USING TRUCK TRACTOR LOGS TO ESTIMATE TRAVEL TIMES AT CANADA-U.S. BORDER CROSSINGS IN SOUTHERN ONTARIO

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1. Background

This paper documents an approach for measuring travel times at Canada-U.S. border crossings using truck tractor logs. The motivation for the study was to develop some empirical evidence to address heightened concerns about border security after the terrorist attacks of September 11, 2001. One of the biggest fears in the months directly after the attacks was whether the vast amount of trade exchanged between Canada and the U.S. would be threatened by potentially increased wait times at the border. Though the effects of border security on transit times are a real concern, unfortunately, no routine data sources exist for measuring crossing times. What we show here is how trip-level tractor logs can be used as a means of filling this important data gap. A distribution of tractor logs can provide information not only on the average time to cross the border but also on the travel time variability, a critical variable in the logistics business.

2. What are truck tractor logs?

Tractor logs provide a summary report of the progress of a trip between origin and destination. Two main technologies exist for collecting a truck's trip data.

1. Currently, the most popular form is **real-time vehicle tracking services** provided either through a satellite-based service such as Cancom/Qualcomm or through Global Positioning System (GPS) units installed on the vehicles (examples of GPS services are AirIQ, PeopleNet, and

Highway Master). Real-time services typically collect information on the geographic coordinates (i.e. latitude and longitude) of the vehicle, date and time stamps, and vehicle speed. A wireless transmitter is normally used to permit remote tracking of the vehicle by the dispatch office.

2. The other approach, less popular now, but historically the dominant mode of vehicle tracking, is a **tachograph** device installed in the vehicle. A tachograph is an instrument that records vehicle speed, time of day, and distance travelled on a circular paper disc. Though geographic coordinates are not collected directly by the tachograph, vehicle positioning can be inferred by assuming a route and aggregating distance along the route. With no geographic positioning, real-time tracking is not possible with tachographs.

Though the technologies are quite different, they both collect data at the trip level and thus can be used to evaluate travel times and speeds over discrete parts of a trip, including borders.

3. Data sources used in the study

With the assistance of the Ontario Trucking Association, Transport Canada obtained tractor log data from two for-hire trucking firms based in Southern Ontario. The two carriers graciously agreed to share copies of their log data on their most frequent runs to the United States. One carrier supplied copies of their GPS-based tractor logs from January 2, 2002 to April 19, 2002, while the other supplied copies of tachograph cards from December 2000 to April 2002. All major border crossings in Southern Ontario were covered, specifically the Ambassador Bridge at Windsor/Detroit, the Peace and Queenston-Lewiston Bridges in the Niagara region and the Blue Water Bridge at Sarnia/Port Huron. Over the spring and summer of 2002, Transport Canada analysed the log data for several thousand trips, tabulating by direction and by time of day. Each source of data will be described in turn starting with the GPS-based logs.

4. GPS-based tractor logs
Transport Canada received over 1,100 GPS-encoded tractor logs from the first participating carrier, broken down by the following crossings:

Ambassador Bridge: 320 round trips
Peace and Queenston-Lewiston Bridges: 342 round trips
Blue Water Bridge: 465 round-trips

Useable data that could be extracted from the GPS logs were a series of checkpoints containing latitude and longitude, date and time stamps to the nearest minute, and descriptions of each checkpoint. On average, a checkpoint was added to the tractor log every fifteen minutes although additional points were recorded every time there was a remote communication between the truck and the dispatch centre.

One complication with the GPS logs was that an accurate estimate of distance was not included for each checkpoint. This was remedied by estimating linear distance travelled using the geographic information system (GIS) TransCAD. TransCAD handles linear referencing, a function that assigns the distance travelled along a trip (i.e. mileposts) to a series of latitude and longitude coordinates located along the trip's route. In this study, all checkpoints in the logs were geo-coded in TransCAD and a linear distance was subsequently attached to each point. Once all points in the log were identified in time and space, a border zone was isolated for each trip and summary statistics on average times and speeds were computed.

4.1. Analysis of Ambassador Bridge using GPS tractor logs
Owing to the relatively infrequent polling interval (i.e. 15 minutes on average) of GPS checkpoints, it was not possible to define precisely the same border zone for each trip; however, after examining all trips, a 5 km section around the Ambassador Bridge was selected for the border zone. Based on the distribution of the checkpoints, out of 320 valid trips, 311 trips could be used to look at crossing times outbound

from Canada to the U.S., and 257 trips could be used to look at crossing times inbound from the U.S. to Canada.

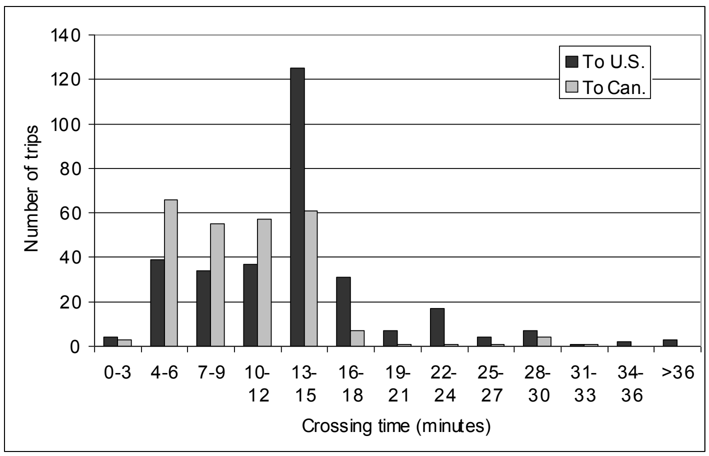

Figure 1: Average crossing time at Ambassador Bridge

The histogram in Figure 1 shows that it took quite a bit longer to travel outbound to the U.S. than inbound to Canada. The average crossing time to the U.S. was 14 minutes with a standard deviation of 6.5 minutes, while the average time to cross into Canada was 10 minutes with a standard deviation of 5 minutes.

One convenient way in which to measure the reliability of travel time, an important performance indicator, is to use a Buffer Time Index (BTI).[2] A buffer time index is calculated as the percentage difference between the 95th percentile crossing time and the average time; it gives a rough indication of the amount of time that needs to be built in to the crossing time to avoid delay at the border. For the Ambassador Bridge, the 95th percentile crossing time to the U.S. was 25 minutes giving a BTI of 81 [(25/14)-1)*100], while the corresponding time for crossings to Canada was 16 minutes giving a BTI of just 57.

4.2 Temporal variation at Ambassador Bridge

One of the real advantages of trip-level logs is that one can analyse the distribution of crossing times by day of the week and by hour. For the carrier treated here, there did not appear to be any strong pattern in the crossing times by month or by day of the week. The distribution by time of day was skewed very much to the hours between midnight and 6 am for trips to the U.S. (40% of the trips) and from 6 am to 9 am for inbound trips to Canada (35% of trips). The average crossing times at these time periods were the lowest for each direction, at under 13 minutes for trips to the U.S. and less than 9 minutes for trips to Canada.

4.3 Importance of border time for the total trip

Another asset of a tractor log is that information for the whole trip is available. This permits one to calculate how much time is spent at the border as a share of total travel time. For the run through Ambassador Bridge, time spent at the border (both directions taken together) accounted for less than 3% of total trip time. This share was very stable over the period showing no tendency to rise or fall with a standard deviation of 1.2 percentage points.

4.4 Analysis of Niagara-area crossings using GPS tractor logs

The route taken on trips to western New York used two bridges in the region: on the U.S.-bound leg trips crossed at Queenston-Lewiston Bridge while on the return leg to Canada trips crossed via the Peace Bridge at Fort Erie/Buffalo. Based on the distribution of the checkpoint data, the border zone was defined to be 5 km long at Queenston-Lewiston and 7.5 km long at Peace Bridge. Out of 342 total trips, 330 trips were used to calculate travel times to the U.S. and 341 trips were used to calculate times back into Canada.

The histogram in Figure 2 shows the distribution of average crossing times in the Niagara region. Average travel time at Queenston-Lewiston Bridge was 13 minutes with quite a bit of rightward skew in the distribution (the mode was 6 minutes and the median was 9 minutes). The standard deviation of the distribution was 11.4

minutes. Average (inbound) crossing time at the Peace Bridge was higher at 18 minutes with a standard deviation of 9.8 minutes. Given the greater skew and more spread in the distribution for Queenston-Lewiston crossing, it is not surprising that the Buffer Time Index (BTI) was much higher at Queenston-Lewiston Bridge than at Peace Bridge. The 95th percentile transit time of the former was 33 minutes giving a BTI of 161, while at Peace Bridge the 95th percentile time was 36 minutes giving a BTI of 100. Thus, while the outbound average crossing time at Queenston-Lewiston was quite a bit lower than at Peace Bridge, the average time was not really an accurate reflection of the entire travel time distribution.

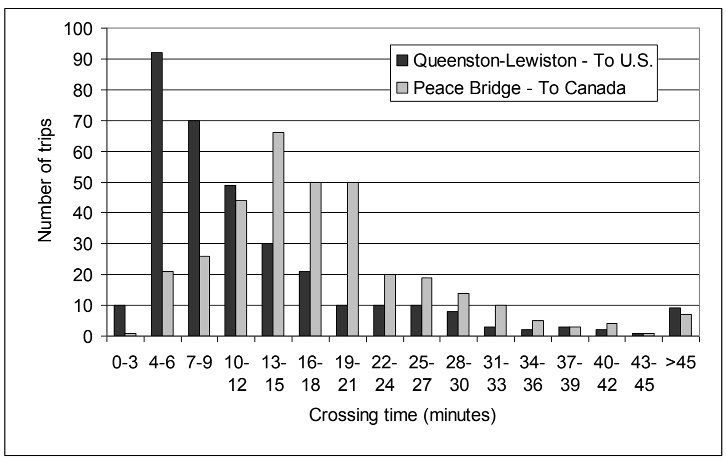

Figure 2: Average transit time at Niagara region crossings

4.5 Temporal variation at Niagara-area crossings

As with the Ambassador Bridge, average travel times at the two Niagara crossings did not display strong monthly or daily patterns. Hourly patterns were similar to Ambassador Bridge with most outbound trips occurring between midnight and 6 am. Average crossing times were lowest during this period at less than 8 minutes. The slowest period was after 6 pm at about 20 minutes. The patterns

were not so clear-cut at the Peace Bridge. Crossing times were more evenly distributed by time of day although there was a small tendency for crossing times to rise after 12 noon. Significant delays during the traditional peak periods from 6 am-9 am and 3 pm-6 pm were not observed.

4.6 Importance of border time for the total trip

Time spent at Niagara-area borders accounted for about 5.5% of total travel time. Most of the trips had border shares clustered tightly around this average figure.

4.7. Analysis of travel times at Sarnia using GPS tractor logs

The third major crossing for which GPS tractor log data were collected was the Blue Water Bridge at Sarnia/Port Huron. Based on the distribution of the checkpoints, a 5 km border zone was defined around the Blue Water Bridge. Out of 465 total trips, 415 trips could be used to analyse outbound movements to the U.S. and 360 trips could be used to analyse return trips to Canada.

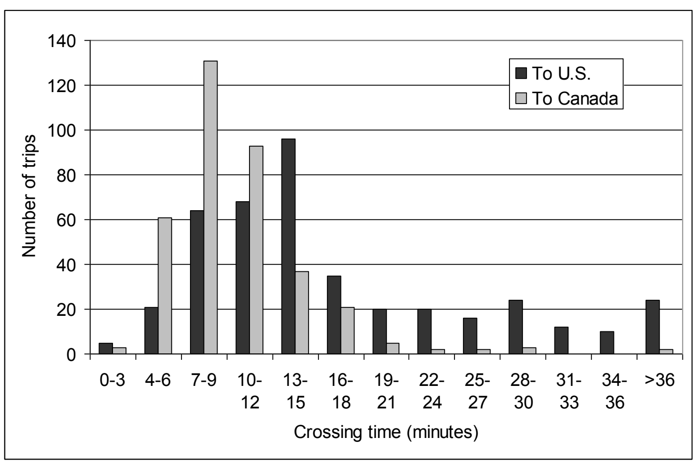

Figure 3: Average transit times at Blue Water Bridge

The histogram in Figure 3 depicts the distribution of average transit times at Blue Water Bridge. As was seen with the Ambassador Bridge, it took longer to cross into the U.S. at Sarnia than it did to return to Canada. The average outbound crossing time was 17 minutes with a standard deviation of 10, while the average inbound times was about 10 minutes with a standard deviation of 5.

Given the wider spread in the outbound distribution, it is not unexpected that the Buffer Time Index was much higher for trips to the U.S. The 95th percentile crossing time was 39 minutes for outbound trips versus only 17 minutes for inbound trips, producing a BTI of 125 for outbound trips and only 68 for inbound trips.

4.8 Temporal variation at Blue Water Bridge
Unlike the other crossings, there was a pretty strong pattern in crossing times by day of the week. Average travel times appeared to be lowest on Monday and Tuesday for both directions, about 16 minutes for trips to the U.S. and 8-10 minutes for trips to Canada. The slowest day of the week for outbound trips was Wednesday while Friday was slowest for inbound trips.

Trips to the U.S. were clustered in the morning with all but 13 reaching the border before noon. Average crossing times between midnight and 6 am were less than 16 minutes, while average times from 6 am to 9 am were slightly less than 19 minutes. Trips to Canada were clustered after 9 am with almost half of the trips reaching the border between 9 am and noon and all but 16 trips arriving at the border between 6 am and 3 pm. Crossing times into Canada showed a tendency to rise during the day from less than 9 minutes between 6 am and 9 am to 10 minutes from 9 am to noon and further to 12 minutes between noon and 3 pm.

4.9 Importance of border time at Sarnia for the total trip
Time spent at borders was not a significant factor for trips using the Blue Water Bridge. Border crossings represented about 3.5% of the total travel time with most trips clustered around this average share.

5. Tachograph-based tractor logs

The tachograph cards supplied by the other participating carrier covered the period from December 2000 to April 2002. Tachographs record trip information on a minute-by-minute basis using a set of styluses much like a heart rate monitor does. The data are documented as continuous lines around a disc-shaped card and are used by trucking firms to track drivers' hours of work and to monitor vehicle speeds. It is a tedious and laborious process to take information off the tachograph cards as the data must be read manually and transcribed by hand.

For this study, data were obtained for the Ambassador, Peace and Queenston-Lewiston Bridges. As was done with the GPS tractor logs, a border zone was identified for each crossing. Then, each trip across the border zone was profiled by transferring information from the tachograph cards into a database. The driver ID, vehicle number, start (end) dates/days of week, and checkpoint times were recorded as were the estimated crossing times for the border zone and other trip segments. The border crossing times for 1,500 one-way trips were documented in this manner.

5.1 Crossing times at Ambassador Bridge using tachograph data

For the Ambassador Bridge, 207 outbound trips to the U.S. and 173 inbound trips to Canada were available for analysis. According to the tachograph data, average transit times at Ambassador Bridge were considerably higher than were seen with the GPS data. The average outbound time was calculated to be about 40 minutes with a standard deviation of 30 minutes. Average inbound time was about 30 minutes with a standard deviation of 25 minutes (See Figure 4).

As the histogram in Table 5 reveals, there were very long tails to the crossing time distribution at Ambassador Bridge. The 95th percentile time for trips to the U.S. was 80 minutes which gives a buffer time index of over 170. For inbound trips, the 95th percentile time was 100 minutes which gives a BTI of 147.

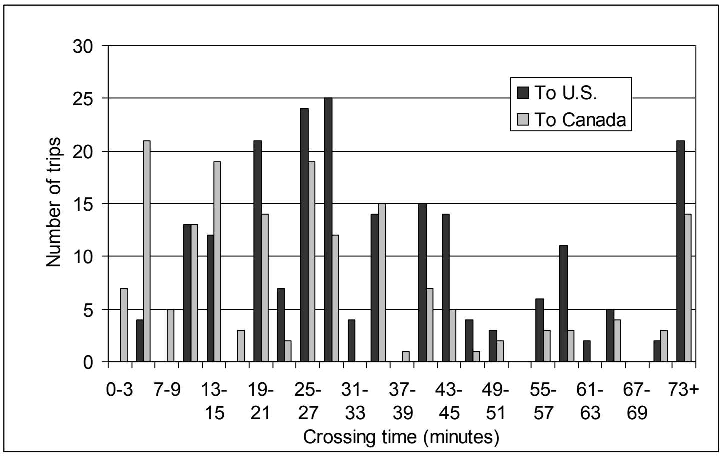

Figure 4: Average transit times at Ambassador Bridge

5.2 Differences in crossing times before and after 9/11/2001

Since the tachograph evidence pre-dates the terrorist attacks of 9/11/2001, it is possible to evaluate any difference in crossing times before and after this date. Surprisingly, average crossing times to the U.S. actually fell at Ambassador Bridge after 9/11/2001. The average crossing time prior to this date was 43 minutes, compared to 36 minutes after. However, the difference was not statistically significant at the 95% level as the computed t-statistic was only 1.6. For trips to Canada, average times before and after the terrorist attacks were virtually identical. These data, although by no means representative of all travel, at least do not show dramatic increases in travel times at Ambassador Bridge, post 9/11.

5.3. Crossing times at Queenston-Lewiston Bridge using tachograph data

As was seen with the GPS logs, the majority of trips to the U.S. through the Niagara gateway used the Queenston-Lewiston Bridge. In the tachograph dataset, there were 521 trips to the U.S. via Queenston-Lewiston and 390 trips to Canada. The average outbound

time was about 16 minutes with a standard deviation of 15 minutes, while the average inbound time was a bit higher at 24 minutes with a standard deviation of 24 minutes (see Figure 5). Once again, the tachograph distribution was skewed to the right. The 95th percentile time for outbound trips to the U.S. was 40 minutes which yields a buffer time index in excess of 150. For return trips to Canada, the 95th percentile time was 80 minutes which generates a BTI of over 230.

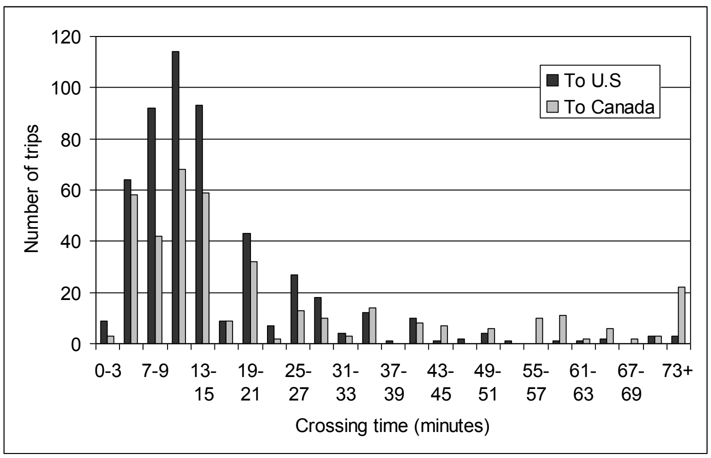

Figure 5: Average crossing times at Queenston-Lewiston Bridge

5.4 Differences in crossing times before and after 9/11/2001

There was no observed difference in crossing times to the U.S. pre- and post-9/11. There was a slight reduction in inbound travel times at Queenston-Lewiston Bridge after 9/11/2001 (26 minutes to 22 minutes) but this difference was also not statistically significant at the 95% level (t-stat only 1.3).

5.5 Crossing times at Peace Bridge using tachograph data

As was also seen with the GPS data, most of the trips in the tachograph dataset used the Peace Bridge to return to Canada. Nearly

180 trips had an inbound leg via Peace Bridge compared to only 29 outbound trips. (See histogram in Figure 6.)

The average outbound transit time at Peace Bridge was 53 minutes with a standard deviation of 24. All but one of these trips was made before 9/11/2001. The average inbound transit time was about 30 minutes with a standard deviation of 28. Given the large degree of variation the buffer time index at Peace Bridge was high. The 95th percentile travel time for inbound trips was over 80 minutes generating a BTI of nearly 170. The BTI for outbound trips was about 80.

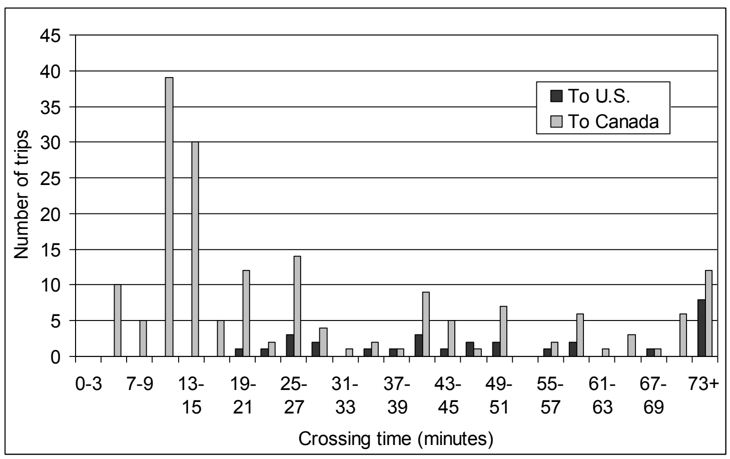

Figure 6: Average crossing times at Peace Bridge

5.6 Differences in crossing times before and after 9/11/2001

For inbound trips to Canada the average transit times fell slightly post-9/11 but were not statistically significant (t-stat was only 0.4).

6. Comparison of results with other studies

Given that the dataset in this study is based on only two carriers, it is interesting to compare our results with other studies. The only recent study for which similar analyses were performed was commissioned

by the U.S. Federal Highway Administration (FHWA)[3] in 2001. This study attempted to measure crossing times at major borders through direct observation at the border facility. Results from the FHWA study are compared against ours in Table 1. As can be seen, the GPS-based tractor log data stacked up fairly well against the FHWA estimates. The average crossing times were not dramatically different and the time distributions, as represented by the buffer time index, also seemed reasonable.

	Average crossing time (min.)			Buffer time index		
Bridge	Tachograph	GPS	FHWA	Tachograph	GPS	FHWA
Ambassador - To U.S.	34	14	20	116	81	66
Ambassador - To Canada	22	10	9	125	57	56
Queenston - To U.S.	14	13	n.a.	156	161	n.a.
Peace - To Canada	34	18	22	108	100	75
Blue Water - to U.S	n.a.	17	34	n.a.	125	135
Blue Water - to Canada	n.a.	10	6	n.a.	68	47

Table 1: Comparison of travel time results with FHWA study

With the exception of the Queenston-Lewiston Bridge, the tachograph data yielded higher average crossing times and consistently larger buffer time indexes than the FHWA numbers. This implies that average times vary depending on the type of carrier and the goods carried. *(Note that the tachograph numbers presented here were restricted to the period January-April 2002 to be more comparable with the GPS data. As a result, the numbers in this table differ from the numbers presented in section 5.)*

7. Summary and next steps

The objective of the study was to test the potential for using tractor logs to estimate travel times at border crossings. As we have shown here, truck tractor logs can yield information on both average travel times as well as travel time variability. Since data on whole trips are summarised in the logs, it is possible to analyse the variation in travel times by a number of factors including time of day, day of the week, share of total travel time, and by individual crossing and geographic location.

Of the two methods, the most promising for future work is more than likely logs obtained through real-time vehicle tracking services. As was mentioned in section 5, tachographs, although a reliable data collection method, require too much manual intervention to be used in large quantities. GPS-based logs, by contrast, do not suffer this limitation as the data are electronic and can be analysed with spreadsheet software. The other huge advantage is the coordinate information contained in the GPS-based logs. Most conventional data sources on trucking movements lack a direct link to the road network over which the trucks move—a fairly critical gap given that location is one of the most important characteristics of road transport. Such was not the case with the GPS-based tractor logs as the checkpoints closely matched the highway network over which the trucks travelled.

Future work will focus on the following areas:

- Obtaining a better cross-section of carriers. A sample of one or two carriers is sufficient to demonstrate the method but is obviously inadequate for making any firm inferences about border crossing times. Crossing times may depend on the type of goods being carried as well as the size and reputation of the carrier and thus will need to be controlled for in any future research.
- More and better coverage by time of day. Although the trips presented here make up a fairly large dataset, significant gaps were detected at various times of day. For example, a large percentage of the observations in the database reached the border before 6 am. For improvement, it would be necessary to collect trips over the entire day to reduce selection bias.
- GPS-based tractor logs need more detail. Checkpoints collected at fifteen-minute intervals are not really sufficient to analyse border issues. As pointed out earlier, it was difficult to identify a proper border zone because the checkpoints never lined up precisely on the border boundaries for each trip; in some cases no points at all fell along the border zone. This created a potentially large source of bias in the tractor log data as most of the border times clustered around the 15-minute level, suspiciously close to

the standard polling interval. To alleviate this problem it will be necessary to have more frequent polling of the truck's location.

- Tractor logs need a good measure of distance travelled. A big flaw in the data TC received was the absence of valid odometer readings for each checkpoint; this necessitated a complicated procedure for estimating distance using linear referencing. If tractor logs are to be analysed on a large scale, a proper measure of distance will be necessary. Should checkpoint data be obtained at much finer intervals, distance measurement could probably be made directly using straight-line calculations.
- Create stable relationships with data providers. This analysis could not have taken place without the generous cooperation of the participating carriers. Any future work will require strong relationships with the data providers to ensure that the information is treated with care and the confidentiality of the carriers is respected.

Reference

Texas Transportation Institute, The Texas A&M University System and Battelle Memorial Institute, *Evaluation of Travel Time Methods to Support Mobility Performance Monitoring*, April 2002.

Endnotes

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[1] The views expressed here are those of the authors and do not represent the views of Transport Canada.
[2] The concept of a Buffer Time Index was presented in the FHWA paper, *Evaluation of Travel Time Methods to Support Mobility Performance Monitoring*.
[3] *Evaluation of Travel Time Methods to Support Mobility Performance Monitoring* [http://ops.fhwa.dot.gov/freight/pmeasure/]