Analysis of a Transit Bus as Probe Vehicle for Arterial Performance Measurement

By Sutti Tantiyanugulchai (A) and Dr. Robert L. Bertini (M)

Introduction

With data increasingly available from Intelligent Transportation Systems (ITS) deployments, we now have increasing power to develop and test the use of actual performance measures. On freeways, important measures like density, average speed, travel time, and delay are often estimated directly using data from inductive loop detectors. For arterials with numerous signalized intersections, performance measures are more challenging due to more complex traffic control and many origins and destinations.

For site-specific arterial performance measurement, traffic conditions are usually evaluated using travel time and delay studies. However, these studies are limited temporally and spatially, and are time consuming and costly. With ITS, the floating probe vehicle technique can be applied over larger areas (corridors or entire urban areas) and longer time periods (all day, every day). Floating probes respond to changes in traffic flow as they traverse the network, and can transmit location and travel time data to a traffic management center at frequent intervals using Automatic Vehicle Location (AVL). In the case of a transit fleet with AVL deployed, these potential floating probes are already in the traffic stream today. Transit AVL systems are currently used primarily for managing transit operations in real time. This article explores their applicability for measuring arterial performance. The sponsors of the project include the Tri-County Metropolitan Transportation District (TriMet), the Oregon Department of Transportation (ODOT), and the City of Portland.

TriMet provides transit service with more than 600 buses along major arterials in Portland. Each vehicle is equipped with a Bus Dispatch System (BDS) including AVL, which consists of a differential Global Positioning System (GPS) receiver, automatic passenger...
Can Buses Predict Your Travel Time?

(Continued from page 1)

counters, wireless communications, and stop-level data archiving capabilities. The BDS records bus arrival and departure times at each geo-coded bus stop, as well as recording the maximum instantaneous speed achieved between stops.

Data

The study location is a 2.5-mile corridor on Powell Boulevard in Portland, Oregon. The corridor, illustrated in Figure 1, runs from SE 39th Avenue across the Willamette River on the Ross Island Bridge to downtown Portland at SW First Avenue. Each end of the corridor serves as a time point for the route. The corridor serves approximately 50,000 vehicles per day with peak travel westbound during the

A.M. peak and eastbound during the P.M. peak. This study focuses on the portion of data in the westbound direction only using BDS and test vehicle data obtained on Nov. 1, 2001.

For the transit probe investigation, Route 9 was selected for analysis on Powell Boulevard. Route 9 provides service between the Gresham Transit Center and downtown Portland with approximately 80 trips per direction per day. The study corridor includes 13 westbound and 12 eastbound stops. In the study corridor, TriMet provides a scheduled mean trip time of 10.65 min, with trip times ranging between 8 min during the off-peak and 13 min during the peak. On Nov. 1, 2001, the mean observed dwell time was 16.3 sec per stop with an average of 2 passengers boarding and 1 passenger alighting per stop served. The buses stopped at an average of 8 stops to serve passengers.

The BDS provides a unique source of transit monitoring information in both real-time and archived formats—the data are available for all buses on all days. For each geo-coded stop on each bus trip, the BDS records arrival time, departure time, number of boardings and alightings, and location. In addition, the system stores the maximum instantaneous speed achieved between stops. As shown in Figure 2, each stop has an imaginary 100-foot diameter circle inscribed around it. If the bus does not stop at stop i, the BDS records the times that the bus crosses the circle as the “arrive time” and “leave time” for stop i. If the bus stops at stop j, then the BDS records the time that the door opens as the “arrive time,” records the “dwell time” (the time the door was open), and records the “leave time” as the time the bus leaves the stop circle. Also at each stop where passengers are served, the BDS automatically records the number of boardings and alightings at both doors.

As a control, non-transit test vehicles equipped with GPS devices were dispatched during the study period to collect simultaneous corridor time, location and travel time information. The GPS devices were programmed to record each test vehicle’s precise location (latitude-longitude) with a time stamp every three seconds. Transit AVL data were also obtained for the same days and times for this study. Note that the transit data is location-based, since the BDS system recorded data at preprogrammed geo-coded stop locations, while the test vehicle GPS data is time-based, recorded at specific time intervals. This article will demonstrate how fusing the location-based data with the time-based data can reveal important relationships between the two sources.

Bus Probe Analysis

A preliminary investigation of the BDS data and test vehicle data was conducted using vehicle trajectories, constructed by plotting the cumulative distance each bus traveled on the y-axis and time on the x-axis. A trajectory’s slope at any time t is the speed at that time and location.

To develop an algorithm to relate the bus data to actual traffic conditions, experiments using the BDS data were conducted using “hypothetical” and “pseudo” bus scenarios. Non-transit vehicles do not decelerate and accelerate to serve passengers, so the “hypothetical bus” concept considers a potential non-stop bus trajectory by subtracting the dwell times. The resulting non-stop trajectory is an approximation of how a bus would travel if it did not stop to serve passengers.

The BDS recorded the maximum instantaneous speed achieved between pairs of stops. Recognizing that a bus does not perform like regular vehicles in the traffic stream, a “pseudo bus” trajectory was created by stringing together segments of a trip where the pseudo bus traveled at its maximum speed between each pair of stops. This was based on the hypothesis
Figure 3: Comparison of actual, hypothetical, and pseudo bus trajectories

Figure 4: Comparison of test vehicle trajectories to bus trajectories
that the maximum speed could approximately reflect the speeds of non-transit vehicles along the route.

Figure 3 (previous page) shows the "hypothetical," "pseudo," and actual bus trajectories. All three trajectories began at the same departure time. For example, Bus Trip 1, Hypothetical Bus Trip 1 and Pseudo Bus Trip 1 began at 7:00:10 A.M. Pseudo bus trajectories reflect the shortest travel times; for example, Pseudo Bus Trip 4 finished its trip at 7:34:19 A.M., faster than Hypothetical Bus Trip 4 and Bus Trip 4 by 3:55 and 4:31 min respectively. The mean pseudo bus speed was 32.3 mi/h, twice the actual mean bus speed (16.9 km/h); and the mean hypothetical bus speed was 20.1 mi/h, about 1.3 times the mean actual bus speed. Pseudo bus speeds varied the least along the route. The comparison between the pseudo buses and the test vehicles is the most relevant and will be described below.

The relationships between travel times and speeds of the test vehicles and the three bus scenarios were analyzed. Figure 4 (previous page) plots bus trajectories, corresponding hypothetical and pseudo trajectories, and test vehicle trajectories for three trips. This figure shows that the actual bus and test vehicle trajectories had similar shapes at the beginning of their trips, indicating both were experiencing congestion. Subtracting the horizontal offsets that result from congestion shows the test vehicle link speeds were substantially higher than those of the actual bus and are similar to the pseudo bus speed.

To verify this, test vehicle and pseudo bus travel times and speeds were compared by departure time. Test vehicle and pseudo bus travel times were plotted versus departure time in Figure 5(a). Travel time trend lines indicate that all vehicles spent more time traversing the study corridor during the morning peak period (7:00–9:00 A.M.). The speeds of the test vehicles and pseudo buses were also plotted against the departure time as shown in Figure 5(b). The speed scatter plots show that vehicles traveled at lower speeds during the morning peak period as well. Traffic conditions improved after the peak period as shown in Figure 5(b), at 9:30 A.M. Test vehicles were traveling at approximately 33 mi/h. The mean travel times for all four scenarios are also plotted on Figure 6.

It was determined that the mean test vehicle corridor travel time was 1.23 times the pseudo bus travel time. However, the test vehicle and pseudo bus travel times were found to be more similar on the bridge. Figure 6 shows that the test vehicle mean travel time was lower than the pseudo bus mean travel time on the bridge, yet higher when comparing their mean corridor travel times. This is assumed to occur because traffic conditions on the bridge are nearly free flow, allowing the test vehicles to achieve higher speeds than the buses.

Corridor speeds were derived by dividing the total travel distance by the net travel time. As shown in Table 1, the test vehicle speed was 0.84 and 0.90 times the pseudo bus speed for the entire corridor and on the bridge respectively. Figures 7(a) and 7(b) also show a comparison between bridge travel times and speeds in detail. Both test vehicle and pseudo bus travel times and speeds were scattered close to one other, and their trend lines were close and partially overlapping.
In a national study, average U.S. bus travel times were reported as 4.2 min/mi (14.3 mi/h) in the suburbs, 6.0 min/mi (10 mi/hr) in the city, and 11.5 min/mi (5.2 mi/h) in the central business district. Figure 6 shows a mean travel time of 9:24 min, or 3.8 min/mi, faster than the national data reported. Table 1 also shows a comparison of test vehicle and bus speeds, showing that test vehicle speeds were 1.63 times greater. The national averages indicate that non-transit vehicles usually travel 1.4 to 1.6 times faster than buses.

A three-dimensional speed contour technique was used to assist in visualizing the speed differences between the buses and the test vehicles spatially and temporally (Figure 8). Speed contour plots for buses and test vehicles were generated using distance and time as the x- and y-axes, respectively, with speed plotted on the z-axis. The speed contour diagram shows that the test vehicle speed changed smoothly on the surface due to the availability of data every 3 sec while the changes in bus speeds were more coarse since the number of bus data points was more limited. The concave surface reflects slower traffic conditions compared to other patterns on the surface. As vehicle i or bus j traversed through distance and time diagonally on the surface, concave and convex surface features describe the varying traffic conditions resulting from acceleration and deceleration. A concave surface feature, as an example, indicates that a vehicle faced queued traffic downstream and accordingly decelerated. A steep slope on the surface represents a faster change in vehicle speed. After the lowest point on the surface, traffic conditions began to return to unqueued conditions as the vehicle accelerated. By viewing the differences between the two speed surfaces, one can locate specific locations and times that the test vehicles experienced conditions that were different from those experienced by the buses.

Conclusion

From this preliminary study, it is shown that it is possible to explain actual arterial traffic conditions using archived transit vehicle AVL information. From the set of transit data used herein, the “pseudo bus” trajectory, generated from the maximum instantaneous speed achieved between each stop, was found to most reliably predict the trajectory of non-transit vehicles. Key performance measures like travel time and speed should also be described using the relationship established.
between the test vehicle and the pseudo bus. This study found that the test vehicle travel time was 1.23 times the pseudo bus travel time. Conversely, it was shown that the average test vehicle speed was 0.84 times the maximum instantaneous speed achieved by the buses. While this study focused on only one direction during the morning peak for one day, further analysis on both traffic directions on additional days is ongoing. These results will provide a greater level of confidence to the study results. However, it is possible that this preliminary study could be helpful in developing systems to assist transit agencies and traffic engineers in better understanding arterial performance or providing arterial traffic conditions to drivers.

**Acknowledgments**

The authors gratefully acknowledge Steve Callas of TriMet, who generously provided the BDS data. Chie Taniguchi, Tung Ly, John Fasana, Lara Downs, Tu Ho, Huy-Thac Tran, Ahmad Qayoumi, Michael Kehano, Renee Summers, Monica Leal and Shazia Malik collected the test vehicle data. Ahmed El-Geneidy assisted donating $250 to the District’s $1,000 award for having this year’s Best Student Chapter. Congratulations to MSU on receiving this award and for your generosity in helping other students!

At the Western States luncheon, Wilma Wilcox-Mylorie was presented the District’s Lifetime Achievement Award, and Tim Harpst was presented the Individual Achievement Award. Congratulations to both for receiving the District’s most prestigious awards! A complete list of District 6 award recipients is presented in a separate table. Congratulations to all of this year’s award winners. Your efforts to improve ITE and the transportation profession are greatly appreciated!

District 6 also did well at the International level. The Southern California Section was selected as the Best International Section, and Montana State University was selected as the Best Student Chapter. Congratulations! In addition, Bob Crommelin was selected as the Institute’s 71st Honorary Member, and Tim Harpst was elected as the 2004 International Vice President. Congratulations to both of you on your outstanding accomplishments!

Past International President Jenny Grote swore in the newly elected officers at the end of the Western States luncheon. Congratulations to all of you! Please refer to the Highlights of the Annual Board meeting and Annual Business Meeting column for a summary of the election results and District Board of Direction motions.

As I conclude my last President’s message, I want to express my sincere appreciation to all those that provided me an opportunity to serve ITE. While there are too many to mention individually, I would like to acknowledge the members of the District 6 Board, the Committee Chairs, and LAC members that I have had the opportunity of working with as well as my family and employer who consistently supported me. Thanks to all of you and especially to you the membership! It has truly been an honor and a privilege to serve ITE at the District level over the past three years and I look forward to the upcoming year with Randy McCourt’s leadership.

---

**President’s Message**

(Continued from page 1)

competition, culminating in each team maneuvering a race car through an obstacle course complete with signals and a roundabout. As this event was so popular, the number of allowed entries was increased to accommodate all those students that were interested in participating. Pat Gibson generously donated $250 to the District’s $1,000 award so that each of the five members of the winning team could receive $250. Thanks, Pat, and congratulations to the winning team.

The number of students attending the annual meeting this year was quite impressive. Thanks to all of the Sections and Chapters that sponsored students though travel and International registration fees. I would encourage each of the Sections and Chapters to sponsor a student at future meetings. A special thanks to the Montana State University Student Chapter for increasing student attendance at the meeting. The MSU students graciously donated the $1,000 travel expenses award they received for having this year’s Best District 6 Student Chapter to the UNLV Student Chapter. Congratulations to MSU on receiving this award and for your generosity in helping other students!

At the Western States luncheon, Wilma Wilcox-Mylorie was presented the District’s Lifetime Achievement Award, and Tim Harpst was presented the Individual Achievement Award. Congratulations to both for receiving the District’s most prestigious awards! A complete list of District 6 award recipients is presented in a separate table. Congratulations to all of this year’s award winners. Your efforts to improve ITE and the transportation profession are greatly appreciated!

District 6 also did well at the International level. The Southern California Section was selected as the Best International Section, and Montana State University was selected as the Best Student Chapter. Congratulations! In addition, Bob Crommelin was selected as the Institute’s 71st Honorary Member, and Tim Harpst was elected as the 2004 International Vice President. Congratulations to both of you on your outstanding accomplishments!

Past International President Jenny Grote swore in the newly elected officers at the end of the Western States luncheon. Congratulations to all of you! Please refer to the Highlights of the Annual Board meeting and Annual Business Meeting column for a summary of the election results and District Board of Direction motions.

As I conclude my last President’s message, I want to express my sincere appreciation to all those that provided me an opportunity to serve ITE. While there are too many to mention individually, I would like to acknowledge the members of the District 6 Board, the Committee Chairs, and LAC members that I have had the opportunity of working with as well as my family and employer who consistently worked around ITE commitments. Thanks to all of you and especially to you the membership! It has truly been an honor and a privilege to serve ITE at the District level over the past three years and I look forward to the upcoming year with Randy McCourt’s leadership.

---

**Thank You**

Thank you, my fellow ITE members, for the opportunity to serve you and the Institute over the next three years. I very much appreciate the input I have received from members throughout the ITE family as I traveled during this year’s campaign. I will use the valuable insight you have provided me as I join the Executive Committee.

ITE exists to help provide us with the tools we need to do our jobs better. We have heard much over the past year of the significant work done by the International Board of Direction in updating ITE’s Strategic Plan. The goals I spoke to during my travels this year fit well with the key areas identified in this plan. I look forward to helping implement specific efforts in the areas of:

- Broadened membership services;
- Increased workforce development opportunities;
- Enhanced communication among our members and with elected leaders and the public; and

- Encouraging worldwide growth in our membership so we can all learn from the diversity and knowledge of transportation professionals everywhere.

Tim Harpst, ITE International Vice President Elect