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OPTIMIZING THE SPATIAL LOCATION FOR EMS VEHICLES: A CASE IN DELHI- NCR REGION

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ABSTRACT
The objective of this chapter is to improve and optimize the Emergency medical services (EMS) system in Delhi. This includes minimising the response time through ambulance reallocation. As per the call data sheet the demands within various regions of Delhi explain mixed range of response time from base location to the demand location ranging from 10 minutes to 50 minutes. As per the data analysis, demand calls have been segregated according to 11 sub-regions within Delhi. Average response time is calculated depending on the priority of the emergency. A relationship between the current demand and base locations is created. This relationship is used to determine the optimized base stations which is done using Weighted mean algorithm.
Keywords: Ambulances, CATS, allocation, relocation

INTRODUCTION
The primary objective of Emergency medical services (EMS) is to offer the critical medical intervention and timely transportation to the hospital for patients unable to reach medical centre. In EMS, the system receives requests for ambulances via an emergency toll free telephone number which is 102 in India. The demand is analysed depending on the severity or priority level of the emergency and the emergency vehicles are dispatched accordingly to the scene. When not being assigned to a case the ambulance and it screw waits at a strategic location called the home station to better match the anticipated demand. Once the assignment is completed, the ambulance gets back to its base station.
The increasing number of emergency medical calls resulted in a rising demand of more efficient EMS systems. Urgent symptoms such as heart attack, stroke, bleeding and trauma that immediately require major medical care could deteriorate into death in a very short period. Therefore, well quality EMS is crucial and EMS response time is critical to such life-saving routines. The objective if the chapter to reduce that response time by strategic relocation of ambulances across the different regions with varying demands.

BACKGROUND
Types of Emergency Medical Service
EMS classification varies from country to country. According to the level of severity, EMS vehicles are primarily divided in two categories:

- **Basic Life Support (BLS) services**
- **Advanced life support (ALS) services**

Basic life support (BLS) vehicles are fitted with the only the basic and essential equipment's along the staff trained with administering rudimentary medical emergency skills.
Advanced Life Support (ALS) on the other hand are ambulances are staffed and equipped to provide a higher level of care in an emergency. It includes advanced life support equipment's along with paramedics- EMTs who are more skilled and can administer drugs and other emergency treatments to

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stabilize the patient. An important point of two-tiered systems is that ALS and BLS vehicles have different standards of response time.

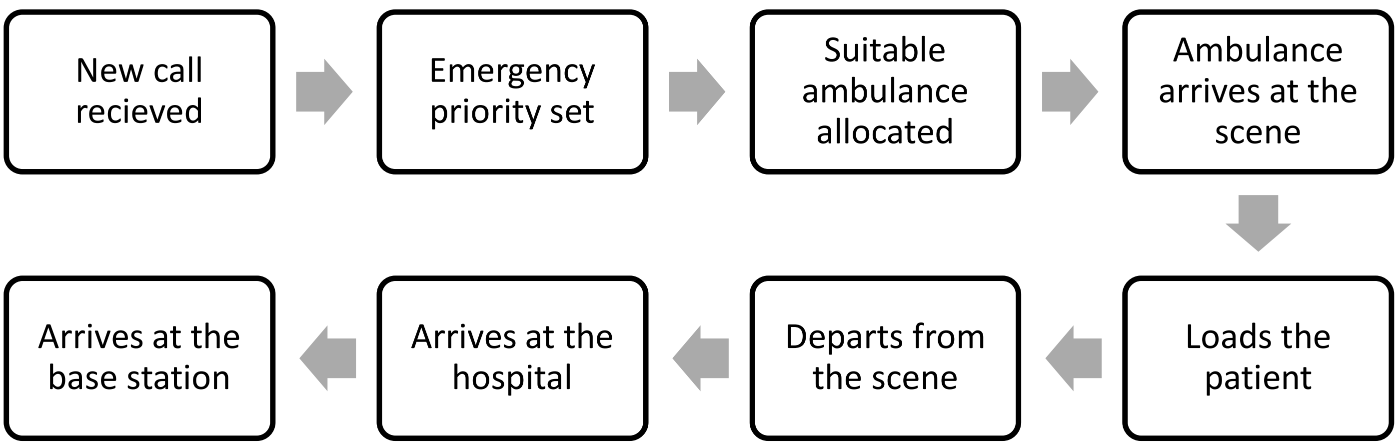
Working of EMS System

When an emergency takes place, call is made to EMS centre. A dispatcher records its location, address, type of emergency, and determines its priority level (1, 2, 3 and 4 for example; 1 is the most urgent priority) and then selects type of EMS (ALS or BLS) depending on the type of emergency. Calls of the same priority are handled in a first come first served basis. In case of multiple coverage, if a higher priority call arises within the same coverage area of the base station, the existing call is kept on hold and higher priority call is served first. Meanwhile, alternate BLS is served at the existing demand location.

At the scene of emergency, ALS or BLS team provides acute medical care such as first aid, providing oxygen if necessary to the patient at the demand location. Later EMS loads the patient in the ambulance and arrives at the nearest hospital. The EMS teams remain there for some time until they deliver the patient.

Once the call is served, EMS becomes available and returns to its base station to serve further demand calls.

Figure 1. Flow Chart of an EMS System



Works in the field of EMS

Various countries have organised EMS system in different ways. There have been studies in the field of EMS prediction using Support Vector Machining. (Nasiri et al. 2009, Chiu et al. 2010, Mehta et al.2007). Majorly studies adopted the classification model.

Albert Y. Chen and Tsung-Yu Lu et al 2014 focused on potential of SVM regression capabilities and additionally integrating GIS for visualization of forecast results.

GIS is incorporated in demand forecasting to understand the distribution of the data, which enabled examination of the existing spatial allocation of medical resources (Lerner et al. 1999; Warden. 2007; Ong et al. 2008). Patio et al. (1998) summarized the advantages and disadvantages of the ANN and suggested the suitable situations, such as large data sets, the multivariate time series forecasting problems.

ANN is also been applied to various EMS research area. Its ability to generalise and model nonlinear relationships and multilayer feed forward neural network (MFNN) are known as a general way at

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building relationships between inputs and known outputs (Smith & Gupta, 2000). Setzler et al. (2009) applied ANN to predict EMS call volume. They suggested that ANN do not require assumption of the properties of data, and it can model complex data pattern which are difficult to observe or describe.

The scope of the problem involves static relocations as dynamic ones occur at unknown time intervals causing a rise in the fuel cost thus resulting in a financial surge. ADP known as automatic Data processing is used as suggested by Dr. Verena Schmid (2007). Reference from analysis of AVL components of the GPS system for mapping is taken as suggested by Čedomir et al (2014).

AMBULANCE ALLOCATION RELOCATION PROBLEM

EMS in India

Currently, India does not have a fully functioning centralized body which provides guidelines for training and operation of Emergency Medical Services (EMS). EMS in India is scattered and is not accessible throughout the country. In Delhi, EMS is managed by Centralised Accident and Trauma Services (CATS).

Medical emergencies such as fracture, fever, and syncope are responded to by BLS ambulances; emergencies such as cardiac arrest, seizures, snake bite, unconsciousness, burns, and pregnancy-related emergencies are usually responded by ALS ambulance.

The initial step of simulations is the representation of the locations. Appropriately sized regions were selected based on location of the calls. They were 11 districts of the city – North, Central, East, West, South, New Delhi, North East, North West, Shahadra, South West and South East with data of pickup points and node positions.

METHODOLOGY

Data Extraction

The data required for the project was taken from the Centralised Accident & Trauma Services (CATS) authority under the Delhi government for EMS call data for December 2017.

The data received included the following:

1. Reference ID: A unique id tied to each call.
2. Date and Time of the Call: Time Stamp of the Event
3. Call sign of ambulance: Sign of Ambulance that has responded.
4. Vehicle ID.
5. Ambulance Response Time: Time taken by ambulance to reach the patient from the start of all.
6. Operator Response Time: Time taken by operator to respond and dispatch an ambulance.
7. Patient Handover Time: Time taken by ambulance to handover the patient to hospital after contacting the patient.
8. Address: The exact address given by the caller and the region assigned according the call origins.
9. Type of emergency: Emergency, High, Medium, low

The data was further processed and analysed for getting optimized results.

Data Processing

The first requirement was to get call date, time, response time of ambulance and region from where call originates.

After initial pre-processing the following is highlighted

1. Total Number of Calls: 25,726
2. Number of High and Emergency priority calls: 8,896

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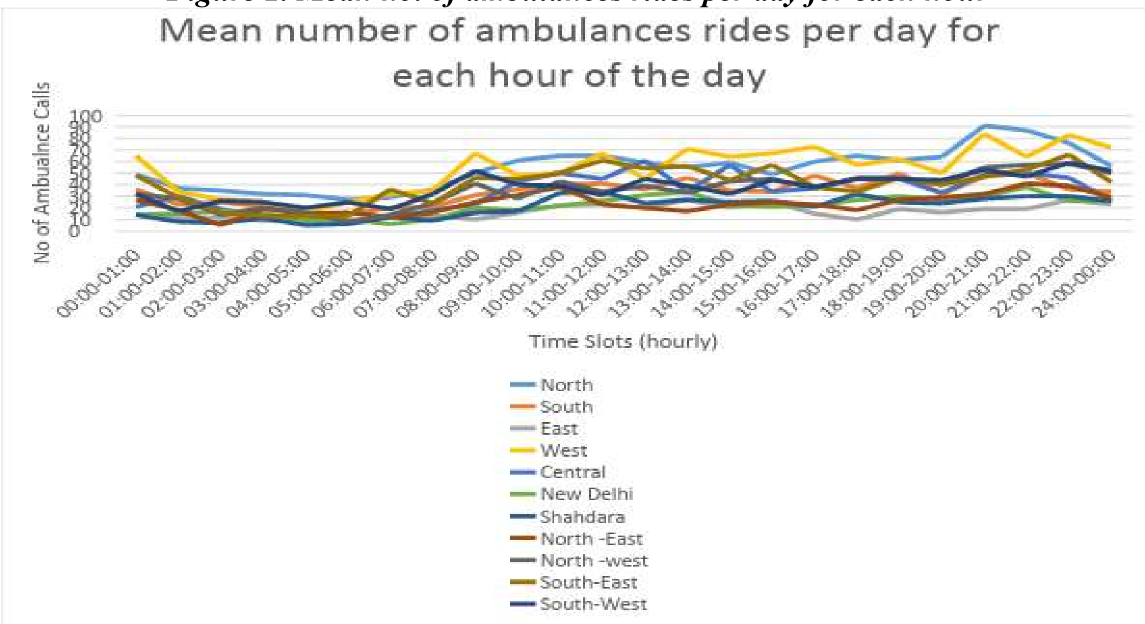
3. Number of Medium priority calls: 13,626
4. Number of low priority calls: 3,207

Figure 1 demonstrates the average number of ambulance required per day. Number of rides per day for each hour of one region correlates to all other regions. We observe that there is a peak between 7-10 am in the morning and similarly from 7pm in the evening.

Figure 2. Mean no. of ambulances rides per day for each hour



Allocation Of Ambulances

The initial step of simulations is the representation of the locations. Appropriately sized regions were selected based on location of the calls. They were 11 districts of the city – North, Central, East, West, South, New Delhi, North East, North West, Shahadra, South West and South East with data of pickup points and node positions as shown in Table 1.

Table 1. Region wise ambulance allocation

City Districts	Number of Ambulances allotted
North Delhi	32
South Delhi	28
East Delhi	18
West Delhi	28
Central Delhi	23
New Delhi	23
Shahdara	16
North –East	15
North –west	33

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South-East	28
South-West	26

Data was processed by finding the node positions in all 11 regions using geo spatial analysis. These node positions were found by finding the accident-prone location points with the help of the patient pickup address and the number of calls received for the December month. Further, the coordinate positions i.e. Latitude and longitude position for the nodes of every region was obtained.

Mathematical Model

Ambulance Relocation Problem

To obtain the mathematical model, following are the assumption taken to get accurate results:

1) Only High and Emergency type of calls were considered in the model. Low and medium type of emergencies included sending the ambulance to drop the patient back and hence were neglected.
2) For calculating the mean latitude and longitude base stations, formulae has neglected the curvature of the earth. It is considered flat.
3) The model is considered to be using static ambulances. Dynamic ambulances are not considered.
4) Location points covered by a particular base station's ambulance will operate with one district only.
5) Number of ambulances at the base stations are considered to be sufficient to serve the calls of their location points

The mathematical model plans to distribute the ambulances optimally amongst all 11 regions. The number of regions is denoted by Z. Each region consists of location of demand (dz, z∈Z) which represents accident prone areas. xd and yd are the latitude and longitude coordinates of the demand location respectively. The set of optimised location of the base stations will have same subset as that of demand location I (I⊂Z) is denoted by bi, (i∈I). The resultant solution will be expressed in the form of coordinates as Xb and Yb (latitude and longitude respectively), which can be later plotted on the map.
The model uses weighted mean algorithm to solve the ambulance reallocation problem. The objective function minimizes the total weighted response time. The call volume of demand (cz) at a demand point is considered as weight to the response time. The coordinates of the base station were calculated by using the following algorithm:

$$X_b = \frac{\sum_{i=1}^{n} c_d x_d}{\sum_{i=1}^{n} c_d} \qquad (1.1)$$

$$Y_b = \frac{\sum_{i=1}^{n} c_d y_d}{\sum_{i=1}^{n} c_d} \qquad (1.2)$$

Algorithm

Following are the steps used to achieve the mathematical model:
Step 1: Divide the High and Emergency calls according to the regions z∈Z and estimate the size of each set. Sort each set according to the increasing order of the coordinates xd and yd.
Step 2: Divide the sorted calls into small no. groups of to take out precise solution. Each region has 3-5 groups.
Step 3: Multiply each co-ordinate with their corresponding weight or the call volume. Solution to this are denoted as x' and y'
Step 4: Take the summation of the whole group of x' and y 'and divide it with the number of call volume

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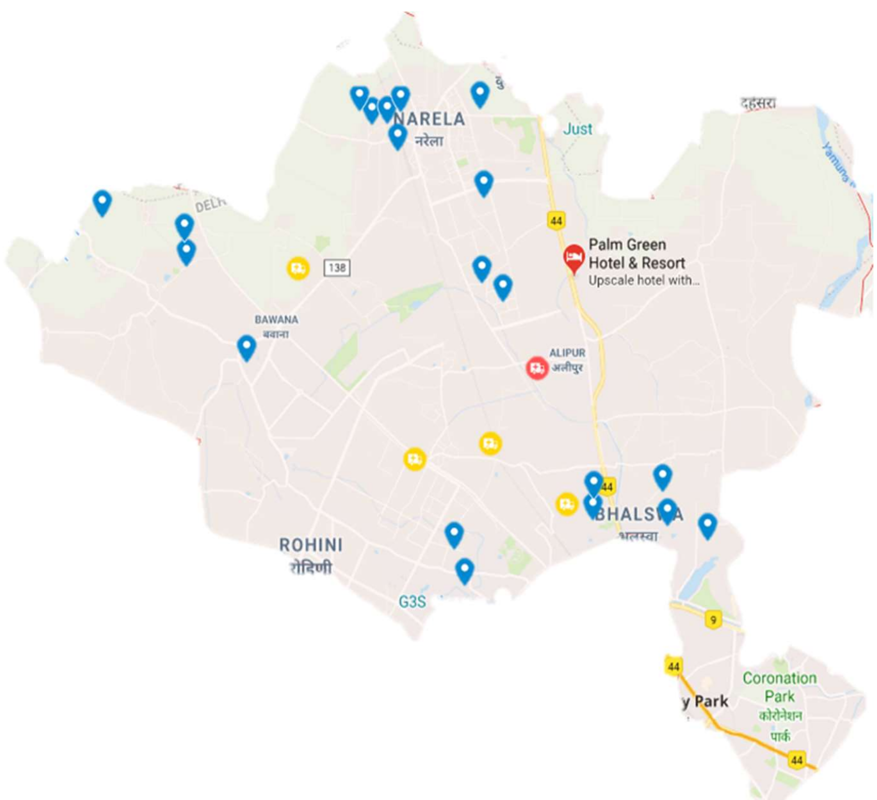
of that subsequent group.
Step 5: Plot the coordinates of the base station (Xb and Yb) obtained on the map and determine their location.
Step 6: The response time of the new optimised base stations are calculated with the location points

RESULTS

The mathematical model and algorithm were utilised for ambulance relocation in New Delhi. The base station coordinate location is obtained for each region. There were 9 Low priority stations serving almost 150 calls from the demand locations,20 Medium priority stations serving 150-250 calls, and 11 High priority station serving more than 250 calls. CATS contains a total of 153 ambulances which was divided among the stations depending on the priority. Low priority stations have 2 ambulances, medium ones have 4 ambulances while the high priority stations have 5 ambulances. Figure 2. shows deployment of ambulances in Delhi. For rural area, an EMS can reach within the time limit of 20 minutes or more. Urban area, on the other hand, has small time limits 10-12 min. According to the simulation, the average response time for high emergencies comes out to be 15 minutes. Since the mathematical model optimises the response time weighted by the ambulance demand, ambulances will be located nearby area with high call volume.

Figure 3: Ambulance deployment in 11 regions of Delhi

1. *North Delhi*



2. *South Delhi*

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3. *East Delhi*

4. *West Delhi*

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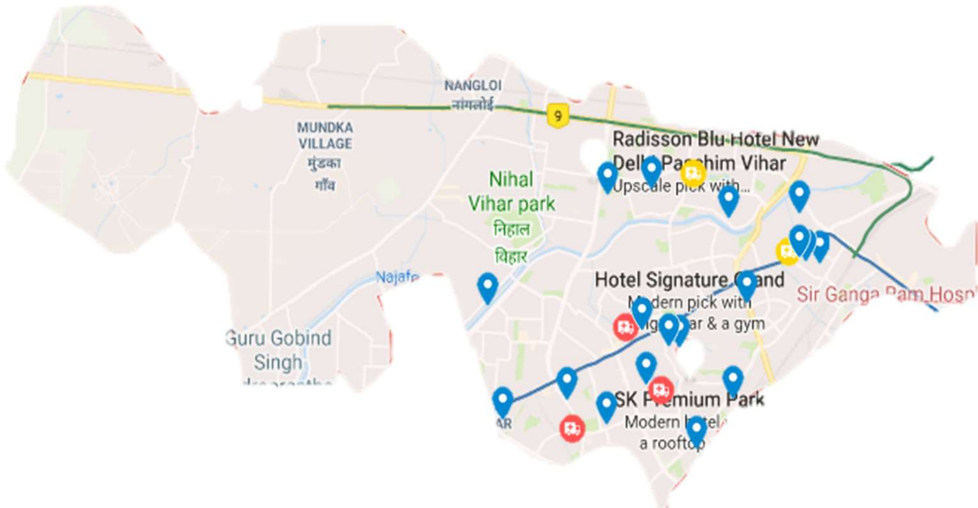

5. *Central Delhi*

6. *Shahdara*

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7. *North East*

8. *North West*

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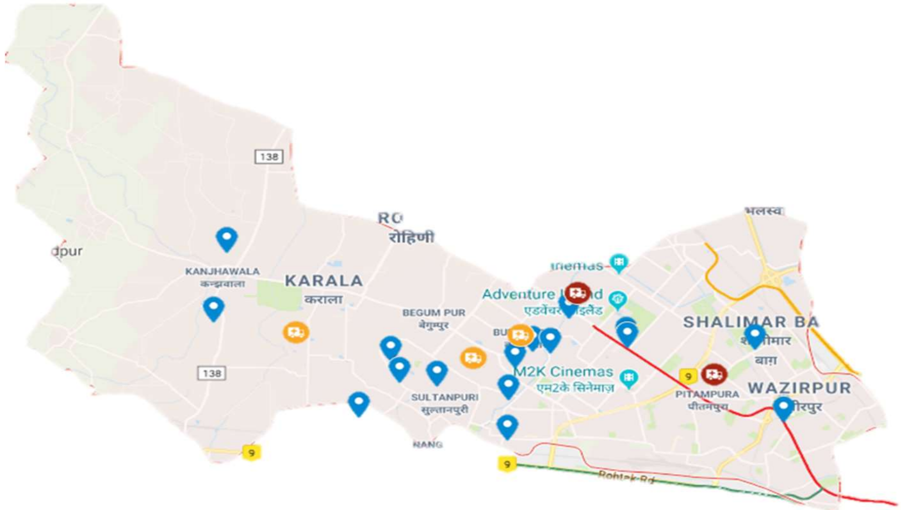
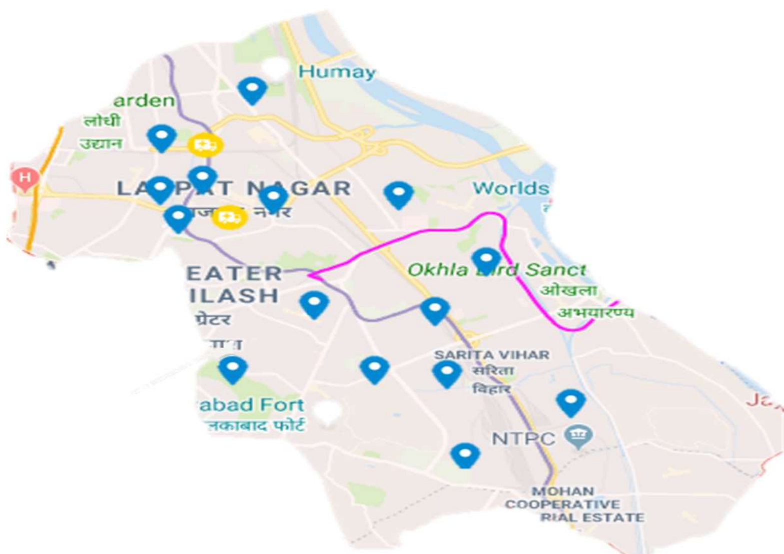


9. South East



10. South West

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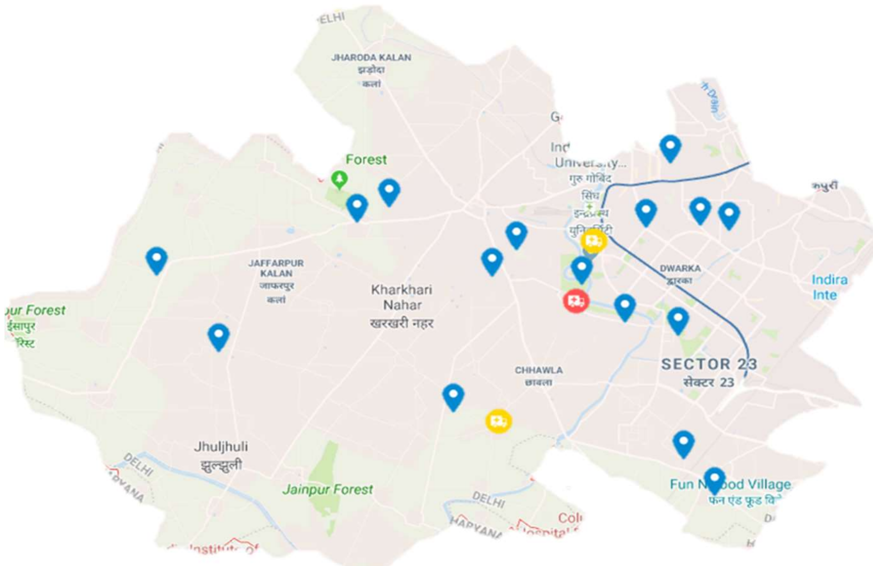
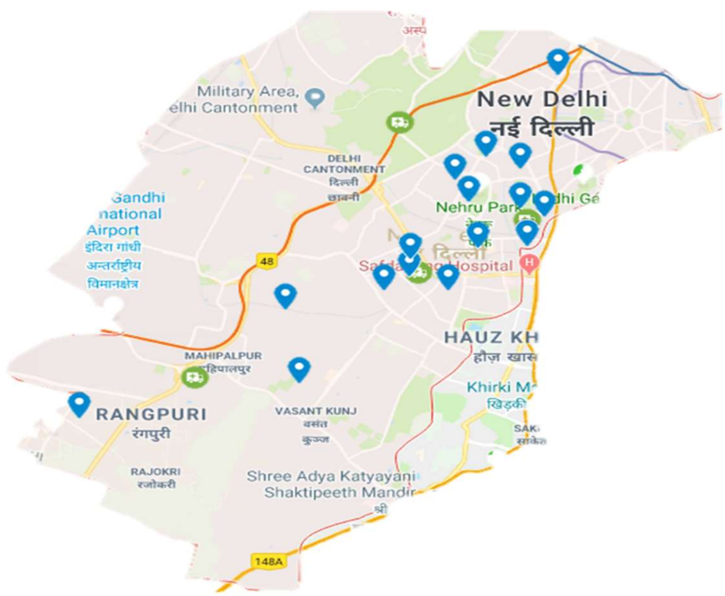


11. New Delhi



CONCLUSION

The optimized base stations were calculated for 11 districts that Delhi was divided in using weighted mean method of latitude and longitude coordinates of locations. Further, response time was calculated for average response time to be 15 minutes. Ambulances were optimally distributed among all the base stations.

KEY TERMS AND DEFINITIONS

1. Demand Location: It is the location from where calls are received to the system to report incidents. It can be a patient's address or a site of an accident. The calls can be varied depending on the priority of emergencies.

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2. Ambulance Station or Base Station: It is the location where the ambulances are deployed. Each ambulance station is assigned within regions around Delhi depending on the demand locations.

3. EMS Response Time: It signifies the time taken from when a demand call is received at the region's base station, to when the ambulance arrives at the patient's address or the demand location

4. Total Service Time: It is the response time plus the time taken by ambulance to reach back its base station.

5. Coverage: It is a performance metric of an area which is defined as the probability that EMS response time in an area would be below a standard set time.

6. Dispatchers: People who are responsible for receiving calls, obtaining priority of the calls, making dispatch and relocation decisions, and recording all the details of cases.

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