Quantification of congestion using Fuzzy Logic and Network Analysis using GIS

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ABSTRACT

In India, Congestion is defined using V/C ratio. However, Passenger Car Unit (PCU) used to estimate the volume as well as capacity is subjective in nature and these are not directly measurable units. Therefore, the actual capacity of the road is not determined and thus the value of congestion becomes subjective in nature. Hence, in this project the directly and precisely measurable quantities such as Speed and Inter Vehicular Distance (IVD) are the two parameters considered for input in the Fuzzy model. The main objective of the project is to quantify congestion using Fuzzy logic and to help the policy makers and traffic managers to alleviate congestion and to help them in traffic management using Network analysis for urban and rural roads.

The study area considered for quantifying congestion is the old Mahabalipuram road (Tidel Park road). Using the 'video graphic survey method' the values for Speed and IVD are collected and substituted in the model. Totally nineteen rules are formed for the model. The results obtained from the model is calibrated and validated with the conventional method of determining congestion.

The network analysis using GIS was carried out in Egmore zone. Totally twenty-three themes are generated for the study area. The four basic network analyses such as the most direct path between two points, the optimum route between many points, the closest facility to any given point and the service areas for any facility or trade are performed in this study area. The results obtained out of these analyses can be displayed to the user either through the computer console or by the hardware board developed for this purpose.

From the above study it is inferred that the conventional way of determining congestion using volume and capacity is not matching with the actual traffic conditions. Therefore, the really measurable parameters such as Speed and IVD are some of the inputs which best quantify the congestion in par with reality. Using these directly measurable quantities, the subjectivity of the conventional method of determining congestion using V/C ratio is removed. This project combines the advantages of both Fuzzy logic and GIS to offer public, policy makers and traffic managers a new means to assess and to alleviate congestion as short and medium term measures.

1.0 INTRODUCTION

There has been a phenomenal growth of motor vehicles in India in the recent past. The disproportionate growth in the traffic vis-a-vis growth in road length, along with unauthorised encroachments on road space, lack of traffic and lane discipline and deficiencies in traffic control have contributed to the increasing problem of congestion in urban areas. In addition to increased travel time and delays, traffic congestion increases air pollution due to vehicular emissions.

There is no consistent definition of congestion in terms of a single measure or set of measures that considers severity, duration, and spatial extent. Measures related to travel time and speed are the most flexible and useful for a wide range of analyses. Congestion can be defined as follows.

- Congestion is travel time or delay in excess of that normally incurred under light or free flow travel conditions.
- Unacceptable congestion is travel time or delay in excess of an agreed upon norm. The agreed upon norm may vary by type of transportation facility, travel mode, geographic location and time of day.

Research organization and technical bodies have recommended standards and specifications for all design parameters to the generalized situations. But the congestion severity on an urban road is affecting the general design condition in a diverse ways and the recommendations become ineffective. The type and intensity of congestion depends on many quantifiable factors such as volume, speed, headway, ratio of slow moving and fast moving vehicles etc. In this context, the quantification and evaluation of congestion severity has been taken as an important research to give a modification to the generalized design procedures and also to suggest the remedial solutions for releasing congestion. In this study an approach is given to identify the suitability and type of technique that can be effective and also a model is built to quantify the congestion using fuzzy logic.

Fuzzy set theory is based on a set theory, which allows for the vague boundary of a set, and thus, it enables the analysis of problems involving ambiguity & uncertainty.

"*As complexity rises precise statements lose meaning and meaningful statements lose its precision*"- Zadeh's law of incompatibility.

2.0 QUANTIFICATION OF CONGESTION USING FUZZY LOGIC

- Quantification of Congestion is done using Mat lab (fuzzy tool) software with Speed and Inter Vehicular Distance (IVD) as inputs. The ranges for Speed are set based on IRC 106:1990 guidelines and IVD are calculated from the Green shields formula given below.
  S = 21 + 1.1 V, Where S = Spacing in feet and V = Speed in M.P.H
  In this study, this formula is converted to S.I Units and reframed as follows:
  S = 6.42 + 0.21 V
  Where S = Spacing in meters and V = Speed in KM.P.H
  Using this equation the ranges are mathematically fixed for the inputs in this model.
- Based on the above values, the membership functions (ranges) for the inputs are defined in linguistic variables (i.e. in words rather than numbers).
- The rule base (user defined conditions) was developed using nineteen rules in the rule editor. Actually 25 rules are applicable to this model, since some of the rules are not existing in reality; they are removed from the model (e.g. When Speed is VHigh and IVD is Vlow the Congestion can't be defined, since these are not possible in reality). Then the output 3D surface is obtained from the model. If there are any spikes in 3D surface, it indicates errors in the model. These errors can either due to rule base or due to membership values. The errors in the membership functions and rule bases are corrected by the trial and error method. Therefore, if a user enters the value of Speed and IVD, the model displays the level of congestion.

The above equation is based on the assumption that all vehicles travel at the same speed and are spaced at equal intervals. This formula provided a basis for measuring capacity in relation to speed and spacing, relying mainly on the empirical approach wherein relationships between two or more variables were developed from field observations. There are totally 19 rules framed for this model. The rule viewer through which the values of congestion is obtained .

From the analysis and results it is inferred that the output obtained from fuzzy model is depicting the real time dynamic nature of the traffic congestion. Hence, the model is validated for its reliability.

3.0 NETWORK ANALYSIS USING ARCVIEW GIS

- To help the policy makers and traffic managers for Route Optimisation and other network analysis, the Orthophotos (1:3000) were used. The Road network and other features (Banks, Hospitals, Hotels etc.) were manually digitized from the traced map using ArcView3.2 GIS software and fed in the format acceptable to the system. The Coverage was then converted to Arc/Info format and digitization errors were rectified.
- The coverage was projected and transformed. The various transportation attributes like length, name of the road, type etc was fed into the system. Alternate routes are drawn based on the given user conditions and impedance on each links using ArcView3.2 Network Analyst.
- The output such as locating the closest facilities, the Optimum Route between any two points, to build service areas and to find out drive time analysis are derived. Output is presented in the form of maps.

3.1 Arc View Network Analyst

The Arc View Network Analyst extension enables users to solve a variety of problems using geographic networks (i.e., streets, highways, rivers, pipelines, electric lines, etc.) such as finding the most efficient travel route, generating travel directions, finding the closest facility, or defining service areas based on travel time. Arc View Network Analyst adds an integrated graphical user interface providing access to the network modeling capabilities.

The study area selected for the research work is Egmore Zone in Chennai City. The base map is collected and digitised for creating layers of road networks and other accessories. Topology is created between spatial and non-spatial data. Through shortest distance, the traveller is guided with traffic information's. Thus the traffic information will be passed on to the user using GIS technique

3.2 The most direct path between two points

The Arc View Network Analyst extension enables to solve a variety of problems based on geographic networks (e.g.., streets, highways, rivers, pipelines, utility lines). It solve problems such as finding the most efficient travel route across town, generating travel directions, finding the closest emergency vehicle or service facility to an incident, or defining service areas or sales territories based on travel time.

The direction guideline is given below.

Starting from Graphic pick 1, Turn right onto Poonamalle High Road, Travel on Poonamalle High Road for 34.62 m, Turn right onto Gengu Reddy Street, Travel on Gengu Reddy Street for 316.73 m, Turn left onto Poosala Gangu Reddy Street, Travel on Poosala Gangu Reddy Street for 141.17 m, Travel on for 175.38 m,Turn left onto PCO Road, Travel on PCO Road for 11.87 m, Continue straight onto Vengu Pillai Street, Travel on Vengu Pillai Street for 216.12 m, Turn left onto Halls Road, Travel on Halls Road for 22.71 m, Continue straight onto Gandhi Irwin Road, Travel on Gandhi Irwin Road for 576.70 m, Turn right onto Kennet Lane, Travel on Kennet Lane for 357.75 m, Turn right onto Pantheon Road, Travel on Pantheon Road for 92.75 m, Turn left into Graphic pick 2. Total distance traveled is 1945.79 m

3.3 The optimum route between many points

Improve the efficiency of the operations by finding the best routes around town or across the country. Delivery locations can be added by interactively pointing at locations, using mapped locations, or even geocoding an address or street intersection on the fly. The Arc View Network Analyst can even reorder the deliveries optimizing their order as needed.

It can find the best routes based on the shortest distance or time between where we are and where we want to go. It can even find the best routes during rush hour and at midnight, by changing what "cost" the network should use to route on. "Cost" refers to how "expensive" it is, typically in terms of time or distance, to travel from one point to another. To solve the problem it need clear directions. The Arc View Network Analyst allows the user to generate detailed directions along the route, providing as-you-need-it solutions for common problems.

3.4 The closest facility

It eliminates guesswork and locates the closest available resource at a moments notice. Dispatch the closest vehicle to a location, or find the nearest valve in critical situations. Weight the user's decisions on the information that matters most to them: costs, time, and distance. Locate the closest facility(s) by time or distance. The user can even have the Network Analyst report the closest 5 facilities within a 10-minute drive. The Network Analyst will avoid construction and other obstacles as needed as well, providing the best solution for the user.

3.5 Build Service Areas

To find out what areas and who are the service provider based on the location. It creates a service area around the facility, defined by distance or time. It plans for the future by examining where the "holes" are in existing services. Analyze customer profiles by overlaying planned service areas and census information, showing the areas of potential growth. It also builds travel areas that can be served by the facilities (e.g., in 5, 10, or 15 minutes).

3.6 Drive time analysis

The Arc View Network Analyst includes the ability to create clear directions customized to suit the user needs. The user can also specify what data to use when generating directions and what distance units should be used in the directions. An important feature of the Arc View Network Analyst is the ability to use additional landmark points within the directions. The directions will include these additional data features, resulting in clearer, easier to understand information. Arc View Network Analyst can also do point-to-point routing (known as mid-arc routing, as opposed to

endpoint-to-endpoint routing) and can reference local landmarks when reporting route directions. The geographic network data can be based on Arc Info coverage's, shape files, or CAD drawings. Arc View Network Analyst also includes a suite of more advanced network analysis tools that can be accessed through Avenue requests. Developers will be able to deliver very sophisticated network analysis applications based on these extended capabilities.

3.7 Answering Based on Different Criteria

The Arc View Network Analyst can use any cost field for its calculations. This means the user can solve the questions based on drive time, street length, traffic conditions, or any of a number of criteria. This allows the user to move beyond simple distance based routing and make use of the additional information available today.

3.8 Build Custom Solutions

The Arc View Network Analyst adds additional functionality to Arc View and Avenue (Arc View's robust object oriented scripting environment). The user can build complete customized solutions from simple tools to complete applications using the power of Avenue and the Arc View Network Analyst.

4.0 CONCLUSION

The crux of the problem of urban transport is congestion of traffic. This results in increased number of trips, increased journey time, travel cost, mental agony and reduced accessibility. Widening of roads is not possible due to the intense developments on either side of the road. Heterogeneity of the traffic is the perpetual problem, which cause severe congestion. This project combines the advantages of both Fuzzy Logic Technology and GIS. It offers public a new means to access spatial information without owning expensive GIS software. It can also facilitate spatial data sharing within transportation agencies and between transportation department and other government agencies. Thus helps the commuters to plan their trip in advance to save time and energy.

Hence, this project gives a methodology to quantify congestion using fuzzy. In essence fuzzy logic opens the door to computers that understand and react to the language and behaviour of human beings rather than machines. From this study it is able to understand that, the present system of defining congestion using V / C ratio is not matching with reality. Thus, the fuzzy logic model helps us to alleviate congestion in the short-to medium-term.

Cars and traffic control systems can make use of the vague information derived from the natural environment that in turn can be fed into "expert" systems and so provide accurate recommendations to vehicle drivers, the police, motoring organisations and of course, local authorities. The effect such systems will have on the traffic scene is too early to say, but clearly they will give planners and traffic authorities some breathing space when considering long-term objectives and likely solutions.

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