GIS FOR TRANSIT ROUTE INFORMATION

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Abstract

Transit capacity is arguably more complex than highway capacity. It deals with movement of both people and vehicles, depends on size of transit vehicles and how often they operate, and reflects the interaction between passenger traffic concentrations and vehicle flow. Quality of service reflects the transit-user perspective and should be measured by a quantitative measurement or prediction of how a transit route, facility, or system is operating under specified demand, supply, and control conditions. Thane city in Mumbai Metropolitan Region of Maharashtra State, India is the study area for this work. The GIS database for Thane was established by geo-referencing through GPS and digitisation of satellite imageries. Various toolboxes for transit service quality measures have been developed in TransCAD, a transportation-planning package in GIS platform. The code for all the tools is written using GIS Developer's Kernel available with TransCAD. All the above tools are developed as add-ins in TransCAD. This paper presents the details of various tools of transit service measures developed as a part of transit route information system. It is concluded that the developed GIS tools for quality of service will become more meaningful if the geographic data is digitized at dwelling unit level.

Keywords: Geographical information system (GIS); Multi modal route system; transit capacity and quality of service
Topic Area: B1 Public Transport and Intermodality

1.Introduction

Over the past half a century, highway systems all over the world have helped to develop regional and national economy by enhancing access for goods, services, and people. They have given us easier access to both work and leisure. But the traditional model for surface transportation is reaching its limit. In many areas systems are operating at or beyond capacity. Because of space and budget constraints and environmental concerns, building new and bigger roads is not the answer. As in most areas, personal vehicles dominate transportation. Traffic in metropolitan areas frequently slows to a crawl as too many vehicles pour onto the streets and highways. The task of providing effective transportation choices to accommodate our current and future growth has become increasingly complex. The rapid development of residential suburbs past the outer reaches of our urban areas has forced to depend exclusively on personal vehicles for transportation. Increasingly, traffic congestion and delays are spreading to more streets and highways, not only during rush hours but also during non-peak hours.

With the on going severe traffic congestion problems, the need to attract automobile users to public transit is very much evident and needed. However, achieving this concept is more easily said than practiced, unless some changes can take place to improve drastically the public transit services. In the developing countries overcrowding, excessive waiting time, long and inconsistent travel time, poor and unreliable services are usually observed in bus transit system. Not to mention their own internal problems, as such, the need to improve the operational performance and standard of the bus services is urgently required. The level of service technique and performance indicator analysis technique can be applied as diagnostic tools to identify operational inefficiency and ineffectiveness at the route level and network level. This type of analysis is a routine practice by many transit agencies in the developed countries for monitoring, reporting and developing strategies to improve the transit performance. However, no attempts have so far been made to utilize this indicator analysis in developing countries. This paper deals with the measurement of quality of public transit services in GIS environment.

2. Quality of service measures

Transit capacity is arguably more complex than highway capacity. It deals with the movement of both people and vehicles, depends on the size of the transit vehicles and how often they operate, and reflects the interaction between passenger traffic concentrations and vehicle flow. Quality of service reflects the transit-user perspective and should be measured by a quantitative measurement or prediction of how a transit route, facility, or system is operating under specified demand, supply, and control conditions. Each quality of service measure has been divided into six levels of service, representing ranges of values for a particular service measure. The quality measures of urban transit can be placed in two strategies as transportation hygiene factors and level of service indicators (Alter, 1976). Different elements of a transit system require different performance measures as listed below.

2.1 Transit stop

A bus stop is an area where one or more buses load and unload passengers. From the user's perspective, frequency, which comes under measures of availability, determines the number of times an hour a user has access to the transit mode, assuming that transit service is provided within acceptable walking distance and at the times the user wishes to travel. Frequency LOS can vary by time of day or week: for example, a service may operate at LOS B during peak hours, LOS D midday, and LOS F at night. In GIS, one can easily determine the frequency of a particular stop using macros and Add-ins of GISDK for any transit facility. From the passenger's perspective, passenger loads (Measures of quality) reflect the comfort level of the on-board vehicle portion of a transit trip both in terms of being able to find a seat and in overall crowding levels within the vehicle (Bakker, 1997). GIS software can be effectively used for calculating passenger loads at transit stops in the form of map wizards and themes.

2.2 Route segments

Hours of service which comes under measures of availability, also known as "service span," is simply the number of hours during the day when transit service is provided along a route, a segment of a route, or between two locations (Transit capacity and quality of service manual, 2000). It plays as important a role as frequency and service coverage in determining the availability of transit service to potential users. Several different measures of reliability (Measures of quality) are used by transit systems. The most common of these are: on-time performance, headway adherence (Florian et al, 1994). However, when vehicles run at frequent intervals, *headway adherence* becomes important to passengers, especially when vehicles arrive in bunches, causing overcrowding on the lead vehicle and longer waits than expected for the vehicles.

2.3 Systems

Service coverage (Measures of availability) is a measure of the area within walking distance of transit service. Since it is a system-wide measure, service coverage LOS takes more time to calculate and requires more information than do the transit stop and route segment LOS measures. This task can be simplified through the use of a geographic information system (GIS). Transit/Auto Travel Time (Measures of quality) is an important factor in a potential transit user's decision to use transit on a regular basis is how much longer the trip will take in comparison to the automobile. The level of service measure is the door-to-door difference between automobile and transit travel times, including walking, waiting, and transfer times (if applicable) for both modes. It is a measure of how much longer (or in some cases, shorter) a trip will take by transit.

3. Necessity of GIS, TransCAD and GISDK

Conventional methods of transportation and transit planning require lot of data collection, storage of the data and analysis of the collected data for the improvement of the transportation systems performance. GIS is used to validate transportation information within the organization, with the help of Intranet applications (Trepanier, 2000). There are many uses of GIS in transit, including display and analysis of bus routes, facilities, trip planning, route choices, on-time performance data, and origin and destination of ridesharing and para transit clients (Choi, et. al., 2000).

GIS also act as the decision support system to the decision makers. Public transit is one of the functionalities of TransCAD, with capabilities that greatly exceed those of other planning packages (Sadek, et al., 1999). It has special data structures for handling transit routes in all their natural complexity. Routes may be stored, displayed, edited and analyzed. An important feature is that transit routes can be directly placed on the streets so that interaction between autos and transit can be treated explicitly. We can use the software by choosing commands from the menus, clicking command buttons in a toolbar, in choosing tools from a toolbox. It displays information in four types of Windows as maps, data views, charts and layouts.

TransCAD includes geographic information system development kit (GISDK) and Caliper Script programming language. GISDK is a comprehensive development environment that allows the user to customize the software in many ways. GISDK also allows the user to launch other applications and communicate with other applications and programs written by the user (GISDK, Programmer's guide, Volume-I, 1999). This capability makes it a powerful platform for developing and testing new analytical procedures. It also provides a complete solution for the development of decision support systems. In this work all the toolboxes for transit quality of service measures have been developed in TransCAD using GISDK.

4. Study area and data set

Thane Municipal Corporation (TMC), which forms the core of the study area, comprises 11 sectors within which there are 95 municipal wards. This is the smallest unit at which planning data is currently available. The total area is 128 sq.km and the population in 2001 was16 lakhs. However, some wards in the periphery of the TMC are quite large and have sparse population. Larger wards have been subdivided into two or three smaller zones for analysis. Consequently, the travel demand in the study area is analyzed on the basis of 115 traffic area zones (TAZ) within the TMC area as shown in Fig 1. The GIS database for Thane was established by geo-referencing through GPS and digitisation of satellite imageries (PAN+LISS-III merged) of National Remote Sensing Agency (NRSA), India and IKONOS of Space Imaging. The digitized maps thus created were transformed in to intelligent transportation information system by attaching the appropriate attributes. The digital maps of TAZ, transportation network and multi modal route system (MMRS) have been generated in GIS environment using Auto desk Map and TransCAD softwares.

4.1 Highway and transit network

The integrated transportation network in the study area includes road and rail (Fig. 2); and, the multi modal public transit network shown in Fig.3 covers route system of bus, rail, intermediate para transit (IPT) and also the proposed mass rapid transit system (MRTS). All the non spatial attributes of the links were collected by network inventory, and speed and delay surveys. Link attributes collected include length, carriageway type, type of operation (one-way/two-way), number of lanes, average speed, etc as shown in Table 1. Public Transport Network includes all road links on which bus and IPT operate and rail links on which commuter rail and MRTS operate/contemplated to operate. Details of routes, frequencies, seating capacities, maximum load factor and fares for all modes have been collected and attached to the respective route layers of the MMRS. The transport network was properly connected to all zone centroids by means of dummy links. The base year transport network has 232 road links and 6 rail links. and the MMRS includes 101 bus routes, 93 IPT routes, 2 rail routes and also 2 proposed MRTS routes. The transport network for the future years were obtained by incorporating the additional links that are likely to come up.

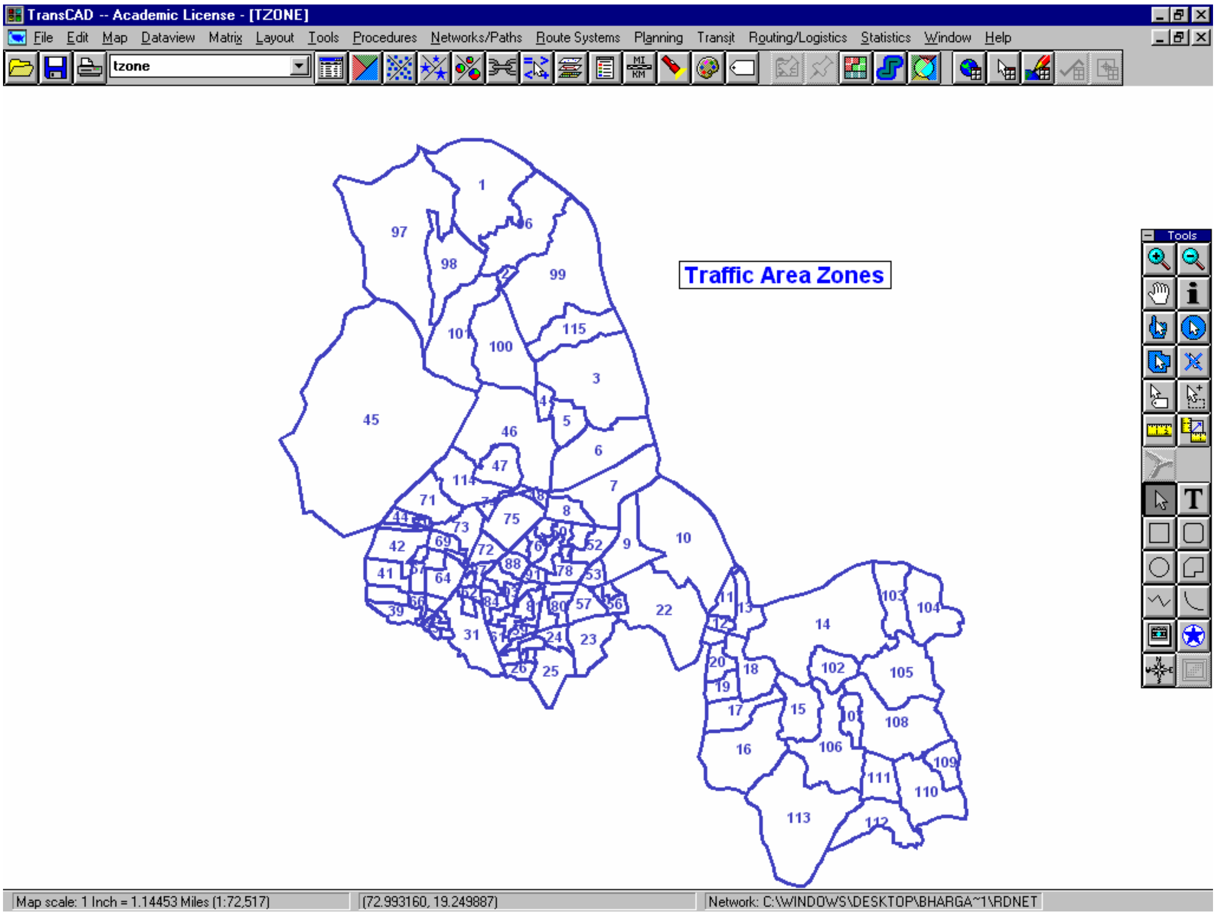

Fig.1 Traffic Area Zones

5. Preparation of route system

Routes are stored in route system. A route system is a map layer that contains a collection of routes. Every route in a route system can have data associated with it. Selected features from a regular line layer (streets, highways, railroads) are used to define the route.

TransCAD uses several files on the hard disk or file server to store information about the location and characteristics of the routes. To create the route system database for the transit planning, a geographic file containing the line layer of study area has been developed. The line layer is developed connecting all 115 internal zones and 7 external zones. This file consists of two layers, one is node layer and the other is link layer. By adding stop table to the route system file, TransCAD creates another empty layer for the stops. The next step in creating the route system is creating the network. TransCAD uses this network to find the shortest path between points we mark on the map. Route editing tools are used to add a new route, to extend or cut the existing route, to save a new route, to delete a portion of the route, to add a duplicate route, to add or to delete a stop on the route, etc. Fig.4 shows the route segments and stops created.

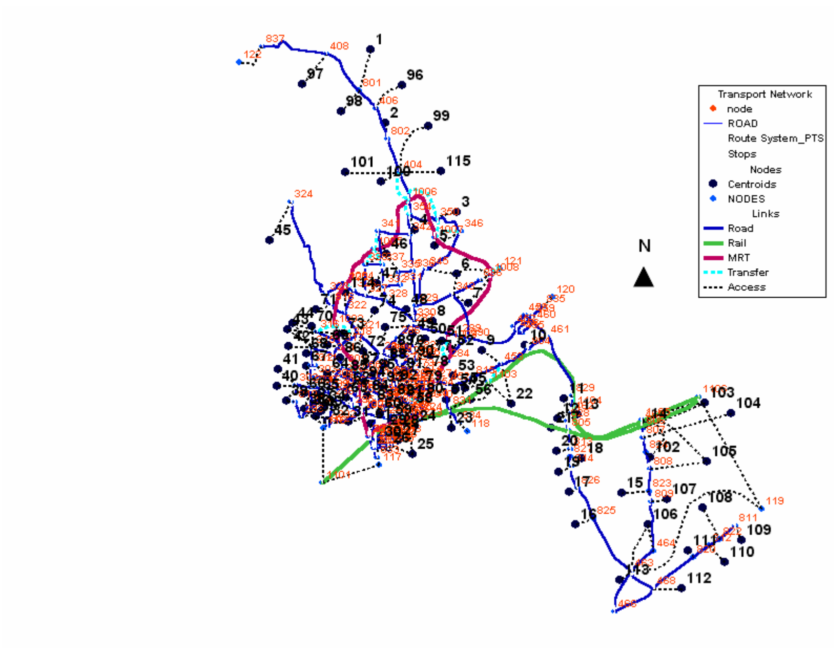

Fig 2 Integrated Transport Network

5.1 Other layers required for analysis

Along with road, node and route layer, few more layers are required for the level of service analysis. These are three separate layers of stops-buffers for the analysis of frequency of the stops and to show the origin and destination of each route; routes-buffer layer to show the service coverage area of the route system and hours of service of each route; and zone area buffer to show the population density in the area around the route system as shown in below Figs. 5 and 6. The data added to these buffer layers can be viewed as Dbase files.

5.2 Matrices

Matrices hold data such as distance, travel times, and flows that are essential for many transportation applications. Matrices used for the analysis are transit travel time matrix, auto travel time matrix and travel time from stop to stop for the created route system.

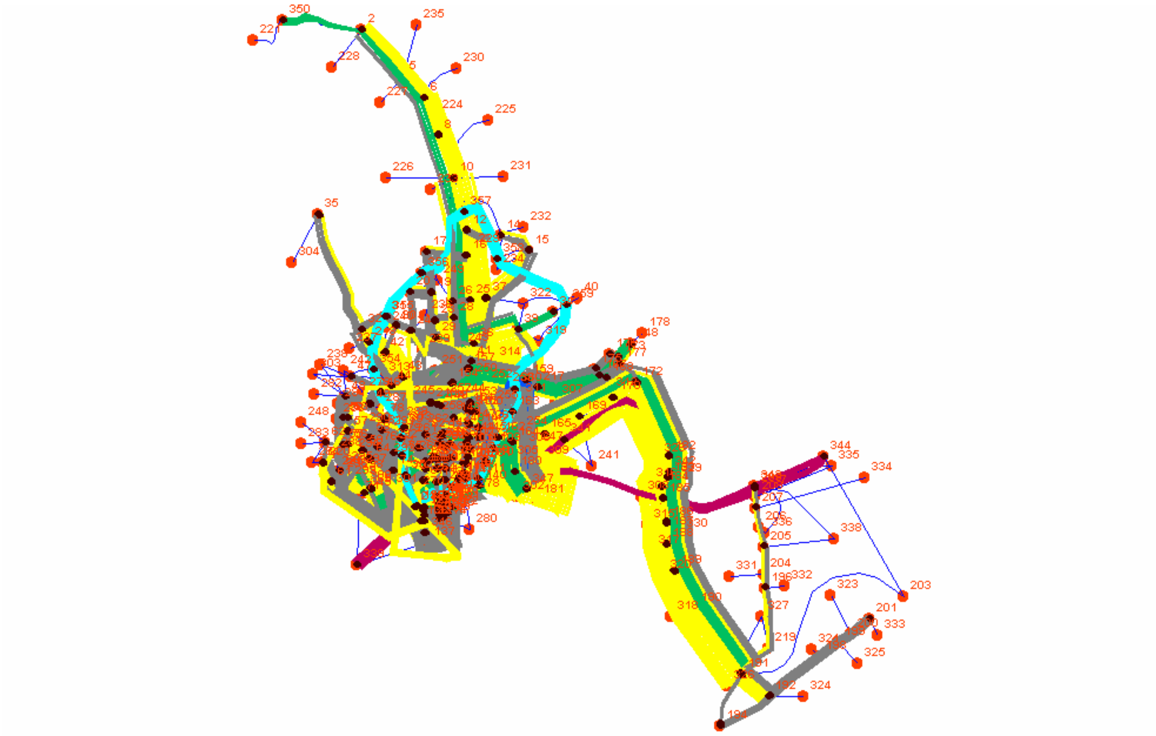

Fig 3 Multi Modal Route System

Table 1 Link Details of transport network

Link Type	No. of Lanes	Type of Carriageway	Capacity per hour(PCU)
11	Two lane	Undivided	1100
12	Three lane	Undivided	1500
13	Four lane	Undivided	2510
17	Four lane	Divided	2600
18	Six Lane	Divided	3800
19	Eight lane	Divided	6200

Table 2 Other links used in the network

Link Type	Details
20	Local train network
21	Connection from highway to local train network – walking only
22	Zone centroid to highway– walking only
23	Zone centroid to local train network – walking only
24	MRTS network
25	Road to MRTS connection– walking only
26	Zone centroid to MRTS– walking only

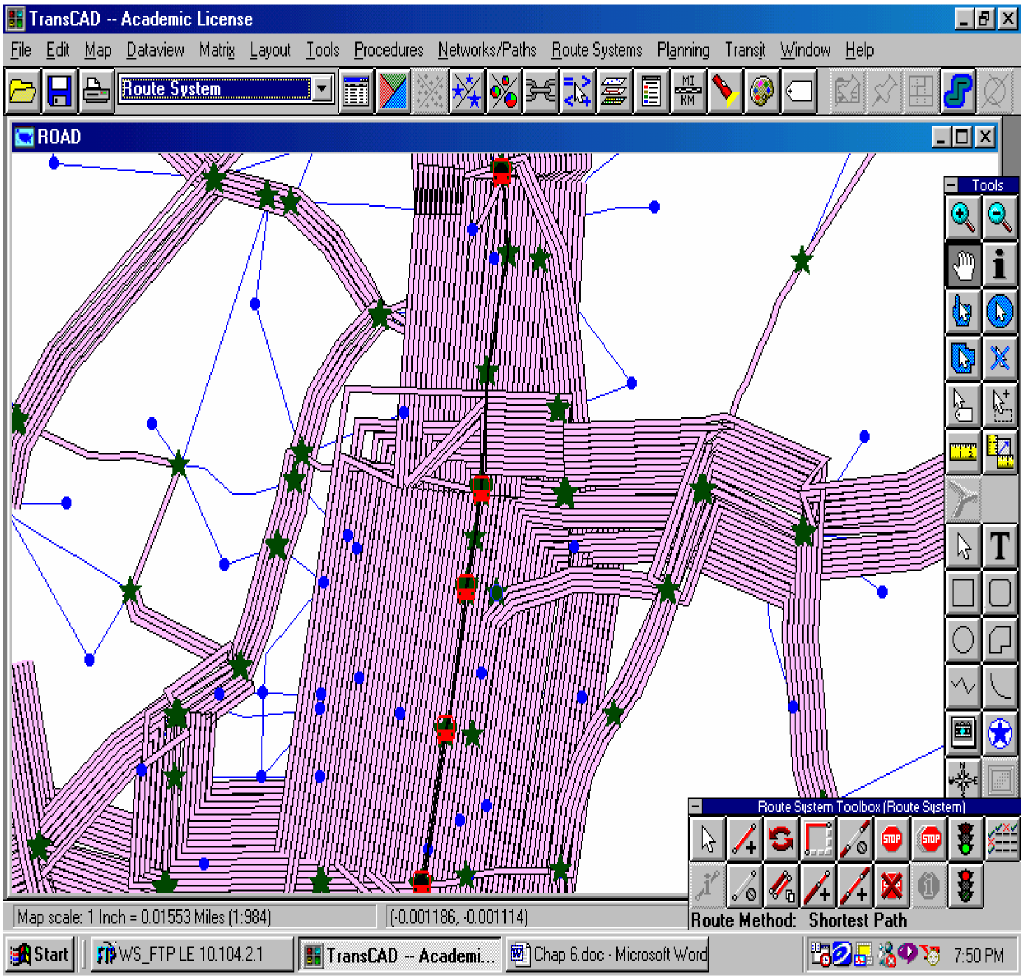

Fig 4 Route Segments & Stops of Route System

6. Transit level of service (TLOS) tool box

Transit level of service toolbox was developed for the route system created based on transit quality of service measures. This is the main toolbox that contains different buttons as shown in Fig.7. These are explained in the following subsections.

6.1 Frequency button

In level of service (TLOS) toolbox, this is a button to calculate and to visually find out the frequency at each stop on different routes according to LOS concepts and also can visually interpret and compare the results with standard frequency level of service values. By clicking this button in main toolbox, the main box disappears and “ bus route” toolbox appears on the screen. “Bus Route” toolbox contains “Routes” pop down menu and “ Get Stops” button. With this toolbox we can select a particular route from the pop down menu and get the stops on that route by clicking “Get Stops” button. This leads to the appearance of another toolbox called “Bus Stops” on the screen. It also contains one “ Stop” pop down menu, “LOS at stop” button, “Legend” button and “Exit” button. After selecting a particular stop from the pop down menu, clicking “ LOS at Stop” button gives the level of service of that stop in the form of predefined bands in the map. By clicking “ Legend” button, one can easily compare the results visually as shown in the Fig. 8. Clicking “ Exit” button will go one step back from the existing toolbox.

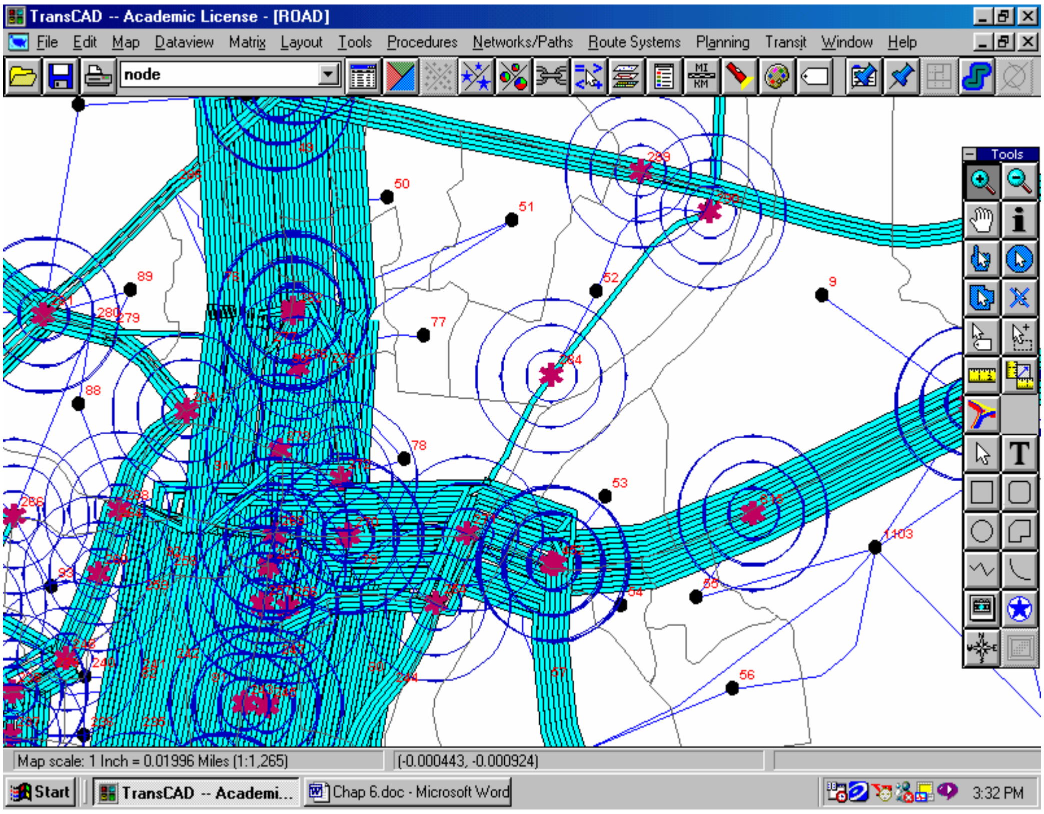

Fig 5 Stops Buffer Layer

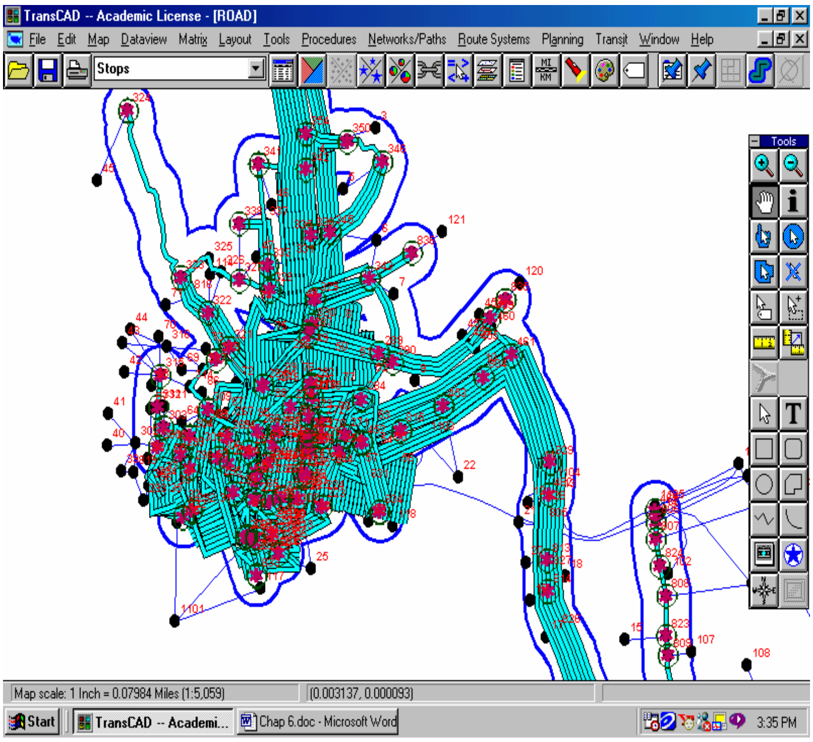

Fig 6 Routes Buffer Layer

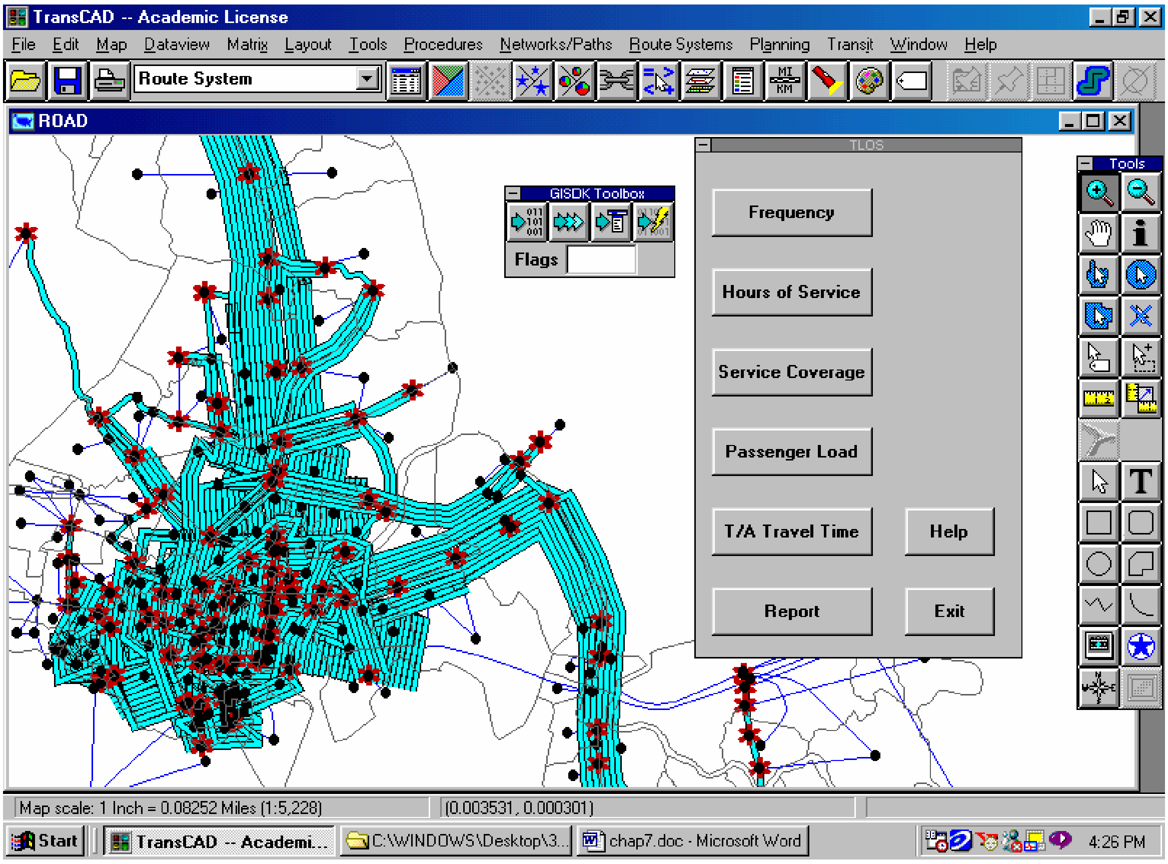

Fig 7 Transit Level of Service Toolbox

6.2 Hours of service button

This is a button to calculate and to visually find out the hours of service of each route based on headways and also can visually interpret and compare the results with standard (HOS) level of service values. By clicking this button in main toolbox, the main box disappears and “ hours of service” toolbox appears on the screen. “Hours of service” toolbox contains “Routes” pop down menu and “ Cal of HOS” button, “Legend” button and “Exit” button. With this toolbox we can select a particular route from the pop down menu. After selecting a particular route from the pop down menu, clicking “ Cal of HOS” button gives the level of service of that route in the form of predefined bands in routes buffer layer. By clicking “ Legend” button, one can easily compare the results visually with standard values as shown in Fig. 9. Clicking “ Exit” button will go one step back from the existing toolbox.

6.3 Service coverage button

In level of service (LOS) toolbox, it is a button to calculate and to visually find out the population density in the study area and to find out the Service Coverage Area (SCA) by the route system. It is found that the population served by this route system is 55.47%. By clicking this button in main toolbox, the main box disappears and “ Service Coverage” toolbox appears on the screen. “Service Coverage” toolbox is having “ Population Density” button, “Transit coverage” button, “Cal of SCA” button and “Exit” button.

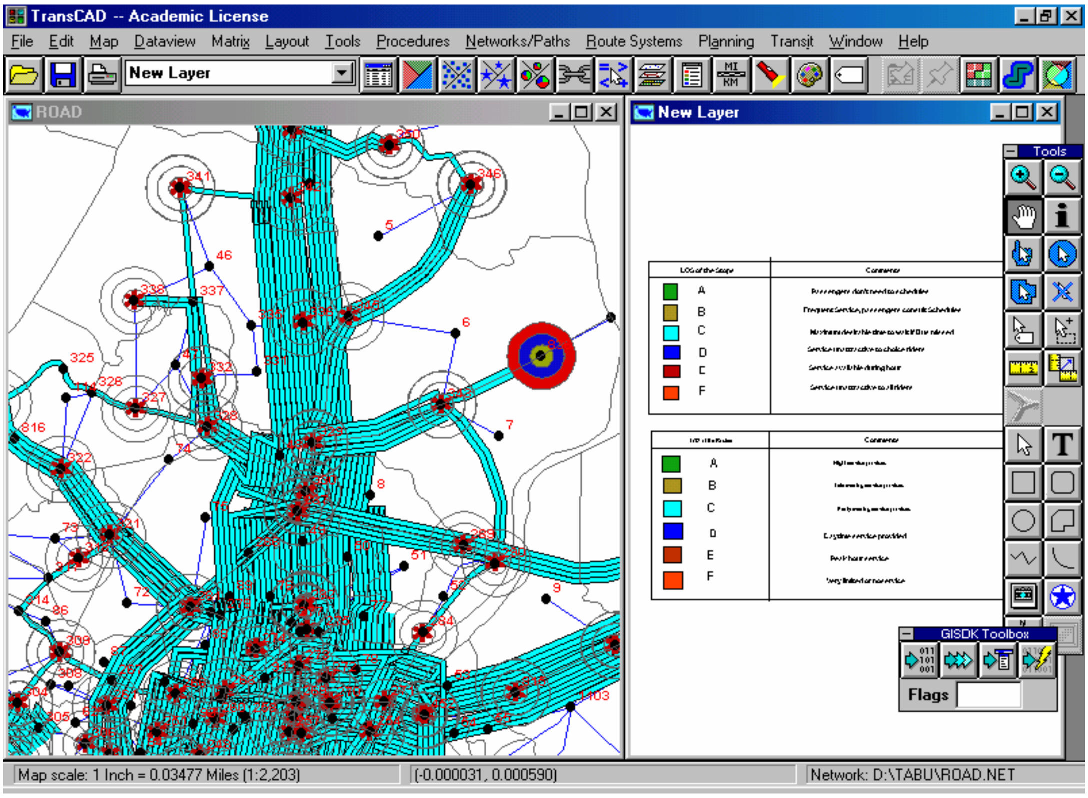

Fig 8 Frequency Level of Service Comparison

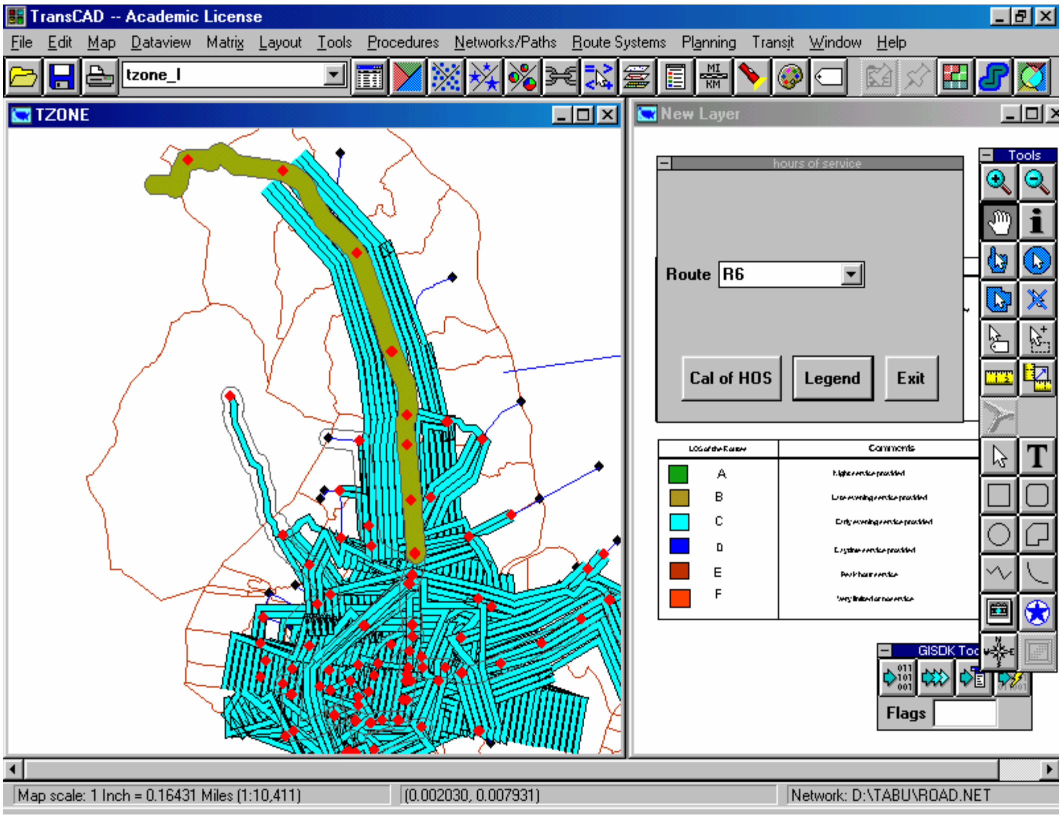

Fig 9 Hours of Service Level Comparison

With this toolbox we are able to visually see, the area covered by the route system in the form of predefined bands around the route system in routes buffer layer. By clicking " Cal of SCA" button, a macro will be activated to calculate the population covered by this system and show the numerical result and the level of service of this system as shown in Figs. 10 and 11. By using this toolbox one can create population theme on zones layer, by clicking " Population Density" button. Using these two themes, the third button calculates coverage area of the transit system. "Exit" button will go one step back from the existing toolbox.

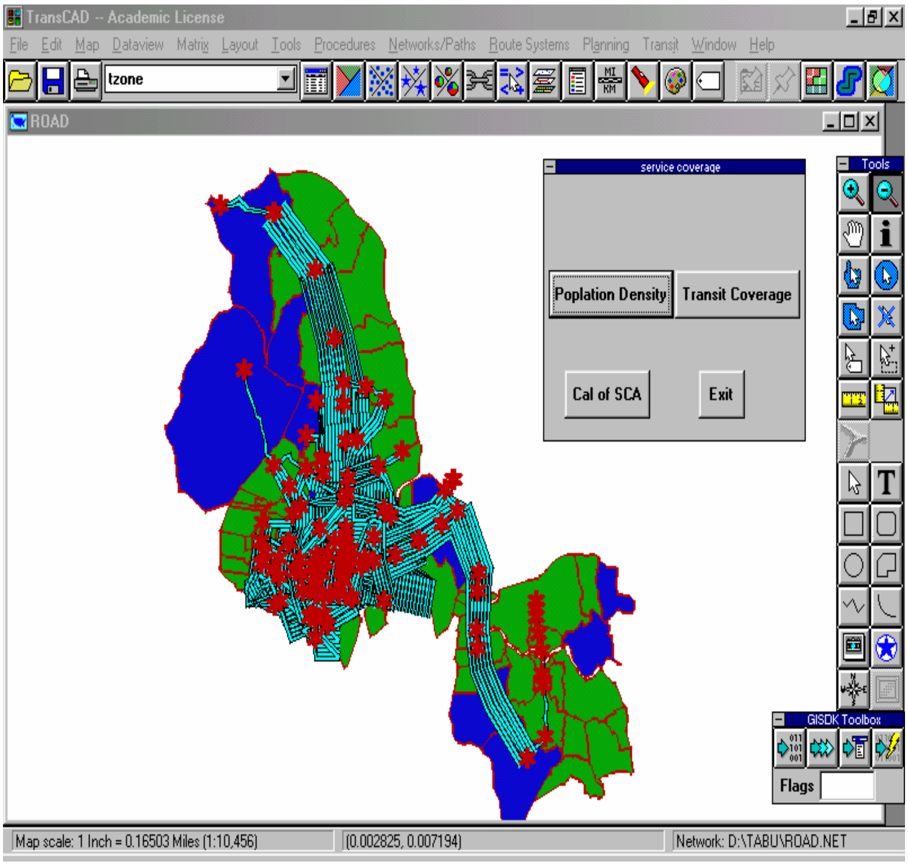

Fig 10 Population Density Theme

6.4 Passenger load button

In Transit level of service (TLOS) toolbox, this is a button to calculate the passenger flow per hour on each route and to find out the LOS of the selected route depending upon V/C ratio and passenger load rate. By clicking this button in main toolbox, the main box disappears and "Passenger load" toolbox appears on the screen. "Passenger load" toolbox contains one "Routes" pop down menu, "Transit Flow" button, "Load Rate" button, "V/C Ratio " button and "Exit" button as shown in Fig. 12. With this toolbox we can select a particular route from the pop down menu. After selecting a particular route from the pop down menu, clicking " Transit flow" button gives the number of transit riders per hour using the route from transit assignment results. By clicking "V/C Ratio" button, first it calculates the capacity of that particular route based on its headway and then calculates the V/C Ratio.

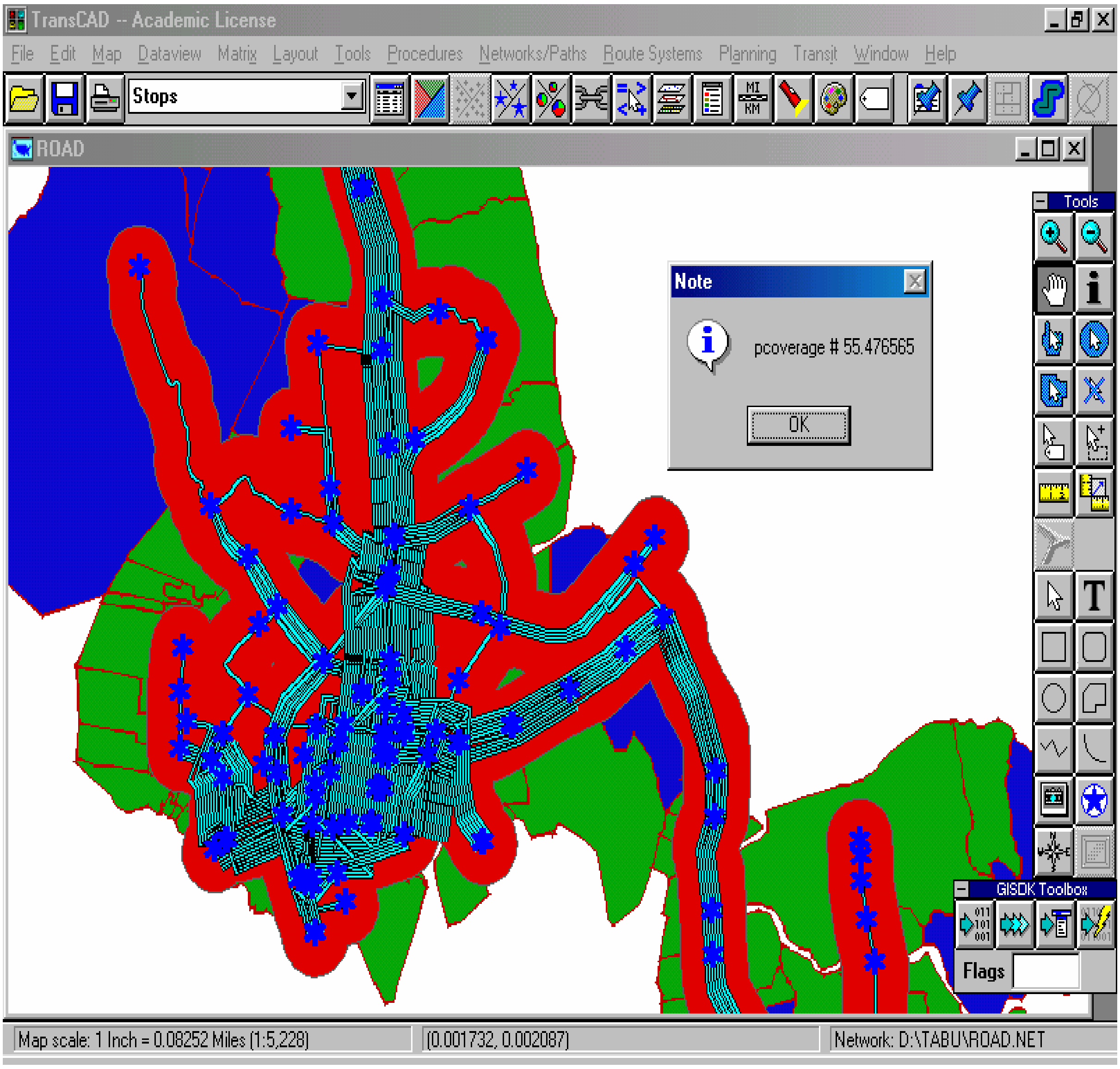

Fig 11 Transit coverage area

At the same time it also reports the level of service of that route taking LOS concepts as discussed earlier. By clicking "Load Rate" button, a macro calculates the number of passengers per bus and display the result along with the LOS of the route. Clicking "Exit" button will go one step back from the existing toolbox.

6.5 Transit and auto travel time button

In Transit level of service (TLOS) toolbox, this is a button to calculate and to visually find out the travel time difference between transit and auto vehicles on a particular route. With that difference in travel time it can also calculate the level of service of that route at system level taking LOS concepts. By clicking this button in main toolbox, the main box disappears and "Travel time" toolbox appears on the screen.

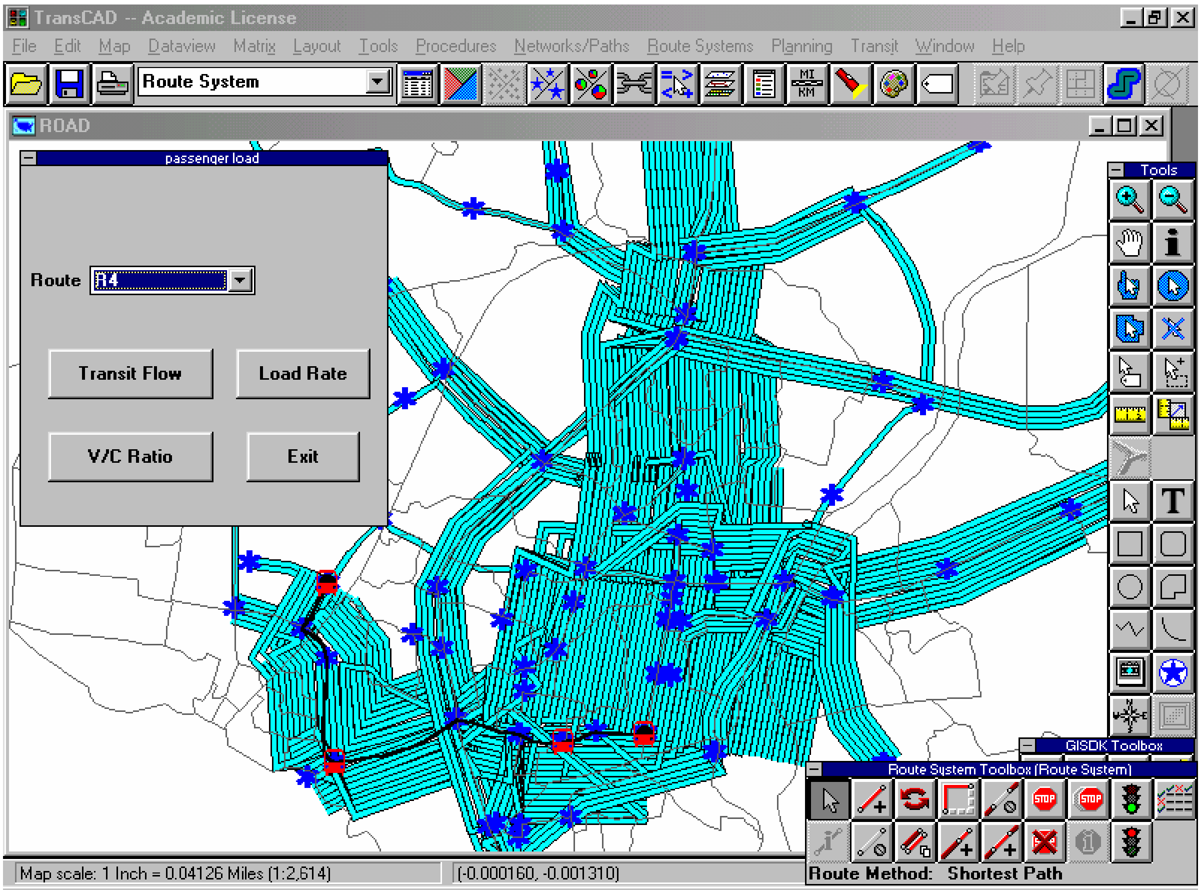

Fig 12 Passenger Load tool box

"Travel time" toolbox is having "Routes" pop down menu and "Route travel time difference" button, "Get Stops" button and "Exit" button. With this toolbox we can select a particular route from the pop down menu. After selecting a particular route from the pop down menu, clicking " Route travel time difference" button collects the information from the transit travel time matrix and auto travel time matrix. By calculating the difference in these two values and by comparing with the standard level of service values, it returns the LOS grade of that particular route. In "Travel time" tool box, clicking "Get Stops" button leads to the appearance of another toolbox called "Bus Stops" on the screen as shown in Fig. 13. It also contains one "Stop" pop down menu, origin and destination pop down menus, "Travel time" button and " Exit" button. After selecting origin and destination from the two pop down menus, clicking "Travel Time" button will give the time required to travel between those two points through transit. "Exit" button will take one step back from the existing toolbox.

6.6 Help button

Transit level of service toolbox (TLOS) also contains "Help" button to provide guidance to the transit users in calculating level of service of the route system and provides help in using different buttons.

6.7 Report button

In addition to providing a variety of maps, the TLOS tool can generate summary reports for many calculations. Clicking on this button, creates a *notepad* file on the screen and gives the information in the form of detailed report. This TLOS module is capable of generating a variety of reports that summarizes the data, including the following: Frequency LOS at selected stop, Hours of service LOS of selected route, Travel times between TAZs, Service Coverage area LOS by the route system andTransit Auto travel time LOS.

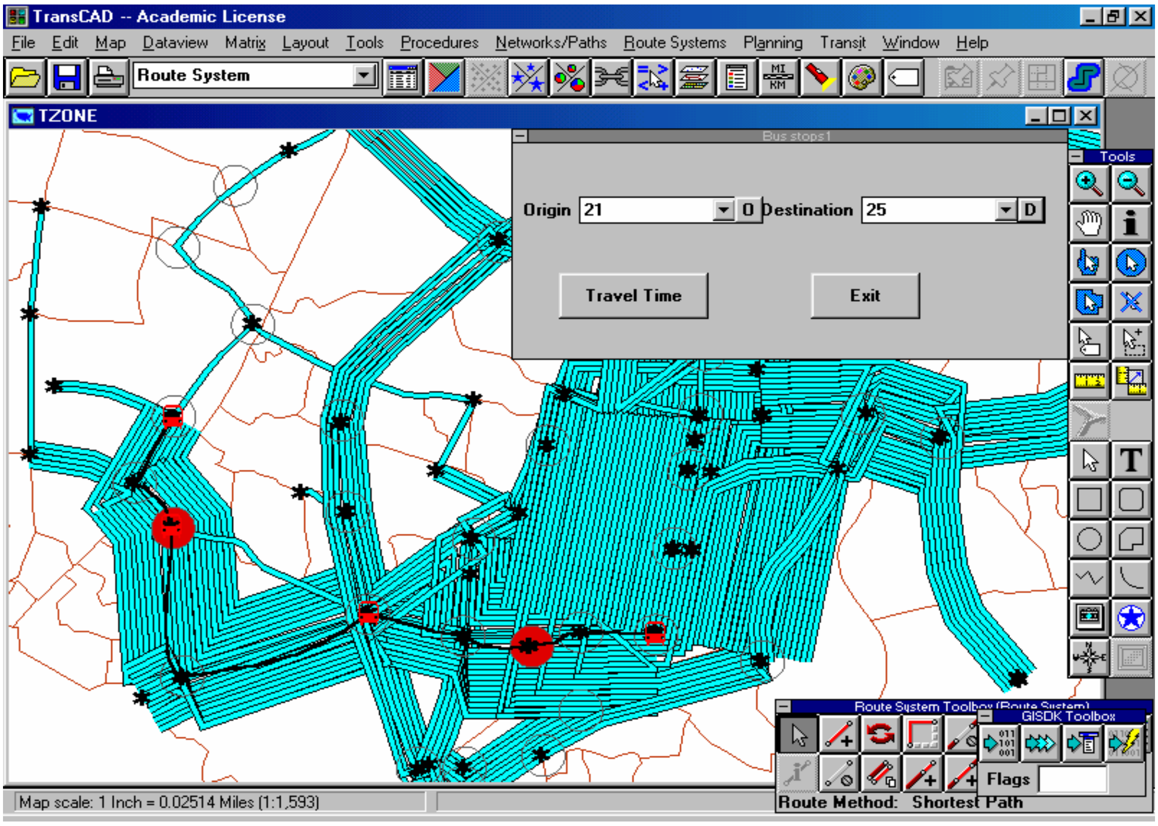

Fig. 13 Origin And Destination Stops Tool Box

7. Conclusions

Quality of service reflects the passenger's perception of transit performance. It measures both the availability of transit service and its comfort and convenience. Quality of service depends to a great extent on the operating decisions made by a transit system, especially decisions on where transit service should be provided, how often and how long transit service should be provided, and what kind of service should be provided. To decide these aspects it is essential to analyze the performance of transit routes. This type of analysis required a large database. For this purpose GIS is used to produce sophisticated analytical models or simple informative maps that enhance communication about transit services. GIS has the capacity to display and store a large amount of data, integrate data of different types, sources, and scales on a single platform. More importantly, GIS can then be used to analyze that information**.**

It has been demonstrated that how a transit level of service toolbox could be developed in GIS environment using the Developer's Kernel available with TransCAD, a transortation planning software package. The toolbox developed has different buttons and dialog boxes to calculate and to visually show the frequency at every stop, passenger loading on every route, hours of service, area coverage and travel time difference on each route, etc. Another important feature is that these modules take the results from the transit assignment wherever required. The developed GIS tools for quality of service, however, will become more meaningful if the geographic data is digitized at dwelling unit level.

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