Modelling view to reduce urban traffic congestion

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Abstract - **Urban traffic congestion is an important concern of authorities which affects the journey time of the Road users in the metropolitan cities. It is important to understand and Model the criteria of congestion and influencing factors for transportation planning especially to reduce delays and congestion pricing. This paper aims to develop an equation using simplistic method on the influencing factors of traffic congestion, such as Density of intersections, width of carriage way, Pedestrian crossings, U-Turns, available foot path space, Parking areas, Homogeneity in road network, and segregation of heterogeneous traffic. The factors chosen to develop the model are based on real time video graphic survey in the selected urban traffic corridor with a view to develop a model among the measurable factors and the factors like driver behavior, local traffic rules, pedestrian crossings and functioning of traffic control systems etc,in the background.The real data collected from different trips made on the selected roadway in the study route including Cyber towers of Hi-tech city in Hyderabad is used to practically evaluate delays and note the factors of congestion. The results show that, the density of intersections, the density of U-turns, number of pedestrian crossings, non- homogenous road network and density of Bus-stops have positive effect on travel time and delays in Hyderabad city roads. It is also observed that there is cumulative negative effect of fixed factors like Geometrics, Land Use and Road Infrastructure, and traffic parameters like headways, delays and capacity of road on travel time. In Summary, this function has a simple structure and high flexibility so that it can be used as a tool for other cities, having heterogeneous traffic.**

Keywords - **Congestion, Delay, Modelling, Traffic, Travel time, headway**

INTRODUCTION

Traffic congestion is one of the major problem related with traffic engineering and urban planning. Traffic in cities is increasing continuously especially in key cities of developing countries. The implications of traffic congestion on all kinds of road networks in the urban spheres are not only affecting the economy expressed as congestion pricing but also producing significant impact on environment and life style. The increased necessities of goods transportation and passengers, the increase in personal vehicle ownership i.e, registered over the last decade with exponential growth worldwide is demanding rapid infrastructural development to cater the needs and the increased traffic needs to frequent failures of urban transportation system resulting in delays and traffic jams.

The researchers of transportation planning have been struggling to find ways of analyzing and describing congestion which is evident from the large number of competing models and approaches that have been developed. The models developed based on fluid dynamics were found to be accurate and universally applicable in the first instance, but later it is understood that the congestion, unlike fluid flow, is not a purely physical phenomenon but indeed the result of trip making decisions by people and driver behavior that is dynamic in nature minute-by-minute. The planners must take into account the qualitative and the quantitative pace of life, characteristics of congestion and other factors. The models and policies developed on account of congestion on different road networks for the developed countries may not fit well to developing countries.

The primary objective of this paper is to propose a model with contributing and measurable elements causing traffic congestion based on real time data obtained from videographic survey with a view to develop framework for congestion relief.

The definitions of congestion from the research literature can be broadly categorized into three groups: (i) demand capacity related, (ii) delay travel time related and (iii) cost related. The definitions of congestion are (i) congestion may be defined as the state of traffic flow on a transportation facility characterized by high densities and low speeds related to some chosen reference state (with low densities and high speeds). Bovy and Salomon et al (2002) (ii) In the transportation realm, congestion usually relates to an excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower – sometimes much slower – than normal or free flow speeds Cambridge systematics and TTI et al (2005) (iii) Traffic congestion refers to the incremental costs resulting from interference among road users VTPI et al (2005).

LITERATURE REVIEW

Levinson and Lomax (1996) discussed desired attributes of a congestion index and suggested that a congestion index should (i) be easy to communicate, (ii) measure congestion at a range of analysis level (a route, subarea or entire urban region), (iii) measure congestion in relation to a standard, (iv) provide a continuous range of values, (v) be based on travel time data because travel time based measures can be used for multimodal analysis and for analyses that include different facility types, and (vi) adequately describe various magnitudes of congested traffic conditions.

Lomax et al (1997) indicate that an ideal congestion measure would have (i) clarity and simplicity (understandable, unambiguous and credible), (ii) descriptive and predictive ability (ability to describe existing conditions, predict change and be forecast), (iii) statistical analysis capability (ability to apply statistical techniques to provide a reasonable portrayal of congestion and replicability of result with a minimum of data collection requirements), and (iv) general applicability (applicability to various modes, facilities, time periods and scales of application).

Akgüngör and Bullen (2007), Kim and Benekohal (2005), Prasanna (2013), and Chaudhry and Ranjitkar (2013) are among the few researchers who compared field estimated delay with different existing models. It was observed that in case of higher degree of saturation, the HCM and Webster's methods overestimated the delay.
To cope with existing heterogeneous traffic conditions, Hoque and Imran (2007) proposed a modified Webster's formula for Bangladesh based on actual saturation flow rate. But the proposed method has been developed based on ill-conditioned data, and hence it is not reliable.
Pooja Gupta, N.G.Raval (2016) proposed a model for Ahmedabad city under heterogeneous condition which gave values near to the observed values and the delay is more due to longer cycle times.
In the recent years, Raval and Gundaliya (2012) modified Webster's delay formula for non-lane-based heterogeneous traffic condition by introducing an additional adjustment factor according to observed field delay. Results obtained were observed to be in close proximity to the field data. However, the model was not statistically strong enough as it was modified only to suit the local heterogeneous traffic conditions of a particular city. Therefore, to make the model statistically valid and widely accepted, more data from different sites need to be added and remodify it.
Prasanna and Dhinakaran(2013) measured delay in field and compared it with the HCM 2000 delay model. It was observed that delay based on actual field data was more satisfactory as compared to the HCM equation.
Other works based on Webster's and the HCM method includes studies by Dion et al. (2004), Kim and Benekohal (2005), and Varia et al. (2001). Quiroga and Bullock (1999) developed a delay method based on global positioning system (GPS) data. Delay was determined from the distance-time, speed-time, and acceleration-time diagrams for a travel time run. A linear relationship is observed between stopped delay and control delay.
Thamizh et al. (1995) developed a probabilistic method to estimate delay at three pretimed signalized intersections of Chennai, India. It was argued that the probabilistic model, unlike Webster's model, considers the variation in traffic composition over time. As a consequence, results predicted using this method are more accurate. However, the model was formulated by expanding the uniform delay equation using Taylor's expansion series, while neglecting the other terms of the delay equation. In addition to that, use of Taylor's series introduced a truncation error into the system. Therefore, the model was bound to produce errors in estimation of delay.
Sofia et al. (2014) proposed a regression model based on field data to estimate delay at signalized intersection with heterogeneous traffic. This model is based on data at two intersections of a particular city that may not represent wide variation in traffic conditions generally observed in a metro city.
Minh et al. (2010) modified Webster's method based on Taylor's series and compared it with field delay. The modified formula gave satisfactory result.
Three conclusions can be drawn from the summary of literature given previously. One, HCM and Webster's delay models have been extensively used in different countries. However, the geographical transferability of these models is in doubt as traffic conditions are different in different countries. Two, very few studies have been conducted in developing countries where traffic is of mixed nature and lane discipline is not strictly followed. Three, studies under mixed traffic conditions as observed in developing countries have the major limitation of data set and in some cases results are from one intersection only (Fawaz and Khoury 2016). This study presents the objective of developing the delay model under highly heterogeneous traffic conditions as observed in metro cities of India.
The parameters considered in the previous studies are:

Parameters involved in models

S.no	Delay model	Parameters used in model
1	Field delay by Simpson's one third rule	Queue length
2	Field delay by HCM 2010 method	Counts of number of vehicles in queue and number of vehicles stopping
3	HCM 2010 delay model	Flow rate (V), Saturation flow rate (S), Capacity (c), Degree of saturation (V/S), Platoon ratio (Rp)
4	Webster's delay model	Flow rate (V), Saturation flow rate (S), Capacity(c),Volume to capacity ratio (V/c)
5	Arpita Saha's model	Volume to capacity ratio (V/c), Platoon ratio (Rp)
6	Modified Webster's (Raval and Gundaliya's) model	Flow rate (V), Saturation flow rate (S), Capacity (c),Degree of saturation (V/S), % two wheelers

Study area

Cyberabad is a rapidly growing IT corridor with many MNC's located on the west zone of the Hyderabad city. The study area comprises of 5km radius with cyber towers junction as its centre. Two major corridors were selected for analysis of traffic scenario in the existing transport system. The details of the road network digitised through GIS mapping is presented in table no.1 An overall road network of 329.25km length is found in the subject area of 78.54 sqkm. The composition of present road network consists of BT road length of 164.34km and CC road length of 104.27 km.

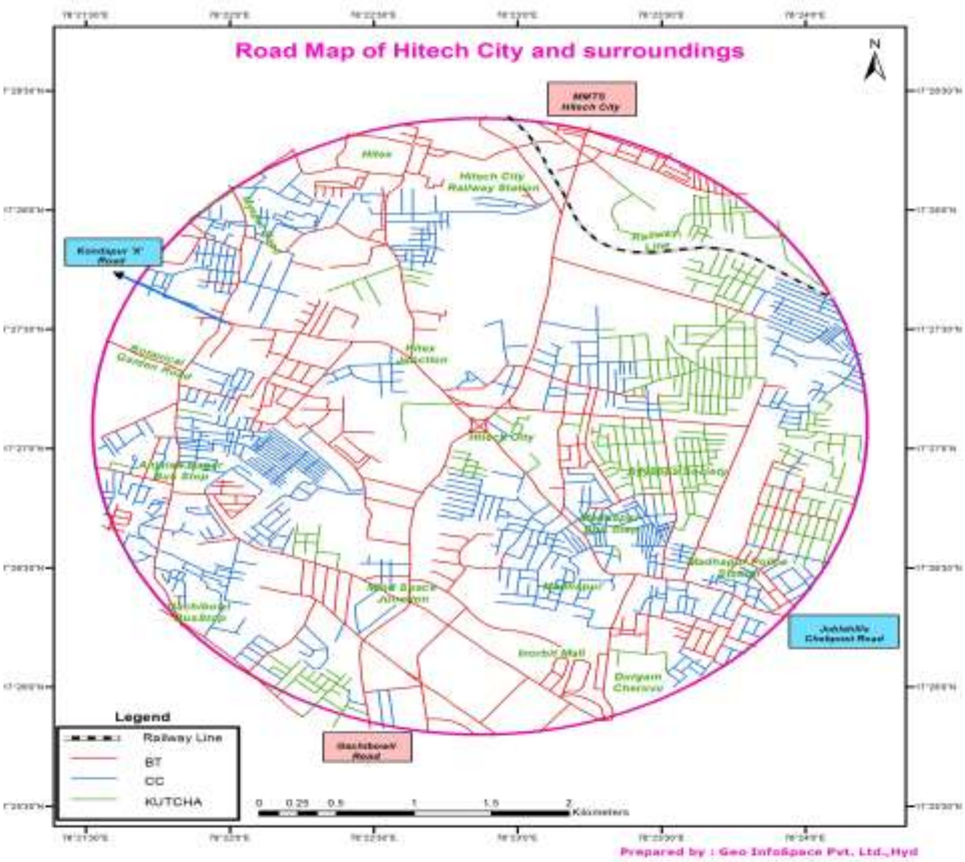


Fig.1 **Composition of Road Network**

Road widths in ft	BT – Road (m)	CC - Road (m)	KUTCHA-Road(m)
10	-	8139.695559	-
15	35.059315	3516.094518	-
20	609.962191	8506.268517	1362.427037
25	2024.493719	15816.788419	6534.605180
30	15025.431263	35351.521819	29991.219387
40	11949.279922	20823.775762	8206.410696
50	14627.799432	8431.414223	3036.380101
60	12182.146735	2199.686611	1510.909417
80	11159.728180	1482.766088	-
100	14839.102234	-	-
120	17913.338339	-	-
150	63972.043475	-	-
Total	**164338.384807**	**104268.011515**	**50641.951818**

Data Collection and Extraction

Two major routes were identified for data collection and analysis. Data collection primarily involved videographic survey to record samples on traveltime, delay and headways during peak and off peak hours of the selected route from JubleeHills to Kondapur junction via cyber towers. The delay time is recorded during each trip in the selected route using floating car method. The factors causing delay were identified during each trip to understand the input parameters for delay modelling.

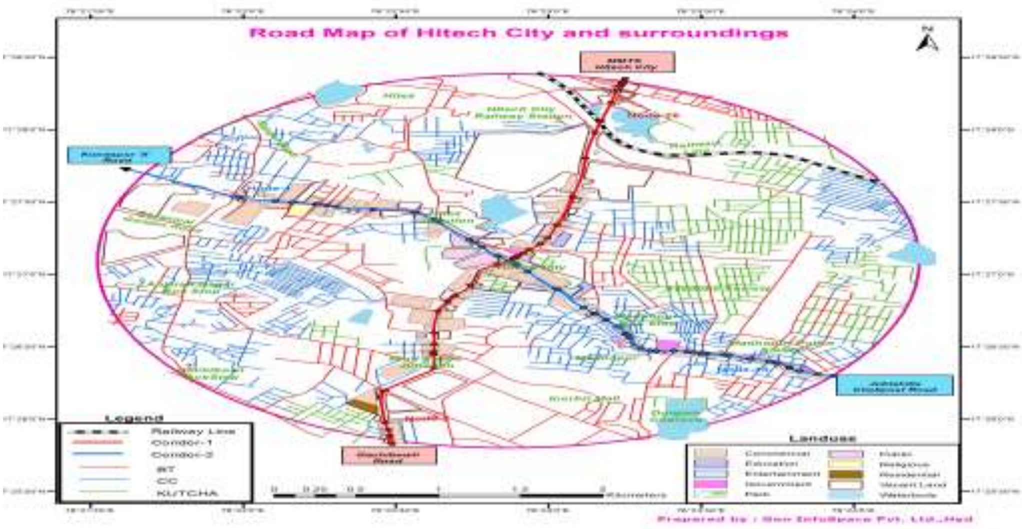


Fig 2.

Kondapur Junction to Jubilee Hills Check Post via Cyber Towers

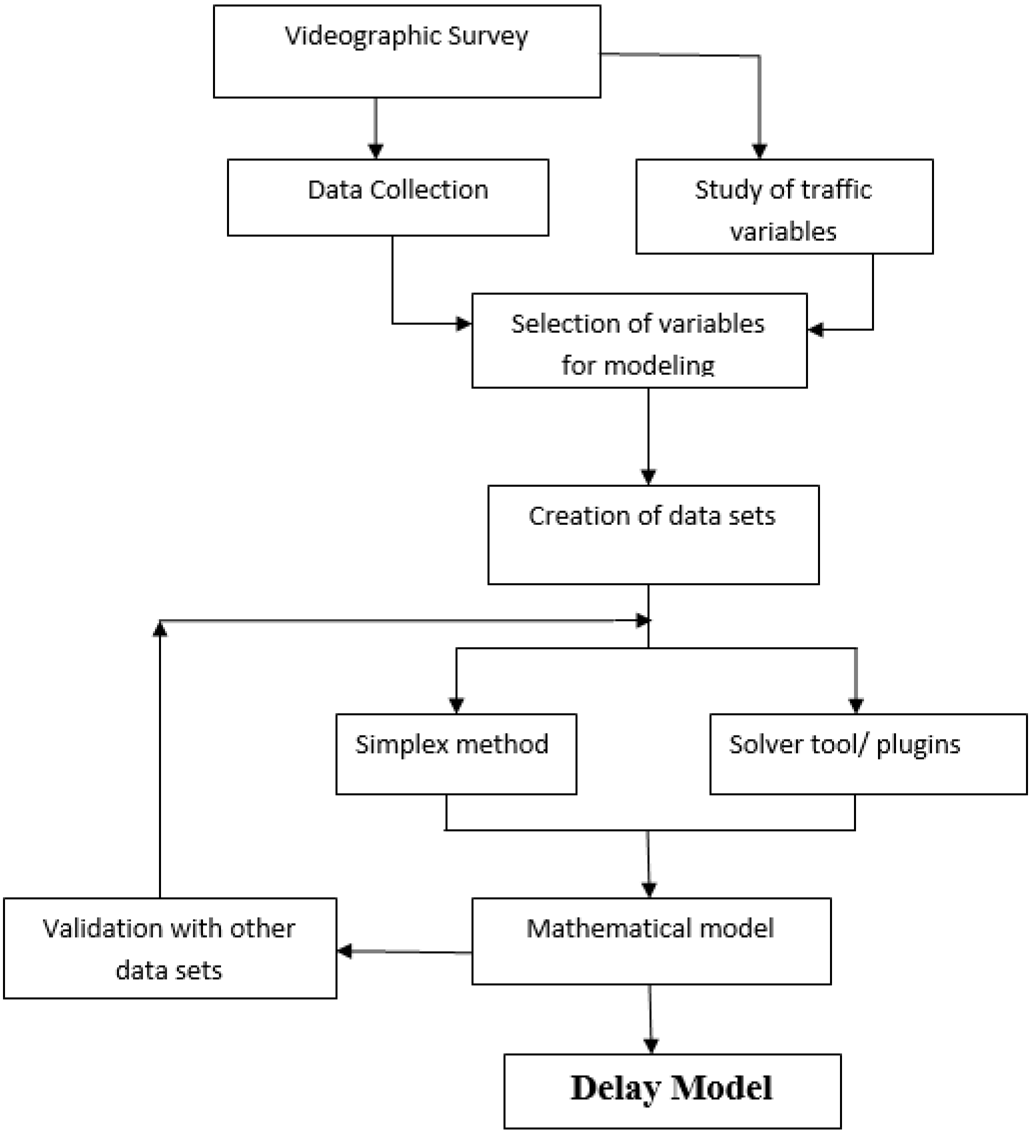
S.no	Trip No	Time of the day	Total Delay in 'Sec'	Travel Time	
				Min	Sec
1	**Trip 1**	**10.30-11.30a.m**	**148**	**14**	**15**
2	**Trip 2**	**7.00-8.00p.m**	**394**	**16**	**10**
3	**Trip 3**	**8..30-9.30p.m**	**429**	**27**	**05**
4	**Trip 4**	**10.30-11.30a.m**	**756**	**21**	**06**
5	**Trip 5**	**6.00-7.00p.m**	**850**	**24**	**16**

Jubilee Hills Check Post to Kondapur Junction via Cyber Towers

S.no	Trip No	Time of the day	Total Delay 'Sec'	Travel Time	
				min	Sec
1	Trip 1	10.30-11.30a.m	356	16	10
2	Trip 2	7.00-8.00p.m	279	24	10
3	Trip 3	8..30-9.30p.m	424	20	10
4	Trip 4	10.30-11.30a.m	723	23	05
5	Trip 5	6.00-7.00p.m	659	25	20

Methodology

The traffic flow characteristics are studied by conducting videographic survey through floating car method in the selected route within the confined boundaries of the study area. With a view to findout measurable contributing factors in the travel patterns, and observations made in terms of delay in off peak and peak flows are mainly due to geometric characteristics including lane width,u-turns and traffic related factors like headway and volume capacity ratios. It is observed that developing a model for optimisation of delays is highly complex in nature due to multiple variables involved from the direction of geometrics, traffic and demand of travel due to rapid urbanisation and metropolitan culture. To simplify the model and extend its adaptability to other metropolitan cities the variables like headway, lanewidth and volume capacity ratio are chosen. Based on the delay values obtained from the videographic survey datasets are developed by limiting headways as per IRC guidelines. The overall methodology is shown below.



Model development

Analysis of the problem: The three-variable function that represents the delay problem is mathematically represented as a linear function Delay = C_1*HW+C_2*X+C_3, for the constants C_1, C_2, C_3 using the experimental data and using the multiple regression method, to find the constants, HW: Headway, LW: Lane width, X: Volume to capacity ratio. It will be taken to a function of only two variables because lanewidth is constant during the sample experiment which is 7 meters, so it does not influence the value of the function to be minimized. So a linear function is identified for the constants using the experimental data given and using the multiple regression method, to find the constants .After having the objective function, we have a problem of optimizing this function finding the minimum value of delay.

Next the multiple linear regression method is used, to create a function of several variables, using experimental data. Multiple linear regression is a natural extension of the simple linear regression model which consists in considering more than one explanatory variable. The multiple regression model studies the relationship between a variable of interest Y (variable response or dependent) and a set of explanatory or return variables X1, X2,. . . , Xp.In the multiple linear regression model, it is assumed that the regression function that relates the dependent variable to the independent variables is linear, that is:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta pXp + \varepsilon$$

Where β0 is the independent term. It is the expected value of Y when X1,. . . , Xp are zero. β1, β2,. . . βp are the partial coefficients of the regression:, β1 measures the change in Y for each unit change in X1, keeping X2, X3,. . . , Xp constants, β2 measures the change in Y for each unit change in X2, keeping X1, X3,. . . , Xp constants,βp measures the change in Y for each unit change in Xp, keeping X1,. . . , Xp-1 constants &ε is the observation error due to uncontrolled variables.

The model in matrix form is as follows:

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} = \begin{pmatrix} 1 & x_{11} & \cdots & x_{1p} \\ 1 & x_{21} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{np} \end{pmatrix} \cdot \begin{pmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{pmatrix}$$

Assigning the notation to the respective matrices, the expression becomes:

$$Y = x\beta + \varepsilon$$

To estimate the vector of parameters β we can apply the method of minimums squares, as in the simple linear model, and the result will be in the following way:

$$\beta = (X^tX)^{-1} X^tY$$

Where X^t denotes the transposed matrix of X.

The Model is developed using the excel plugin tools for analysis to implement the multiple regression method using the experimental data.The input variable cells and the output variable are defined in the Excel. In this way Excel will generate the constants sought in the linear regression multiple model.

$$Delay = C_1 * HW + C_2 * X + C_3$$

So,C_1 = 287.993,C_2 = 2127.127and C_3 = 264.4 are obtained. The problem of minimizing this objective function is solved using the simplex method to minimize the objective function. Suppose D> 0 to discard negative delays and D = 0 since these values are excluded from the logic of the problem. Applying the simplex method to the optimization problemThe ideal value of D = 0 and V / C = 0 was excluded when configuring Solver, since it is outside the logic of the practical problem.Considering the optimal values of Headway , HW= 2 and X= 0.320 (32 %) the minimum value D(HW,V/C)= 0.010 (1 %).The results obtained with the simplex method to minimize the objective function with the restrictions given {("2≤ HW ≤3" @"0 < V/C ≤1")}.

$$D (HW,V/C) = -287.993 * HW + 2127.127 * X -264.4$$

The proposed delay model is validated using the other data set and the results were almost similar.

Conclusions

1. It was observed that expected delays are highly unpredictable due to various influencing factors which are specific to the time of travel and the road connectivity.
2. It is found that very few studies have been conducted in the developing countries where the traffic is heterogeneous and nonadherence of lane discipline is predominant.
3. Among several methods available in the literature, the conventional methods like HCM and Webster's models are widely used and have either underestimated or overestimated the delay.
4. The present study proposes the simplex method which is best suited to minimise the delay.
5. The results obtained from simplex method to minimize objective function will slightly change when the sample size of data set is elaborated by obtaining more field observations.
6. The coefficients in the objective function will vary with different values of lane widths. However in the present study lane width is taken as 7m as the study route is of two-lane.
7. To develop a more comprehensive model subject to the limitations of specified geographical conditions, large data set are to be recorded for the analysis.
8. The model developed doesn't take into account the impedance of traffic due to various geometrics connected with the traffic corridor as there are enormous possibilities of the field conditions in different types of transport segments.

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