TRAVEL DEMAND MODELING FOR EMERGENCY TRIPS IN THE CONTEXT OF A DEVELOPING MEGA CITY

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Declaration

It is now declared that this thesis/project report, in whole or in part, has not been submitted elsewhere for any Degree or Diploma award.

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Dedication

To our parents and teachers

for

their unwavering support and guidance.

Thank you for believing in us and shaping our journey.

Acknowledgement

All praise belongs to the All-Powerful Allah, by whose kindness we could finish our Research objective. We shall always give Allah our most sincere gratitude, the kindest and most compassionate.

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Preamble

In the field of transportation planning, demand patterns for work travels, business trips, educational trips, etc., have been extensively studied over the years. However, no research has been conducted to determine the demand for emergency travel. So, the study aims to evaluate trip patterns for Emergency Trips. Additionally, it recommends relevant policies to enhance the new health facilities based on zonal demand and to avoid scattered development of hospitals. The research is titled as “Travel Demand Modeling for Emergency Trips in the Context of a Developing Mega City”. The research’s final goal was achieved by integrating three objectives which are, i). analyzing the pattern of emergency response to understand the current practice. ii). Developing a trip generation model for emergency trips and iii). Formulating an OD/PA matrix for emergency trips.

Abstract

In recent years, underdeveloped and developing nations have struggled to manage medical emergencies and faced obstacles such as response time reduction, insufficient medical resources, dispersed hospital development, etc. An unoptimized EMS model could be the cause of this issue. To decrease EMS response time, scientifically comprehending the emergency travel pattern is necessary. Numerous researchers have undertaken initiatives to optimize the EMS, and their approaches have centered on the location-allocation of emergency vehicles and hospitals, the optimization of extant medical resources, etc. It still needs to be determined how the scattered development of hospitals affects trip generation, zonal travel demand and supply, future medical resources, etc. This study aims to determine the current travel pattern of hospital emergency patients, the significant factors influencing trip production and attraction, and a production attraction matrix to comprehend the zonal distribution of emergency trips in a developing city like Dhaka. Data were collected through hospitals and emergency room questionnaire surveys. Using GIS analysis, Dhaka city was divided into 23 internal and 6 external zones. Regression models were prepared to predict zonal trip productions and attractions. The zonal production-attraction values obtained from the regression models were used as the input of the Gravity Distribution model. Finally, a Production-Attraction matrix was formed from the gravity distribution model to comprehend zonal distribution. The study can benefit policymakers in optimizing EMS in underdeveloped nations and reducing the EMS response time.

Keywords: EMS**,** Response time, Production-Attraction Matrix, Gravity Distribution, Regression, Emergency Travel Pattern, Zonal Production-Attraction, Zonal Distribution.

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CHAPTER 1: INTRODUCTION

1.1 Background and Motivation

The Emergency Medical Services (EMS) deliver initial care to critically ailing and injured patients indoors and outdoors (Bahrami et al., 2011). The purpose of EMS is to deliver immediate, high-quality medical treatment to those experiencing urgent, life-threatening medical crises (Zhang & Jiang, 2014). The time it takes to dispatch an ambulance and arrive at the spot to pick up an emergency patient, called the response time, is a crucial aspect of emergency medical services (EMS) that significantly impacts patient outcomes (Bahrami et al., 2011).

In low- and middle-income countries (LMICs), one-third of all fatalities are attributable to time-sensitive medical emergencies (Razzak & Kellermann, 2002). Such situations include cardiac arrest, motor vehicle accidents, and maternal health issues such as childbirth. According to the World Health Organization (2015), 14.64 percent of all global deaths and disability-adjusted life years are caused by time-sensitive illnesses and injuries like ischemic heart disease, perinatal conditions, diarrheal disease, traffic accident injuries, and suicide-attempt injuries, with 49.4 percent of these injuries being the result of accidents, falls, and suicide attempts (Maghfiroh et al., 2018).

Researchers and international organizations have repeatedly emphasized the need for a greater emphasis on emergency medical services in low and middle-income countries (LMIC) over the past decade (Boutilier & Chan, 2020). Despite extensive evidence that emergency medical services in LMICs saves lives (Sodemann et al., 1997, Schmid et al., 2001), access and availability continue to be a significant issue in developing nations (Kobusingye et al., 2005, Levine et al., 2008).

Research conducted by the Overseas Unit of TRRL has revealed that road accident injury rates (i.e. injury per 10,000 licensed vehicles) in developing countries are frequently 20 times higher than in Western Europe and North America. Perhaps even more alarming is the fact that, while mortality rates in developed nations have consistently declined over the past two decades, they have risen in a significant number of developing nations (Jacobs & Sayer, 1983). In India, each week, nearly 9,000 people are injured in traffic accidents. In 2013, the most recent year for which data are available, 469,900 individuals were injured due to road accidents (Singh, 2017). In a developing nation like Zimbabwe, traffic accidents increased by 54.6% between 1985 and 1994, from 19,558 to 30,248. During this period, traffic-related injuries increased by 59%, while traffic-related fatalities increased by 41.5%. Nearly everywhere in the developing world, both accidental and deliberate injuries are rising significantly (Zwi et al., 1996). So an effective Emergency Medical Service (EMS) system is of great concern nowadays and can reduce deaths.

Response time is an important performance measure for any emergency medical service (EMS). According to research, adults who suffer from non-traumatic OHCA (out-of-hospital cardiac arrest) had a 7% decrease in survival until hospital discharge and a 9% decrease in favorable neurological prognosis for every minute of delay in EMS response time in Taipei. Patients with OHCA had better results if emergency medical services arrived within 8 minutes, but those who waited more than 11 minutes had a lower likelihood of survival (Chen et al., 2022).

Most developed nations follow a standard for typical EMS response time, but underdeveloped and developing nations still need such standards or requirements. For example, Iran accepts 8 minutes as a typical EMS response time standard (Bahrami et al., 2011). In North America, a 9-minute response time has been accepted as the emergency norm (*SASKATCHEWAN EMERGENCY MEDICAL SERVICES (EMS) REVIEW*, n.d.). The mean EMS response time in Virginia state was 12 minutes, with 72% of all responses found occurring within 10 minutes (Commonwealth of Virginia, 2004). The Standard for EMS response time was about 10 minutes in Monterrey, Mexico. EMS in Hanoi, Vietnam, was expected to arrive within 30 minutes (*Emergency Medical Services*, 2006).

However, similar standards for EMS response time do not exist in underdeveloped or developing nations. A developed nation like Mexico has an average EMS response time of

4.5 minutes, whereas, in a developing nation like Austria, the EMS response time was six times greater than in Mexico due to no EMS response time standards (Roudsari et al., 2007). Our study area, Bangladesh, a developing nation, also lacks standards for EMS response time.

Hospitals in underdeveloped countries are scattered and haphazardly developed without adequate planning of hospital necessities based on supply and demand. Development organizations concentrated more on the hospital projects they funded than on ensuring whether the hospital could satisfy the demand of a locality or not (Talukder & Rob, 2011). Therefore, the framework of healthcare service delivery needs to be more robust and well-planned enough to provide adequate healthcare access to meet the zonal demands in developing nations like Bangladesh.

1.2 Problem Statement

Over the years, demand pattern for work trips, business trips, educational trips etc. are heavily explored in the field of transportation planning. However, little or no work has been done to understand the travel demand of emergency trips. There are currently no pre-existing models for OD-matrix-based movement tracking that may be used to improve the EMS model.

As response time is an important performance indicator of EMS, in order to minimize the emergency response time, it is crucial to understand the emergency travel pattern through a scientific approach. Vast research is available on reducing EMS response time by relocating ambulances, but how the demand is met is still unaddressed. Moreover, underdeveloped and developing countries have fewer facilities for dealing with medical emergencies, which results in longer response times.

In recent times, numerous research has been done on hospital location-allocation. However, the effects of scattered hospital growth on emergency trips have yet to be explored. Researchers have tried to provide solutions to optimize EMS but have only focused on optimizing present medical resources rather than future ones.

1.3 Purpose and Objective

This study aims to investigate emergency travel patterns and develop a trip-generation regression model that predicts emergency trips based on relevant zonal characteristics. Finally, the study will establish a trip distribution model from the generated trips using the previously developed trip generation model to identify travel patterns and potential hospital choice behavior of individuals, leading to policy recommendations for EMS optimization and transportation planning. The objectives are,

- Analyzing the pattern of emergency response and understanding the current practice of processing emergencies.
- Developing a trip generation model for emergency trips.
- Formulating an OD/PA matrix for emergency trips.

1.4 Scope of the Study

The thesis works towards exploring the travel pattern during emergencies and identifying the factors influencing emergency trips. The study will use a trip-generation regression model to forecast emergency trips based on zonal characteristics and analyze the trip distribution pattern. The study can contribute to the broader field of transportation planning by optimizing EMS in developing countries.

1.5 Organization of the Thesis

The thesis contains a total of five chapters which are briefed below,

Chapter 1: **Introduction-** This section discusses the background and motivation, the problem statement, the purpose and objective and the scope of the study.

Chapter 2: **Literature Review-** This section discusses the supplementary literature that helped to conduct the study.

Chapter 3: **Methodology and Data-** This section contains the methods to acquire and analyze data, the progressive workflow of the study, description of the methods used to generate results.

Chapter 4: **Analysis and Results-** This section presents the results obtained from the analyzed data and the interpretation of the results.

Chapter 5: **Conclusion and Recommendations-** This section summarizes the results of the study and makes recommendations for future policy.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Every year, a huge number of fatalities, are caused by inadequate access to emergency services and delays in the transportation of patients to hospitals (Hashemi et al., 2022). Two components are crucial in the emergency response system: Location of the emergency facility and transportation networks on which Emergency medical services highly relies on (Liu et al., 2021). Several studies suggested that understanding of the local resources and demand is a crucial factor for EMS (Al-Shaqsi, 2010), (Meskin et al., 1997). But there is scarcity of studies on identifying the demand of emergency services in locality based and establishing emergency services according to that demand.

2.2 Emergency Medical Service - Global Perspective

There are substantial organizational, resource, and overall quality disparities in EMS systems, particularly between developed and developing nations. The EMS systems in developing nations pose a variety of challenges, such as a lack of financing, infrastructure, equipment, constrained access to transportation training, regulations and coordination (Roudsari et al., 2007).

Emergency medical care has not traditionally been a priority in developing nations' health systems. A major barrier to care is the lack of emergency medical transportation. This could also occur for a number of reasons, such as a shortage of proper vehicles, a lack of adequate roadways, or a shortage of funding for transportation services (Razzak & Kellermann, 2002). Lack of structured models, inadequate training focus, financial worries, and sustainability in light of increased demand for services are all barriers to establishing effective emergency medical care (Razzak & Kellermann, 2002).

According to a prior study from Nigeria, A significant barrier is proper access to medical services and long-term road transportation (Solagberu et al., 2009). Another study states that Zimbabwe Crews have to travel quite a distance to reach the location of emergency service because of the area's stipulated population and insufficient hospitals (Thomson, 2005).

A distinct Emergency Medical Service System (EMSS) framework has been established in China to integrate with the country's regional healthcare system (Page et al., 2013). In Hong Kong, ambulances are operated out of ambulance depots for providing rapid transportation to emergency care (Page et al., 2013). A team in Malaysia concluded in their study that improving transportation, and improving communications were necessary steps to lower maternal mortality (Geefhuysen et al., 1998). A study showed that investment in transportation and a better communication system resulted in Sierra Leone a doubling of the use of emergency delivery services and a 50% drop in case mortality (Samai & Sengeh, 1997).

EMS systems in Asia are at various stages of development and maturity (Rahman et al., 2015), (Sun et al., 2017). For instance, the EMS is developed and organized in Singapore, Japan, and Korea, but it is still in its infancy in other developing nations (Ong et al., 2013). Major issues with EMS in Nepal include the fragmented system, excessive demand-low supply, unfairness of the service (Bhandari & Yadav, 2020). In a developing nation with limited resources, Pakistan is exploring the possibilities of public-private partnerships for serving an effective EMS system (Ali et al., 2006). The study in Pakistan also stated that In the future, EMS systems should concentrate on how they may enhance the community's adoption of ambulances through imparting public education and introducing fresh concepts, including the use of GIS to increase efficiency (Ali et al., 2006).

2.3 State of the Art in EMS Practices

Prior to 2000, the majority of research on emergency responses was qualitative and descriptive. The early studies for the planning of EMS facilities include many aspects like Emergency ambulance resource optimization which primarily involves the minimal covering model that seeks to reduce the number of ambulances required to cover all demand points and the maximal covering model, which seeks to increase the overall demand coverage given a feet of fixed size (Brotcorne et al., 2003).

Recent years have seen an increase in the use of specified, validated assessment methodologies and/or evidence-based approaches to assess an emergency service (Tseng et al., 2018). To improve service performance of EMS many approaches have been identified like mathematical modeling and simulation-based optimization (Hatami-Marbini et al., 2022), geographic information system (GIS)-driven web-based directory system (Bhadoria et al., 2020), p-median problem (pMP) aiming at reducing the total or average amount of time required to travel between demand centers and the closest facilities (Takedomi et al., 2022), and smart ambulance traffic management system -SATMS (Dumka & Sah, 2020).

Several studies suggested that understanding of the local resources and demand is a crucial factor for EMS (Meskin et al., 1997). Emergency medical care systems must adjust to local needs as well as the demographics and disease epidemiology that are specific to individual communities (Anthony, 2011). Unfortunately, there is a lack of data on the specifics of these local needs worldwide (O.C. et al., 2005). Trip Generation and Distribution therefore can play a significant role for understanding the local demand and utilization of emergency service location according to that demand.

CHAPTER 3: METHODOGY & DATA

3.1 Study Area:

The study was carried out utilizing the map of Dhaka city. The administrative boundaries of Dhaka North City Corporation and Dhaka South City Corporation were delineated into ward levels using shape files. The DNCC is entrusted with 36 of Dhaka's 94 wards, while the DSCC is in charge of 58. The word boundaries are illustrated below in Figure 3. 1: Study Area: Dhaka City,

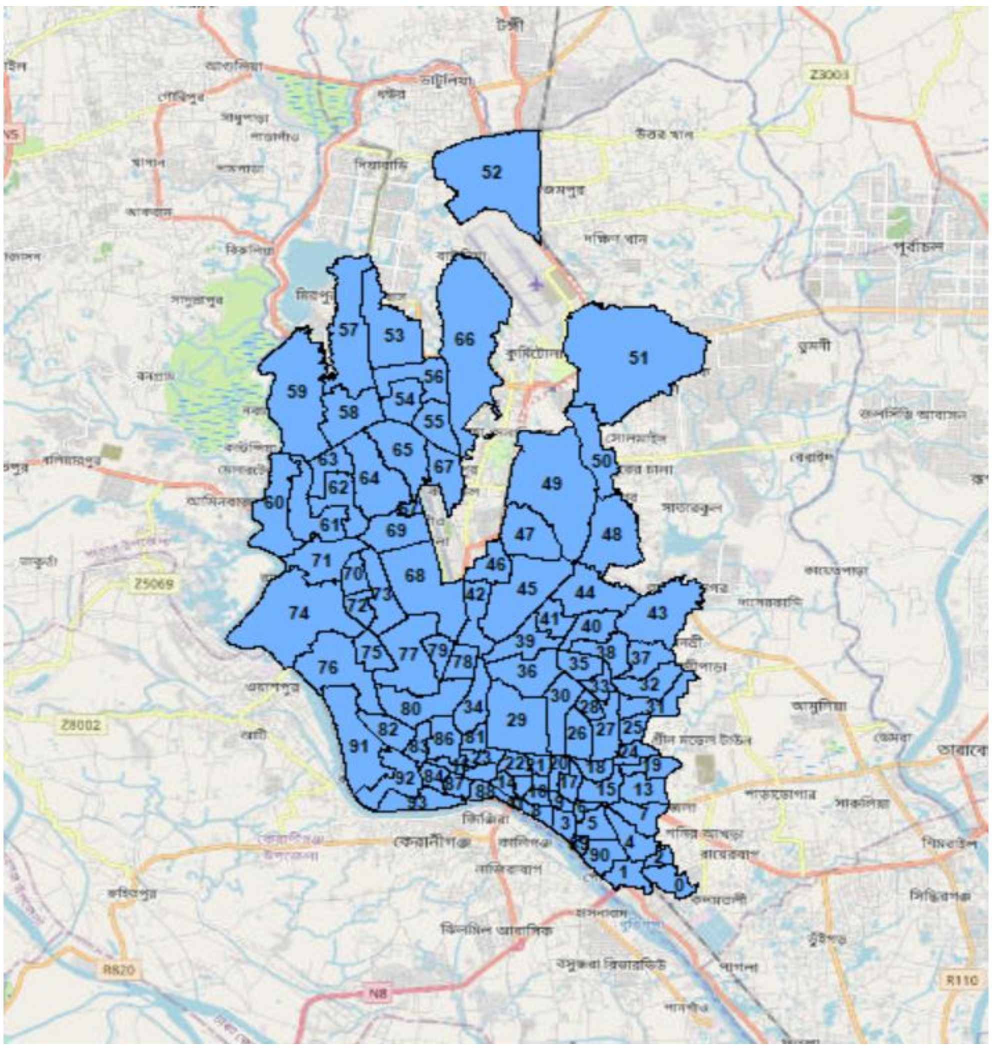

Figure 3. 1: Study Area: Dhaka City

3.2 Data Collection

The study was conducted by primarily considering four data segments.

- Political Boundaries with their Demographic Data
- Hospital Data with Location Inventory
- Road Network Data
- Emergency Room Survey Data

The study was initiated by collecting zonal data from the Geo-planning for Advanced Development Centre. The Zonal data, specifically the shapefiles of DNCC and DSCC, encompassed demographic information pertaining to each ward. This information included the total population, male-female population proportion, population density, and age distributions within each ward. In addition to the collection of Zonal data, network data was also obtained from the same source. The shapefiles encompass essential data regarding the road network, including data on road classification, width, and area within each ward. To gather information regarding the number of emergency cases that occur daily, the size of the hospital's floor space, and its amenities, a short survey was constructed. An additional data source was utilized to gather the data for the Emergency Room Survey. The study commenced by collecting a total of 1,242 responses through the administration of 24 distinct types of inquiries pertaining to demographic characteristics, socioeconomic status, current medical conditions, and related factors. Subsequent to a data screening process, partial responses were eliminated. The ultimate dataset comprised 1,135 responses, which were subjected to individual response analysis, is shown below in Table 3. 1 :Hospital Data with Location Inventory,

Table 3. 1 :Hospital Data with Location Inventory

SI	Hospital Names	Type of Hospital	Number of emergencies	Total Floor Area (m2)
1	Uttara Adhunik Medical College Hospital (BMSRI)	Private	75	19310.72
2	RMC Hospital	Private	13	1458.42
3	Shaheed Monsur Ali Medical College and Hospital	Private	50	30337.86
4	Uttara Crescent Hospital	Private	15	2833.44
5	Shin Shin Japan Hospital	Private	12	1958.46
6	Hi-Care General Hospital Ltd.	Private	23	1446.48
7	Lubana Hospital	Private	8	1941.45
8	Uttara Lake View Specialized Hospital	Private	7	1579.14
9	Kuwait Bangladesh Friendship Govt. Hospital	Government	20	1954
10	Mohila O Shishu Hospital	Private	5	3472.1
11	Aichi Hospital Ltd.	Private	35	7609.47
12	Kingston Hospital	Private	50	4752
13	Islami Bank Hospital Mirpur	Private	160	8634.24
14	Mirpur General Hospital & Diagnostic Centre	Private	10	921.3
15	Al Helal Specialized Hospital Dhaka	Specialized	40	4540.51
16	Aalok Hospital Ltd	Private	70	3405.12
17	DR. AZMAL HOSPITAL LTD.	Private	20	2609.19
18	Delta Medical College and Hospital	Specialized	50	1685.5
19	OGSB Maternity Hospital	Government	10	152
20	Shaheed Suhrawardy Medical College and Hospital	Public	600	61080
21	National Institute of Cardiovascular Diseases & Hospital	Public	400	91144.8
22	National Institute of Kidney Diseases & Urology	Public	30	33862.48
23	Bangladesh Shishu Hospital & Institute	Public	300	17600
24	National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR)	Specialized	300	21724.34
25	DPRC Hospital	Specialized	45	2147.97
26	Bangladesh Specialized Hospital	Private	30	5595.45

SI	Hospital Names	Type of Hospital	Number of emergencies	Total Floor Area (m2)
27	IBN SINA Medical College Hospital, Kallyanpur	Private	150	12253.95
28	Al-Razi Islamia Hospital (Pvt) Ltd.	Private	30	
29	Bangladesh Medical College Hospital	Private	40	5165.28
30	IBN Sina Specialized Hospital	Specialized	60	2093.4
31	Naaz E Noor Hospital Limited	Private	15	2301.05
32	Anwar khan modern College	Private	25	4972.86
33	BRB Hospital	Private	120	6140.61
34	Central hospital Dhanmondi	Private	50	9471.6
35	Comfort Center	Private	25	3128.58
36	Dhanmondi General and Kidney Hospital	Private	22	1340.88
37	Dhanmondi Hospital LTD	Private	12	1036.68
38	Health and Hope Hospital	Private	22	2817.72
39	Lab Aid	Private	70	17751
40	Samorita Hospital	Private	35	14070.36
41	SIBL Hospital	Private	25	5648.6
42	Square Hospital	Private	100	9725.52
43	Impulse Hospital	Private	10	18205.04
44	Bangabandhu Sheikh Mujib University hospital	Government	53	21102.27
45	Birdem	Private	170	27585.44
46	Dhaka Medical College Hospital	Government	800	83857.9
47	National medical College	Private	300	15897.64
48	Sir Salimullah Medical College	Government	450	14745.34
49	Sumona Hospital	Private	50	323.94
50	Central Police Hospital	Private	85	10973.88
51	Islami Bank Hospital Kakrail	Private	110	5858.19
52	Ad-Din Medical College Hospital	Private	80	8049.05
53	Dr. Sirajul Islam Medical College	Private	25	7993.65
54	Dhaka Community Hospital	Private	20	4396.59

SI	Hospital Names	Type of Hospital	Number of emergencies	Total Floor Area (m2)
55	Holy Family	Private	50	2982.12
56	Insaf Baraka Kidney and General Hospital	Specialized	80	6533.94
57	Monowara hospital	Private	40	4539.06
58	Rushmono Specialized Hospital	Private	60	1690.44
59	Khidmah Hospital Private Limited	Private	120	1012.08
60	Better Life Hospital	Private	30	8350.08
61	Advanced Hospital	Private	20	2095.38
62	Famous Specialized Hospital	Specialized	10	1572.48
63	Farazy Hospital	Private	60	1344.9
64	Unity Aid Hospital	Private	20	1640.32
65	Yamagata-Dhaka Friendship General Hospital	Private	5	1869.46
66	National Institute of Cancer Research & Hospital (NICRH)	Specialized	40	25044.69
67	National Institute of Disease of the Chest and Hospital (NIDCH)	Government	50	7146.5
68	Sheikh Russel National Gastro Liver Institute & Hospital (SRGIH)	Specialized	15	24213.7
69	AMZ Hospital	Private	25	648.52
70	Badda General Hospital	Private	20	824.28
71	Shahabuddin Medical College hospital	Private	22	3847.5
72	Baridhara General Hospital	Private	15	1350
73	Senior Citizen Hospital	Private	15	1050.24
74	United Hospital	Private	60	26808.67
75	Evercare Hospital	Private	100	28981.8

3.3 Work flow of the Research:

3.3.1 Workflow of Data Processing:

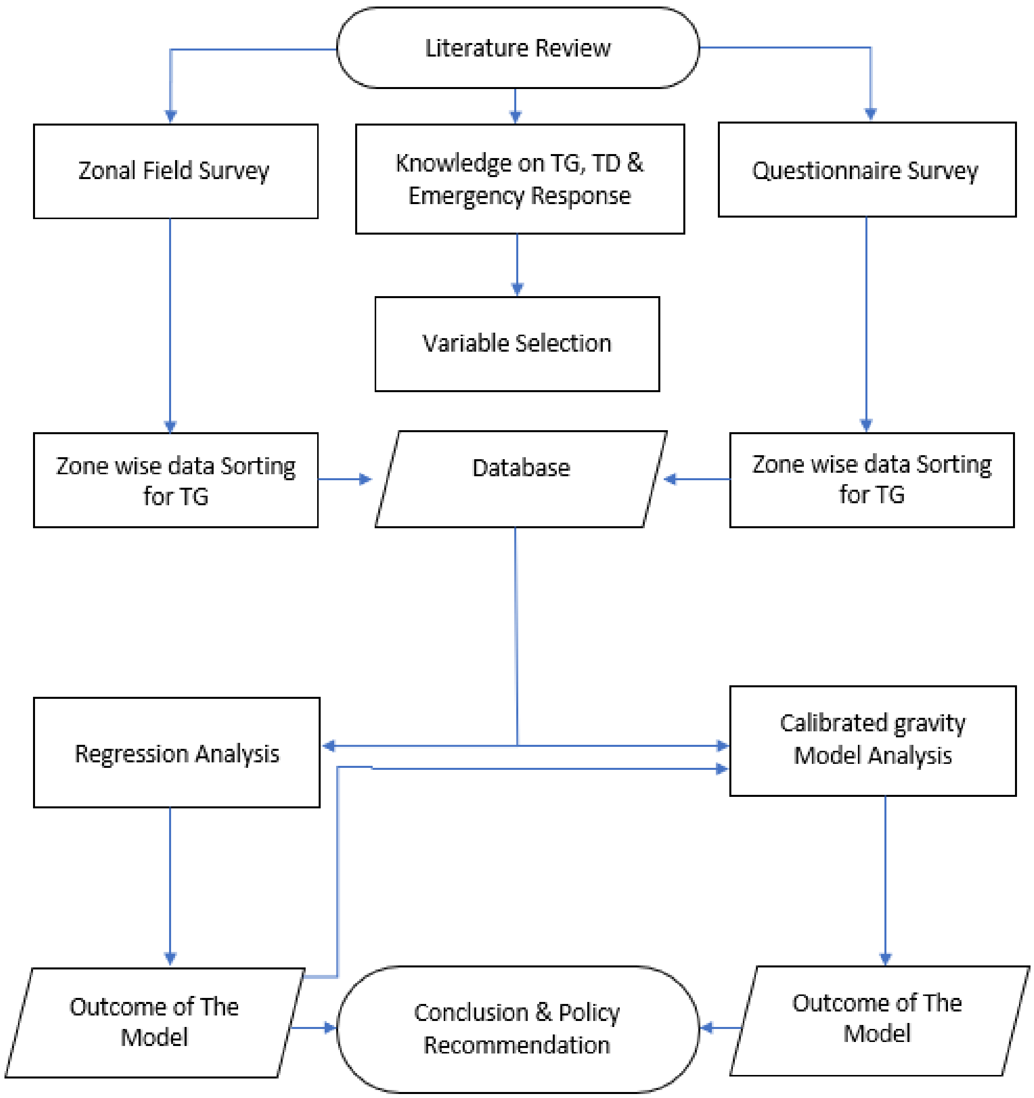

Figure 3. 2: Flow Chart of Data Processing

3.3.2 Workflow for Trip Generation:

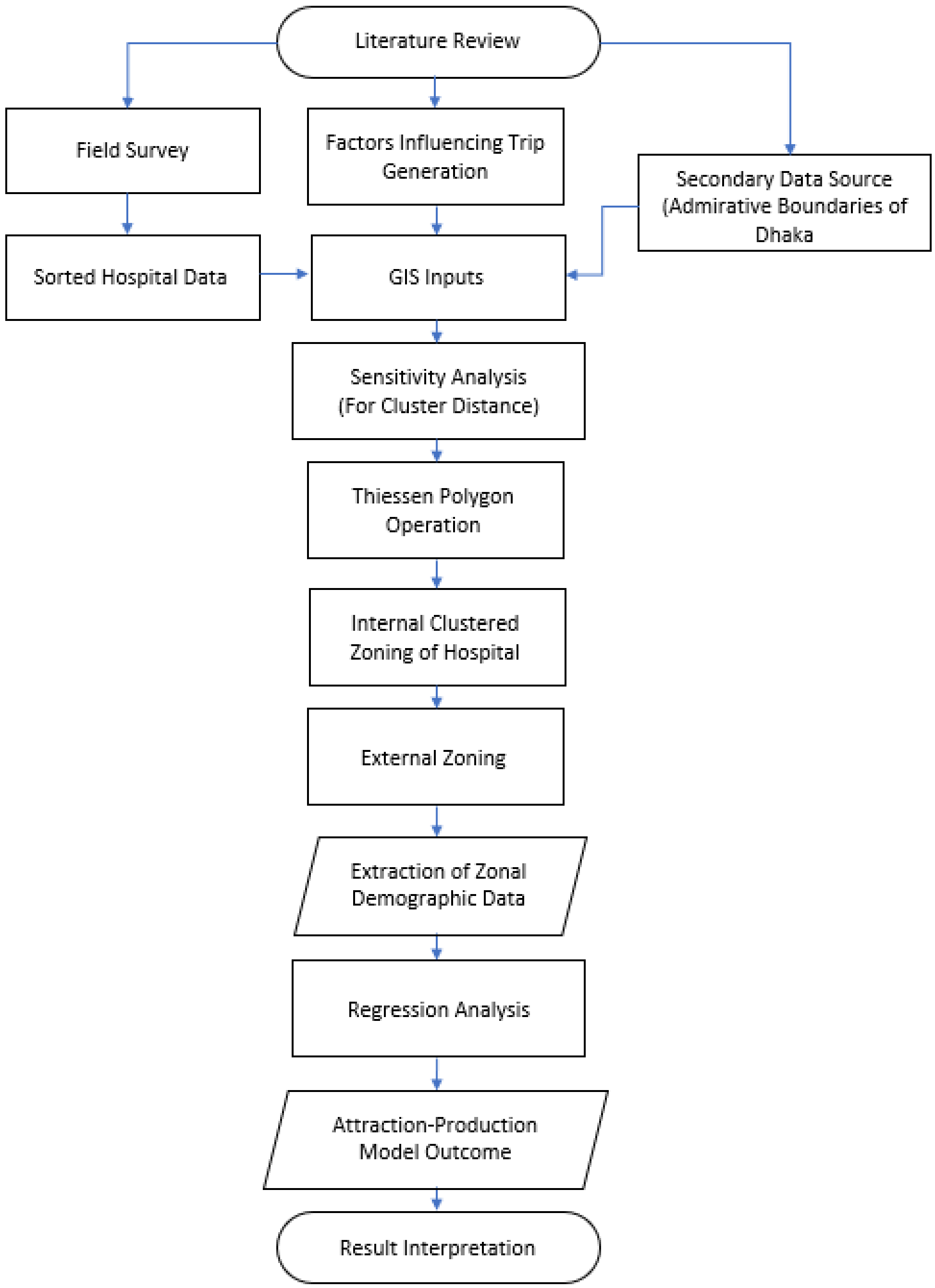

Figure 3. 3: Flow Chart for Trip Generation

3.3.3 Workflow for Trip Distribution:

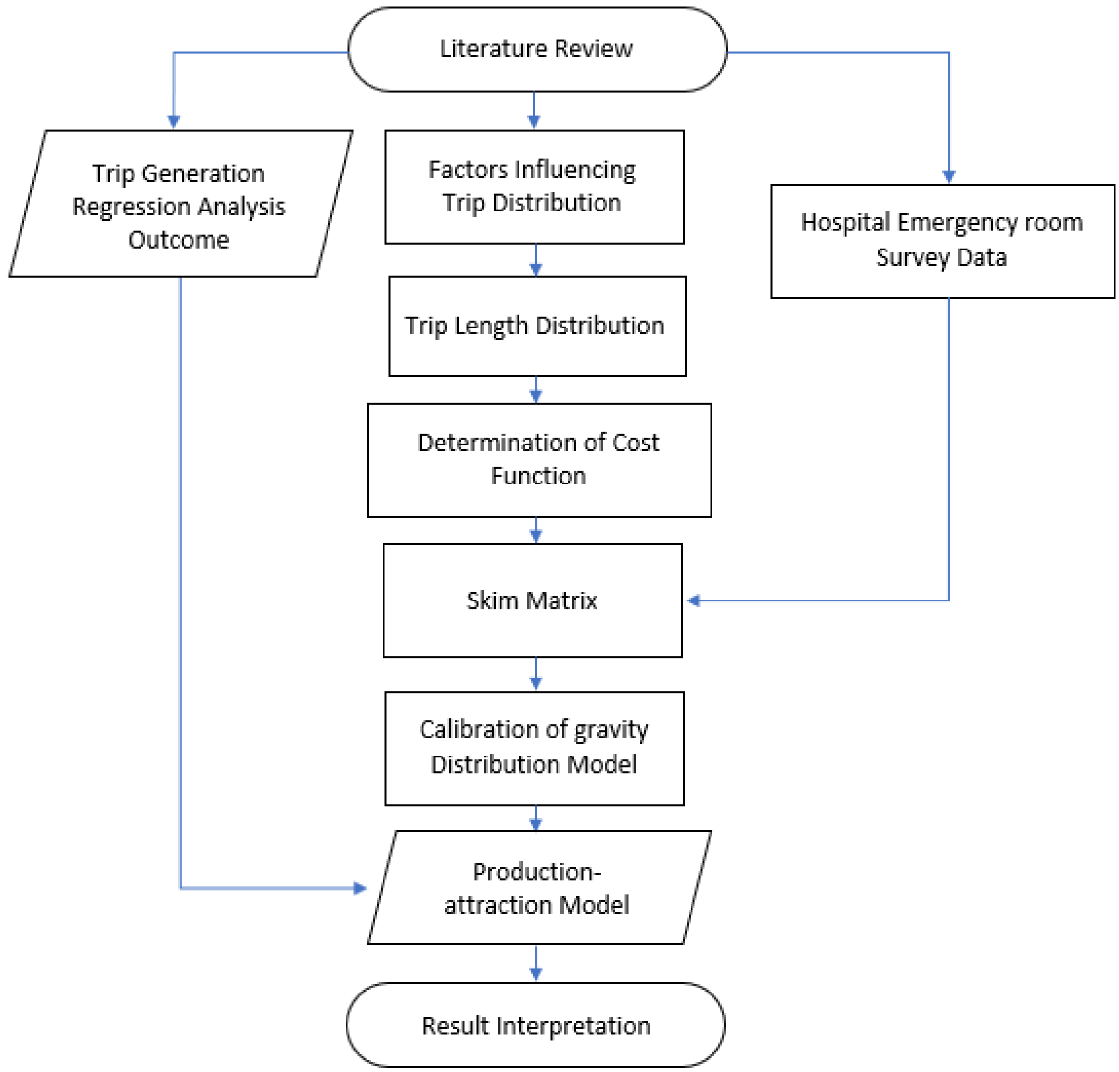

Figure 3. 4: Flow Chart for Trip Distribution

3.4 Travel Demand Modeling:

Emergency medical services in several urban areas exhibit suboptimal performance due to challenges from rapid urbanization and the decentralized distribution of medical facilities. The study's objective is to examine the emergency response pattern to gain insight into the prevailing methodology. The conventional approach of employing a four-stage process to simulate travel demand is a valuable initial step toward devising solutions for addressing Emergency Medical Services (EMS) issues. Trip generation comes first in this process, then moves on to trip distribution.

3.4.1 Trip Generation Model:

The initial stage of the conventional sequential forecasting process is trip generation. The subsequent procedures are contingent upon the results obtained from trip generation analysis. Hence, the accuracy of the underlying assumptions that form the basis of trip generation analysis and the level of precision exhibited by the trip generation models are crucial determinants that impact the overall accuracy of the prediction (Gouuas et al., n.d.). The process of trip generation is a crucial element of conventional transportation models that seeks to predict the assemble number of trips generated (Pi) and attracted to (Aj) each zone within the study area.(Abdel-Aal, 2014). The Multiple Linear Regression Model was employed in the trip generation model to investigate the interrelationships among variables and identify the significant variables in EMS modeling. The determination of the total number of generated trips from the study area, which is the dependent variable, is achieved by utilizing multiple linear regression equations as a function of independent variables (Zenina & Borisov, 2014). For attraction model,

$$Y = a + \beta 1\, X1 + \beta 2\, X2 + \beta 3\, X3 + \dots\dots + \beta n\, Xn \qquad (1)$$

Where,

Y is the independent variable (No. of attractions)

X_1, X_2,.. are the independent variables (Number of hospitals, floor area, area of road type)

βs are the regression coefficients that depict the changes of Y based on the changes of the variables (X_1, X_2, .. X_n).

Similarly for production model, the equation remains same,

$$Y = a + \beta 1\, X1 + \beta 2\, X2 + \beta 3\, X3 + \dots\dots + \beta n\, Xn \quad (2)$$

Where,

Y is the independent variable (No. of productions)

X_1, X_2,.. are the independent variables (Population density, age distributions, gender, land use type)

βs are the regression coefficients that depict the changes of Y based on the changes of the variables (X_1, X_2, .. X_n)

3.4.2 Trip Distribution Model:

The trip distribution model constitutes the second phase of travel demand models. The P-A matrix (Production-Attraction Matrix) is generated by matching trip takers' production and attraction numbers, as trip generation models predict. The trip matrix is a structured format that displays the number of trips generated from specific origins and directed toward particular destinations (Abdel-Aal, 2014). During the 1960s and 1970s, gravity trip distribution models acquired popularity and remain prevalent in contemporary usage. Wilson (1967, 1970) applied the principle of entropy maximization to derive and provide an interpretation for the doubly constrained gravity model (Goncalves, 1993). To conduct the study a doubly constrained gravity model is used and expressed as follows

$$Tij = Ai\, Oi\, Bj\, Dj\, f(cij) \quad (3)$$

$$Ai = \frac{1}{\Sigma j \; Bj \, Dj \, f(cij)}$$

$$Bj = \frac{1}{\Sigma i \; Ai \, Oi \, f(cij)}$$

$$f(cij) = friction\ factor\ or\ deterrence\ function$$

Where,

Tij the number of trips going from i to j;

Oi the total number of trip production by zone i;

Dj the total number of trips attracted to zone j;

$f(cij)$ the generalized cost function of travel from i to j;

Ai, Bj the balancing factors which ensure that the flow consistency conditions connected with Oi and Dj are met;

In order to properly calibrate a gravity model, it is necessary to possess a robust representation of the trip matrix from the base year. This requirement necessitates a substantial sample size. This requirement is not merely a theoretical necessity but a mathematical characteristic of the calibration algorithms predominantly devised in the 1970s (Celik, 2010). In order to achieve optimal coefficient β for each specific purpose in calibrating gravity models, an iterative process was employed whereby the coefficient was adjusted until the estimated trip length distribution produced by the model reached convergence with the observed distribution.(Abdel-Aal, 2014)

CHAPTER 4: ANALYSIS AND RESULT

4.1 Introduction

This chapter presents the research findings obtained through data analysis using several proposed methods. Initially, a sensitivity analysis was conducted utilizing ArcGIS version 10.8 to establish the cluster distance parameter, which was then used to generate the hospital clusters. Subsequently, the Thiessen polygon procedure was executed to perform the internal zoning. The zonal demographic data were extracted through the utilization of the clipping operation and finally employed in the Multiple Linear Regression model. The regression model generated two outputs: the count of productions and attractions. These outputs were eventually utilized as inputs in the trip distribution model. The trip distribution model was calibrated to ascertain the veritable deterrence function, which was later used to compute each zone's ultimate cell values of production and attraction matrix in the event of emergency trips.

4.2 Descriptive Statistics

4.2.1 Sensitivity Analysis to Cluster Hospitals

The hospital cluster distance encompassing the highest number of hospitals was determined through sensitivity analysis. Through the implementation of GIS analysis, the observation was made regarding the distance at which the most significant quantity of hospitals was included.

The sensitivity analysis for determining the cluster distance is presented below in Table 4. 1: Sensitivity Analysis with Figure 4. 1: Cluster Distance Determination showing relevant graphs,

Table 4. 1: Sensitivity Analysis

SENSITIVITY ANALYSIS					
Cluster Distance	Avg_Area	Max_Area	Min_Area	STD_Area	Range
100	8.995709316	21.456254	1.971554	4.082285006	19.4847
200	9.903080783	21.456254	1.971554	4.095106978	19.4847
300	11.38410383	22.934149	3.54224	5.15442022	19.391909
400	12.76072386	26.374022	3.54224	5.489992895	22.831782
500	14.38208175	26.37402	5.59858	5.508298328	20.77544
550	16.2394039	26.37402	5.59858	5.408584524	20.77544
600	16.5751098	24.033986	5.59858	5.589687338	18.435406

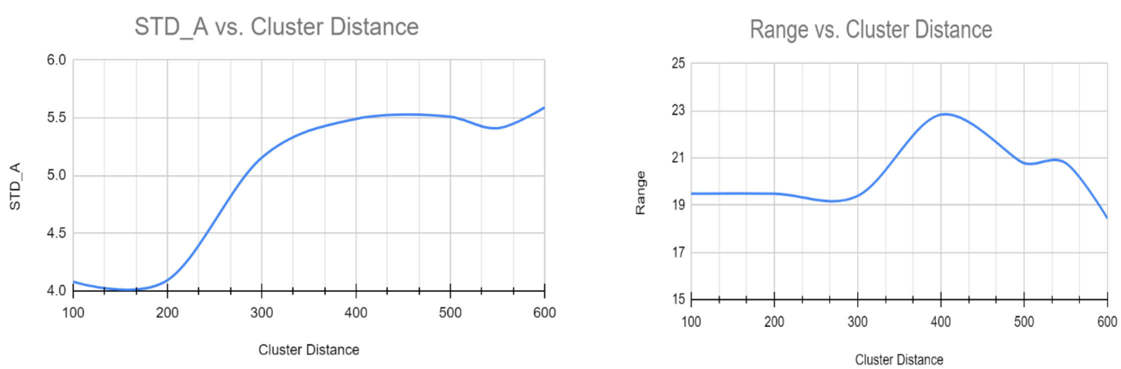

Figure 4. 1: Cluster Distance Determination

The sensitivity analysis results conducted using GIS data indicate that the graphs exhibit apparent features beyond a distance of 500 meters. This signifies that a cluster proximity of 500 meters effectively encompassed the majority of the closest hospitals.

The presented figure in Figure 4. 2: Clustered Hospitals depicts the clustered representation of 75 hospitals, which have been grouped into 23 distinct clusters.

Figure 4. 2: Clustered Hospitals

4.2.2 Internal Zoning

The Thiessen polygon operation was executed in GIS by inputting the coordinates of clustered hospitals. This endeavor's primary objective was to split Dhaka's city map into internal zones, disregarding ward boundaries and in accordance with the clustering of hospitals. A set of 23 internal zones were established. The Clipping Operation was employed to extract demographic data from each of the 23 zones individually. The demographic data categorized by zone was utilized in a regression analysis to predict the overall number of productions. The GIS map along with the determined zone number is presented below in Figure 4. 3: 23 Internal Zones,

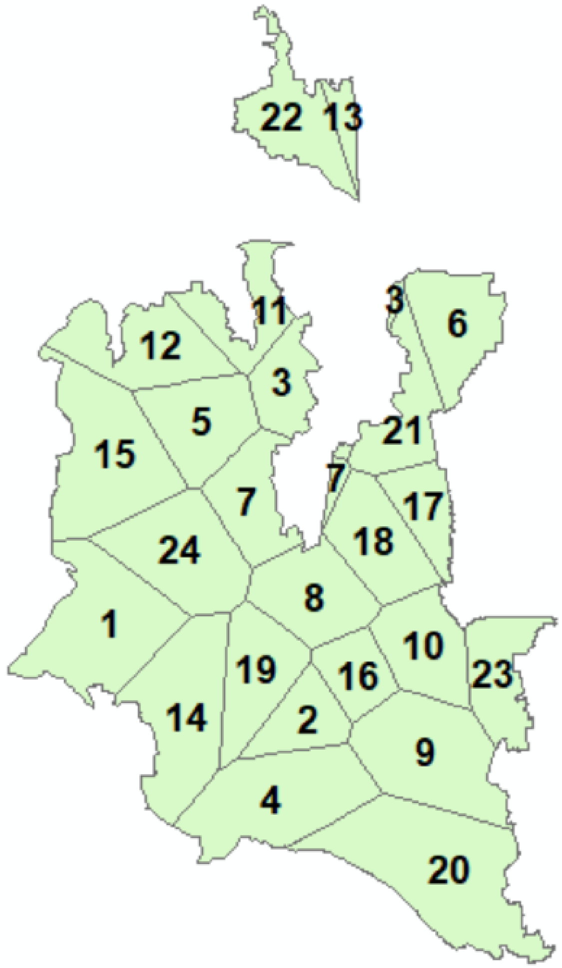

Figure 4. 3: 23 Internal Zones

4.2.3External Zoning

The process of External Zoning was carried out by considering the entrance points that are connected to the major national highways of Dhaka city. Six distinct external zones were established based on the respective apertures.

Zone 25: N3-N5

Zone 26: N5-N8

Zone 27: N8-N532

Zone 28: N532-N1

Zone 29: N1-N301

Zone 30: N301-N3

The external zones are illustrated below in Figure 4. 4: 6 External Zones,

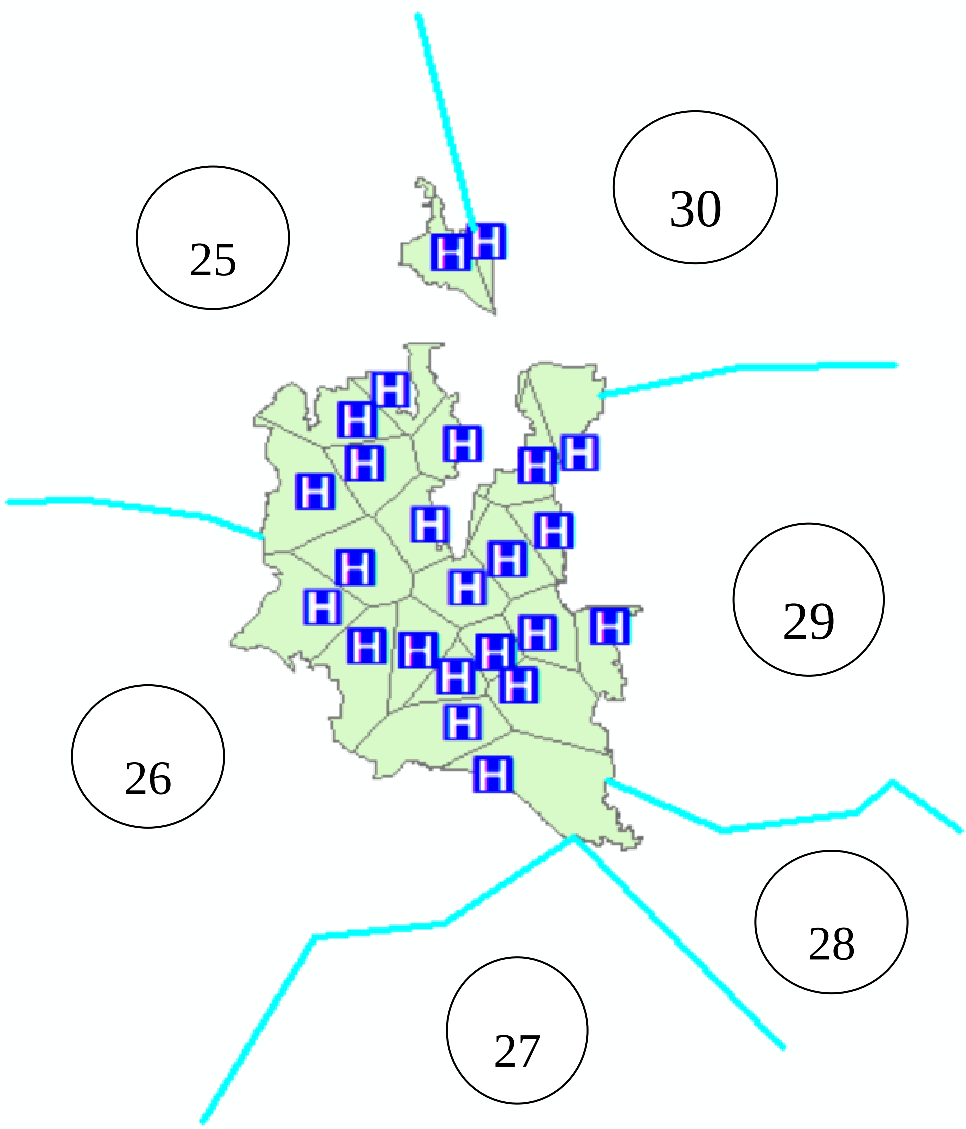

Figure 4. 4: 6 External Zones

4.3 Trip Generation

The first stage of the conventional four-step approach for estimating travel demand is trip generation models. Each traffic analysis zone (TAZ) in the research region is given an estimated number of trips that it generates and attracts (Huntsinger et al., 2013).

Trip generation variables are influenced by the socioeconomic characteristics and geography of a region. There are some socioeconomic parameters are which are commonly used in modeling of trip generation including household number, population, age, income, area, gender. For EMS trip generation, the variables have been chosen based on literature findings, engineering judgment and expert opinion. And through the regression analysis, the variables for production and attraction model were found to be significant.

4.3.1 Production Model

Table 4. 2: Variable Used for Production Model

Independent Variables		**Justification**
X1	Total Floor Area	Gross Floor Area of Station (Mohd Shafie et al., 2021) Plot area of the industry (Patel et al., 2018) Service and office floor area (Dodeen et al., 2014)
X2	No of Hospitals	Number of apartments (Zenina and Borisov, 2013)
X3	Number of Private Hospitals	Experts' opinion and Engineering judgment
X4	Number of Specialized Hospitals	Experts' opinion and Engineering judgment
Dependent Variables		
Y	Number of Attraction	Output of Production Model in Trip Generation Modelling

Table 4. 3: Results of Production Model

Intercept and Variables	**Coefficient**	**Standard Error**	**t-value**	**Significance**
Intercept	10.8190076	11.7102930	0.924	0.0685
Household Number	0.0007346	0.0003936	1.866	0.0793
Population	-0.0003060	0.0001475	-2.074	0.0536
Area (KM^2)	1.8967196	1.3849221	1.370	0.0886
People of Age > 64	0.0061577	0.0032128	1.917	0.0723
Multiple R-squared: 0.3342 **Adjusted R-squared:** 0.1775				
F-statistic: 2.133 on 4 and 17 DF				
p-value: 0.121				

Number of Productions = 10.8190076 + 0.0007346**X1** - 0.0003**X2** + 1.8967196**X3** + 0.0061577**X4** (4)

All of the coefficients are proven significant at 90% Confidence Interval. From the equation, we can determine that the number of productions will be increased with the increase of household number, area of that region and decrease slightly with the increase of population. The number of aged populations will also raise the production number specifically population of age>64.

It is noted that the model has Multiple R-squared value of only 33.42%, still this study is able to provide the basis for future studies to construct a reliable multiple linear regression analysis for developing production model for any city regarding the planning of emergency medical services.

4.3.2 Attraction Model

Table 4. 4: Variables used for Attraction Model

Independent Variables		**Justification**
X1	Total Floor Area	Gross Floor Area of Station (Mohd Shafie et al., 2021) Plot area of the industry (Patel et al., 2018) Service and office floor area (Dodeen et al., 2014)
X2	No of Hospitals	Number of apartments (Zenina and Borisov, 2013)
X3	Number of Private Hospitals	Experts' opinion and Engineering judgment
X4	Number of Specialized Hospitals	Experts' opinion and Engineering judgment
Dependent Variables		
Y	Number of Attraction	Output of Production Model in Trip Generation Modelling

Table 4. 5: Results of Attraction Model

Intercept and Variables	Coefficient	Standard Error	t-value	Significance
Intercept	11.74	77.36	0.152	0.081
Total Floor Area	0.007463	0.0011061	7.037	2×10^{-06}
No of Hospitals	139.2	110.1	1.264	0.023
Number of Private Hospitals	-138.7	104.0	-1.334	0.020
Number of Specialized Hospitals	-209.3	136.3	-1.535	0.043
Multiple R-squared: 0.8193 **Adjusted R-squared:** 0.7767				
F-statistic: 76.71 on 1 and 20 DF				
p-value: 3.854×10^{-06}				

Number of Attractions =11.74 + 0.007463**X1** + 139.2**X2** - 138.7**X3** - 209.3**X4** (5)

At a 90% Confidence Interval, all of the coefficients are found to be significant. According to the equation, the number of productions will rise as the number of hospitals and total floor area expand, while it will decline as the number of private and specialized hospitals increased.

The model has a Multiple R-squared value of 81.93% which is highly satisfactory. This study can be considered as the groundwork for future research to build a highly acceptable multiple linear regression analysis for developing any attraction model regarding the planning of emergency medical services.

4.4 Trip Distribution

The Doubly Constrained Gravity Distribution model was used for trip distribution and the equation was,

$$Tij = Ai\ Oi\ Bj\ Dj\ f(cij) \quad (3)$$

As $f(cij)$ in this equation is a deterrence function or cost function which is unique for any region and depends on the trip length distribution of that specific region, it is needed to calibrate it in order to use it in the trip distribution model.

4.4.1Trip Length Distribution

Trip length distribution is a plot of the trip frequencies within a specific trip length range vs. the trip length ranges. From the emergency room survey data, the time to leave the origin and the time to reach the destination of the surveyed individuals was found. Subtracting the former one from the later one the trip lengths for each of the 2007 individuals' responses were calculated in minutes. After plotting the trip frequencies vs. the trip length, trip length distribution was generated as the graph presented in Figure 4. 5: Trip Length Distribution,

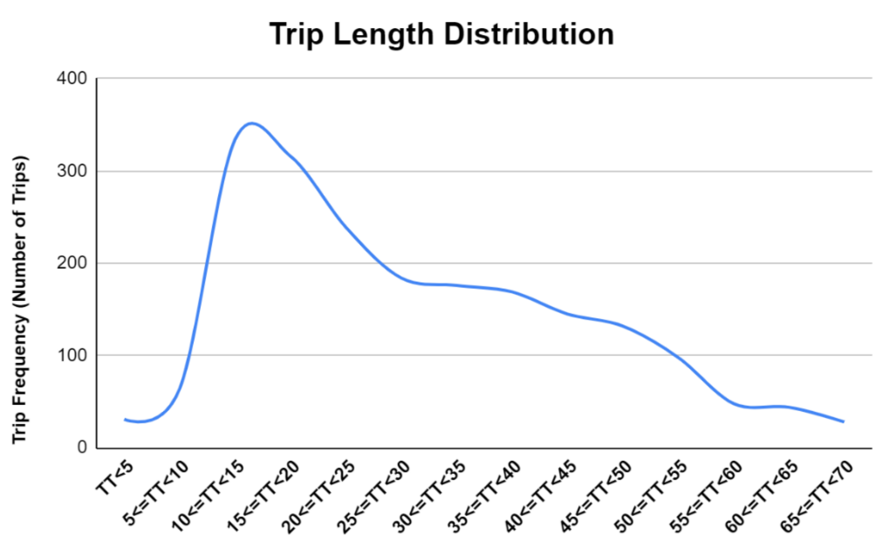

Figure 4. 5: Trip Length Distribution

The mean trip length from the actual data was calculated and found to be 31.62 minutes.

4.4.2 Skim Matrix:

For each origin-destination zone pair, a skim matrix, also known as “Generalized Cost Matrix”, offers trip time, distance, costs, or a mix of those (*Travel Forecasting Resource*, n.d.).

As the zone ids along with hospital clusters were already defined through GIS analysis using the Thiessen Polygon, the zonal location of each of the individuals could be tracked. From the emergency room survey data, the approximate location of the origin and exact location of the destination of the individuals were found. Using the origin locations, the coordinates were determined, and after that, using GIS, the zone ids of the origin locations were identified. As the travel time data was sorted beforehand, combining the GIS data and travel time data, travel time between zones was found, forming the skim matrix. Figure 4. 6: Individual’s Production and Attraction Zone Identification represents the identification of the zone number of the individuals’ productions and attractions,

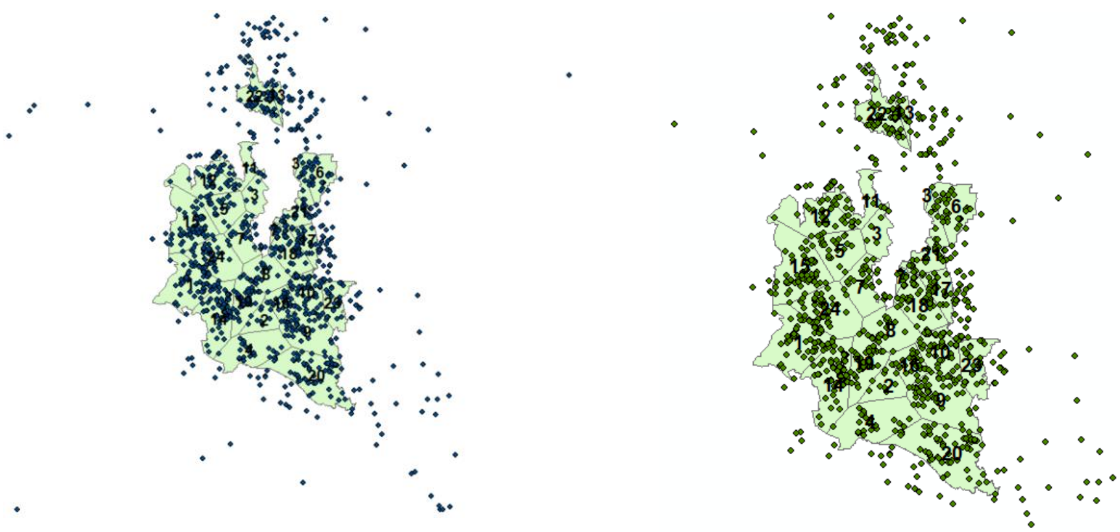

Figure 4. 6: Individual’s Production and Attraction Zone Identification

The final skim matrix is presented below in Table 4. 6: Skim Matrix Using Travel Time,

Table 4. 6: Skim Matrix Using Travel Time

Zone ID	Zone ID																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25(E)	26(E)	27(E)	28(E)	29(E)	30(E)
1	0.00	41.25	0.00	35.00	30.00	0.00	0.00	36.25	45.00	35.00	45.00	0.00	0.00	17.86	20.00	40.00	42.50	35.00	27.73	20.00	31.67	0.00	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	12.50	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.50	0.00	15.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	15.00	0.00	15.00	0.00	0.00	0.00	25.00	40.00	0.00	0.00	0.00	20.00	42.50	0.00	0.00	0.00	35.00	25.00	23.33	0.00	0.00	0.00	55.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	45.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	20.00	20.00	0.00	0.00	27.50	55.00	55.00	52.00	50.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	80.00	0.00	0.00	45.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	40.00	35.00	35.00	30.00	37.50	0.00	0.00	25.00	0.00	47.50	46.67	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	27.50	20.00	0.00	0.00	25.00	0.00	40.00	0.00	0.00	0.00	25.00	25.00	45.00	36.67	31.67	37.50	0.00	20.00	12.50	52.50	30.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	20.00	0.00	40.00	0.00	0.00	0.00	20.00	21.25	20.00	0.00	0.00	0.00	20.00	0.00	28.75	0.00	26.67	35.00	0.00	22.50	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
9	35.00	20.00	0.00	24.00	0.00	0.00	0.00	20.00	17.50	12.50	0.00	32.50	0.00	33.33	40.00	22.86	47.50	0.00	33.71	0.00	32.50	30.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	13.33	20.00	0.00	31.25	0.00	0.00	0.00	21.67	16.25	11.30	0.00	0.00	0.00	25.00	0.00	24.62	35.00	56.67	33.33	60.00	0.00	45.00	23.13	35.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	45.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	12.50	15.00	0.00	50.00	0.00	0.00	37.50	0.00	0.00	0.00	35.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	55.00	0.00	40.00	24.38	0.00	0.00	35.00	0.00	0.00	0.00	10.00	0.00	27.50	0.00	55.00	53.33	40.00	0.00	65.00	0.00	0.00	0.00	41.67	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	13.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	21.67	0.00	35.00	0.00	0.00	0.00	25.00	25.00	43.33	0.00	0.00	20.00	12.29	0.00	35.00	45.00	0.00	18.25	46.67	45.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00
15	45.00	52.50	0.00	56.67	19.17	0.00	0.00	32.50	10.00	0.00	36.67	22.50	0.00	26.25	16.82	55.00	45.00	0.00	36.25	0.00	37.50	35.00	55.00	21.67	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	17.50	0.00	0.00	0.00	0.00	0.00	20.00	15.00	17.50	0.00	0.00	0.00	0.00	35.00	15.83	35.00	0.00	30.83	0.00	35.00	30.00	32.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	35.00	0.00	0.00	40.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	31.67	0.00	20.00	16.25	0.00	35.00	0.00	13.75	20.00	15.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
18	30.00	36.67	0.00	0.00	35.00	0.00	0.00	15.00	25.00	30.00	0.00	0.00	0.00	28.33	0.00	22.50	16.00	17.86	32.50	40.00	20.00	20.00	20.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	21.67	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	12.50	0.00	28.00	35.00	0.00	15.21	40.00	32.50	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	22.50	0.00	26.75	0.00	0.00	0.00	36.67	26.67	31.67	0.00	0.00	0.00	35.00	0.00	45.00	0.00	0.00	39.00	28.64	0.00	50.00	43.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	30.00	0.00	0.00	35.00	30.00	0.00	0.00	16.67	18.33	0.00	0.00	21.88	25.00	45.00	37.50	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	75.00	0.00	60.00	0.00	0.00	0.00	0.00	0.00	25.00	20.00	0.00	24.44	20.00	0.00	0.00	55.00	110.00	25.00	0.00	0.00	21.43	0.00	75.00	0.00	0.00	0.00	0.00	0.00	0.00
23	15.00	55.00	0.00	60.00	0.00	0.00	0.00	0.00	30.00	40.83	0.00	0.00	60.00	25.00	0.00	0.00	35.00	0.00	32.50	0.00	40.00	40.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	51.67	0.00	45.00	20.00	0.00	0.00	45.00	0.00	48.33	0.00	0.00	0.00	17.50	20.00	37.50	45.00	45.00	30.00	0.00	0.00	25.00	45.00	15.63	0.00	0.00	0.00	0.00	0.00	0.00
25(E)	0.00	57.78	0.00	100.00	30.00	0.00	0.00	40.00	0.00	0.00	30.00	36.00	45.83	42.50	25.00	56.50	35.00	80.00	35.00	0.00	35.00	36.79	0.00	78.75	0.00	0.00	0.00	0.00	0.00	0.00
26(E)	0.00	20.00	0.00	35.00	30.00	0.00	0.00	0.00	80.00	0.00	0.00	50.00	55.00	0.00	0.00	41.67	0.00	0.00	0.00	51.67	90.00	0.00	75.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27(E)	65.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.67	0.00	0.00	0.00	0.00	0.00	43.33	55.00	0.00	67.50	31.67	40.00	0.00	70.00	61.67	0.00	0.00	0.00	0.00	0.00	0.00
28(E)	0.00	52.50	0.00	46.67	0.00	0.00	0.00	0.00	40.00	57.50	0.00	0.00	0.00	0.00	0.00	56.25	60.00	0.00	62.50	50.00	0.00	65.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29(E)	0.00	35.00	0.00	47.50	40.00	0.00	0.00	36.25	25.00	31.00	0.00	35.00	0.00	30.00	40.00	47.50	25.00	0.00	37.00	57.50	36.67	22.50	20.00	125.00	0.00	0.00	0.00	0.00	0.00	0.00
30(E)	40.00	84.00	0.00	90.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.00	35.25	0.00	35.00	60.00	17.50	53.33	42.50	100.00	50.00	45.21	50.00	85.00	0.00	0.00	0.00	0.00	0.00	0.00

4.4.3 Calibration of the Deterrence function or Friction Factor:

There are several pre-existing deterrence functions' equations in the previous studies. According to the trip length distribution, appropriate deterrence function equation for the study is to be selected the and calibrated to simulate the study region's scenario.

De Dios Ortúzar and Willumsen (2011) defined some of the popular graphical forms of friction factors in their book named “Modelling Transport” which are presented in Figure 4. 7: Popular Graphical Forms of the Deterrence Function,

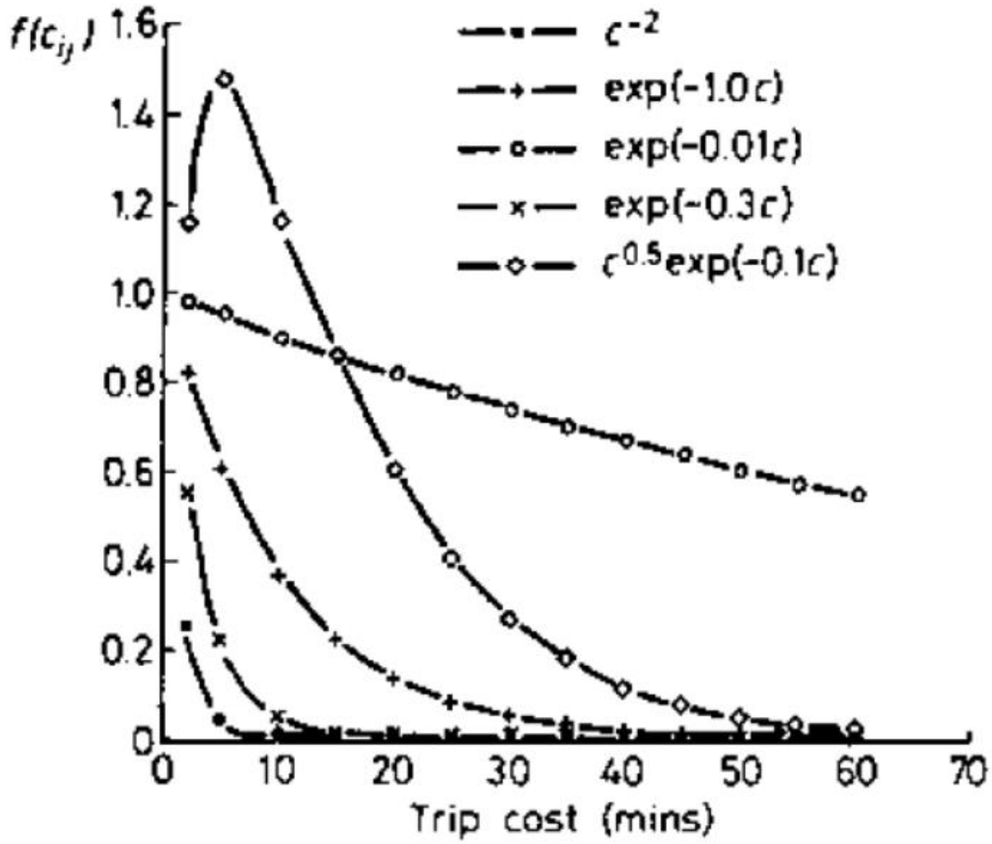

Figure 4. 7: Popular Graphical Forms of the Deterrence Function

According to “Figure 4.7”, the closest fit with a curve according to the trip length distribution was identified to be as follows,

$$f(cij) = cij^{n}\exp^{\beta cij} \quad (6)$$

To calibrate the above equation, it was needed to calculate the *n* and the β value. The *n* value was kept as 0.5 and the β value was adjusted using an iterative approach with an initial assumption of 0.1. After that, the deterrence function was applied to each cell of the skim matrix. The same function was applied to all of the cells to come up with an initial estimate of the trip matrix. The row totals are then compared to the total target trip production from each zone obtained from the emergency room survey. Similarly, the column totals were compared to the target attraction values of each zone. Next, a series of correction factors were applied for the column values keeping the row correction factors as unity. The equation for correction factor was,

$$ai = \frac{Target\ Attraction\ from\ each\ zone}{Row\ total},\ \ bj = \frac{Target\ Production\ from\ each\ zone}{Column\ Total}$$

$$Where, ai = Column\ Correction\ Factor$$

$$bj = Row\ Correction\ Factor$$

For the next iteration, the cell values from previous iteration were adjusted using both the row and the column correction factors. The row total and column total were again compared to the zonal target trip production and attraction respectively and the correction factors for both the production and attraction were determined. In this way the cell values were adjusted until the row totals become equal to the zonal target production values, and the column totals become equal to the zonal target attraction values. Finally, the expected average trip length was calculated and compared to the mean trip length of the actual trip length distribution which was 31.62 minutes. The equation used to calculate the expected average trip length was,

$$Expected\ Average\ Trip\ Length = \frac{\Sigma xij * cij}{\Sigma xij}$$

$$Where, xij = Trip\ matrix\ cell\ value\ of\ ith\ row\ and\ jth\ column$$

$$cij = Skim\ matrix\ cell\ value\ of\ ith\ row\ and\ jth\ column$$

From the initial iteration, the expected average trip length was found out to be 24.80 minutes which was not equal to the actual average trip length for the study region. Therefore, the β value was adjusted until both the expected average trip length and the actual average trip length were equal. The calibrated β value came out to be 0.0264 and the final equation for the deterrence function was,

$$f(cij) = cij^{0.5}\ \mathrm{exp}^{0.0264*cij} \qquad (7)$$

Easa (1993) showed the calibration procedure of Gravity Distribution model showed in Figure 4. 8: Flow Chart of the Calibration of Friction Factor,

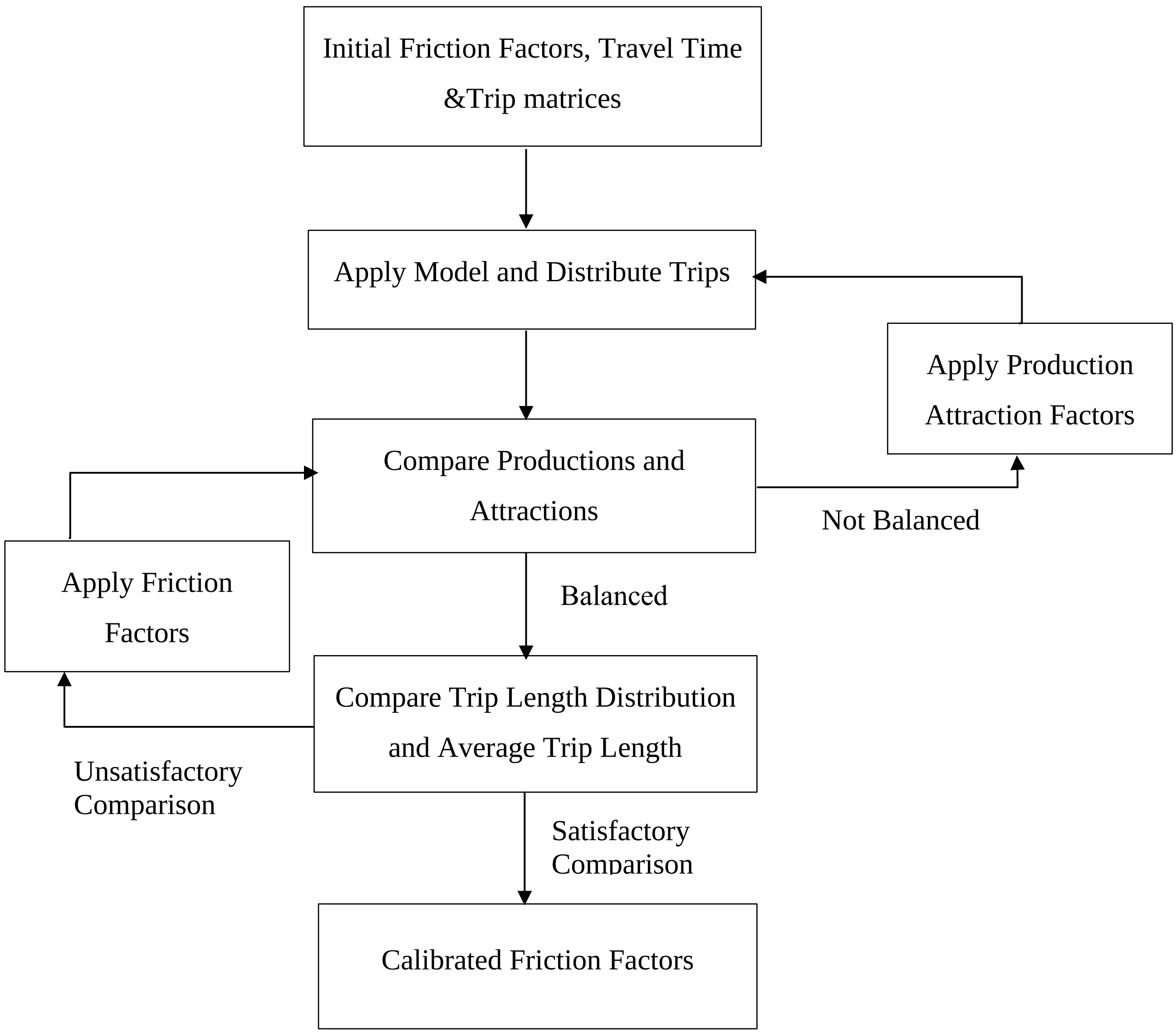

Figure 4. 8: Flow Chart of the Calibration of Friction Factor

4.4.4 The Doubly Constrained Gravity Distribution Model:

From the trip generation model, the equations for measuring zonal productions and attractions were derived. The equation for attraction model was as follows,

$$Number\ of\ Attractions = 11.74 + 0.007463 * X1 + 139.2 * X2 - 138.7 * X3 - 209.3 * X4 \quad (5)$$

$$Where, X1 = Total\ Floor\ Area\ \left(\frac{m2}{1000}\right)$$

$$X2 = Number\ of\ Zonal\ Hospitals$$

$$X3 = Number\ of\ Private\ Hospitals$$

$$X4 = Number\ of\ Specialized\ Hospitals$$

Based on the zonal characteristics, the Attraction values were calculated as follows in Table 4. 7: Zonal Attractions,

Table 4. 7: Zonal Attractions

Zone ID	Number of Attractions
1	261.5
2	305.5
4	776.77
5	21.41
8	148.1
9	138.36
10	82.61
11	47.7
12	84.05
13	249.22
14	13.98
15	94.55

Zone ID	Number of Attractions
16	214.69
17	52.95
18	431.69
19	585.21
20	273
21	231.23
22	469.98
23	6.71
24	1706.03
Total	6195.24

The equation for the Production model was as follows,

$$Number\ of\ Productions = 10.8190076 + 0.0007346 * X1 - 0.0003 * X2 + 1.8967196 * X3 + 0.0061577 * X4 \quad (4)$$

$Where, X1 = Household\ Number$

$X2 = Population$

$X3 = Area\ (km2)$

$X4 = People\ older\ than\ 64\ years$

Similarly, based on zonal characteristics the production values were also calculated and presented in Table 4. 8: Zonal Productions,

Table 4. 8: Zonal Productions

Zone ID	Number of Productions
1	48.3
2	32.2
4	43.0
5	47.0
8	41.2
9	48.2
10	60.8
11	34.0
12	45.3
13	31.9
14	71.7
15	43.5
16	27.1
17	36.6
18	46.5
19	45.9
20	57.1
21	41.2
22	31.9
23	47.7
24	59.9
Total	940.8

The total number of productions must be equal to the number of attractions because every trip originating from a specific location must be destined for another location. As the total number of productions did not match the total number of attractions, the zonal production values were factorized to match the total number of zonal attractions. The factored zonal production values are presented below in Table 4. 9: Factored Productions,

Table 4. 9: Factored Productions

Zone ID	Number of Productions
1	317.99
2	212.11
4	282.85
5	309.54
8	271.27
9	317.35
10	400.23
11	223.82
12	298.08
13	210.01
14	471.88
15	286.25
16	178.36
17	240.92
18	306.41
19	302.39
20	375.86
21	271.44
22	210.01
23	314.28
24	394.19
Total	6195.24

For the final Production-Attraction matrix, each cell value was calculated using the Doubly Constrained Gravity model equation,

$$Tij \ = \ Ai \ Oi \ Bj \ Dj \ f(cij) \qquad (3)$$

$$Where, f(cij) = Calibrated\ Friction\ Factor = cij^{0.5}\ \exp^{0.0264*cij}$$

$$Ai\ and\ Bj\ are\ the\ balancing\ factors\ which\ esure\ that\ the\ flow\ consistency$$

$$conditions\ connected\ with\ Oi\ and\ Dj\ are\ met.$$

$$Oi = Zonal\ Production$$

$$Dj = Zonal\ Attraction$$

This is also an iterative method. For the initial iteration, the *Bj* values were assumed as unity (1) and *Ai* values were calculated using,

$$Ai \ = \ \frac{1}{\Sigma j\ Bj\ Dj\ f(cij)} \qquad (8)$$

For the next iteration, B_j values were calculated using the A_i values obtained from the previous step using,

$$Bj \ = \frac{1}{\Sigma i\ \ Ai\ Oi\ f(cij)} \qquad (9)$$

In this way the iterations were carried out until both the calculated total number of Productions (O_{i1}) and Attractions (D_{j1}) were equal or very close to the Targeted total number of Productions (O_i) and Attractions (D_j) respectively.

The final PA matrix is presented below in Table 4. 10: Final PA Matrixs,

Table 4. 10: Final PA Matrix

P/A	1	2	4	5	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Ai	Oi	Oi(1)
1	0.00	8.19	50.09	0.99	7.41	6.69	4.77	3.26	0.00	0.00	0.46	12.43	8.23	1.85	40.77	22.62	29.85	10.84	0.00	0.00	109.39	4.68E-06	**317.99**	**317.84**
2	0.00	47.48	0.00	5.21	0.00	0.00	0.00	0.00	0.00	0.00	2.24	0.00	48.06	0.00	0.00	109.21	0.00	0.00	0.00	0.00	0.00	7.30E-06	**212.11**	**212.19**
4	0.00	10.25	57.67	0.00	8.59	7.47	0.00	0.00	0.00	26.38	0.38	0.00	0.00	0.00	42.29	23.95	30.62	0.00	0.00	0.00	75.13	5.23E-06	**282.85**	**282.73**
5	0.00	12.33	0.00	1.55	0.00	0.00	0.00	6.70	8.29	0.00	0.00	19.02	10.33	2.40	50.46	26.84	0.00	0.00	0.00	0.00	171.48	4.86E-06	**309.54**	**309.41**
8	0.00	9.90	46.44	0.00	8.36	8.52	5.30	0.00	0.00	0.00	0.45	0.00	9.30	0.00	43.89	20.76	0.00	11.52	0.00	0.00	106.70	5.50E-06	**271.27**	**271.14**
9	57.13	15.11	83.82	0.00	12.77	13.03	7.80	0.00	7.22	0.00	0.63	15.67	14.79	2.59	0.00	32.20	0.00	16.23	38.00	0.48	0.00	4.72E-06	**317.35**	**317.48**
10	50.80	12.29	64.23	0.00	10.34	10.55	6.22	0.00	0.00	0.00	0.55	0.00	11.91	2.51	35.99	26.30	22.10	0.00	25.47	0.41	120.41	3.71E-06	**400.23**	**400.09**
11	0.00	55.96	0.00	7.64	0.00	0.00	0.00	29.29	37.20	0.00	2.36	0.00	0.00	14.29	0.00	0.00	0.00	75.31	0.00	2.42	0.00	7.40E-06	**223.82**	**224.46**
12	0.00	8.93	63.66	1.41	10.20	0.00	0.00	0.00	6.51	0.00	0.60	0.00	8.81	2.11	51.82	0.00	22.25	0.00	0.00	0.00	121.61	4.97E-06	**298.08**	**297.90**
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.66	94.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	95.89	0.00	0.00	7.27E-06	**210.01**	**210.34**
14	0.00	16.62	83.58	0.00	13.81	14.11	7.10	0.00	0.00	42.44	0.73	0.00	14.66	2.97	0.00	39.33	37.63	15.16	0.00	0.00	183.62	3.16E-06	**471.88**	**471.76**
15	32.84	6.85	35.90	1.06	7.73	7.93	0.00	3.66	5.17	0.00	0.44	12.37	6.48	1.78	0.00	20.61	0.00	10.09	23.75	0.22	109.37	5.25E-06	**286.25**	**286.25**
16	0.00	15.77	0.00	0.00	13.33	13.46	8.44	0.00	0.00	0.00	0.00	17.47	15.47	3.22	0.00	34.68	0.00	16.46	39.67	0.49	0.00	8.54E-06	**178.36**	**178.46**
17	0.00	10.83	0.00	1.07	10.07	0.00	0.00	0.00	0.00	0.00	0.51	0.00	12.01	2.78	0.00	25.53	0.00	13.95	32.53	0.40	131.19	6.28E-06	**240.92**	**240.88**
18	41.63	9.09	0.00	0.98	8.70	8.82	5.25	0.00	0.00	0.00	0.46	0.00	10.22	2.38	47.74	22.52	25.96	12.22	27.87	0.35	82.17	4.87E-06	**306.41**	**306.35**
19	0.00	15.27	0.00	0.00	0.00	12.96	0.00	0.00	0.00	0.00	0.68	0.00	14.50	3.13	0.00	35.76	38.17	16.47	0.00	0.00	165.33	4.97E-06	**302.39**	**302.27**
20	0.00	23.19	127.19	0.00	17.21	19.52	11.57	0.00	0.00	0.00	0.95	0.00	17.87	0.00	0.00	46.55	66.42	0.00	44.72	0.62	0.00	3.94E-06	**375.86**	**375.82**
21	0.00	0.00	0.00	0.00	10.33	0.00	6.28	0.00	0.00	28.25	0.54	0.00	0.00	2.85	57.16	0.00	0.00	14.55	32.67	0.32	118.43	5.51E-06	**271.44**	**271.38**
22	0.00	5.16	38.60	0.00	0.00	0.00	5.97	4.79	0.00	28.47	0.52	0.00	0.00	1.72	11.36	26.29	0.00	0.00	30.34	0.00	56.80	7.15E-06	**210.01**	**210.04**
23	79.10	12.41	63.91	0.00	0.00	15.30	8.32	0.00	0.00	28.89	0.84	0.00	0.00	3.85	0.00	40.72	0.00	18.43	42.04	0.63	0.00	4.77E-06	**314.28**	**314.45**
24	0.00	9.85	61.69	1.50	9.26	0.00	5.57	0.00	0.00	0.00	0.65	17.58	12.04	2.52	50.21	31.34	0.00	0.00	37.04	0.37	154.39	3.77E-06	**394.19**	**394.01**
Bj	2.60	2.04	0.89	27.58	4.54	4.85	8.07	11.74	7.03	2.66	44.43	7.45	3.06	11.88	1.59	1.12	2.56	2.67	1.41	90.99	0.39			
Dj	**261.50**	**305.50**	**776.77**	**21.41**	**148.10**	**138.36**	**82.61**	**47.70**	**84.05**	**249.22**	**13.98**	**94.55**	**214.69**	**52.95**	**431.69**	**585.21**	**273.00**	**231.23**	**469.98**	**6.71**	**1706.03**		**6195.25**	
Dj(1)	**261.50**	**305.50**	**776.77**	**21.41**	**148.10**	**138.36**	**82.61**	**47.71**	**84.05**	**249.22**	**13.98**	**94.55**	**214.69**	**52.94**	**431.69**	**585.21**	**273.00**	**231.23**	**469.98**	**6.71**	**1706.03**			**6195.24**

The error was calculated by,

$$\% \ ERROR = \Sigma|O_i - O_{i(1)}| + \Sigma|D_j - D_{j(1)}| \qquad (10)$$

= 2.96%, which was acceptable.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The Chapter here summarize the findings, Policy and recommendations of the study. The Study will make us to gather knowledge about the pattern of emergency trips and responses. Also propose the Limitations and the for the future scope of the study.

5.1 Background

This paper analyzed two very common Trip generation and Trip Distribution Model. The initial phase of the research was Focused on Trip generation Modelling. There initially adopted GIS based approach where 24 zones were zoned based on Questionnaire survey to prepare a Map for the Attraction and Production Model. A Regression model was proposed to analyze Attraction and Production trips. The zone-specific extracted variables from the attraction model are number of Hospitals, Floor area, Road type and from the production model are population density, Age distribution, gender, Land use.

After development of the regression model based on zonal characteristics, The study established a Trip Distribution model from the extracted data of Trip Generation Model. This model is proposed to identify the emergency travel patterns and formation of the OD matrix. PA was formed based on the data extracted before and then outcome of the model could be presented after several of trial.

Thus, Various strategies combined like GIS based zoning, Attraction- Production model based on zoning, several calibrations for distribution to optimize EMS.

This study will provide basic understanding about the formulation strategies for Travel Demand Modelling and emergency travel pattern.

5.2 Major Findings

The purpose of the study is to understand the pattern of emergency response and understanding the current practice of processing emergencies. The study will provide the basic understanding about the response of EMS.

The analysis shows the initial phase of the research focused on trip generation modeling where regression models were developed for Trip generation and Trip Distribution. The adjusted R-squared value for Attraction Model 0.7767 and for Production model adjusted R-squared value 0.1775. The major findings of trip generation are variables like Number of zonal hospitals, zonal gross hospital floor area, number of specialized and private hospitals are significant for the Attraction model and Household number, Population, Age>64, Area are significant variables for the Production model.

The findings of Trip distribution are average trip length, cost function, skim matrix. The Major findings from Gravity Model is that it can now predict trip pattern for emergency trips and also can define the PA matrix.

5.3 Policy Development:

From perspective of a developing country like Bangladesh, the main idea has little been discovered. So, there is a scope to discover the EMS in an explicit way. Policymakers can select the location of new health facilities based on zonal demand using our proposed methodology and avoid scattered development.

5.4 Limitations and Future Scope:

The main idea of the study is novel as little, or no work has been done before to understand the travel demand of emergency trips. The study analyzed the emergency response of a trip. The strategies like doing trip generation based on zoning along with trip Distribution by the data from attraction and production models are something that hasn't explored or explored a little. But there are some limitations of the research.

Firstly, the present study is limited in Data collection as data is collected from only selected hospitals and there was no proper Questionnaire maintained for zoning of the hospital. Secondly, the zonal distance used in analysis were based on the centroidal distances instead of the actual distances. Thirdly, the study is based on optimizing present medical resources rather than future resources. Again, the study was only limited to small city like Dhaka. So, there is a scope for future more research trying the same study for larger area. It would be worth trying the study for larger sample sizes for more accurate results in the future.

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Appendix

EMS Questionnaire

Event specific (socioeconomic)

1. What is the age of the patient?
   ☐ <18 ☐ 18 – 25 ☐ 25 – 35 ☐ 35 – 50 ☐ 50 – 60 ☐ 60 – 65 ☐ ≥65

2. What is the sex of the patient?

   ☐ Male ☐ Female ☐ Transgender
   ☐ Prefer not to say

3. What is the income of the patient (in BDT)?
   ☐ <10k ☐ 10-15k ☐ 15-20k ☐ 20-25k ☐ 25-35k
   ☐ 35-45k ☐ 45-55k ☐ 55-65k ☐ 65-100k ☐ 100k+

4. What is the education level of the patient?
   ☐ Illiterate
   ☐ No formal education
   ☐ Drop-out from Primary level education
   ☐ Primary/ Ibtedayi
   ☐ Drop-out from Secondary level education
   ☐ Secondary (Includes Trace Certificate/SSC Vocational)/ Dakhil
   ☐ Higher Secondary (Includes 2 years of 4-year Diploma in Engineering & Nursing, HSC Vocational)/ Alim
   ☐ Diploma/Vocational (Not a Bachelors, similar to Associates)
   ☐ Graduate / Fazil
   ☐ Postgraduate / Kamil

5. What is the profession of the patient?
   ☐ Govt. employee
   ☐ Teacher
   ☐ Private employee
   ☐ Doctor
   ☐ Self-employed (business)/Freelance
   ☐ Engineer
   ☐ Garment worker
   ☐ Student
   ☐ Day laborer/ Rickshaw-puller
   ☐ Other: ____________________

6. How severe was the emergency?

☐ Severely life threatening
☐ Life threatening
☐ Not life threatening but will cause long term damage
☐ Minor injury / will not cause long term damage
☐ Non injury/ neutral / recovered

7. Did the patient have similar medical history before?

☐ Yes ☐ No ☐ Don't know

8. Who brought the patient to the hospital? (MA)

☐ Family/Relative ☐ Neighbor ☐ Bystander
☐ Others (Specify): ____________

9. What is the age of the person who brought the patient to the hospital?

☐ <18 ☐ 18 – 25 ☐ 25 – 35 ☐ 35 – 50 ☐ 50 – 60 ☐ 60 – 65 ☐ ≥65

10. What is the sex of the person who brought the patient to the hospital?

☐ Male ☐ Female ☐ Transgender
☐ Prefer not to say

11. What is the income of the person who brought the patient to the hospital (in BDT)?

☐ <10k ☐ 10-15k ☐ 15-20k ☐ 20-25k ☐ 25-35k
☐ 35-45k ☐ 45-55k ☐ 55-65k ☐ 65-100k ☐ 100k+

12. What is the education level of the person who brought the patient to the hospital?

☐ Illiterate
☐ No formal education
☐ Drop-out from Primary level education
☐ Primary/ Ibtedayi
☐ Drop-out from Secondary level education
☐ Secondary (Includes Trace Certificate/SSC Vocational)/ Dakhil
☐ Higher Secondary (Includes 2 years of 4-year Diploma in Engineering & Nursing, HSC Vocational)/ Alim
☐ Diploma/Vocational (Not a Bachelors, similar to Associates)
☐ Graduate / Fazil
☐ Postgraduate / Kamil

13. What is the profession of the person who brought the patient to the hospital?
☐ Govt. employee
☐ Teacher
☐ Private employee
☐ Doctor
☐ Self-employed (business)/Freelance ☐ Engineer
☐ Garment worker
☐ Day laborer/ Rickshaw-puller
☐ Student
☐ Other: ______________________

14. Did person who brought the patient to the hospital have similar experience (Taking an emergency patient to hospital) before?

☐ Yes ☐ No

(Spatial and Temporal Data)

15. What was the approximate time of the emergency?

16. When did you decide to take the patient to the hospital?

17. Where did you leave from?

18. What time did you leave?

19. When did you arrive at the hospital?

20. Which hospital did you take the patient to?

21. When did the patient first get medical attention?

22. Did the patient receive any pre hospital medical care?

☐ Yes ☐ No

(Destination Choice)

23. Do you know how to use your phone to find out nearby hospital locations and roadway traffic?

- ☐ Yes
- ☐ No

24. How did you determine the route used to access hospital?

- ☐ Using google map
- ☐ Taking help from the bystanders
- ☐ Relying on the driver of the vehicle
- ☐ Others (Specify)______________________

25. Based on the emergency, did you use the wrong side of the road while accessing the hospital?

- ☐ Yes
- ☐ No

26. Does the hospital you brought the patient to provide ambulance to bring patient to hospital?

☐ Yes ☐ No ☐ Don't know

27. Do you know the phone number of the hospital you took the patient to?

☐ Yes ☐ No

28. Did you contact the hospital before bringing the patient?

☐ Yes ☐ No

29. Did you face any difficulty while bringing the patient to hospital?

☐ Traffic congestion ☐ Bad weather ☐ Bad road condition
☐ Political unrest situation ☐ Legal issues ☐ Other (Specify)_____

30. Do you know any other nearby hospitals you could take the patient and get treatment immediately?

☐ Yes ☐ No

If yes:

i. Please name the hospitals and mention why you decided not to take the patient there.

31. Why did you take the patient to this hospital?

32. What was the initial out of pocket expenditure at the hospital?

(Mode choice- General)

33. In terms of calling emergency support, what do you prefer?

- ☐ Government helpline (999)/app
- ☐ Third party app
- ☐ Dial up numbers
- ☐ Help from bystanders/nearby police
- ☐ Others (Specify)________________

34. How do you rate the availability of transport in that area?

	Readily available	Available	Somewhat available	Not so available	Very difficult to avail
Ambulance					
Rickshaw					
Rental car					
CNG					
Taxicab					
Human hauler					
Taxicab					
Van					
Motorcycle					
Electric Rickshaw					
Tractor					
Pickup					
Uber/Pathao					

35. How do you rate the rapidness of transport of these modes for that particular case?

	Very Rapid	Rapid	Neutral	Slow	Very Slow
Ambulance					
Rickshaw					
Rental car					
CNG					
Taxicab					
Human hauler					
Taxicab					
Van					
Motorcycle					
Electric Rickshaw					
Tractor					
Pickup					
Uber/Pathao					

36. How do you rate the convenience of each mode?

	Very convenient	Convenient	Neutral	inconvenient	Very inconvenient
Ambulance					
Rickshaw					
Rental car					
CNG					
Taxicab					
Human hauler					
Taxicab					
Van					
Motorcycle					
Electric Rickshaw					
Tractor					
Pickup					
Uber/Pathao					

37. How do you rate the expense of the modes?

	Very Expensive	Expensive	Neutral	Cheap	Very cheap
Ambulance					
Rickshaw					
Rental car					
CNG					
Taxicab					
Human hauler					
Taxicab					
Van					
Motorcycle					
Electric Rickshaw					
Tractor					
Pickup					
Uber/Pathao					

38. Which factor do you consider the most important while choosing a mode for emergency transfer?

☐ Availability ☐ Rapidness ☐ Expense ☐Convenience

☐ Other (Specify)_______________________

39. If there were no constraints (time/convenience/rapidness/expense) what would be your preferred mode?

☐ Your own car ☐ Rental car ☐ Rickshaw

☐ Ambulance ☐ CNG ☐ Taxicab

☐ Human hauler ☐ Electric rickshaw ☐ Van

☐ Motorcycle ☐ Tractor ☐ Pick up

☐ Bus ☐ private vehicle of bystander

☐ Uber ☐ Other (Specify): _______________

(Destination Choice)

40. Which factor do you think have the most impact in choosing a hospital?

- ☐ Nearest to the emergency point
- ☐ Specialization of the hospital for the specific type of emergency
- ☐ Recommendation (of the driver, police, neighbor or bystander)
- ☐ Patient preference (most known to patient)
- ☐ Attendant's preference (most known to attendant)
- ☐ Sudden decision
- ☐ Others (Specify): ___________________________________

41. While accessing hospitals, which matter do you think need improvement the most according to your opinion?

- ☐ Better integration of ambulance to 999 ☐ Ambulance dispatch time
- ☐ Quality of ambulances ☐ Affordability of ambulances
- ☐ Emergency response time ☐ Integration of ambulances with hospitals
- ☐ Others (Specify)________________________

50. Which type of hospital do you prefer in general?

- ☐ Government ☐ Private
- ☐ Hospitals with medical colleges
- ☐ Specialized for specific purpose
- ☐ Others (Specify)_____________

51. What do you think is the main advantage of Government hospitals?

- ☐ Cost ☐ Easily accessible ☐ Availability in close proximity
- ☐ Qualified doctors ☐ Well-equipped
- ☐ Others (Specify)_________________

52. What do you think is the main disadvantage of Government hospitals?

- ☐ Slow to respond ☐ Over-crowded ☐ Negligence
- ☐ Delayed test results ☐ Service ☐ Under staffing
- ☐ Doctors' unavailability at a vital time ☐ Others (Specify)_____________

53. What do you think is the main advantage of Private hospitals?

- ☐ Rapid response ☐ Service ☐ Availability of doctors at vital time
- ☐ Qualified doctors ☐ Well-equipped ☐ Availability in close proximity

☐ Priority given to patients ☐ Presence of dedicated emergency vehicles
☐ Others (Specify)________________

54. What do you think is the main disadvantage of Private hospitals?
☐ Cost ☐ Distance ☐ Lack of equipment ☐ Service
☐ Others (Specify)______________

55. What do you think is the most significant factor in choosing the hospital?
☐ Cost ☐ Rapid response ☐ Service ☐ Equipment
☐Staffing ☐ Distance ☐ Situation ☐ Other (Specify)_____

56. If there were no constraints (expense/availability/service) where would you take the patient?
☐ Public Hospital ☐ Private hospital ☐ Others (Specify)_________________

57. In hospitals which sector in your opinion needs improvement the most?
☐ Affordability ☐ Equipment ☐ Qualified doctors ☐ Proper staffing ☐ Faster emergency response ☐ Faster test results ☐ Service
☐ Ambulance attachment ☐ Increasing number of hospitals
☐ Control overcrowding ☐ Resource allocation
☐ Other (Specify)____________________

58. How satisfied are you with the existing Emergency Response Facility?
☐ Very satisfied ☐ Satisfied ☐ Neutral ☐ Unsatisfied ☐ Very unsatisfied

59. What is the condition of the patient?
☐ Brought dead ☐ Died at the hospital after treatment ☐ Undergoing treatment
☐ Discharged ☐ Others (Specify) _______________

If the patient died at the hospital after treatment,

i. Did he/she die because of the emergency to which he/she was admitted??
☐ Yes ☐ No
ii. After how many days of treatment did he/she die?

If the patient was discharged,

i. The patient was discharged in which condition?
☐ Handicapped/ Permanently damaged
☐ Temporarily damaged
☐ Discharged immediately after minor treatment
☐ Others (Specify)__________