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APPLICATION OF GEOSPATIAL TECHNOLOGY TO FREEWAY MANAGEMENT SYSTEM

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ABSTRACT

Corresponding with the increase in development in Freeway constructions in India, it requires intensifying standard and highly effective Freeway management system. The study entailed review of literature outlining the available lane management techniques (LMT) for freeways to apply these techniques to manage the lane traffic of newly constructed Freeways. Also, literature recommends the speed criteria's depends on the basic principles of speed limit includes safety, economic and constant for the vehicles on the freeways to avoid accidents on the freeways. This study aims to study various operations of Freeway Management System (FMS) such as Lane use control, Ramp Control, Incident management etc. An application strategy of Geographic Information System (GIS) in Freeway Management System is proposed specially for Incident management on the freeways. This strategy includes collection of the previous accidental data on the freeway, analysis of the data according to various parameters such as type of vehicle incurred in the accident, speed of that vehicle at the time of accident, cause of accident; according to above information defining the black spots on the freeways, providing some accident prevention measures on that spots, indicating the nearest available hospitals and closest path to that hospital from the accident spot using Gram++ software according to available time, traffic and road conditions. It fully utilizes the advantage of computer and GIS technology to modernize the management of freeway.

Keywords : ArcGIS, Basic principle, Gram++, Freeway, Lane management, System.

I. INTRODUCTION

According to, The Highway Capacity Manual defines a freeway as a divided highway with full control of access and two lanes use for two opposite directional traffic which are continuously separated by raised barrier or by planting trees which provides uninterrupted flow of traffic. Freeways were generally planned and designed to provide continuous, free flow to vehicles, high speed functioning of vehicular traffic on roads. For control of speed of vehicle on freeway, type of pavement to be used for construction of freeway, safety precautions of public as well as vehicle on freeways it is required to maintain a good management system for freeway.

Freeway management requires maintaining balance between goals and objectives of freeways. Freeway Management system (FMS) is defined as set of components which are come together to facilitate the overall objectives or goals of the management system. Freeway management system consists of management about traffic on freeways, freeway infrastructure safety and emergency management, ramp management and control, incident management, performance management, accident prevention.

Now, It is requires to build highly efficient and standard freeway management system so that application scheme of Geographic Information System (GIS) In Freeway Management System (FMS) is proposed which contains dynamic segmental technology. GIS offers evidence of assistant decision-making in routine management business. Hence the purpose of application of GIS in Freeway Management system is to expands and strengthen efficiency of management. This FMS realized the integration management of spatial data and attribute data.

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II.   VARIOUS OPERATIONS OF FREEWAY MANAGEMENT SYSTEM

Freeway Management System includes all the personnel, operational scenarios and mechanisms. FMS combines all above parameters to control and manage the traffic flow on the freeways more impressively.

Following are the various operations performed by the FMS:
Lane Use Control
The main purpose to control the lane use of freeway is to boost the efficient use of the available existing pavement within right-of-way of the road. Some examples which are used for lane use control includes Large truck restrictions, mainline metering, Temporary shoulder utilization, reversible lane operations.

Ramp Control
For Freeway traffic control the Entrance Ramp Control method is mostly used method. The main objective of this method is to control of vehicles entering freeway so that demand does not exceed the capacity of freeway.

Ramp Metering is the strategy used for ramp control. It limits the rate of the entering traffic to freeway in such a way that the capacity of the freeway does not exceed downstream of on-ramp.

High-Occupancy Vehicle (HOV) Priority Treatment
Next operation of the Freeway Management System is to furnish preferential treatment to Carpools, Vanpools, Buses and other HOV on the Freeway to develop travel time asset for the vehicle occupants and review the number of vehicles on the freeway. These treatments include special lanes, priority access ramp controls for HOV vehicles.

Incident Management
Out of all the Freeway Management operations, incident management gives the considerable potential operational and safety advantage to freeway motorists. Incident Management system needs the operation and pre-planned use of human and technological resources to use the freeway to full capacity quickly and effectively after an accident occurs. It includes other freeway management functions such as the following:
- Surveillance.
- Control center operation.
- Freeway service patrols.

Freeway Mainline Control
Freeway mainline control meant for the regulation, warning, and instruction to the freeway traffic in order to maintain more uniform and more stable traffic flow on the freeways to reduce the potential of rear-end collisions, if congestion develops, facilitate accident management and recovery from congestion, divert freeway traffic to alternate routes to utilize corridor capacity, and change the directional capacity of the freeway by use of reversible lanes.

III.   LANE MANAGEMENT TECHNIQUES (LMT) FOR MULTILANE FREEWAYS

Reference [4], presents the various lane management techniques in order to control traffic flow on freeways by means of restricting lane use by vehicle type and limiting speed by lane by vehicle type. Based on the practical experience on eight-lane freeway and the literature reviews five lane management techniques are established. These are as follows:

Limit speed by lane
In this method speed of the various types of vehicles on every lane of freeways is restricted within both maximum and minimum in such a way that vehicles can't exceed maximum speed and can't be less than the minimum.
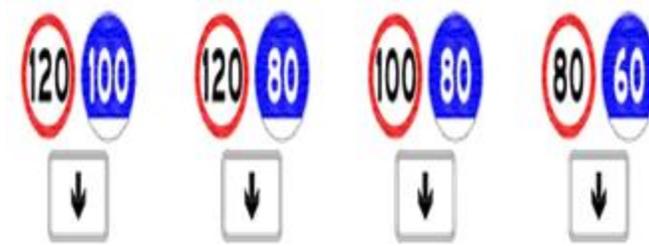
Fig. 1. Limit speed by Lane [4]

Fig. 2. Limit speed by Vehicle Type [4]

Fig.1.shows that Maximum speed for first lane from left is 120 km/h and minimum speed is 100 km/h; same for second lane Maximum and minimum speed are 120 km/h and 80 km/h and so on.

Limit speed by vehicle type
In this technique, various speeds are given to different types of vehicles. Vehicles are classified according to their size, weighing capacity, their weight when moving on freeways.

As shown in Fig.2, in this method, maximum speed for small vehicles such as car is 120 km/h and minimum speed is 80 km/h and for large vehicles such as trucks, containers, trailers maximum speed is 100 km/h and minimum speed is 60 km/h.

Limit speed both by lane and vehicle type
In this method first two lanes from left are set for small vehicles and their maximum and minimum speeds are different from other lanes and other vehicles. Next two lanes are set for large vehicles and their speeds are also different on these lanes.

According to Fig.3 First and second lanes are for small vehicles and their maximum and minimum speeds are 120 km/h and 80 km/hr respectively and same for the next two lanes which
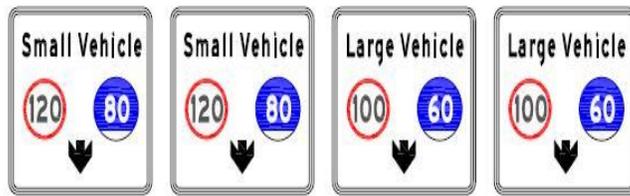
Fig.3. Limit speed both by lane and vehicle type [4]
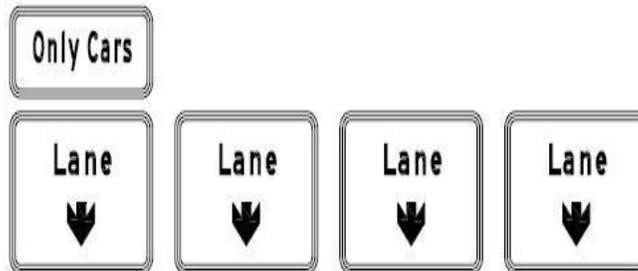
Fig. 4. Lane only for cars [4]

are set for large vehicles with maximum speed 100 km/hr and minimum speed 60 km/hr Small and large vehicles are discriminated by the size and speed of vehicles, according to which the lane can be restricted in different maximum and minimum speed limits.

Car only Lanes
In this method, the first lane of every freeway from the left is used only for small cars and it is marked "Only Cars" and the other lanes have no limits. Fig.4 above shows 'Car only lanes' method in which first lane from left is available only for carpools.

Truck-restricted lanes
In this method, first lane from the left is used only for small passenger cars and the second lane for the bus. Trucks and big containers are restricted only in the third and fourth lane and they are not allowed in first two lanes, but buses are also allowed in truck restricted lanes. With respect to different vehicle types, different maximum and minimum speed limits are set for different lanes.

From Fig.5, the first lane have the maximum speed is 120 km and the minimum speed is 100 km which is for only cars; the second lane have the maximum speed is 120 km and the minimum speed of 80 km which is for only buses; for the third and fourth lane the maximum speed of 100 km and the minimum speed of 60 km set on which trucks and buses are allowed.
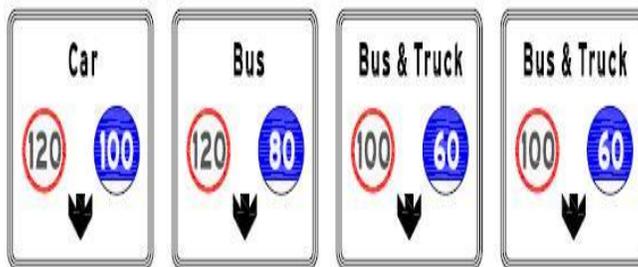
Fig.5. Truck-restricted lanes [4]

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IV.   APPLICATION OF GEOSPATIAL TECHNOLOGY TO FMS

This paper mainly depends on the application of Geospatial technology to Freeway Management System. Specifically, GIS technology is applied in the Incident Management Operation out of the various operations described in above paragraphs of FMS. Incident Management includes providing the Ambulance facility at the accident point as early as possible in minimum time after the incident using the Geospatial Technology. To carry out this work Gram++ software is used. Using an eight-lane freeway in Mumbai City of Maharashtra i.e. Eastern Freeway we developed incident management model using GIS technology.

Methodology
Methodology used for the Application of Geospatial technology is shown in the format of flow diagram in below Fig.6. It includes Finalization of study area, Database creations, collection of accidental data and their multicriteria analysis using ArcGIS software.
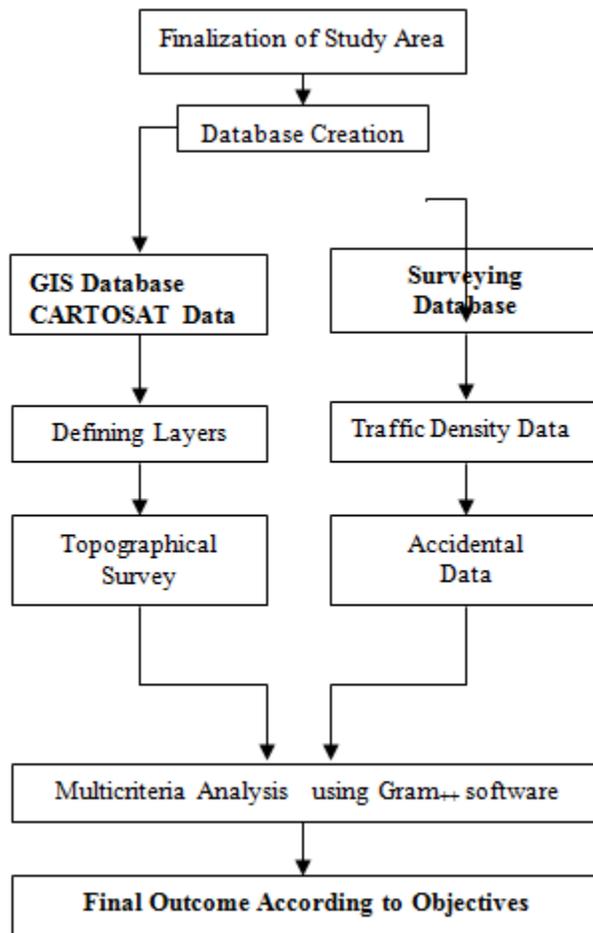
Fig.6 Flow Diagram of Methodology adopted

Study Area
Study area selected to this project work is Eastern Freeway, Mumbai. The authority of MMRDA has grouped to built important 16.9 km long Eastern Freeway project considering the present situation of traffic, Future traffic and other transportation demands. This Freeway is divided into 3 parts:

Part 1: Eastern Freeway - Chhatrapati Shivaji Maharaj Vastu Sangrahalay to Anik Junction. It includes Elevated corridor of 9.29 km long Eastern Freeway 17.2 m wide, 2+2 lanes.
Part 2: Anik-Panjarpol Link Road - It includes 5 bridges, 3 underpasses, 2 tunnels, 1 foot over bridge, 4.3 km, 4+4 lanes.
Part 3: Panjarpol-Ghatkopar Link Road. It includes 3 km long, 17.2 m wide, 2+2 lanes.

Database Creation
There are two databases created for this work namely GIS database and the surveying database. GIS database also known as CATOSAT data. It includes defining various layers and digitizing it in the ArcGIS software. Database such as Road layer included all the roads major roads, minor roads, highways exist in Mumbai Region. Next layer is of Hospital building layer present in the Mumbai city.

Surveying database includes the data that we get from surveying on the Freeways (in case of this project). For the project of Application of Geospatial Technology to Freeway Management System various surveying databases are required such as accidental data for the particular freeways, traffic data. Accidental data includes information about the accident happened on the freeway. This information about accident may contain particular location of the accident, number of deaths if any, reason for happening of that accident. It may be helpful to maintain the speed of the vehicle at that particular accidental spot and to take some precautionary measures to stop such accidents.

Accident data collection
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Accident data collection

Table. no. 1 Past accidental data for Eastern Freeway, Mumbai

Sr. No.	Black spots on EFM	No. of accidents	Date	No. of deaths	Injured Persons	Reason	Type Of Vehicle
1	Panjarpol-end of highway	1	10/10/2017	1	2	High speed of vehicle	Two-wheeler
2	Exit near nawab tank road and dockyard (near Anderson house)	1	6/12/2015	2	1	Driving on wrong side of freeway	Four Wheeler (Audi and

							taxi)
3	Stretch near Chembur	1	7/10/2016	3	2	High speeding and lost control over the vehicle.	SUV
4	Jijamata Nagar Entry	1	7/19/2016	3	2	Head on collision	SUV and Taxi
5	Near Chembur Exit	1	12/27/2017	3	0	Slippery road	Four Wheeler
6	Sewri exit	1	11/5/2016	3	2	Lost control over vehicle	Four Wheeler
7	Near Wadala (pole 264) on the southbound lane towards Chembur	1	8/25/2016	0	3	Lost control over vehicle	Four Wheeler

Table. no. 2 Name of Hospitals in the Mumbai city & Mumbai sub-urban areas and their Information(Sample)

Sr. no.	Name of Hospital	Latitude, Longitude	Time to Travel (min.)	Distance from black spot (km.)	Ambulance Facility	Nature	Phone No.	Emergency
1	Holy Spirit Hospital, Guru Gobind Singh Marg, Takshila, K/E Ward, Zone 3, Mumbai, Greater Bombay, Mumbai Suburban, Maharashtra, 400093, India	19.1295546, 72.8657412	60	32.5	YES	PRIVATE	022-28248500/1 /2 /3 /4	YES

Table no.1 shows the past accident data for the Eastern Freeway, Mumbai. It shows information regarding number of accidents happened on that particular point, date of that accident, number of deaths in that accident, number of injured persons, reasons for the accident and the type of vehicle. This data helps to locate the black spots on the freeway.

There are 7 black spots found on the Eastern Freeway, Mumbai. These are Panjarpol-end of highway, Exit near nawab tank road and dockyard (near Anderson house), Stretch near Chembur, Jijamata Nagar Entry, Near Chembur Exit, Sewri exit and Near Wadala (pole 264) on the south bound lane towards Chembur.

Hospital Data
Table no.2 shows the sample of data collected with respect to available 55 hospitals in the Mumbai city and Mumbai sub-urban areas. The data includes the hospital name, their address, the location co-ordinates of the particular hospital in the form of Latitude and Longitude, time of travel from Black spot to the hospital, Distance of that

Fig.7 Image shows preparation of database in Microsoft access database

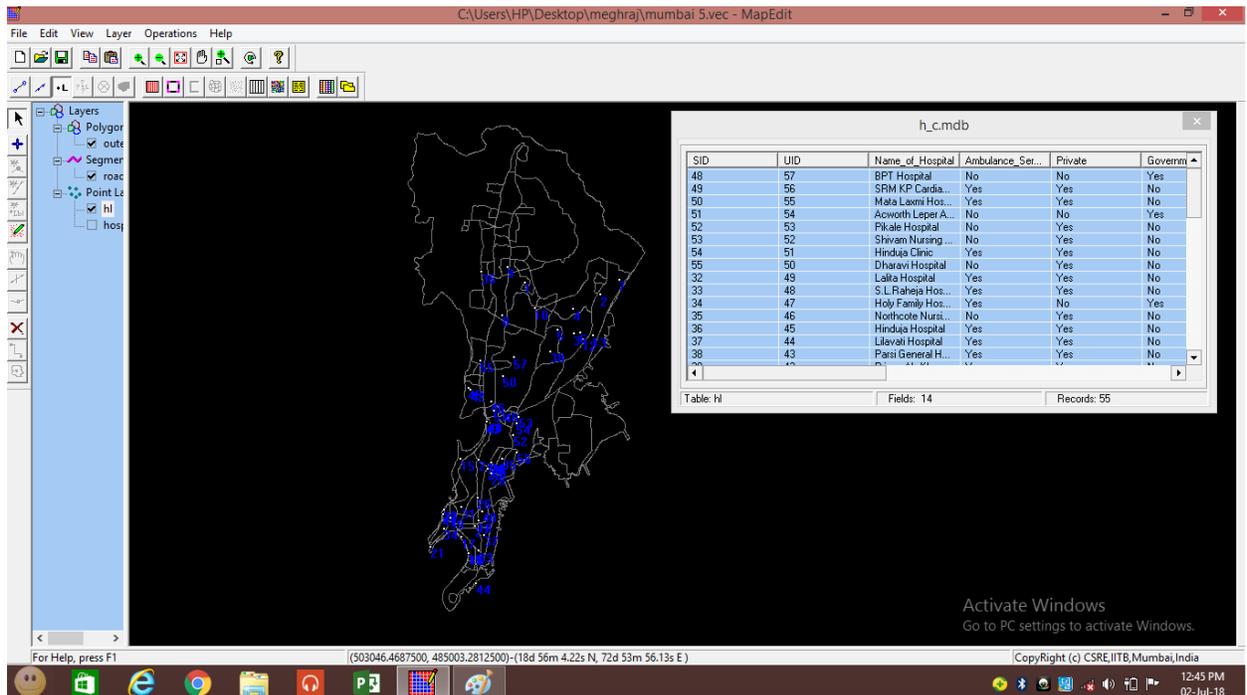*Fig.8 Image shows digitized Mumbai city map with boundary, roads, hospital locations and their information table.*

hospital from black spot, ambulance facility, Nature of the hospital (Government or Private), Contact number, Timings etc. The data of the hospital required for the database creation is added in MS access 2007 to create MS access database file which is required to run queries in Gram++.

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Fig.7 above shows the database created in MS access software for black spot no. 2.

Find the Hospital from the point of accident on freeway according to various parameters
The Vector analysis tool of Gram++ allows us to make the Database required to locate the closest hospital according to the various parameters as shown in the Table no. 2 such as travel time, ambulance service etc.

To add field data to table in database MS Access is used. The database file of Mumbai city map is used in vector GIS. Fig.8 shows digitized Mumbai city map with boundary, roads, hospital locations and their information table. The vector GIS contain vector query module, tin module, network module. Vector query module basically used for running query and find out best solution. Vector query is very important to Mumbai city map vector file. By running query find the more alternatives of hospitals and that will helpful for hospital selection process. By this query find out nearby hospitals, time of travel to hospital from black spot in very few time. Also it is used to compare with other hospitals with respect to their nature, facilities available and evaluate of each hospital. Let us see, 1 query about black spot 2.

Query:
Find out the Hospital having Private nature with available ambulance facility, within the area of maximum 20 kilometers from accident spot and having working hours of less than 24 hours.
If Freeway system manager wants to know the information about hospitals having Private nature with available ambulance facility, within the area of maximum 20 kilometers from accident spot and having working hours of less than 24 hours in Mumbai then, he easily get the related information within minutes just by running the query in GIS vector analysis.

Procedure:
- ✓ Open GRAM++ → vector analysis → vector query → open vector file of GIS_Map_Mumbai.
- ✓ Click on tools → open query option → select simple query
- ✓ Then enter the condition of query Fig. 9 i.e. Private= "Yes", Ambulance_Service="Yes", Distance_KM< "20" and Work_hours< "24.
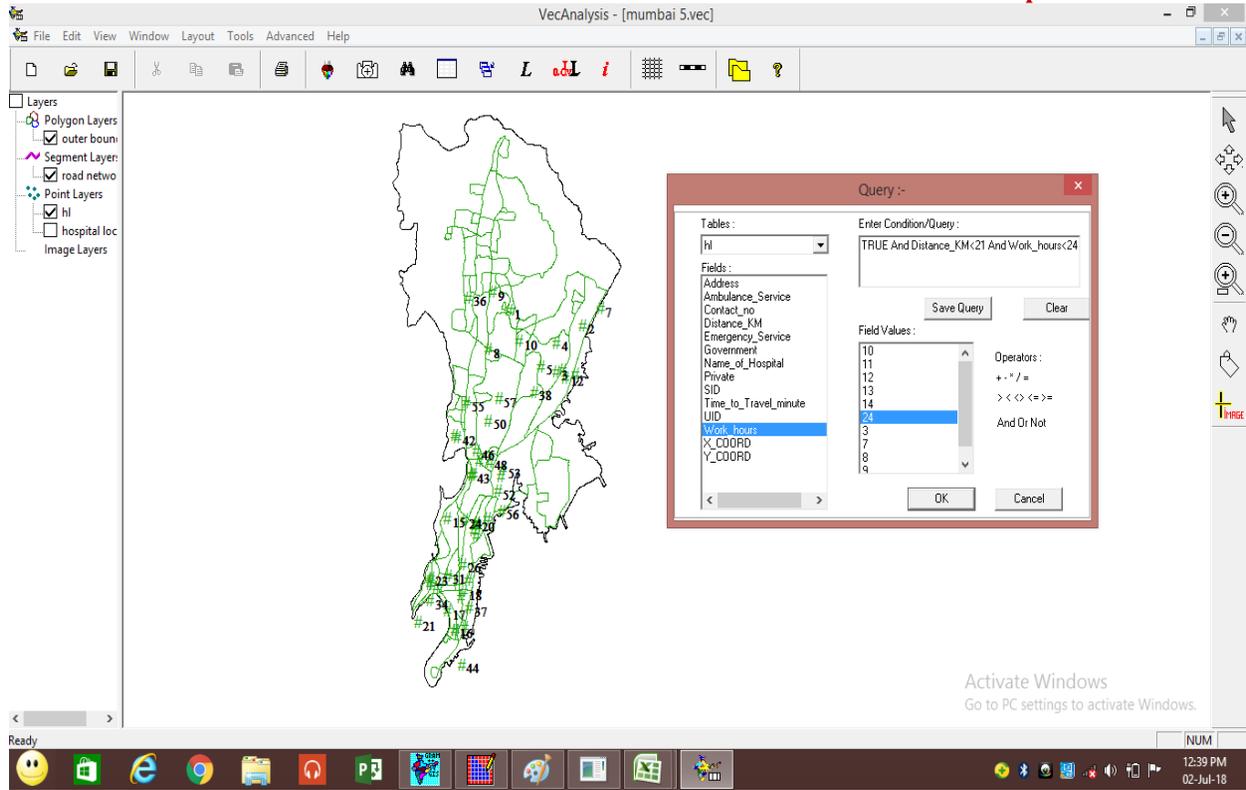- ✓ Then click on OK button to get result of query.
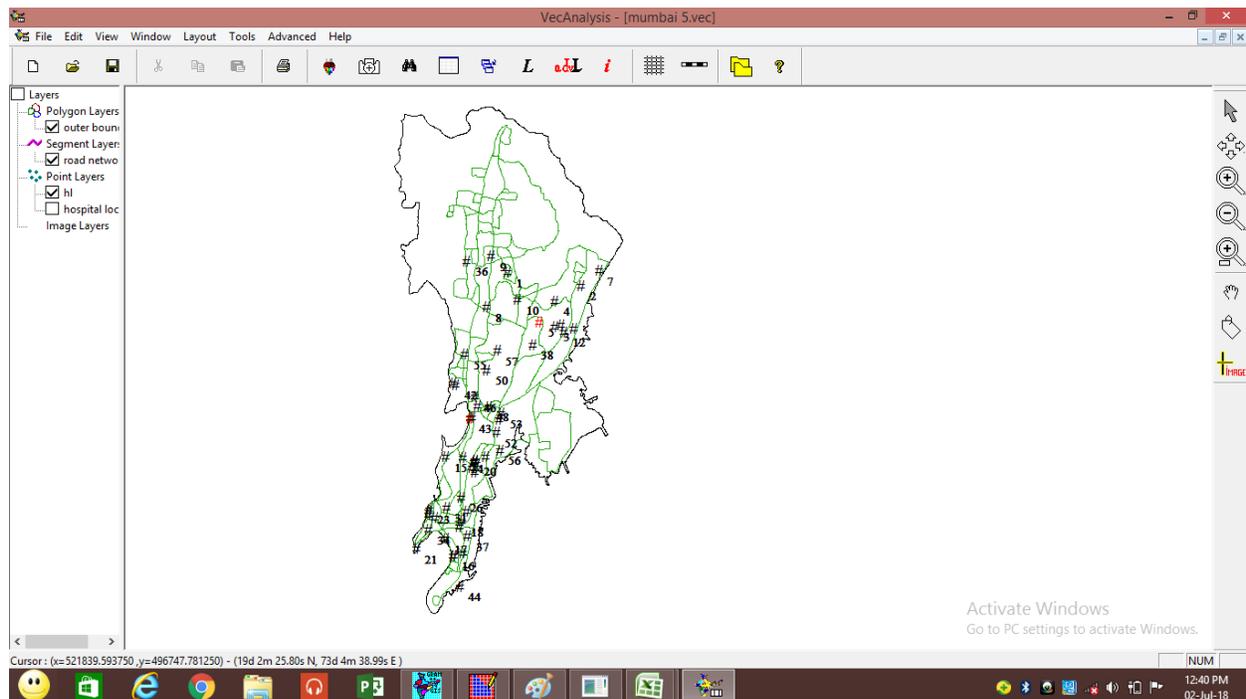
Fig. 9 Image shows condition of query.

Fig. 10 Image shows result i.e. hospital location having query condition.

Result of Query:

Fig. 10 shows the result of this query, is 2 out of 57 hospitals of private nature, available ambulance facility, within the area of maximum 20 kilometers from accident spot and having working hours of less than 24 hours in Mumbai.

Fig. 11 Image shows result of query.

Fig. 11 Shows the all the information about the hospitals having the query criteria.

Utility of Query:

This query helps to give idea about the Hospitals having Private nature with available ambulance facility, within the area of maximum 20 kilometers from accident spot and having working hours of less than 24 hours in Mumbai.

☐   It is very easy to find out best hospital with having Private Nature with available ambulance facility, within the area of maximum 20 kilometers from accident spot and having working hours of less than 24 hours in Mumbai.

☐   And hence it helps to saving the time.

V.   CONCLUSIONS

In this research paper five lane-management techniques are studied namely limit speed by Lane type, by vehicle type, by combination of lane and vehicle type, car only lanes and truck restricted lanes according to status of traffic flow, traffic volume and number of lanes of freeway. The conclusions are summarized as follows:

1.   Lanes of the freeways should be designated build on traffic volume and traffic characteristics
2.   Minimization of the conflict between large and small vehicles can decline lane change frequency and hence reduce average speed difference in multilane.

This paper studies various methods of speed limit of vehicles on the freeways to avoid accidents based on design speed, operation speed environmental factors and road alignments.

The Geospatial technology is applied for the Freeway Management System. This paper introduced the main concepts of the FMS specifically for the Incident Management of FMS. GIS queries play an important in emergency requirements of ambulance. GIS network gives the information of shortest route between accident location and the available hospital according to the requirements.

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