Study On Travel Time Reliability Indices For An Urban Road Corridor In India

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Abstract- *Now a days road traffic conditions in Indian cities are getting worse day by day. Unpredictable travel-time delays in urban road networks in India due to traffic problems like congestion, road-accidents etc. has raised serious concerns about transport system quality. This is the crucial reason why traffic and transportation planners have to seriously look into the issue and develop a strategic plan to ensure travel time reliability and demand for reliable mobility and desired level of service on the urban roads. Travel time reliability analysis is vital parameter to evaluate quality of traffic service on a road network. During last two decades, the vehicular population in Indian cities has grown at rate of 10%, p.a. whereas the road length has increased only at rate of 3.4% p.a. This has resulted in to serious situation of delays due to congestion along selected corridors during specific hours of week days due to largely uniform and inflexible work-school-business activity schedule. Mapping of effect of congestion through travel time reliability study along busy corridors can help travellers to take suitable decision related to their time of departure as well as choice of route alternative. This may eventually increase the efficiency of transport system usage. For the present study, a 3.9 km long 3 lane dual carriageway arterial corridor in south west zone connecting Athwa & Piplod in Surat city is selected. The corridor selected for the study connects residential, recreational and commercial land uses with business and trade activities. In view of the dominance of two wheelers in the stream with more than 60% share, the study has been carried out by using two wheeler as the test vehicle. Eight numbers of runs are conducted during morning peak hours (8.00 am to 11.00 am) and evening peak hours (4.00 pm to 7.00 pm) by driving two wheeler fitted with performance box with the traffic stream. Four junctions and five links along the corridor are analysed with the help of speed profile and its variation. The extracted speed data is used for evaluating travel time indices such as 95th percentile travel time, Buffer time index and planning time index as per NCHRP practice. The results will be useful to plan traffic regulation and control measures for effective utilisation of the vital transport corridor of the city.*

Keywords:- Arterial road; Performance box; Travel time indices.

I. INTRODUCTION

Traffic congestion is a major problem that is also related to the performance of transportation systems from perspectives of both road users and operators. Whether using private car or public transport, travel time is a significant measure for quantifying the level of congestion and the quality of the service. Increasing travel times directly affect the quality of -the service. It not only affects driver route choice behaviour but also it is used in the assessment of transportation system performance. In past few years, the reliability of transport systems has been widely recognized as a key issue in transport planning and evaluation world. Travel time reliability is significant to many transportation system users, whether they are vehicle drivers, transit riders, freight shippers, or even air travellers. A personal and business traveller values the reliability because it allows them to make better use of their own time. Travel time is one of the most important measurements for evaluating the operating efficiency of traffic networks and accurate and reliable travel time information has become increasingly important for traffic engineers, daily commuters, residents, business owners etc. Chen *et al*. (2003) stated that travel time reliability is "an important measure of service quality for travellers". Personal and business travellers value reliability because it allows them to make better use of their own time. Nam *et al*. (2006) argued that travellers' tastes for travel time and travel time reliability vary across times of day and that route choice is based on a combination of travel time, travel time reliability, and cost. However, the travel time experienced by a traveller making a trip on an arterial segment is not just the result of his or her own travel choices (destination, mode, route, speed), but also the choices of many other travellers, not necessarily only those traveling the same segment. Moreover, a substantial component of driver behaviour may not be classified as rational choice behaviour, but rather a product of the different characteristics of individual drivers; for example attention level, driving style, risk assessment, and their vehicles, such as acceleration and deceleration capabilities (Van Lint, J.,2004). Therefore, the travel time reliability on arterial networks is usually not only a function of traffic flow, driver behaviour, traffic composition, link capacity and speed limit, but also involves numerous other factors such as signal timing, roadway and intersection geometries, adjacent land use and development, median type, signalized intersection spacing, and conflicting traffic from cross streets. In this study, Performance-Box devices which brought a new perspective to the transportation engineering community to gather vehicle information has been used. These devices are enabled to collect the information such as time, speed and distance etc. This information might be saved into the device for its future analysis, it can be used on vehicle to vehicle analysis systems, or send it to a server in Real-Time for its immediate analysis, for instance it can be used to explain the vehicular dynamics of urban cities as micro and macroscopic simulations and travel time estimations.

II. MEASURES OF TRAVEL TIME RELIABILITY

Traditionally volume to capacity ratios and level of service measurements are used to describe the travel conditions (Highway Capacity Manual, 2000). In more recent years, researchers hypothesized that the value of travel time models may have been omitting important reliability considerations, and a model that includes both reliability as well as travel time should be used. Travel time reliability is defined as the consistency or dependability in travel times during a specified period of time under stated conditions. Travel time reliability is also one of the most understood measures for road users to perceive the current traffic conditions, and help them make smart decisions on route choices, and hence avoid unnecessary delays. Various measures developed for the measurement of travel time reliability are briefly described in figure 1.

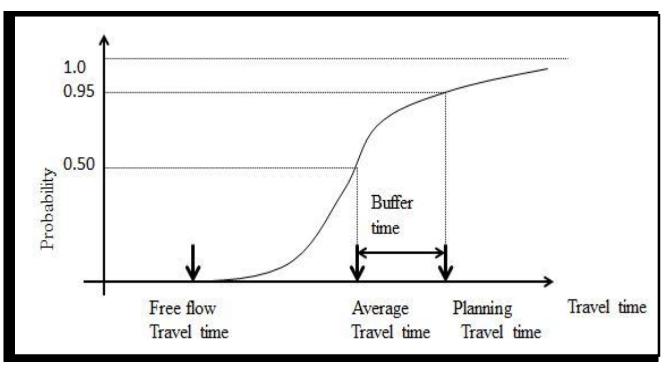


Fig 1. Cumulative Probability Distribution Function for Travel Time

2.1. 95th Percentile Travel Time

Amount of delay will be on the heaviest travel days for specific travel trips or routes? The 95th percentile travel times are reported in minutes and seconds and should be easily understood by commuters familiar with their trips. This measure has the disadvantage of not being easily compared across trips, as most trips will have different lengths. Hence simplest measure of travel time reliability is 95th or other percentiles travel times for specific travel routes or trips, which indicates the severe condition of delay in travel times. 95th percentile travel time indicates that 19 out of 20 working days travel is in time to work. This measure ideally suited for traveller information.

2.2. Buffer Time Index (BTI)

Buffer Index (BI) is a measure of trip reliability that expresses the amount of extra buffer time needed to be on time for 95 percent of the trips (e.g., late for work on one day out of the typical 20-work-day month.) BTI is expressed as under:

$$\text{Buffer Time Index (BTI)} = \frac{\text{95th \% Travel Time} - \text{Average Travel Time}}{\text{Average Travel Time}} \qquad (1)$$

For example, a buffer index of 40 percent means that a traveller should budget an additional 12 minutes for a 30 minutes average peak trip time to ensure 95% on time arrival.

2.3. Planning Time Index (PTI)

This index represents the amount of total time a traveler should have to ensure on time arrival. It also represents the extra time that is included by most of the travelers when planning peak period trips. The planning time index differs from the buffer index in a manner that it includes typical delay as well as unexpected delay. PTI is expressed as under:

$$\text{Planning Time Index (PTI)} = \frac{\text{95th \% Travel Time}}{\text{Free Flow Travel Time}} \qquad (2)$$

For example, a planning time index of 1.60 means travelers plan for an additional 60% travel time above the off-peak travel time to ensure 95% on time arrival.Time Index would be a preferred travel time reliability measure since it is based on average travel time; for those who are not familiar with that, planning time index may be preferred as it is based on free flow travel time (Pu, W., 2010).

Selected studies carried out for assessing travel time reliability are briefed below: Abishai Polus (1979) analyzed travel time and operational reliability on arterial routes. Reliability is viewed in terms of the consistency of operation of the route under investigation and defined in terms of the inverse of the standard deviation of the travel time distribution. Utilizing arterial travel time data from the Chicago area, both a regression and a statistical model are shown to serve as efficient techniques in predicting reliability. Kate Lyman & Robert L. Bertini (2008) used the measured travel time reliability indices for improving real-time transportation management and traveller information using archived ITS data. Using data from Portland, Oregon, several reliability measures are tested including travel time, 95th percentile travel time, travel time index, buffer index, planning time index, and congestion frequency. Archived freeway data is used to illustrate ways of reporting reliability, analyse changes in travel time reliability between 2004 and 2006 using different travel time reliability measures, and explore methods for prioritizing freeway corridors. Some trends were noticed, including increasing travel times and worsening reliability in the morning peak. Study also reports that travel time increases during the early afternoon and decreases in the late afternoon or evening. Susilawati, Michael et al. (2010) This study assessed the ten corridors of the Adelaide Metropolitan road network's travel time reliability by using the Buffer Time and Planning indices. This study examines the selected corridors of the Adelaide Road networks by using the eight consecutive years of travel time data. From the data analysis, it is found that there were many differences in buffer time index results among the corridors.

III. DATA COLLECTION

It is necessary to develop a sampling plan to collect data for selected time periods and at selected locations. Time is the basic element for defining reliability based performance measures of any road network system. Travel time can be measured mainly in two ways such as direct measurement and indirect measurement. Direct measurements of travel times can be measured either by probe vehicles or by traditional floating car method. These methods are the best methods but these methods have drawback that the probe vehicles are currently not widely deployed and floating car method suffers from extremely small samples **(NCHRP, Report 2006)**.

3.1. Study Corridor Profile

The corridor considered in the analysis is located in the Surat metropolitan area along Athwa lines radial corridor of south Surat. Three lane dual carriageway arterial road designed and is constructed by the Surat Municipal Corporation as a part of a plan to connect Surat City with its airport, Magdalla Sea Port and Dumas Village. The most of the shopping malls and cinema theatre are situated alongs this road. Study stretch considers 3.9 km road segment having similar road geometry along the whole length. The study has been carried out by using two wheeler as the test vehicle. Eight numbers of runs are conducted during morning peak hours and evening peak hours as per schedule given in table 1. Four junctions and five links along the corridor. Figure 2. shows location of corridor in Google image of the southern part of city.

Table 1. Details of Survey Schedule.

Day	Date	Morning Peak	Evening Peak
Wednesday	October 30th, 2013	8:00 am to 10:30 am	4:30 pm to 7:00 pm

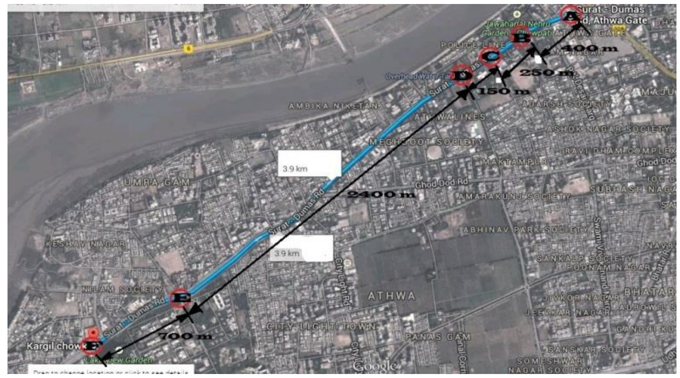


Fig 2. Study Corridor (Athwa to Kargil Chowk): Google Image

The Block diagram in Figure 3 below shows the location details of junctions and mid-blocks of stretch selected as the study corridor.

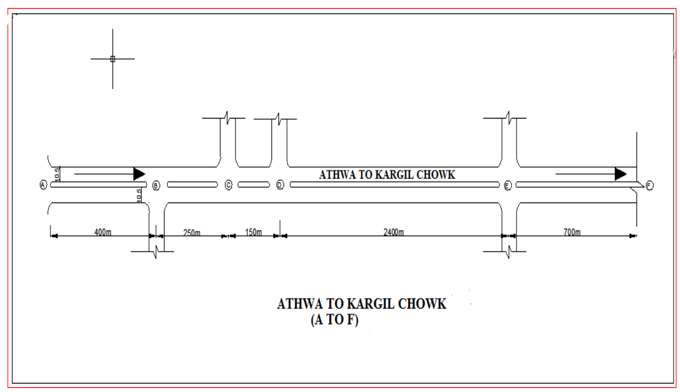


Fig 3. Block Diagram of Study Corridor (Athwa to Kargil Chowk)

All the junction are unsignalised and traffic movement is by regulated mini roundabouts or island. Table 2 shows details of study segments.

Table 2. Detail Study Segments

Segment	Length (m.)
A-B	0-400
B-C	400-650
C-D	650-800
D-E	800-3200
E-F	3200-3900

3.2 GPS Method (performance Box)

Performance Box is a self-contained GPS data logger and Performance Meter. A 10Hz fully calibrated GPS engine is used to provide accuracy and precision. The data can be stored on a removable SD flash card. Real time results are displayed on the back-lit LCD display. A USB connection allows data to be downloaded to a laptop for further in-depth analysis. Figure 4. and Figure 5. Below shows; the speed – time profile and the speed – distance profile created by the Performance Box during survey.

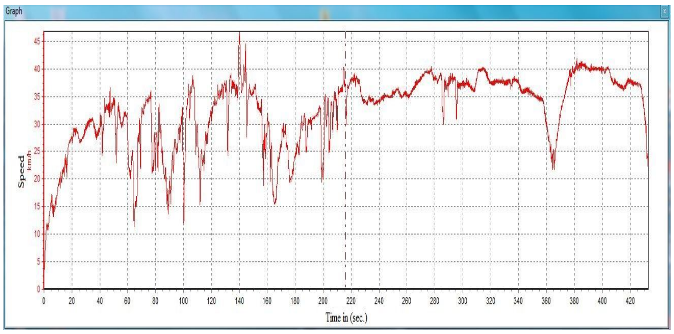


Figure 4 Speed – Time profile

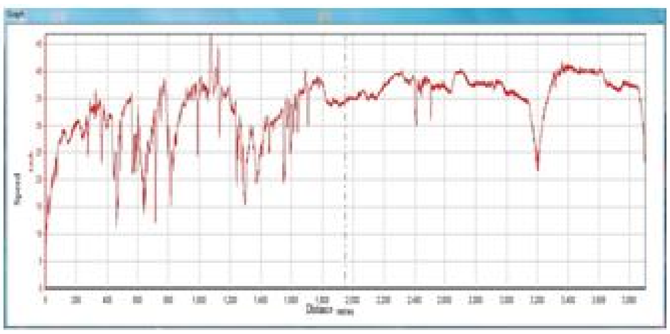


Figure 5 Speed – Distance profile

From the above graphs, it is clearly seen that the speed reduces at the approach of intersections in the stretch and acceleration is also observed as the vehicle leaves the intersection. This observation can also be interpreted by analysing the table 3 below showing the values of time and speed w.r.t distance on the stretch. 16 numbers of similar observations are made and analysis is carried out for every 100 meter length. The sample analysis been carried out in Microsoft excel and is presented here for the reference.

Table 3. Values of Time & Speed With Respect to Distance

Segment	Dist(m)	Time(s)	Speed(km/h)
A	0	0	0
	2.7	1.53	10
	41.9	11	20
	100	20	27.46
	183.41	30.7	30
	200	32.68	30.42
	300	44.74	33.02
B	**400**	**56.07**	**29.86**
	500	70.58	32.41
	600	82.59	33.34
C	**650**	**91.02**	**17.42**
	700	98.01	29.48
D	**800**	**109.66**	**29.84**
	900	122.7	34.21
	1000	133.03	37.81
	1064.7	139.33	40
	1100	142.48	37.34
	1200	152.43	34.66
	1300	166.02	16.02
	1400	181.02	24.79
	1500	193.42	30.75
	1600	205.49	33.86
	1700	215.83	36.09
	1800	225.52	37.69
	1900	235.89	34.54
	2000	246.34	34.94
	2100	256.49	34.87
	2200	266.57	37.47
	2300	275.89	39.49
	2400	285.22	33.63
	2500	294.99	36.93
	2600	304.78	36.99
	2700	314.26	39.83
	2800	323.65	38
	2900	333.2	38.21
	3000	342.85	35.53
	3100	352.94	34.94
E	**3200**	**364.66**	**23.42**
	3300	376.09	38.03
	3400	385.1	40.56
	3500	394.05	39.72
	3600	403.07	39.82
	3700	412.5	37.11
	3800	422.17	36.91
F	3900	432.7	22.51

IV. STUDY ANALYSIS AND RESULTS

95th percentile travel time, Buffer index, planning time index a reliability measure recommended by NCHRP are selected for the present study. For the given road environment and control condition, travel time is function of traffic volume. As traffic volume can vary randomly at a location during an interval within an analysis period, travel time is also expected to show random variation. To account for this variation standard deviation in travel time for each segment during all eight runs in morning and evening peak periods is found out. Based on this 95% confidence limits of Travel time for each segment is calculated as under.

Travel Time Upper limit (TT_{UL}) = $TT_M + 3\sigma$ (3)

Where,
TT_M = Mean Segment Travel Time during an analysis period.
σ = Standard deviation in Segment Travel Time during an analysis period.

Travel Time Lower limit (TT_{LL}) = $TT_M - 3\sigma$ (4)

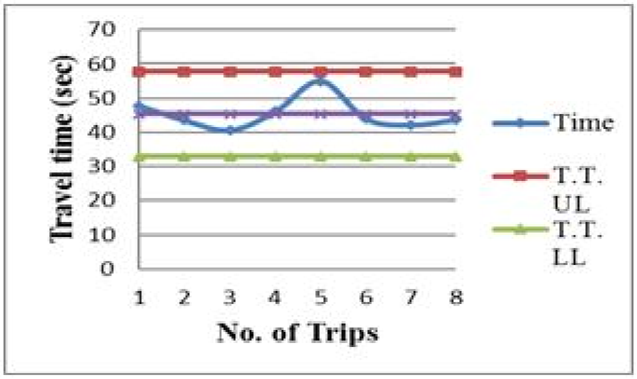
Where,
TT_M = Mean Segment Travel Time during an analysis period.
σ = Standard deviation in Segment Travel Time during an analysis period.

Following table 4 shows the result of each section for morning peak hour (M.P.H) in terms the mean, standard deviation(S.D.), travel time in upper limit(T.T.UP) and travel time in lower limit(T.T.LL).

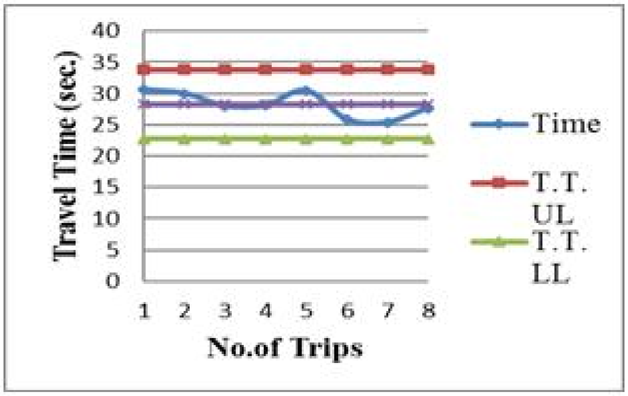
Table 4. Mean, Standard deviation, Upper limit and Lower limit of Travel Time (M.P.H.)

Segment	Mean(sec.)	S.D.(sec.)	T.T.UL(sec.)	T.T.LL(sec.)
A-B	45.32	4.14	57.74	32.9
B-C	28.25	1.85	33.8	22.7
C-D	16.67	1.38	20.81	12.53
D-E	236.01	16.74	286.23	185.79
E-F	65.54	4.84	80.06	51.02

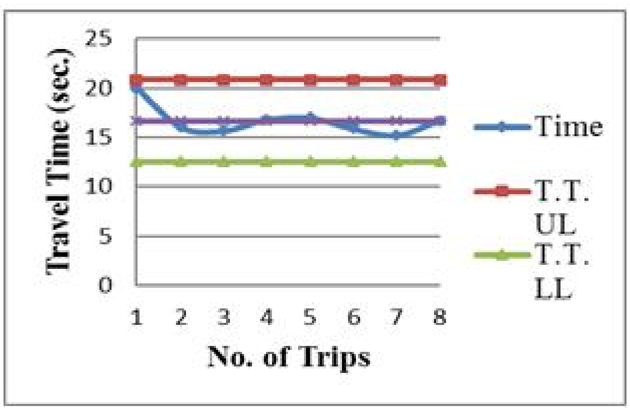
Figure 6 (a) to (e) shows mean travel time observed during eight runs during morning peak hour and the lower and upper boundaries of travel time for each segment.



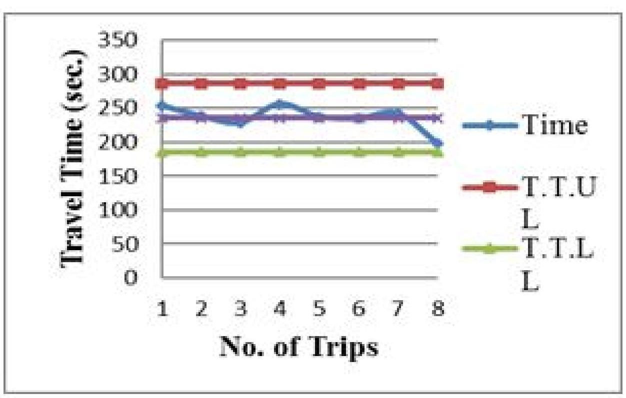
(a) Segment A-B



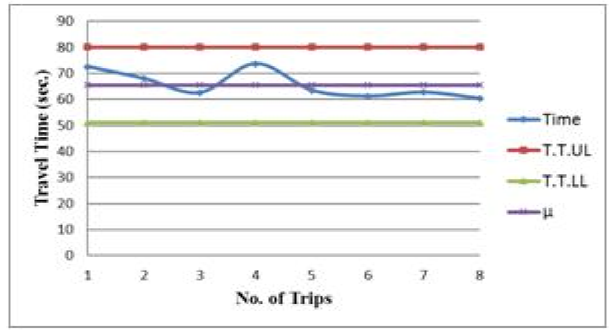
(b) Segment B-C



(c) Segment C-D



(d) Segment D-E



(e) Segment E-F

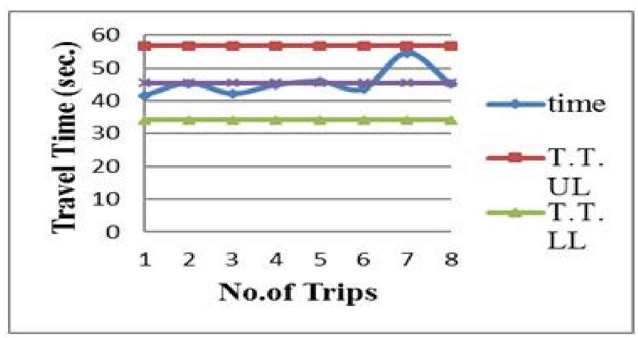
Fig 6. (a) to (e) Mean, Upper and Lower Limit of Travel Time For Segments.

Following table 5 shows the result of each section for evening peak hour Finding the mean, standard deviation(S.D.), travel time in upper limit(T.T.UP) and travel time in lower limit(T.T.LL) for evening peak hour (E.P.H.).

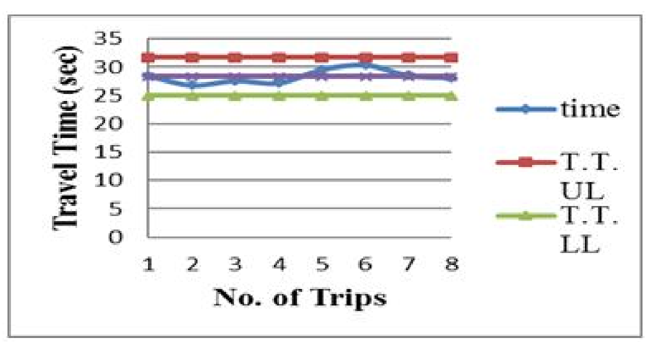
Table 5 Mean, Standard deviation, Upper limit and Lower limit of Travel Time (E.P.H.)

Segment	Mean(sec.)	S.D.(sec.)	T.T.UL(sec.)	T.T.LL(sec.)
A-B	45.4	3.76	56.68	34.12
B-C	28.36	1.12	31.72	25
C-D	18.22	1	21.22	15.22
D-E	231.21	16.98	282.15	180.27
D-F	64.51	3.7	75.61	53.41

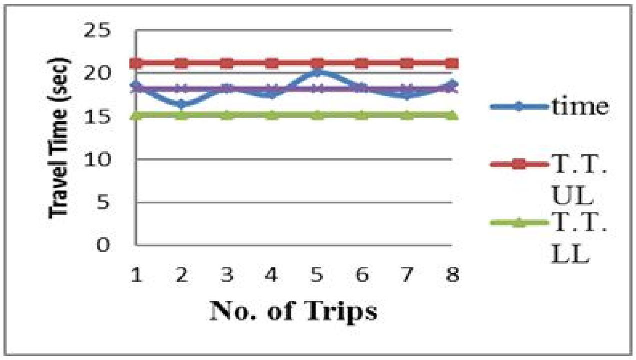
Figure 7 (a) to (e) shows mean travel time observed during eight runs during evening peak hour and the lower and upper boundaries of travel time for each segment.



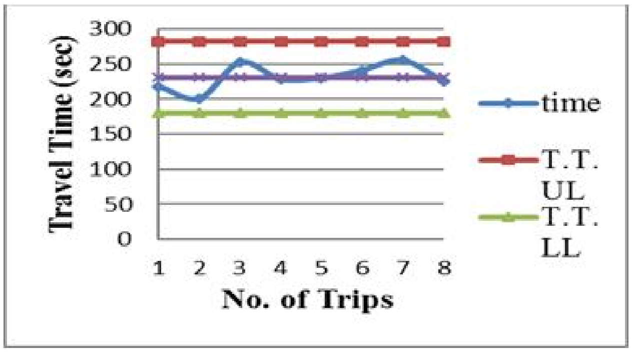
(a) Segment A-B



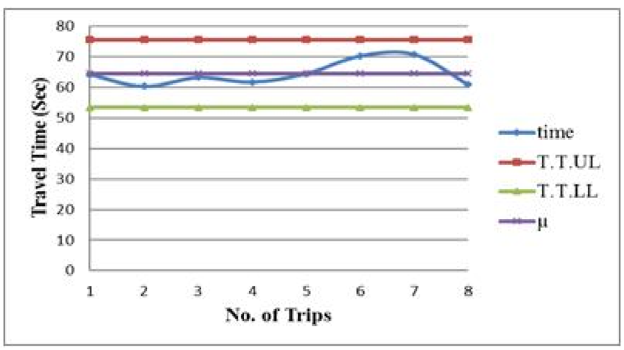
(b) Segment B-C



(c) Segment C-D



(d) Segment D-E



(e) Segment E-F

Figure 7 (a) to (e) Mean, Upper and Lower Limit of Travel Time for Segment.

4.1 Travel Time Reliability Framework

Due to limited size of sample it becomes difficult to assess 95th Percentile Travel Time. The problem is resolved statistically by adopting one tailed t-distribution to calculate travel time corresponding 95th percentage confidence level, as under:

$$95^{th} \text{ Percentile Travel Time} = TT_M + t_{n-1}(\alpha/2)^* (\sigma/\sqrt{n}) \quad (5)$$

Where,
TT_M = Mean Segment Travel Time during an analysis period.
$t_{n-1}(\alpha/2)$ = t- Statistic value
σ = Standard deviation in Segment Travel Time during an analysis period.
n = No. of Trip (sample=8)

Using 95th Percentile Travel Time, travel time indices such as travel time index, Buffer Time index, planning time index and percentage of variation are calculated.

95th percentile travel time reliability for five segment of the study corridors are tabulated in Table 6.It can be noticed from the table that three lane corridor is giving higher 95th % travel time in five segments during morning peak periods. Highest value of 95th percentile travel time is observed in segment (D-E). Highest value of Buffer Time index is observed in segment (B-C). Also Travel Time Index and Planning Time Index of highest value are observed in segment (B-C).

Table 6 Travel Time Indices (M.P.H.)

Segment	95th T.T. (sec.)	TTI	BTI %	PTI	σ	% of variation
A-B	48.09	1.56	6.11	1.67	4.14	9.13
B-C	35.03	1.56	24	1.95	1.85	6.55
C-D	17.60	1.53	5.57	1.63	1.38	8.28
D-E	247.23	1.49	4.75	1.58	16.74	7.09
E-F	68.59	1.55	4.60	1.63	4.84	7.38

95th percentile travel time reliability for five segment of the study corridors are tabulated in Table 7. It can be noticed from the table is giving higher 95th % travel time in five segment evening peak periods. Highest value of 95th percentile travel time is observed in segment (D-E). Highest value of Buffer Time index observed as segment (A-B). Also Travel Time Index and Planning Time Index shows highest values observed for segment (C-D).

Table 7 Travel Time Indices (E.P.H.)

Segment	95th T.T. (sec.)	TTI	BTI %	PTI	σ	% of variation
A-B	47.92	1.57	5.56	1.66	3.76	8.28
B-C	29.11	1.57	3	1.61	1.12	3.95
C-D	18.88	1.68	3.62	1.75	1	5.49
D-E	242.58	1.53	4.91	1.56	16.98	7.21
E-F	66.99	1.53	3.84	1.6	3.7	5.74

V. CONCLUDING REMARKS

Travel time indices for five segments of study corridor have been found out based on traffic survey on typical week day. 95th percentile travel time is found to vary from 242-248 sec. for longest section D-E to 17-19 sec. for shortest section C-D during morning as well as evening periods. According to travel time index value, travel time during peak hours is expected to be more by 49% to 68% compared to off peak condition periods. Travelers need to budget at least 5% more time while traveling on all segments except on segment B-C for which 24% more time than the mean travel time is needed to be 95% confident of on time arrival at destination. Planning time index values indicate that travelers must expect 56% to 95% more travel time during peak period than the off peak period travel time on different segment so as to ensure 95% on time arrival. Among all segments, variability in travel time is observed to be highest for segment D-E during morning and evening peak hours with maximum standard deviation of about 17 sec.

REFERENCES

[1] Asakura, Y. and Kashiwadani,M. (1995), Traffic Assignment in a Road Network with aded Links by Natural Disasters , Vol.1(3) ,pp.1135-1152.

[2] Asakura, Y. and Kashiwadani,M. (1991). Road Network Reliability Caused by Daily Fluctuation of Traffic flow. Proc., of the 19th PTRC, Summer Annual Meeting in Brighton, Seminar G, pp. 73-84

[3] Cambridge Systematics, Inc.; Dowling Associates, Inc.; System Metrics Group, Inc.; Texas Transportation Institute (2008). Cost-Effective Performance Measures for Travel Time Delay, Variation, and Reliability, NCHRP Report 618, Transportation Research Board, Washington,

[4] DC.Cambridge Systematics, Inc., High Street Consulting Group, Trans Tech Management, Inc., Spy Pond Partners, Ross & Associates (2009). Performance Measure Framework for Highway Capacity Decision Making, NCHRP Report 618, Transportation Research Board of National Academies, Washington, DC.

[5] Chao Chen & Alexander Skabardonis & Pravin Varaiya (2003) Travel Time Reliability As A Measure Of Service Transportation Research Board January Washington, D.C. P.N.

[6] Kate Lyman & Robert L. Bertini (2008) Using Travel Time Reliability Measures to Improve Regional Transportation Planning and Operations Transportation Research Board JanuaryPolus, A.,(1979) "A Study of Travel Time and Reliability on Arterial Routes," Transportation, Vol. 8, pp. 141-151.

[7] Susilawati et al.(2010) Travel Time Reliability Measurement for Selected Corridors in the Adelaide Metropolitan Area