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A GIS-based Network Analysis to Determine the Shortest Route and Service Area of Fire Stations to Hospitals for Emergency Response: A Case Study of Dhaka City Corporation

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ABSTRACT

Fires at hospitals are a typical occurrence that frequently causes considerable health and property damage. Fire stations should be well-equipped and prepared to give aid to hospitals in times of emergency. Response time is an important factor in determining the quality of a fire station's service. It is crucial for response times to be as short as possible. This response time is determined by the condition of the emergency response vehicle as well as any potential impediments or prohibitions on the road network. Hospitals in Bangladesh are also prone to fire accidents, and in times of emergency, the current road network, congestion, and unplanned land use create difficulties in providing an effective supply of fire service. The current study is an effort to model the shortest route for a fire service to go through a road network using GIS technology and application on the tertiary hospitals of Dhaka City Corporation Area. This allows fire stations to take the shortest route possible, reducing emergency response time and helping to save lives and property.

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LIST OF ABBREVIATIONS

ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ANN	Average Nearest Neighbor
DCC	Dhaka City Corporation
DNCC	Dhaka North City Corporation
DSCC	Dhaka South City Corporation
NFPA	National Fire Protection Association
GIS	Geographic Information System

CHAPTER 01: INTRODUCTION

1.1 Background

Fire safety has become one of the lingering concerns for the residents of Dhaka City. Congested roads, heavily spaced buildings, narrow lanes, and lack of fire prevention knowledge has made the residents of the city vulnerable to fire incidents. (Rahman and Tawhid,2014). The geographical accessibility of fire stations on an urban scale is crucial. One of the most important factors to consider when looking for a location of fire station that maximizes accessibility is response time. If a fire department is placed on a site where it provides inadequate service, it will incur more costs and as well as endanger the safety and security of people's health. (U.S Fire Administration, 2018). Response time of fire stations becomes a concern when a city is expanding or filling in its geographical area. (U.S Fire Administration, 2018). In Dhaka, this issue is more complex as the fire stations might not be thoughtfully located considering the distribution of different land classes. (Rahman and Tawhid,2014). Hospitals are one of the most common places where fire accidents occur. According to NFPA, hospital fires account for about 9% of all reported fires each year. In Bangladesh, 21,074 fires were reported across the country in 2020. Of these, 90 fires broke out in different hospitals and clinics (Fire Service and Civil Defense, 2021). The Fire Service inspected 432 government, non-government hospitals and among these hospitals only 11 (2.5%) private hospitals were found to have enough fire safety equipment. Besides, 421 (97.5%) hospitals were rated risky or high-risky.

Some hospitals have had significant fires in recent years. Medical equipment is one of the causes of hospital fires. Because of the increasing delivery of oxygen during the Covid-19 epidemic in 2021, the danger of fire in ICUs rose. There is higher oxygen pressure due to high flow nasal cannula in the ICU, so even a small spark catches fire. (Department of Health, Hospital and Clinic, 2021). ICU unit of Dhaka Medical College had a fire emergency due to spark in oxygen supply. In addition, an explosion of an air conditioner caused a fire disaster at Mugda General Hospital. The fire originated at catheterization laboratory and later spread to the intensive care unit (ICU) of the hospital and there were 8 fatalities. (Department of Health, Hospital and Clinic, 2021). These fires not only endanger lives, but also cause property damage costing millions of dollars. In addition, the fire service must invest money in fire equipment to battle the fire. According to a Fire Service and Civil Defense report, the rescue cost during fire occurrences in hospitals is

substantially more than the damage cost. Therefore, it is important that fire stations have easy access to hospitals to respond to fire emergencies in a timely manner.

1.2 Objective

Setting objectives that are explicit, exact, relevant, and unambiguous is critical for any study. Three objectives have been formulated for our study as well.

1) To identify the service area of existing fire stations

2) To find out shortest route for providing fire service from fire stations to hospitals

3) To determine the response time for assessing the service of fire stations

1.3 Rationale

According to NFPA (National Fire Protection Association), the standard response time of fire stations to any fire incident is 9minutes 20 secs. However, according to a survey data, to arrive at any fire incident spot between two stations in Dhaka, the maximum travel time from either direction of those two stations may take at least 27 minutes which is almost three times than the international standards. (Rahman and Tawhid,2014).

Hospitals of Dhaka are vulnerable to fire incidences, so when these incidences occur it is important that fire stations could provide their service within a time that would save both life and cost. There are 399 hospitals and 15 fire stations in Dhaka City Corporation Area. The study focused on 23 tertiary level hospitals, including specialized hospitals. Tertiary hospitals are vital because individuals from all across the country seek to them for medical care. If a fire broke out at one of these hospitals, the number of casualties and damage would be substantially higher. As response times prolong, people's safety and security are compromised. The study was conducted to establish the optimum route from fire stations to hospitals. In the event of a fire, the stations may take this route and respond quickly. This allows the stations to provide quality fire service to hospitals as well. The study was also carried out to see if the fire stations are strategically positioned so that they can respond quickly within standard time by delineating the service area.

1.4 Scope

The study about the "A GIS-based Network Analysis to Determine the Shortest Route and Service Area of Fire Stations to Hospitals for Emergency Response: A Case Study of Dhaka City Corporation" provides some scopes from different aspects. Although the study has been conducted on 23 tertiary hospitals of Dhaka City Corporation, it can be conducted on primary and secondary level hospitals as well. By collecting real travel time data, exact response time of fire stations to hospitals can be determined. Besides, collecting least cost data using shortest route also provide a scope of conducting least cost analysis.

1.5 Limitation

While the study has presented several chances for more study and analysis, it has also experienced certain challenges. We were unable to perform a field survey to collect real- travel time data due to time constraints. As a result, the optimum route from fire stations to hospitals was not established using real-time data. Besides, we could not also conduct the least cost analysis.

CHAPTER 02: METHODOLOGY

The strategy of conducting a research project that outlines the way in which research is to be started, conducted, and conclude. For a successful research, methodology is one of the key issues. The following methodology has been adopted to fulfill the objectives of our study.

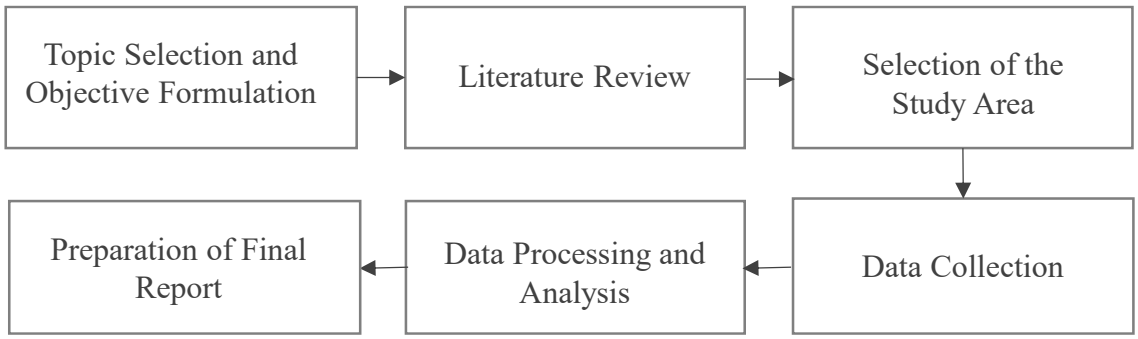

Figure 2.1: Methodological Framework of the Study

2.1 Topic Selection

At first, the topic of the project was selected. The project was entitled as "A GIS-based Network Analysis to Determine the Shortest Route and Service Area of Fire Stations to Hospitals for Emergency Response: A Case Study of Dhaka City Corporation".

2.2 Objectives formulation

Objectives contribute a lot to conduct the study in a systematic way. They are like guidelines that help to form the complete structure of the study. In this study, three objectives were formulated.

2.3 Literature Review

For generating ideas, Similar research works based on GIS tools were reviewed. Also related articles, journals, documents, and thesis papers were checked out.

2.4 Selection of the Study Area

Dhaka City Corporation area has been selected as the study area for the project.

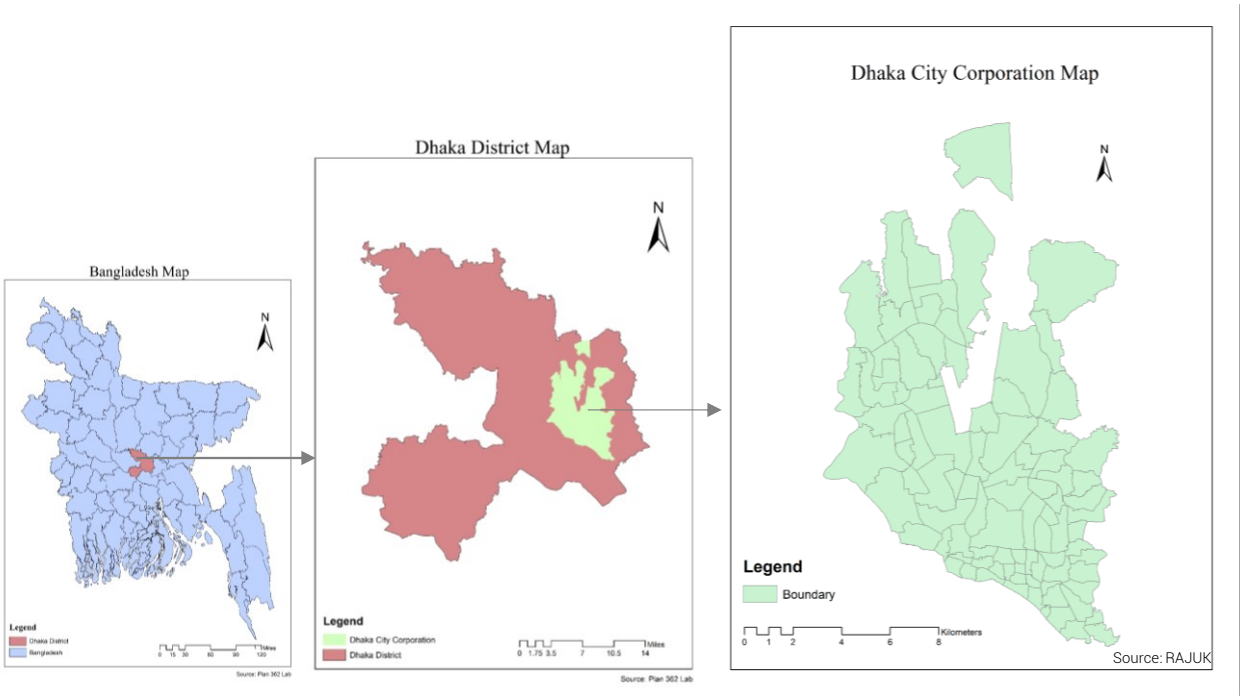

Figure 2.2: Selection of the Study Area

2.5 Data Collection

Data collection is an essential part of any study as it will provide the required information of the context. Without the collected data, we cannot go ahead with the analysis and come to any conclusion. For this project, only secondary data related to the topic was collected. Secondary data refers to those which are not collected directly by the surveyor but from other sources like published data source and unpublished data source. To conduct our project the shape files of Dhaka City Corporation boundary, road network and existing land use of Dhaka Metropolitan area were needed. Shape files of road network and existing land use of Dhaka Metropolitan were collected from RAJUK and shape file of Dhaka City Corporation boundary was collected from Sheltech.

2.6 Data Processing

Data processing is the process of taking raw data and converting it into usable information. Raw data is gathered, processed, analyzed, and stored before being displayed in a usable way. For this project, secondary data were processed and analyzed with ArcGIS and R. For better analysis, graphs, charts, and tables were prepared.

2.7 Preparation of Final Report

The main purpose of this study is to identify the service area of existing fire station within DCC boundary and propose shortest routes from fire stations to hospitals. For this study, all the works have been done sequentially and documented in this paper. This report reveals the final output of our study. This report includes, data processing in ArcGIS interface and data analyzing, result and discussion based on the analysis of the data, major findings of this study, recommendation and conclusion.

CHAPTER 03: LITERATURE REVIEW

Fire stations are part of urban critical infrastructures and key primary respondents in emergencies (Murray and Grubesic 2007). The main role of fire service is to protect lives and resources from fire hazards (Blum 1971; Johnson 2008; Murray 2013). The number of existing fire stations, their location, and service area determine the level of performance of fire services within a particular area (Johnson 2008). A reasonable plan of fire services should first address the issue of service area delimitation for fire emergency facilities (Zhou et el, 2020). Fire services' performance can also be represented by the speed of handling the fire case, where greatly influenced by the travel speed of the fire trucks to the fire location. There are many variables that can affect the travel time of the fire trucks, there are travel distance, fire trucks speed, time of fire case, traffic conditions and type of land use on the route traversed. Therefore, it is necessary to carry out an analysis in determining the fastest route for the firefighter by considering some variables in order to get the fastest route alternatives and optimize the performance of the Fire Service in handling the fire case. (Astor and Hariani, 2021).

This chapter discusses the definition of GIS and application of GIS for fire incident Management. Moreover, previously published similar works using GIS based tools have also been discussed in this chapter.

3.1 Geographic Information System (GIS)

A definition and understanding of GIS is significant to the context of this research as it serves as a framework on which this study is based. The term Geographic Information System can be defined in several ways depending on the capability and purpose, for which it is applied (Hasnat, 2016)

Geographic Information Systems can be defined as computer-based systems designed to function specifically on spatial information. Since its growth in the early 1970's, GIS technology has been used to acquire, manipulate, store and display geographic data for purposes of planning. "Over the past two decades GIS technology has improved so fast that it is now being used as an indispensable tool for effective and efficient use of geographic data" (Anorff, 1993). Significant tool-based definition of GIS is that given by Dymon, (1990) which states that 'GIS as a powerful set of tools for acquiring, storing, retrieving, analyzing, transforming and displaying spatial data from the real world for a particular set of purposes'. . Potestio, (2000) defined geographic information system

as having the capability to describe what is going on around our environment in reference to a location on a map. Dempsey, (2004) editor of the GIS lounge stated that by integrating spatial data with attribute data, GIS can be used to analyze and solve a wide range of problems in any discipline. All the above stated definitions match this papers objective, GIS is defined more clearly using the following building blocks:

Data: The initial data is collected through ground survey by the use of survey equipment and GPS machine. Data can exist both in digital format and analogue format before the analysis is done. For this project, it involved:

Time data and velocity data, which identifies the distance from which service area of the fire stations are calculated.

The street data, which identifies the roads that take the fire trucks to the hospitals during emergency situations.

Software: this helps in the spatial analysis and networking. It involves geocoding, editing and production of a map layout. Most of the GIS software that are used in the analysis include ARCGIS, MAP INFO, and many others.

Hardware: this includes the workstation with sufficient memory, storage, graphics, and processing capabilities to support the GIS software.

People: This includes people with GIS technologies and skills which is used to analysis and implementation of the final geographic information.

In conclusion, GIS technology provides the capability to analyze, dissect, and plan for fire protection problems quicker and with greater details (Hasnat, 2016).

3.1.1. Network Analysis

Background knowledge of a network can be beneficial to the understanding of transportation network analysis (Hasnat,2016). A network is essentially a set of lines known as segments or edges connected or joined by a set of vertices known as nodes or junctions. A GIS stores these edge and junction features with their attributes. Spatio-temporal networks are networking whose topology and parameters change with time. These networks are important to applications such as emergency

traffic planning and route finding (George et al. 2007). The use of GIS for network analysis is essential for improving emergency response routing based on travel time information (Alivand et al. 2008, Panahi and Delavar 2008). Sadeghi-Niarki et al. (2011) stated that network analysis is a powerful tool in the GIS environment for solving the optimal path in a network.

3.1.2. Service Area

Service Area helps to determine the service coverage extent of a facility within specified impedance. Thus, Service areas created by Network Analyst also help evaluate accessibility by exposing any deficiency in facility service coverage within a given time and area. In ArcGIS Network Analysis, accessibility is measured in terms of travel time, distance, or any other impedance on the network (Hasnat,2016). Curtin et el, (2018) stated that the demarcation of service area is one of the most important issues in spatial partitioning, as a reasonable service area delimitation always increases the efficiency of facilities service. It has been widely studied in various fields, for example, trade zones planning, medical services area planning, and police patrol areas planning.

3.1.3 Shortest Path Analysis

Shortest path analysis is important because of its wide range of applications in transportation (Lim and Kim 2005). Naqi et al. (2010) stated that the shortest path helps calculate the most optimal route. And Verbyla (2002) defined optimal routing is the process of delineating the best route to get from one location to another. The best route could be the shortest or fastest depending on how it is defined by the GIS users (Naqi et el, 2020). The shortest path can be computed either for a given start time or to find the start time and the path that leads to least travel time journeys (Alazab et al. 2011, Alivand et al. 2008, Kim et al. 2005). The major factors involved in network analysis are cost (length), description (road type), restriction (turns. Speed limits) hierarchy (road level), parameter (define set of rules) and direction (Naqi et al. 2010).

3.2 Application of GIS for Emergency Fire Response

No other technology allows for visualization of an emergency or disaster situation as effectively as GIS. With the ability to place critical data such as resources, events, conditions, weather, assets, and threats onto the actual geography of disaster area, emergency managers now could make

decisions based upon a realistic representation of the visual data (Greene, 2002). Md et al. (2004) stated that GIS provides quick real-time visualization of pattern, trends map location and easily comprehend multi-layered geospatial framework of various emergency situations. As a result, a quick and accurate decision can be taken to save lives and properties. Mitchell (1998) showed how GIS has been used in the fire department in the city of Tacoma, Washington to create response zones for all its functional fire stations. Travel time away from station outside the street was computed using GIS. The result displayed a reliable response zone map which will enable fire fighters to know which fire service is closest to respond to a fire incident. The map also shows which fire station will act as back up if necessary, using the second closest fire station to incident site. O' Looney (2000) used the city of Willson, North Carolina as a case study to describe two real life scenarios where GIS has been applied in the fire service. He used GIS analysis to improve fire station coverage. the analysis showed that if two stations where relocated there would be no need for a new fire station to be built. He also described how GIS was used to analyze the number of emergency calls that come into the Fairfax fire station in Willson, North Carolina. The analysis showed that a large number of the emergency calls came in during afternoon rush hour from the freeway. Therefore, in order to ensure quick response, the fire department decided to position few fire trucks close to the freeway during the day.

According to Coleman (2002) fire service organizations are increasingly developing new applications of GIS technology for enhancing their emergency services delivery. If a fire department fails to take advantage of technology in its effort to become more effective and more efficient, the fire department will become obsolete over time.

3.2.1 Service Area of Fire Stations

According to Uddin and Warnitchai (2020), service area coverage is a function of accessibility. Zhou et el (2022) conducted a study on delimitation of the service area of fire stations with fire risk analysis in Nanjing city, China. He delimits the service areas of fire stations based mainly on a 2D polygon, such as block units, which is hard to take into account the variation of fire risk across regions. In addition, the existing service areas of fire stations ignore the actual route of rescue vehicles, which may consume a large amount of rescue time. He explained that fire engines reach the locations of incidents through the route of a street network, and in practical applications, the main attention of planners is also paid to the division of network segments for understanding

the accessibility of fire emergency service. Hence, he suggested that it may be more appropriate to define the service areas of fire stations using the constraint of the street network.

3.2.2 Shortest Path Analysis for Emergency Fire Response

In GIS optimum route is found out by using shortest path analysis of Network Analysis tools. Various applications of these tools have been made in fire disaster response and management problems. Using GIS in emergency routing offers a powerful capability for network analysis, visualization, and management of urban traffic network (NICOARĂ and HAIDU, 2014).

Nanang Nggufron, et al (2019) conducted a search for the best route for the Semarang city fire fighter. The study stated that based on the parameters of the level of road congestion which combines 2 parameters, there are road length and road density, it will produce 7 best routes for each fire station taken. In the study of determining the fastest route for firefighters in the city of Cirebon, Astor and Hariani (2021) used the Geographic Information System (GIS) modeling method to identify several variables that affect the speed of the fire trucks, there are distance and congestion points. The result showed that the fastest travel time for fire truck in Cirebon City is mostly influenced by the travel distance. However, in conditions of high traffic flow, a route with a longer distance but does not cross a congested road segment can produce a faster travel time when compared to a shorter route but crosses congested roads.

3.3 GIS and Emergency Fire Response: Bangladesh Context

Islam and Adri (2020), tried to explore the existing capacity of Fire Service and Civil Defense authority in Dhaka city and the preparedness of the citizens in combating fire accidents. From a survey that study found the incapability of the concerned authority to provide sufficient help during fire accidents as, there were only 15 fire stations with an average of 35 employees along with two vehicles (one water tender and another is pump) for each station in Dhaka City.

Hasnat et el (2018) conducted a study how effectively GIS can be used for emergency management for one of the most densely populated areas of Dhaka, the capital of Bangladesh. The study proposed an optimum route model by considering the actual roadway network frictions of old Dhaka. Current scenarios of disaster response have been assessed using spatial analysis tools of ArcGIS. The major facilities conducted in this study are the response time from nearby firefighting

stations and medical centers/hospitals. The analysis result shows that the four fire stations can only reach 14.28% of the area within 15 minutes of any incident with the current road network condition, which means 85.72% of the area vulnerable to fire hazards. The average maximum response time of fire service is found to be 26.7 minutes to some locations of the study area. However, with an improved road network with lesser frictions have reduced average response time of 11.6 minutes, resulting a 44% reduction in response time.

This chapter reveals that majority of articles and research acknowledge the importance GIS in the various phases of emergency fire response. The literature review helps to establish that fire services can utilize desktop GIS to produce an effective and efficient emergency service delivery.

CHAPTER 04: DATA PROCESSING

Network analysis can solve a series of questions related to linear networks such as roads, railways, facilities and utilities. Common applications of network analysis are route finding, identifying closest facilities by calculating minimum distance or response time, calculation of coverage areas (e.g. areas within 10 minutes' walk of hospitals), (comber et al.,2008).

There are several ways to find out the shortest distance from point A to point B. Arch GIS software uses Dijkstra algorithm (ESRI, 2014). The minimum route from the starting point to every other vertex is searched by the algorithm until it reaches to find the shortest path as much possible.

In our study, network analysis has been done using ArcGIS to determine the service area and shortest route of the fire stations to hospitals. Data processing has been done in various stages. Initially secondary data collection (the base map of Dhaka City Corporation, road network, hospital and fire stations) and data preparation have been done for the purpose of network analysis. After that the network topology and the network dataset have been built. Finally, the road network analysis has been applied to the data of road network, fire stations and hospitals.

4.1 Emergency Facilities Mapping: Fire Stations and Tertiary Hospitals

To begin with the process, the shape files of Dhaka Metropolitan area has been brought to Arc-GIS 10.4 interface. Then selection tool has been applied to identify the hospitals and fire stations within the boundary of Dhaka Metropolitan area. Following the procedure, 729 hospitals and 32 fire stations are selected. After that, clip tool has been used to identify the hospitals and fire stations within the boundary of Dhaka City Corporation. This tool is used to cut out a portion of one or more feature class and that is useful for creating a new feature class. The new feature class contains a geographic subset of the features in another, larger feature class. Using clip tool, it has been found that 399 hospitals and 15 fire stations are situated within the Dhaka city corporation. 23 tertiary hospitals have been selected among the 399 hospitals using the selection tool.

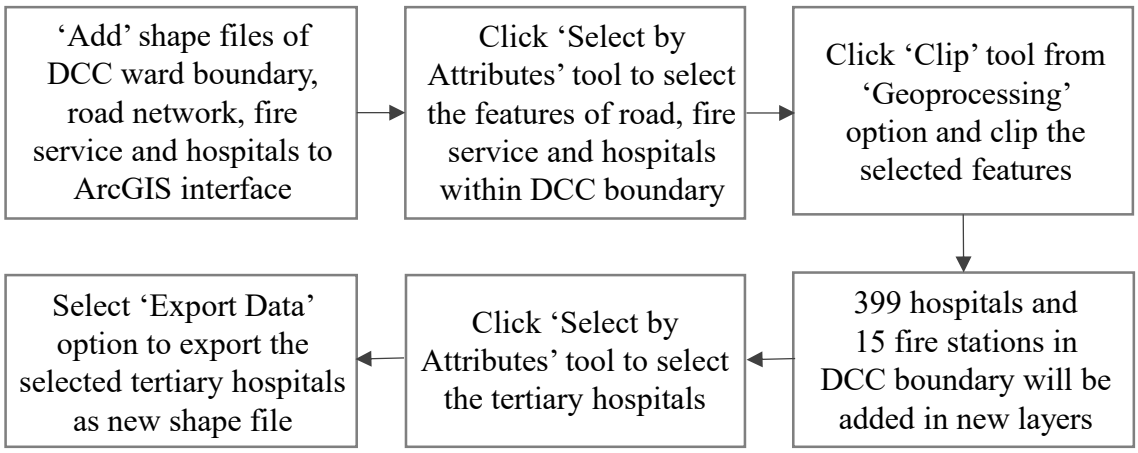

Figure 4.1: Process of Mapping the Hospitals and Fire Stations within Study Area

4.2 Determination of Service Area of Fire Stations

With network analysis, service areas can be found around any location on a network. A network service area is a region that includes the accessible streets which lie within specified search impedance. For example, 10 minutes' service area of a fire station that encompasses all the streets that can be reached in 10 minutes.

For delineating the service area, a new network dataset has been created in the folder of the catalog box where the shape file of road network is located. Then network analyst has been turned on to create new service area. At this point, service area analysis will be appeared in table of contents. Several options will be emerged on. Then, 15 fire service stations are loaded at "load locations" within 'Facilities' option. To input the service distance of fire stations, search impedance will be found in "analysis settings". The distance of service area is calculated by multiplying the average traffic speed of Dhaka (seven km/hour) and the standard response time (nine minutes and twenty seconds). After the completion of polygon and line generation, service area of fire stations will be shown as output.

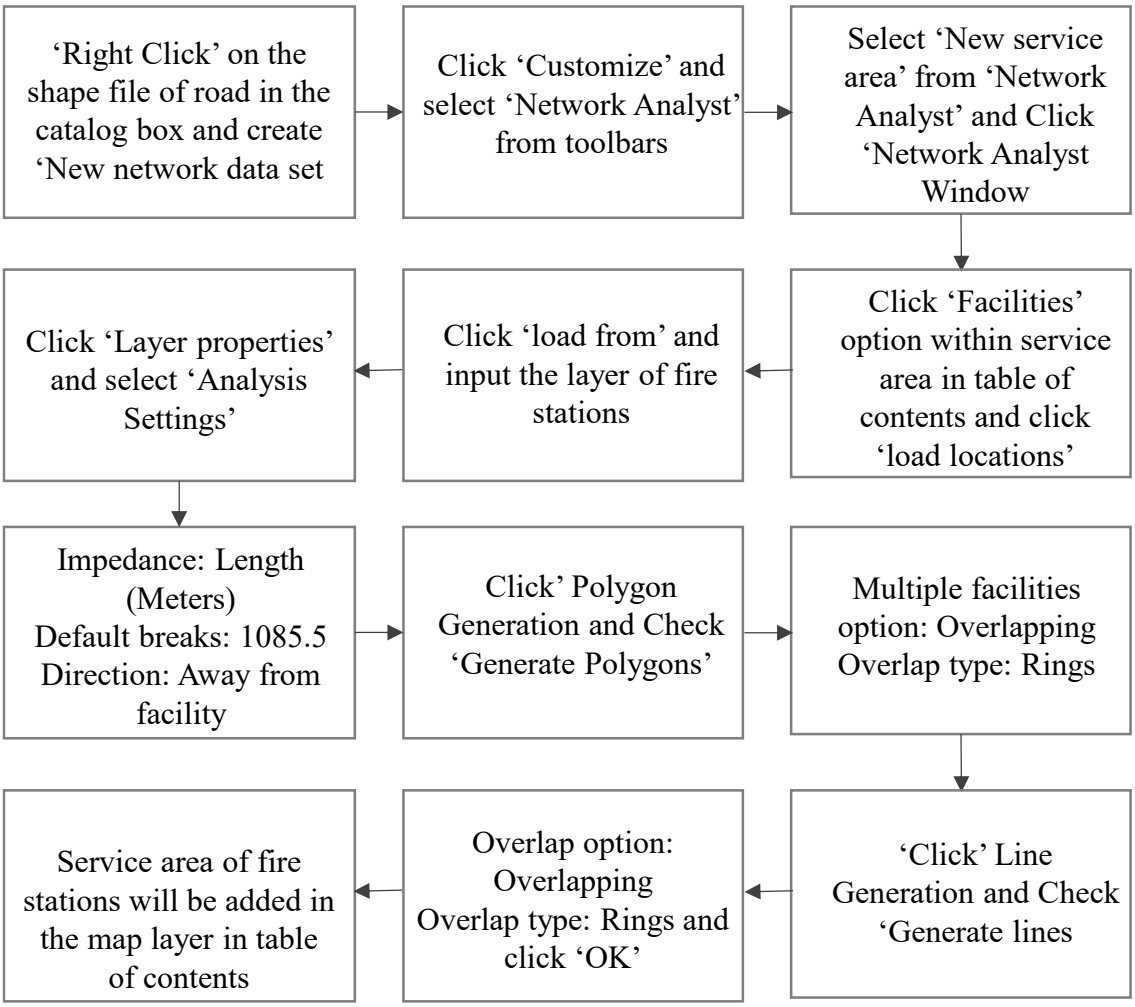

Figure 4.2: Process of Determination of Service Area of Fire Stations

4.3 Determination of Shortest Path

The initial procedure of defining the shortest path is similar to determine service area because initially, a new network dataset of road network is created in catalog box. Then, network analyst is selected to create new route from a specific fire station to hospitals. After that, 'Create network location tool' is selected to input the start point and end point for generating the shortest routes. Under the network analyst to create new route, fire station is selected as starting point and hospital is selected as end point. After that, GIS software solves the shortest route between fire station and hospital.

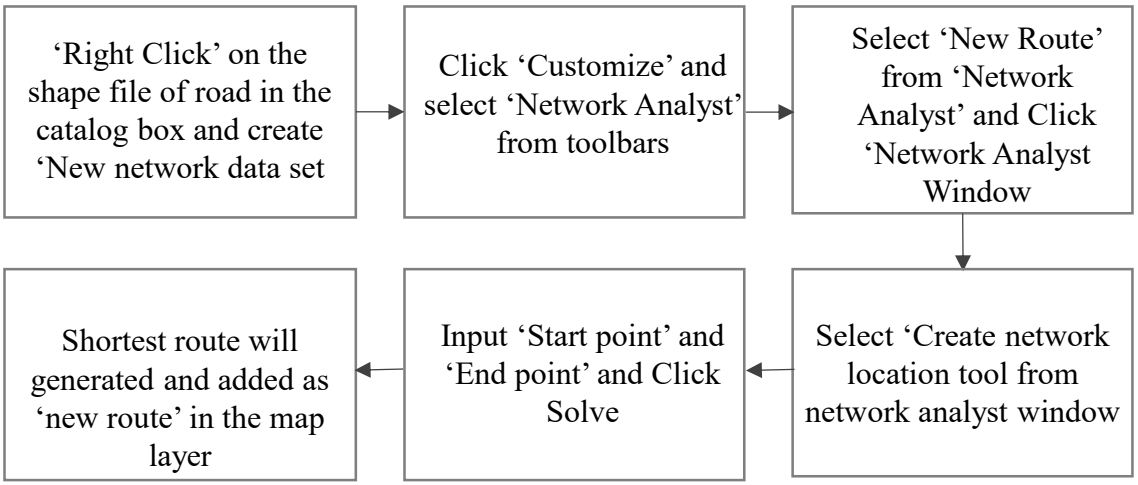

Figure 4.3: Process of Determination of Shortest Route in ArcGIS

There are 15 fire stations in the study area and shortest routes have been identified from each fire station to nearby hospitals following the mentioned procedure of determination of shortest route. After this procedure, distance between fire stations and hospitals along the shortest routes have been determined. Also, response time of each fire station for the identified shortest routes have been calculated to assess the service of fire stations.

CHAPTER 05: RESULT AND DISCUSSION

5.1 Service Area of Fire Stations

The service area of the selected 15 fire stations within the Dhaka City Corporation boundary has been determined in order to observe whether the selected tertiary hospitals fall within the service area. According to world bank data, the average vehicular speed in Dhaka city in seven kilometers per hour. For the determination of the service area of the fire stations, average vehicular speed (seven kilometers/hour) in Dhaka city and emergency response time of fire stations (nine minutes and twenty seconds, NFPA standard 1710) have been considered. Figure 5.1 represents the service area of the fire stations where each station delineates a coverage area with a distance of 1088 meters from the fire stations.

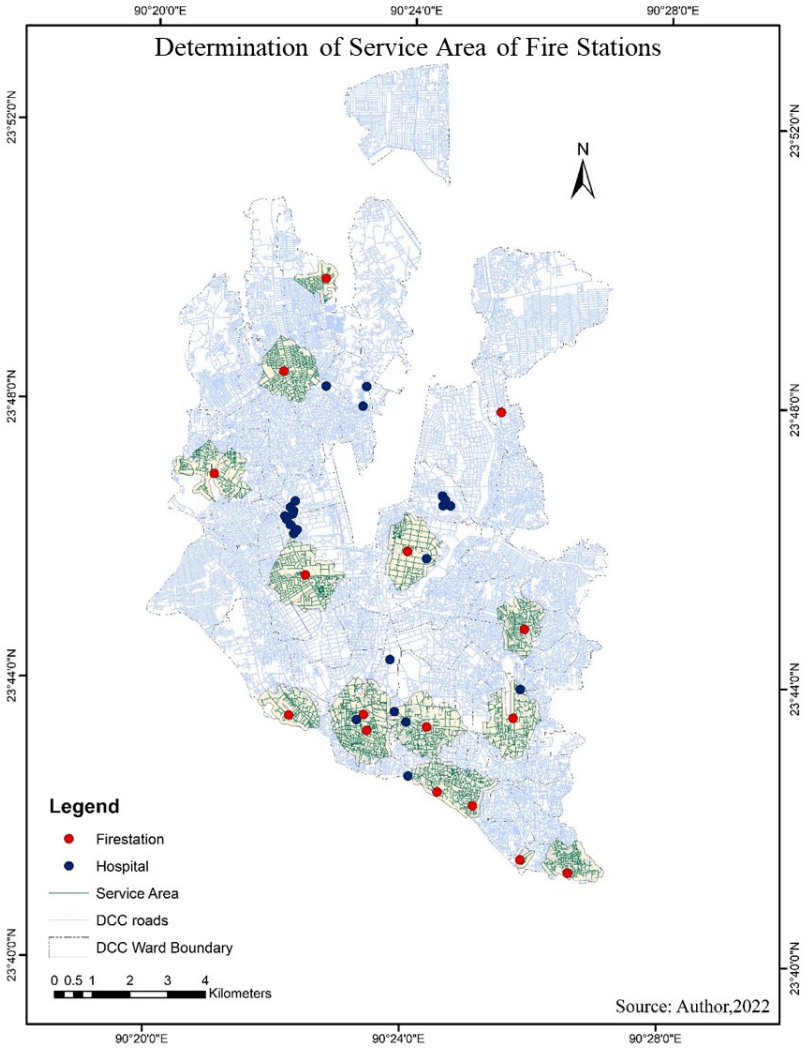

Figure 5.1: Determination of Service Area of Fire Stations

From figure 5.1, it is observed that very few of the selected hospitals are situated within the service area while most of the hospitals are located outside the service area of nearby fire stations.

In the Dhaka North City Corporation (DNCC) area, the number of selected tertiary hospitals is higher than the number of fire stations. There are seventeen tertiary hospitals and only six fire stations in the DNCC area. Figure 5.2 shows that only one tertiary hospital is situated within the

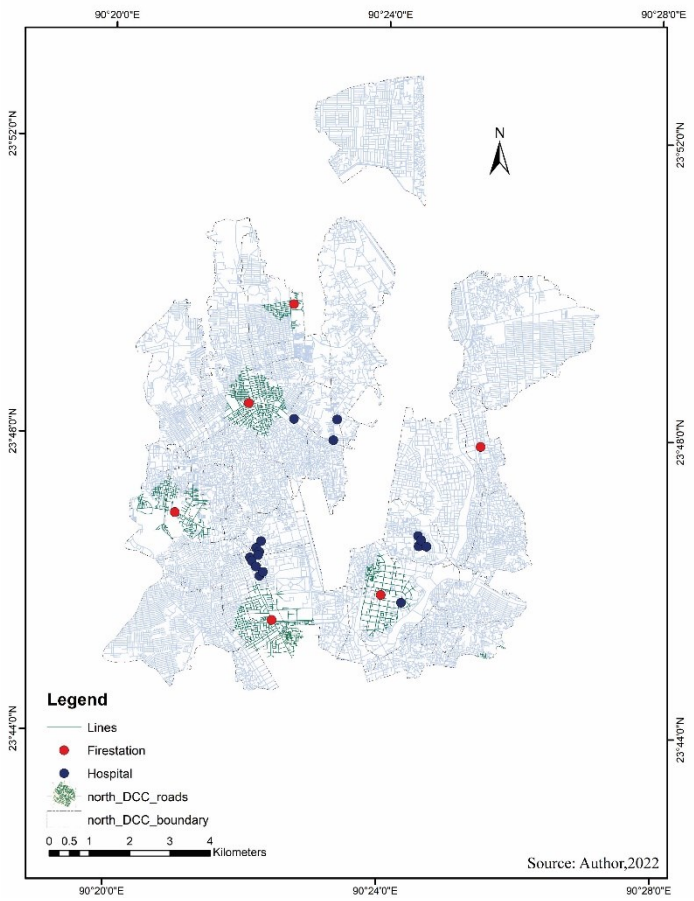

Figure 5.2: Service Area of Fire Stations in DNCC Boundary

service area of a fire station. In ward 41 and ward 45 of the DNCC area, a cluster of hospitals can be seen, which falls outside the service area of nearby stations, which is a matter of major concern.

Table 5.1: Average Minimum Distance and Average Response Time of Fire Stations within DNCC Area

Average Distance (m)	Average Response Time(min)
2603.091	22.94

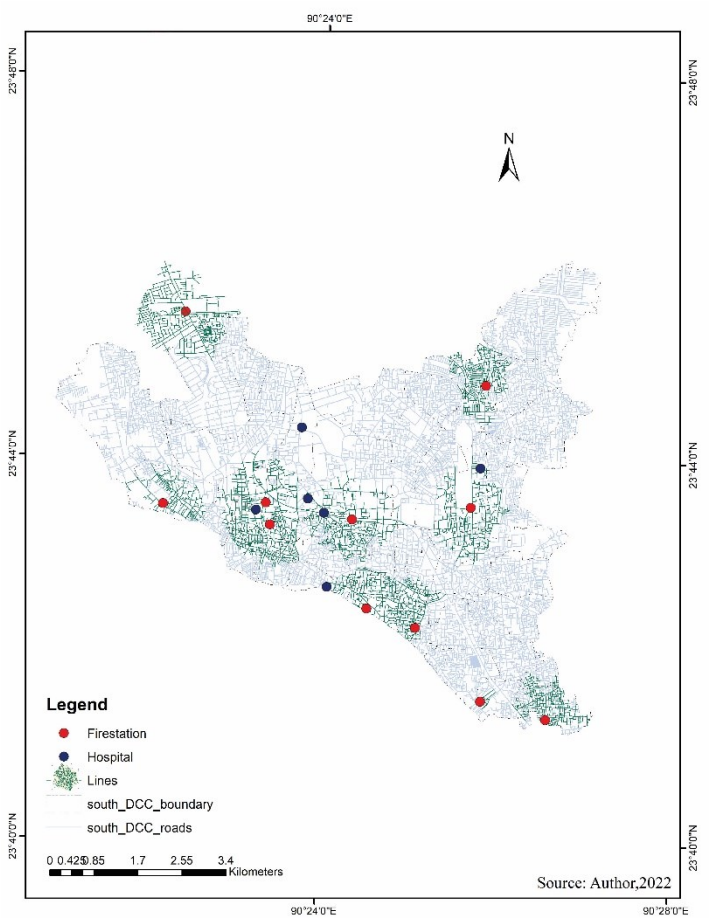

Figure 5.3: Service Area of Fire Stations in DSCC Boundary

In Dhaka South City Corporation (DSCC) area, number of selected tertiary hospitals are lower than the number of fire stations. There are only six selected tertiary hospitals and nine fire stations in DSCC area. Five hospitals fall within the service area of fire stations. In DSCC area, fire stations are closely located while absence of adequate number of fire station is seen in DNCC area. Only six of the selected tertiary hospitals area located within the service area of fire stations.

Table 5.2: Average Minimum Distance and Average Response Time of Fire Stations within DSCC Area

Average Distance(m)	Average Response Time(min)
2246	19.36

From the given tables 5.1 and 5.2, average distance of fire stations to hospitals in both DNCC and DSCC area can be observed which are 2603.091 meters and 2246 meters respectively. Both the

average distance exceeds the standard distance (1085 meters) of service area of fire stations. At the same time, average response time of fire stations in DNCC and DSCC are 22.94 minutes and 19.36 minutes respectively which is higher than the NFPA standard of minimum response time (Nine minutes twenty seconds) of the fire stations. Both the average distance and response time of fire stations in DNCC area is higher than DSCC area. More focuses should be given to reduce the distance and response time of fire stations in DNCC area.

5.2 Shortest Route from Fire Stations to Hospitals

To facilitate emergency response during fire hazards in hospitals, the shortest path from each station to nearby hospitals has been identified. Figure 5.4 shows the identified shortest routes from the fire station to the hospitals. Initially, shortest path analysis has been done for the hospitals

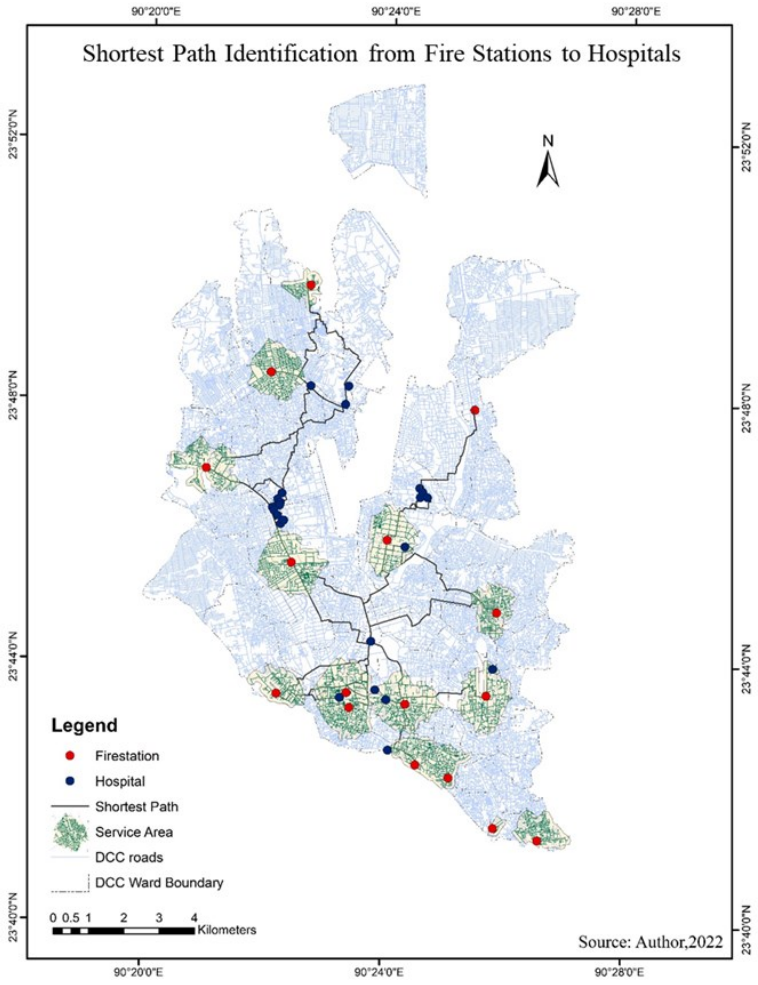

Figure 5.4: Shortest Path Identification from Fire Stations to Hospitals

which are located within the service area of the fire stations, as well as response time for the shortest routes has been calculated. For the hospitals that fall outside the service area, the shortest path has been identified with respect to nearby fire stations. After determining the shortest path from fire stations to hospitals, the response time of each fire station to hospitals has been calculated. For the calculation of response time, the distance of each shortest route and the average vehicular speed of Dhaka (seven kilometers per hour) have been considered.

Figure 5.5 shows three identified routes from the National Institute of Traumatology and Orthopedic Rehabilitation to three nearby fire stations. Response time for these three routes has been calculated. The fire station that has the lowest response time following the shortest route has been chosen as the nearest fire station. In a similar way, the shortest route for the selected tertiary hospitals has been calculated.

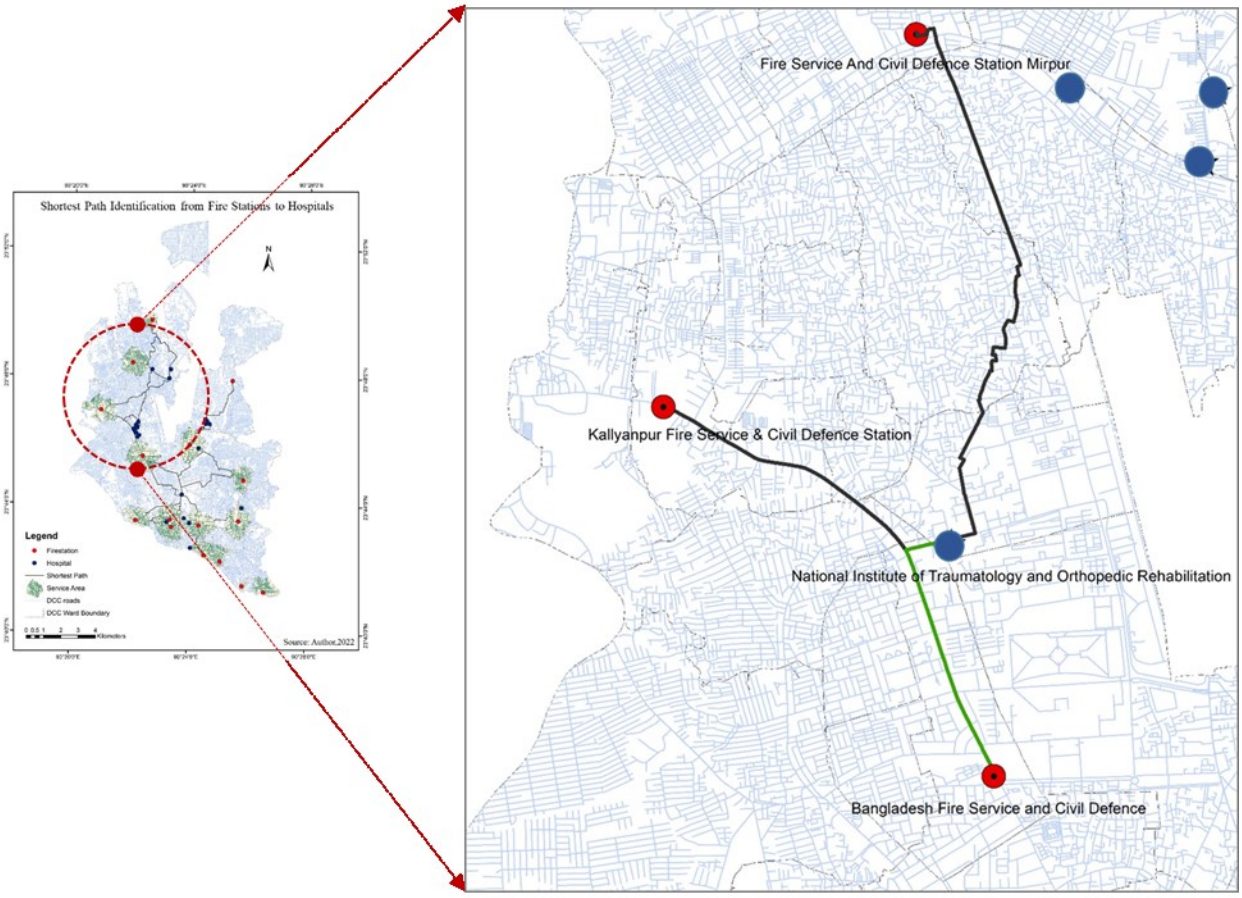

Figure 5.5: Identification of Nearest Hospital with Shortest Route

The following table shows the distance and response time for the identified shortest routes from the fire station to the hospitals.

Table 5.3: Identification of Nearest Fire Service through Determining Response Time

Hospital	**Fire Station**	**Distance (km)**	**Response Time (min)**	**Minimum Response Time (min)**
1. Bangladesh Shishu Hospital and Institute	Bangladesh Fire Service and Civil Defense	2152.27	18.39547009	18.39547009
	Kallyanpur Fire Service & Civil Defense Station	2453.18	20.96735043	
2. BIRDEM General Hospital	Bangladesh Fire Service and Civil Defense	1981.65	16.93717949	16.93717949
	BD Fire Service and Civil Defense Head Quarter	2464.79	21.0665812	
	Lalbagh Fire Station	2482.89	21.22128205	
	Fire service and Civil Defense, Tejgaon	3473.99	29.69222222	
	Fire Defense & Civil Defense Station	3867.75	33.05769231	
	Bangladesh Fire Service and Civil Defense	3975.74	33.98068376	
	Fire service and Civil Defense, Tejgaon	3991.4	34.11452991	

	Khilgaon Fire Station & Civil Defense Station	5312.22	45.40358974	
3. Dhaka Dental College and Hospital	Fire Service And Civil Defense Station Mirpur	2812.75	24.04059829	24.04059829
	Pallabi Fire Station	5188.13	44.34299145	
	Kallyanpur Fire Service & Civil Defense Station	5762.83	49.25495726	
4. Dhaka Medical College Hospital	Lalbagh Fire Station	439.11	4.0567	4.0567
	Bangladesh Fire Service and Civil Defense	763.9	6.7890	
	Fire Defense & Civil Defense Station	3203.56	27.3808547	
5.Govt. Homeopathic Medical College and Hospital	Fire Service And Civil Defense Station Mirpur	3292.65	28.14230769	28.14230769
	Pallabi Fire Station	4783.244	40.88242735	
6.Institute of Diseases of the Chest and & Hospital	Fire service and Civil Defense, Tejgaon	2387.67	20.4074359	20.4074359
	Fire Service & Civil Defense Station, Baridhara	3599.61	30.76589744	
7. Maternal and Child Health Training Institute	Bangladesh Fire Service and Civil Defense	376.82	3.220683761	3.220683761

	Lalbagh Fire Station	538.11	4.599230769	
	Fire Defense & Civil Defense Station	2208.66	18.8774359	
8. Mugda Medical College and Hospital	Dhaka Inland Container Depot Fire Station	893.45	7.636324786	7.636324786
9. National Ashtma Center	Fire service and Civil Defense, Tejgaon	2204.66	18.84324786	18.84324786
	Fire Service & Civil Defense Station, Baridhara	3752.79	32.07512821	
10. National Center for Control of RFHD	Bangladesh Fire Service and Civil Defence,1	1438.02	12.29076923	12.29076923
	Kallyanpur Fire Service & Civil Defense Station	2851.87	24.37495726	
11. National Institute of Neurosciences and Hospital	Kallyanpur Fire Service & Civil Defense Station	2609.64	22.30461538	22.30461538
	Kallyanpur Fire Service & Civil Defense Station	2794.833926	23.88746945	
12. National Institute of (NITOR)	Bangladesh Fire Service and Civil Defence,1	2183.43	18.66179487	18.66179487

	Kallyanpur Fire Service & Civil Defense Station	2446.3	20.90854701	
	Kallyanpur Fire Service & Civil Defense Station	2469.95	21.11068376	
13. National Institute of Burn and Plastic Surgery	BD Fire Service and Civil Defense Head Quarter	546.83	4.673760684	4.673760684
	Dhaka Inland Container Depot Fire Station	3546.26	30.30991453	
14. National Institute of Cancer Research & Hospital	Fire Service & Civil Defense Station, Baridhara	3525.64	30.133333	30.133333
15. National Institute of Cardiovascular Diseases	Bangladesh Fire Service and Civil Defense	1525.94	13.04222222	13.04222222
	Kallyanpur Fire Service & Civil Defense Station	2809.2	24.01025641	
16. National Institute of Ear, Nose and Throat	Fire service and Civil Defense, Tejgaon	935.93	7.999401709	7.999401709
	Khilgaon Fire Station & Civil Defense Station	4813.96	41.14495726	
17. National Institute of Kidney Diseases & Urology	Bangladesh Fire Service and Civil Defense	1691.06	14.45350427	14.45350427

	Kallyanpur Fire Service & Civil Defense Station	2380.92	20.34974359	
18. National Institute of Mental Health and Hospital	Bangladesh Fire Service and Civil Defense	1769.22	15.12153846	15.12153846
	Kallyanpur Fire Service & Civil Defense Station	2463.54	21.05589744	
19. National Institute of Neurosciences & Hospital	Bangladesh Fire Service and Civil Defense	2612.92	22.33264957	22.33264957
20. National Institute of Ophthalmology & Hospital	Bangladesh Fire Service and Civil Defense	2311.78	19.75880342	19.75880342
21. Shaheed Suhrawardy Medical College and Hospital	Bangladesh Fire Service and Civil Defense	1586.45	13.55940171	13.55940171
	Kallyanpur Fire Service & Civil Defense Station	2827.9	24.17008547	
22. Sheikh Russel Gastro liver Institute & Hospital	Fire service and Civil Defense, Tejgaon	2327.22	19.89076923	19.89076923
23. Sir Salimullah Medical College	Sadarghat Fire Service and Civil Defense Station	1183.14	10.11230769	10.11230769

	BD Fire Service and Civil Defense Head Quarter	1761.47	15.05529915	
24. Unani & Ayurvedic Medical College and Hospital	Fire Service And Civil Defense Station Mirpur	1369.57	11.7057265	11.7057265
	Pallabi Fire Station	4734.51	40.46589744	
	Bangladesh Fire Service and Civil Defense	6485.55	55.43205128	

5.3 Statistical Analysis to Assess the Response Time of Fire Stations

To assess the response of the shortest routes, some statistical analyses have been done to determine whether the identified response time of fire station follows a normal distribution or not.

Figure 5.6 denotes a rightly skewed histogram of response time of fire stations. The distribution of the response time is not symmetrical, and the response time of the fire stations are not normally distributed. As the distribution of response time is rightly skewed, it reveals the fact that response

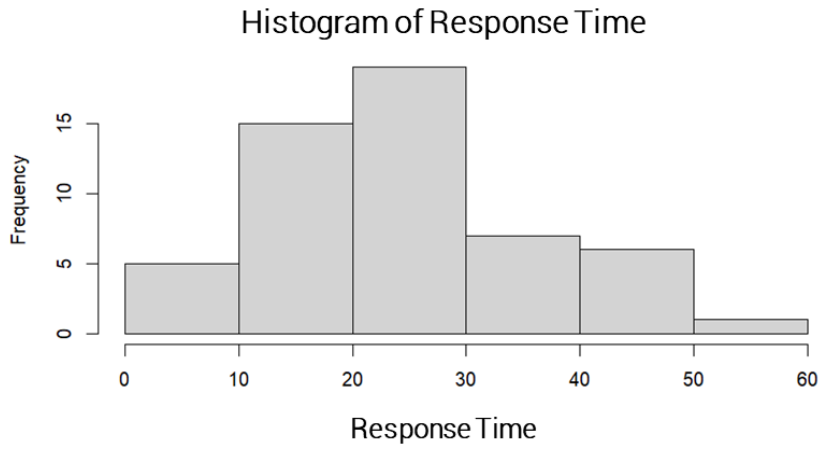

Figure 5.6: Histogram of Response Time of Fire Stations

time of majority of the fire stations fall within the range of 20 to 50 minutes which is higher than the NFPA standard response time (Nine minutes twenty seconds) of fire station.

Statistical Test: Along with the visual statistical analysis, Andarson-Darling test and the CVM test has used for statistical test. Both tests provide a p-value of 0.03459 and 0.02085 which are less than 0.05 proving that the response time of fire stations does not follow a normal distribution.

Box whisker plot: A box plot has been illustrated to show the range of response time. The mean response time is 23.5027 minutes which is higher than the NFPA standard response time (Nine minutes twenty seconds) of fire station.

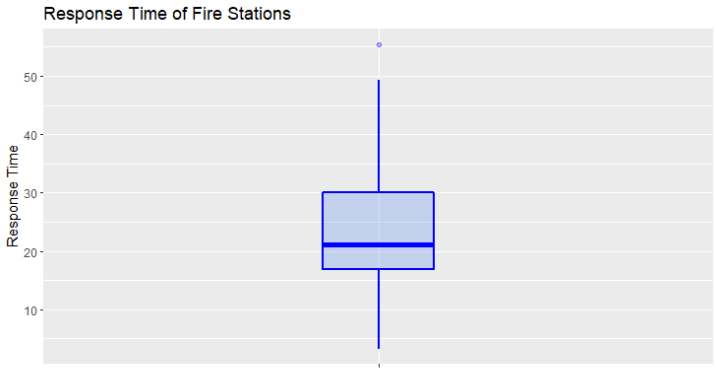

Figure 5.7: Box Plot of Response Time of Fire Stations

ANN Statistical Analysis: To analyze the pattern of spatial distribution of fire station, average nearest neighborhood statistical analysis has been done. The result shows that the distribution of fire stations follow a dispersed spatial distribution which implies, at the time of selecting locations for fire stations less priority was given to the location of the existing hospitals. As a result, majority of the hospitals are located outside the service area of fire stations.

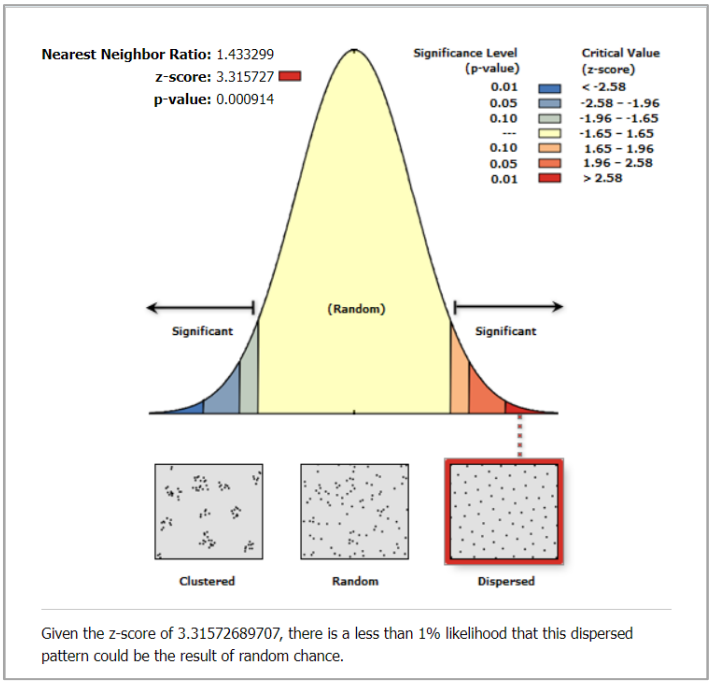

Figure 5.8: Average Nearest Neighborhood Summary

5.4 Major Findings

Determination of the service area of the 15 fire stations and assessing the spatial distribution of hospitals as well as the response time of the optimum routes from fire stations to hospitals have enlighten us with some significant insights which are

Dhaka North City Corporation area has insufficient fire stations. Most hospitals are located outside the service area of the nearby fire stations.

The spatial distribution of fire stations is dispersed, which may have contributed to increased response time even while taking the optimum route. Response times for the identified shortest routes range from 15 to 30 minutes, regardless of the National Fire Protection Association's minimum response time for fire service nine minutes and twenty seconds.

The average response time of the fire stations is 23.5027 minutes, which is much longer than the NFPA requirement for fire service response time (nine minutes and twenty seconds).

CHAPTER 6: RECOMMENDATION AND CONCLUSION

6.1 Conclusion

A GIS based application for emergency response of fire services has been developed to manage fire in hospitals as well as to mitigate the impacts of fire accidents. Finding suitable routes in emergency situations is a critical issue. Our study focuses on network analysis to determine the service area and shortest route of the existing fire stations in Dhaka City Corporation area. Current scenarios of response time have been assessed using spatial analysis tools of ArcGIS. Following the GIS based analysis, the shortest routes have been proposed from fire station to hospitals in the study area. It is now possible to detect the hospitals that fall outside the service area of the fire station. With the help of this application, the shortest route from fire station to nearby hospitals can followed for immediate response during any critical situation in hospitals.

6.2 Recommendation

Based on our analysis of the service area of fire stations and identified shortest routes, some recommendations are given to improve the emergency response of fire service and minimize the impacts of fire accidents in hospitals.

1. New locations for fire service can be proposed so that majority of the tertiary hospitals fall within the service area of the fire stations.

2. Each fire station should keep the documentation of the shortest routes to hospitals for reducing response time during emergency. At the same time, drivers of the fire brigade should be conscious about various situations which includes one-way streets, streets under repair or other blockings along the network whenever there is an emergency call.

3. Direct landline connection should built among hospital and nearby fire stations so that hospitals can reach to the nearest fire station during any critical situation.

4. During critical situation, fire services can be provided with separate lanes to reduce the response time.

5. There can be strict laws for vehicles that create blockage for fire trucks during times of fire emergency.

6. National level policy makers should develop guidelines so that tertiary hospitals could be located within the service area boundary of fire stations.

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GLOSSARY

AD test: AD test or Anderson–Darling test is a statistical test of whether a given sample of data is drawn from a given probability distribution.

Average Nearest Neighbor: Average Nearest Neighbor measures the distance between each feature centroid, and its nearest neighbor's centroid location.

CVM test: CVM test or Cramer-von Mises's test is an empirical distribution function omnibus test for the composite hypothesis of normality. It uses the summed squared differences between observed and expected cumulative proportions as the test statistic.

Emergency Facilities: Emergency facilities are buildings, structures, equipment, or systems that are used to deliver emergency services to the citizens, such as fire protection, ambulance service. Fire stations, health center and clinic, police stations deliver emergency service during critical situation.

Least-Cost Path Analysis: Least cost path analysis is a distance analysis tool within GIS that uses the least cost path or the path between two locations that costs the least to those travelling along it to determine the most cost-effective route between a source and destination.

Tertiary Hospital: A tertiary hospital is a hospital that provides tertiary care, which is a level above secondary health care, that has been defined as highly specialized medical care, usually provided over an extended period of time in large hospitals, that involves advanced and complex diagnostics, procedures and treatments performed by medical specialists.