Evaluation of Travel Time Reliability on Urban Arterial

Pagidimarry Gopi
Post Graduate student,
Civil Engineering Department,
NIT Kurukshetra,
Kurukshetra, India

Dr. S. N. Sachdeva
Professor,
Civil Engineering Department,
NIT Kurukshetra,
Kurukshetra, India

A. K. Bharati
Ex-Asst.Professor,
Civil Engineering Department,
NIT Kurukshetra,
Kurukshetra, India

***Abstract*— Improvements in standard of living of people and increased economic activities have resulted in a corresponding increase in traffic across existing transport networks. Hence, there is a need for examining the performance of this networks/corridor. The main objective of this study is to evaluate the travel time reliability measures of uninterrupted urban arterial corridor in the Delhi Road network during peak hours of a working day and non-working day. To do this, various existing travel time reliability indices are considered and are examined. The advantage of travel time reliability is that, it can be used in performance evaluation as a new evaluation technique and also it can be used as travel time related information to the system users. Reliability measures such as planning time index (PTI), Planning Time (PT) and Buffer Time Index (BTI) are studied.Results reveal that reliability measures are more capable of evaluating the performance of urban arterial corridor.**

Keywords*— *Travel Time Reliability, Urban arterial, License Plate Matching, Planning time, Planning time index, Buffer time index

I. INTRODUCTION

Urban population of Indian cities is increasing at the rate of 3% per annum with major focus on metropolitan cities. Travel time has become a crucial performance parameter for evaluating urban corridors and networks for traffic control and regulation. During last two decades, the vehicular population in cities has grown at rate of 9.8%, the road length has increased only at 3.4% rate. Information on time of travel between a pair of origin and destination is key input for decision regarding time of departure, mode of travel and route by an individual traveler. Unpredictable travel-time delays in urban road networks in India due to traffic problems like congestion, road-accidents etc, are creating serious concerns about transport system quality. Travel time reliability is one of the parameters which evaluate the quality of traffic service on the urban road and is also significant to many transportation system users, whether they are vehicle drivers, transit riders, or freight movers. Reliability has been studied within many fields such as electronic system, power system, transportation system etc. Travel time reliability studies have extensively used travel time distribution as a tool for developing various reliability indices such as Planning Time (95% travel time), Buffer Time Index (BTI) and Planning Time Index (PTI) (Margiotta 2002, FHWA Report 2006, Van lint et al., 2004 and Asakura 2006). All these reliability indices are useful to improve regional transportation planning (Lyman K et al. 2008) and measuring the performance of the transportation system (Ravi sekhar et al. 2007).This measurement is useful when evaluating network performance under normal daily flow variations. The main advantage of this type of measurement is that, it is useful to the both the transport planners as well as the system users.

II. LITERATURE REVIEW

Two approaches are mainly available in the literature for measuring travel time reliability of road transportation system those includes mathematical based travel time reliability measurements (Asakura and Kashiwadhani, 1991; Lee et.al, 2000; Chen et.al.2003) and empirical based measures (FHWA Report 2006). Mathematical based reliability measurements are developed based on conventional User Equilibrium (UE) route choice principle, whereas empirical based reliability measures are developed based on travel time distribution which is obtained by travel time history of users experience for the particular link/road. Particularly, empirical based measures are relatively easy to understand by non-technical road users. Federal Highway Administration (FHWA) has defined travel time reliability as consistency or dependability in travel time, as a measure from day to day and or across different times of the day (FHWA Report 2006; Margiotta 2002). Performance indicators such as 95thpercentile travel time, Buffer Index (BI) and Planning Time Index (PTI) were developed under this category. Travel time distribution is the base for development of all these indices. These indices are discussed in the following. (FHWA Report 2006):

A. *95th Percentile Travel Time*: It is the 95th percentile travel time of the measured travel time of the route. It represents travel time on some of the heaviest traffic days.

B. *Buffer Time Index (BTI)*: It is the ratio of buffer time (extra budget time) to average travel time. Where buffer time is the difference between 95thpercentiletravel time and the average travel time

C. Planning time Index (PTI): It is the ratio of 95th percentile travel time to free flow travel time.

III. STUDY AREA AND DATA COLLECTION

A. Study Area

Study area for present study is capital of India, New Delhi where traffic condition is becoming worse day by day. A section of about 1.7 km on urban arterial road is selected. For present study, typical corridors of arterial road having no any intersection are selected within the selected study stretch.

B. Data Collection

Data used in this study were collected on a section of arterial road in New Delhi, India. The section from Oberai hotel to Lajpatnagar metro station (Figure 1) (length 1.7 km) was considered for modeling the travel time distribution. This section is 6-lane divided carriageway having 10.5 m road width in each direction with no major merging and diverging within the selected 1.7 km of the road section. One direction traffic from Oberoi Hotel to Lajpatnagar metro station was considered in this study (Figure 1). This arterial corridor serves the traffic coming from main city to South Delhi. Data were collected on working and non-working days during morning hours between 8 AM to 12PM on two days; (July 06, 2012 and July 08, 2012) and during evening hours between 3 PM to 7 PM. It captured peak and non-peak traffic volume to ensure that travel time would vary due to traffic volume alone.

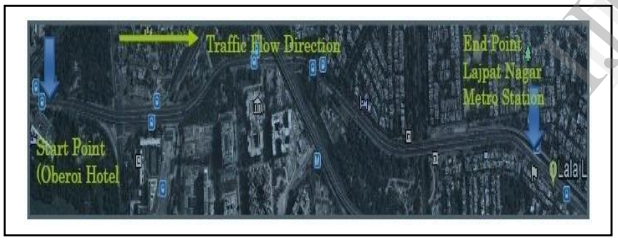

Fig.1 Study area: Urban arterial corridor on Lala LajpatRai Road in Delhi

IV. METHODOLOGY

License plate matching technique was used for measuring the travel time in the study area (Figure 2). This method consists of collecting vehicle license plate numbers and arrival times at entry and exit points of the section, matching the license plate between entry and exit points and computing travel time from the difference in arrival times. Video cameras were installed at entry and exit locations of the study area to capture the vehicle license plate for all categories of vehicles. Speed data was estimated through third video camera installed at the entry point of the section. Five categories of vehicles were identified during the study period on this corridor. The present study is focused on travel time variation of cars, 2W, 3W, NMV and HV with varying traffic volume and their proportion in the traffic stream. The average vehicular composition is presented in figure 3 and 4.

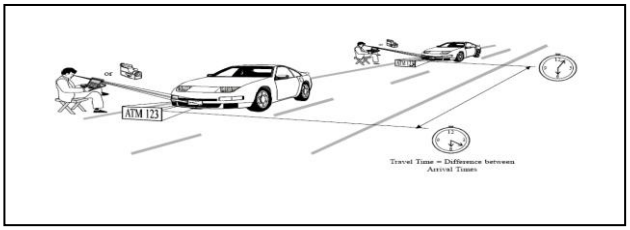

Fig.2 License plate matching technique

The statistical parameters such as minimum, maximum, mean, Standard Deviation of travel time for the study area at various time intervals in the morning and evening hour was calculated.

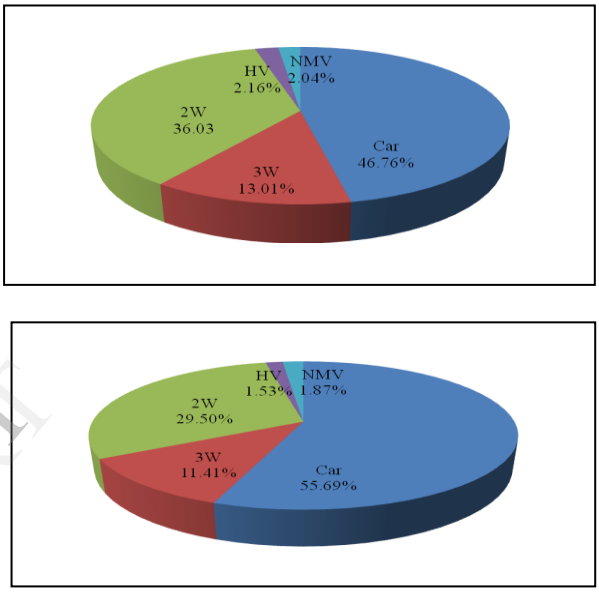

Fig. 3 Traffic Composition on study Corridor during Morning Hours and Evening Hours (Working day)

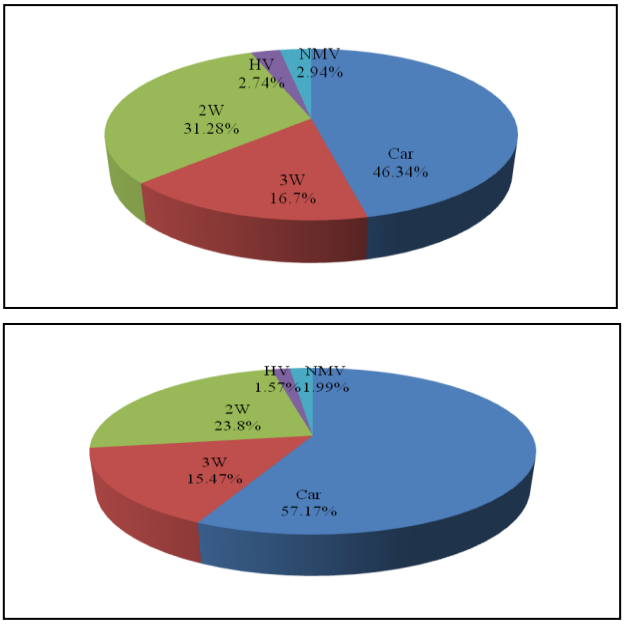

Fig. 4 Traffic Composition on study Corridor during Morning Hours and Evening Hours (Non-working day)

V. TRAVEL TIME ESTIMATION

The travel time was estimated using the License plate matching technique. The statistical parameters such as minimum, maximum, mean, Standard Deviation of travel time for the study area at various time intervals in the morning and evening hour was calculated and presented in Table 1 to Table 4. The variation of these factors is shown in Figures 5 to 6.

- Maximum standard deviation recorded on Friday for three lane road is 57 seconds in between 8:45 to 9:00 am for morning peak and 83 seconds occurring in between 5:00 to 5:15 pm in the evening peak. Range of standard deviation in morning peak period is higher than evening peak period which interprets the higher variability in travel time in the Morning peak period.
- Maximum standard deviation recorded on Sunday for three lane road is 83 seconds in between 10:00 to 10:15 am for morning peak and 63 seconds occurring in between 5:15 to 5:30 pm in the evening peak. Range of standard deviation in Evening peak period is higher than morning peak period which interprets the higher variability in travel time in the evening peak period.

TABLE 1. STATISTICAL SUMMARY OF TRAVEL TIME (06/07/12 MORNING HOURS)

Time Period (08/07/12 Morning)	**Statistical Measures**			
	Min.	*Max.*	*Avg.*	*Stand. Devi.*
8:00 – 8:15	89	365	130	55
8:15 – 8:30	93	297	122	37
8:30 – 8:45	80	187	115	21
8:45 – 9:00	93	154	117	14
9:00 – 9:15	103	255	142	68
9:15 – 9:30	87	216	117	23
9:30 – 9:45	87	301	126	44
9:45 – 10:00	93	313	127	38
10:00-10:15	93	352	146	83
10:15-10:30	87	406	124	34
10:30-10:45	103	361	126	38
10:45-11:00	106	406	135	48
11:00-11:15	101	222	128	19
11:15-11:30	87	398	142	51
11:30-11:45	95	343	137	44
11:45-12:00	106	414	137	51

TABLE 2. STATISTICAL SUMMARY OF TRAVEL TIME (06/07/12 EVENING HOURS)

Time Period (08/07/12 Evening)	**Statistical Measures**			
	Min.	*Max.*	*Avg.*	*Stand. Devi.*
3:15-3:30	71	190	107	23
3:30-3:45	73	412	121	53
3:45-4:00	71	123	99	12
4:00-4:15	83	367	122	57
4:15-4:30	78	166	107	20
4:30-4:45	83	153	103	13
4:45-5:00	87	414	119	60
5:00-5:15	79	335	108	32
5:15-5:30	74	407	120	65
5:30-5:45	77	339	117	50
5:45-6:00	77	271	111	35
6:00-6:15	76	343	108	44
6:15-6:30	83	401	119	45
6:30-6:45	81	306	122	36
6:45-7:00	84	388	124	69
3:15-3:30	71	190	107	23

TABLE 3. STATISTICAL SUMMARY OF TRAVEL TIME (08/07/12 MORNING HOURS)

Time Period (06/07/12 Morning)	**Statistical Measures**			
	Min.	*Max.*	*Avg.*	*Stand. Devi.*
8:15 – 8:30	119	368	154	76
8:30 – 8:45	130	315	142	44
8:45 – 9:00	107	380	156	39
9:00 – 9:15	117	306	162	57
9:15 – 9:30	117	415	153	38
9:30 – 9:45	111	312	154	37
9:45 – 10:00	115	378	162	44
10:00-10:15	106	415	144	22
10:15-10:30	93	292	147	39
10:30-10:45	65	396	155	19
10:45-11:00	108	382	162	27
11:00-11:15	136	253	170	38
11:15-11:30	129	406	160	30
11:30-11:45	122	312	161	41
11:45-12:00	128	405	152	6

TABLE 4. STATISTICAL SUMMARY OF TRAVEL TIME (08/07/12 EVENING HOURS)

Time Period (06/07/12 Evening)	Statistical Measures			
	Min.	*Max.*	*Avg.*	*Standard Deviation*
3:15-3:30	85	369	125	82
3:30-3:45	73	361	119	61
3:45-4:00	76	367	107	51
4:00-4:15	73	386	117	57
4:15-4:30	78	397	117	65
4:30-4:45	70	376	110	44
4:45-5:00	73	307	121	54
5:00-5:15	92	393	137	83
5:15-5:30	98	363	132	58
5:30-5:45	102	226	140	24
5:45-6:00	93	226	127	30

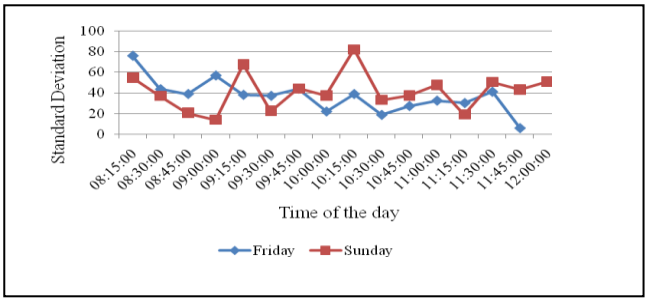

Fig. 5 Standard Deviation (Friday and Sunday-Morning)

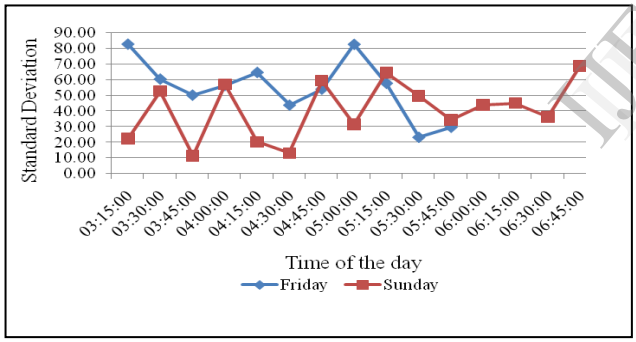

Fig. 6 Standard Deviation (Friday and Sunday -Evening)

VI. RESULTS AND DISCUSSION

Travel time reliability measures such as 95th percentile travel time, Planning time index and Buffer time Index are shown in tables 5 and 8. The variation of these factors is shown in Figures 7 to 12.

TABLE 5. TRAVEL TIME RELIABILITY MEASURES OF URBAN CORRIDOR IN DELHI (MORNING HOURS)

Time Period 06/07/12 Morning Hours (08:00AM to 12:00 PM)	Reliability Measures		
	PT (95%)	*PTI*	*BTI*
8:15 – 8:30	297	1.81	0.81
8:30 – 8:45	194	1.36	0.36
8:45 – 9:00	268	1.71	0.71
9:00 – 9:15	300	1.86	0.86
9:15 – 9:30	257	1.68	0.68
9:30 – 9:45	180	1.17	0.17
9:45- 10:00	185	1.14	0.14
10:00-10:15	164	1.13	0.13
10:15-10:30	172	1.17	0.17
10:30-10:45	178	1.15	0.15
10:45-11:00	189	1.18	0.18
11:00-11:15	245	1.44	0.44
11:15-11:30	186	1.16	0.16
11:30-11:45	178	1.10	0.10

TABLE 6. TRAVEL TIME RELIABILITY MEASURES OF URBAN CORRIDOR IN DELHI (EVENING HOURS)

Time Period 06/07/12 Evening Hours (03:00PM to7:00PM)	Reliability Measures		
	PT (95%)	*PTI*	*BTI*
3:15-3:30	171	1.37	0.37
3:30-3:45	255	2.14	1.14
3:45-4:00	121	1.13	0.13
4:00-4:15	250	2.13	1.13
4:15-4:30	280	2.38	1.38
4:30-4:45	178	1.61	0.61
4:45-5:00	265	2.19	1.19
5:00-5:15	267	1.95	0.95
5:15-5:30	251	1.91	0.91
5:30-5:45	181	1.30	0.38
5:45-6:00	188	1.48	0.48

TABLE 7. TRAVEL TIME RELIABILITY MEASURES OF URBAN CORRIDOR IN DELHI (MORNING HOURS)

Time Period 08/07/12 Morning Hours (08:00AM to 12:00 PM)	Reliability Measures		
	PT (95%)	*PTI*	*BTI*
8:00 – 8:15	219	1.69	0.69
8:15 – 8:30	207	0.41	0.71
8:30 – 8:45	147	1.28	0.28
8:45 – 9:00	134	1.15	0.15
9:00 – 9:15	314	2.22	1.22
9:15 – 9:30	143	1.23	0.23
9:30 – 9:45	233	1.86	0.86
9:45- 10:00	165	1.31	0.31
10:00-10:15	351	2.40	1.40
10:15-10:30	155	1.26	0.26
10:30-10:45	138	1.09	0.09
10:45-11:00	146	1.09	0.09
11:00-11:15	163	1.28	0.28
11:15-11:30	202	1.43	0.43
11:30-11:45	213	1.55	0.55
11:45-12:00	234	1.70	0.70

TABLE8. TRAVEL TIME RELIABILITY MEASURES OF URBAN CORRIDOR IN DELHI (EVENING HOURS)

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Time Period 08/07/12 Evening Hours (03:00PM to7:00PM)	Reliability Measures		
	PT (95%)	*PTI*	*BTI*
3:15-3:30	138	1.29	0.29
3:30-3:45	215	1.78	0.78
3:45-4:00	117	1.19	0.19
4:00-4:15	244	2.00	1.00
4:15-4:30	134	1.26	0.26
4:30-4:45	118	1.14	0.14
4:45-5:00	177	1.49	0.49
5:00-5:15	122	1.13	0.13
5:15-5:30	252	2.11	1.11
5:30-5:45	248	2.12	1.12
5:45-6:00	133	1.20	0.20
6:00-6:15	127	1.18	0.18
6:15-6:30	182	1.53	0.53
6:30-6:45	145	1.20	0.20

A. 95th Percentile Travel Time

The 95th % travel time explains how much delay will take place on the heaviest travel days on these routes. This also depends on the length of the route.

- Highest value of 95th percentile travel time observed on Friday for three lane corridors was 300 seconds at 9:00 to 9:15 am in morning peak period and 280 seconds at 4:15 to 4:30 pm in the evening peak period.
- Highest value of 95th percentile travel time observed on Sunday for three lane corridors was 351 seconds at 10:00 to 10:15 am in morning peak period and 252seconds at 5:15 to 5:30 pm in the evening peak period.

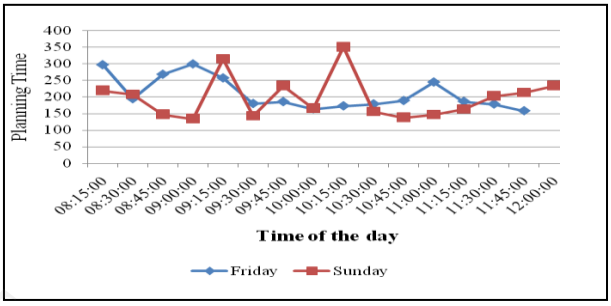

Fig. 7 Planning Time Profile (Friday and Sunday -Morning)

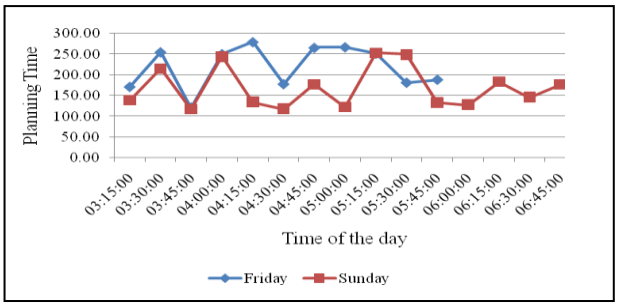

Fig.8. Planning Time Profile (Friday and Sunday -Evening)

B. Buffer Time Index (BTI)

Buffer time is the extra time required over the average travel time to reach the destination on time.

- Highest value of Buffer Index for Friday on three lane corridor was observed as 0.86 at 09:00 to 09:15 am and 1.38 at 4:15 to 4:30 pm for morning and evening peak period.
- Highest value of Buffer Index for Sunday on three lane corridor was observed as 1.40 at 10:00 to 10:15 am and 1.11 at 5:15 to 5:30 pm for morning and evening peak period.

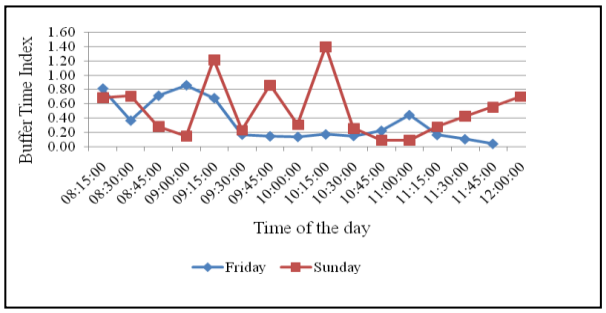

Fig. 9 Buffer Time Index Profile (Friday and Sunday -Morning)

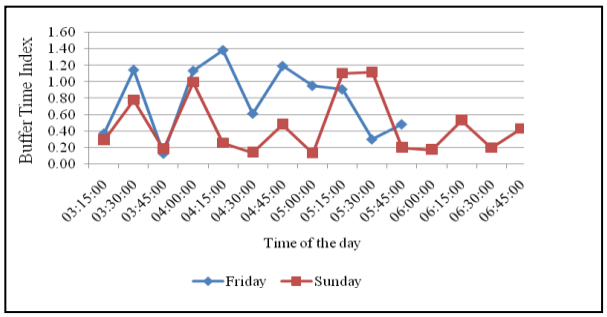

Fig. 10 Buffer Time Index Profile (Friday and Sunday -Evening)

C. Planning Time Index (PTI)

Planning Time Index represents the total travel time that should be planned when an adequate buffer time is included. Planning Time Index differs from the BI in that it includes typical delay as well as unexpected delay.

- The highest value of PTI for Friday on Three lane study corridor was observed 1.86 at 09:00 to 09:15 am in morning peak period and 2.38 at 4:15 to 04:30 pm in the evening peak period.
- The highest value of PTI for Sunday on Three lane study corridor was observed 2.40 at 09:00 to 09:15 am in morning peak period and 2.11 at 5:15 to 05:30 pm in the evening peak period.

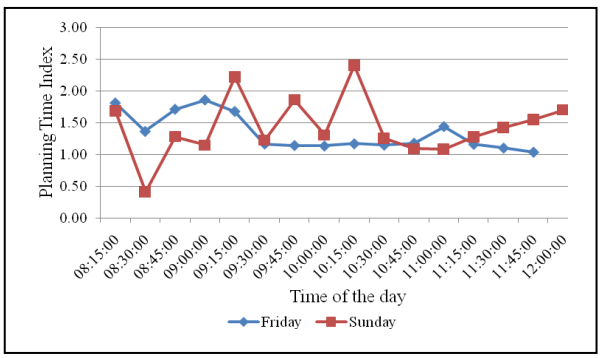

Fig.11. Planning Time Index Profile (Friday and Sunday -Morning)

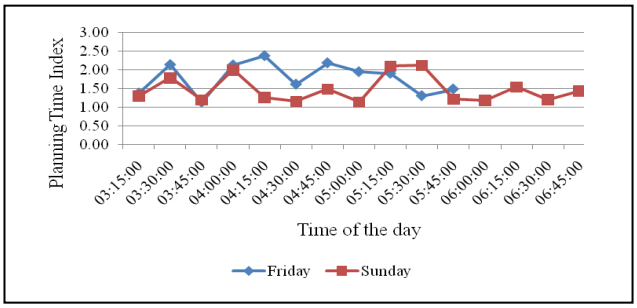

Fig.12 Planning Time Index Profile (Friday and Sunday -Evening)

VI. CONCLUSION

Travel time reliability measures are important for evaluating the operational efficiency of any road corridor. This study has been attempted the way in which travel time reliability can be measured. Travel time has been estimated by vehicle license plate matching method by using video graphic data for urban arterial in New Delhi and the travel time reliability analysis have been carried out. This study identified the requirement of travel time reliability measurements for measuring performance of road corridor in India than the traditional measures. Highest PTI value obtained for working day during morning peak hour (9:00 AM to 9:15 AM) is 1.86. This indicates that travel time is 1.86 times of free flow travel time. Highest BI value obtained during the same period was about 0.86. This indicates that travelers should budget an additional 138 seconds buffer to ensure 95% on time arrival at the destination on study Corridor. The mean 95th % travel time for urban corridor varied between 164 seconds to 300 seconds during morning hour and 121 seconds to 280 seconds in the evening hours. Highest PTI value obtained for non-working day during morning peak hour (10:00 AM to 10:15 AM) is 2.40. This indicates that travel time is 2.40 times of free flow travel time. Highest BI value obtained during the same period was about 1.40. This indicates that travelers should budget an additional 205 seconds buffer to ensure 95% on time arrival at the destination on study Corridor. The mean 95th % travel time for urban corridor varied between 134 seconds to 351 seconds during morning hour and 117 seconds to 252 seconds in the evening hours.

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