Paper Number 18-01695

COMPARISON OF BLUETOOTH AND BUS GPS DATA FOR ESTIMATING ARTERIAL TRAVEL TIME AND TRIP CHAINING

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ACKNOWLEDGEMENTS

The authors acknowledge the support provided by Chennai city police for the installation of the Bluetooth stations across the city. The authors also acknowledge the support from the Centre of Excellence in Urban Transport, IIT Madras, India for the GPS data collection. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the sponsoring organizations. These contents do not constitute a standard, specification, or regulation.

INTRODUCTION

Mode choice is affected by a variety of factors including level of service attributes such as travel time, cost and reliability (*1*)(*2*)(*3*). Indian conditions are known to possess a heterogeneous mix of vehicles with a lack of lane discipline. Under such conditions, traditional methods such as automatic license plate readers (*4*) and automatic number plate recognition (*5*) may not yield accurate travel time estimates. However travel times and its reliability provide a measure of mobility and valuable data for mode choice decisions and transportation planning. This paper discusses two different data collection techniques to compute and compare travel time and reliability across three different modes (surface route, city buses and metro, which is the term for the rail service in the city), and provides a methodology for estimating trip chaining.

Bluetooth technology is one of the most simple, reliable and cost effective methods to estimate travel time (*6*)(*7*). The travel times are estimated using the MAC address matching technique (*8*). Bluetooth sensors reported to capture up to 2% of the traffic stream vehicles are efficient in yielding satisfactory travel time results (*8*)(*9*)(*10*). However, due to increased security on many phones, this proportion appears to be deceasing.

Another established method of estimating stream travel time is using the data from GPS (*11*)(*12*)(*13*). Kumar et al. developed an algorithm based on Kalman filtering technique to predict the travel times on urban corridors using the GPS data from the local transit buses (*14*). The data were validated after removing the bus stop dwell times and the results were found to be reasonable.

Trip chaining patterns are an integral part of travel behavior studies. Researchers have primarily relied on household travel surveys (*16*) and data from GPS devices (*17*) to study the trip chaining patterns. There is an inherent sampling bias associated with the Bluetooth data, and it is difficult to distinguish devices on a non-auto mode (pedestrians and bicyclists) and devices or vehicles that have stopped en route (trip chaining) (*15*). The last part of the present study explores the use of Bluetooth data to understand the trip chaining behavior of travelers.

METHODOLOGY AND STUDY CORRIDOR

Bluetooth MAC address matching was used to compute the travel time on the surface routes. GPS data, after removing delay associated with bus stops, from the local city buses were used to estimate the bus travel time in the corridor. These times were compared with the deterministic travel time of the metro, computed by manual observations. The paper concludes by comparing the adjusted bus GPS data with Bluetooth data to estimate the proportion of trip chaining that occurs in the corridor during various time periods of the day.

The study was conducted on the Trichy-Chennai highway, which runs between the Chennai International Airport (origin) and Little Mount (destination). The 7.7 km (4.78 mi) stretch of highway is served by three primary modes of transportation: road, bus and metro.

The surface route serves a heterogeneous mix of vehicles including motorcycles (two-wheelers), three-wheelers, passenger cars and trucks. The traffic volume on this corridor is approximately 225,080 vehicles per day (obtained using video feed), with more than 50% motorcycles. 62 buses with a frequency of 3 to 4 trips per day, were running in the study stretch. The metro service in the corridor has a scheduled frequency of 15 minutes.

Bluetooth data from surface routes

Bluetooth data on surface routes was collected from four Bluetooth monitoring stations (BMS) located at Chennai International Airport (origin), Little Mount (destination), near Kannan Colony and near Madras Race Club. Raspberry Pi units with a 13dBi antenna were used as Bluetooth sensors. Data collection was carried out for a week from May 27 to June 2, 2017 and travel times were estimated using MAC address matching technique.

GPS data from buses

GPS data from buses was collected for one month from May 9 to June 20, 2017, although data was not available for the week of May 24 due to sensor failure. GPS data included timestamp, latitude, longitude and a unique bus identifier, and was logged every 10 seconds and stored in an SQL database server. Geographic distance between two consecutive pairs of latitude and longitude data was calculated using Haversine formula (*18*). From this, travel times were estimated using distance and the timestamps.

Metro

For security reasons, BMS could not be installed on the metro. The metro operates on a fixed schedule, and the travel times were directly measured by researchers who traveled on the metro and noted down travel times between stations and the dwell time at each station. Based on observations, the metro travel time was found to be 12.5 minutes for the entire study route, including dwell time.

FINDINGS

The Bluetooth penetration rate is the number of Bluetooth devices detected divided by the total number of vehicles on that section during the time period (*10*). The penetration rate in this study was found to be 0.34%. Table 1 shows the matches between BMS locations over the period of one week. There are 666 matched devices from BMS3 to BMS1 (destination to origin, traveling south) and 87 matched devices from BMS1 to BMS3 (origin to destination, traveling north). One possible reason for smaller sample in the northbound direction may be deviation to Koyambedu, a major bus hub 9 km (5.6 mi) north of the north bound origin point. Due to the low Bluetooth sample size northbound, the analysis was mainly focused on the southbound direction.

TABLE 1 Number of matches between Bluetooth stations

	BMS 1	BMS 2	BMS 3	BMS 4
BMS 1		1849	87	36
BMS 2	1210		190	83
BMS 3	666	354		650
BMS 4	173	129	109	

The reliability of the three modes was evaluated using the interquartile range (IQR), which is the difference between the 75th and 25th percentile travel times. A small IQR value represents a very reliable corridor, indicating that most of the vehicles experienced very similar travel time while traversing the corridor.

Figure 1 shows a sample plot. It can be seen that bus travel time is more reliable than the surface route travel time. On an average, the IQR for buses is 1.84 minutes on weekdays and 1.74 minutes on weekends, substantially lower than the IQR for the surface routes, which was 2.71 on weekdays and 3.02 on weekends. The surface route has a heterogeneous mix of vehicles with different operating speeds, which may be the reason for this wider range.

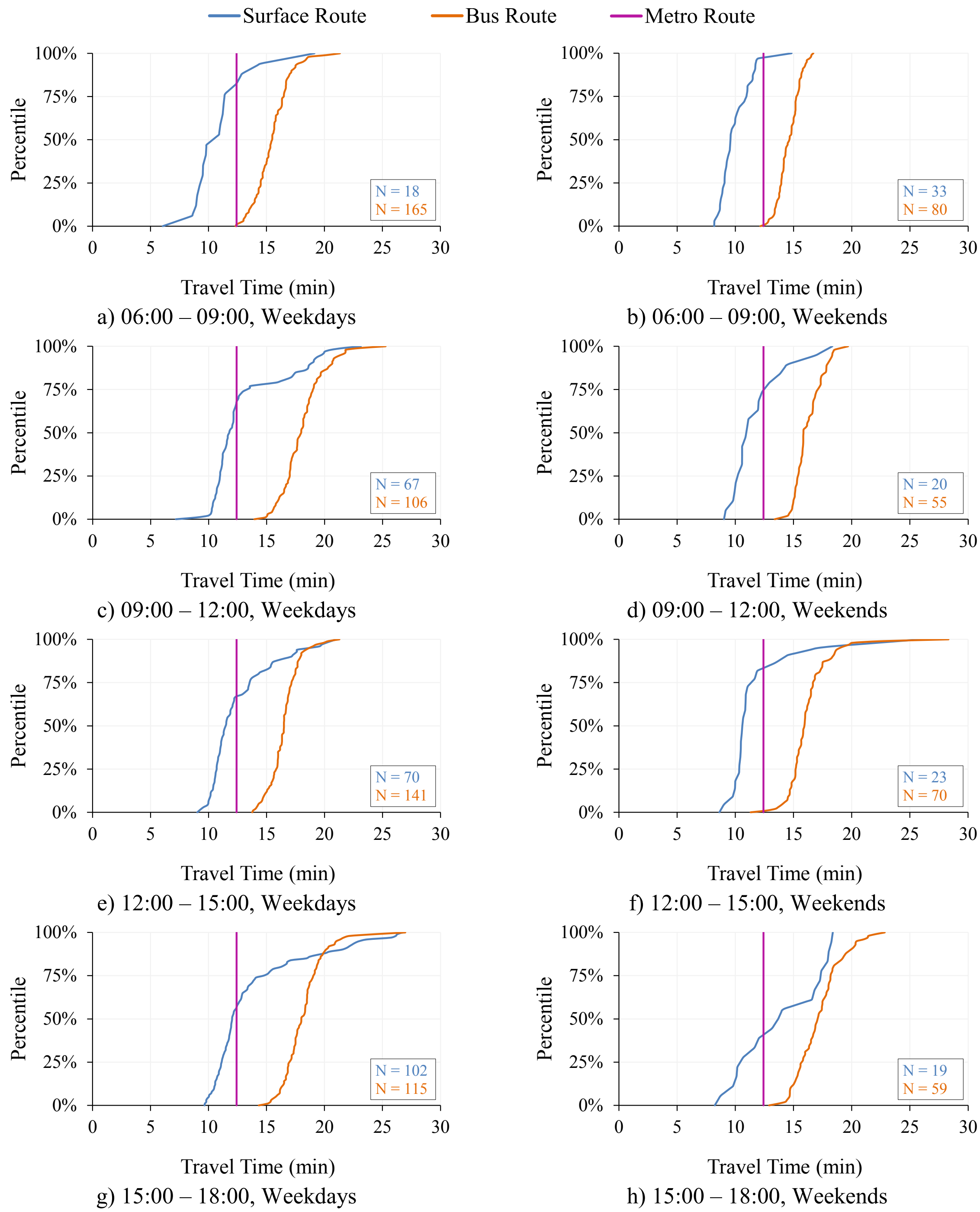

FIGURE 1 Travel time CFD's for different time periods of day for Southbound direction

Using GPS data to characterize stream travel time

Although Bluetooth MAC address matching provides a reliable estimation of travel times, it cannot yield satisfactory results when penetration is low. The bus GPS data generated travel times with patterns similar to the surface route, but slightly more. This extra offset reflects the dwell time at bus stops. Hence, the bus stop dwell time was calculated based on the duration the bus is at a complete stop or travelling at very low speeds, within 150 meters on either side of the bus stop. For each trip, the dwell time was subtracted from the total travel time to compute the adjusted bus time.

Comparison of adjusted bus and surface street travel time

Figure 2 shows the travel time CFD's for the surface route (solid blue), bus route (dashed orange) and the adjusted bus route (solid orange) in the southbound direction during weekdays and weekends. The adjusted bus data closely aligns with the surface route in most cases. The median difference in travel time between the adjusted bus data and the surface route can be found to be less than 0.3 minutes during all time periods, except the evening period (15:00 – 18:00) on weekends.

The close correlation between the results from the adjusted bus route travel time and surface route Bluetooth data suggests that travel times estimated using the GPS data obtained from the local city buses can be used as a reasonably accurate indicator of the corridor travel time.

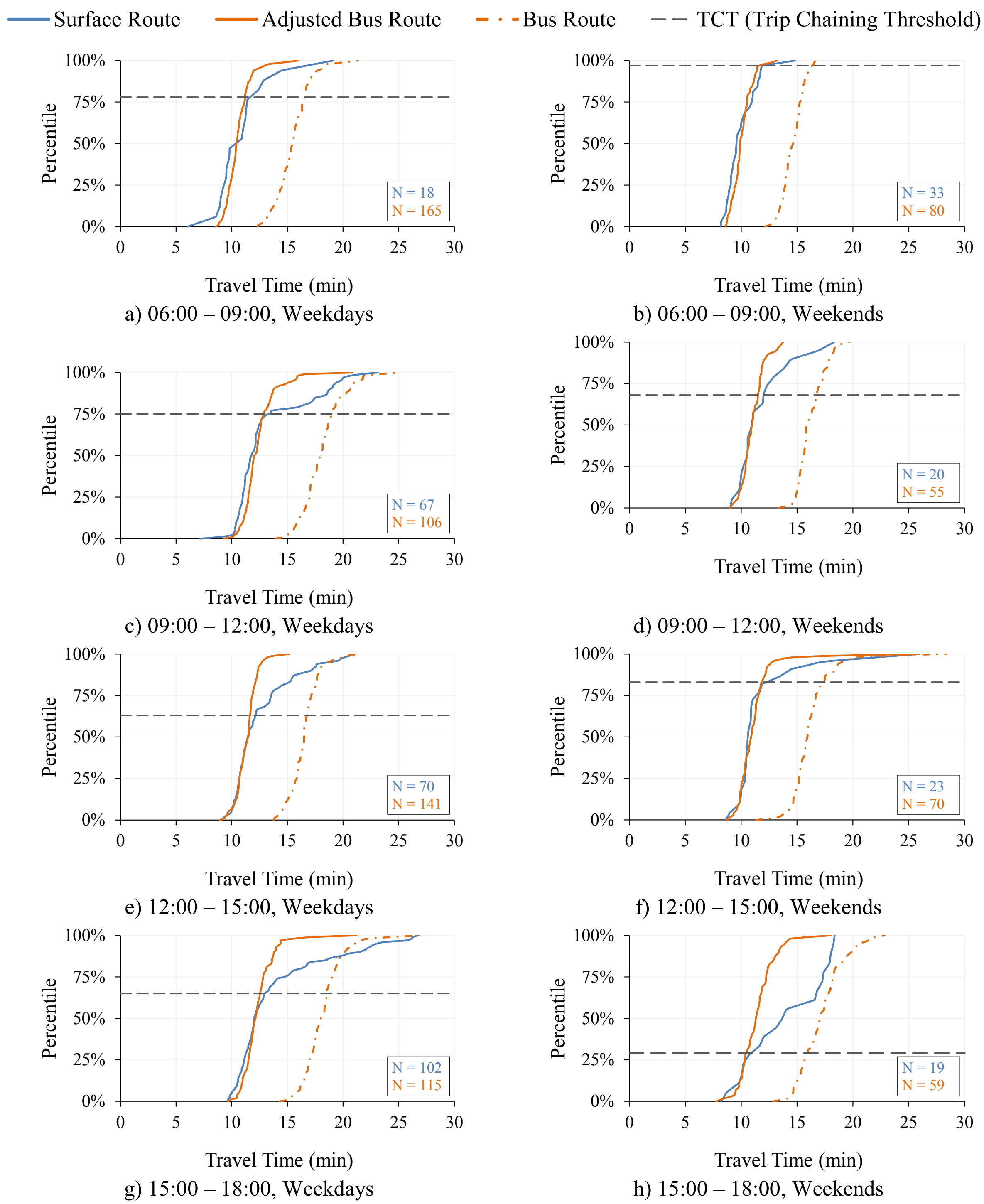

Figure 2 Travel time CFD's for different time periods of day for southbound direction

Trip Chaining

Comparing the surface route and adjusted bus route CFD's in Figure 2, there is a considerable deviation in the travel times, especially at higher percentiles (shown by the black dotted line). If the bus data represents the stream travel time, these deviations in the Bluetooth data may be bicyclists and trip chaining vehicles such as those stopping for gas, coffee, answering the phone or an errand. For this analysis, it is assumed that these represent trip chaining. Table 2 shows percentage of trip chaining vehicles for different times of the day for different thresholds on weekdays and weekends. It is difficult to fix a threshold for identifying the trip chaining as the perceptions could vary across individuals. A higher percentage of trip chaining is observed in the evening hours than the morning hours, perhaps reflecting fewer side trips on the morning commute to work.

TABLE 2 Estimated Trip Chaining Percentages for different time periods

	Weekdays						Weekends					
Threshold (minutes)	0.5	1	2	3	4	5	0.5	1	2	3	4	5
06:00-09:00	22%	18%	8%	4%	0%	0%	3%	1%	0%	0%	0%	0%
09:00-12:00	25%	22%	21%	19%	15%	10%	32%	23%	15%	8%	3%	0%
12:00-15:00	37%	32%	21%	17%	11%	8%	17%	14%	10%	7%	5%	4%
15:00-18:00	35%	29%	24%	20%	15%	14%	71%	64%	54%	43%	41%	32%

CONCLUSION

This paper discussed two different data collection techniques to compute and compare the travel time and reliability across three different modes (surface route, city buses and metro) on an urban corridor in Chennai, India. Bluetooth MAC address matching was used to compute the travel time on the surface routes, and the GPS data from the local city buses was used to estimate the bus travel time. The findings from the study indicate that GPS data obtained from buses can be used to estimate the corridor travel time, which may be especially useful in India, where most of the cities have an integrated network of buses running on all the major routes. Surface route vehicles were found to be quicker than buses. However, the buses had a more reliable travel time with a lower IQR.

A method to estimate the percent of trip chaining surface route vehicles was also presented based on a comparison of Bluetooth data and the adjusted bus travel times. These results indicated that trip chaining proportions (Figure 2) varied from virtually no trip chaining during the 06:00-09:00 time period on weekends to a very high proportion during the 15:00-18:00 period.

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