A STUDY OF DYNAMIC TRAFFIC ASSIGNMENT USING STATISTICAL METHODS FOR URBAN SCENARIO.

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Abstract. Rapid urban growth is resulting into increase in travel demand and private car ownership in urban areas. In the present scenarios, the existing techniques have failed to match with the demands that lead to traffic congestion, vehicular pollution and accidents. Traffic congestion is a major problem in urban road networks. With traffic congestion on roads, the delay to the road users has been increased and the road networks reliability is decreasing. Before decade, four stage modelling was used as transportation planning tool to evaluate transportation facilities on the system of transportation. But this kind of planning is not enough or not applicable to cover the dynamic properties for now existing situations and conditions. Hence, there is a need of dynamic technique to be applied for the present condition of congestions. The major theme of this dynamic traffic assignment (DTA) is to manage the traffic situations in networks through real time measurement, detection, communication and control. Dynamic traffic assignment was studied for more than four decades and many of the research works are been conducted but there is a lack in dynamic traffic assignment techniques research relating to Indian scenario especially for urban road networks. In this research the survey is done through a questionnaire which is given to the VNR VJIET College of Engineering students to record their origin, destination, travel time, mode of transport. The origin is taken as JNTUH as all the trips are moving over NH 65 to reach the destination, there are two routes i.e. one is along Pragathi Nagar and another is along Nizampet route. The origin, destination, travel times, distance all these parameters are considered for the study. Travel times and the corresponding volume on the selected routes are taken and linear regression model is developed, and user equilibrium assignment and system optimal assignment techniques are analysed for the obtained equations, the number of trips and the vehicle total time is calculated.

Keywords: DTA, urban road networks, Regression analysis, User equilibrium method, System Optimal assignment.

1 Introduction:

Traffic congestion is when the vehicles on the road gets slower in their travel speed or stay in standby condition is termed as traffic congestion. This in general terms is also called as traffic jam. Traffic congestion may result in the condition like decrease in capacity levels of the road, due to the various conditions and reasons like occurrence of accidents and road diversions. The congestion is very common scenario in many cities and hence several methods are used to reduce it. Congestion levels are very higher in the many states in India especially like Kolkata, Delhi, Bangalore and Mumbai and it costs approximately to Rs1.45 crores annually according to Global Consultancy Firm studies. In Hyderabad the average traffic speed decreased from 27.1kmph to 18.5kmph as per the traffic survey due to congestions on the roads. To examine the congestion difficulties and to mitigate them, there is a need of traffic assignment models. Traffic assignment is defined as the selection of route preference between the origin and destination and vice versa. It may be also called as route choice or route assignment.

The main objective of traffic assignment are i) to estimate zone to zone travel cost

ii) to obtain the reasonable link flow to identify the highly congested links iii) the available routes between the origin and destination. The inputs that are required are i) number of routes available between the zones ii) different routes between the zones iii) travel time of each and every available route iv) a decision rule or algorithm to solve the problem statement. The outputs obtained from the results of trip assignment are i) inter-zonal trips by mode of transport ii) to predict the resulting flow on each and every link.

Static assignment is the first model or type of traffic assignment which is a deterministic model based on relation of speed and density. Static assignment is to allocate the set of drivers with fixed origin and destination on the network of roads to obtain user equilibrium and system optimal solution. In this, trips are aggregated into into time period by zone priority but are not simulated by individual. The advantages of static assignment are route choice capability, integration with travel demand models, computing very fast. The major disadvantages of static assignment are, it provides no information regarding the analysis period and aggregate trip tables.

Dynamic traffic assignment is more aggregate, neglecting and great simplifying variations in behavior and vehicle types. It can handle large networks and maintain route choice. It can simulate each vehicle continuously through time like micro models. It can be deterministic and well as stochastic. DTA is a new technique used now a days, it is of practical importance because the models have wide range of applications in the future. DTA is an active research that aims to capture the time dependent phenomena such as queue spillback, bottlenecks, temporal congestions. DTA components of travel will depend on Wardrop's principles. DTA models can be used to generate forecast of traffic that describe the congestions levels will vary with time. The data required for static and for dynamic is almost same but only the difference is DTA models require path delay operators. There are two major types of DTA models that those deploy rule- based simulations and other which don't depend on simulations but instead depend on equations and inequalities. The simulation based DTA models are very accurate and provide proper information and position of the vehicles with respect to the time. ITS and ATMIS are integrated with simulation-based modelling. This model helps in visualizing the obtained outputs. The available software for DTA modelling is DYNA SMART P, DYNAMEQ, TRANUS, AIMUSM and others, but this cannot be used because of the commercial proceedings for the simulations. The other type of DTA is based on analytical methods which uses the mathematical equations. The analytical approach considers macroscopic and microscopic traffic behavior and defined properties in terms of optimality conditions and

adhere to dynamic Wardrop's principle. The methods available are User equilibrium, system optimum assignment, frank Wolfe algorithm, gradient projection method, mathematical programming, variational inequality, optimal control theory.
This research studies the macroscopic, mesoscopic assignments of the vehicles and an attempt is made to develop a model using user equilibrium, system optimum assignment and Frank Wolfe algorithm. However, this model mentioned are majorly used to describe the traffic congestions. For this research the survey is done through questionnaire regarding the origin and destination, their travel times and travel costs.

1.1 Objectives of the study:

i. To develop a DTA model for the urban road networks
ii. To estimate the effect of different parameters on the network with respect to time
iii. To calculate the number of trips and the vehicle total time through User Equilibrium equations generated and System Optimal equations

2. Literature Study:

Few studies were made by researchers regarding the dynamic traffic assignment. Some of them are discussed as below.

Azad Abdulhafedh (2017) developed a comparison between three models. The main model offers a harmony DTA to counter the substantial clogged urban system. The model uses Dyna MIT-P re-enactment based DTA to get arrange execution estimation, for example, time subordinate streams, travel times promotion line length. The second model offer a method to find path marginal cost. DTA model that evaluate the effect of moving bottleneck and on network performance in terms of travel times and the traveling path based on mesoscopic simulation

Melissa Duell (2015) develops a model and this was the first large scale developed in Australia. This project in Australia have assembled and synthesized much data sources including the Sydney strategic travel model, the road network model, the household travel survey, the Sydney GTFS data and traffic volume count data. The research team in Sydney wanted to extend the deterministic DTA model to account for violation of day to day traffic flows.
Gaeteno Fusco (2013) involves the study of developing a QDTA model that the deals with the time dependent traffic and its demand and simulating traffic congestion on the urban road networks. This model allows to simulate several hours of traffic on large urban congested roads in very less time using standard computer. The model can produce traffic situations which is compared with the more complex simulations based DTA models.

Inchul Yang(2012) proposed a DTA model can readily applied to judge the transportation planning and operational management and investment plans regarding dynamic control strategic and advances signal coordinate system. The proposed Gradient Projection algorithm uses the Hessian Matrix in conjunctions with step sizer to obtain the better and faster convergence.
Camille (2011) proposes a model named VISTA (visual interactive system for transportation algorithm) and gives the information about the incident presence and availability of alternate routes and tom improve or enhance the incident management and to reroute the traffic from the congested zones.

Zhengu(2008) describes about a multi-class analytical DTA model. The interdependence among the user classes are modelled. The solution is depending on bi- level modelling which is designed using iterative optimizing algorithm.

Shuguang(2003) discuss about a model based on kinematic wave theory, the average queue length experienced by the vehicles entering into the link at interval K is calculated. The queue size while entering the link and leaving the link are calculated.

Henry X.liu(2002) develop a DTA model with probabilistic time and perceptions, the perceptions considered are under dynamic and stochastic networks. The model considers the risk-taking behavior of the travelers as stochastic. The solution algorithm shall be the combination of relaxation approach, stochastic network loading and methods of successive average.

Jayakrishnan(1995) studies about the modified Greenshields's equation and Bi-Level programming. The travel time are not decreasing and convex with the density therefore the link cost function is derived from Greenshields derivations and the results obtained are accurate and can be applied to different networks.

3. Methodology:

The methodology adopted for the present research is shown below

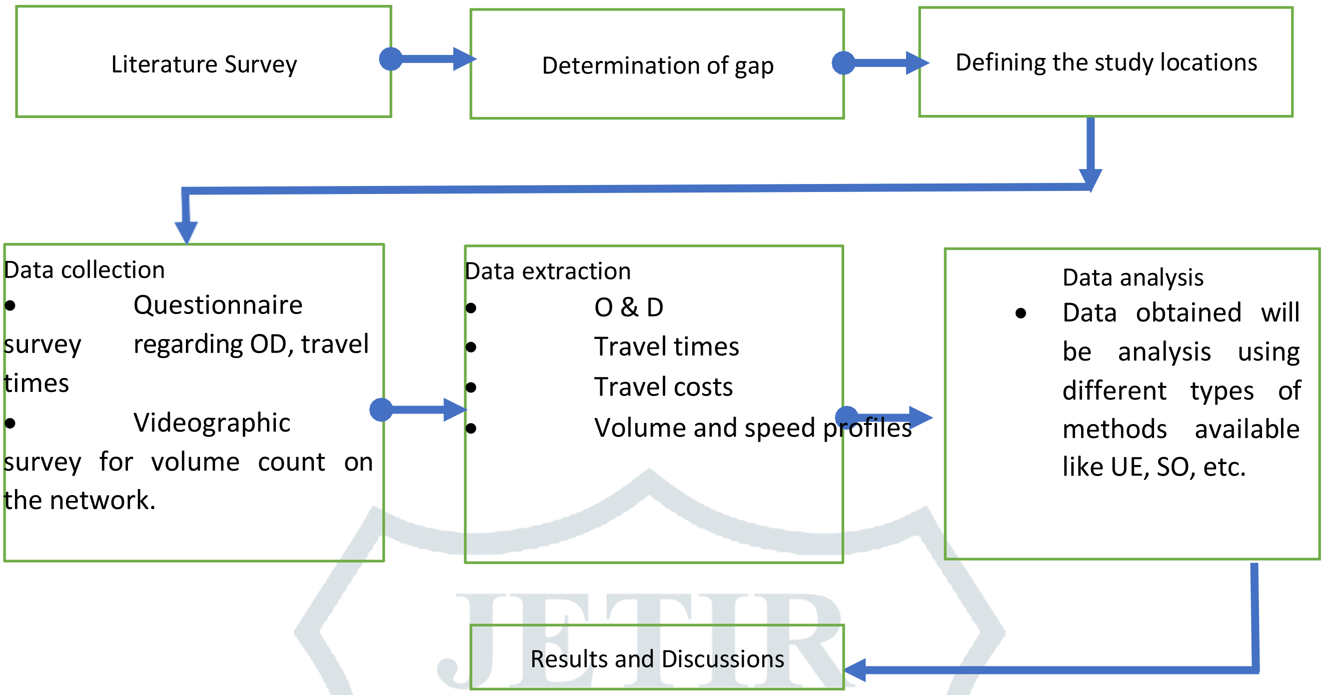

Fig.1 Schematic approach of methodology of research work

4. Data Collection:

Data is collected through the Questionnaire forms from the students of VNR College of Engineering regarding their trip details like origin, destination, travel time, travel mode, route preference. From the obtained data, the trips are categorized as per their localities, each trip is analyzed from JNTUH to VNR VJIET despite any origin. The trips between JNTUH and VNR VJIET are distributed via Nizampet and Pragathi Nagar. The locality maps are below.

Fig no.2 Pragathi Nagar location

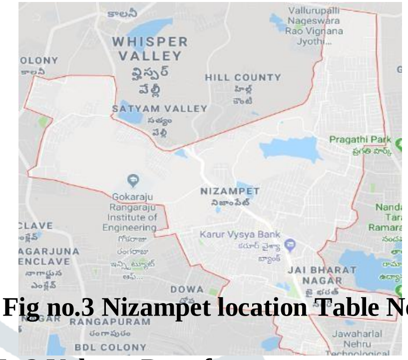

Fig no.3 Nizampet location

Table No. 1 Volume Data for Pragathi Nagar

Travel Times	Volume
10	392
13	574
15	656
17	704
18	704
20	881
23	921
25	1052
30	1224
32	1339
35	1445
40	1544

Table No.2 Volume Data for Nizampet

Travel times	Volume
10	786
15	1018
20	1342
25	1718
30	2082
35	2363

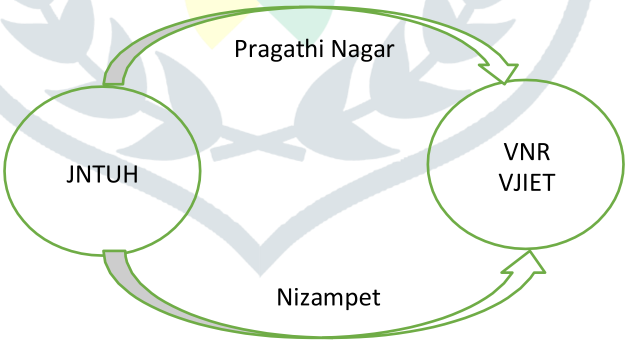

Fig. No. 4 Alternate routes for the destination from origin

The above fig no. 4 states that to reach VNR VJIET college of engineering, we are provided with two different routes i.e. one is via Pragathi Nagar and Nizampet route. The above data reflects the travel times for different averaged traffic volumes. The travel times are obtained from questionnaire survey and the volume survey is done through videography to determine the average traffic volume. The actual 5-minute interval volume is estimated from videography survey which can be represented in excel sheet attached separately along with the paper.

4.1 User Equilibrium Assignment:

The user equilibrium is based on Wardrop's first principle which defines that the no driver unilaterally decreases their travel cost by redirecting to the alternate route. User equilibrium (UE) for the O-D pair can be written as

$F_k (C_k\text{-}U) = 0$ (1)

$C_k\text{-}U >= 0$ (2)

Where, F_k is the flow on path k, C_k is the travel cost on path k, U is the minimum cost, the equation has two states,

i) If $C_k\text{-}U = 0$, from the equation 1$F_k \geq 0$. This means that all used path will have the same travel times.

ii) If $C_k\text{-}U \geq 0$, then from the equation 1, F_k=0.

This implies the every single utilized way will have travel times more prominent than least cost ways, where F_k is the stream on the way k, ck is the movement cost on way k and u is the base expense.

4.1.1 Suppositions in User Equilibrium Assignment:

i) The user should have the good knowledge of the travel cost.

ii) Travel time on a given connection is an element of the stream on that interface as it were.

iii) Travel time capacities are sure and expanding.

The solution for the above balance conditions given by the arrangement of a proportional nonlinear numerical streamlining program.

Minimize, Z= $\sum_a \int_0^{x_a} t_a(x_a)\,dx$ (3)

Subject to, Z= $\sum_k f_k^{r,s} = q_{r,s}$ (4)

$x_a = \sum_r \sum_s \sum_k \delta_{a,k}^{r,s} f_k^{r,s}$, $f_k^{r,s} \geq 0, x_a \geq 0$ (5)

Where, x_a is a equilibrium flow in link a

t_a is travel time of link a

$f_k^{r,s}$ is flow on path k connecting the O-D pair.

The equations above mentioned are flow conservation equations and non-negative constraints. The constraints hold the point to the minimize the objective function. The equations mentioned will represent the User Equilibrium principle. The total can be divided into 2 types i.e. one which carries the flow and other is which don't carry the flow along the path on which the travel time is greater than or equal to minimum O-D travel times. If the stream design fulfils these conditions no driver can better off by singularly changing courses. All the available different routes may can same or higher travel times. The User Equilibrium problem is convex because the travel time functions are monotonically increasing, and the links travel time is independent of the flow. Hence to solve such convex problem, Frank Wolfe method can be adopted further.

4.1.2 System Optimal Assignment:

The system optimal depends on the Wardrop's second principle, in which drivers incorporate with the other drivers in order to minimize their travel times of the system. This assignment can be taken as a model which minimize the congestion where drivers are asked to use the routes. But this model is not a behavioral realistic model but can be used to help the transportation planners and engineers which help to manage the traffic to minimize the travel costs, hence can obtain an optimum equilibrium assignment.

Minimum Z= $\sum_a x_a t_a(x_a)$ (6)

subject to $\sum_k f_k^{r,s} = q_{r,s}$ (7)

$x_a = \sum_r \sum_s \sum_k \delta_{a,k}^{r,s} f_k^{r,s}$ (8)

Where, x_a is a equilibrium flow in link a

t_a is travel time of link a

$f_k^{r,s}$ is flow on path k connecting the O-D pair.

4.2 Mathematical modelling:

The statistical analysis like linear regression which explains the relationship between dependent and independent variables has been used to obtain the utility function of the different routes i.e. Pragathi Nagar and Nizampet route. The obtained volume is considered as independent variable and travel times is considered as dependent variable. The graphs are plotted between volume and travel time, a linear equation is obtained through regression analysis for two routes separately and the R^2 value obtained for both the routes. Hence it is applicable to use the obtained equations. The obtained equations are replicated with user equilibrium equations.

5. Results and Discussions:

From the utility equations obtained from linear regression, the further User Equilibrium analysis and system optimal analysis are performed. The R^2 values of the utility equations obtained from the regression analysis is 0.9436 for Pragathi Nagar route and for Nizampet route is 0.9902, hence the equations obtained can be suggested to use for the analysis.

Y= 0.0258X-0.6275 (9)

Y= 0.0153X-1.0048 (10)

The equation (9) represent the linear equation for the Pragathi nagar route and equation (10) represent the linear equation for Nizampet route.

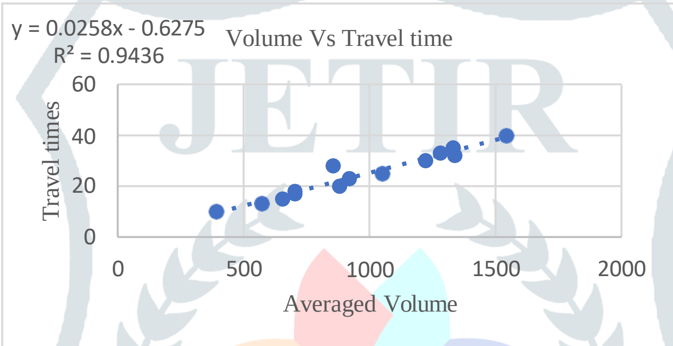

Fig no. 6 The plot made between the travel time of Pragathi Nagar route with corresponding volume

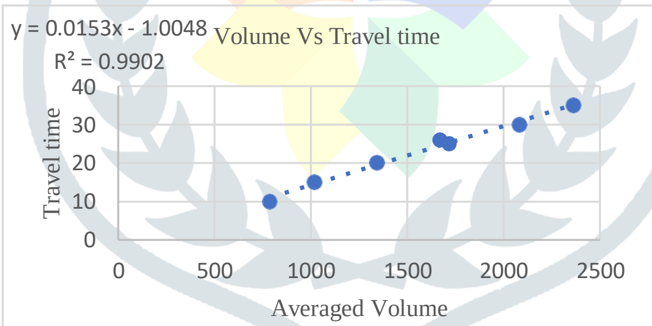

Fig no. 7 The plot made between the travel time of Nizampet route with corresponding volume

The points which make a linear trendline are only taken into consideration for the analysis.

The equations obtained are analyzed with the user equilibrium model and system optimal assignments.

5.1 User Equilibrium Assignment:

$$\text{Min } Z = \int_0^{x_1} 0.0258x - 0.6275 + \int_0^{x_2} 0.0153x - 1.0048 \qquad (11)$$

$$= 0.0258\frac{x_1^2}{2} - 0.6275x_1 + 0.0153\frac{x_2^2}{2} - 1.0048x_2 \quad (12)$$

Subject to

$x_1 + x_2 = 127$ (The total number of trips to reach the destination are 127) Substituting $x_2 = 127 - x_1$, the equation can be formulated as the following equation. Min Z = $0.0258\frac{x_1^2}{2} - 0.6275x_1 + 0.0153\frac{(127 - x_1)^2}{2}$

$$- 1.0048(127 - x_1)^2 \quad (13)$$

Differentiate the above equation x_1 and equate to 0 and obtain the x_1 , x_2 values and lead to the solution of $x_1 = 39.96$ and $x_2 = 87.03$, the values are approximated to

$x_1 = 40$ and $x_2 = 87$

The equations (11) & (12), are analyzed with the system optimal assignment model and the total travel time is obtained.

5.2 System Optimal Assignment

Min Z(x) = $x_1 * (0.0258x_1 - 0.6275) + x_2 * (0.0153x_2 - 1.0048)$ (14)

$$= 0.0258x_1^2 - 0.6275x_1 + 0.0153x_2^2 - 1.0048x_2 \quad (15)$$

Subject to

$x_1 + x_2 = 127$ (the total number of trips to reach the destination are 127) Substituting $x_2 = 127 - x_1$, the equation can be formulated as the following equation. Min Z(x) = $0.02583x_1^2 - 0.6275x_1 + 0.0153(127 - x_1)^2 - 1.0048(127 - x_1)$ (16)

Differentiate the above equation x_1 and equate to 0 and obtain the x_1 , x_2 values and lead to the solution of $x_1 = 42.68$ and $x_2 = 84.32$, the values are approximated to $x_1 = 43$ and $x_2 = 84$.

The above values are substituted in the equation (15), which give the Z(x) as 44.271

6. Conclusions:

The obtained trips from the questionnaire survey are 127 trips from different origins to VNRVJIET among which - trips are made via Pragathi Nagar and - trips are made via Nizampet. But as per the user equilibrium analysis the obtained results are 40 trips via Pragathi Nagar and 87 trips via Nizampet. The obtained values are quite opposite to that of the real time trips because the drivers are habituated to the Pragathi Nagar route, as it is the shortest among both the routes even though it has few difficulties. But, no driver can unilaterally reduce his/her travel costs by shifting to another route. Also as per the system optimal assignment analysis we obtain the total vehicle time.

The limitation of this approach is that it assumes that the travel time on the path is the function of the flow on that path but perfectly it is not the scenario because travel time depends on many other factors like number of access points, road conditions, geometric parameter, and many more. We assumed that the user has perfect knowledge of the path cost but that might not be real at all the cases as there may be a new user using the road, who doesn't know about the path cost. Further research can be done by taking few other parameters and further analysis can be done through Frank Wolfe Algorithm to obtain the solution.

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