considered a dynamic (on the web) truckload directing and booking issue with time windows working in over-soaked conditions. That is, the normal request entry rate surpasses the limit of the armada to give benefit inside adequate time windows, and the entomb entry time between progressive

request demands is short. In this paper, rather than tolerating and serving every one of the requests, they made astute acknowledgment and separating choice techniques that consider framework status and request qualities. It would result be able to in huge operational advantages for framework effectiveness and reaction time. Also use of information routes to support the decision making of evacuating and routing is not considered in literature. The ample of existing Emergency Response Service deal with the following problems.

(a) **Coverage Problem:** Satisfying all calls of services with the minimum vehicles due to the narrow roads.

(b) **Location Problems:** Location of the fire service stations and the affected areas can be obstructed because of the steps roads.

Haghani et al. built up a model to evaluate a constant Emergency Medical Service (EMS) vehicle reaction framework that utilizations continuous travel time data and helps the crisis vehicle dispatchers in allotting reaction vehicles and directing those vehicles through non-congested routes. They utilized the transportation organize, represented by 62 joins and 38 hubs, of Arlington County, VA as the investigation arrange. Data collected from investigation of the current information was utilized to create likelihood thickness capacities portraying the worldly, spatial and need circulation of the demand calls. They utilized recorded travel time data and alteration coefficients to get a normal pinnacle and normal pinnacle travel time between any two hubs i and j. They additionally expected that the recorded normal travel time will deal with all variables that affect travel time, for example, episodes, blockages, and flag controls, and so on. Be that as it may, existing records and authentic information won't help for this situation on account of the dynamic way of the post-catastrophe condition.

4. Profile of the Study Area

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. A list of all wards of the DCC was collected from the office of the Capital Development Authority or Rajdhani UnnayanKartripakhya. 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.

4.1 Present state of spatial morphology of Old Dhaka area

4.1.1 Road Network: The periphery of old Dhaka has wide primary roads, within the city the roads are mainly secondary roads and connector. So, once the flow ingress within the city from outside it is like other side of funnel therefore a bottleneck situation exists. Within the Mahalla like Tantibazar, Shakharibazar only the rickshaw and pedestrian can move. The vehicles that ply on the roads are bus, trucks, mini bus, pick up, human hauler, rickshaw, private car, jeep and horse cart. This well mix creates traffic havoc in old Dhaka. It

is found that the total road length in the DCC area is 3000km. The total area of roads in old part of Dhaka city is very negligible compared to the requirement. The graph shows the amount of road types of Dhaka city below:

4.1.2 Present State: Studies show that at present three distinctive types of urban settlements exist in Dhaka City. These are the indigenous, planned, and informal settlements. The indigenous settlement, commonly called "Old Dhaka", is characterized by its high-density mixed land use pattern, typically ceding the outer layer to commercial uses and retaining the inner part for residential and manufacturing uses. The historic root of Old Dhaka retains the customary features it innate from the past. But with the passage of time the deplorable old Dhaka demands redevelopment to make it livable.

4.1.3 Complex Uses of the Study Area: The researcher found out that unauthorized uses of the buildings in the study area enhanced the vulnerability and complexity. There are mix uses of buildings with residential, commercial, administrative and service related activities. The common practice of the dwellers is to use ground floor for storage of various business goods, shops and upper floor for residing. Almost 90% of the building has the same arrangement. The storage in ground floor is full of inflammable materials which increases the possibility of hazards. The height of the buildings in the study area is low comparing to the other part of the city yet the destruction density remains same due to the congestion of the area. Only 8 % of the building is constructed by the competent engineer. 42% of the dwellers do not know that whether their buildings are constructed by competent engineer or not. Therefore, statistics reveal that the potential vulnerability of Shakhari bazar buildings remain more compared to other area. In Shakhari bazar 80% buildings are masonry building and the age of the buildings are more than 100 years. The gap between buildings is least in Shakhari bazar. During the survey this research surveyed the education on preparedness of any incident. Almost 90% of the responders are not clear how they respond during the disaster.

5. Co-relation between emergency rescue organization and accessibility

The sound management of the disaster can ensure the smooth prosperity and development of a country. And this can be best achieved by participation of all government ministries including defense force non-government organization (NGO) and collective approach from all levels of community. To accumulate all this different organizations in a single management system need a well define action framework this will guide the respective organizations to achieve their goal. These organizations also need well understanding and better relation among them for coordinated response during emergency. In the most countries of the world, the role of armed forces during disaster has got the trend to play an active or leading role in disaster management because of its well-trained manpower, supply system, self-sustainability, chain of command and mobilization power. In Bangladesh perspective an action framework develop under which all the organizations work according to revised Standing Orders on Disaster (SOD) 2010. Yet it is not the military who response first. It is BFSCD which is the first responding organization of the government. This researcher will mainly focus on the functioning procedure of BFSCD.

5.1. Operational Procedure: The BFSCD vehicles have more or less same types of operating procedure. However, the aerial platform ladder and multipurpose fire and rescue vehicle are the vehicles with greater dimension and most important tools in FSCD. For successful operation, the minimum space requirement has been shown below:

5.2. Correlation: The vehicle movement has inter-relationship with the width of the roads, traffic ability and smooth road surface. Route planning based on a cycle of monitoring, planning, implementing, adjustment to the network, which is not adhered by the authority in case of Dhaka. Total 9% area of Dhaka is covered by roads but pavement area is only 6%, where as in developed cities 25% of total area is covered by pavement. In the current street organize 65 % streets need adequate street width to oblige mechanized crisis vehicles. A Street is said to be available if the street width is equivalent or more than 4.5 meters by the mechanized vehicle. Indeed, even a street width is 4.5 m in old Dhaka, is not open because of street side occupation by the sellers. A crisis vehicle requires stopping, working and moving amid its operation. Along these lines, least street width assumes single essential noteworthy part for the crisis vehicle. Along these lines street width and vehicle development is needy to each other.

6. The system design and the survey system in the selected application area of research

This research intent to develop a shortest path to reach the destination within minimum possible time with all the operational equipment's and rescue vehicles of BFSCD and armed forces division. The intended system developed basing one spatial data and non-spatial data such as road type, road network, road width, and volume and speed relation in peak and off-peak hour.

6.1. Data Collection Procedure

Data collection procedure includes various data collection techniques conducted at different level of the research work. Both primary and secondary data were collected. Primary datas were collected from different field survey. Secondary datas were collected from different agencies like Bangladesh Fire Service and Civil Defense (BFSCD), Disaster Management Bureau (DMB), Bangladesh Road Transport Authority (BRTA), Dhaka City Corporation (DCC) etc.

6.2. Survey Method and Selection of the Study Area

6.2.1. Origin-Destination (O-D) Survey Method: This researcher used O-D method to conduct the survey. Origin is the point from where trip started and destination is the point where trip ends. Basically, the data's that are collected basing on the factors that are likely to influence travel pattern.

The researcher selected the study area from the access point of view of emergency vehicle from different point of origin to destination. There are four origins from four fire stations and a common destination Shakharibazar.

1. Palashi Barrack fire Station (PBFS) to Shakharibazar.
2. Lalbag Fire Station (LBFS) to Shakharibazar.
3. Siddiquebazar Fire Station (SBFS) to Shakharibazar.
4. Shadarghat fire Station (SFS) to Shakharibazar.

6.2.2. Moving Observer Method: In this method, the speed and flow can be obtain by travelling in any mode against and with the flow, with the flow and number of vehicles overtakes him and number of vehicle he overtakes.

6.2.3. Mode of Transport: This researcher used private car and local bus for the research purpose. The timings used below were the travel time by private car.

6.2.4. Palashi Barrack fire Station to Shakhari Bazaar: The survey conducted in three periods of the day. Peak hour considered from 9 am to 12 pm and 4 pm to 8 pm in day time. Off peak hour considered from 12 am at night till morning 7 am. Average hour considered from 12 pm to 4 pm at day time. First

survey conducted at 9 am of the day from PBFS. The journey started at 9 am from PBFS and reached to Shakhari Bazar at 10:35 am. The total time taken for the journey is 1 hour 30 minutes. Second survey conducted from 2 pm to 3.15 pm. Third survey conducted from 12 am to 12.30 am at night. The following table shows the comparative study of the journey periods.

6.2.5. Response Survey

This researcher conducted a survey taking random sample from Shakharibazar and asked ten pertinent questions to the inhabitants. The answers were interesting and relevant to the study area. This survey conducted in the field using close ended questionnaire. The following questions were asked to different people and the answers were represented in graphics.

What are the principal causes of inaccessibility in the road network of old Dhaka was the main question. The factors are given below:

1. Excessive population density in Old Dhaka.
2. Unplanned urbanization and lack of control on mixed land use.
3. Excessive growth of private cars.
4. Unauthorized on-street parking and allowing building construction without sufficient parking facilities.
5. Poor traffic management system and not implementing existing traffic regulations.
6. Insufficient footpath and encroachment of footpath by hawkers and vendors.
7. Not providing importance on transportation in town planning, narrow roads and lack of roads.
8. Uncoordinated development and maintenance work by various agencies (WASA, Titas Gas, BTCL, etc).
9. Unauthorized rickshaws.

6.3. Findings of the Field Survey

The different field survey shows the time requirements from the origin to destination is far from the standard time. If the existing condition prevails then the loss of man and materials is obvious. From the second part of the survey it is seen that the public perception about accessibility. They opine that the roads are narrow, mixed motorized and non-motorized vehicles slow down the speed, unplanned urbanization, poor integration of land use and transportation is the root cause of inaccessibility.

7. Shortest path analysis

This researcher uses ArcGIS 10.2 to find the most suitable path to reach a destination from the point of origin. In this paper, total four fire stations in old Dhaka are taken as origin and Shakharibazar is the destination for all the fire stations. An alternative route is also selected to see the variation in reaching the incident point in case of emergency.

7.1. Methodology of Shortest Path Network Analysis

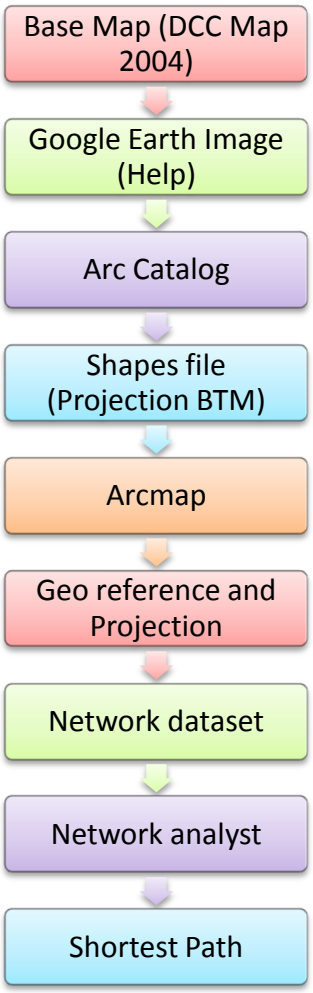

Figure 1: Process of Creating Shortest Path

7.2. Shortest Path for Polashi Barrack Fire Station (PBFS) to Shakhari Bazar

The detailed description of the route to be travelled between selected Origin PBFS to the destination Sakhari bazar is given below:

a. Origin PBFS.
b. Head south follow Dhakeshwari road 500 m.
c. Turn left to follow Lalbag road 320m.
d. Lalbag road turns slightly left to become HoronathGhosh road450m.
e. Continue up to Chawk bazar following Urdu road210m.
f. Slight right onto Chawk bazar ShahiMoshjid road 110m.
g. Turns left onto water works road 290m.
h. Continue up to Mitfort road 600m.
i. Turn right toward AhsanUllahroad 350m.
j. Turn right onto Islampur road then turn left onto Islampur road 600m.
k. Destination Shakhari Bazar 250m.
l. Total length from origin to destination 3.7 km.

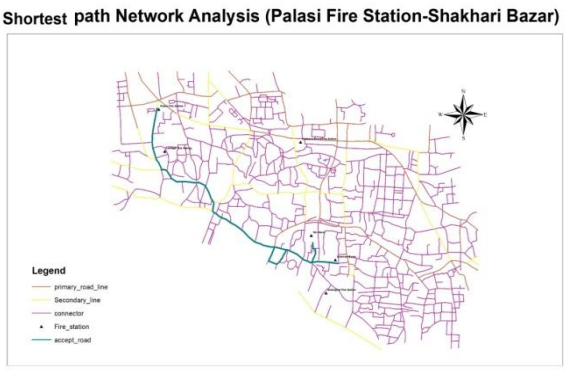

Fig.2: SP Showing PBFS to Sakhari Bazar

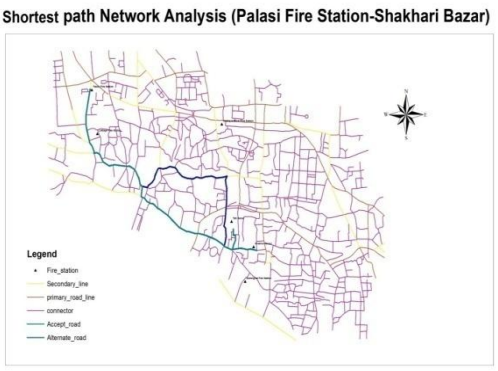

Fig.3: Alternative Shortest Path Showing PBFS to Sakhari Bazar

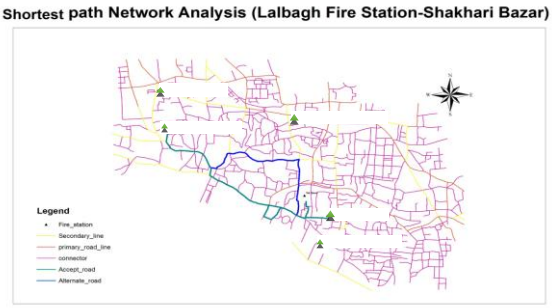

Fig.4: SP Showing LBFS to Sakhari Bazar

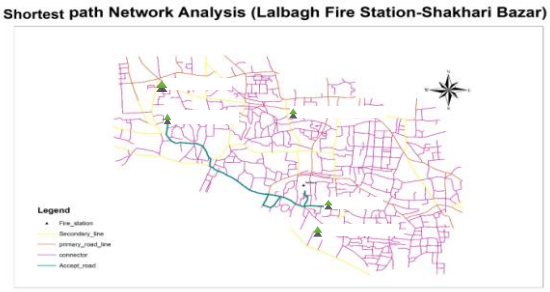

Fig.5: Alternative Shortest Path Showing LBFS to Sakhari Bazar

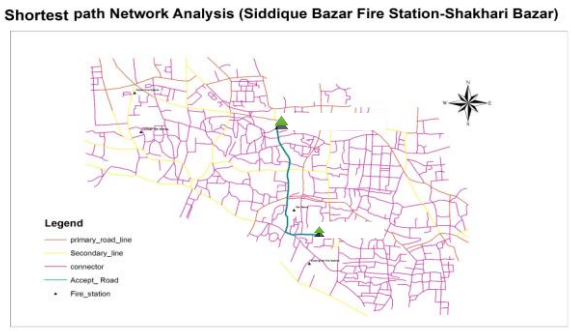

Fig.6: SP Showing SBFS to Sakhari Bazar

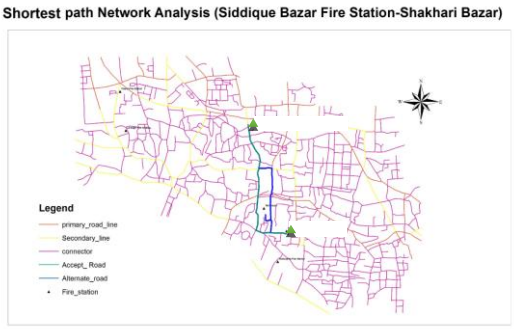

Fig.7:Alternative Shortest Path Showing SBFS to Sakhari Bazar

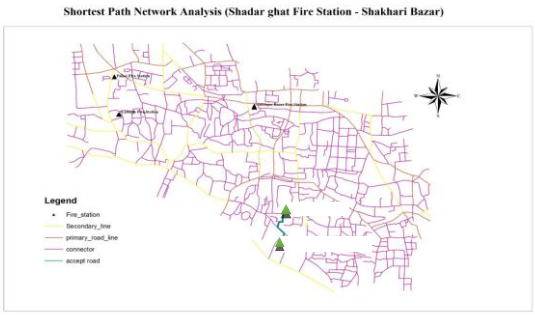

Fig. 8: SP Showing SFS to Sakhari Bazar

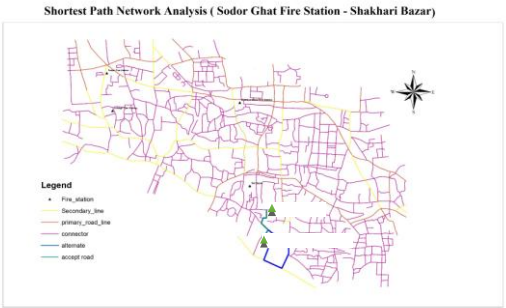

Fig 9:Alternative Shortest Path Showing SFS to Sakhari Bazar

8. Major findings

This study is mainly focused on determining the accessibility of vehicle from different origins. While doing so effort was taken to find out each alternative. Besides, survey was conducted to get the perception of the dwellers. However the major findings are listed below:

a) **Polashi Barrack Fire Station to ShakhariBazar**: The shortest path found out by GIS through water works road and Mitford road are unsuitable for emergency big vehicles but suitable for emergency pick up and ambulance. Though the distance is more in alternative paths but very much suitable for all the vehicles and take less time.
b) **Lalbag Fire Station (LBSF) to Shakhari Bazar**: The route is almost same as PBSH as the two stations are collocated.
c) **Siddique bazar Fire Station (SBFS) to Shakhari Bazar**: The route via Alauddin road is the shortest route. But due to narrow secondary road it takes more time than alternative road which is via English road and North South road.
d) **Shadarghat fire Station (SFS) to Shakhari Bazar**: The shortest route is the most suitable one. The alternative route takes much longer time.

Creating and enhancing accessibility in street network appear to be an appropriate starting point for post disaster rescue and recovery operation in unplanned urban city like old Dhaka. The shortest path analysis indicated that possible route to follow after disaster yet the open space is an acute problem in urban area. Therefore, the proposed idea seems to be place specific and provide sustainable solution after the disaster.

9. Recommendations

In this study an endeavor is made to determine the most suitable shortest route to reach the destination from origin with regards to their accessibility. Based on the survey, shortest path analysis coupled with KII and FGD the following recommendations were made:

a) Initiative should be taken to broaden the road in the old Dhaka city.
b) Provision should be made to ensure safe and unobstructed movement of fire and rescue vehicle by reducing the traffic jam within the study area.
c) Arrange mock training to reach an incident point within the existing traffic.
d) DSCC should take immediate step to ensure 30 feet road width around the building for easy access of fire tender and effective firefighting.
e) Immediate destruction of dilapidated building to reduce the risk and increase the width of the connector.
f) Finally increase the capability of BFSCD with high capacity small vehicle which suits the road network.

10. Conclusions

The congestion scenario in old Dhaka is the matter of great concern. Previous experience says that if any disaster takes place the losses will be unmanageable like Nimtoli fire incident. Keeping the incident in mind this researcher found out suitable access route for BFSCD vehicles. Most effective fire fighting vehicle in BFSCD is 12meterlong and 2.5 meter in width. So, it needs a considerable amount of space during maneuver. Most of the areas in old Dhaka are too congested and narrow road provision makes its condition worse. This research identifies the narrow road which does not have the provision to access the modern fire fighting vehicle. Accessible networks with alternatives were identified from the GIS plotting from each origin to destination. But During the physical survey it is seen that the secondary roads that are shown accessible are not at all suitable to use during emergency due to dead traffic and mixture of motorized and

non-motorized vehicle. Vendors took partial control of the road by their shops and all the roads have poor above head clearance due to unplanned electric wire.

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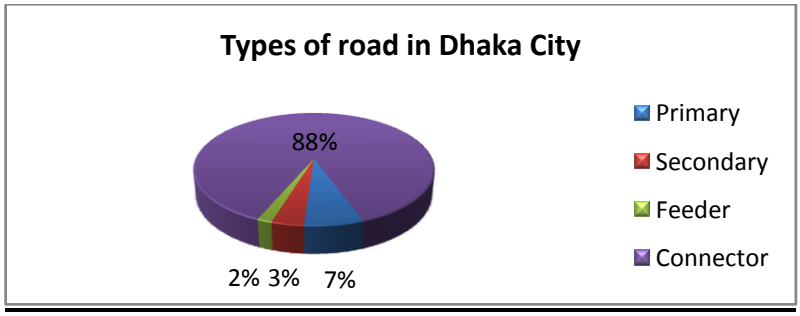

Figure 10: Types of Roads in Dhaka City

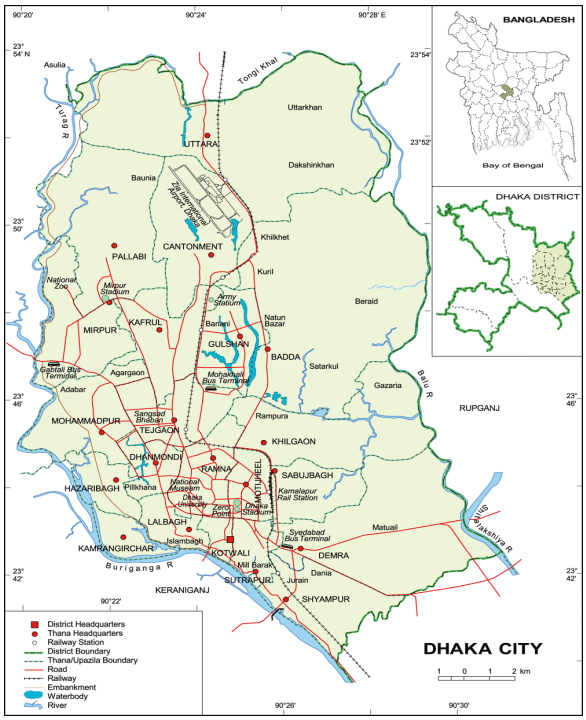

Figure 11: Map Showing Fire Station in Old Dhaka

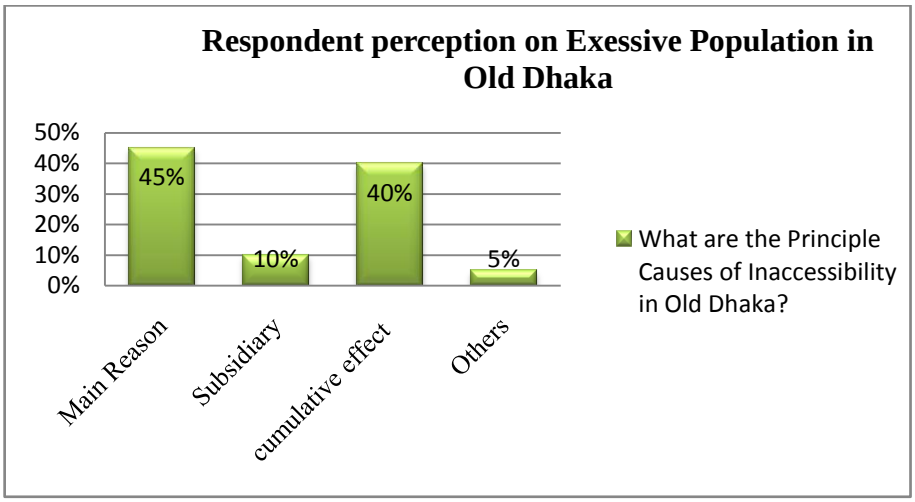

Figure 12: Excessive Population of old Dhaka

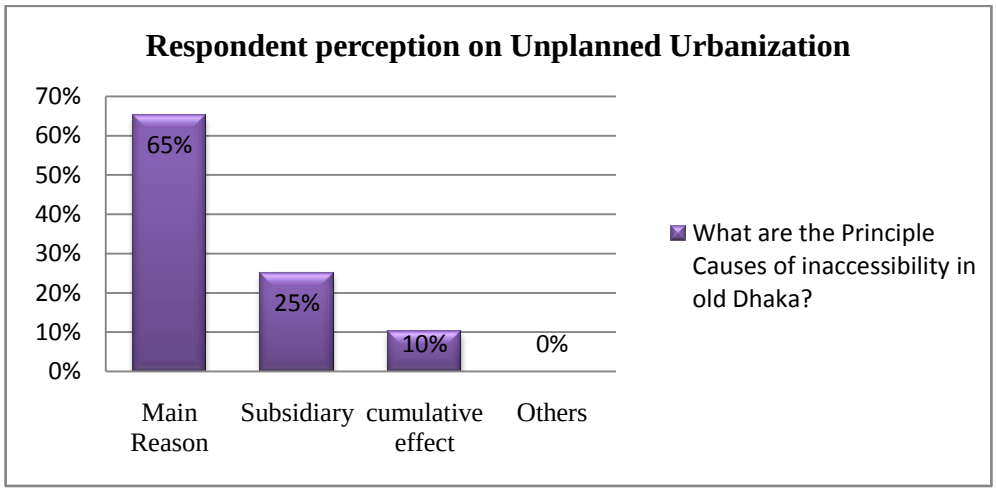

Figure 13: Unplanned Urbanization

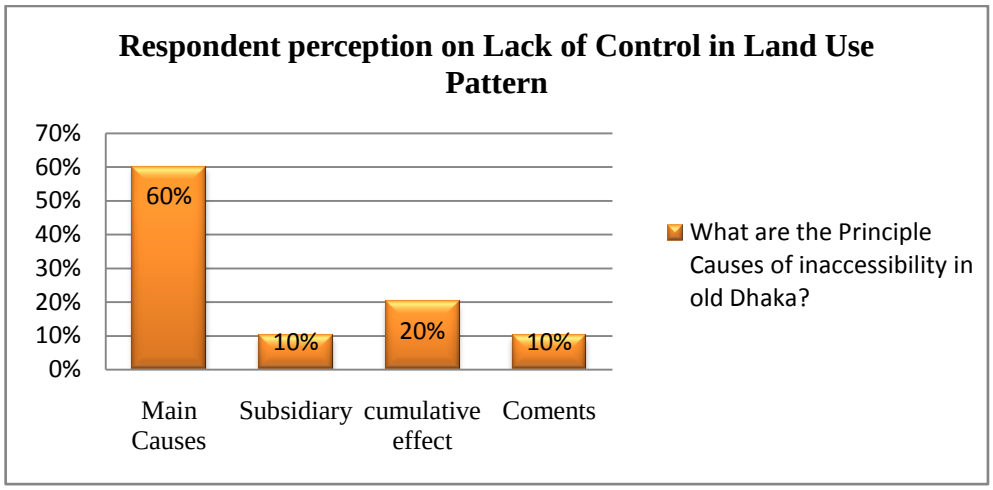

Figure 14: Lack of Control in Land Use pattern

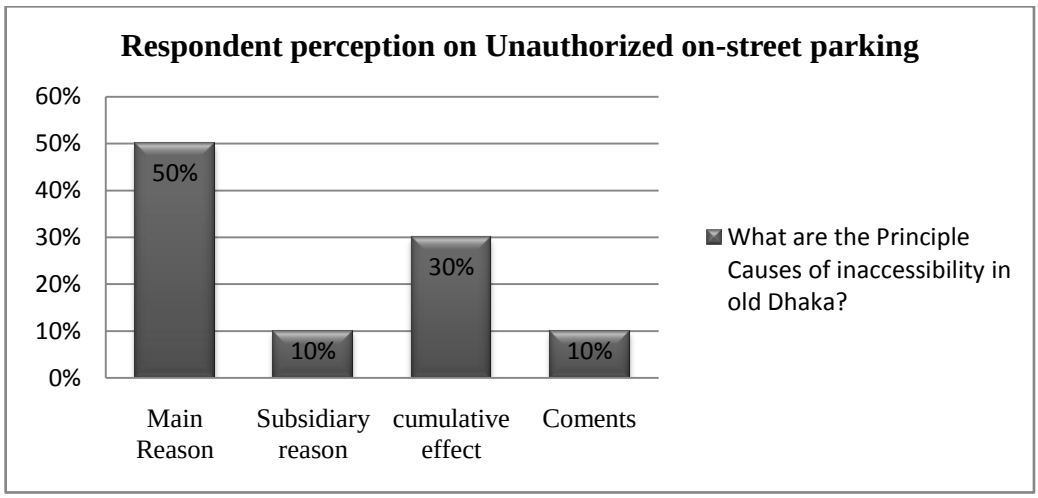

Figure 15: Authorized on Street Parking

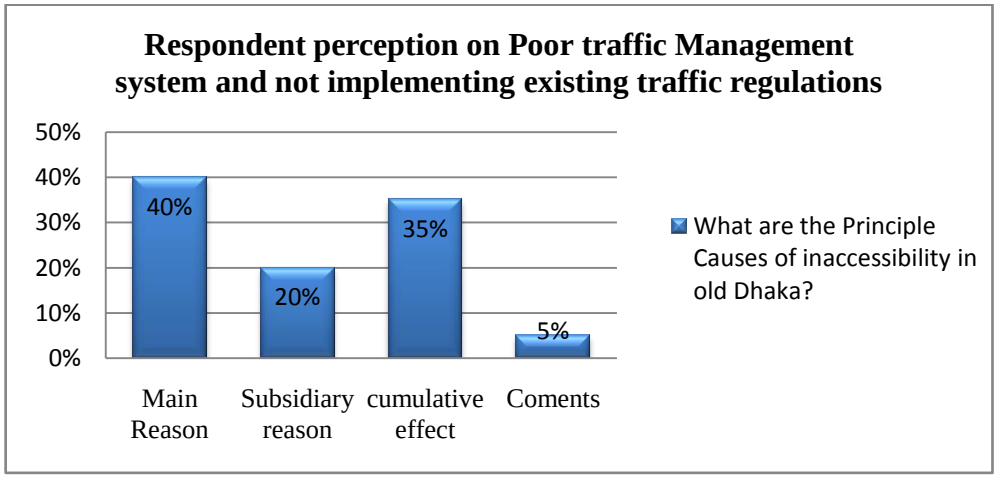

Figure 16: Poor Traffic Management

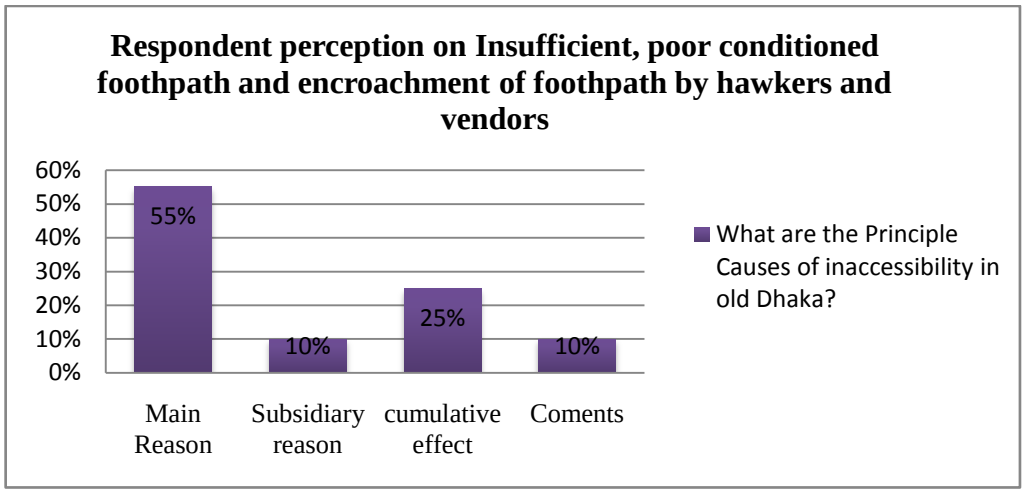

Figure 17: Insufficient, Poor Conditioned Footpath and Encroachment of Footpath by Hawkers and Vendors

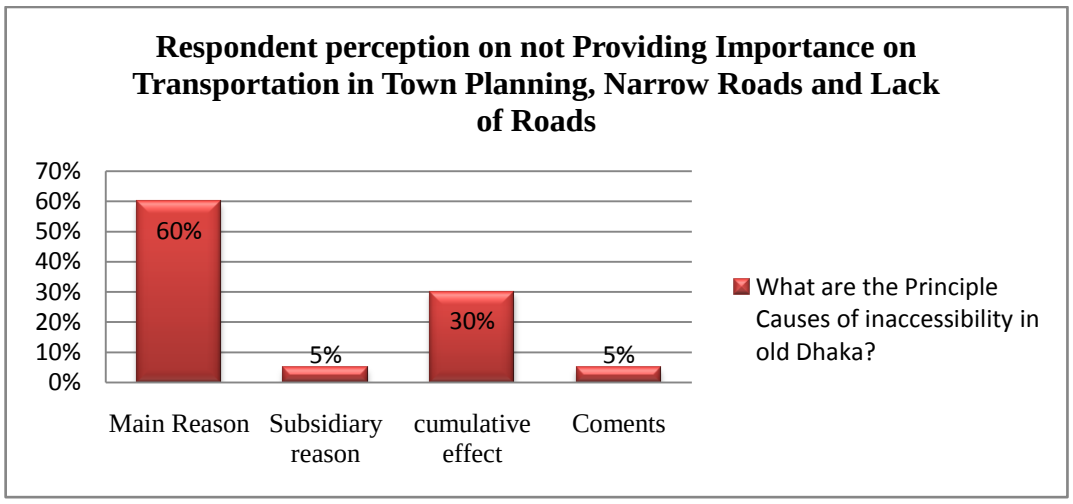

Figure 18: Uncoordinated development and maintenance various agencies

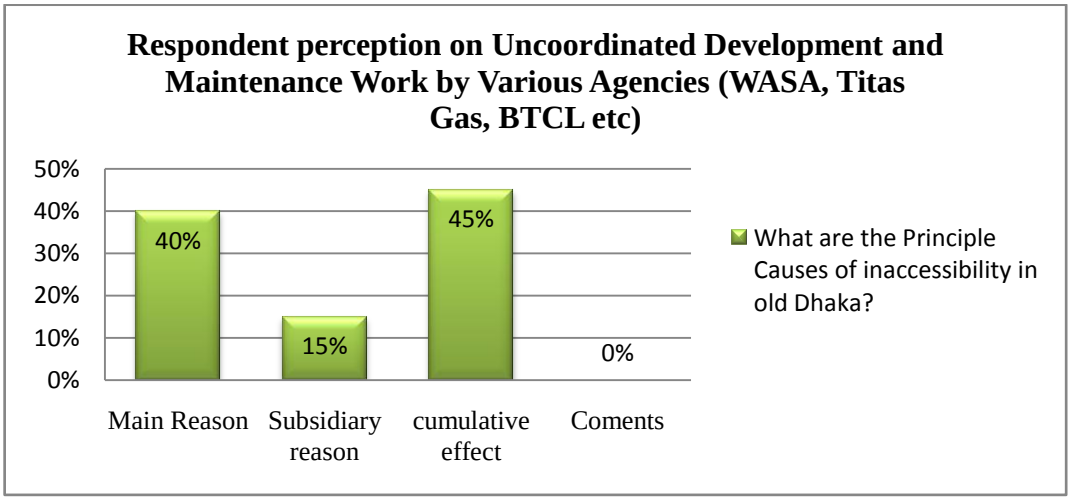

Figure 19: Narrow Roads and Lack of Roads

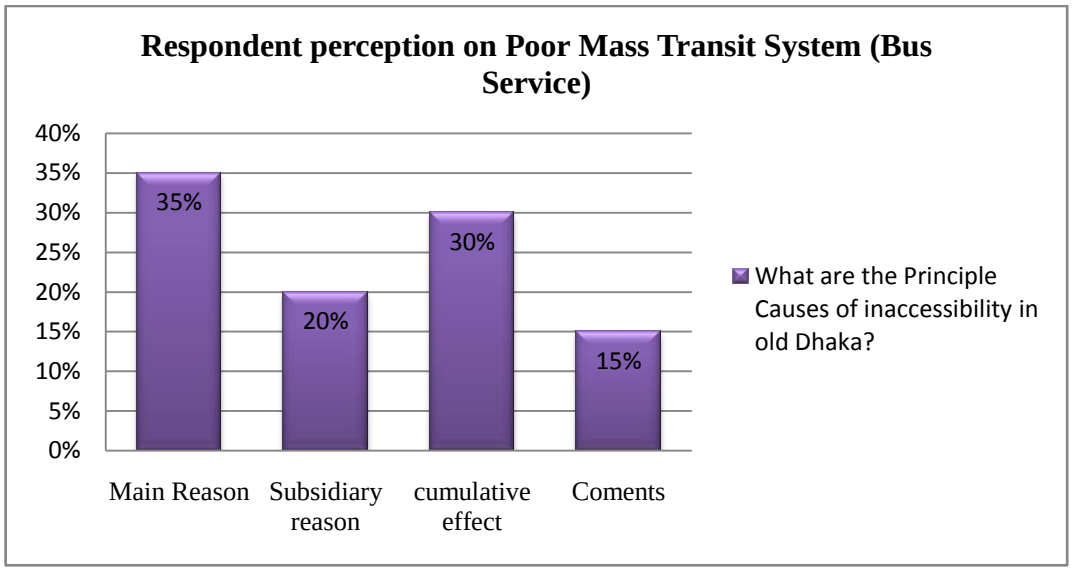

Figure 20: Poor mass transit system

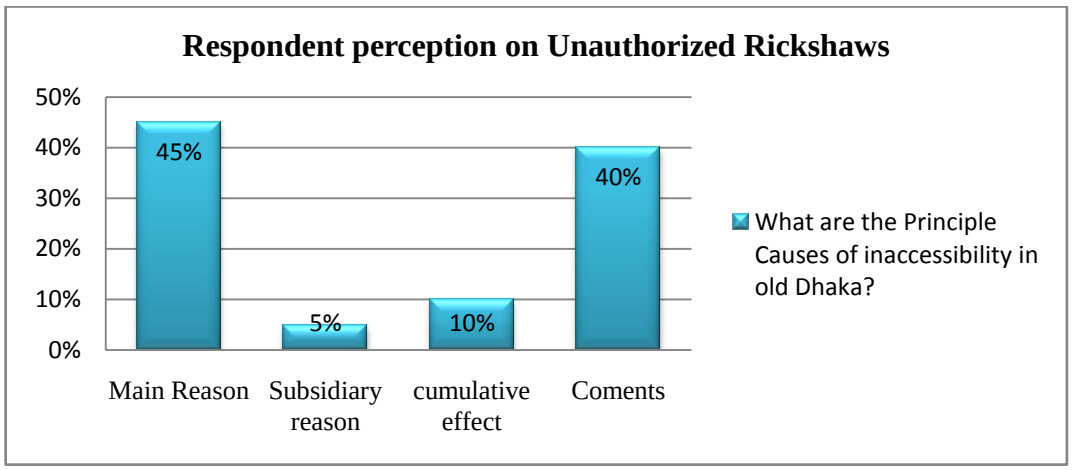

Figure 21: Unauthorized Rickshaw

Table 1: Requirement of Width Height and Turning Radius for FSCD Vehicle

Type of appliances	Min width of access road (m)	Min clearance of height (m)	Turning circle between walls(m)	Turning Circle diameter between curb (m)	Min width of gate way (m)	Laden weight (ton)
Pumping Appliances	3.7	3.7	19.2	16.8	3.1	12.5
Hydraulic platform	3.7	3.4	29	29	3.1	17

Table 2: Time Showing Friday Peak, Off Peak and Average Hour

Serial No.	**Distance in km**	**Standard Time**	**Time Taken Friday**		
			Peak hour	**Off peak hour**	**Average Hour**
			9 am to 11:59 am And 4 pm to 8 pm	12 pm till morning upto 7 am	12 pm to 4 pm and 8 pm to 12 pm
1	4.8 km	15minutes	15 minutes	15minutes	15minutes

Survey on Saturday

Table 3: Time Showing Saturday Peak, Off Peak and Average Hour

Serial No.	**Distance in km**	**Standard Time**	**Time Taken Friday**		
			Peak hour	**Off peak hour**	**Average Hour**
			9 am to 11:59 am And 4 pm to 8 pm	12 pm till morning upto 7 am	12 pm to 4 pm and 8 pm to 12 pm
1	4.8 km	15minutes	1 hour &15 minutes	20 minutes	1 hour &15minutes