Travel time reliability as a level of service measure for urban and inter-urban corridors in India

Anish Kumar Bharti[1], Ch. Ravi Sekhar[2,*] and Satish Chandra[2]

[1]Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee 247 667, India
[2]CSIR-Central Road Research Institute, New Delhi 100 025, India

The present study demonstrates the application and usefulness of travel time reliability as a level of service (LOS) measure for urban arterial and inter-urban highway corridors on Indian roads. For travel time estimation, automatic vehicle license plate number data were collected through *TrafficMon* system. This system is a fully video-based enforcement system designed to measure the speed of vehicles passing in view of the camera, and read the vehicular license plate number. This system was implemented at the entry and exit side of the identified three study corridors and data were collected during morning and evening peak periods. The data were analysed and various travel time reliability measures were evaluated. The study also attempts to correlate reliability measures such as planning time (PT), buffer time (BT), planning time index (PTI) and buffer time index (BTI) with volume-to-capacity ratio which is the most widely used LOS measure for Indian roads. Analysis of results indicated that at LOS B the travel time of intercity highway was 40–46 sec/km, whereas it was 64–80 sec/km and 75–135 sec/km for urban uninterrupted and interrupted corridors respectively. The planning time for LOS B was more on urban arterial corridors when compared to inter-urban corridor for the same width of the carriageway. The upper limits of LOS B for PT were 132 sec/km and 63 sec/km for uninterrupted urban corridor and intercity highway corridor respectively. Other parameters of reliability like PTI and BTI were also evaluated and their values for different ranges of volume-capacity ratio were presented for identified corridors.

Keywords: Automatic license plate method, buffer time index, capacity, travel time index, travel time reliability, urban arterial.

THE importance of travel time reliability compared to other network reliability measures such as connectivity reliability or capacity reliability has resulted in several studies in the area of transport network reliability. Earlier, an user equilibrium (UE) based mathematical model was developed to measure the travel time reliability of a road transportation system[1]. Empirical-based studies were initiated by the federal highway administration[2]. Travel time reliability is useful for transport system planners as well as users[3]. It can be used in policy assessment and also provides travel time-related information to users[4]. Chen *et al.*[5] stated that travel time reliability is an important measure of service quality for travellers.

Level of service (LOS) is a quantitative stratification of a performance measure or measures that represent quality of service[6]. The LOS concept, initially introduced in the 1965 highway capacity manual (HCM), is a localized measure and is used to analyse the operation of specific locations of highway sections[5]. The HCM defines six levels of service, ranging from A to F for each service measure. It uses density as the service measure for multi lane highways and average overall travel speed for arterials and urban street segments[6]. Other service measures considered for various system elements in the 2010 HCM are density for freeway sections and per cent time spent following and average travel speed for two-lane highways. These measures do not capture the variability in travel time. Although travel time, LOS, and delay are all related and provide different summaries of the underlying traffic conditions, only travel time-based statistics capture the variability experienced by individual drivers. The preliminary study carried out by the Strategic Highway Research Programme (SHRP) on incorporating travel time reliability into HCM 2010, is the first in a series of major investments in studying the reliability of service provided on transportation systems[7]. Reliability-based performance measures do not answer the question 'how is the traffic today', but answer the question 'what is the probability that traffic will be bad today'. Reliability is couched in terms of variation in travel time for any given trip or set of trips[8].

Travel time reliability has not yet been fully developed as a parameter of LOS for Indian roads. Although travel time reliability is a scientific approach to evaluate the performance of a network under uncertainties, it has not been explored in India particularly with respect to its applicability to mixed traffic conditions. There is need to redefine LOS of roads in India to better describe the

*For correspondence. (e-mail: chalumuri.ravisekhar@gmail.com)

actual traffic conditions matching the perception of road users.

Travel time variation can be observed on urban and intercity highway corridors on various Indian roads. This variation is mainly due to demand side, supply side and other external factors. The objective of this study is to evaluate the performance of urban as well as intercity highway corridors in and around Delhi using travel time reliability indices such as planning time (PT), planning time index (PTI), buffer time (BT) and buffer time index[2]. These measures were compared with the volume–capacity ratio (V/C) of the study section. The capacity of the study corridor was estimated through empirical data and the relations between V/C ratio and reliability indices were established.

Literature review

This section provides literature related to travel time reliability measures of a transportation system and LOS criteria and indicates how the reliability measures can be adopted for quantifying the level of service for a transportation system. Studies have developed travel time reliability measures based on empirical data on travel time distribution on a transportation system. Travel time reliability measures such as PT, BT, PTI and BTI are most widely adopted measures in the literature. These indices were initially introduced by Federal Highway Administration (FHWA)[2]. PT is the 95th percentile travel time of the measured travel time distribution on a route. BT is the difference between 95th percentile travel time and the average travel time, also called an extra budget time. PTI is defined as the ratio of 95th percentile travel time to free flow travel time. BTI is defined as the ratio of buffer time to average travel time.

US-HCM, historically among the most important reference guides used by various transportation professionals, is useful for planning, design, preliminary engineering and operational analysis[6]. It provides analytical concepts for characterizing traffic flow, capacity, quality-of-service (QOS) and LOS, which are useful. US-HCM provides guidance on analysing facilities, segments, and points for uninterrupted-flow roadways, such as freeways and multilane highways. It distinguishes between capacity and other performance measures, such as density, speed, delay, number of stops, queue length and volume-to-capacity ratio[9].

Though travel time and travel time reliability are increasingly recognized as important mobility performance measures, HCM lacks a method to address these mobility performance measures for specific types of facilities such as freeways, multilane highways and urban corridors. HCM provides the LOS on freeways based on density in terms of passenger cars per mile per lane (pc/mi/ln). However, traffic movement has dynamic characteristics and density calculation is not readily available from field, which makes it difficult to track the performance of the freeways based on the current method. Therefore, travel time and/or travel time reliability based performance measurement is a great concept to replace the existing method[10].

Chen *et al.*[5] and Lyman and Bertini[11] examined the application of travel time reliability measurement as a criteria for LOS. As the typical LOS method does not reflect user's experience during the trip, Chen *et al.*[5] discussed the use of travel time reliability in place of LOS. Lyman and Bertini[11] investigated travel time reliability measure to quantify congestion. The study examined five minute interval data to compare BTI, TTI and PTI for three consecutive years of daily travel time along the Portland highways. They found that even though the three travel time reliability indices gave the same pattern along the roadway, PTI gave a higher index than the other two. Therefore, they compared only BTI and TTI to give priority for congestion relief through incident response systems, bottleneck improvements, and better traveller information and proposed a ranking system to select the highest priority corridor. Ravi Sekhar *et al.*[12] carried out a comprehensive evaluation of various travel time reliability indices on different corridors of the Hanshin expressway road network. They suggested PT and PTI to be more useful for personal traffic and BT and BTI for commercial traffic.

Tanabe *et al.*[13] found that the appropriate functional hierarchy of road may be disturbed by travel time uncertainty. These findings suggest that a reliability index of travel time is a useful and important measure to evaluate both actual LOS and functional hierarchy of roadway network. Kittelson and Vandehey[9] conceptualized and described several ideas to use travel time reliability to establish freeway LOS. However, it is still in preliminary stage and there is a lack of consensus on the best approach. This study brings harmony among all the volume-to-capacity ratios and replaces them with travel time and travel time reliability thresholds for the urban interrupted and uninterrupted corridors and intercity highway corridors.

Study area and data collection

Study area

Three study corridors were identified to collect the traffic data such as traffic volume, speed and travel time data. The physical characteristics of each study corridor are given in Table 1. The detailed description of each study section is discussed below.

Lala Lajpat Rai Road (C-1) in New Delhi is a 6-lane divided carriageway having 10.5 m road width in each direction. There is no major merging or diverging within the section of 1.7 km of the road. Bhisma Pitamah marg

Table 1. Physical characteristics of identified study sections

Corridor id	Name of the road section	Type of the corridor	Number and width of the lane	Direction of traffic flow considered	Length of the corridor (km)
C-1	Lala Lajpat Rai Marg, New Delhi	Uninterrupted flow urban arterial	6-lane divided carriageway. Width of the carriage way is 10.5 m	Oberoi Hotel to Lajpatnagar	1.70
C-2	Bhishma Pitamah Marg, New Delhi	Interrupted flow urban arterial with four arm signalized intersection	6-lane divided carriageway. Width of the carriage way is 10.5 m	Lodi road to Inner ring road	1.50
C-3	National Highway 10 Near Sampla village	Interstate national highway (uninterrupted flow)	6-lane divided carriageway. Width of the carriage way is 10.5 m	New Delhi to Rohatak	4.70

Table 2. Total traffic volume on indentified study corridors

		Total traffic volume (vehicles)	
Name of the section	Date and day of survey	Morning hours 7 : 30 a.m.–11 : 30 a.m.	Evening hours 3 : 00 p.m.–7 : 00 p.m.
Lala Lajpat Rai Marg, New Delhi (C-1)	31 March 2013, Sunday	15,252	18,124
	2 April 2013, Tuesday	16,136	18,392
	3 April 2013, Wednesday	13,552	19,808
Bhishma Pitamah Marg, New Delhi (C-2)	6 October 2013, Sunday	3,880	6,492
	7 October 2013, Monday	6,612	9,768
	8 October 2013, Tuesday	7,304	10,792
National Highway 10 near Sampla village (C-3)	1 June 2014, Sunday	3,364	3,348
	2 June 2014, Monday	2,672	2,188
	3 June 2014, Tuesday	2,164	2,712

(C-2) is also a 6-lane divided carriageway having 10.5 m road width in each direction, but with one signalized intersection in the study corridor. Both the urban study corridors have the facility for pedestrians to walk on both sides of the road. The interstate highway corridor National Highway-10 (C-3) is of 4.5 km length and is a 6-lane divided carriageway having 10.5 m road width in each direction. There is no major merging or diverging on this study corridor. The start and end point of the study section was 500 m away from the nearest intersection to mitigate the effect of acceleration and random arrival of vehicles approaching the trap.

Data collection

For this study, traffic volume data, vehicular speed data on trap length and automatic vehicle license plate data on study corridor at the entry and exit locations of study corridor were collected (Figure 1). The data were collected during morning hours (7 : 30 a.m. to 11 : 30 a.m.) and evening hours (3 : 00 p.m. to 7 : 00 p.m.). These timings were selected to capture the variation in travel time due to traffic volume. The traffic volume as well as speed data were collected on a trap length of 60 m on each study corridor. The trap section was identified on the entry side of the study corridor and was marked in the traffic flow direction as mentioned in Table 1. Video graphic method was employed for collection of traffic and speed data. A video camera was installed on its stand and placed on the footpath of the corridor away from the moving traffic to cover the entire length of the trap. For automatic license plate data *Trafficmon* system[14] was used which is further discussed in the later part of the paper.

Traffic volume and composition data

Traffic volume data was extracted from video graphic data on each study section for the study period of 4 h in the morning and 4 h in the evening. This data is presented in Table 2. From this table, it is seen that higher traffic volume was observed in the evening than in the morning on urban arterial roads. However, on inter-city highway corridors, the same amount of traffic was observed both in the morning and evening. The average traffic volume on C-1 was 3745 veh/h in the morning, and 4694 veh/h in the evening. Moderate traffic volume was observed on C-2 where the traffic volume was 1483 veh/h during morning hours and 2254 veh/h during evening hours. On

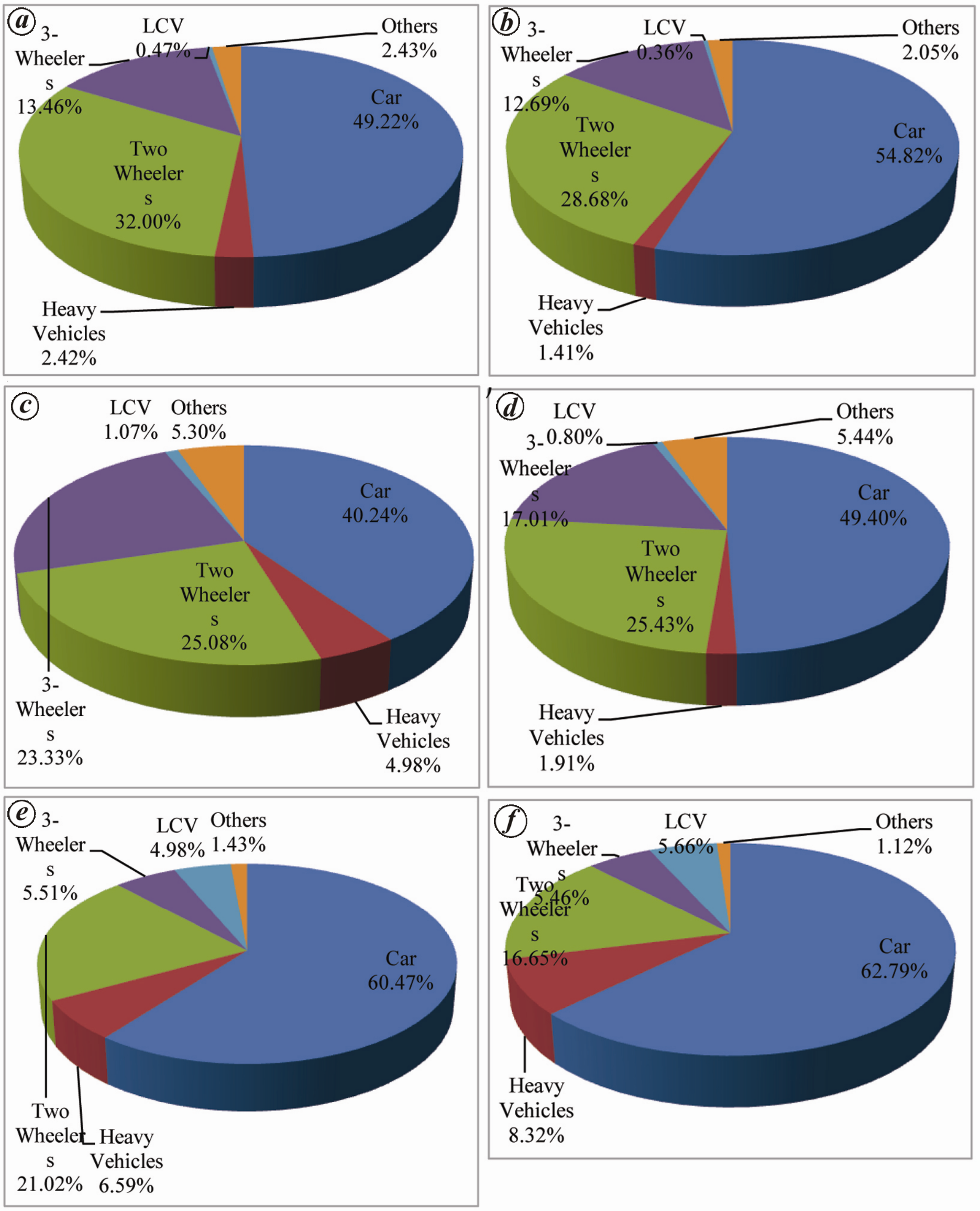

Figure 1. Composition of traffic on various study corridors. ***a***, During morning hours on C-1; ***b***, During evening hours on C-1; ***c***, During morning hours on C-2; ***d***, During evening hours on C-2; ***e***, During morning hours on C-3; ***f***, During evening hours on C-3.

intercity highway the average traffic volume was comparatively low at 685 veh/h. The vehicular composition on the study section for morning hours and evening hours is presented in Figure 2. The most predominant composition was 45% in the morning and 52% in the evening. Motorized two wheelers constituted about 36% in the morning and 25% in the evening.

Automatic license plate data

License plate matching technique was used for measuring travel time on all three study corridors. For this, *Trafficmon* system[15], a fully video-based enforcement system devised for measuring the speed of the vehicle passing in the view of the camera was used. It also reads the vehicle

Table 3. Sample size for matching of license plate numbers

Name of the section	Morning hours (7 : 30 a.m.–11 : 30 a.m.)			Evening hours (3 : 00 p.m.–7 : 00 p.m.)		
	Total cars	Sample size	Percentage matching	Total cars	Sample size	Percentage matching
Lala Lajpat Rai Marg, New Delhi (C-1)	22,084	10,161	46	30,903	11,104	36
Bhishma Pitamah Marg, New Delhi (C-2)	7,217	1,984	27	13,404	3,465	26
NH 10, Near Sampla village (C-3)	4,988	2,284	46	5,253	2,735	52

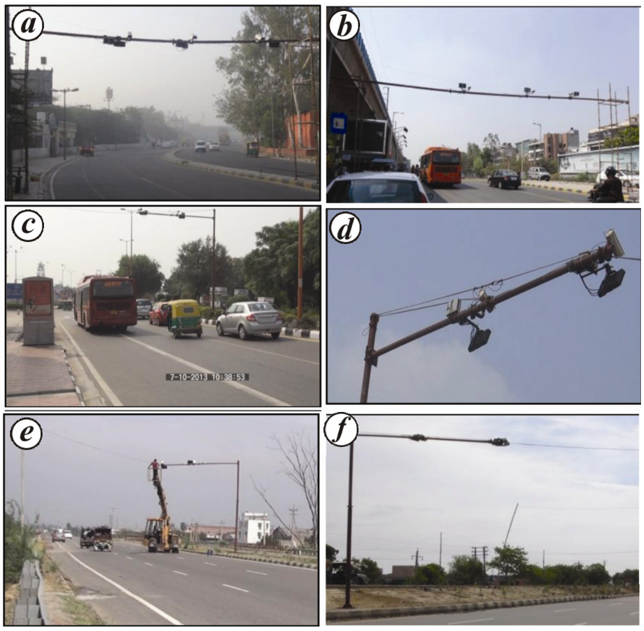

Figure 2. Installation of IP based video cameras. ***a***, Entry side of Lala Lajpat Rai Marg (C-1); ***b***, Exit side of Lala Lajpat Rai Marg (C-1); ***c***, Entry side of Bhishama Pitamah Marg (C-2); ***d***, Exit side of Bhishama Pitamah (C-2); ***e***, Entry side of NH10 (C-3); ***f***, Exit side of NH10 (C-3).

license plate number through vehiscan, a real time optical character recognition system. This system detects and reads license plate numbers through a video streamed in real time from an internet protocol (IP)-based video camera which is mounted on the median facing the vehicle front portion. IP-based video cameras were installed at the entry and exit locations of each study corridor to capture the vehicle license plate for all categories of vehicles (Figure 2). Three days which included two working days and one non-working day continuous data were collected for this part of the study on each study section. The objective of this survey was to estimate travel time for the study area for the period, i.e. 7 : 30 a.m. to 11 : 30 a.m. and 3 : 00 p.m. to 7.00 p.m. In this survey, vehicle license plate numbers and their arrival times at the entry and exit points of the study corridor were recorded automatically. Subsequently, license plates at the entry and exit points were matched and travel time was calculated from the difference in arrival times at these two points. Only passenger cars, including both small and big cars were considered for this part of the study for estimating travel time due to time and resource constraints. On an average 41%, 27% and 49% of vehicle license plate numbers were matched for uninterrupted urban arterial corridor, interrupted urban corridor and intercity highway corridor respectively (Table 3). License plate of two-wheelers could not be identified properly from videos and hence analysis was restricted to cars only. Statistical parameters such as minimum, maximum, mean and standard deviation of travel time data for the study area at various time intervals were calculated, which are presented in the next section.

Estimation of travel time

The average travel time and standard deviation of travel time for working and non-working days on all three study corridors are presented in Figure 3. As observed, the maximum average travel time on a working day was 115 sec/km, 251 sec/km and 50 sec/km on corridors 1, 2 and 3 respectively. The respective values on a non-working day were 89 sec/km, 170 sec/km and 50 sec/km. The minimum average travel times for these corridors on a working day were 66 sec/km, 105 sec/km and 45 sec/km and on a non-working day were 58 sec/km, 107 sec/km and 42 sec/km. The trend of average travel time was similar on urban arterial corridors. However, the average travel time profile of interrupted flow corridor had higher gradients than uninterrupted flow corridor. The intercity highway corridor showed insignificant variation in average travel time. Higher average standard deviation (SD) of 40 sec/km was observed on working and non-working days on corridor 2. The SD on corridor 1 was 29 sec/km and on corridor 3 was 10 sec/km. All SD profiles of the study corridors showed no clear peaks during evening and morning hours.

Estimation of travel time reliability

Planning time and buffer time

A travel time reliability of 95% for all study corridors (Figure 4) shows that the variation of planning time on working days was 91–203 sec/km, 144–320 sec/km and 55–77 sec/km on study corridors C-1, C-2 and C-3

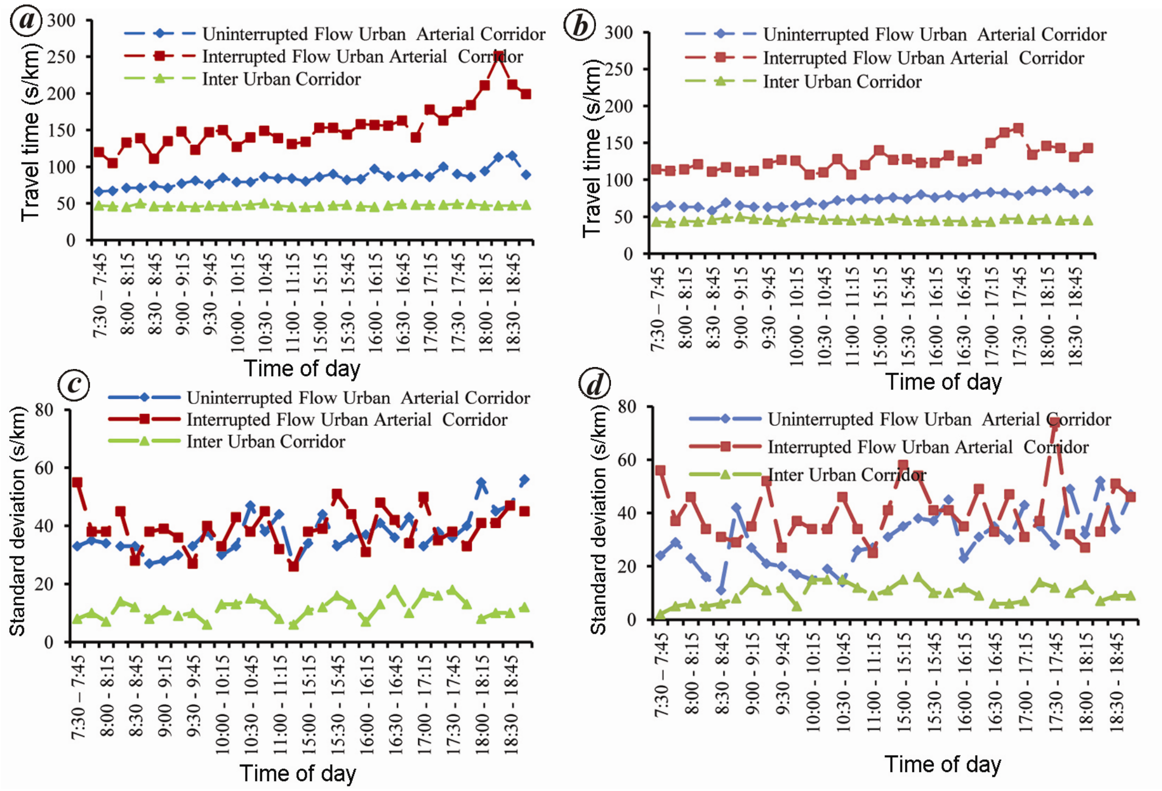

Figure 3. Average travel time and standard deviation (SD) on study corridors. ***a***, During working day; ***b***, During non-working day; ***c***, During working day; ***d***, During non-working day.

respectively. Higher planning time was observed on corridor C-2 followed by C-1 and C-3. Buffer time on a working day was 19–118 sec/km, 32–93 sec/km and 10–29 sec/km on study corridors C-1, C-2 and C-3 respectively. On a non-working day, the 95th percentile travel time reliability for all study corridors was in the range of 72–200 sec/km, 153–345 sec/km and 45–74 sec/km on study corridors C-1, C-2 and C-3 respectively. Buffer time on working days varied in the range 9–111 sec/km, 28–175 sec/km and 2–28 sec/km on study corridors C-1, C-2 and C-3 respectively. The average PT (95th percentile travel time) was marginally lower on non-working days when compared to working days on inter highway corridor (C-3). Significant difference in PT was observed during non-working days when compared to working days on urban arterial corridors (C-1 and C-2).

PTI and BTI for all study corridors are presented in Figure 5. From this figure it can be identified that the variation of PTI on working days was 1.6–3.5, 3.5–7.7 and 1.2–1.7 on study corridors C-1, C-2 and C-3 respectively. Higher PTI values were observed on corridor C-2 followed by C-1 and C-3. BTI on working days varied in the range 0.2–1.3, 0.2–0.7 and 0.2–0.6 on study corridors C-1, C-2 and C-3 respectively. On non-working days, the PTI for all the study corridors was in the range 1.2–3.4, 3.7–8.3 and 1.0–1.7 on C-1, C-2 and C-3 respectively. Corresponding values for BTI on working days were 0.1–1.4, 0.2–1.0 and 0.1–0.6 on C-1, C-2 and C-3 respectively. The average PTI was the same on working and non-working days (1.4) on inter highway corridor (C-3). However, in the case of urban arterial corridors, significant difference in PTI values was observed. The average PTI value on uninterrupted urban corridor was 2.3 and 1.8 on working and non-working days respectively. However for an interrupted urban corridor it was 5.1 on working days and 4.6 on non-working day.

Estimation of capacity

The main problem in developing the analytical speed-flow relationship on Indian roads is the heterogeneity of traffic. The vehicles in the mix produce different impedance due to their varied static and dynamic characteristics. Hence simply adding the number of vehicles does not give the authentic speed flow relationship. For this reason, the vehicles are normally presented in terms of a standard type of vehicle using certain conversion factors. Generally, a passenger car is adopted as a standard vehicle and therefore the factor is known as passenger car unit (PCU). Many studies have developed methods to estimate PCU for a vehicle type. There exists large variation in PCU values adopted in different parts of the world. In the present study, vehicles of different types

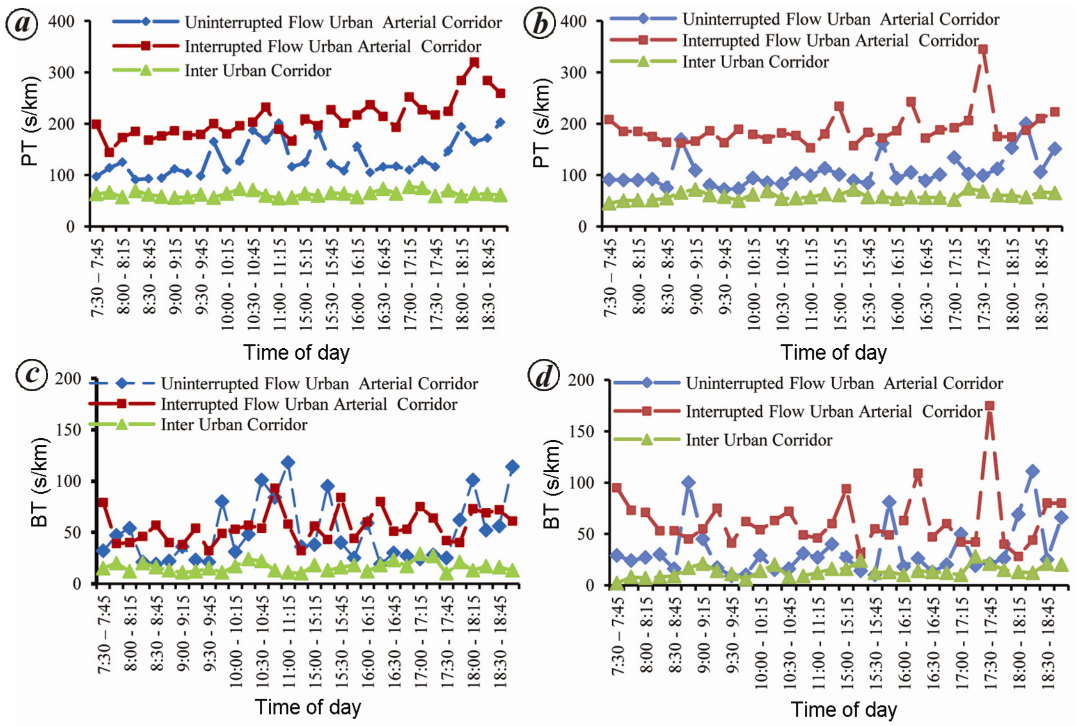

Figure 4. Planning time and buffer time comparisons among study corridors. ***a***, During working day; ***b***, During non-working day; ***c***, During working day; ***d***, During non-working day.

were converted into equivalent number of standard cars by using PCU factors as given by[15]

$$PCU_i = \frac{V_c / V_i}{A_c / A_i}, \quad (1)$$

where PCU_i is the passenger car unit value of *i*th type of vehicle; V_c/V_i the speed ratio of the standard car to the *i*th vehicle and A_c/A_i is the physical rectangular area ratio of the standard car to the *i*th vehicle.

In India ITS technologies are yet to be implemented on highway road network in a traditional way; therefore measurement of density in the field is difficult. Hence speed and volume data were used to calculate traffic density using the fundamental relationship between speed, flow and density. This relationship was used to develop the speed–density curve and then the complete theoretical speed–volume curve as shown in Figure 6. Similar curves were drawn for the other two corridors as well. The average capacity of all three sections selected for the present study is estimated to be 6003 pcu/h/dir, 5965 pcu/h/dir and 6017 pcu/h/dir for C-1, C-2 and C-3 respectively.

Travel time reliability as a level of service measure

The assessment of operational performance of uninterrupted traffic flow corridor and interrupted traffic flow corridor is a challenging task for any transportation engineer/planner due to dynamic and mixed traffic movement. A qualitative traffic measure is considered in the scale of LOS A–F in the US-HCM[6], a widely used manual in the world. The criteria of LOS are mainly based upon density along with speed for uninterrupted flow corridors and control delay for interrupted flow urban corridor. The calculation of density is difficult from field data. Therefore the travel time and travel time reliability-based approaches are becoming important to measure the performance of urban and inter-urban road corridors. In this study five variables were considered for determining the LOS criteria. These are average travel time per kilometre, planning time per kilometre, buffer time per kilometre, PTI and BTI. The LOS ranges were defined after performing K-mean clustering in MATLAB software[16]. The silhouette index was estimated for different numbers of clusters for the empirical data. Tables 4–6 illustrate the ranges of different LOS with respect to travel time, PT and BT and PTI and BTI parameters obtained after applying K-mean clustering using four clusters. In India LOS criteria is better understood in terms of volume–capacity ratio (V/C) and hence this study estimates reliability based LOS with reference to V/C ratio.

LOS based on travel time and V/C ratio

Table 4 presents the travel time based V/C ratio for all three study corridors. The LOS ranges of V/C ratios were

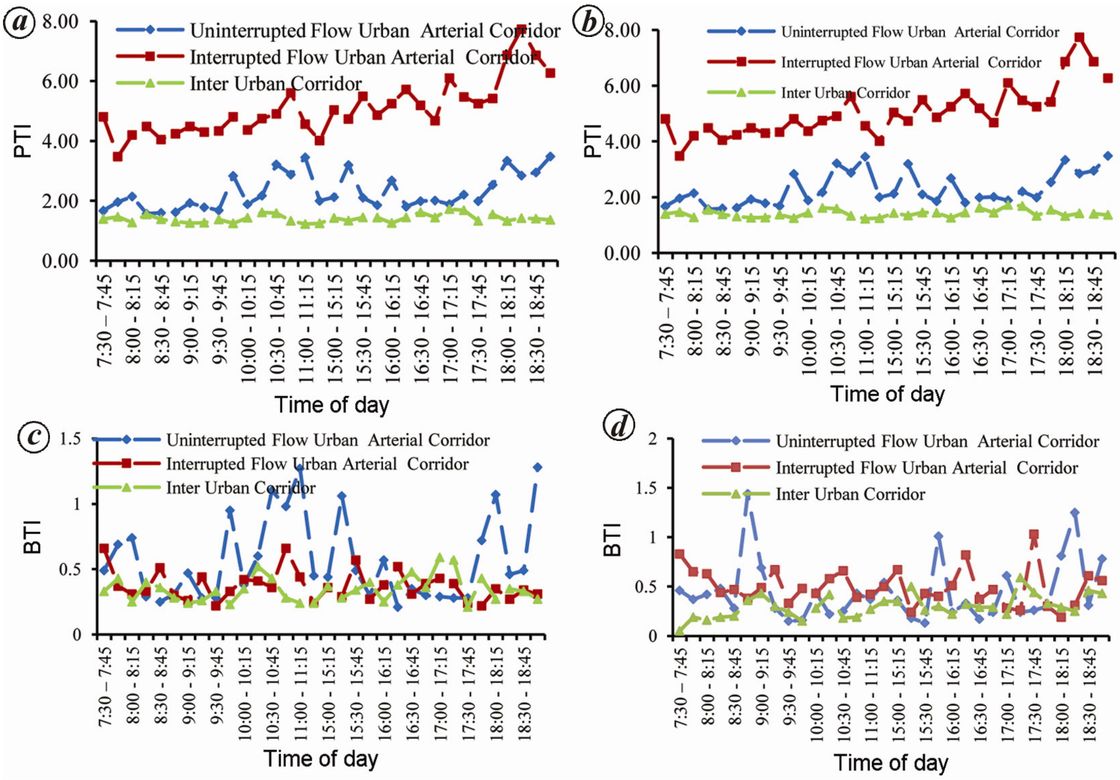

Figure 5. Planning time index and buffer time index on study corridors. ***a***, During working day; ***b***, During non-working day; ***c***, During working day; ***d***, During non-working day.

Table 4. Travel time measures versus volume to capacity ratio (V/C)

	Lala Lajpat Rai Marg (C-1)		Bhishma Pitamah Marg (C-2)		National Highway 10 (C-3)	
LOS	V/C	TT	V/C	TT	V/C	TT
A	<0.29	<64	< 0.20	<75	<0.21	<40
B	0.29–0.47	64–80	0.21–0.38	75–135	0.21–0.43	40–46
C	0.48–0.64	80–95	0.39–0.50	135–186	0.44–0.61	46–50
D	0.65–0.80	95–136	0.51–0.71	186–279	0.62–0.82	50–65
E	0.80–1.0	>136	0.71–1.0	>279	0.82–1.0	>65

defined based on the *K*-means cluster analysis. Four clusters were decided in which the data were grouped. Based on the mean of the cluster, the centre of each cluster was decided. Further Euclidean distance between each data point and the centre of each cluster was estimated. The entire process was done by using MATLAB software. The clusters were validated by silhouette method. At LOS B, the travel time on intercity highway (C-3) was 40–46 s/km whereas it was 64–80 s/km on uninterrupted urban corridor and 75–135 s/km on interrupted urban corridor. The upper threshold value of travel time for a given LOS increased significantly for the urban corridor due to uncertainty in the travel time. LOS B represents zone of stable flow; drivers have reasonable freedom to select their desired speed. Beyond this LOS, operation of individual users is affected by interaction with others in the traffic stream. That is the reason for taking this while comparing the performance of test sections using LOS.

Reliability LOS-based on PT and BT

Table 5 presents travel time reliability LOS corresponding to V/C threshold for PT and BT. As seen, the 95th percentile travel time for LOS B is more for urban arterial corridor when compared to inter-urban corridor for the same width of carriageway. The upper limit of LOS B for PT is 132 s/km, 171 s/km and 63 s/km for corridors C-1, C-2 and C-3 respectively. In the case of BT, the threshold of difference between the 95th percentile and the 50th percentile travel time for LOS B is 38 s, 38 s and 14 s for corridors C-1, C-2 and C-3 respectively. BT is

Table 5. TTR LOS based on planning time (PT) and buffer time (BT)

	Lala Lajpat Rai Marg (C-1)			Bhishma Pitamah Marg (C-2)			National Highway 10 (C-3)		
LOS	V/C	PT	BT	V/C	PT	BT	V/C	PT	BT
A	0.0–0.29	<73	<5	0.00–0.20	<87	<10	0.0–0.21	<43	<5
B	0.29–0.47	73–132	5–38	0.21–0.38	87–171	10–38	0.21–0.43	43–63	5–14
C	0.48–0.64	132–209	38–128	0.39–0.50	171–239	38–69	0.44–0.61	63–86	14–31
D	0.65–0.80	209–325	128–225	0.51–0.71	239–317	69–174	0.62–0.82	86–132	31–73
E	0.80–1.0	>325	>225	0.71–1.0	>317	>174	0.82–1.0	>132	>73

Table 6. TTR LOS based on planning time index and buffer time index

	Lala Lajpat Rai Marg (C-1)			Bhishma Pitamah Marg (C-2)			National Highway 10 (C-3)		
LOS	V/C	PTI	BTI	V/C	PTI	BTI	V/C	PTI	BTI
A	0.00–0.29	<1.09	<0.05	0.00–0.21	<1.82	<0.01	0.00–0.21	<0.89	<0.03
B	0.29–0.47	1.09–1.37	0.05–0.57	0.21–0.38	1.82–3.24	0.01–0.31	0.21–0.43	0.89–1.01	0.03–0.29
C	0.48–0.64	1.37–1.63	0.57–1.21	0.39–0.50	3.24–4.50	0.31–0.63	0.44–0.61	1.01–1.11	0.29–0.63
D	0.65–0.80	1.63–2.34	1.21–2.24	0.51–0.71	4.50–6.74	0.63–1.32	0.62–0.82	1.11–1.45	0.63–1.32
E	0.80–1.0	>2.34	>2.24	0.71–1.00	>6.74	>1.32	0.82–1.00	>1.45	>1.32

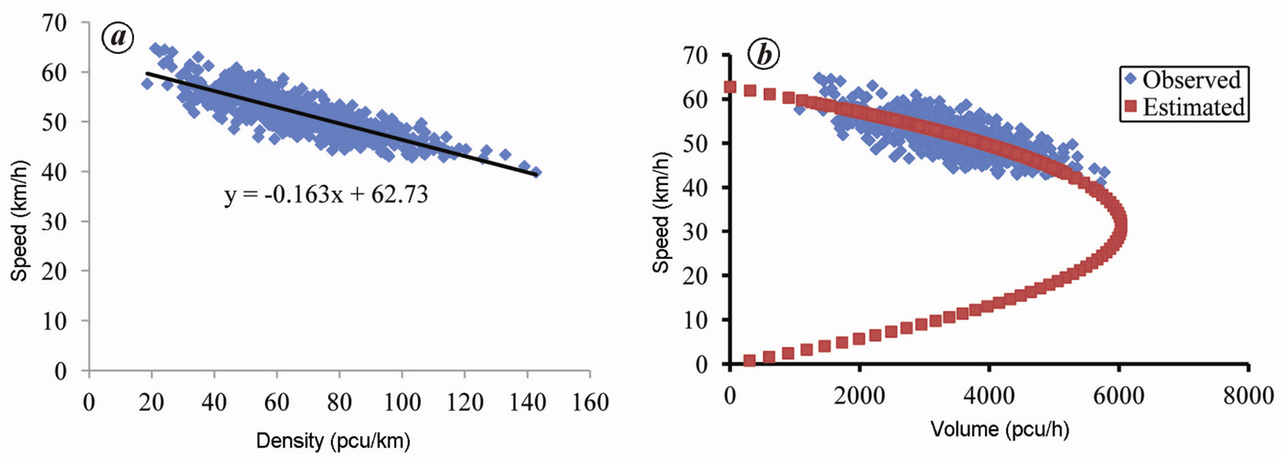

Figure 6. Speed volume relationships of the identified study corridors.

comparatively more on the uninterrupted urban corridor than that for the interrupted urban corridor. This is mainly due to higher average travel time on the uninterrupted corridor. Therefore PT is a better representation than BT for LOS on urban arterial corridors.

Reliability LOS-based on PTI and BTI

Table 6 illustrates the PTI and BTI values for different ranges of *V*/*C* ratios at different LOS on the three study corridors. The PTI-based LOS threshold tends to increase from interrupted urban corridors to uninterrupted urban arterial corridors, whereas BTI values do not follow any trend. From this, it can be inferred that PTI is a more appropriate performance LOS measure than BTI for urban as well as intercity highway corridors.

Conclusions

The present study is an attempt to measure travel time reliability on urban arterial and intercity highway corridors in India. Travel time was estimated by automatic vehicle license plate matching method using IP-based video graphic data on urban and inter-urban corridors in Delhi and the travel time reliability was analysed. The results of the travel time analysis indicate that the threshold of PTI corresponding to LOS B was 1.37 and 1.01 for urban uninterrupted and intercity highway corridors respectively. This means that travel time on the urban uninterrupted study corridor is 1.37 times more than free flow travel time. However the same threshold for interrupted flow urban corridor is 3.2 times more than free flow travel time. This is an important conclusion for trip makers and planners. PTI LOS threshold tends to increase from interrupted urban corridors to uninterrupted urban arterial corridors, whereas for BTI, the values do not follow any trend. The upper limit of LOS B for PT is 132 s/km, 171 s/km and 63 s/km for corridors C-1, C-2 and C-3 respectively. In the case of BT, the threshold for LOS B is 38 s, 38 s and 14 s for corridors C-1, C-2 and C-3 respectively. Travel time reliability is currently not used in transportation planning or for performance evaluation of corridor/network in India. This study demonstrates its usefulness and the importance of travel time reliability for road transportation communities in India.

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