Some approaches for measuring transit times at border crossings

The lack of statistics on the efficiency of border crossings constitutes a significant transport data gap. Different metrics can be envisioned (e.g. vehicle throughput, evaluation of customs processes), but the principal performance measure is arguably the amount of time it takes to clear the border zone. Travel time is a simple, easy-to-understand concept that can be measured with precision; unfortunately, it is not simple to measure in practice owing in large part to the sizeable number of vehicles crossing the border daily. Some selected approaches (not exhaustive) for the direct measurement of travel times are listed below:

I. Probe vehicles/tractor logs (e.g. Transport Canada study)
II. License plate matching (e.g. 2001 FHWA study)
III. Vehicle re-identification using conventional traffic counting technology (e.g. Berkeley Highway Laboratory)

Each will be discussed in turn, followed by a brief discussion on next steps and potential approaches for collecting border data in a coordinated fashion.

I. Probe vehicles/tractor logs

A very simple approach for measuring crossing times is to collect data on individual vehicle trips that pass through the border. A border zone of fixed length can be defined and identified and the time it takes to move through this zone can be recorded by taking time stamps at the start and end of the zone. Data can be collected in a variety of ways depending on the technology used and who does the data collection. Some examples are listed below

1. Test vehicles (Hire vehicles and drivers to record travel time data manually or with a GPS receiver)
2. Automatic vehicle identification (AVI) using transponders (e.g. Highway 407)
3. Tractor logs from satellite-based tracking services or GPS-based tracking services

1. Test vehicles

The simplest approach is to hire a number of vehicles to drive back and forth across the border. A laptop computer fitted with a GPS receiver records the travel time at various checkpoints along the way.

Advantages	Disadvantages
1. Easy to start up since all that is needed is a vehicle, driver and laptop computer with GPS receiver. 2. Considerable amount of data can be collected since the GPS can record in one-second intervals.	1. Very laborious way to collect data since someone actually has to drive the vehicle back and forth across the border. 2. Difficulty getting a representative sample since one would need dozens of runs per day. 3. Difficult to collect data continuously
Comment: too laborious to be a feasible approach for continuous data collection	

2. Automatic vehicle identification

Electronic toll collection technology can be used to measure segment travel times through the tracking of unique vehicle transponder signatures on a toll highway. When a vehicle equipped with a transponder enters a toll collection zone, an antenna on the roadside detects the vehicle and sends a timestamp of that vehicle's location to a central server for processing. Travel times can be computed by taking differences in timestamps for a given vehicle over different parts of the electronic toll highway.

Advantages	Disadvantages
1. Travel time data can be collected with precision 2. Data can be collected continuously 3. Minimal personnel requirements 4. Lane specific 5. Potentially large sample of vehicles available	1. Limited by extent of the electronic toll highway 2. Only vehicles with tags are captured – lack of coverage for out of province/state vehicles 3. Privacy issues – able to track individual vehicles 4. Cost-prohibitive if used only for travel time calculations since vehicle owners would have to purchase transponders
Comment: potentially useable only if electronic toll collection exists at the border; not feasible as a stand-alone method	

3. Tractor logs

Rather than using test vehicles to collect data, one can obtain access to trip-level data collected by trucking firms' vehicle tracking services. Many carriers, especially long-haul carriers, employ remote vehicle tracking services to manage their fleets and provide remote communications with their trucks. Two types of services currently exist:

1. Satellite-based tracking provided by Cancom in Canada and Qualcomm in the U.S.
2. GPS–based tracking provided by a large number of companies (e.g. AirIQ, Highway Master, Turnpike Global Technologies, PeopleNet)

Segment travel times can be calculated from these services by comparing time stamps of geographic checkpoints entered onto an electronic log file recording a truck's progress from origin to destination. The geographic checkpoints are precisely recorded (latitude and longitude down to the second typically) but the polling interval between checkpoints can vary widely: satellite services usually offer hourly polling intervals (largely a function of the high cost of satellite time) while GPS services vary between 5 and 15 minutes (it is possible for GPS services to record at finer intervals but the added detail is normally overkill for a trucking firm and is therefore not normally encountered).

Some GPS services offer the ability to add checkpoints automatically when a truck crosses over a fixed boundary line (e.g. a provincial border). This aids in the identification of a proper border zone, and hence comparability in the travel time information.

Advantages	Disadvantages
1. Novel way to piggyback off data that are already being collected 2. Geographic information is precise 3. Potentially large sample of vehicles available 4. Fixed border zones can be defined by some GPS service providers 5. Minimal personnel requirements 6. Data relatively easy to process	1. Collection is limited to the carriers willing to participate - potential source of bias since they may cross the border differently from other trucks (time of day; release status) 2. Polling intervals are normally not fine enough to identify the border properly 3. Data can be costly especially if Customisation of truck logs is needed 4. Privacy issues – hours of work
Comment: not perfect (since the sampling is not random) but a simple way to collect transit times	

II. License plate matching

License plate matching has traditionally been a popular method for collecting travel time information. A variety of techniques exists for plate matching ranging from manual methods right up to full video capture and computer-based recognition of plates. The method behind plate matching is very simple: two collection stations are established defining a fixed zone: vehicle license plates and their accompanying time stamp are recorded at the upstream location and are recorded again at the downstream location. Individual plates are then sorted at both locations and the identical ones matched. The difference in time stamps for the matched set of plates measures the travel time.

State-of-the-art plate matching uses high definition video cameras to collect images of license plates at upstream/downstream locations; the video tape is transcribed into a digital format and the license plate characters are then recognised using sophisticated optical character recognition (OCR) software. Once the plate images are digitised, identical plates are matched and the corresponding time information is used to measure travel times.

Manual license plate matching was used by the U.S. Federal Highway Administration (FHWA) to measure crossing times at selected border crossings in 2001.

Advantages	Disadvantages
1. Large sample of vehicles can be collected 2. Travel time data are precise 3. Can analyse data over short periods of time during the day 4. Image recognition/matching can be automated	1. Cameras and OCR equipment very expensive to purchase 2. Costly to undertake – need field personnel to man cameras/carry out data collection 3. Image recognition success depends on image quality 4. Costly to do at night 5. Privacy issues 6. Requires skilled personnel 7. Costly to collect data continuously
Comment: an effective method for collecting data on a short-term, ad hoc basis; too expensive for continuous collection	

III. Vehicle re-identification using traffic counters/weigh-in-motion scales

A third, more experimental, but very promising, method for calculating travel times uses a process known as vehicle re-identification to match vehicles at conventional traffic counter sites. By their nature traffic counter/classifiers are only capable of measuring activity that directly passes over their sensors. (e.g. volume, speeds, road occupancy) and have not typically been used to measure segment travel times. However, research by Benjamin Coifman of Ohio State University and others has exploited the ability of counter/classifiers to measure the lengths of individual vehicles to trace sequences of vehicles between upstream/downstream traffic counter sites. The algorithm is fairly straightforward:

- The lengths of vehicles in the traffic stream are measured by a suitable traffic counter/classifier at an upstream and downstream location;
- Each downstream measurement is compared to a large number of upstream measurements to identify all the upstream observations that could have produced the downstream vehicle
- Possible matches are weighted by the length of uncommon vehicles in the traffic stream and results are entered into a vehicle match matrix
- Building on the notion that vehicles usually maintain their order between counting stations, a true (but unknown) match for a given vehicle is likely to be preceded or followed by a possible match for adjacent vehicles.
- Match rates are improved by looking at short sequences or platoons of matched vehicles (usually more than two-vehicle sequences)
- The most likely offset order (i.e. the first vehicle downstream was the fifth vehicle upstream, the second downstream was the sixth upstream) between the two stations is then calculated.

Advantages	Disadvantages
1. Can piggyback on existing traffic counting infrastructure—cost savings 2. Collects data on entire traffic stream 3. Can operate continuously 4. Can cover all lanes of traffic 5. Works in congested conditions 6. Privacy concerns avoided 7. Estimated travel times are very consistent with "ground truth" 8. Can re-identify over several kilometres of highway 9. Low personnel requirements—process is automated 10. Could be linked up to an ATIS (e.g. variable message sign) for real-time information 11. Could work with several different traffic sensors (loops, WIM)	1. Largely experimental (Berkeley Highway Laboratory has been field testing the method) http://www.cs.berkeley.edu/~zephyr/BHL/ 2. Reliability of traffic sensors (e.g. loops) is an issue—requires regular maintenance 3. Initial hardware costs may be high, depending on counter technology used, but this could be easily partnered between interested agencies
Comment: though experimental, this method has the best potential to provide continuous travel time information	

General comments and next steps

If it is desirable to have a method that measures travel times at borders continuously, reflects all the vehicles in the traffic stream, is accurate, and cost-effective for long-term use, then it is hard not to recommend the vehicle re-identification approach. On balance, it has a superior list of advantages to the other methods with few accompanying disadvantages. The biggest unknown is whether it will work in a border crossing context. Empirical evidence suggests that it should not be a problem since it has been tested on Interstate 80 near Berkeley since May 2000.

If there is sufficient interest by members of the Transborder Working Group, perhaps it would make sense to do further research on this method with a goal to doing a field test at one or more border crossing sites. Given the extensive use of traffic counting technology in state/provincial highway departments, it might be a perfect opportunity to piggyback on existing infrastructure/expertise and develop travel time profiles with very little upfront and ongoing expenditure.

Recommendation: a sub-committee be formed to investigate the feasibility of using vehicle re-identification techniques to estimate travel times at border crossings. If deemed feasible, a field test at selected crossing(s) will be undertaken subsequently.

Important references:

FHWA's *Travel Time Data Collection Handbook* (PL-98-035) has been an invaluable resource for this note.

Vehicle re-identification:

Coifman, B., and Cassidy, M. "Vehicle Reidentification and Travel Time Measurement on Congested Freeways", *Transportation Research: Part A,* 2002, vol 36, no 10, 2002, pp. 899-917.

Coifman, B., and Cassidy, M. *Automated Travel Time Measurement Using Vehicle Lengths From Loop Detector Speed Traps,* University of California - PATH, 2000.

Coifman, B. "A New Algorithm for Vehicle Reidentification and Travel Time Measurement on Freeways", *Proc. of the 5th International Applications of Advanced Technologies in Transportation Engineering,* ASCE, 1998, pp 167-174.

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