

DEVELOPMENT OF WEBGIS BASED REAL TIME ROAD TRAFFIC INFORMATION SYSTEM

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ABSTRACT:

Rapid increase in road traffic density results into a serious problem of Traffic Congestion (TC) in cities. During peaks hours TC is very high and hence public search least congested path for their journeys in order to minimize travel time and hence transportation cost. In this study, a new empirical model was developed to estimate congestion levels using real time road Traffic Parameters (TPs) such as vehicle density, speed, class and vehicle-to-vehicle (V2V) gap. These real time road TPs were collected using latest generation Inductive Loop Detector (ILD) technology. Further, a WebGIS based Road Traffic Information System (RTIS) for Dehradun city was developed for real time TD analyses and visualisation. This RTIS is very useful for public and user departments for planning and decision making processes. No other such system is available in India, which handles multiple traffic parameters simultaneously to provide solution of day-to-day problems.

1. INTRODUCTION

Due to rapid increase in population, there is a huge increase in the road traffic in the cities, which rises a new set of problems in urban areas. Mainly it leads to increase in Traffic Congestion (TC) levels and hence its associated effects such as accidents, air and noise pollutions, wastage of time, resources and money pose major concerns to the public. During peaks hours TC is very high and hence public search the least congested path for their journeys so that travel time and hence transportation cost can be minimized. For the solution of road network related problems like optimal path calculation etc., the key responsible factor is impedance which can be calculated using travel distance or travel time or any other factor responsible (like TC) for transportation cost. Therefore, it is very important to monitor where the congestion is and how it can be measured on real time basis. The congestion is not a directly measurable quantity and is a challenging task because it varies from city to city, country to country and depends on user's perspective (human perception). TC in cities depends on so many factors like static factors (road width, road network structure etc.) and dynamic factors (traffic signal timings, traffic movement parameters etc.). Dynamic factors changes with time and have crucial role to play in traffic management, planning and control. There are so many methods present in the literature like artificial neural network, fuzzy classifiers, empirical models etc. to estimate TC. In literature, few authors estimated congestion using one TP (speed) and few estimated using two TPs (speed and density). In this study, a new empirical model is developed to estimate real time Level Of Congestion (LOC) using four TPs namely vehicle speed, density, class/type and V2V gap.

Another practical problem is how to optimally collect these real time TPs from the road network? For this, there are many existing technologies like Inductive Loop Detector (ILD), video image detection, microwave RADAR, infrared sensors, laser scanner, pneumatic road tubes, piezoelectric sensors, magnetic sensors, acoustic sensors, GPS, blue tooth technology, airborne sensors (Antoniou, Balakrishna, & Koutsopoulos, 2011) etc. All

these technologies have some advantages and disadvantages because of environmental conditions (like rain, fog, storm, smog, etc.), time conditions (like day and night) and heterogeneous traffic conditions particularly in developing countries like India. ILD technology has less disadvantages and more advantages as these detectors are installed below the road surface layer and have least disturbance of environmental conditions, no disturbance of day and night conditions, and minimum disturbance of traffic heterogeneity in the cities. In this study, ILD technology is used to collect real time traffic information of Dehradun city, India.

After estimating congestion level on the road segments, the same data has to be integrated with a web platform with suitable tools for providing solution of user specific problems and visualisation of TD. Geographic Information System (GIS) technology has a potential to handle such problems and capable to publish the solutions on the web with advanced data analysis and handling tools. WebGIS based intelligent transport system with the help of spatial database and real-time TD will keep public updated about the changing traffic conditions and hence helps in route planning. The development of WebGIS based real-time RTIS and integration of sensor data with this system is a very difficult task in order to handle real-time situations. Thus, the main objective of this study is to develop an integrated framework for WebGIS based real-time RTIS which includes TD collection using inductive loop technology, development of new empirical model for real time LOC estimation, calculation of real time alternative optimal paths and visualisation of TD.

2. LITERATURE REVIEW

There are many ways to collect TD. As described by Leduc (2008) the TD collection techniques can be divided into two main categories intrusive and non-intrusive. In intrusive methods, the traffic collection equipment is located on the road like inductive loops, piezoelectric sensors etc. While non-intrusive methods, equipments are generally placed along the

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roads and do not come in direct contact with the vehicles like video camera, laser scanner etc.

There can be multiple different combinations to create a traffic data collection system. Video, SONAR and microwave can be used to measure the flow of all incoming and outgoing links of intersection node (Gentili & Mirchandani, 2012). A combination of piezoelectric sensors and inductive loops can be used to classify vehicles based on tire width/footprint (Golla, Mukherjee, & Harvey, 2013). Inductive loops are the traditional but reliable traffic surveillance technology and one of the primary data source used in practice (Ali, George, Vanajakshi, & Venkatraman, 2011), (Lopes, Bento, Huang, Antoniou, & Ben-Akiva, 2010), and (Lin, Dahlgren, & Huo, 2004).

Route calculation has an important role to play in emergency responses and decisions (Choosumrong, Raghavan, & Realini, 2010). Finding alternate routes which are more natural using human knowledge of the paths by multiple shortest path routines was discussed by (Bader, Dees, Geisberger, & Sanders, 2011). Most routing algorithms return a single route between the source and destination but there is a gap between the path generated by mathematical computation and a good alternative path.

Choosumrong, Raghavan, & Bozon (2012) proposed an approach for finding shortest path, shortest time and safest path in a dynamic situation under real-time road conditions using pgRouting algorithm. The study was focused on to enhance open source routing algorithms by modifying the functioning of pgRouting software. The entire system implements the dynamic routing using open source geospatial software (using the PostGIS and pgRouting extensions for the PostgreSQL DBMS). Zhang & He (2012) uses pgRouting quick speed, convenient operation features and provide the improved shortest path calculating method which aims at putting forward the road level and preferred the highway.

Posawang, Phosaard, Polnigongit, & Pattara-Atikom (2010) used a method to classify the congestion using ANN. They used human opinions from web survey to train the ANN model that classifies congestion into three classes light, heavy and jam on the basis of velocity, and traffic flow. Bauza, Gozalvez, & Sanchez-Soriano (2010) discussed CoTEC (COoperative Traffic Congestion detECTION), an approach using V2V communications and fuzzy logic to estimate the road TC. "CoTEC uses the Cooperative Awareness Messages (CAM) or beacon messages that vehicles periodically broadcast, mainly for safety purposes, to monitor the road traffic conditions.

Rao & Ramachandra Rao (2016) and K. Zhang & Xue (2010) defined traffic-rate R_t as a metric to describe current road traffic condition which is given by

$$R_t = \frac{S_{in} + 1}{S_{in} + S_{out} + 1} \quad (1)$$

Where S_{in} and S_{out} are the number of vehicles that enter into the road and the number of vehicles that leave the road during $[t, t + \Delta t)$ time interval?

They assigned a threshold λ for each road segment and proposed an experimental formula to calculate λ dynamically which is given by

$$\lambda = \frac{L * N}{V(T + D)} \quad (2)$$

Where V is the mean speed of vehicles on the road, T is an estimation showing how long can a vehicle stay on the road, D is the traffic light duration, L represents length of the road and N represents number of lanes. $L * N$ is the capacity of the road. The rules to identify traffic status on a road are given as follows-

1. $0 \leq R_t < \lambda$ FREE traffic
2. $\lambda \leq R_t < 2\lambda$, NORMAL traffic
3. $2\lambda \leq R_t < 3\lambda$, ALERT traffic
4. $3\lambda \leq R_t < 4\lambda$, BUSY traffic
5. $4\lambda \leq R_t < 1$, OVERLOAD traffic.

In most cases the value of $\lambda = 0.23$. When the traffic state comes under ALERT messages will be sent to the vehicles near that road segment.

2.1 Inductive Loop Detector (ILD) Technology

2.1.1 Working Principle: ILD works on the principle of Faraday Law of Induction. When the vehicle is moving over the inductive loop (energized by a low voltage signal from the detector electronics), the magnetic field eddy currents are generated. The eddy currents, caused by the body and chassis of vehicle, opposes the magnetic field of the loop and thus results in a decrease in loop inductance. Inductance and frequency are inversely proportional therefore with the decrease in loop inductance there is a resultant increase in frequency. It thus follows that by analysing the positive change in frequency, the loop detector is able to sense the presence of a vehicle over a loop.

2.1.2 Ground Segment: Figures 1 shows locations on the road pavement for the installation of the inductive loops in the road lanes at a roundabout. Eight loops are required in order to detect all type of vehicular movement at a roundabout connected with four double lane roads.

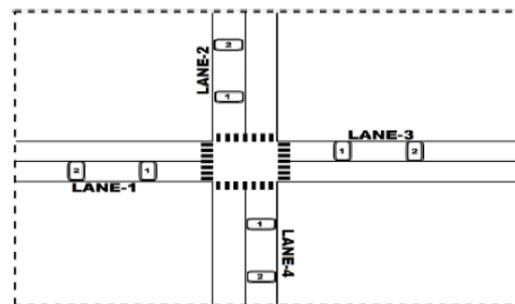


Figure 1. Identification of loop locations across the Road junction

The detailed configuration for installation of loops is shown in Figure 2. Each loop is of hollow rectangular/square shape in which cable is poured (3 or more turns) along the edge of the rectangle/square. There are two loops per lane connected in series in order to develop high amount of inductance. These loops are then connected to the electronics unit of ILD device placed at roadside (or pole).

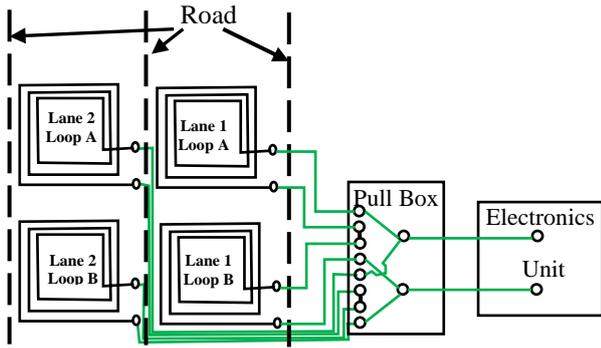


Figure 2. A detailed structure of Loop Configuration and connection with electronics unit through pull box.

2.1.3 Vehicle Signature: There are different types of vehicles in terms of size and amount of metal present in them, and as they pass over the inductive loop embedded in the road surface, an inductance signature is developed, called vehicle signature. This signature is different for different categories of vehicles. Figure 3 shows basic vehicle signature obtained from inductive loops.

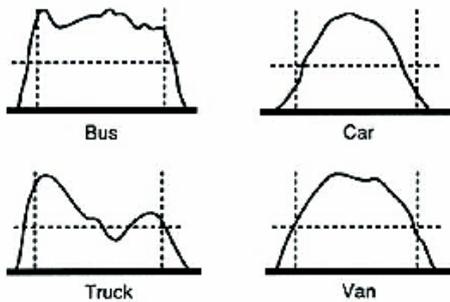


Figure 3. Inductive Curves/Signatures of different vehicles

2.1.4 ILD Architecture: This part of section shows the inductive loop detector/sensor architecture to capture the traffic information as shown in Figure 4. As the vehicle passes over the inductive loop, it generates analog waveform to detect the vehicle presence on the loop. This vehicle presence analog waveform goes to loop electronics units where it gets digitized and performed sensitivity analysis and then goes to microprocessor. In microprocessor this digitized signature gets processed as per Indian traffic situations through customization and then derived vehicle parameters and stored locally in the system and also transmitted through GPRS to the centralised server for further analysis.

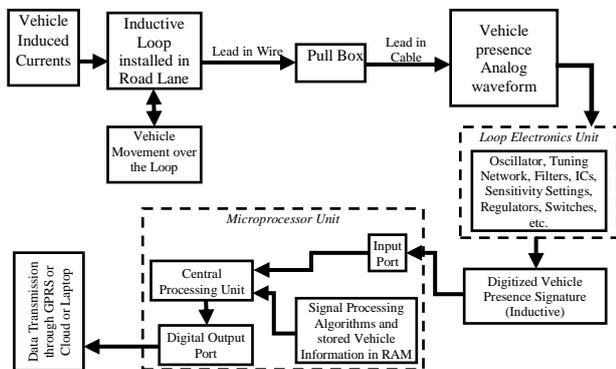


Figure 4. Architectural Diagram ILD Technology to capture, store and transmit the real time TD.

2.1.5 Parameter Extraction: The TPs can be measured using vehicles inductive loop signatures. As there are two loops, let us consider the inter-centre distance of both the loops is 'd' and length of vehicle is 'D'.

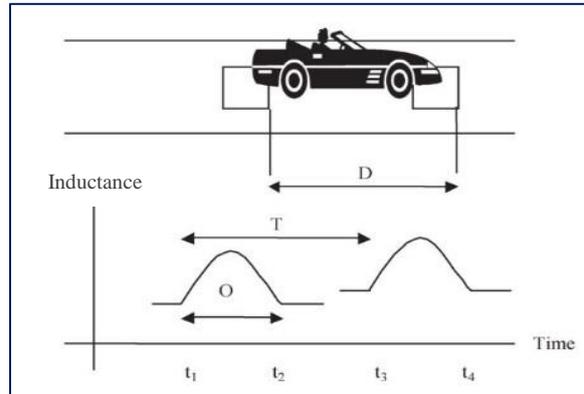


Figure 5. Loop Inductance Curves as vehicle passes over both the loops in a same lane

Let the vehicle is entering over the first loop at time t_1 and leave the first loop at time t_2 and then enters over second loop at time t_3 and leaves the second loop at time t_4 . The speed (v) and length (and hence class/type) of vehicle can be calculated as

$$\text{Speed } (v) = \frac{d}{t_3 - t_1} = \frac{1}{2} \left(\frac{d}{t_3 - t_1} + \frac{d}{t_4 - t_2} \right) \quad (3)$$

$$\text{Length}(D) = \frac{v[(t_2 - t_1) + (t_4 - t_3)]}{2} \quad (4)$$

Let the first vehicle is leaving to first loop at time T_1 and second vehicle is entering over the first loop at time T_2 . The vehicle-to-vehicle gap is given by

$$H = T_2 - T_1 + v_1(t'_2 - t'_1) \quad (5)$$

Where v_1 , t'_1 and t'_2 are the speed of first vehicle, and entering time & leaving times of first vehicle over first loop respectively.

3. STUDY AREA

Dehradun, the capital city of the state of Uttarakhand, India was chosen as the study area. The study area lies between latitude 30.1° N to 30.4° N and longitude 78° E to 78.3° E. and at an elevation of 640 Meters from mean sea surface. The inductive loop detectors were installed at five junctions (8 loops per junction) namely Astley Hall, CMI Chowk, Darshanlal Chowk, Prince Chowk and survey Chowk in Dehradun city as shown in Figure 6.

The two inductive loops per lane were installed underground and cable was poured (3 or more turns) along the edge of hollow square frame (side length 1.5m, edge width 2 cm, edge depth 10 cm). The site scene is shown in Figure 7.

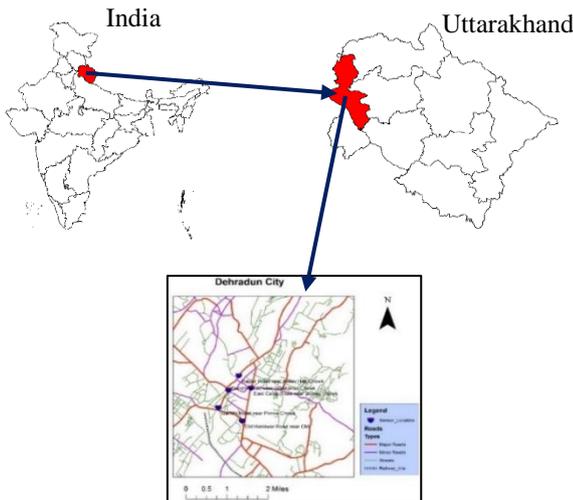


Figure 6. Map of Study Area with installed sensor locations



Figure 7. Installation of Loops under Road Pavement

Latest generation M680 Vehicle counter and classifier (Figure 8) based on inductive loop technology supplied by Clearview Intelligence, United Kingdom based Company, is used to collect the TD at five locations in the Dehradun city. It can be used in both slow and fast moving traffic environments. It uses two

inductive loops per lane and captures vehicle-by-vehicle information including date, time, lane detail, vehicle flow direction, headway (V2V gap), speed, length and class.



Figure 8. M680 ILD Device

4. MATERIALS AND METHODS

This section of study describes the detailed methodology opted for the work done. Flow chart shown in Figure 9 describes the WebGIS framework development, GIS digital database generation, LOC modelling, integration and analysis and visualisation of road traffic information. Firstly, a digital GIS database of study area was generated and the TD was incorporated in database. The dynamic impedance factor i.e Level Of Congestion (LOC) was estimated using new proposed empirical model. The database along with the empirical model was integrated with WebGIS framework of real time RTIS. WebGIS framework was developed along with different web tools of data visualisation, network analysis, trend analysis and then it was published on the Geoweb server as Web Map Server (WMS) and Web Map Server-Time (WMS-T). Finally, the real time analysis for alternate path calculation and visualization of TD in GIS platform was done for better planning and decision-makings.

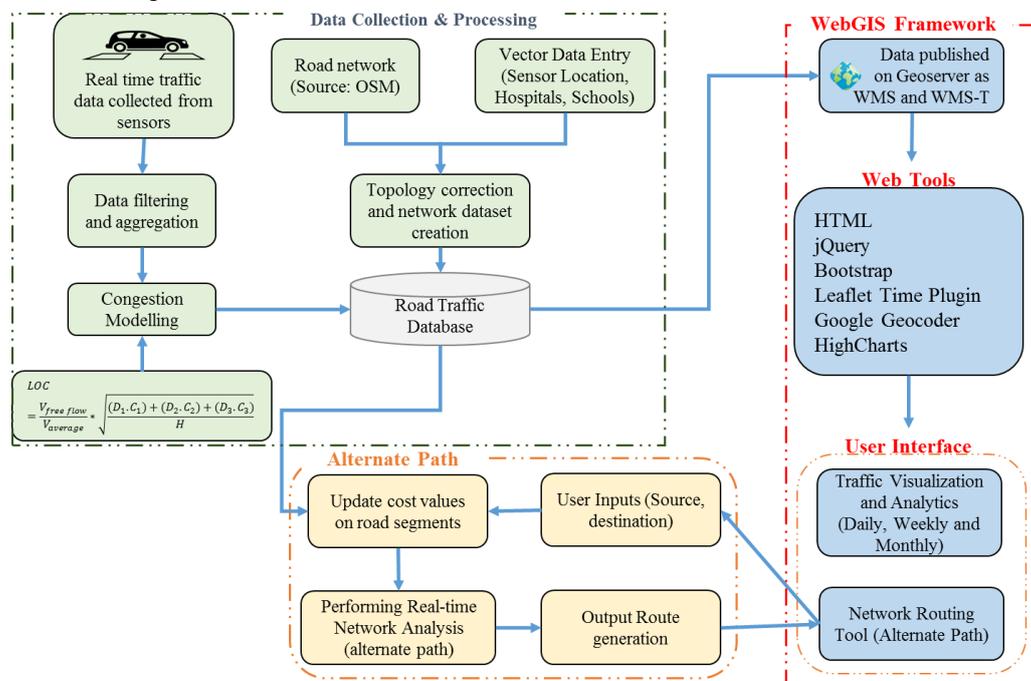


Figure 9. Methodological Flow Chart of WebGIS based real Time RTIS

4.1 Data collection and Processing

In order to make the vehicle by vehicle TD (originally in text format) compatible with GIS database, the TD is aggregated and loaded to the database using Python scripting. The data aggregation process averages the vehicle speeds, V2V gap, and also classify the type of vehicles into 3 categories namely light, medium and heavy on the basis of vehicle length. A python GUI was made for the transformation of TD from text to CSV format which is shown in Figure 10.

The aggregated data is then loaded into PostgreSQL with PostGIS extension for further processing. During the data conversion process a time and sensor id field were added to the converted data. The time field denotes the time interval in which the data is aggregated and sensor id helps to identify the sensor location and lane detail.

This helps to create a time series data along with geometry for visualization. A separate table is also generated to store daily, weekly TD trends, which is useful for analyses and derivation of important traffic related information in Dehradun city.

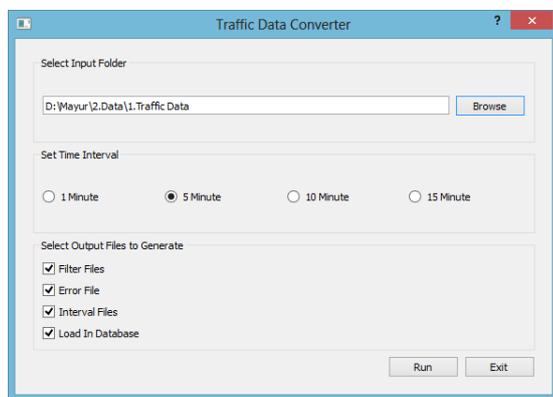


Figure 10. Python GUI for Data Aggregation

4.2 Level of Congestion (LOC) Modelling

Many different models are given in literature for estimating congestion on the road but the nature and cause of congestion in India is different. In this study, an empirical model is developed to model the dynamic congestion level on the road-using real time TD. The proposed index (LOC) is related to Travel Time Index (TTI) developed by Schrank & Lomax (2005). The TTI is given by

$$TTI = \frac{T_{PeakPeriod}}{T_{FreeFlow}} = \frac{V_{FreeFlow}}{V_{PeakPeriod}} = \frac{V_{FreeFlow}}{V_{average}} \quad (6)$$

Where $V_{FreeFlow}$ and $V_{average}$ are vehicle speed in free flow condition and during peak time. If $TTI = 2$, it means actual journey time will be twice that of free flow condition. This index is only depending upon the speed of the vehicles moving on the road, therefore not able to give actual travel time in the cities. Three more TPs namely vehicle density (D), vehicle class (C) and V2V gap or headway (H), were introduced in addition to vehicle speed. The new proposed index (LOC) is given by

$$LOC = \frac{V_{FreeFlow}}{V_{average}} \sqrt{\frac{D_1C_1 + D_2C_2 + D_3C_3}{H}} \quad (7)$$

Where D_1, D_2 and D_3 are the vehicle densities of vehicles classes C_1, C_2 and C_3 respectively.

C_1, C_2 and C_3 are light, medium and heavy classes of vehicles respectively and each class is assigned a weight to model the congestion level. The weights assigned to these categories of vehicles C_1, C_2 and C_3 are 0.2, 0.3 and 0.5 respectively. H is the average value of V2V gap (headway) in a fixed interval.

The real time impedance factor (RTIF) for network analysis defined as

$$RTIF = T_1 + \frac{V_{FreeFlow}}{V_{average}} \sqrt{\frac{D_1C_1 + D_2C_2 + D_3C_3}{H}} \quad (8)$$

Where T_1 is the time required to cross a particular road segment under free flow conditions. This is the best-suited impedance factor for real time solutions of transportation problems in Dehradun city.

4.3 Development of WebGIS Framework and user Interface

After the data processing and storing in database, a 3 tier client server architecture (Figure 11) based WebGIS application was developed for displaying the traffic information to the users. The client side interface was made using HTML and JavaScript. For the development of Client side user interface various libraries were used which are described below:



Figure 11. Client Server Architecture

4.3.1 Leaflet: Leaflet is a popular lightweight open-source JavaScript library for creating mobile friendly interactive maps. Apart from displaying maps there are many plugins available in leaflet like time dimension, custom markers and popups etc. The time dimension plugin was used in this study for time series visualization of the TD. The time dimension plugin requires a time enabled layer for proper working (<http://leafletjs.com>).

4.3.2 Google Geocoder: The address entered by the user is in text form with no spatial information. For the network routing tool, the coordinates or address of the location are needed. Geocoding is the process of transforming addresses into coordinates, which can be used in this transformation algorithm. For this Google Maps JavaScript API was used for Geocoding services. (<https://developers.google.com/maps>).

4.3.3 Highcharts: Highcharts is a JavaScript library for creating interactive charts on web applications. It supports many different types of charts like line charts, bar graphs, pie charts etc. The highcharts were used to display common traffic trends on the client side. These charts are dynamic and changes with respect to corresponding changes in TPs in database from time to time (<https://www.highcharts.com>). Using these libraries an interactive WebGIS based online interface was created for displaying traffic information.

4.3.4 Geoserver: Geoserver is an open source server and is used for sharing and publishing geospatial data on the web. It is used for creating the Web Mapping Services (WMS), Web Feature Services (WFS), etc., which are useful in displaying of the geospatial data in the WebGIS domain. The data after conversion is stored in PostGIS database. This data is published on the Geoserver along with time dimension as a WMS-T. Different styles were provided to the layers using the sld created in QGIS. The styles help to color and format the lines and point layers. (<http://geoserver.org>).

4.4 Alternate path Tool

The alternate path tool uses pgr_dijkstra algorithm for finding the shortest path in a network, which is available in pgRouting module, available under PostGIS extension. Following are some of the important spatial queries used for finding the shortest path between the multiple geolocations.

4.4.1 pgr_nodenetwork: The road network of Dehradun was downloaded from OSM (Figure 12) and was cleaned and edited properly wherever required. pgr_nodenetwork creates nodes at every intersection of road network and breaks them in smaller separate segments as shown in Figure 13.

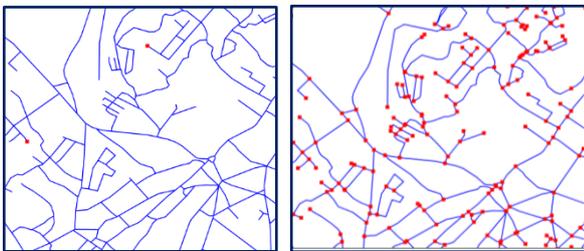


Figure 12: Road network without and with Nodes at intersection points

4.4.2 pgr_createTopology: pgr_createTopology function will create a new table which contains all the starting and ending points of the roads called as source and target. These source and target values are later used to identify the network edges.

4.4.3 pgr_dijkstra: This is used to find the shortest path between starting and ending vertex for a graph/road network with path costs. Cost can be distance, time or actual costs, which is affected by real time traffic scenarios. In this study, RTIF is used as a cost function.

4.4.4 pgr_fromAtoB: The dijkstra function requires source and destination vertex id for finding the path which is not available at most of the locations. So a wrapper function was created which converts the coordinates of the source and destination into vertex id by find the nearest node. This process simplifies the location selection and makes it more user friendly.

5. RESULTS AND DISCUSSIONS

This section highlights the results obtained in the study and are shown in different sub-sections as-

5.1 WebGIS Interface

The developed online interface created to display TD, is shown in the Figure 13. The created webpage contains the traffic information in the form of maps and tables and is visible to the users. The real time vehicle speeds are also displayed by different colours like green, red and brown, which indicates high, medium and low speeds respectively. There are four sections in the interface namely View Traffic, Data Store, View Trends and Alternate Path.

5.1.1 View Traffic: Under this subsection, users can see the TD on different times like daily, weekly etc. The users can select the option of their choices in terms of proper date & time by using attached calendar, and thus corresponding TD will be displayed. A view of this section is shown in Figure 13. Three Optional layers of hospitals, schools and Dehradun wards is also added for better information transmission. The time slider helps the user to view traffic condition at a particular time. The TD is displayed under the 'View Table' tab, which can be hidden and expanded. The actual pictures of these locations are also stored in the database, which can also be access here by clicking marker.

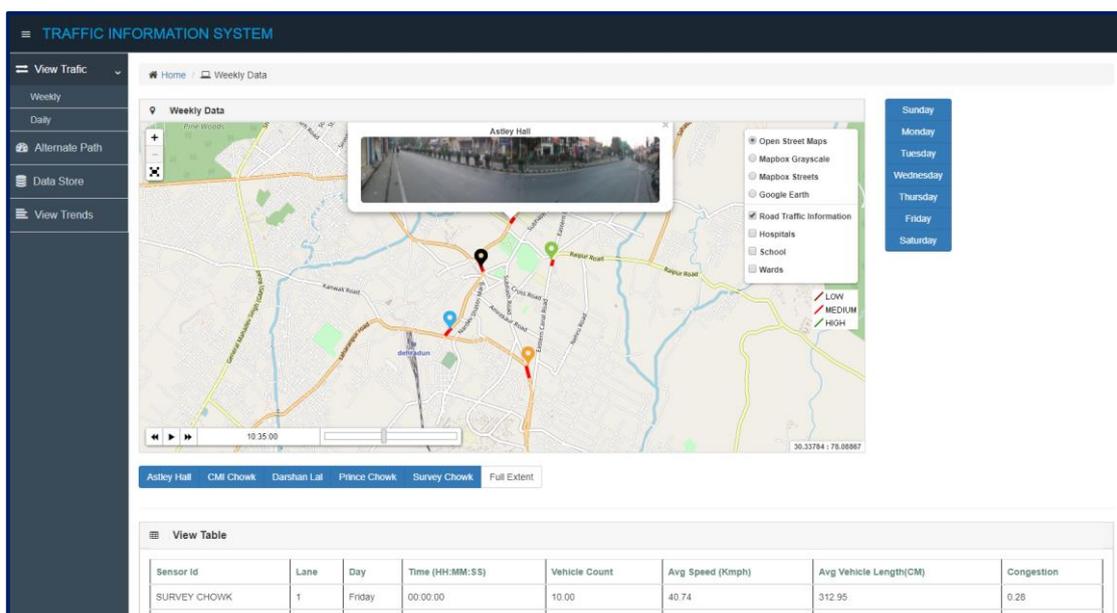


Figure 13. Traffic Information System Homepage

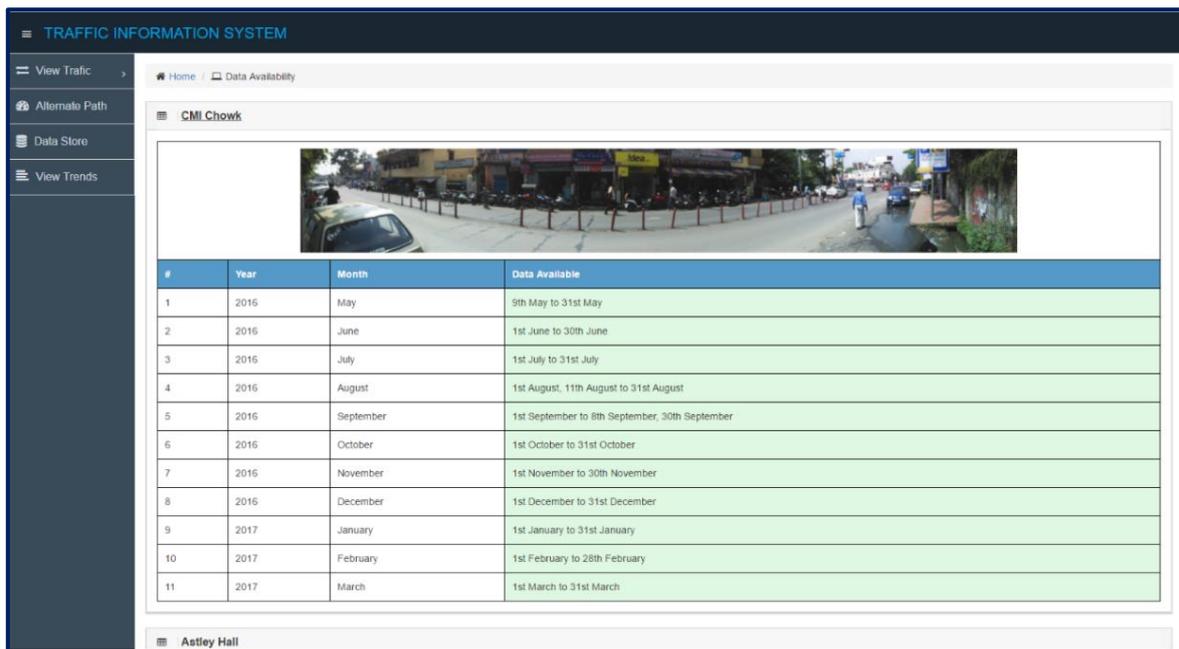


Figure 14. Traffic Data Storage in RTIS

5.1.2 Data Store: The traffic information system has real time as well as historical TD, which can be accessed in data store section (Figure 14). Store section helps to users to browse the data and check whether the data is available for that period on that sensor location. The lane-wise TD includes vehicle counts, speed, vehicle class and headway and the same can be downloaded using download option. This data will be useful for the researchers and transport departments for various planning and decision making purposes.

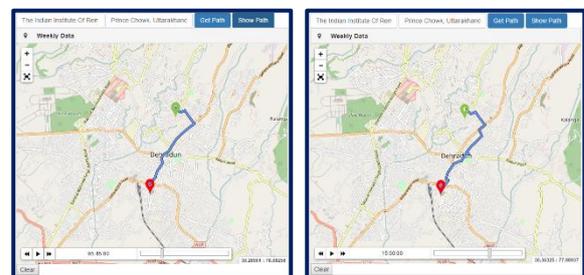
5.1.3 View Trends: The user can also view the changes in traffic conditions graphically over a period of time under the 'View Trends' section of traffic information system. In this section some common traffic trends like daily traffic count on weekdays and monthly traffic variations are shown in Figure 15. The user can zoom in/zoom out the graph and select the locations for better visualisation.



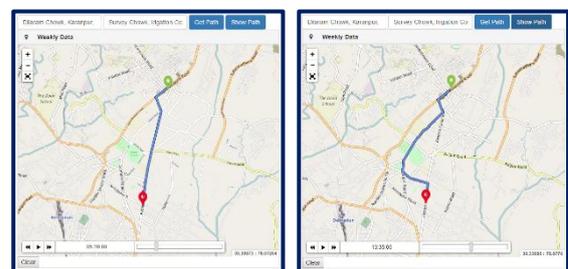
Figure 15: Visualization of Traffic Trends in the form of graphs

5.1.4 Alternate Path: The 'Alternate Path' section displays the optimal route with least actual travel time on that instant between the points of interests. Figures 16(a), (b), (c), and (d) show the shortest path between same sets of origin and destination at different times of the day.

This change in the optimal route is because of variation in real time road traffic conditions on the roads. Generally, in the morning time the traffic on the roads is small and hence the optimal path is of less distance between origin and destination but during peak hours more traffic is there on these shortest routes and hence it searches an optimal alternate route of less traffic or in other words the route of low level of real time TC.



Shortest Path Morning b) Shortest Path Afternoon



c) Shortest Path Morning d) Shortest Path Afternoon

Figure 16. Real Time Alternative Optimal Path Calculation between the origin and destination

5.2 LOC Estimation

The graph in the Figure 17 shows the variation in travel time across a road segment for full day. The travel time is high between 8 AM to 9 PM and low in the night time.

The time varies from as low as 11 seconds at night-time to 80-110 seconds during peak hours. Figure 18 shows the results obtained from the empirical LOC model, which gives estimated travel time index across a road segment during peak hours.

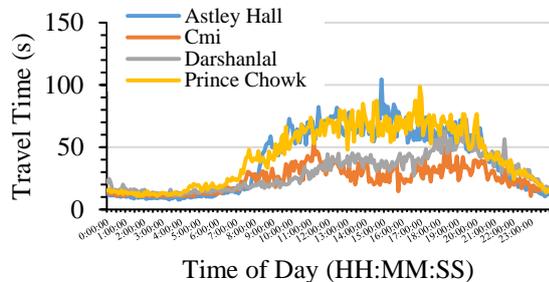


Figure 17. Variation in Travel Time at four junctions for full Day

From these values, the traffic condition on the road can be estimated as free flowing, low, medium heavy and serious jam.

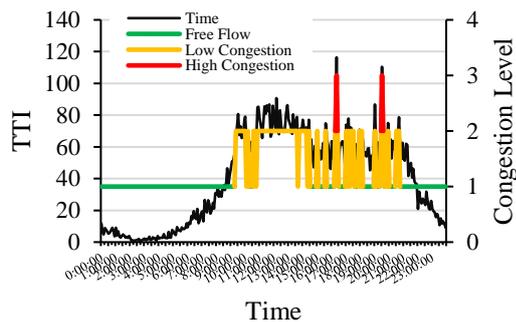


Figure 18. Congestion Levels estimated at Astley Hall for full day

6. CONCLUSIONS

Real-Time TD is an essential component of a traffic information system in order to provide real time solutions to the users particularly urban road transportation network analysis. This study presents an integrated framework for collection of real time TD and development of a real-time traffic information system for TD analyses, and visualisation of real time & historical traffic data trends in the city hotspots. ILD technology is used to collect real time traffic information, which includes multiple traffic parameters in Dehradun city at five major hotspots. The real time road TC level was estimated using a self-developed empirical model; the results of this model are very good and able to handle heterogeneous traffic conditions in Dehradun city (India). This real time RTIS is very much useful for the user departments for emergency services and planning & decision-making processes. No other such system is available in India, which handles multiple traffic information simultaneously to perform real time analysis and display of the data.

Recommendations: The performance of the ILD technique may further improved by introducing modification in design

of loops installed on the road lanes for better data collection in heterogeneous traffic conditions specially in Indian cities. There are so many urban problems like travelling salesman problem, vehicle routing problem, service areas calculation etc. can also be incorporates in this real time RTIS which will enable the system as a full fledge traffic information system to provide the real time solution of above problems.

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