An approach to GIS-based traffic information system using Spatial Oracle

Subhas Barman*, Atanu Sarkar,
Rajat Kamal Roy, Sourav Saha,
Kajal Rajak and Joydeep Sarkar

Department of Computer Science and Engineering,
Jalpaiguri Government Engineering College,
Jalpaiguri, West Bengal, 735101 India
Email: subhas.barman@gmail.com
Email: inmymission@gmail.com
Email: rajatkamal49@gmail.com
Email: souravsaha964@gmail.com
Email: kazal2013razak24@gmail.com
Email: joydeepsarkar5@gmail.com
*Corresponding author

Abstract: Traffic congestion is a threat to the economical, environmental, social and sustainable development of a city. The traffic management has always been an issue of concern for urban areas of a city. Geographic information system (GIS) offers an effective solution to the traffic management of a city and it helps the peoples to find out necessary information regarding traffic, road, location and direction of a destination. General traffic system is limited in data sharing and it is difficult to achieve integration in data processing. In this work, an urban traffic management system based on geographic information system (GIS) is implemented to handle the roads, landmarks, sensitive areas and traffic information for urban traffic police locus. Our work solves various traffic related problems and retrieves the traffic centres that have to be alert in different situations. The detected shortest path is visualized with the connected paths in our approach.

Keywords: geographic information system; GIS; traffic management; connected paths; roads; shortest path; landmarks; Spatial Oracle.

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Biographical notes: Subhas Barman received his BTech degree in Computer Science and Engineering from Kalyani University, West Bengal, India and MTech degree in Information Technology from Indian Institute of Technology, Kharagpur. Currently, he is an Assistant Professor in the Department of Computer Science and Engineering at Jalpaiguri Government Engineering College, Jalpaiguri, West Bengal. His current research includes GIS, data mining and security.

Atanu Sarkar is a student of final semester in BTech in Computer Science and Engineering at Jalpaiguri Govt. Engineering College, West Bengal, India. His current research includes GIS and traffic management.

Rajat Kamal Roy is a student of final semester in BTech in Computer Science and Engineering at Jalpaiguri Govt. Engineering College, West Bengal, India. His current research includes GIS and traffic management.

Sourav Saha is a student of final semester in BTech in Computer Science and Engineering at Jalpaiguri Govt. Engineering College, West Bengal, India. His current research includes GIS and traffic management.

Kajal Rajak is a student of final semester in BTech in Computer Science and Engineering at Jalpaiguri Govt. Engineering College, West Bengal, India. His current research includes GIS and traffic management.

Joydeep Sarkar is a student of final semester in BTech in Computer Science and Engineering at Jalpaiguri Govt. Engineering College, West Bengal, India. His current research includes GIS and traffic management.

1 Introduction

In the advancement of information and communication system (ICT), peoples are using online services for decision making using internet. The availability of smart phone, palmtop, etc. helps people to access internet from any where and any time. In this context, geographical information systems (GIS) are getting more and more attention to provide geographical location of a place. People searches different location-specific information such as position, nearby locations, nearest landmarks and connected paths. A geo-spatial-based information system may provide spatial data as well as non-spatial information also.

Presently, many GIS tools are available to process geographical data. Spatial Oracle is a fundamental tool which can define, store, process and manage the spatial as well as non-spatial data jointly with relational database management system. In Spatial Oracle, layer wise data models are defined and inter-layer interaction-based query processing is also possible efficiently. In Barman et al. (2015), a Spatial Oracle-based map implementation is proposed. Now-a-days, GIS-based data management is being essential in many applications. Spatial data from vehicles tracking devices are collected to monitor public vehicles. Mobile devices are also produces different GPS-based data and these data need to be represented in a GIS map for analysis and better understandability. Even big data analysis and social media-based spatial data analysis also demand some GIS operations for efficient processing of spatial data. In literature, there are many approaches for GIS data management (Lamsal et al., 2013; Barman et al., 2015; Thomas et al., 2017; Zhang et al., 2014).

The GIS-based traffic information systems are also being popular to get traffic, route and landmark related information via web. Even traffic jamming is becoming a serious problem throughout the world. The population, poor infrastructure and worse traffic system are the causes behind traffic jamming. Based on census data, the population of Kolkata City amounted in 4.8 million. The rate of enhancement of population will directly affect the growing risk of growing traffic problems, such as congestion and accidents, which decreases the performance of service of a road network. Therefore, we certainly need a mechanism of traffic management system which will minimise the traffic problems.

With the increasing significance of urban traffic problems, the application of GIS to urban traffic management can greatly improve the operation efficiency of urban traffic system. Urban traffic management system based on GIS has become an important part of traffic management system (TMS). The GIS-based TMS is an open and comprehensive system engaged in control, management and decision-making. It can compute query and display the corresponding results in a map. For performing mutual query between graphics and text information, it has an electronic map system (MapViewer) and a database system (Oracle 11g).

It is such a common news at this time to hear that a particular place has caught fire and the Fire Brigade is late to reach the spot because of the traffic and the crowd. The result is casualties and huge loss of property. We need a decision-making system to help the Fire Brigade to reach the spot via the shortest path and the path with lighter traffic. Moreover, the Fire Brigade team needs the complete information regarding nearest water-bodies from the spot. In this case, GIS-based information system is very useful. The important areas should be brought under CCTV camera surveillance which could aid us in dynamic traffic monitoring. In any medical emergency, peoples need to know the nearest hospitals from their present address and corresponding shortest path to the nearest hospitals is very important to reach the hospital on time.

In this paper, a GIS-based traffic information system is proposed. The Spatial Oracle is used to implement a GIS-based traffic information system of a city. We have applied Oracle 11g to implement the back-end database. MapViewer and map-builder is used to make the visualisation of user's queries.

1.1 Motivation

People want to know the shortest path of his/her target place from his/her current location. Mainly, when a visitor is new to a city, he/she wants to know the location of his/her target place with respect to a well-known landmark. Even, with the live status of traffic update, any traveller may reassigned his/her path to avoid any traffic hazard for some events like, possession of political party, road accident and road blocks by peoples (either political demand or protest of common people). Moreover, people may want to know the road network of a city from his/her home. All the above concerns are the motivation of our work.

The rest of the paper is organised as follows. In Section 2, we discuss the existing work on traffic management systems. In Section 3, we discuss our proposed approach for traffic management system. The implementation and query execution results are presented in Section 4. Finally, the paper concludes in Section 5.

2 Related work

The rapidly increasing vehicle population in India, spurred by the population growth and economic upturn lays a critical burden on traffic management in the metropolitan cities and towns of the country (Lamsal et al., 2013). The cumulative growth of the passenger vehicles segment in India during April 2007–March 2008 was 12.17%. In 2007–2008 alone, 9.6 million motorised vehicles were sold in India. Economy-induced automobile usage is complicated further by the constant in flux of rural population in the urban areas, thus making enormous demands on the transportation infrastructure in an overloaded region. The heterogeneity of economy and the physical limit on how much additional infrastructure a city can hold complicate transport management further. World Bank reports that the economic losses incurred on account of congestion and poor roads alone run as high as $6 billion a year in India (Vanajakshi et al., 2010).

The origin of the formal traffic management system programs dates back to the 1960s with the development of the electronic route guidance system, or ERGS in the USA. The objective of ERGS was to provide drivers with route guidance information based on real-time traffic analysis. The system used special hardware located at various intersections across the road network, on-board 2-way devices in vehicles that would form the hub of communication between the driver and the ERGS system, and a central computer system that processed the information received from the remote systems (Peng et al., 2011).

Recently, vehicle tracking systems (VTS) are used in vehicles to track the vehicle. A VTS receives the location data from tracking devices and visualise the location of vehicles using the location data. The collected data are used to generate a map and a report based on the location data. Thomas et al. (2017) proposed a high-performance cluster-based method to store, process and retrieve dynamic geo-spatial data to track and plot the vehicle locations as clusters to provide an informative view. Therefore, huge amount of geo-spatial data from large numbers of vehicles demand an efficient storage of spatial data. The GIS-based information systems may need a specialised spatial data definition language to define, store, update and manage geo-spatial data. In this context, Spatial Oracle (an extension of Oracle) provides an infrastructure along with relational database management system. Barman et al. (2015) proposed a smart map implementation process using Spatial Oracle. They used layer-based data classification technique to define a data model. Layers of interest are identified and data models are defined. Then, corresponding data extracted from different sources are entered into the spatial database.

In Zhang et al. (2014), an efficient storage method of huge GIS data is proposed. The authors analysed the GIS data features like volume, data types, and complexity of data structures and the impact of the features on data storage and processing. They proposed a method of GIS spatial data storage using NoSQL (not only SQL) database.

Many researches have been done on the traffic management system. At first, the incident management system broadly follows the concept of traffic management system. The aim of this system is to develop and validate an instrument to measure the critical factors that contribute to the efficiency of decision support in critical incident management systems (CIMS). In the other research on incident management system discuss the collection and retrieval of critical data of metropolitan areas. Efficient road traffic incident management (TIM) in metropolitan areas is crucial for the smooth traffic flow and the mobility and safety of community (Kim et al., 2007).

Table 1 Comparison of existing intelligent traffic management systems

Research	*Description*	*Limitation*
Mirchandani and Head (2001)	Controls the signals in real time and operate them automatically according to the demand in traffic using real time hierarchical optimising distributed effective system (RHODES)	If poor signal control is used, the effective capacity, in terms of served load, is reduced and delay increases substantially.
Dotoli et al. (2003)	This model was modified to take into account the traffic scenarios, the different types of vehicles in the area, as well as pedestrians.	It selects offsets to ensure progression for only one direction. It fails to address the determination of offsets to improve progression for both directions of a traffic network.
Queen and Albers (2008)	Use the real time data that is provided by the induction loop in a traffic management system to monitor current traffic flows in a network by using linear multi-regression dynamic model (LMDM) so that traffic can be directed and managed efficiently.	This paper implements the standard dynamic linear multi-regression (DLM) assumption but the distributional assumption is not taken into consideration on LMDM.
Roozemond (1999)	Apply autonomous intelligent agents in urban traffic control and evaluate the performance of the conventional traffic control system.	The particular techniques proposed are experimental and not yet mainstream, especially when proposed for such a large online application.
Hong et al. (2009)	Discuss on traffic images and focused on multi-anticipative car following behaviour, heterogeneity among individuals and relationship between car following behaviour and road geometry.	This system has a very high cost per data unit, and they only analysed vehicle trajectories for 15 min.
Ozkurt and Camci (2009)	They stress upon knowing the traffic density for traffic surveillance systems and use a neural network approach for the same.	Extracting useful information such as traffic density and vehicle types from these camera systems has become a hassle due to the high number of cameras in use. Manual analysis of these camera systems is now inapplicable.
Atkociunas et al. (2005)	Develops a CCTV-camera-based application and utilised image processing and pattern recognition methods and functional capabilities of a system to monitor the road, initiate automated vehicle tracking, measure speed and recognise number plates.	In complex testing the system fails to perform and more detailed modified algorithm could be implemented.
Verroios et al. (2008)	Proposes a fully distributed approach that uses only the computational resources and communication capabilities of vehicles and requires no fixed infrastructure or centralised servers.	They have partitioned road networks into small regions. This one level fragmentation leads to large number of regions and furnish overheads as far as the transport and processing of protocol requisite data is concerned.

Later, emergency management system (EIMS) followed the concept of TMS. During emergencies, decision making is a challenging task which requires immediate and effective action from responders under the pressure of incomplete and erroneous information (Yoon et al., 2008). In that system, identification of appropriate resources and personnel, proper lines of communication and timely accessibility to relevant procedures can optimise the management capacity of the after effects. To achieve emergency response and recovery effectiveness, responders need to be prepared and trained for various emergency situations and decision support systems. To address some of the decision-making problems, a low cost computer-based training prototype with a decision support system tool was developed (Yoon et al., 2008).

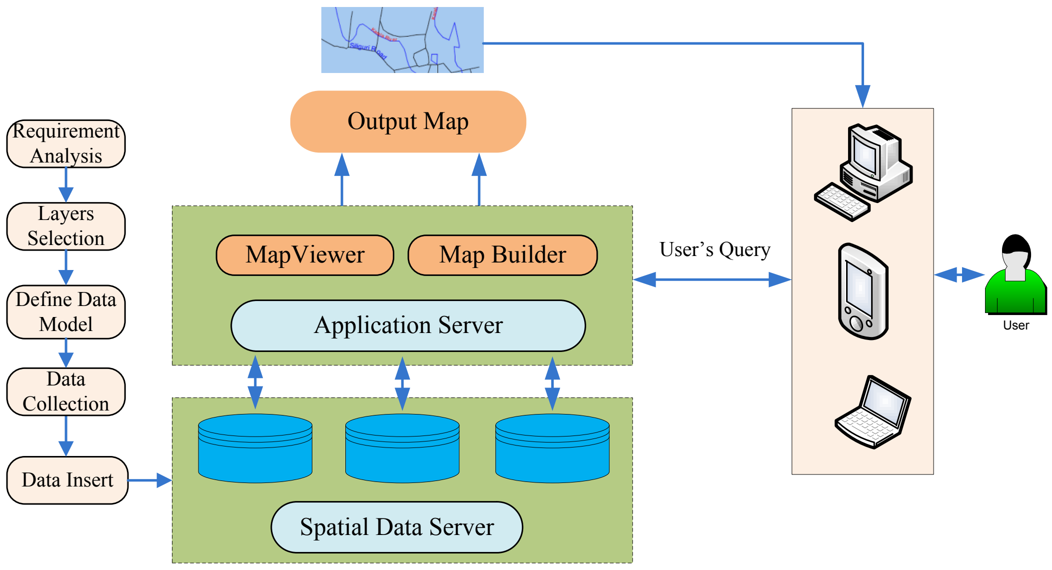
There are more work exist in the area of emergency response management systems and CIMS. Even so, there is in general a lacuna of literature that deals with the issue of measuring the effectiveness of such systems. Clearly, a poor assessment of CIMS efficiency limits the possibility of mitigating future problems. The issue of assessment of CIMS is an understudied area. It is important to point out that this research focused only on the systems component, and not on the people who operate the system or use it. This is being addressed as an area for further research. At the incident site, first responders may encounter unexpected situations which may be beyond the scope of the system. To respond to critical incidents, first responders must be trained. Experts have pointed out that training is essential for effective execution and well-organised pre-planning.

Next, transportation security decision support system for emergency response was developed. Research discussed about the decision support system (DSS) (Yoon et al., 2008) that were designed to assist decision makers with a particular complex problem in a computer-based environment. Initially, a decision support system for emergency response was developed to assess the state of preparation of a transportation agency to respond to emergencies, enable the development of new standard operating procedures and to better train and empower employees in the decision-making process. This research also had some issues regarding optimisation extension, a decision support system might be integrated mathematical models, rules and algorithms in a user-friendly format to minimise incident response time and successful implementation for response to roadway network incidents. The existing works on intelligent traffic management systems are compared in Table 1.

3 Proposed approach

Our work is based on the problem due to the traffic congestion. To address the problem, we need to look for all the data related to urban traffic management. Here, we consider geographical data of a specific city to implement a GIS-based traffic management system. Hence, initial step comprises extraction of spatial data from different sources and storing the spatial data in a structured and relational database. But, before that we need to identify the layers that we are going to concentrate on. After analysing the requirements of the system, all the layers are identified. Basically, the layers accommodate similar type of spatial data within a specific relation. Therefore, we need to decide the database design accordingly. The tables are defined for different layers with all the spatial and non-spatial attributes, properly. The data are extracted from an existing map of the city, so they are taken in co-ordinate form. Then, the insertion of data is carried out to enter the spatial and non-spatial data into the tables. Finally, we design various queries in the Spatial Oracle and process each query on the stored data to obtain the desired results. The output (mode) of the query depends on the query processor and the graphical user interface (GUI). The output of query may be visualised in a map using MapViewer. The overview of our proposed system is given in Figure 1.

Figure 1 Overview of the proposed traffic information system (see online version for colours)



3.1 Different layers of interest

The requirements of the stakeholders are important to understand the area of interest. The requirement analysis results selection of layers in our proposed system. A layer is a collection of similar type geometries described by the same attribute set. For example, a layer in GIS may include any road or river or rail line of any area of a country or can even be any landmark or location. They are defined using a set of attributes, and the attributes can be both spatial and non-spatial (may be a line or a point). The geometries and associated spatial index of a layer are stored in relational database in standard tables. In general, the main layers are roads, administrative building, health centre, educational institute, traffic centres, rail lines and water bodies.

While choosing the layers, it is very important to know the queries of the users. Generally, user may search the path to any place and specially the most convenient path in which there is less traffic or sometime the shortest path. Hence, the road is very important layer, we can find the connected paths from a specific source to a destination. During festive season, traffic jamming and accidental condition, an alternate route is most frequently needed, so this is important layer of our application. Landmark is another important layer because it helps to locate any other location like an accidental spot, exhibition centre and gathering places. At the time of emergency, a rescue team can point out the address of the target places with respect to the location of the nearby landmark. Water bodies are also an important layer in our application. When a fire has spread over an area and fire brigade has gone on that area, they need to use water from nearest water bodies. Rail lines are also effective as layer in our application because when a rail is passed over a railway crossing, the traffic centres nearest to that crossing have to alert more to overcome accidents.

3.2 Data models used in our application

The identified layers are analysed and respective data model for each layer is defined using the characteristics of spatial database. The spatial data model provides a hierarchical structure of elements, geometries, and layers. The elements are considered as the grains for building up a geometry. Therefore, the geometry is used to represent the spatial features of a spatial object and it is modelled as a set of primitive elements. Similarly, a set of geometries forms a layer. An element is the basic building block of a geometry. The fundamental spatial element types are points, line strings, and polygons. A point can represent a building, a landmark, traffic centre, school, office, etc. with a (x, y)-coordinate value. The line string can be used to represent roads, rail lines, rivers, etc. using a string of line segments. Similarly, an urban area of a city can be modelled using polygons element. One coordinate is required to present a point data. A line data needs two coordinates representing a line segment of the element. Only two points are needed to define rectangle (lower left and upper right), whereas other polygons need all points or vertex to be defined with Cartesian coordinate data. Each layer is implemented using the relational data model, where each layer is represented with a relation. Each relation is equivalent to a table which is identified by name and defined by a set of attributes. The type of attributes is either spatial or non-spatial data type and at least one attribute should be spatial attribute. For example, the schema of roads table is defined as follows:

roads(road_id, name, shape, type)

In this table, there are three columns or attributes to describe a road. The road_id means a unique id of a road and it is used as primary key. The road name which is a non-spatial information of a road is stored in the attribute 'name'. The geometric description of a spatial object (roads) is stored in a single row, in a single column shape of object type **GEOMETRY** in roads table. Similarly, the information about all traffic centres of the town are collected and stored in a table traffic. The schema of the table is given below:

traffic(id, name, shape)

where unique id, name and geometric description of the each traffic centre are stored in id, name and shape respectively.

3.3 Storing of spatial and non-spatial data

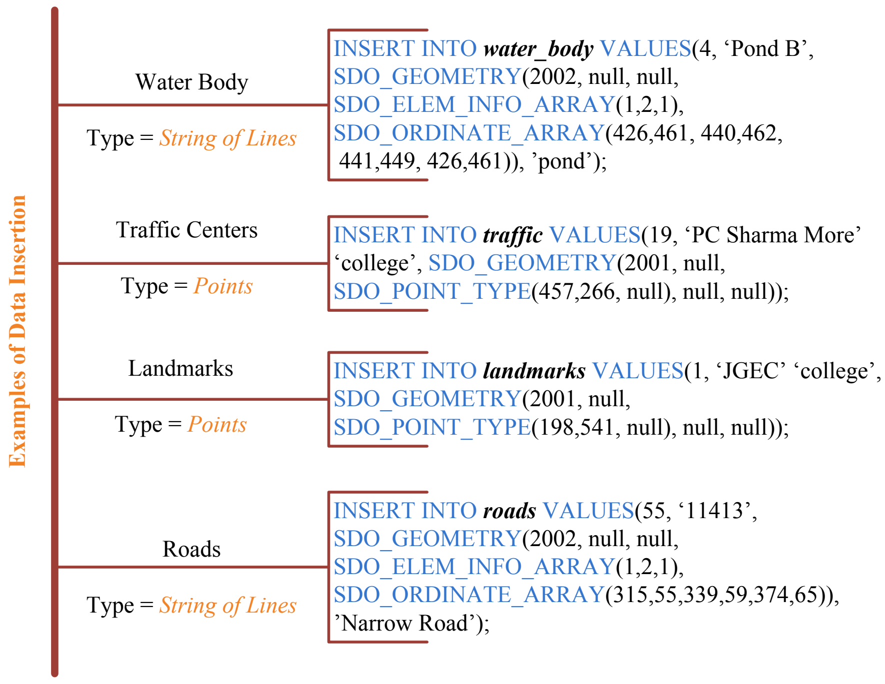
First of all, X-coordinate values as well as Y-coordinate values of important points are extracted from a source (e.g., map image of Jalpaiguri). Then, the respective data (spatial and non-spatial) of an entity (say, landmark, road, etc.) are stored into the respective table. In every record, there must be a spatial data (i.e., (x, y)-coordinate) which is used during spatial query execution. Here, an entity is specified with a spatial data and some other non-spatial data. Spatial part of any object is represented by a location of the object from the origin and geometric shape of the object. Say, the location (with respect to latitude, longitude) of centre of Kolkata is (22.5726, 88.3639) and the shape is point. For simplicity, we consider that the location is represented in (x, y)-coordinate only and the shapes may be point, line, polygon. For example, any road is the string of lines. The boundary of any city, say, Kolkata is represented by a shape of polygon. In

Spatial Oracle, there is an Oracle object type namely, $SDO\_GEOMETRY$ captures the location and shape information of a row of a spatial table. Similarly, the name and id represent the non-spatial information of a row of a table. Standard data manipulation language (DML) is used to carry out the data entry. The data insertion into a spatial table is given below.

```
SQL> INSERT INTO traffic VALUES
( 1, 'BEGUNTARY',
SDO_GEOMETRY
(
2001, – SDO_GTYPE attribute: '2' in 2001 specifies dimensionality is 2.
NULL,
SDO_POINT_TYPE – Specifies the coordinates of the point
( 100, 120, NULL ),
NULL, NULL ) );
```

Here, SDO_GTYPE attribute 2001 specifies a two-dimensional point geometry. Similarly, a line geometry is represented by 2002, a polygon by 2003, and a collection by 2004. Few sample insertion statements are given in Figure 2.

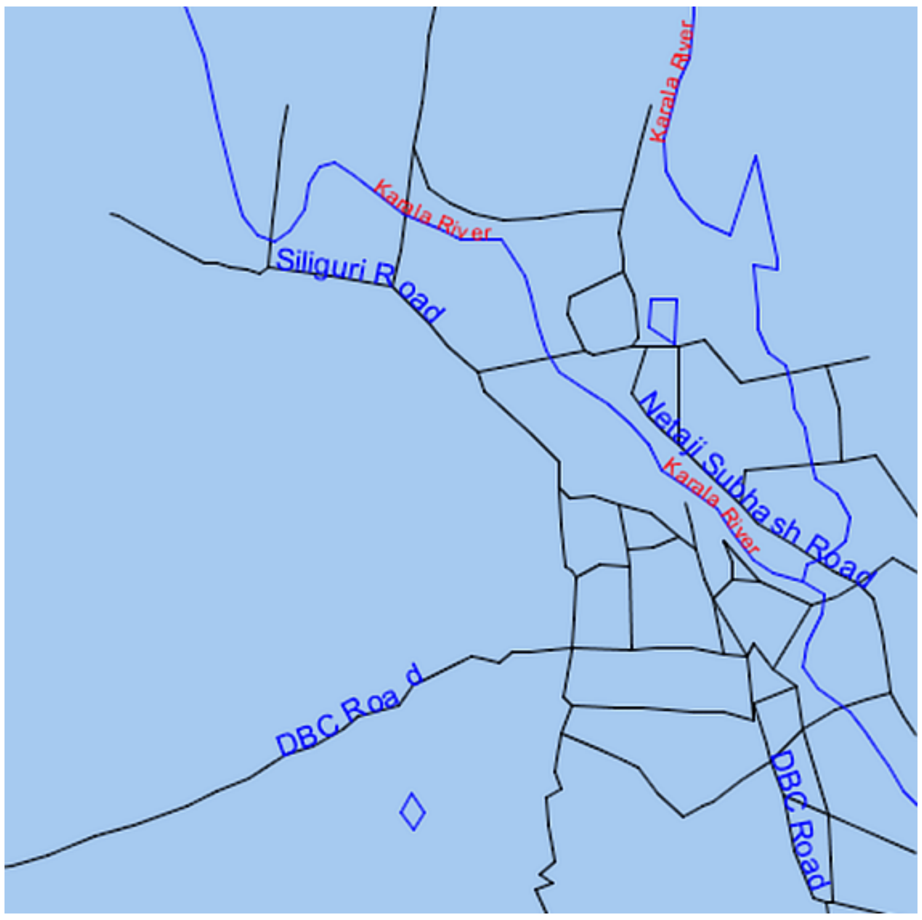
Figure 2 Insertion of data (see online version for colours)



3.4 Processing of efficient query to manage the traffic

All the all spatial/geographical data are populated into the spatial tables using SDO_GEOMETRY. Basically, SDO_GEOMETRY stores the data in the Spatial Oracle. The query and analysis component of the Spatial Oracle provides the necessary functionality to analyse and query the spatial data. There are two subcomponents of the query and analysis component, namely a geometry engine and an index engine. Any query is executed through these components. Say, user wants to see four nearest health centre to a landmark 'Dishary Club'. This type of query is analysed and executed by the Geometry and Index Engines components of the Spatial Oracle. First, all the heath centres are selected from the health_centre table. Distance between the health centres and 'Dishary Club' is calculated. The list of health centres is sorted according to the distances and top four health centres are selected from the sorted list. Moreover, there are many spatial operations like, distance, within, boundary touch, intersect, contain, etc. These types of spatial queries can be executed by the Spatial Oracle. The retrieved spatial data through spatial query execution is used to visualise in a map using the MapViewer components of Oracle technology. Now, each map includes some user defined themes to display the spatial data in a meaningful way. The map is specified with multiple number of themes according to the layer of interest. There are different themes for different layers, say, thick blue lines are used for water-bodies, black lines are used for roads. MapViewer is only used to display the result in a map. A spatial query is executed and visualisation of the same using MapViewer is shown in Figure 3.

Figure 3 Visualisation of the spatial query result using MapViewer (see online version for colours)



4 Results and discussions

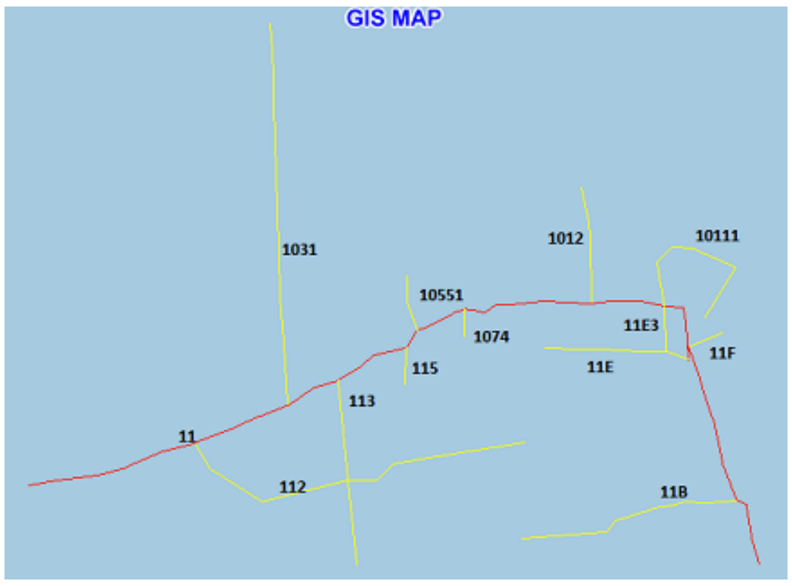
This section describes the experimental setups (i.e., query formulation) and the experimental results (i.e., execution of query) to evaluate the accuracy and the efficiency of our proposed approach.

Query 1: Finding all the roads touching with a main road

If peoples are going through a main road, then they do not have any knowledge about all the normal roads that are connected with that road. Here our application provides a spatial function that tells us which normal roads are connected with the main road where we are currently present. This query also helps a user to find out the important traffic centres that are present on the normal roads connected with the main road. As an example, we consider road '11' as main road and find out all roads touching with this road. The SQL query is given below and the corresponding output of the query is shown in Figure 4.

"select b.name from roads a,roads b where a.name = '11' and
b.type = 'NORMAL ROAD' AND SDO_TOUCH(a.shape,b.shape) = 'TRUE';"

Figure 4 All the roads that are connected with a main road (see online version for colours)

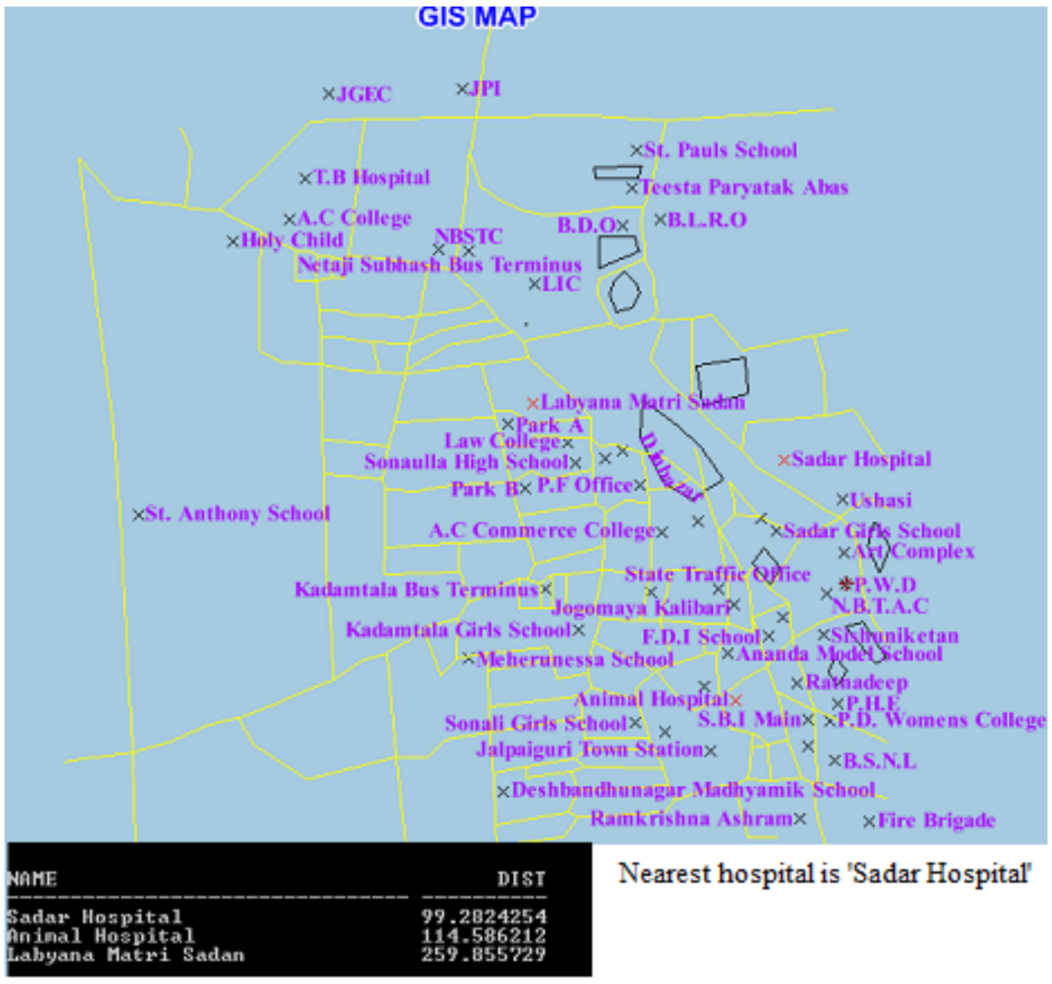


Query 2: Finding all the hospitals within a specific distance from a specific landmark

When a fatal accident is occurred in a busy road or a landmark, we search for the nearest hospital, police station and fire station. By this query a user can easily find out the hospitals present within a specific range of distance from the location of the accident along with their respective distances. So this helps user to take an effective decision about the target location. As an example, we have considered 'P.W.D.' building as a landmark and all the hospitals which are within 300 unit of distance from the 'P.W.D.' building has been targeted to find out. The SQL query is given below and the nearby hospitals from the point of accident (here 'P.W.D. building) are shown in Figure 5.

"SELECT f.name,sdo_geom.sdo_distance(f.shape, r.shape, 0.005) dist FROM
landmarks f, landmarks r WHERE r.name = 'P.W.D' AND
SDO_within_distance(f.shape, SDO_GEOM.SDO_BUFFER(r.shape, 300, 0.005),
'distance = 300') = 'TRUE' AND (f.type = 'hospital');"

Figure 5 All the hospitals within 300 unit of distance from a landmark 'P.W.D' (see online version for colours)

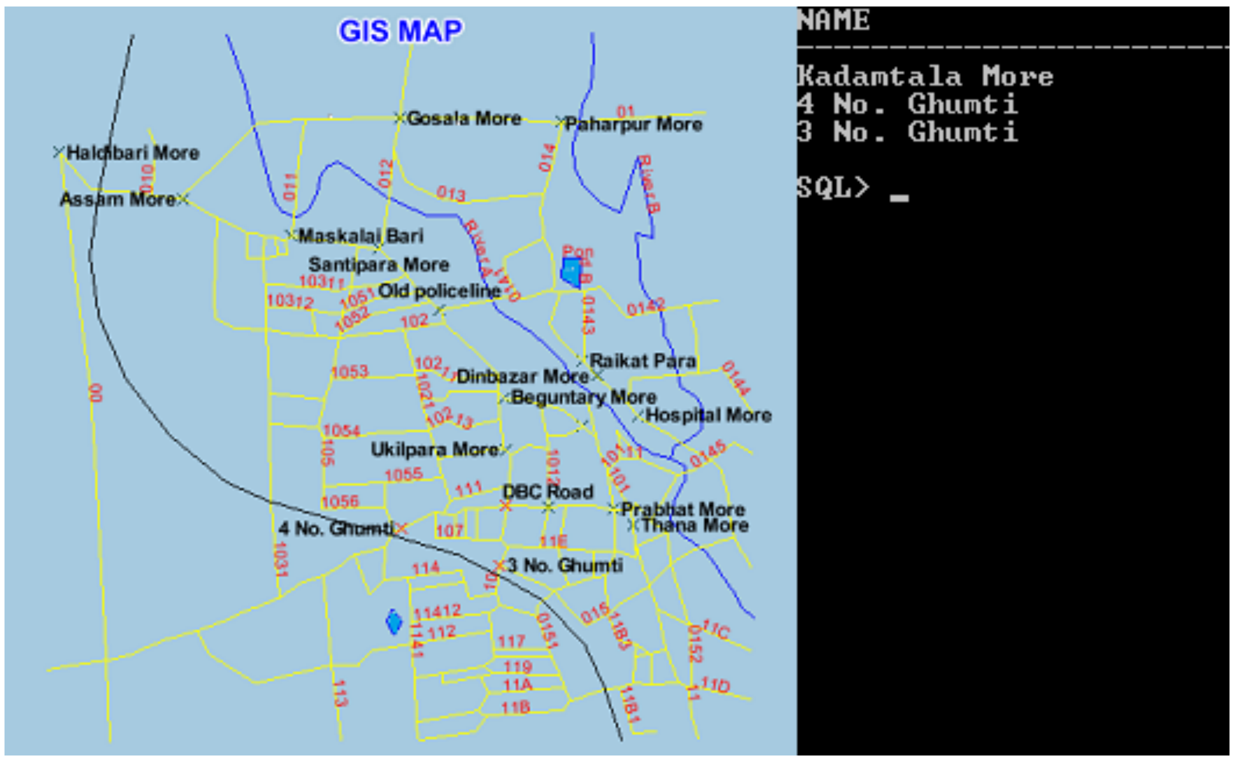


Query 3: Finding nearest traffic centres from a road intersect with a rail line

When a rail is crossed over a rail line the traffic centres nearest to the main road which intersects with the rail line have to be more alert to avoid accident. This query finds all the nearby traffic centres from a main road that intersects with the rail line. As we all know in the time of accident, a fire brigade or an ambulance might have to cross over the rail line, in that time the traffic centres have to be more responsible to clear the traffic jamming that are occurred after the rail crossing. In our example, we consider the rail crossing in the main road '11' and the corresponding location is shown in Figure 6.

"select t.name from traffic t where sdo_nn(t.shape,
(SELECT SDO_GEOM.SDO_INTERSECTION(r.shape, rl.shape, 0.005) FROM roads r, rail_line rl WHERE rl.name = 'RL_RL_RL_RL' AND r.name = '11'),'
SDO_NUM_RES=3') = 'TRUE';"

Figure 6 All the traffic centres nearest from a road ('11') intersects with a rail line (see online version for colours)



Query 4: Finding the shortest path from accidental road to main hospital

When a serious accident occurs in a main road or highway a user must have an idea about how to reach the main hospital in less time. So it is not always important to find out the shortest point to point distance but also a user will feel the glory when he has an idea of all the connected paths from the location of accident to the main hospital, because it might happen the shortest path contains more traffic jamming than the other paths. In that time the path of less traffic will have more significance than the shortest one because the user will able to reach the hospital in less time. This query gives all the connected paths from the source of accident to District hospital and their respective distances. The corresponding location is shown in Figure 7. All the connected paths with their distances from a specific source to specific destination are shown in Figure 8. So a user can easily find out the shortest path by viewing the all the connected paths.

"create table v11 (source, dest, distance) as (select s.name, r.name, SDO_GEOM.SDO_LENGTH(r.shape, 0.005) from first_connect s, first_connect r where r.type! = 'NARROW ROAD' AND s.id! = r.id AND sdo_touch(s.shape, r.shape)= 'TRUE');"

"create table v44 (source, dest, distance) as select source, dest, distance from v11 where dest! = '1012';"

"select sys_connect_by_path(dest,'–>')path, sys_connect_by_path(distance, '+') dist from v44 where dest = (select r.name from roads r, landmarks l where l.name = 'Sadar Hospital' AND SDO_NN(r.shape, l.shape, 'SDO_NUM_RES = 1') = 'TRUE') start with source = '1012' connect by nocycle prior dest = source;"

Figure 7 Shortest path from an accidental road to Sadar Hospital (see online version for colours)

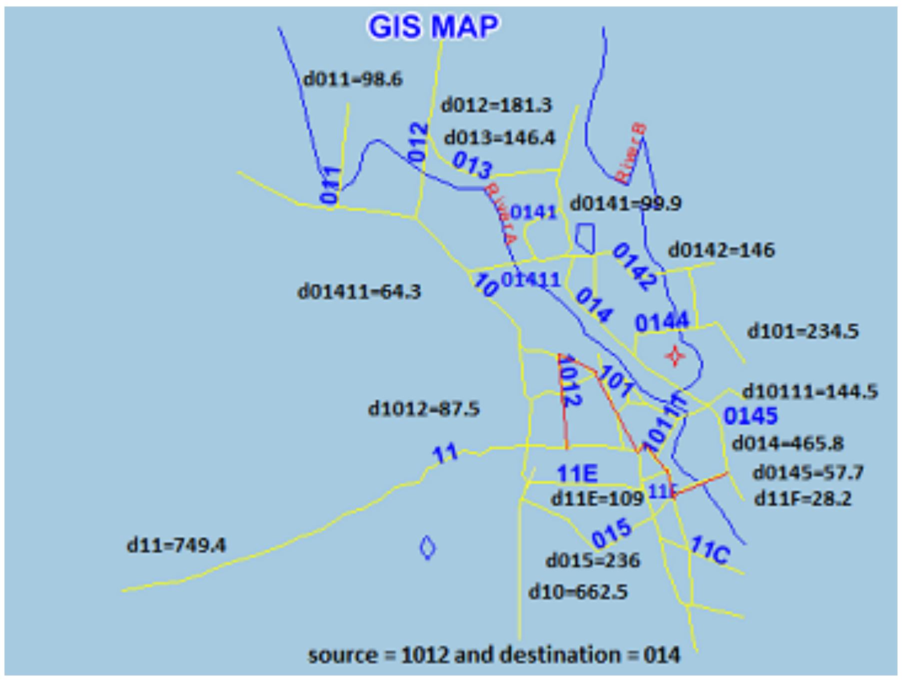


Figure 8 All possible connected paths with their distances from a specific source to specific destination (see online version for colours)

1012->101->015->014
DIS(234.5+236+465.8)=936.3

1012->101->015->10->012->013->014
DIS(234.5+236+662.5+181.3+146.4+465.8)=1926.5

1012->101->015->10->01411->0141->014
DIS(234.5+236+662.5+64.3+99.9+465.8)=1763

1012->101->10->012->013->014
DIS(234.5+662.5+181.3+146.4+465.8)=1690.5

1012->101->10->01411->0141->014
DIS(234.5+662.5+64.3+99.9+465.80)=1527

1012->101->10->015->014
DIS(234.5+662.5+236+465.8)=1598.8

1012->101->11F->11->11E->10->012->013->014
DIS(234.5+28.2+749.4+109+662.5+181.3+146.4+465.8)=2577.1

1012->101->11F->11->11E->10->10411->0141->014
DIS(234.5+28.2+749.4+109+662.5+64.3+99.9+465.8)=2413.6

1012->11->11F->101->10->01411->0141->014
DIS(749.4+28.2+234.5+662.5+64.3+99.9+465.8)=2304.6

1012->11->11F->101->10->015->014
DIS(749.4+28.2+234.5+662.5+236+465.8)=2376.4

1012->101->11F->11->11E->10->015->014
DIS(234.5+28.2+749.4+109+662.5+236+465.8)=2485.4

1012->11->11E->10->012->013->014
DIS(749.4+109+662.5+181.3+146.4+465.8)=2314.4

1012->11->11E->10->01411->0141->014
DIS(234.5+749.4+109+662.5+64.3+99.9+465.8)=2150.9

1012->11->11E->10->015->014
DIS(749.4+109+662.5+236+465.8)=2222.7

1012->11->11E->10->101->015->014
DIS(749.4+109+662.5+234.5+236+465.8)=2457.2

1012->11->11F->101->015->014
DIS(749.4+28.2+234.5+236+465.8)=1713.9

1012->11->11F->101->015->10->012->013->014
DIS(749.4+28.2+234.5+236+662.5+181.3+146.4+465.8)=2704.1

1012->11->11F->101->015->10->01411->0141->014
DIS(749.4+28.2+234.5+236+662.5+64.3+99.9+465.8)=2540.6

1012->11->11F->101->10->012->013->014
DIS(749.4+28.2+234.5+662.5+181.3+146.4+465.8)=2468.1

Query 5: Finding all the possible connected path of roads from the nearest road of fire station to the road nearest of the landmark where accident has occurred and the shortest path from the road nearest to landmark where accident has occurred to the road nearest to water-body

When fire has spread over an area or a landmark then fire brigade has to come in that landmark. As we all know that fire brigade does not pass through the narrow road, so our application find all the connected paths of normal roads from fire station office to the landmark where accident has occurred and also it might be possible that water of the fire brigade has ended before all the fire has not turn out. In that case our application also helps to find the shortest path from the landmark where accident has occurred to the nearest water-body. Shortest path from fire brigade to A.C Commerce College and A.C Commerce College to nearest water body is shown in Figure 9.

“create view v55 (source, dest, distance) as (select s.name, r.name
SDO_GEOM.SDO_LENGTH(r.shape, 0.005) from fire s, fire r
where s.id!=r.id and SDO_TOUCH (s.shape, r.shape)= ‘TRUE’);”

“create view v66(source1, dest1, distance) as select source, dest, distance
from v55 where dest != (SELECT f.name FROM landmarks e, fire f WHERE
e.name = ‘Fire Brigade’ AND SDO_NN(f.shape, e.shape,
‘SDO_NUM_RES= 1’) = ‘TRUE’);”

“create view v77 (source2, dest2, distance) as select source, dest, distance
from v55 where dest != (SELECT c1.name FROM landmarks i1, fire c1
WHERE i1.name = ‘A.C Commerce College’ AND SDO_NN(c1.shape,
i1.shape, ‘SDO_NUM_RES = 1’) = ‘TRUE’);”

“(select sys_connect_by_path(dest1, ‘–>’) as path_to_land,
sys_connect_by_path(distance, ‘+’) as distance from v66 where
dest1= (SELECT c.name FROM landmarks i, fire c WHERE
i.name = ‘A.C Commerce College’ AND SDO_NN(c.shape, i.shape,
‘SDO_NUM_RES= 1’) = ‘TRUE’) start with
source1 = (SELECT f.name FROM landmarks e, fire f WHERE
e.name = ‘Fire Brigade’ AND SDO_NN(f.shape, e.shape,
‘SDO_NUM_RES=1’) = ‘TRUE’) connect by nocycle prior dest1 =source1);”

Figure 9 Shortest path from fire brigade to A.C Commerce College and A.C Commerce College to nearest water body (see online version for colours)

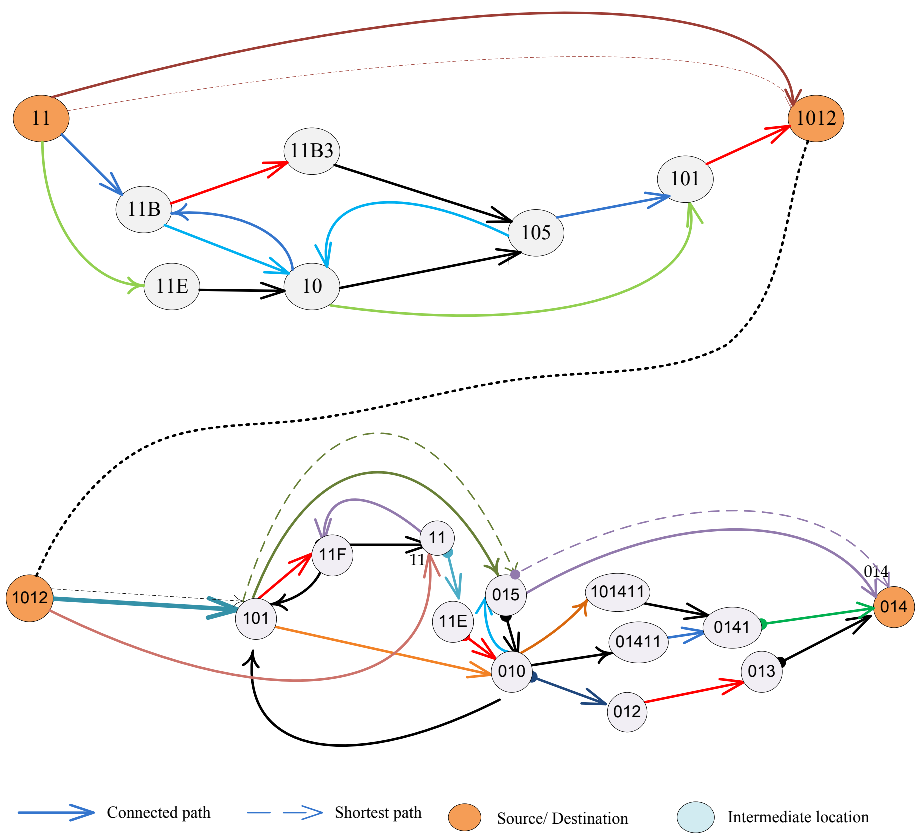


Figure 10 Possible connected paths with their distances from source (fire station) to destination (landmark) (see online version for colours)

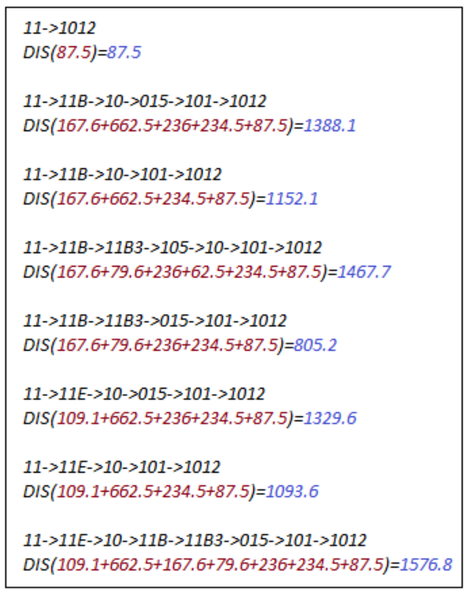
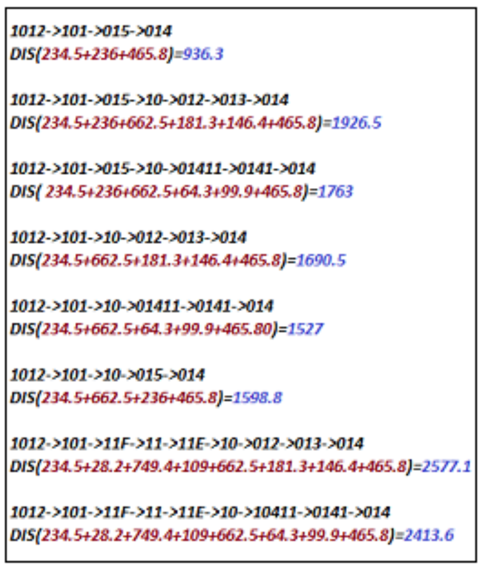


Figure 11 Possible connected paths with their distances from source (landmark) to destination (spot) (see online version for colours)



The output is shown in Figure 10.

> "(select sys_connect_by_path(dest2, '→') as path_to_waterbody, sys_connect_by_path(distance, '+') as distance from v77 where dest2 = (SELECT g.name FROM fire g, water_body wb WHERE wb.name = (select b1.name from water_body b1, landmarks b2 where b2.name = 'A.C Commerce College' AND SDO_NN(b1.shape, b2.shape, 'SDO_NUM_RES = 1') = 'TRUE') AND SDO_NN(g.shape, wb.shape, 'SDO_NUM_RES = 1') = 'TRUE') start with source2 = (SELECT c1.name FROM landmarks i1, fire c1 WHERE i1.name = 'A.C Commerce College' AND SDO_NN(c1.shape, i1.shape, 'SDO_NUM_RES = 1') = 'TRUE') connect by nocycle prior dest2 = source2);"

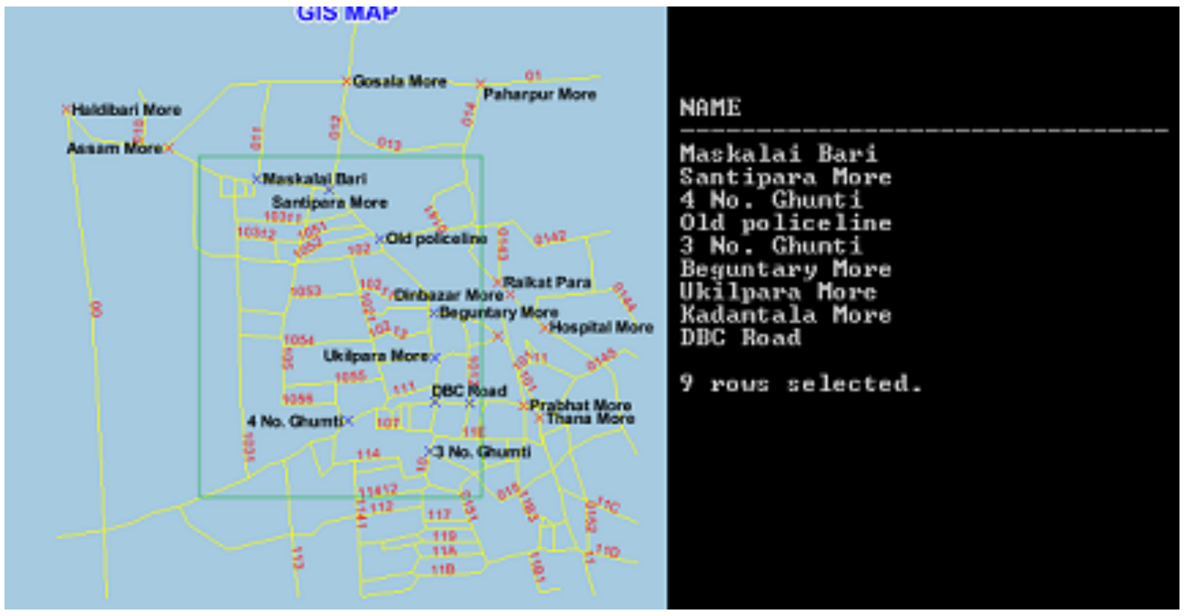
The output is shown in Figure 11.

Query 6: Finding all the traffic centres present inside a user defined polygon

It is always important for an end user to know all the traffic centres or landmarks he has to visit if he wishes to travel through a particular area of interest. Moreover, if an accident has occurred in an important area then all the traffic centres within it has to be more alert. Our application provides all the traffic centres that are present inside the user defined polygon that means the area in which he wishes to travel. In our experiment, we consider a polygon ((10,10) → (10,450) → (450,450) → (450,10) → (10,10)) and search for the traffic centres (or landmark) situated inside the polygon. We have executed the following query and found nine traffic centres within the polygon shown in Figure 12.

```
"SELECT t.name FROM traffic t WHERE SDO_FILTER(t.shape,
mdsys.sdo_geometry(2003, NULL, NULL,
mdsys.sdo_elem_info_array(1, 1003, 1),
mdsys.sdo_ordinate_array(10, 10, 10, 450, 450, 450, 450, 10, 10, 10)),
'querytype = WINDOW') = 'TRUE' AND SDO_RELATE(t.shape,
mdsys.sdo_geometry(2003, NULL, NULL,
mdsys.sdo_elem_info_array(1, 1003, 1),
mdsys.sdo_ordinate_array(10, 10, 10, 450, 450, 450, 450, 10, 10, 10)),
'masktype = INSIDE+TOUCH querytype = WINDOW') = 'TRUE';"
```

Figure 12 All the traffic centres inside a user defined polygon (see online version for colours)



5 Conclusions

We have designed a GIS-based traffic management system of a city (here, we considered, Jalpaiguri, a district head quarter town of West Bengal) to control the traffic loads. The system provides necessary information about the traffic system of a city. It facilitates the stakeholders to take decision regarding traffic information like shortest path selection, following a direction toward the target location. The system supports user's query with spatial queries related to point, string of lines and polygon to handle location, road network and area, respectively. Even, our work supports the hybrid queries combining different layers of interests and non-spatial data. The highlighted portion of our application is a user can find all the connected paths with the respective distances from a specific source to destination. This helps a user not only to find shortest path but also to analyse the path having less traffic load. So an end user can effectively reach to his/her destination like hospitals, health centres, institutes, etc. in less time. Our application also helps the fire brigade staffs to find the shortest path to reach the landmarks where accident has occurred and from that landmark to nearest river if suddenly the water has ended before the fire has not turn out.

The limitations that our application takes more time when to work with the whole map. We nearly about include 86 roads in our application, so if we want to execute connected path query by taking whole map it will take 86! combinations to find out the result which take more memory and more time. So our application is not time efficient when it comes for whole map. So it is the scope of future improvement of our application.

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