# 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

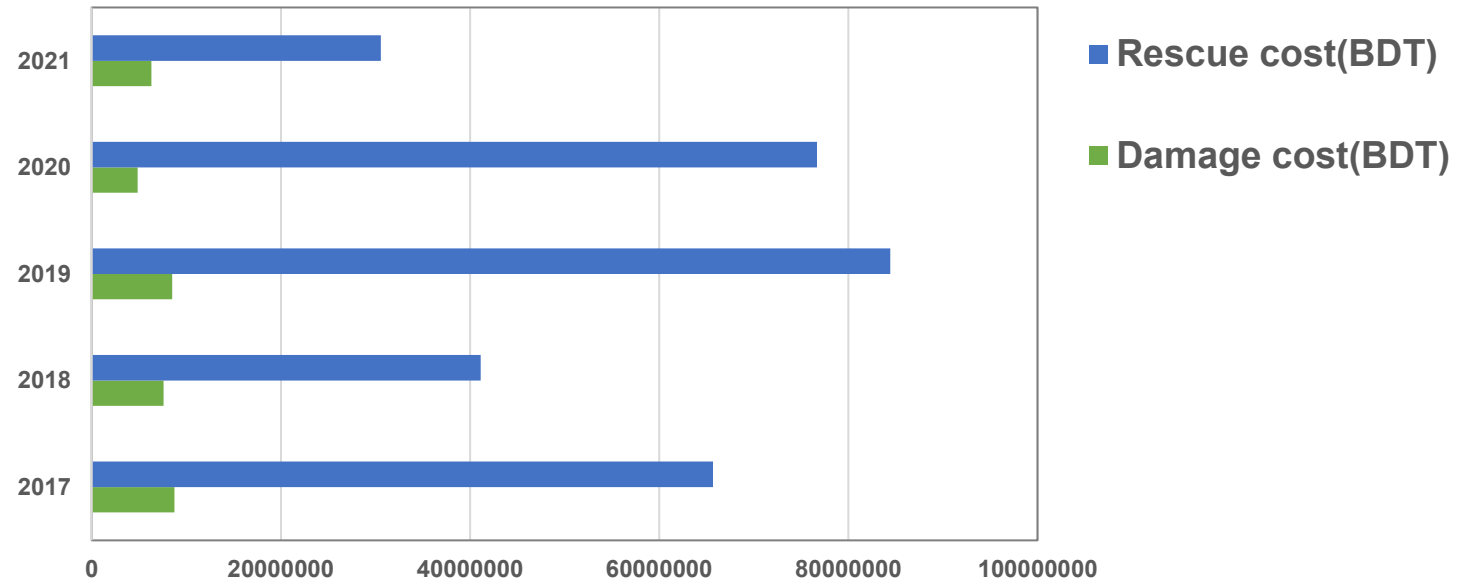**GROUP 02: 1815002, 03, 23, 26, 28, 29**
**LEVEL/TERM: 3/1**

**PLAN 362: GIS AND REMOTE SENSING STUDIO**

## Total Cost during Fire Accidents in Hospital

| Year | Damage Cost (BDT) | Rescue Cost (BDT) |
|------|-------------------|-------------------|
| 2017 | 87,61,377 | 6,56,89,332 |
| 2018 | 75,84,272 | 4,11,17,327 |
| 2019 | 85,23,056 | 8,44,32,448 |
| 2020 | 48,70,962 | 7,66,73,532 |
| 2021 | 63,06,620 | 3,05,76,890 |

**Total Cost during Fire Accidents in Hospitals**



## Total Number of Injured and Deaths during Fire Accidents in Hospital

| Year | No of fire incidents | No of Injured | No of Deaths |
|------|----------------------|---------------|--------------|
| 2017 | 96 | 15 | 13 |
| 2018 | 86 | 10 | 8 |
| 2019 | 105 | 23 | 18 |
| 2020 | 90 | 4 | 10 |
| 2021 | 91 | 13 | 5 |

**Source: Fire Service and Civil Defense**

2

**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.

Among the hospitals:

❏ Only **11 (2.5%) private hospitals** were found to **have enough fire safety equipment**

❏ 421 **(97.5%)** hospitals were rated **risky or high-risky**

# Fire Incidents in Hospitals of Dhaka City

## Dhaka Medical College Hospital, 2021


Source: The Daily Star, 2021


Source: The Daily Star, 2021

**Cause** → **Medical Equipment**

The risk of fire in the ICU of the hospital has increased during the corona period. 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)

**Fatality** → **Number of Death: 03**

# Fire Incidents in Hospitals of Dhaka City

## Mugda General Hospital, October 2021



**Cause** ➡ **Air Conditioner Explosion**

The fire originated at catheterization laboratory and later spread to the intensive care unit (ICU) of the hospital. (Department of Health, Hospital and Clinic, 2021)

**Fatality** ➡ **Number of Injured: 08**

Source: Dhaka Tribune, 2021

# Fire Incidents in Hospitals of Dhaka City

## Shaheed Suhrawardy Medical College Hospital, 2019



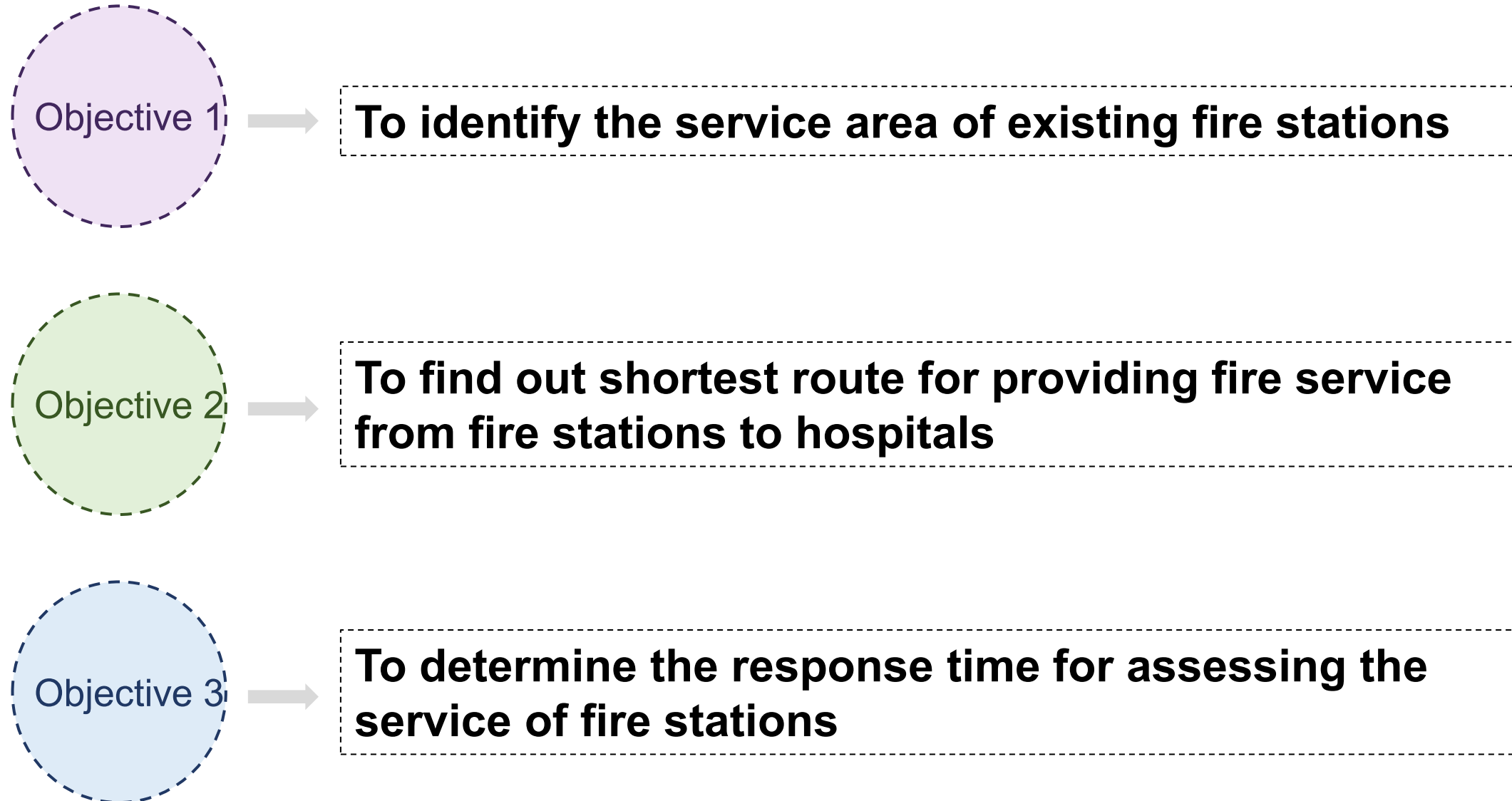Source: The Daily Star, 2019



Source: The Daily Star, 2019

**Cause** → The fire originated at the store room on ground floor and spread to the children ward (Department of Health, Hospital and Clinic, 2021)

**Fatality** → **Number of Death: 01**

# OBJECTIVE OF THE STUDY

**Objective 1** → **To identify the service area of existing fire stations**

**Objective 2** → **To find out shortest route for providing fire service from fire stations to hospitals**

**Objective 3** → **To determine the response time for assessing the service of fire stations**

# METHODOLOGY

| Literature Review | Selection of Study Area | Data Collection | Working Procedure |
|---|---|---|---|
| An overview of the previously published similar works based on GIS tools | Dhaka City Corporation Area has been chosen as the study area. | To produce reliable insights for the project, data was collected and analysed in four processes. | The procedure of Network analysis was conducted in ArcGIS 10.4 |

# LITERATURE REVIEW

## Literature 01

As one of the main functions of GIS, network analysis plays an important role in vehicle routing, traffic tourism, urban planning , electric power, communication and closest facility. **(Min and Wei-fang,2012)**

## Literature 02

In network analysis, the most fundamental and the most critical problem is the computation of optimal route between different locations on a network. **(Zhang et al,2009)**

## Literature 03

Access and service coverage are spatial , the problems related to fire station location have been extensively studied using spatial optimization approaches that integrate GIS and mathematical models. **(Yao et al, 2019)**

## Literature 04

GIS modeling is applied conducting
network analysis to identify the best route
from the location of an incident to a health
care provider in Greater Cairo metropolitan area.
**(Sayed Ahmed et al, 2017)**

## Literature 05

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. **(Hariani and Astor, 2021)**
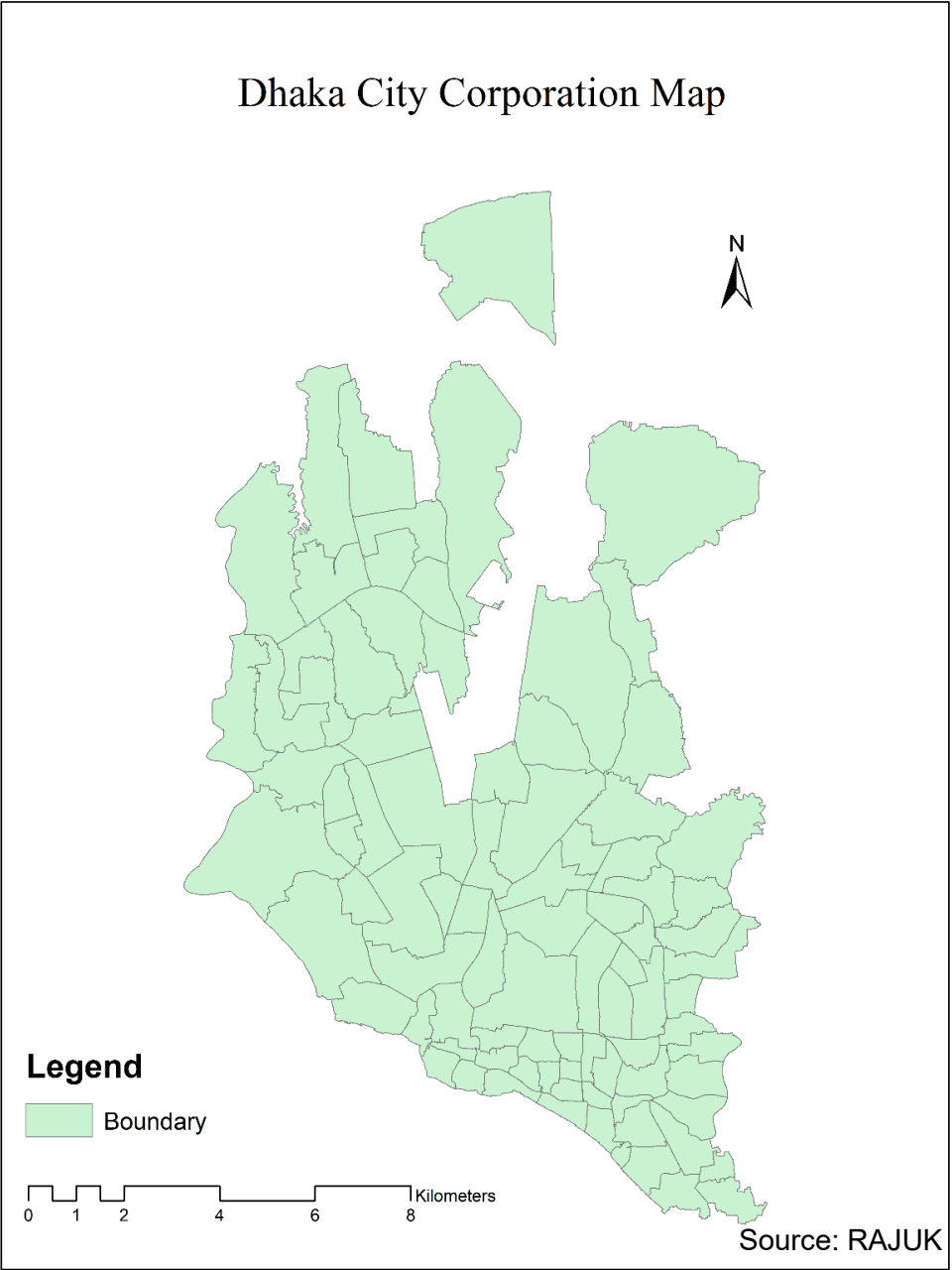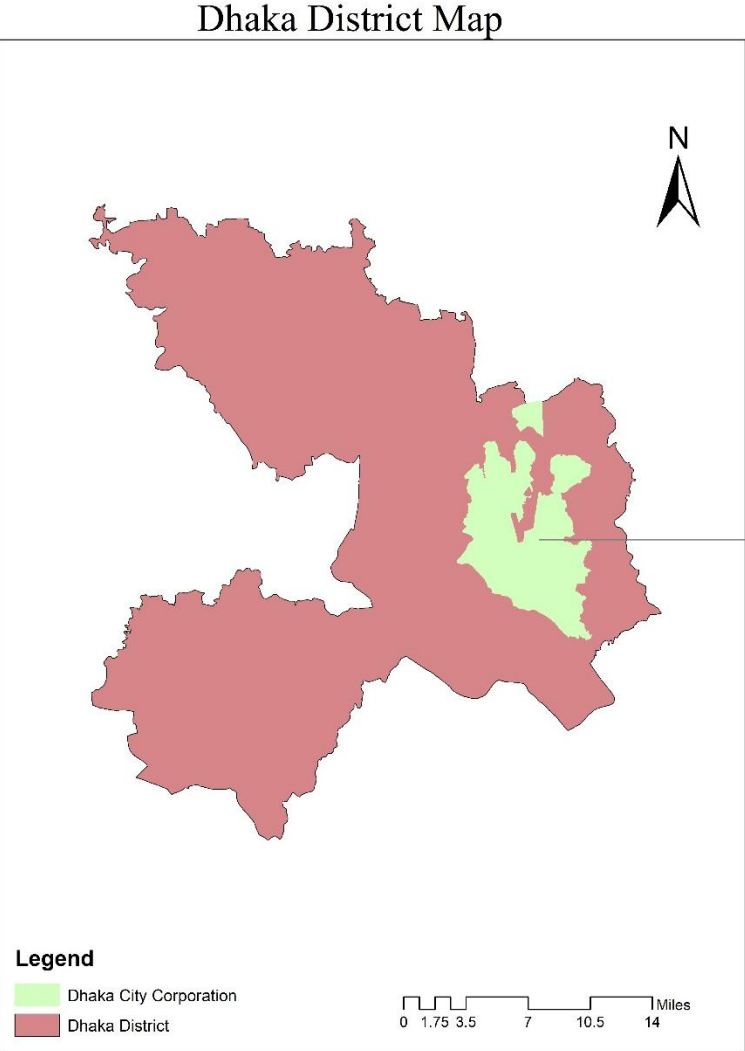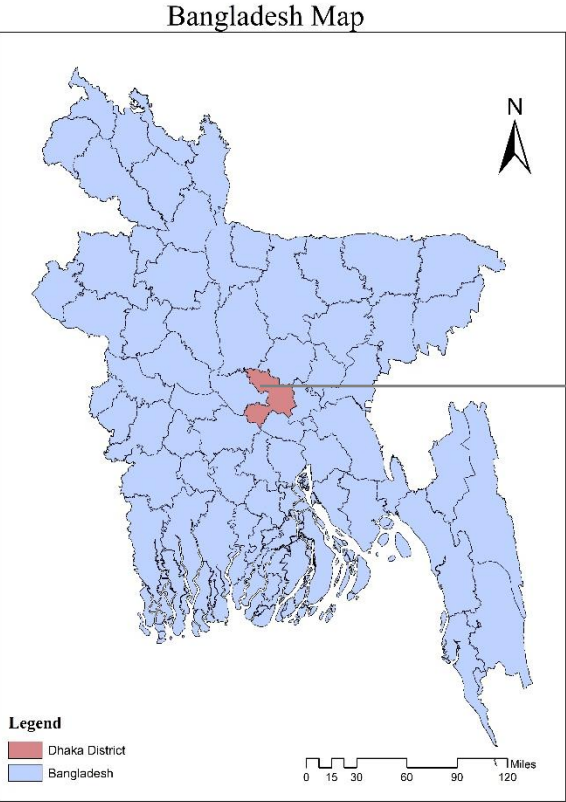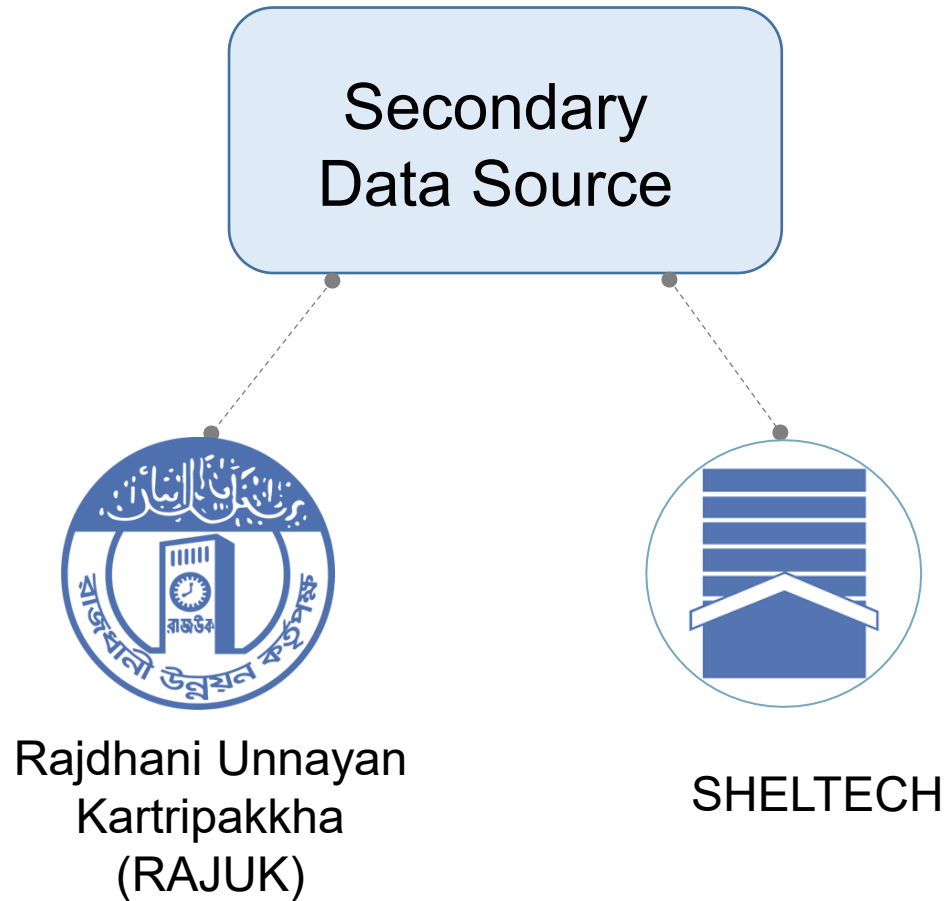
## Literature 06

A GIS based approach has been used for location finding and calculating optimal route for fire emergency vehicles for the convenience of drivers in Myanmar **(Sein and Phyo, 2019)**

# STUDY AREA

## Bangladesh Map

## Dhaka District Map

## Dhaka City Corporation Map

Secondary Data Source

Rajdhani Unnayan Kartripakkha (RAJUK)

SHELTECH

| Collected Data | Source |
| --- | --- |
| 1. Shape file of road network in Dhaka metropolitan area | RAJUK |
| 2. Shape files of existing land use in Dhaka metropolitan area | RAJUK |
| 3. Shape file of Dhaka city corporation boundary | SHELTECH |

# LIMITATIONS

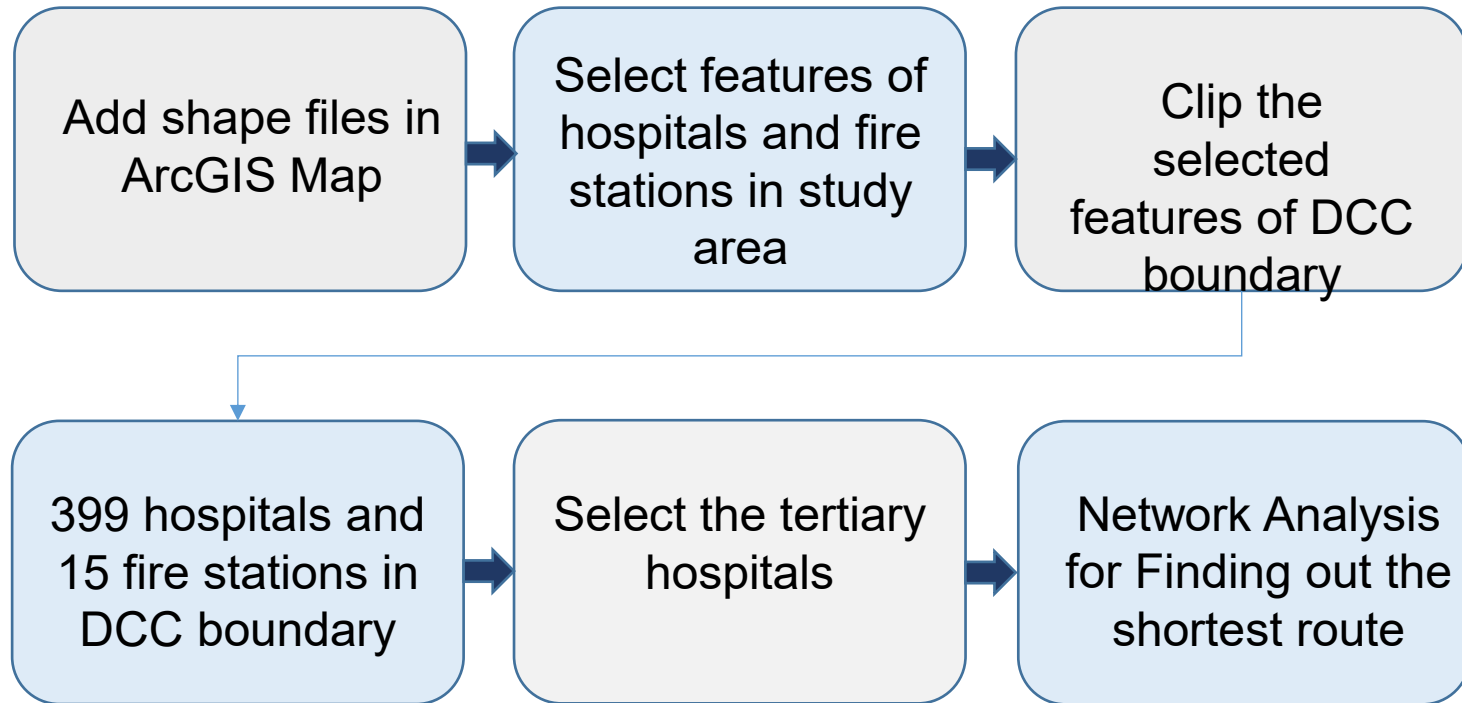**1** Unable to conduct field survey to collect data due to time constraint

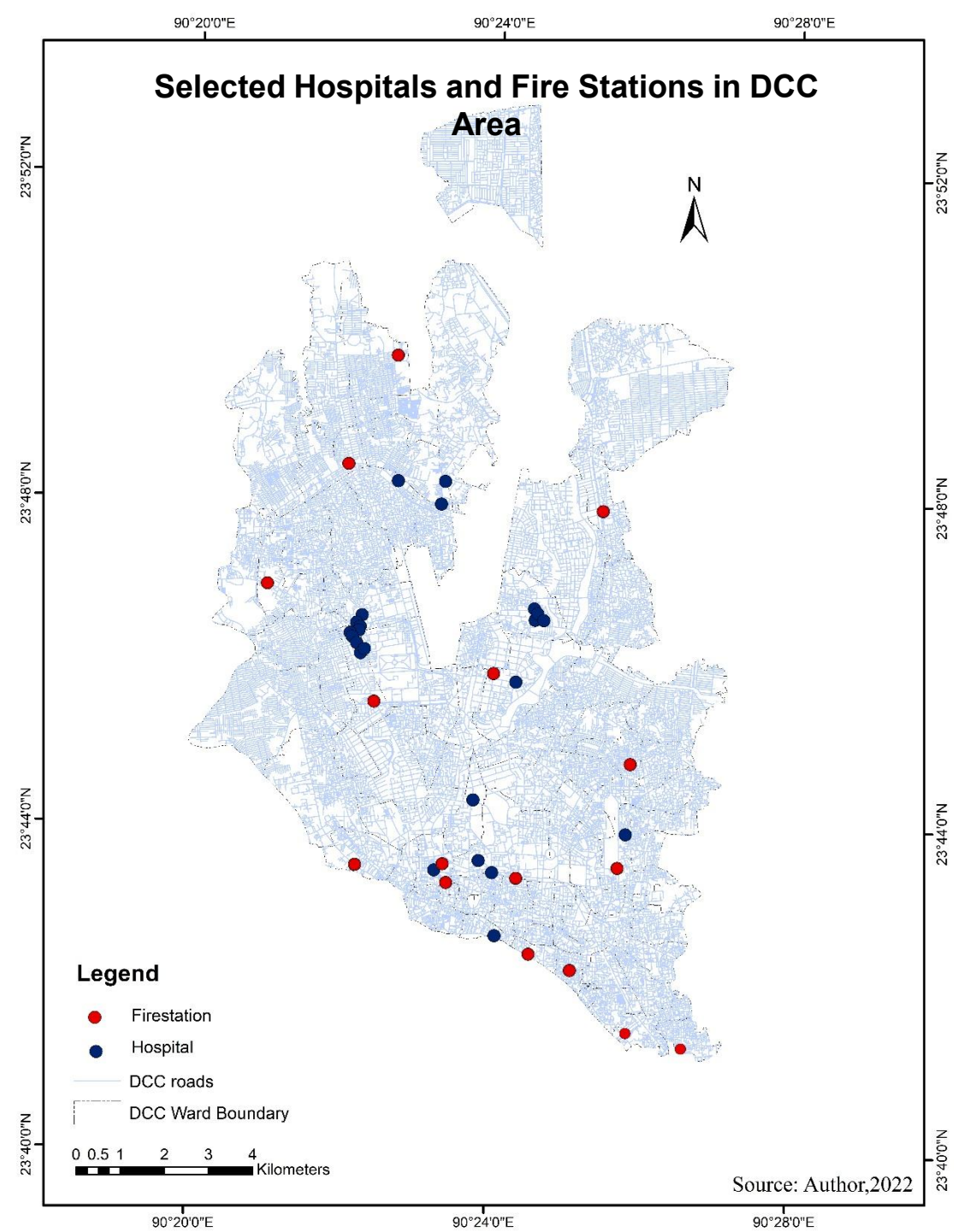**2** Unable to determine optimum route calculating real travel time data

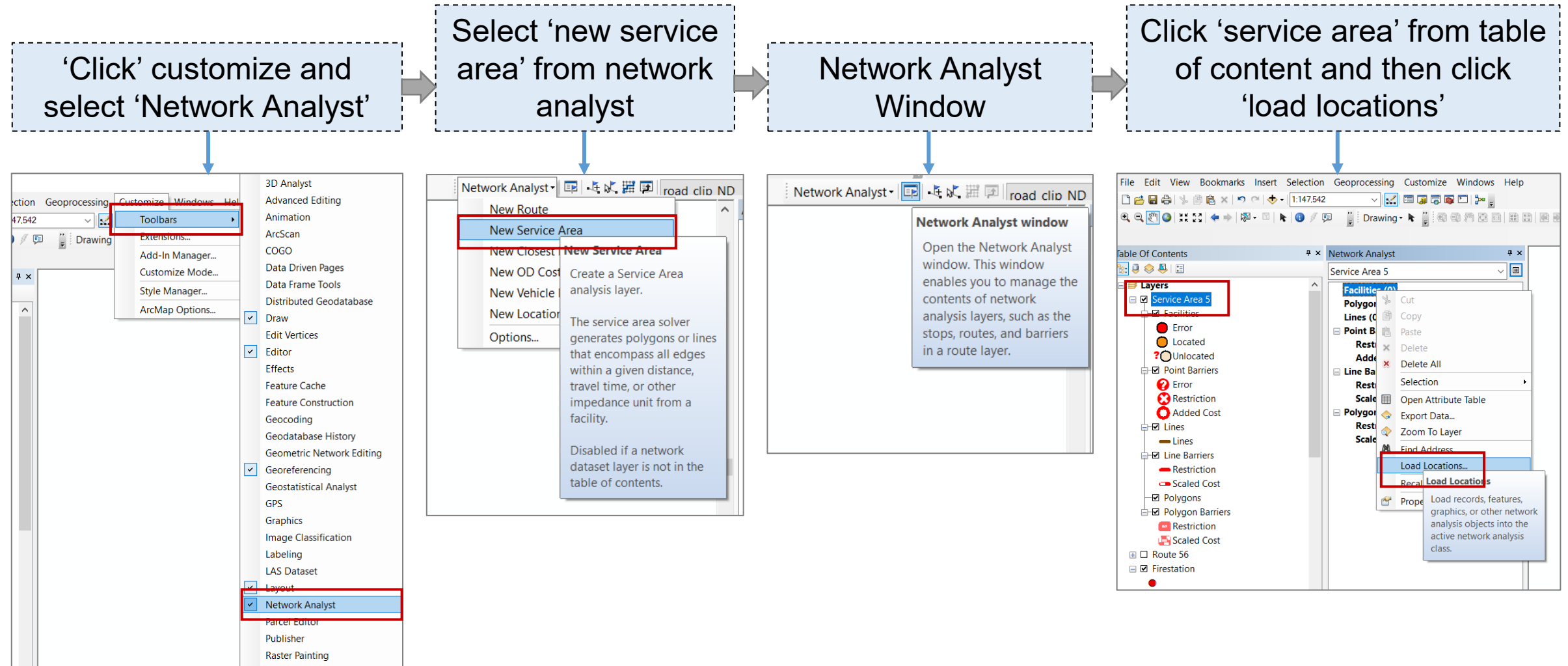**3** Unable to conduct least cost analysis

# WORKING PROCEDURE in ArcGIS 10.4



Add shape files in ArcGIS Map → Select features of hospitals and fire stations in study area → Clip the selected features of DCC boundary → 399 hospitals and 15 fire stations in DCC boundary → Select the tertiary hospitals → Network Analysis for Finding out the shortest route

Selected Hospitals and Fire Stations in DCC Area

# Network Analysis to Determine the Service Area of the Fire Stations
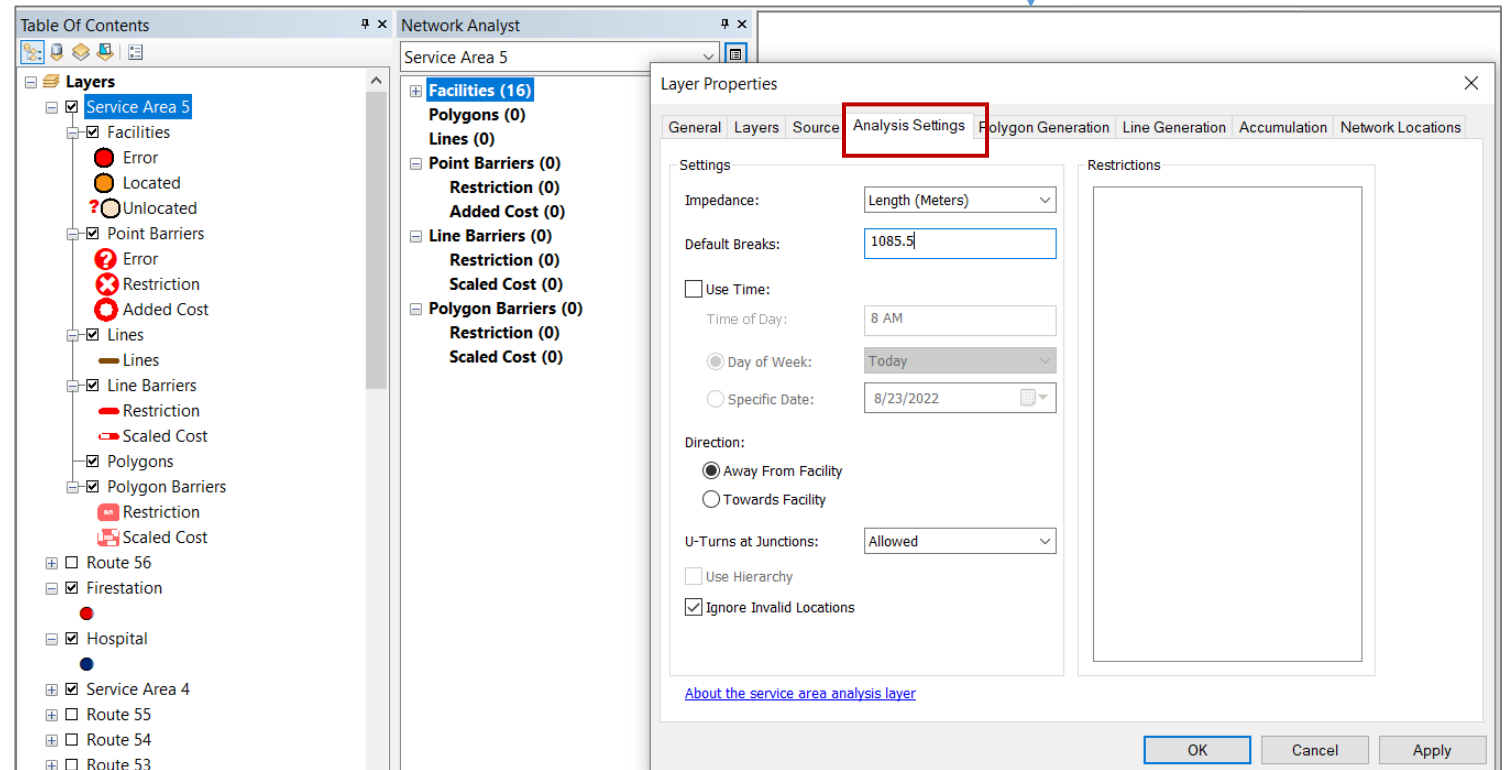
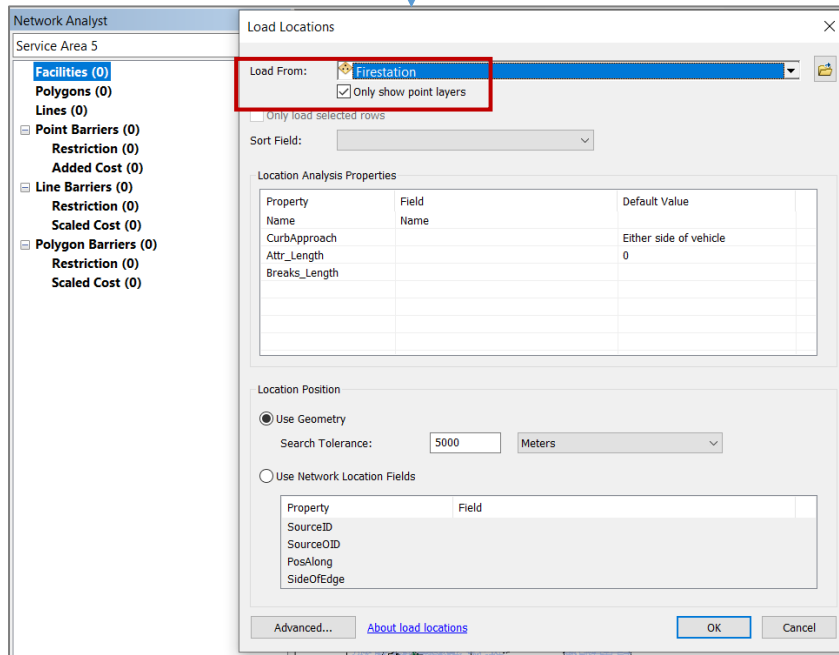# Determination of service area of fire stations



'Click' customize and select 'Network Analyst' → Select 'new service area' from network analyst → Network Analyst Window → Click 'service area' from table of content and then click 'load locations'

# Determination of service area of fire stations

Click 'load from' and input the layer of fire stations

Click 'layer properties' and select 'Analysis Settings'

Impedance: Length (Meters)
Default breaks: 1085.5
Direction: Away from facility

# Determination of service area of fire stations



'Click' Polygon Generation and Check 'Generate Polygons'

Multiple facilities option: Overlapping
Overlap type: Rings

'Click' Line Generation and Check 'Generate lines'

Overlap option: Overlapping
Overlap type: Rings

**Determination of Service Area of Fire Stations**

Determination of Service Area of Fire Stations

Legend
- Firestation
- Hospital
- Service Area
- DCC roads
- DCC Ward Boundary

Source: Author,2022

19

Determination of Service Area of Fire Stations

Legend
- ● Firestation
- ● Hospital
- — Service Area
- — DCC roads
- ⊡ DCC Ward Boundary

0 0.5 1   2   3   4 Kilometers

Source: Author,2022

20

Determination of Service Area of Fire Stations

Legend
- Firestation
- Hospital
- Service Area
- DCC roads
- DCC Ward Boundary

Source: Author,2022
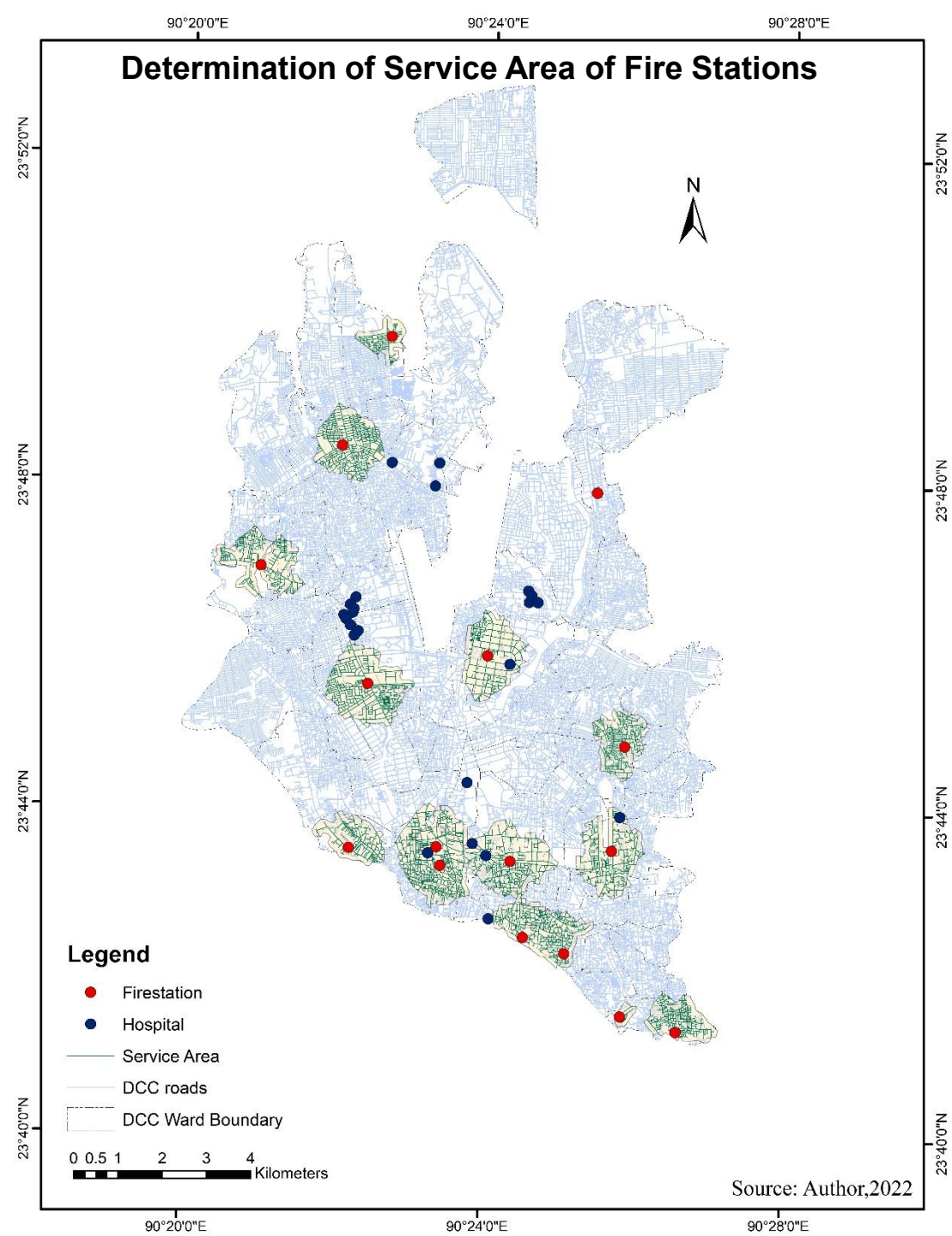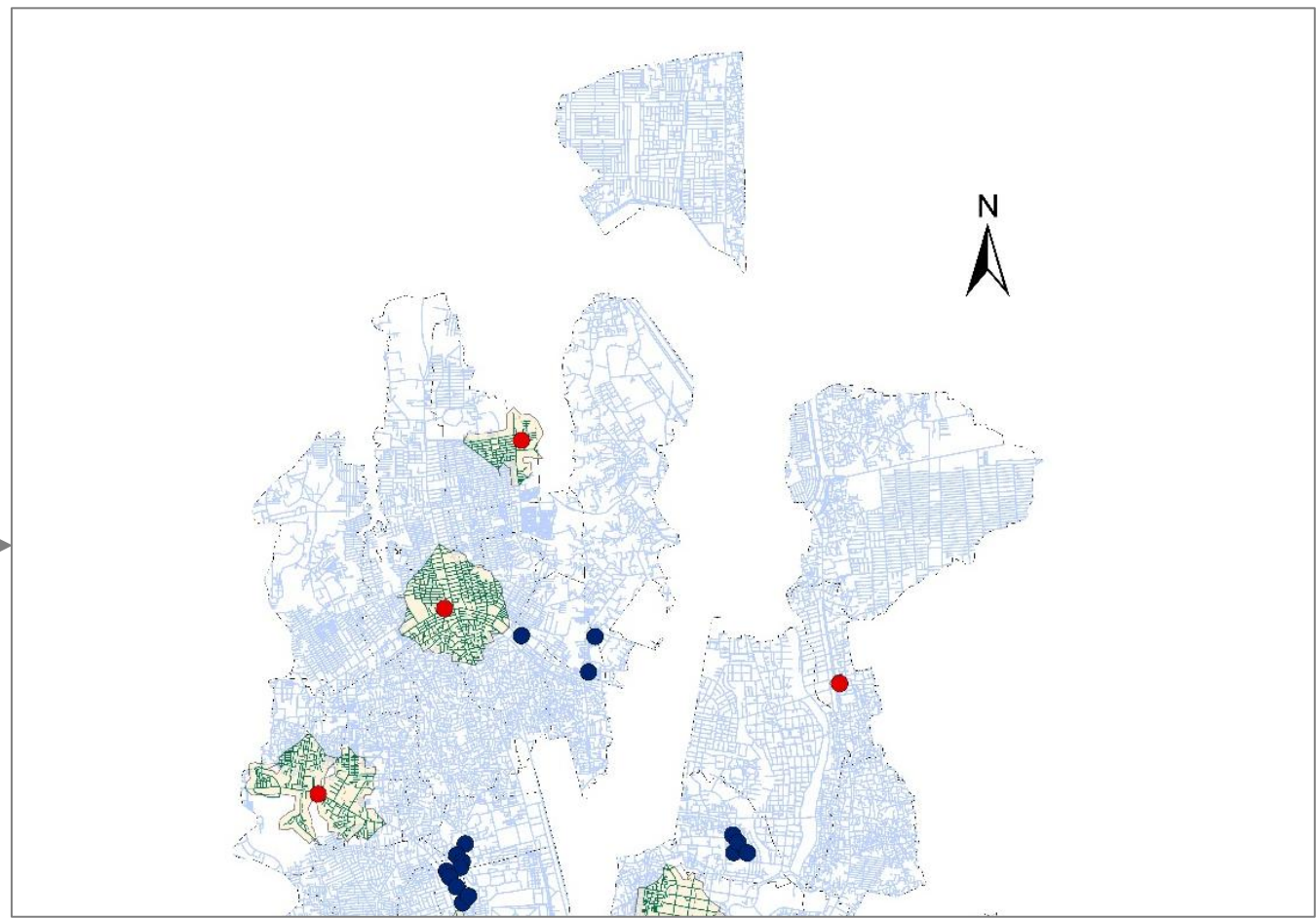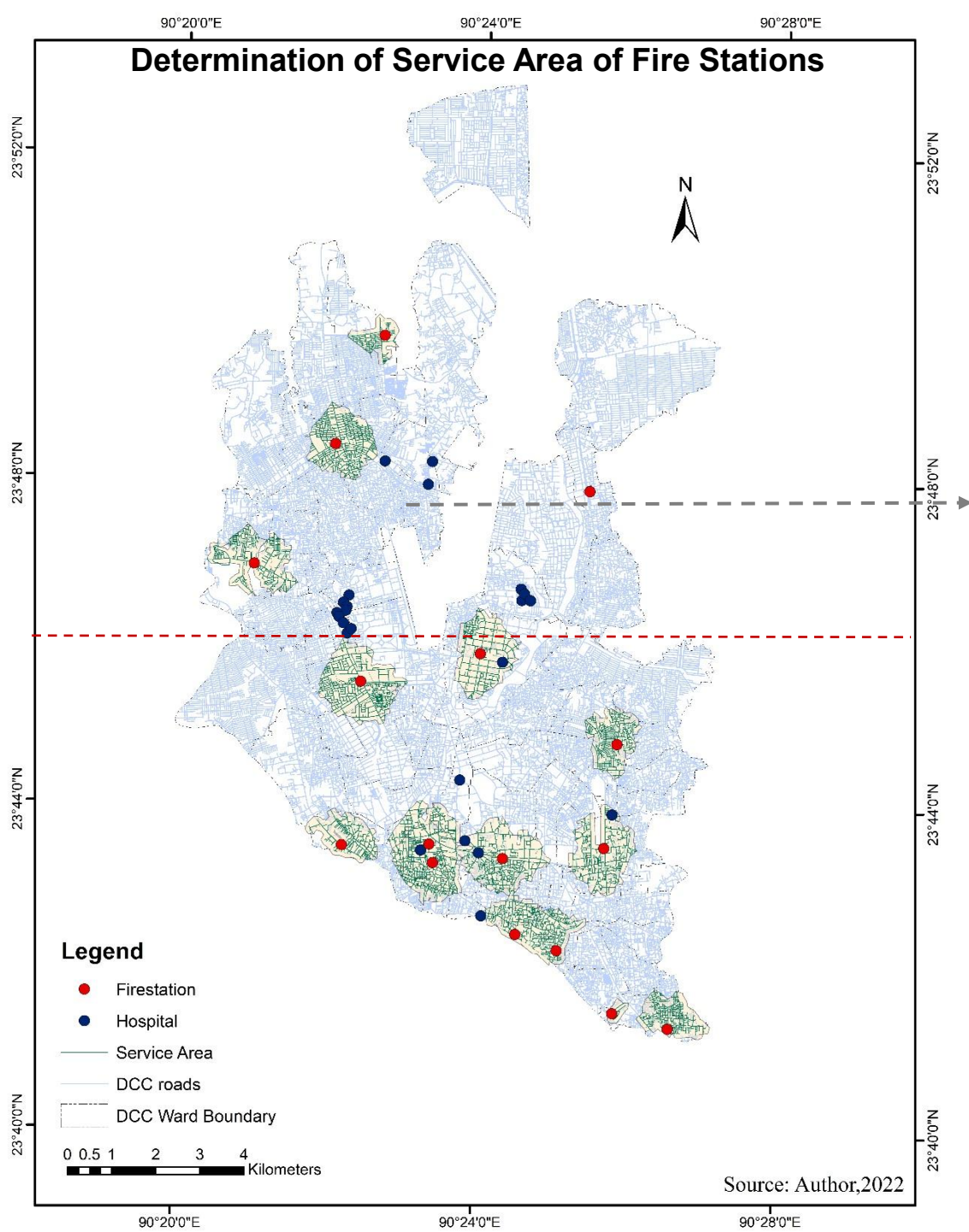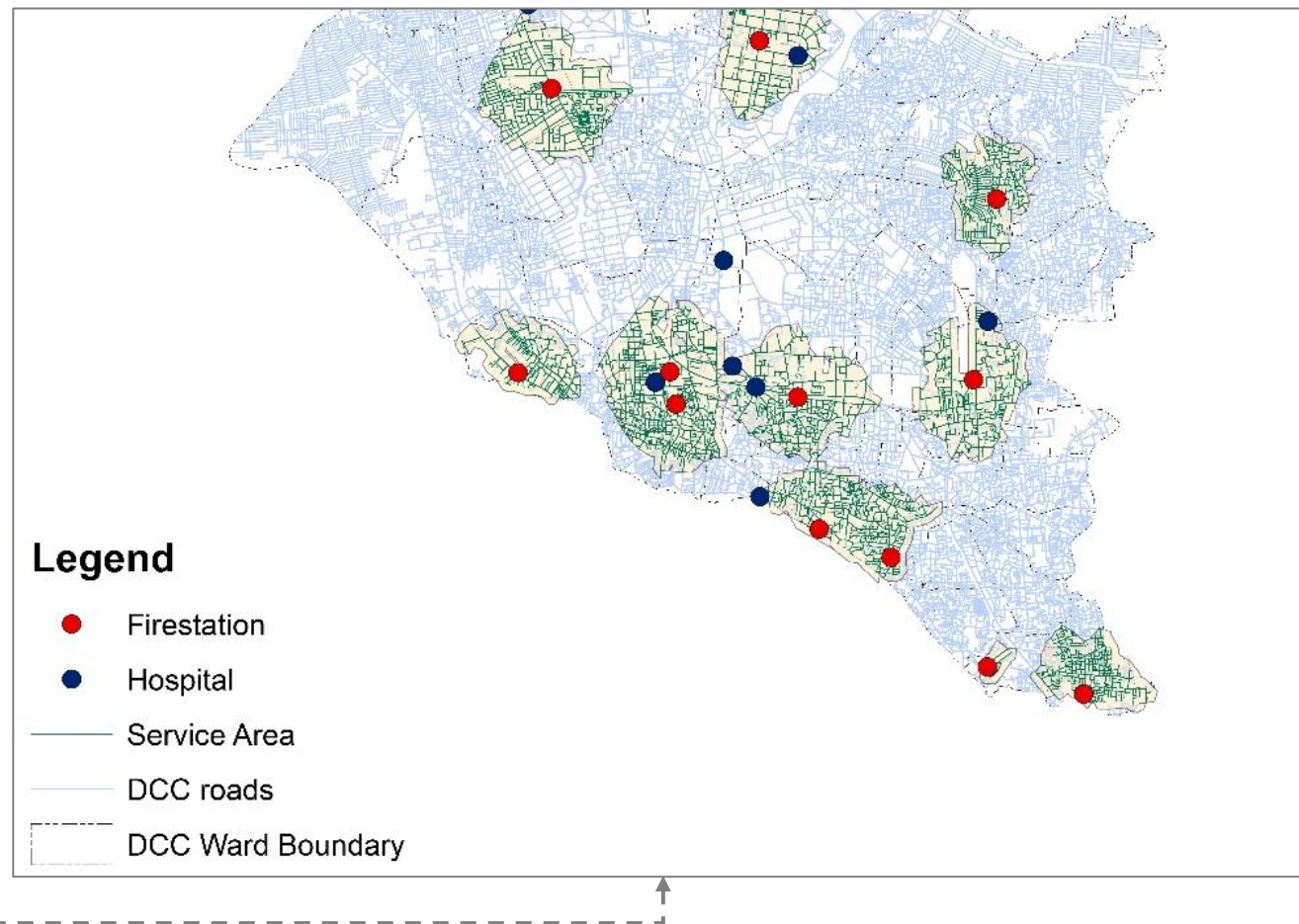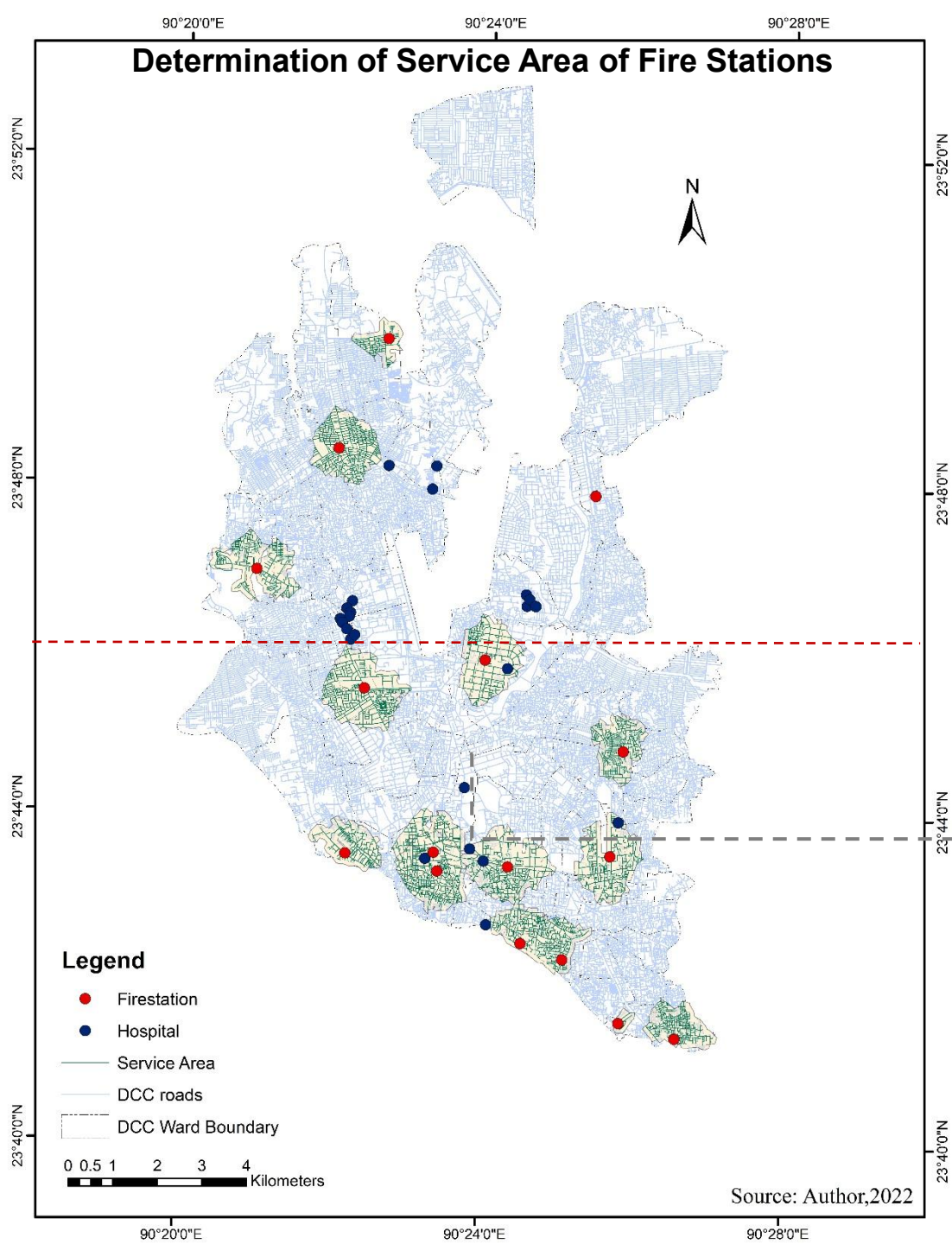
# Network Analysis to Find Out The Shortest Route

'Right click' on the shape file of road

Create new network data set

Select 'Network Analyst' from toolbars

Select new route from network analyst
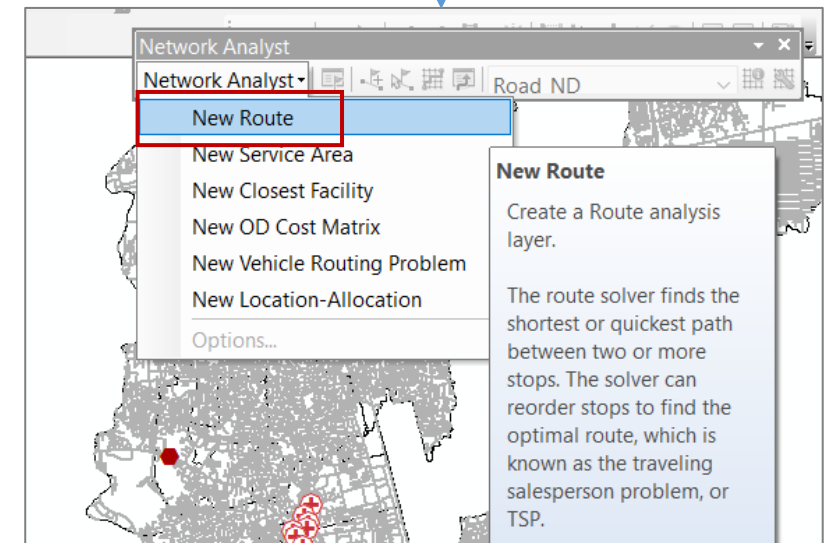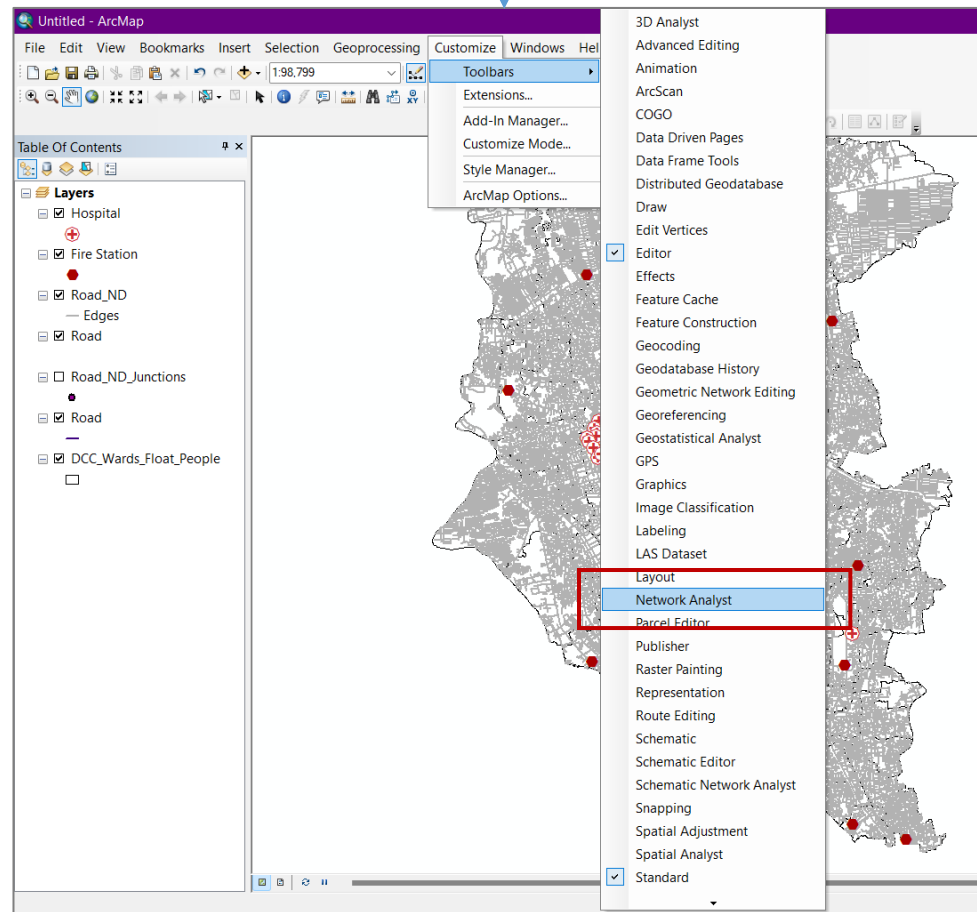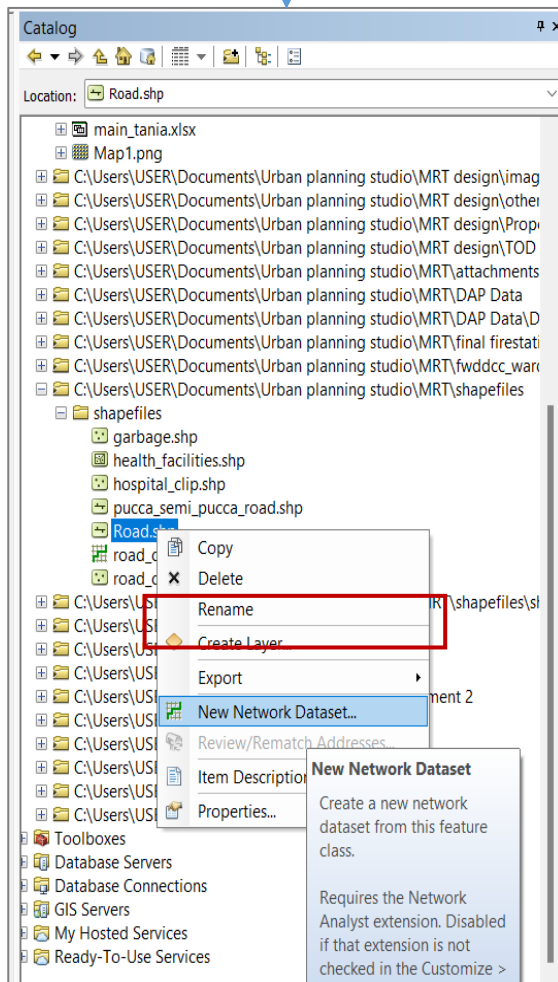
Select 'Create network location tool'
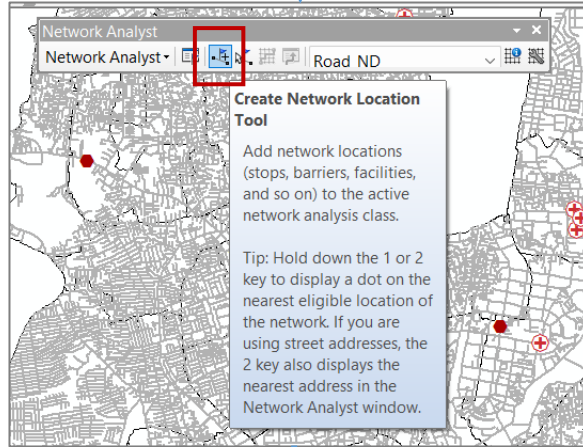
Input 'start point and 'end point' and Click 'solve'
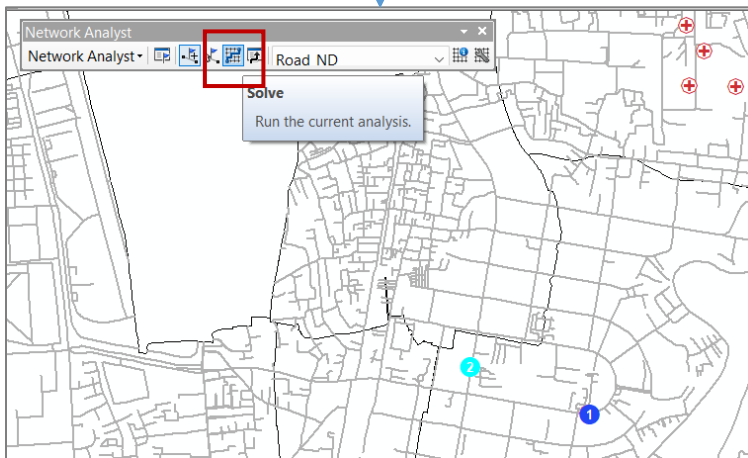
Finding the shortest route between hospitals and fire stations

**Shortest Path Identification from Fire Stations to Hospitals**

Shortest Path Identification from Fire Stations to Hospitals

**Legend**
- Firestation
- Hospital
- Shortest Path
- Service Area
- DCC roads
- DCC Ward Boundary

0 0.5 1    2    3    4 Kilometers

Source: Author,2022

25
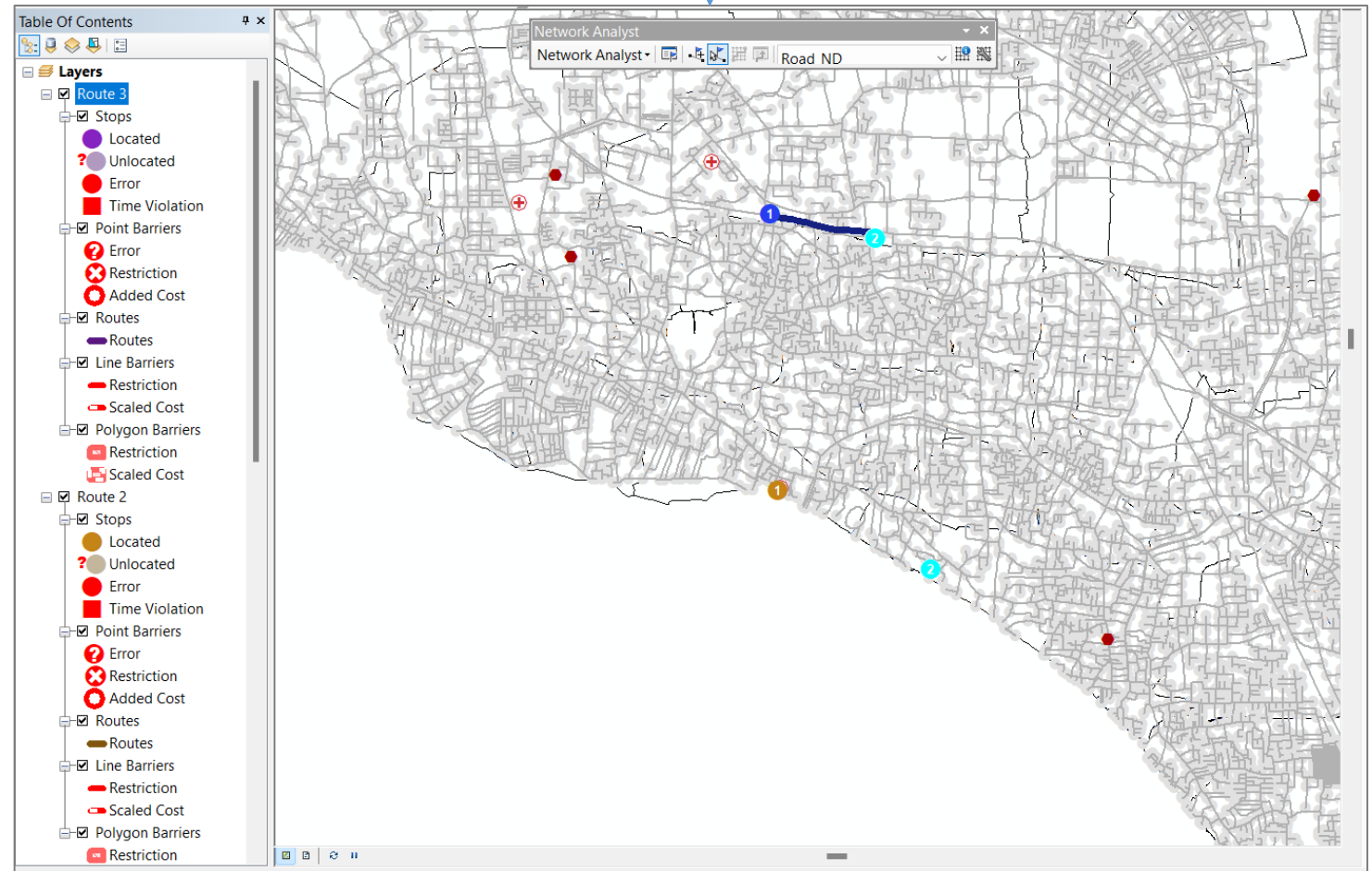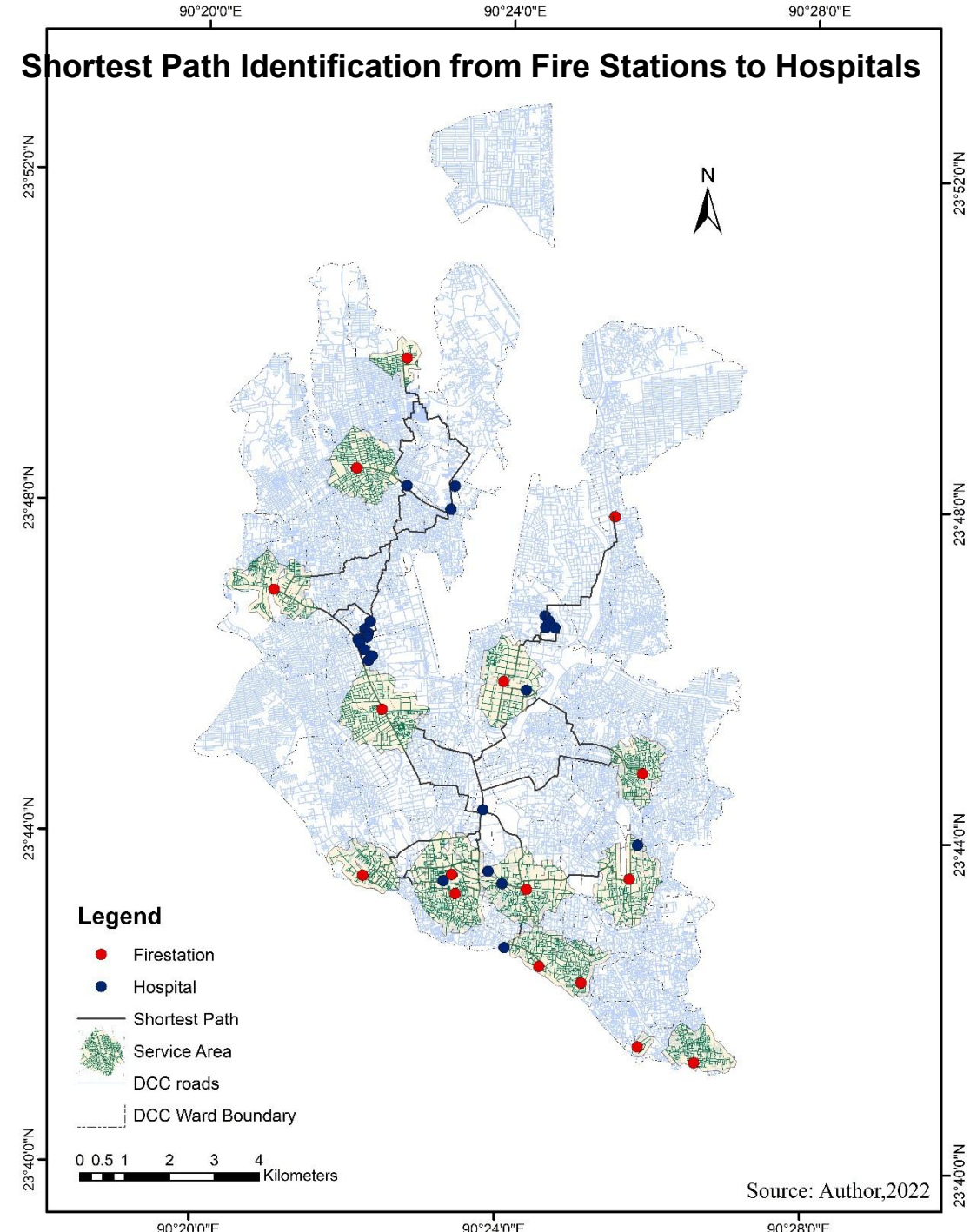
# Identify Nearest Fire Service through Determining Response Time
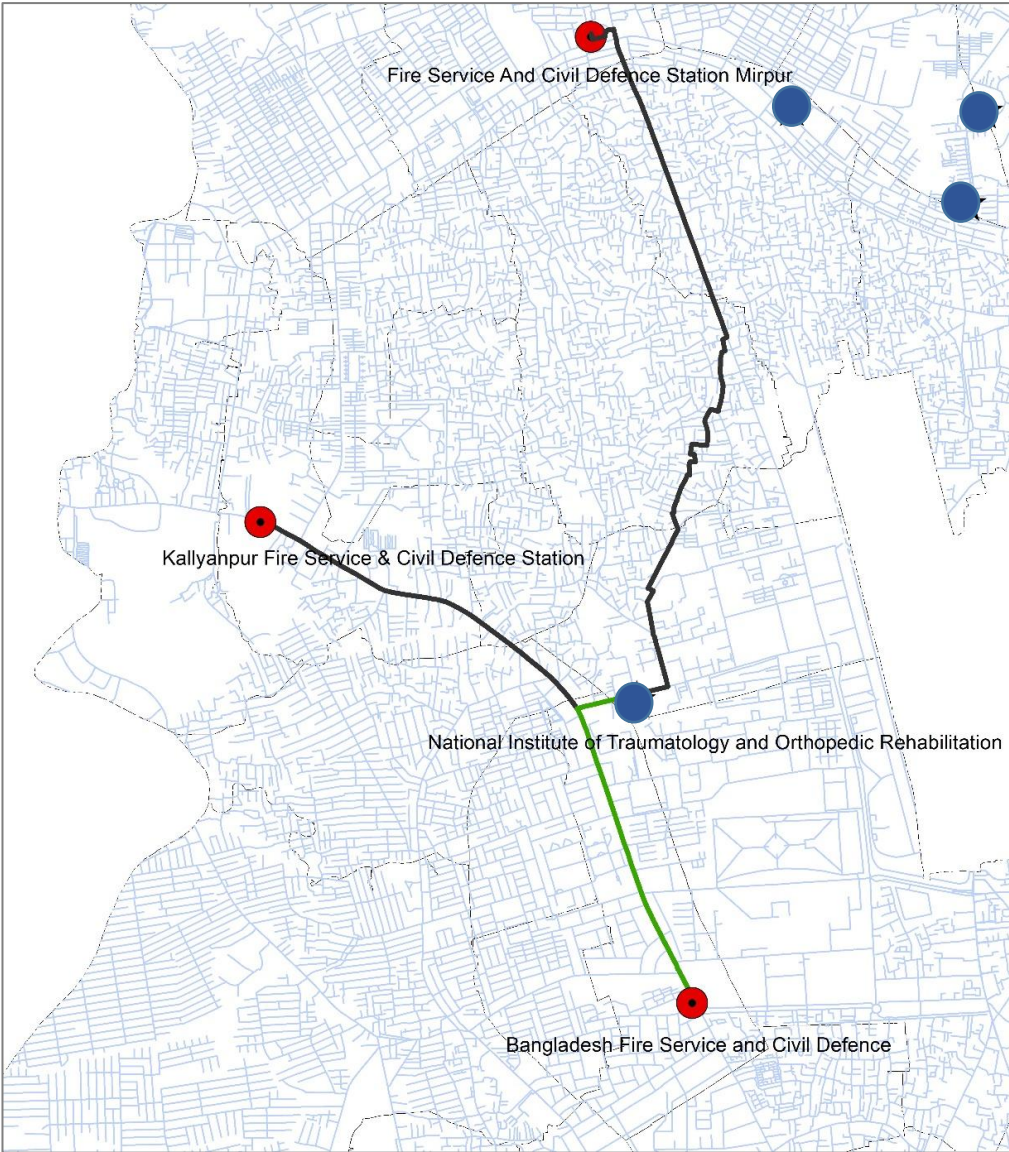


| Hospital | Fire Stations | Distance(m) | Response Time (min) | Min Response Time (min) |
|---|---|---|---|---|
| National Institute of Traumatology and Orthopedic Rehabilitation (NITOR) | Bangladesh Fire Service and Civil Defence,1 | 2183.43 | 18.6617948 7 | 18.66179487 |
| | Kallyanpur Fire Service & Civil Defence Station | 2446.3 | 20.908547 01 | |
| | Kallyanpur Fire Service & Civil Defense Station | 2469.95 | 21.110683 76 | |

Source: Author

| Hospital | Fire Stations | Distance(m) | Response Time (min) | Min 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 Defence 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 Defence & Civil Defence 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 | |

Source: Author

| Hospital | Fire Stations | Distance(m) | Response Time(min) | Min Response Time (min) |
|---|---|---|---|---|
| 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 | |

Source: Author, 2022

| Hospital | Fire Stations | Distance(m) | Response Time(min) | Min Response Time (min) |
|---|---|---|---|---|
| 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 | |

Source: Author, 2022

| Hospital | Fire Stations | Distance(m) | Response Time (min) | Min Response Time (min) |
|---|---|---|---|---|
| 12. National Institute of (NITOR) | Bangladesh Fire Service and Civil Defence,1 | 2183.43 | 18.66179487 | 18.66179487 |
| | Kallyanpur Fire Service & Civil Defence 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 Defence 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 | 4813.96 | 41.14495726 | |

| Hospital | Fire Stations | Distance(m) | Response Time (min) | Min Response Time (min) |
|---|---|---|---|---|
| 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 |
| Source: Author, | Kallyanpur Fire Service & Civil Defense Station | 2827.9 | 24.17008547 | |

| Hospital | Fire Stations | Distance(m) | Response Time(min) | Min Response Time (min) |
|---|---|---|---|---|
| 22. Sheikh Russel Gastroliver 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. Sheikh Russel Gastroliver Institute & Hospital | Fire service and Civil Defense, Tejgaon | 2327.22 | 19.89076923 | 19.89076923 |
| 25. 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 | |

Source: Author,2022

Histogram of hos$`Response Time(min)`
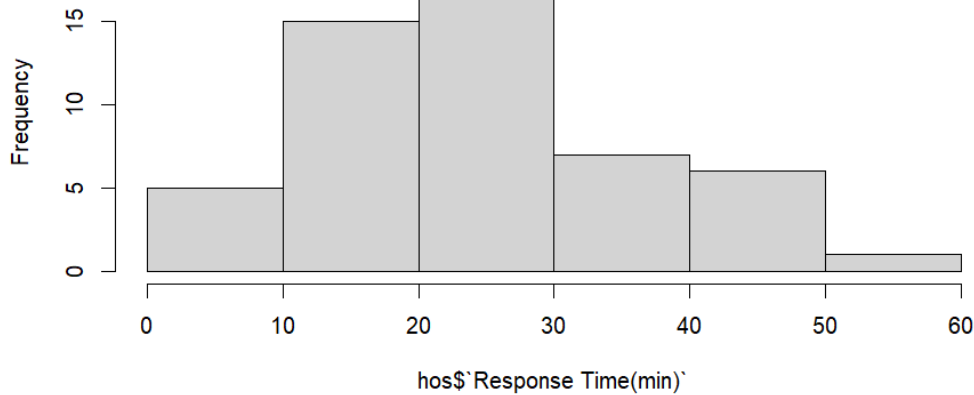


Response Time of Fire Stations
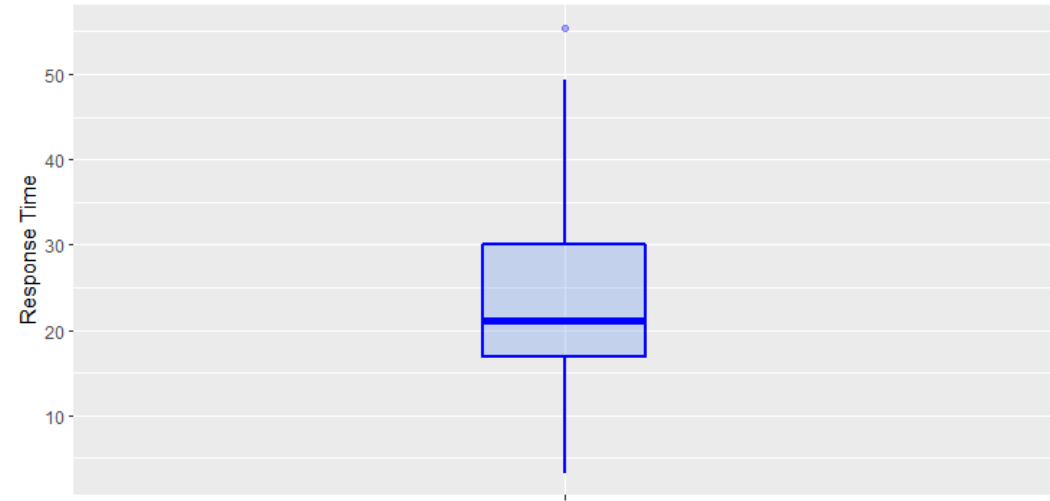
Mean Response Time of Fire Stations: 23.5027 minutes

## Statistical Test to Assess Normal Distribution of Response Time

Anderson-Darling Test: p-value: 0.03459

CVM Test: p-value: 0.02085

Result: The response time of fire stations in not normally distributed.

# Analyzing the pattern of spatial distribution of fire stations



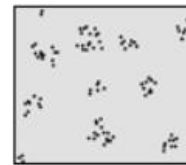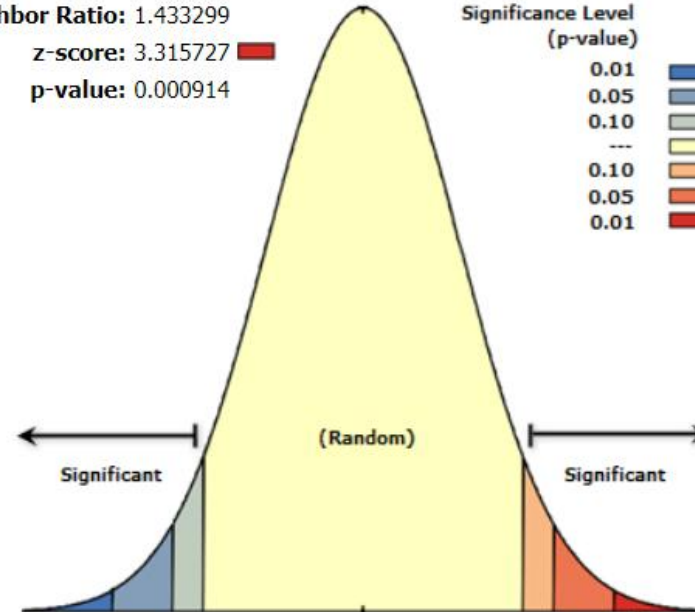**Average Nearest Neighborhood Summary**

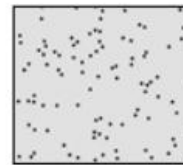Nearest Neighbor Ratio: 1.433299

z-score: 3.315727

p-value: 0.000914

| Significance Level (p-value) | | Critical Value (z-score) |
|---|---|---|
| 0.01 | | $< -2.58$ |
| 0.05 | | $-2.58 - -1.96$ |
| 0.10 | | $-1.96 - -1.65$ |
| --- | | $-1.65 - 1.65$ |
| 0.10 | | $1.65 - 1.96$ |
| 0.05 | | $1.96 - 2.58$ |
| 0.01 | | $> 2.58$ |

(Random)

Significant          Significant
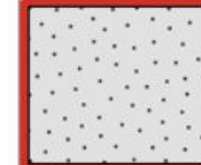
Clustered     Random     Dispersed

Given the z-score of 3.31572689707, there is a less than 1% likelihood that this dispersed pattern could be the result of random chance.

# Major Findings

**1** Determining the service area of fire stations, many of the hospitals are located outside the service area

**2** From Average Nearest Neighborhood statistical analysis, it is identified that the fire stations are dispersedly distributed over the study area.

**3** Mean response time (23.5027 minutes) of fire stations using shortest routes is higher than NFPA standard of response time( 9 minutes 20 seconds)

# Recommendation

**1** Fire stations should record the shortest routes for emergency response. Drivers should be conscious about various situations which includes one-way streets, streets under repair or other blockings along the network

**2** During any fire accidents, people should behave rationally in order to avoid human crowd and blocking the ways of emergency vehicles around the fire incidents

**3** Fire stations should try to maintain the standard of response time during critical situations, otherwise strict law should be imposed

**4** Hospitals should be well equipped to mitigate the impacts during any fire accidents until fire service arrives.

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3. Yao, J., Zhang, X., & Murray, A. T. (2019). Location optimization of urban fire stations: Access and service coverage. Computers, Environment and Urban Systems, 73, 184-190

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7. Fire Service and Civil Defense. (2021). Annual Report. Dhaka. Retrieved from http://fireservice.portal.gov.bd/sites/default/files/files/fireservice.portal.gov.bd/notices/df6ab9b9_26cd_462a_b691_e577c8638ab8/2022-07-31-03-37-2d395addcfa4fead801103437accb3cc.pdf

8. Fire breaks out at Dhaka's Suhrawardy hospital. (2019). Retrieved 10 August 2022, from https://www.thedailystar.net/city/fire-breaks-out-suhrawardy-hospital-dhaka-1702075

# THANK YOU