Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 114 **2022**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2022.114.12

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Reddy, K.T.V.K., Challagulla, S.P. Measurement of delay using travel time reliability statistics in an urban outer corridor. *Scientific Journal of Silesian University of Technology. Series Transport*. 2022, **114**, 143-154. ISSN: 0209-3324.
DOI: https://doi.org/10.20858/sjsutst.2022.114.12.

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MEASUREMENT OF DELAY USING TRAVEL TIME RELIABILITY STATISTICS IN AN URBAN OUTER CORRIDOR

Summary. Unexpected delay on freeways is the prime cause of dissatisfaction in road users. Increasing traffic, adverse environmental conditions, accidents, time, season, location and many more factors influence travel time and cause delay. There is no direct method to estimate delay. It is calculated from trip time estimates. Thus, it is a very big challenge for transportation professionals to develop a model that accurately estimates the trip time for a trip at a particular time, by a specific mode of transport. Subsequently, the reliability of the delay calculated from those trip time estimates is often doubtful. Further, the measurement of delay using the trip time data is another big thing. This paper is a step toward measuring the delay in an accurate way using travel time reliability measures. The study was conducted on the two modes of public transportation (City bus and Auto) in an urban corridor of length 16.3 km, in Hyderabad city, India. In this study, a license plate survey was conducted for data collection, travel time-based statistical analysis was employed for estimation of trip time and by making use of travel time measures, the delay was measured. The approach was validated graphically to portray its accuracy.

Keywords: trip time, travel time, delay, city buses, passenger autos

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1. INTRODUCTION

On the urban outer freeways of large cities, the expectations are to travel close to the speed limit or free-flow travel. However, ever-increasing traffic demand and insufficient road capacities make people spend much more time on their daily trips (Economic Development Research Group, 2005). Travel time reliability (TTR), is the measure of the consistency of travel conditions over time and is an important measure of the performance of transportation systems (Chen et al., 2018). Travel time is an effective factor to measure transport network performance. It exhibits the efficiency of the road network and is easily understood by most travelers (Lomax et al., 2007). Travel time on a given road stretch varies over time and is influenced by various factors (Hojati et al., 2016). These measures are further used for various applications such as the ATIS, to design time schedule for transit system management, freight movers, policy making and transportation planning (Kwon et al., 2011). Measures of travel time reliability attempt to quantify the travel time variability across different months, days and different times of the day. A road network that provides a high level of service obviously has a high level of travel time reliability (Lyman and Bertini, 2008). Developing a measure that relates all those factors to provide a basis for individuals in assessing travel time and delay at a point of time for a particular mode of travel or transport can reduce uncertainty and increase reliability in one’s travel or freight transport. If the travel time and delay can be estimated accurately, travelers can adjust their mode choices, trip patterns and expectations accordingly (Emam and Al-Deek, 2006). Information on both the cost and reliability of transportation modes are necessary to make policies and estimate the benefits to be gained from improving reliability or shifting the users to more reliable transportation modes (Nam et al., 2006).

This paper begins by elaborating on the significance of both the travel time and the delay in transportation planning. Thereafter, it discussed the approach and corresponding definitions, statistics and, ultimately, the calculations used for finding the trip time and the delay estimates, followed by corresponding conclusions.

2. RESEARCH SIGNIFICANCE

There are various methods available to estimate delay. Delay can be calculated either through a mathematical approach from the estimates of travel speed or the multiple single server model up to an acceptable level of accuracy. The measurement of delay will be more accurate when the data corresponds to travel time time-based performance measures, as the travel parameters such as planning time (PT), planning time index (PTI), buffer time (BT), buffer time index (BTI), frequency of congestion (FOC), etc., obtained from the travel time reliability analysis are proved to be accurate and representative. The objective of this study was to measure both trip time and delay by analyzing the collected historical data on a roadway segment along an urban corridor using the TTR analysis. This paper is a step toward presenting how travel time measures are used in the calculation of delay and can result in a better understanding of the performance of the individual modes of the transportation system.

3. METHODOLOGY TO COLLECT TRAVEL DATA

3.1. Study area

In this study, an urban road corridor (Uppal – Ghatkesar) of length 16.3 km was selected in the Hyderabad city of Telangana state, India. It is one of the busiest corridors of the city. Historically, the traffic density has been increasing enormously, leading to severe traffic jams. This occurs even during non-peak hours, leading to variable traffic flow parameters causing discomfort and dissatisfaction for the road users.

3.2. Data collection and retrieval

License plate survey was conducted for the two selected modes of transport (city buses and passenger autos) by videography method, outcomes of which are the trip times of all vehicles in the selected corridor in between the two boundaries marked near the respective bus stops of two end stations, that is, Uppal and Ghatkesar.

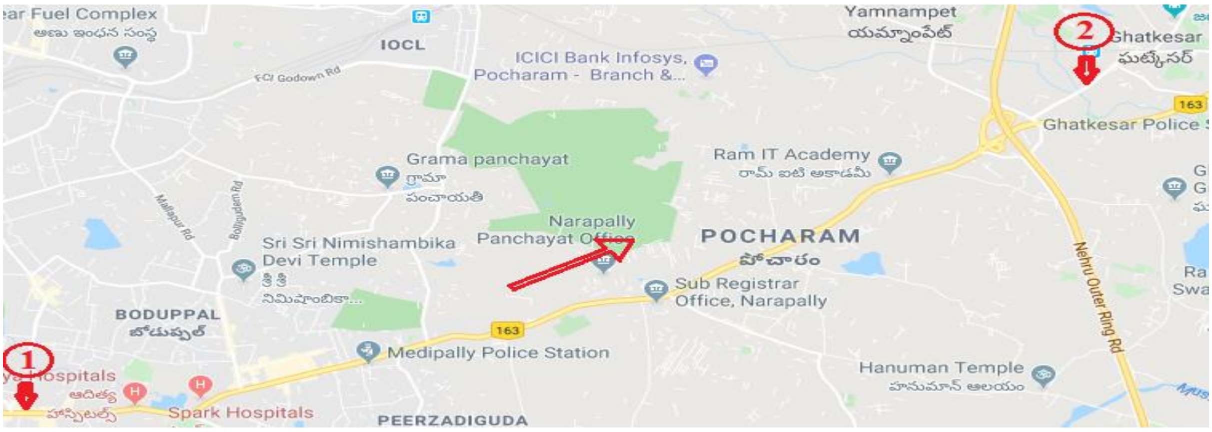

Fig. 1. Geographic location of the selected corridor

The two boundaries are denoted by 1 and 2 in Figure 1, also the direction of the traffic considered is shown by the arrow mark. At each boundary, two cameras (one with 0.5X wide-angle lens and the other with 1X zoom) were mounted on a pole. The recorded video footages were played and a licensed plate survey was carried out. The moment a vehicle enters into the boundary of the corridor is considered its entry time. Similarly, the moment the vehicle completely crosses the boundary line of the corridor is noted as the exit time of that vehicle. The difference between the entry and exit times is the trip time of the vehicle. Trip time includes both the travel time and stopping time at stops and signals. Whenever a vehicle enters into the corridor at the entry point, the observer registers the vehicle's entry time and license plate number, and similarly, at the exit point, both the exit time and license plate number are registered.

Trip time of any vehicle is the difference between the entry time and exit time of the corresponding vehicle. Surveys were conducted during both peak and non-peak hours for four weeks at 30 minutes intervals. Figure 2 shows the road views from the zoom lens and wide-angle lens, respectively. Vehicular classification and respective percentage distribution are shown in Figure 3. However, for analysis, the average trip time of particular modes of transport during working days only was considered, because it was observed that during non-working days, very few congestions occurred. In addition, the whole traffic volume and modes were not used in this research, as the prime focus was on two modes of transport.

Fig. 2. Travel data collection using the videography method

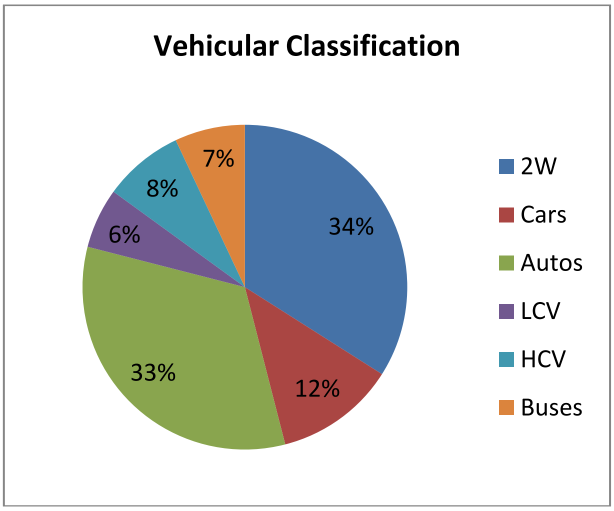

Fig. 3. Vehicular classification and percentage distribution of the study area

In Figure 3, the major portion of the traffic (around 70%) in the study area comprises two-wheelers and autos. Although the buses percentage is less, no separate lanes were provided for them. Hence, due to mixed traffic conditions and bigger vehicular size, the trip times of the buses are often more when compared to the other modes of public transportation.

No compromises were made during the data collection, as the origin and destination of the two selected modes of transport (city buses and passenger autos) are well known. Each considered vehicle must have passed the entire corridor; hence, 100% efficiency was achieved during data collection. In this study, the distribution of trip times of the historical data was analyzed to report specific statistics such as the mean, median, standard deviation, etc. As the degree of variability of trip times can be represented as reliability for the repeated future trips.

4. ANALYSIS AND RESULTS

There are various types of measures widely applied in assessing traffic performances such as planning time (PT), planning time index (PTI), buffer time (BT), buffer index (BI), frequency of congestion (FOC), standard deviation (SD), coefficient of variation (CV), misery index (MI), etc. Of the above-mentioned measures, only a few are considered in this research, as it is confined to the measurement of PT and delay only.

4.1. Travel time-based statistics

In Table 1, the sample size is the number of city buses entered into the corridor during each 30 minutes interval. In the four weeks of travel data collection, the travel data of 20 working days (5 working days per week from Monday to Friday) was considered for the analysis. Hence, for each interval of 30 minutes, for the period of 20 days, 20 such samples were obtained. However, for analysis, the minimum of 20 samples was considered as sample size. For example, from 8.00 a.m. to 8.30 a.m., 20 buses entered the corridor on day-1. As the sample size is 17, we consider only the data that corresponds to the first 17 buses out of the total 20 buses for day-1. Further, the trip times of the first 17 buses, which entered the corridor from 8.00 a.m. to 8.30 a.m. on all the 20 days were averaged. Of the 17 averaged trip times, the minimum and maximum were identified and entered into the respective columns in Table 1. The other statistical measures such as mean, median, SD and CV were calculated over the 17 averaged trip times that correspond to the period of 8.00 a.m. to 8.30 a.m. The statistical measures for each 30 minutes interval were obtained in the same manner.

Tab. 1.

Statistics of four weeks average trip time of city buses

		Statistical measures (trip time)					
Time-period	Sample size	Minimum	Maximum	Mean	Median	SD	CV
Peak Hours							
8.00-8.30	17	34.0	62.5	49.68	50.5	8.60	0.17
8.30-9.00	19	42.0	61.0	51.21	51.5	5.50	0.11
9.00-9.30	21	42.0	72.0	54.98	72.0	7.94	0.14
9.30-10.00	19	28.5	62.0	41.50	36.5	11.70	0.28
Non-Peak Hours							
10.00-10.30	15	30.0	47.5	38.80	37.50	4.19	0.11
10.30-11.00	14	27.0	40.5	32.25	28.50	3.82	0.12
11.00-11.30	16	30.5	41.0	35.28	35.25	2.92	0.08
11.30-12.00	12	29.0	42.5	36.63	40.50	3.56	0.10

Tab. 2.

Statistics of four weeks average trip time of passenger autos

		Statistical measures (trip time)					
Time-period	Sample size	Minimum	Maximum	Mean	Median	SD	CV
Peak Hours							
8.00-8.30	26	25.5	41	32.27	25.75	5.03	0.16
8.30-9.00	31	29.0	46	37.74	35.00	5.09	0.13
9.00-9.30	30	28.0	40	34.32	32.50	3.41	0.10
9.30-10.00	37	26.0	40	34.07	34.00	3.73	0.11
Non-Peak Hours							
10.00-10.30	22	24.5	38.0	29.20	34.5	3.75	0.13
10.30-11.00	21	25.0	37.0	31.38	35.5	4.22	0.13
11.00-11.30	16	24.0	36.0	31.81	34.5	3.89	0.12
11.30-12.00	17	24.0	35.5	29.18	30.0	3.64	0.12

From Tables 1 and 2, it can be seen that there is much difference between the sample sizes that correspond to peak hours and non-peak hours. Further, during peak hours, the difference between the minimum and maximum trip times is quite high when compared with that of non-peak hours, and accordingly, standard deviation is similarly high during peak hours causing uncertain trip time patterns, which in turn causes unwanted delay and congestion for the road users. Whereas, during non-peak hours, both trip time difference and standard deviation vary moderately. It can also be observed that, comparatively, there is much difference in the sample sizes of the passenger autos as their trips vary according to the passenger flow. Whereas, the timings and trips of the city buses are already fixed and are same on almost every single day.

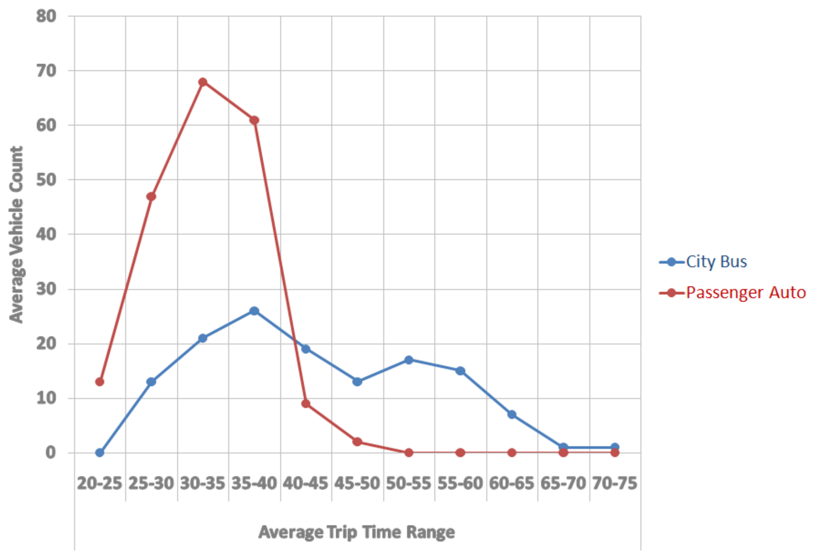

Fig. 4. Trip time distribution of city buses and autos

From Figure 4, it is observed that the average trip time for most of the city buses is in the range of 30 to 60 minutes, and for most of the autos, the average trip time is in the range of 25 to 45 minutes. There is much difference between the average trip time of the city bus and the auto, as the size of an auto is just 15 to 20% of that of the city bus. Nevertheless, there is no significant difference in the average trip time of both when compared with the vehicle sizes. The possible reason for this is that the fare for the auto is collected from the passengers at their respective stops after they alight, thereby increasing the stopping time at each stop. Hence, the total trip time correspondingly increases as well.

4.2. Travel time-based performance measures

Based on the above statistics, the traffic performance parameters of the selected corridor were derived as follows.

Tab. 3.

Travel time-based performance measures during morning hours for city buses

		Travel time-based performance measures							
Time-period	Avg. Trip Time	PT	D1	D2	D3	D4	D5	D6	D7
8.00-8.30	49.68	62.10	28.10	18.10	16.50	15.80	15.60	14.80	11.60
8.30-9.00	51.32	60.10	18.10	12.35	11.20	10.45	10.10	9.95	8.60
9.00-9.30	54.98	67.50	25.50	18,00	16.50	14.50	13.50	13.00	12.00
9.30-10.00	41.50	59.75	31.25	29.25	27.55	25.75	25.35	23.70	23.25
10.00-10.30	38.80	45.05	15.05	8.55	7.95	7.60	7.25	7.05	7.05
10.30-11.00	32.25	37.58	10.58	8.33	7.68	7.58	7.18	5.88	5.58
11.00-11.30	35.28	39.88	9.38	6.50	6.13	5.88	5.88	5.12	4.88
11.30-12.00	36.63	41.40	12.40	6.65	6.10	5.55	5.00	4.45	4.40

Tab. 4.

Travel time-based performance measures during morning hours for passenger autos

		Travel time-based performance measures							
Time-period	Avg. Trip Time	PT	D1	D2	D3	D4	D5	D6	D7
8.00-8.30	32.27	39.12	13.62	12.88	11.62	10.75	6.12	5.50	4.88
8.30-9.00	37.74	45.25	16.25	10.25	9.75	9.25	9.25	9.25	8.75
9.00-9.30	34.32	39.05	11.05	7.05	7.05	6.48	6.05	5.05	4.05
9.30-10.00	34.07	37.60	11.60	4.60	3.70	3.60	3.40	2.60	2.60
10.00-10.30	29.20	34.97	10.47	8.84	8.32	7.97	7.77	7.24	6.72
10.30-11.00	31.38	36.00	11.00	8.50	8.00	8.00	5.00	3.50	3.5
11.00-11.30	31.81	35.62	11.62	4.38	3.88	3.38	2.62	2.62	2.38
11.30-12.00	29.18	34.30	10.30	9.30	8.10	6.60	5.60	5.20	4.80

From Tables 3 and 4, PT is the planning time, which is 95th percentile trip time. For the calculation of delay, seven types of delays D1, D2, D3, D4, D5, D6 and D7 were considered where D1= PT- Minimum trip time; D2= PT- 25th percentile trip time; D3= PT- 30th percentile trip time; D4= PT- 35th percentile trip time; D5= PT- 40th percentile trip time; D6= PT- 45th percentile trip time; D7= PT- 50th percentile trip time. Graphical representation of the performance measures is more effective than numerical presentation.

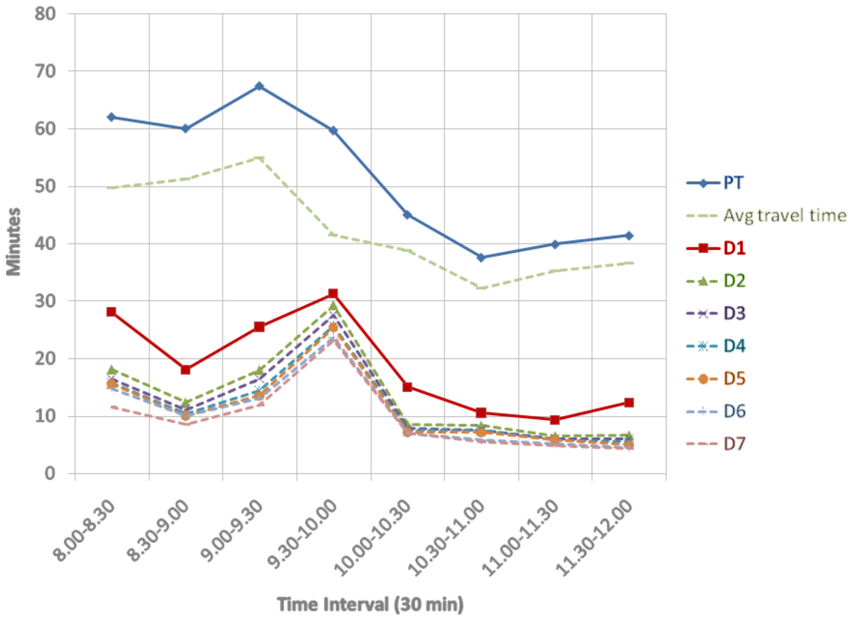

Fig. 5. Graphical representation of delay measures in city buses

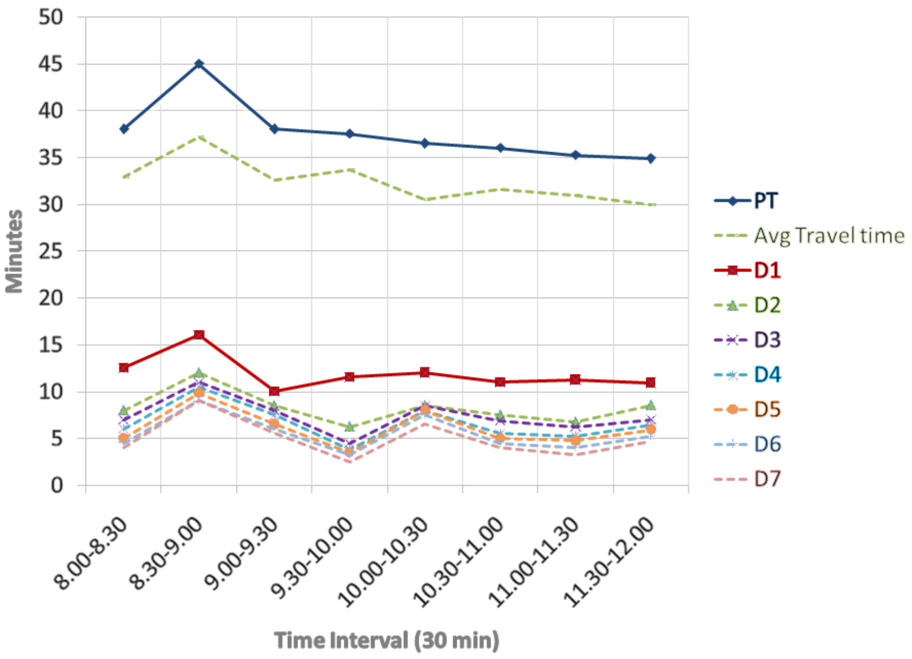

Fig. 6. Graphical representation of delay measures in passenger autos

The line that corresponds to the delay should be parallel to the line that corresponds to the planning time such that both lines follow the same trend, only then will the delay be representative and reliable. Given that PT is considered as the estimated trip time before the trip, if PT is more then the corresponding delay is more and vice versa. Hence, it is clear that both PT and delay are directly related to each other. Therefore, among the seven lines ranging from D1 to D7, whichever line follows the PT line corresponds to PT and gives the most reliable delays. From Figure 5, it can be clearly observed that the graph pertaining to the delay (D1= PT- Minimum trip time) follows the same trend as that of the planning time. This concludes that the D1 is to be taken as the delay.

In Figure 5, it can be observed that the lines corresponding to D2, D3, D4, D5, D6 and D7 are not in the same trend of the reference line that corresponds to that of PT. Hence, with this, D1 (PT- Minimum trip time) is appropriate to be considered as a delay.

In Figure 6, similarly, as in the case of city buses, the line corresponding to D1 (where D1= PT-Minimum trip time) is parallel to the PT line. Further, in the study area, it is observed that the minimum trip times of passenger autos were the same for all non-peak hours and peak hours, thus, not much discrepancy was observed.

5. CONCLUSIONS

(1) In the case of city buses, there were many discrepancies in the values of minimum trip times. In such a case, the traditional way of calculating delay may give incorrect results. Hence, the proposed method is most preferable in such cases.

(2) While in the calculation of delay, the preliminary check must be done to know whether to consider the obtained minimum trip times or not. Because sometimes there may be errors in the collected data.

(3) Plotting the lines of PT and D1 on a graph is sufficient to check the accuracy of the collected data. It is to be verified, whether the lines of PT and D1 are similar or not. If both lines are similar, then, D1 is the delay (D1= PT- Minimum trip time).

(4) If the D1 line is not parallel with that of PT, whichever line is parallel to the PT line is the corresponding line to be considered for the delay.

(5) It can be observed that there is no significant difference between the trip times of city buses and autos in the study area. The possible reason for this is that the fare for the auto is collected from the passengers at their respective stops after they alight, thereby increasing the stopping time at each stop.

6. SCOPE FOR THE FUTURE

The information regarding the travel time-based performance measures needs to be updated daily, monthly, and annually with automatic traffic monitoring equipment so that future transportation development and land use patterns can be planned accordingly. Systems based on artificial intelligence that automatically collect vehicular travel data on roadways will provide the basic data resource for the calculation of travel time-based performance measures in the future.

Acknowledgments

We would like to thank the HOD, Department of Civil Engineering, K. L. University, for permitting us to conduct videographic surveys with the help of the students.

Special gratitude to Dr. Ch. Surya Prakash for the esteemed guidance and support received during the research work. We are thankful for the motivation received to continue this work during the COVID-19 pandemic times and for the continuous monitoring of this project besides the support given in writing the research proposal.

Finally, we wish to express our thanks to the Additional Commissioner of Police (Traffic), Hyderabad, Telangana State, for permitting us to conduct traffic surveys.

Nomenclature

TTR	Travel Time Reliability
ATIS	Advanced Traveler Information System
PT	Planning Time (95th Percentile travel time) (minutes)
PTI	Planning Time Index
BT	Buffer Time (minutes)
BTI	Buffer Time Index
FOC	Frequency of Congestion
SD	Standard Deviation
CV	Coefficient of Variation
MI	Misery Index
2W	Two-Wheelers
LCV	Light Commercial Vehicle
HCV	Heavy Commercial Vehicle
D1	PT- Minimum trip time (minutes)
D2	PT- 25th percentile trip time (minutes)
D3	PT- 30th percentile trip time (minutes)
D4	PT- 35th percentile trip time (minutes)
D5	PT- 40th percentile trip time (minutes)
D6	PT- 45th percentile trip time (minutes)
D7	PT- 50th percentile trip time (minutes)

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Received 11.12.2021; accepted in revised form 30.01.2022