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Congestion Modelling for Heterogeneous Traffic

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***Abstract*— The increase in traffic congestion on many streets and highways is a major concern to travelers, administrators and the society at large. Congestion reduces the effective accessibility of residents resulting in lost opportunities for both the public and business. Hence it is necessary to define congestion and to compute it in terms of various factors that cause congestion. An attempt has been made in this work to measure congestion in terms of Travel Time Index which is the ratio of actual travel time during the existing condition to the free flow travel time. Effect of byroads is quantified and included in terms of the number of vehicle merging with traffic stream and number of vehicles crossing the traffic stream to merge with opposite stream of vehicles. The effect of bus stops is measured as the sum of average time delay due to each bus stop coming under the road stretch. The required data has been collected using both moving car observer method as well as video recording. Detailed information regarding all parameters that affect congestion such as traffic volume, traffic composition, pedestrian crossing, merging, diverging and crossing movements of vehicles and dwell time of bus were collected.**

Travel Time Index of different road stretches could be predetermined once the factors affecting congestion, used in the model could be forecasted. Congestion model once developed will be helpful in calculating, comparing and predicting the level of congestion of different road stretches. Based on this model the congestion occurring in different roads during different hours can be found out and tabulated. This will help in proper planning of traffic movement, by suggesting alternative routes or to divert the traffic based on the congestion during different hours of the day, by keeping a balance between the Travel Time Index of different roads.

I. INTRODUCTION

A. GENERAL BACKGROUND

Traffic congestion is a condition on networks that happens as use increases, and is characterized by slower speeds, longer trip times, and increased queuing. Traffic congestion is a key urban transportation problem that we are facing now a days. Hence, many measures have been taken in order to tone down congestion. Different researchers characterize congestion in different ways. When traffic demand increases the communication between vehicles also increases and reduces the speed of the traffic stream thus increasing the travel time. Peak-hour traffic congestion is one of the major problems of all rising metropolitan regions around the world, which is that too many people want to move at the same time each day. In fact, it is almost sure to get worse during at least the next few decades mainly because of rising population and wealth. Congestion reduces the effective ease of access of residents, activities, and jobs, resulting in lost opportunities for both the public and business. In this paper an attempt has been made to study different measures of traffic congestion and the properties required for a good congestion measure. The merits and demerits of different measures has been studied thoroughly, from which Travel Time Index which is the ratio between actual travel time and travel time during free flow condition is found to be a very good indicator of traffic congestion. Actual travel time taken is the average of the travel times of all vehicles in the stream.

Although traffic congestion is impossible to prevent, there are ways to slow the rate at which it is intensified. Traffic management measures like changing the demand according to time can effectively tackle the situation, especially if used in concise, but nothing can eliminate peak hour traffic congestion from large metropolitan regions here and around the world. A congestion prediction model for the peak hour will be useful for adjusting the traffic through alternative routes and thus reducing the level of congestion.

For the present study, road stretch between two places, Kumaranalloor and Gandhi Nagar in Kottayam, Kerala, which is one of the most congested road stretches in the city, was selected. This study examines the factors such as traffic volume, dwell time of buses, crossing movements of pedestrians, turning movements of vehicles travelling against free flow of traffic. With Travel Time Index proposed by Schrank and Lomax (2002) as function of various factors affecting congestion, a traffic congestion model is developed. Using the new methodology, Travel Time Index of different road stretches could be determined once the factors affecting congestion, used in the model could be forecasted. Target speed is the speed associated with the target Travel Time Index. The target speed can be computed given the target Travel Time Index and the free-flow travel rate or the posted speed limit travel rate. Congestion on short sections can be recognized by comparing the actual Travel Time Index to the target Travel Time Index.

B. PROBLEM STATEMENT

Different measures of congestion have their own advantages and disadvantages. Measuring or estimating Delay time may be used as a measure of congestion for a particular road section but is not particularly useful when making comparisons between different road sections or routes. This is because delay time may depend on definite features (e.g. length) relating to the section. Ratio measures, Level of service measures and indices are also used in quantifying

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congestion. Only a few works have been done to find out congestion based on Travel Time Index (TTI). The advantages in using TTI are that it satisfies almost all the necessary requirements of a good quality congestion measure. The TTI allows for comparisons between routes, links, and sections because it is independent of route length. The study has been standardised only for two lane two way road sections without signalized intersections. The present study deals with the use of Travel Time Index as a constraint for developing congestion model in urban heterogeneous traffic.

C. OBJECTIVES OF THE STUDY

The objectives are (1) to study various measures of congestion, (2) to identify a congestion measure that could incorporate all the factors affecting congestion, (3) to develop a congestion prediction model, (4) to explain hourly variation in congestion in terms of the Travel Time Index.

D. SCOPE OF THE STUDY

The present study is limited to part of State Highway 1 stretching from Kumaranalloor to Gandhi Nagar having a length of 1.4 km. Data was recorded simultaneously using 5 cameras at 5 points in the stretch including entry and exit points. Congestion model was developed using the data collected.

II. LITERATURE REVIEW

A critical review of literatures available on different measures of congestion and development of model were done. Various articles published in many national and international journals were reviewed. Several write-ups in the field of congestion modeling and various text books of traffic congestion were also referred.

Levinson and Lomax (1996) developed a Congestion Index that was keyed to the differences in actual versus desired travel times for different types of roadways. The suggested index provided a continuous scale for assessing the amount of congestion incurred. It contains a wide range of values and was easy to understand and use. The delay rate is particularly well suitable for inclusion in such an index. The delay rate is the difference between the rates of travel in free-flow conditions and those which are being evaluated. A Delay Rate Index (DRI) concept was derived on the basis of LOS, speed, delay rate, and other relationships indicated in the 1985 and 1994 HCM. The suggested Congestion Index concept has several significant benefits. It provides more details on the magnitudes and ranges of congestion in severely congested operating conditions than the traditional LOS concept.

Anjaneyulu and Nagaraj (2009) emphasized the need for defining traffic congestion on a balanced basis and use that for measurement of levels of service on roads. An attempt was made to study the relationship of congestion with speed variations and hence to compute congestion using these speed variations. Detailed speed data collected on a second-to-second basis on the selected road links using electronic distance measuring instrument installed in a test vehicle, together with, a laptop computer and adopting the chase car technique and 5 minute classified traffic volume counts formed the database for this study. Coefficient of Variation of Speed (CV) was found to have a good connection with the operating volume for all the three classes of roads. CV was chosen as the indicator of congestion, which formed the basis for congestion quantification. The CV due to traffic volume together with the Mean Velocity (MV) was used to identify the start, growth, and critical zones of congestion. Quantified level of congestion was then used as a measure of Level of Service (LOS). Five levels of service designated by the letters A to E have been proposed.

Bharti *et al.* (2013**)** conducted a study that explains the application and usefulness of concept of travel time reliability on Indian roads. Travel time data collected on an urban arterial in New Delhi during morning and evening peak periods were analyzed and various reliability and congestion measures were evaluated. Attempt was also made to show a relationship reliability measures such as Planning Time Index (PTI) with congestion measures like TTI. Travel time curves were plotted for each 15 minute time interval and reliability and congestion measures were evaluated during morning peak and evening peak.

Aworemi *et al.* (2009) conducted a study and congestion in some selected areas of Lagos State and developed a multiple linear regression model which examines the causes, effects and possible ameliorative measures of road traffic. The data used in this study were collected during a survey conducted by the authors between January and March 2009. By means of structured questionnaires, data were obtained from a total of 345 Respondents through personal interview. Regression Analysis was used in analyzing the data obtained. This was done in order to establish the relationship between poor road condition, accident, inadequate road infrastructure, absence of integrated transport system, inadequate traffic planning, driver's behaviour and road traffic congestion in Lagos State.

III. METHODOLOGY

The preliminary step is to identify the study area where the problem of congestion is severe. After identifying the study area, the factors that contribute to congestion is found out. In this work, the road way factors such as volume of vehicles, crossing movements of pedestrians, dwell time of buses, turning movements of vehicles are considered. The variation of congestion with respect to these factors is determined. Selection of a suitable parameter that could define congestion is an important task. Travel Time Index is an excellent parameter to quantify the amount of congestion based on the selected factors. Data collection involves video recording at different locations of the study stretch. Moving observer method is used to determine the free flow travel time. From the 18 hours data collected, 4 hour data was extracted with the help of AVS video editor. Data extraction was carried out manually from the recorded video. Classified vehicle count was done for each five minute interval. Multiple linear regression method was used for the development of model. Developed congestion prediction models are validated with 20% of data collected. Mean Absolute Percentage Error (MAPE) was used to validate the model.

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A. *STUDY AREA*

For the present study, 1.4 km State Highway-1 section between Kumaranalloor and GandhiNagar, Kottayam of Kerala state in India was taken. Road section selected is a 6.5m wide two lane two way road with high volume of traffic, pedestrians and comparatively higher value of bus dwell times during the peak hours. The road stretch consists of an un-signalized T intersection and four bus stops. There are 4 major merging and diverging roads within the selected road section. Separate facility for pedestrian walking is not available on both sides of the road.The following Fig.1 shows the study section.

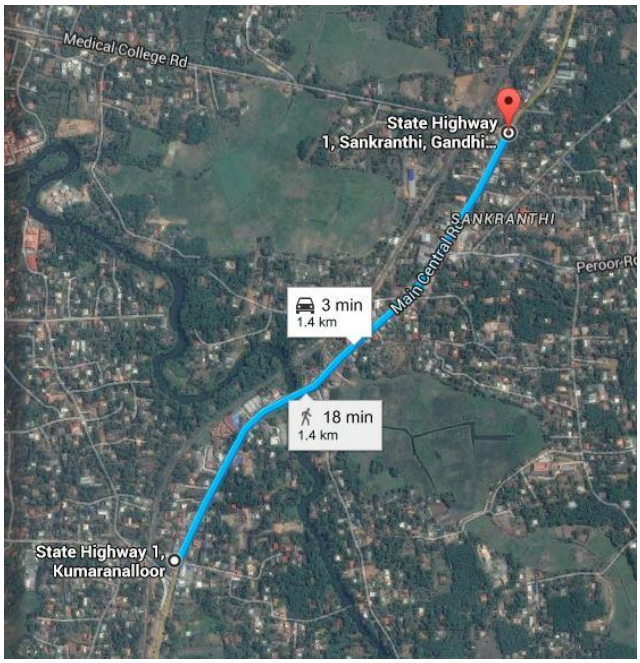

Fig. 1. Study area at Kottayam

IV. DATA COLLECTION AND ANALYSIS

For the present study, a 1.4 km road stretch between two places, Kumaranalloor and GandhiNagar in Kottayam, which is one of the most congested road stretches in the town, was selected. From the observation of the site it was noted that peak traffic volume along this section is from 8:30 AM to 10 AM and from 4:30 PM to 6 PM, also there is another little peak occurring at 12:00 PM, but it's not high to be considered as a rush hour. The noticeable thing here is that, peak hours occur at the same time in both directions. The first rush hour is occurring at the beginning of the working day which is usual in all countries throughout the world. The second rush hour occurs on evenings when people go back to their houses. Data collection in this study was mainly focused during morning hours between 8:30 AM and 10:30 AM, noon hours from 11:30AM to 1:30 PM to obtain off-peak data and evening hours between 4 PM to 6 PM. License plate matching technique has been considered for measuring the travel time of vehicles in the study area. For this, video cameras were installed at 5 locations including entry and exit points of the study area to capture the vehicle license plate for all categories of vehicles. Free flow travel time was calculated using moving car method at 12AM. Traffic volume data is estimated through a video camera installed at Sankranti.

The data collected include actual travel time taken by each vehicle to cross entry and exit points during 5 minute interval, volume of vehicles(pcu) travelling in both directions, number of pedestrians crossing, vehicle composition, merging diverging and crossing movement of vehicles and dwell time of buses. 48 sets of 5 minute data (4 hours) were extracted and sample data collected is shown in Table 1.

A. *MOVING CAR METHOD*

For a complete description of traffic stream modelling, one would require flow, speed, and density. Obtaining these parameters simultaneously is a difficult task if separate techniques are used. In the fundamental equation of traffic flow, flow is given as the product of density and space mean speed. If any two parameters are known, the third can be computed. Moving car or moving observer method of traffic stream measurement has been developed to provide simultaneous measurement of traffic stream variables. Flow and free flow travel time can be obtained using moving car method.

B. *ACTUAL TRAVEL TIME*

5 minutes interval data was taken. Actual travel time is the average travel time taken by vehicles (passing within each 5 minutes) to traverse the selected stretch. In India traffic is mixed. Time taken by vehicles to traverse the section differ from category to category of vehicles. Hence in order to convert actual travel time of each vehicle to a travel time of standard vehicle (car), factors were developed. A sample of 20 vehicles is taken from each category of vehicle and average travel time is found. Car is taken as the standard vehicle and actual travel time is found. Respective factor is obtained by dividing time taken by car to time taken by respective category of vehicle. Now multiplying respective factor with travel time of vehicle chosen, travel time in terms of standard vehicle is obtained. Factors obtained for different category of vehicles is shown in Table 1.

TABLE 1. FACTORS FOR DIFFERENT CATEGORIES OF VEHICLES

Vehicle Category	Factor
Two wheelers	0.934
Three wheelers	0.936
Cars	1
LCVs	1.702
Buses/Truck	0.887

C. *TRAFFIC COMPOSITION*

Six categories of vehicles were identified during the study period on this corridor. Traffic compositions of study corridor during two hour morning peak and two hour evening peak were obtained. Traffic compositions on study corridor during one hour morning peak based on the data collected is shown in Fig 2. It is clear that cars constitute major proportion of the traffic composition followed by two wheelers.

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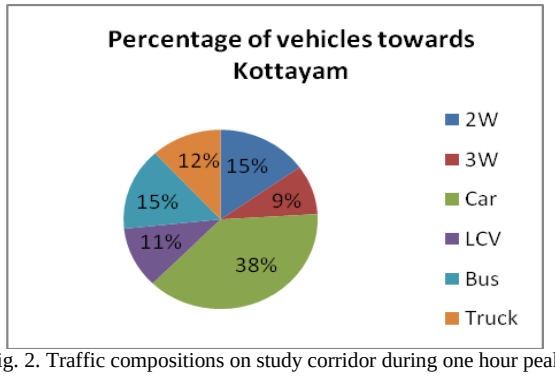

Fig. 2. Traffic compositions on study corridor during one hour peak

D. HOURLY VARIATION OF CONGESTION

TTI gives a direct measure of congestion. A Travel Time Index 1.20 indicates 20 percent longer travel time. Hence the variation in congestion from time to time can be represented with the help of TTI value. Hourly variation in congestion was found for four hour data collected and a sample data showing variation of congestion with time for one hour morning peak is shown in Table 2. From the data it can be inferred that there is a great increase in travel time during morning peak. The time taken to traverse the study section is 81% to 133% longer than free flow travel time.

E. CORRELATION OF VARIABLES

A correlation coefficient is a coefficient that illustrates a quantitative measure of some type of correlation and dependence, meaning statistical relationships between two or more random variables or observed data values. Pearson product-moment correlation coefficient is used here. As a preliminary analysis correlation values of each independent variables with respect to dependent variable TTI was found out and is given in Table 3. It can be noted that four variables are significant since its coefficient value is greater than 0.5.

TABLE 2. SAMPLE DATA SHOWING THE VARIATION OF CONGESTION WITH TIME

Time(AM)	TTI
08:30:00	1.8158
08:35:00	1.8179
08:40:00	2.2751
08:45:00	1.8163
08:50:00	1.9558
08:55:00	1.8481
09:00:00	1.8185
09:05:00	1.8497
09:10:00	1.8212
09:15:00	1.9719
09:20:00	2.3360
09:25:00	1.8244
09:30:00	1.8158

TABLE 3. CORRELATION COEFFICIENTS

Sl No.	VARIABLE	CORRELATION COEFFICIENT
1	Number of pedestrians crossing the traffic stream(P_c)	0.661
2	Volume of merging traffic (V_m)	0.772
3	Volume of traffic diverging to left (V_l)	0.355
4	Volume of traffic diverging to right (V_r)	0.793
5	Volume of traffic crossing the traffic stream (V_c)	0.908
6	Sum of average dwell time of buses (D_w)	0.371

V. MODEL DEVELOPMENT AND VALIDATION

A. MODEL DEVELOPMENT

SYSTAT 13 software was used to develop model. 48 sets of observations were used for making model. In this study multiple linear regression method is used . Travel Time Index calculated is taken as the dependent variable. This TTI is regressed against independent variables. Multiple linear regression analysis is used to predict the value of dependent variable (TTI) based on the values of independent variables. It was found that the higher value of R squared and F-Test value is obtained when TTI is regressed against volume of merging traffic, volume of traffic diverging to left, volume of traffic diverging to right, volume of traffic crossing the traffic stream, sum of average dwell time of buses in each stop and number of pedestrians crossing the traffic stream.
The linear regression model obtained is,

$$TTI = 0.451 + 0.007P_c + 0.019V_m + 0.001V_l + 0.012V_r + 0.018V_c + 0.096D_w \quad (1)$$

R^2 measures the proportion of variation in the dependent variable (TTI) that was explained by the variations in the independent variables. Here 88.40% of the variation is explained by the statistical equation. This shows that the equation is statistically stable. Adjusted R^2 measures the proportion of the variance in the dependent variable which is explained by the variance in the independent variables. 86.7% of variance is explained by adjusted R^2. F-ratio value of 51.860 gives credibility to the effectiveness of the six explanatory variables in causing road traffic congestion. The values of t-statistic come in the range of the standard value of t test from table for 95% confidence interval which is 1.684.

B. VALIDATION OF MODEL

The collected data are classified into two sets. 70% of the collected data is used for calibration of the congestion model, and remaining 30% is used for model validation. The expected values calculated by substituting the values of variables in the obtained model and comparing it with the observed value, MAPE error is obtained. Mean absolute percentage error is calculated for each observation.

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Mean Absolute Percentage Error (MAPE), also known as mean absolute percentage deviation (MAPD) value is used to validate the model. It usually expresses accuracy as a percentage and is obtained by following equation.

$$M = \frac{100\%}{n} \sum_{t=1}^{n} \left(\frac{A_t - F_t}{A_t} \right) \qquad (2)$$

Where,

M = Mean Absolute Percentage Error (MAPE)

A_t= Actual value

F_t = Forecast value.

According to Lewis scale of interpretation, estimation of accuracy (Kenneth and Ronald 1982) for any forecast with a MAPE value of less than 10% can be considered highly accurate.11% - 20% as good, 21% -50% as reasonable and 51% or more as inaccurate. The obtained value of MAPE is 4.54 % which is below 10% and hence the predicted model is highly accurate. The variation of predicted results from the original data is graphically shown below in Fig 3.

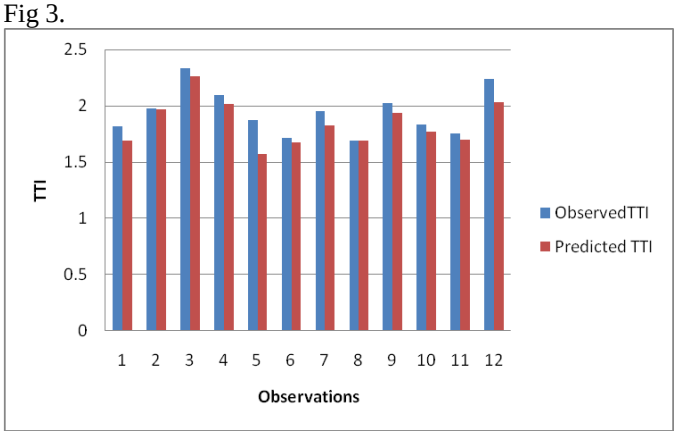

Fig.3. Comparison between observed TTI and predicted TTI

From the Fig. 3 shown above it can be inferred that the observed values of TTI from field and the TTI values obtained from regression model are close.

VI. SUMMARY AND CONCLUSIONS

The present study brings out the importance of using Travel Time Index in defining traffic congestion in urban heterogeneous traffic. In this work a detailed study of different congestion measures have been done and their merits and demerits are compared from which Travel Time Index is found to be the most suitable congestion measure. From the traffic composition in the selected stretch, it is clear that majority of the vehicles are cars. From the analysis of hourly variation of congestion it is observed that vehicles take 81% to 133% longer travel time in traversing the section. From scatter plots and correlation coefficients, independent variables like pedestrian crossing, dwell time of buses, vehicles merging, diverging and crossing the traffic stream are found to be significant in the measurement of TTI and are used in developing the model.

The most important contributor to congestion happens to be the vehicles crossing closely followed by right turning traffic, merging traffic, pedestrian crossing, left turning traffic and dwell time of buses.

The R^2 value of 0.884 indicates that 88.4% of the proportion of variation in the dependent variable (TTI) is explained by the variations in the independent variables. F-ratio value of 51.860 gives credibility to the effectiveness of the six explanatory variables in causing road traffic congestion. The calibrated model showed TTI values closer to the field value. The MAPE value obtained for validation is found to be 4.54%, a value below 10% which indicates that the predicted model is significant.

A. LIMITATIONS AND SCOPE FOR FUTURE WORK

In this study, linear regression model has been used with limited data sequence to forecast future traffic congestion. Consideration of some other socio economic factors is beyond the scope of this study; in future all possible factors could be considered for the congestion model. The model did not consider geometric factors like radius of curvature of the road and influence of the width of road and surface. The project can be extended considering geometric factors and effect of type of road surface and width of road.

REFERENCES

[1] Turner, S. M., Lomax, T. J. and Levison, H. S., (1996), "Measuring and estimating congestion using travel time-based procedures", Transportation Research Record, Journal of the Transportation Research Board, No.1360, 11-19.

[2] Boarnet, M.G., Kim, E.J. and Parkany, E., (1998), "Measuring traffic congestion", Transportation Research Record, Journal of the Transportation Research Board, No.1634, 93-99.

[3] Levison, H.S. and Lomax, T.J.,(1996), " Developing a travel time congestion index", Transportation Research Record, Journal of the Transportation Research Board, No.1564,1-10 .

[4] Anjaneyulu, M.V.L.R. and Nagaraj, B.N., (2009),"Modelling congestion on urban roads using speed profile data", Journal of Indian Road Congress, No.549.

[5] Aworemi, Remi, J., Azeez,A., Adegoke, I., (2009). "A Study of the Causes, Effects and Ameliorative Measures of Road Traffic Congestion in Lagos Metropolis", European Journal of Social Sciences - Volume 11, No. 1

[6] Taylor, M.A.P.,(1992),"Exploring the nature of urban traffic congestion: concepts, parameters, theories and models", pp. 83-105 of the Proceedings of 16th Australian Road Research Board Conference, 16(5), Perth: ARRB.

[7] Aftabuzzaman, Md., (2007)," Measuring Traffic Congestion- A Critical Review". Available: http://www.atrf.info/papers/2007/2007_Aftabuzzaman.pdf [accessed on 10 January 2015]

[8] Downie, A., (2008), "The World's Worst Traffic Jams" .Available: http://content.time.com/time/world/article/0,8599,1733872,00.html [accessed on 15 January 2015].

[9] Hamad, K. and Kikuchi, S.,(2002), "Developing a measure of traffic time congestion: fuzzy interface approach", Transportation Research Record, Journal of the Transportation Research Board, No.1802, 77-85.

[10] Lindley, J.A.,(1987), "Urban freeway congestion: quantification of the problem and effectiveness of potential solutions", ITE journal, 57(1), 27-32.

[11] Lomax, T., Turner, S., Shunk, G., Levinson, H.S., Pratt, R.H., Bay, P.N. and Douglas, G.B.,(1997)," Quantifying congestion, volume 1 & 2", NCHRP Report 398, Washington, DC: Transportation Research Board.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

[12] Hall, R.W. and Vyas, N.,(2000).”Buses as a traffic probe: demonstration project”, Transportation Research Record: Journal of the Transportation Research Board, No. 1731, 96-103.
[13] Schrank, D. and Lomax, T., (2002),” The 2002 Annual Urban Mobility Report”, Texas: Texas Transportation Institute.
[14] Texas Transportation Institute (TTI), (2005),” The keys to estimating mobility in urban areas: applying definitions and measures that everybody understands”, Texas: Texas Transportation Institute.
[15] D/Este, G.M., Zito, R. and Taylor, M.A.P., (1999),” Using GPS to measure traffic system performance”, Computer-Aided Civil and Infrastructure Engineering, 14(4), 255-265.
[16] Roess, R.P., Messer, C.J., Mcshane, W.R., Fruin, J.J., Levinson, H.S. May, A.D. and Dudek, C.L., (1985), “Highway Capacity Manual”, Special Report 209, Washington, D.C.: Transportation Research Board.
[17] Schrank, D. and Lomax, T., (2005), “The 2005 Annual Urban Mobility Report”, Texas: Texas Transportation Institute.
[18] Bharti, A.K., Chandra, S. and Chalumuri, R.S.,(2013),” Performance Evaluation of Urban Arterial in Delhi Using Travel Time Reliability”, Proceedings of the Eastern Asia Society for Transportation Studies, Volume 9.
[19] Rao, A.M. and Rao, K.R.,(2012), ”Measuring Urban Traffic Congestion – A Review ”, International Journal for Traffic and Transport Engineering , 2(4), 286 – 305.
[20] Downs, A., (2004), “Still Stuck in Traffic”. Available: http://www.brookings.edu/research/books/2004/stillstuckintraffic [accessed on 15 January 2015].
[21] IRC 86:1983, “Geometric Design Standards for Urban Roads in Plains”, Indian Roads Congress
[22] Kenneth, D.L. and Ronald, K.K.(1982). “Advances in business and management forecasting”, Emerald Books, Bingley, U.K.