Inventory of Current Programs for Measuring Wait Times at Land Border Crossings

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INTRODUCTION

Congestion at land border crossings in North America has been an important issue for the traveling public and commercial interests for many years. Many people still remember the long lineups of trucks when the borders were closed following the terrorist attacks of September 11, 2001. The media continue to report extensive delays at the busiest crossings.

The measurement of border wait times is of considerable interest to a wide range of stakeholders who depend upon the efficient flow of goods and people between Canada, the United States and Mexico. U.S. and Canadian customs agencies have expressed a desire to identify the programs that are currently in place to measure border wait times. This document provides a summary of the various techniques and technologies, along with the advantages and disadvantages of each.

From a transportation perspective, wait time results when traffic demand approaches or exceeds the available capacity of the supporting infrastructure (e.g. highways, border facilities) and/or the processing capacity of the crossing. While the aforementioned concept is straightforward, quantifying border delay and wait time is complicated by the fact that, at borders, both demand and available capacity are variable rather than constant. Demand varies by time of day, day of week, season, etc., and border capacity can vary and be constrained by operational conditions such as work zones on the highway infrastructure, traffic and border incidents, availability of staffing and lanes, resource availability (e.g., inspection equipment or computer systems), and other uncertainties related to the passengers and/or cargo crossing the border (e.g., missing or incomplete documentation, enhanced interdiction activities, or referral to secondary).[1]

U.S. and Canadian customs agencies have been posting wait time information on their websites since 2002. They currently use a variety of manual methods for measuring border wait times. A summary of the methods used at each crossing by U.S. Customs and Border Protection (CBP) field offices is presented in Table 1. Canada Border Services Agency (CBSA) uses similar techniques. All offices use one or more of the five methods described below:

1. **Unaided visual observation**: Most of the field offices use unaided visual observation to estimate border wait times by noting where the end of the queue is located in relation to pre-determined landmarks. Officials usually have a good sense of how long the wait will be from that point based on past experience. In an effort to ensure that wait times are being accurately captured and consistently reported, some offices also use a lookup table called the Border Wait Time Calculator that incorporates other elements such as the number of booths open.
2. **Cameras**: Where they exist, traffic cameras are used by field office staff to extend their visual range beyond their direct line of sight. This enables them to observe the end of the queue in relation to pre-determined landmarks for longer lineups. The Peace Bridge Authority has taken this one step further by

identifying milestones on the bridge and using a spreadsheet formula that incorporates processing time and the number of booths open to produce a common wait time calculation that the various stakeholders in the region use to broadcast the same information through Variable Message Signs (VMS), a toll-free number, and CBP and CBSA websites.

3. **Driver surveys**: Most of the field offices use driver surveys to help determine wait times. Drivers arriving at Primary Inspection are asked by the customs officer how long they have been waiting in the queue. Some average of the reported times is used as the approximate wait time at that moment. Experience from traffic control operations has shown that drivers tend to overestimate their wait times when they are delayed.
4. **Time stamped cards**: Some 16% of CBP land border ports of entry use some method of time stamping a card or toll receipt at a location upstream of the plaza, and then comparing the time stamp against the current time when the driver arrives at some location further along in the inspection process. The difference between the two times provides a transit time between the two locations.
5. **License Plate Readers**: In Detroit, the Detroit-Windsor Tunnel Company supervisors agreed to assist CBP in their wait time surveys by either sending an e-mail or calling each hour with a list of license plates and what time they entered the toll booths. The license plates are then queried in the Treasury Enforcement Communications System (TECS) license plate record of border crossing (SQPQ) to determine when they were actually inspected at the Primary Inspection booth. In San Diego, during periods of long wait time reports, officers will drive down the Border Patrol Road to observe the commercial vehicle end-of-queue and note license plate number and "corrugation" (enclosing Mexican compound) section number. The arrival time at Primary using TECS is verified to estimate wait times.

Table 1: United States Customs and Border Protection
Land Border Port of Entry Wait Time Methods

U.S. CBP District Field Office	Site Location(s)	Unaided Visual Observation	Cameras	License Plate Reader	Driver Surveys	Time Stamp Cards/ Receipts
BOSTON	Houlton	X	X			
	Calais	X			X	
	Jackman				X	
	Derby Line	X	X		X	Paper
	Highgate Springs	X				
BUFFALO	Buffalo	X	X	X	X	
	Champlain		X			
	Fort Covington	X			X	
	Trout River	X			X	
	Jamieson's Line	X			X	
	Chateaugay	X			X	
	Churubusco	X			X	
	Cannon Corners	X			X	

U.S. CBP District Field Office	Site Location(s)	Unaided Visual Observation	Cameras	License Plate Reader	Driver Surveys	Time Stamp Cards/ Receipts
	Mooers	X			X	
	Overton Corners	X			X	
	Rouses Point	X			X	
	Alexandria Bay	X			X	
	Ogdensburg	X				
	Massena	X				Slip of paper
DETROIT	Detroit	X		X	X	
	Fort Street Cargo	X		X	X	
	Port Huron	X		X		
	Sault Sainte Marie	X	X		X	
EL PASO	El Paso	X	X		X	Toll receipt
	Fabens/Ft. Hancock				X	
	Columbus	X			X	
	Presidio				X	
	Santa Teresa	X			X	
LAREDO	Brownsville	X	X		X	Toll receipt
	Del Rio	X				
	Eagle Pass				X	Toll receipt
	Laredo	X				Toll receipt
	Hidalgo/Pharr	X	X		X	Time stamp
	Rio Grande City	X			X	
	Progreso		X		X	
	Roma	X			X	Toll receipt
SAN DIEGO	Andrade	X	X	X	X	
	Calexico	X	X	X	X	
	Otay Mesa	X	X		X	
	San Ysidro	X	X		X	
	Tecate	X	X		X	
SEATTLE	Blaine	X	X	X	X	
	Lynden	X	X	X	X	
	Sumas	X	X	X	X	
	Eastport	X			X	
	Fort Frances	X			X	
	International Falls				X	
	Raymond	X				
	Sweetgrass	X			X	
	Pembina	X			X	Business card
TUCSON	Douglas	X	X			
	DeConcini	X				
	Lukeville	X	X		X	
	Mariposa	X			X	
	Nogales	X	X		X	
	San Luis	X			X	
	Naco	X				

Unfortunately, the manual collection of wait times by customs staff is quite time consuming and, in fact, outside of their primary mandate. Even worse, concerns with respect to the reliability and timeliness of the distributed wait time information have been expressed by the people who use the information—notably, carriers and the traveling public.[2] For these reasons, there is considerable interest in implementing automated wait time systems that can reliably collect the information with limited human intervention, and quickly distribute it to the users of border wait time information.

USERS OF BORDER WAIT TIME INFORMATION

A decision regarding the selection of border wait time measurement technology cannot be made without first determining how the information will be used and disseminated. Users of wait time information have needs that fall into two major groupings: archived data that monitors the performance of the crossings at some time in the past, and real-time information that enables agencies to better manage and operate the border and informs users' decisions about when, where, and if they should cross the border.

1. Archived data needs:

The following list identifies some of the potential users of historical border wait time information, along with a description of how the information may be used:

- **Customs agencies, transportation agencies:** Would like to measure local system performance by national measures.
- **Infrastructure planners:** Would like to be able to identify when and where delays occur along approach roads to border crossings and in customs plazas, to be able to prioritize new investment in added capacity, and to evaluate the success of those investments.
- **Public agencies:** Public agencies and crossing operators would like to have reliable wait time information in order to manage public perception of the extent of delays to respond to anecdotal statements with hard facts.
- **Customs field offices:** Require reporting of wait times to headquarters, along with a brief explanation when times exceed some pre-defined standard, usually one hour.
- **Customs agencies, toll operators:** Can use historical wait times and patterns to better plan staff schedules.
- **Customs agencies:** Can help market the advantages of trusted programs such as Free and Secure Trade (FAST), NEXUS and Secure Electronic Network for Travelers' Rapid Inspection (SENTRI) by demonstrating reduced delays compared to vehicles not in the program.
- **Crossing operators and duty free operators:** Can market the advantages of their superior crossing times compared to nearby competitors to encourage customers to use their crossing.
- **Tourists and business travelers:** Can plan the best day or time to cross the border, based on the past history of delays.

- **Motor carriers:** Want to record the actual amount of time taken for each of their trucks to cross the border so that they can price the cost of delays and pass it on to their customers through a border congestion surcharge.
- **Motor carriers:** Need to be able to plan the number of trucks/trips required to serve certain demand in the border region.
- **Researchers:** Can use wait time data to calculate the cost of border delays to industry and to engage elected representatives.
- **Private industry:** Can make more informed decisions about where to locate future manufacturing or distribution facilities, based on current and forecasted border congestion.
- **Public transportation agencies:** Can assist in developing and implementing new and traditional transportation demand management and mobility management strategies that result in more efficient use of transportation resources.

2. Real-time data needs:

This list identifies some of the potential users of real-time border wait time information, along with a description of how they may use the information:

- **Drivers:** Where nearby alternatives exist, can choose to use the crossing with the lowest delay. This helps driver decision-making and increases the overall flow by balancing the volume of traffic between the available infrastructure.
- **Drivers:** Can be given expected wait time information when they are on final approach to a border crossing to better manage their expectations.
- **Shippers, motor carriers, logistics planners and local cross-border commuters:** Can determine how much extra time to build-in to their trip when they are getting ready to leave, in order to arrive at their destination on time.
- **Customs agencies, toll operators:** Can better manage current staffing levels in booths.
- **Carriers en route:** Can make decisions about when to stop at a rest area, to avoid logging driving hours while waiting in the queue.

DEFINITION OF BORDER WAIT TIME

Each of the potential users of wait time information will have their own definition of border wait time. Figure 1 illustrates a number of key points in the border region that can be used to define wait time.

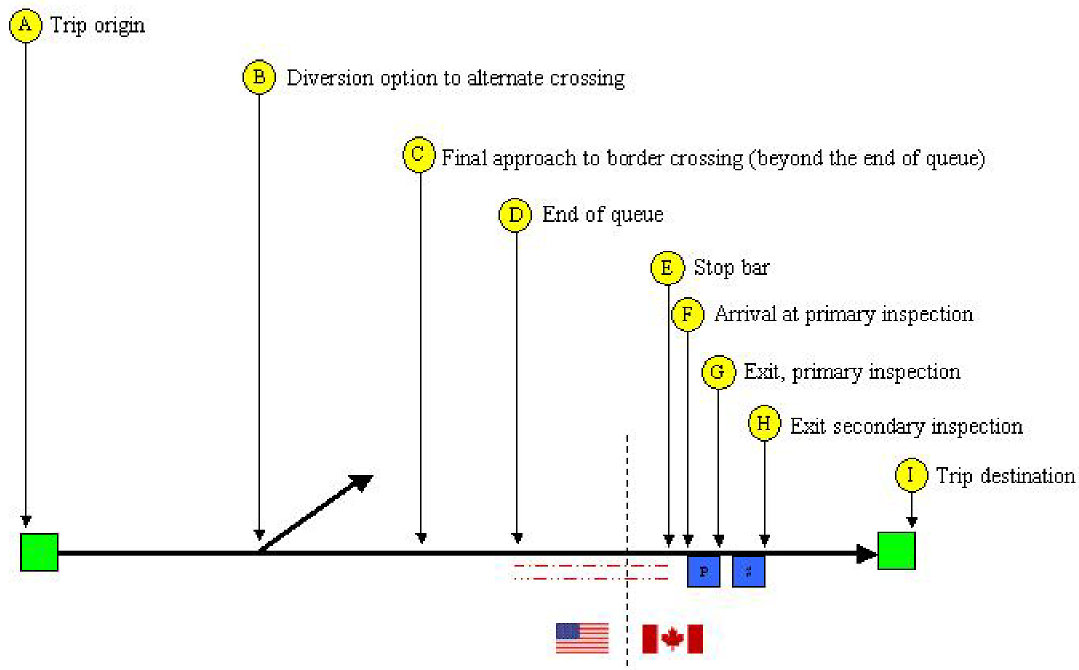


Figure 1: Key points on the approach to the border

As an example, a carrier transporting goods across the border may be interested in measuring the total extra time that a border crossing adds to their trip. In that case, they may be interested in the time it takes to get from point D to point H. Alternatively, a customs agency might be interested in measuring the average time required to process each vehicle at Primary Inspection, that is, the time taken from point F to point G. However, for the purposes of this document, "wait time" will be defined as the time taken to travel from the end of the queue to the arrival at the Primary Inspection booth, represented in Figure 1 as point D to point F. This is the definition that is considered most useful for drivers for making decisions about where and when to cross the border because the time following F varies widely between individuals, and is not due to the general congestion. In some cases, the distance from point D to point G may be easier to measure, and provides an almost equivalent measure because Primary Inspection does not vary greatly between vehicles.

While Figure 1 adequately represents the stages involved in a typical border crossing for cars and trucks at the U.S.-Canada border in either direction (northbound or southbound), the process at the U.S.-Mexico border is slightly different. Commercial vehicles entering the U.S. from Mexico must undergo additional processes, including Mexican export inspection prior to U.S. customs Primary Inspection, and Vehicle State Safety Inspection that occurs upon exit from the customs plaza (see Figure 2).

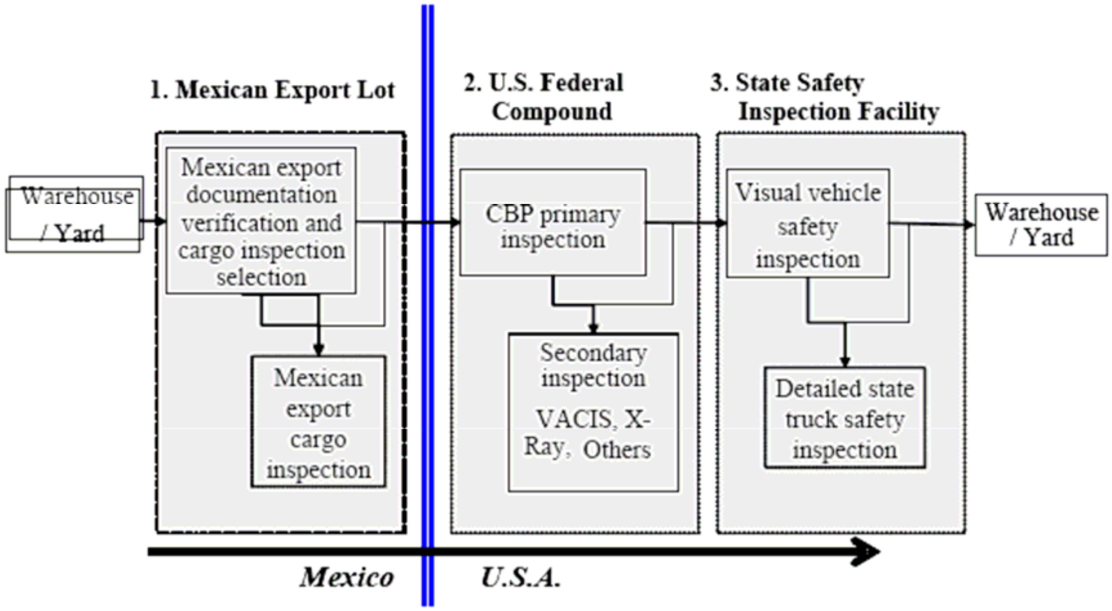


Figure 2: Northbound commercial border crossing process at the U.S.-Mexico border.[3]

BORDER WAIT TIME MEASUREMENT TECHNOLOGIES

To facilitate the measurement of border congestion, a wide of variety of technologies are being used to automatically record border wait times. Each of these technologies has inherent advantages and disadvantages. Some methods are more appropriate than others in a given environment, or produce data that better satisfies the requirements of the stakeholders who need it.

There are essentially three approaches to measuring wait times:

1. Queue Length Measurement;
2. Fixed Point Vehicle Re-identification; and
3. Dynamic Vehicle Tracking.

1. **Queue Length Measurement**: The Queue Length Measurement approach uses technology to measure arrival and departure rates of vehicles and estimate the number of vehicles in the queue. This estimate is usually based on a measure of the length of the queue and an approximate average of the density of vehicles within it. The data is fed into an algorithm that estimates the time that the next vehicle arriving at the end of the queue will take to move through the queue to reach the Primary Inspection booth. This method is ideal for providing real-time information for traveler information purposes. Of course, as soon as the data is recorded, it becomes archived data that can also be used for performance monitoring and other analyses.

2. **Fixed Point Vehicle Re-identification**: This method uses technology to identify individual vehicles at a fixed point upstream of the queue, and then again at the Primary Inspection booth or at some point beyond the inspection facilities. This is represented as points C and F, or C and H in Figure 1. The time difference between the two timestamps provides the travel time between the two points. The wait time attributed only to the queue can be calculated by subtracting out the average time required to travel that distance when there is no queue (i.e. under optimal conditions). This approach is well-suited to the calculation of wait time data for archive purposes. In terms of real-time measures however, the data is already out of date by the time the vehicle reaches Primary Inspection–i.e. if it took the vehicle one hour to get through the queue, then the system accurately provides the wait time for a vehicle that reached the queue one hour ago. The "current" wait time may have radically changed within that hour. The next-arriving driver may experience a very different wait time, which can lead to issues of trust in the data. A more current estimate of the wait time can be achieved by increasing the number of readers along the length of the queue and using trip segment information from multiple vehicles that are in the measurement zone at the same time. The lag time is then reduced to the time it takes for a vehicle to travel between readers. In addition, it is possible to include predictive components to the algorithm that allow the provision of a forecast delay. Further, the vehicle re-identification approach provides some flexibility in terms of what segments are measured because readers can be placed at any point in the crossing process.

3. **Dynamic Vehicle Tracking**: This approach uses some form of wireless signal to determine the location of a vehicle at multiple times along its route. The archived data can then be analyzed to determine how far the vehicle traveled between time intervals on the approach to the border. The segments in the border zone are summed to produce a wait time. This approach is well-suited to the collection of archived data for performance monitoring purposes. Data is either transmitted on a continuous basis or logged on board the vehicle for later download. Logged data can be made available more quickly by installing readers in the border region that can download the data as soon as a vehicle completes the crossing, but it still suffers from the same lag as the vehicle re-identification method—that is, the data is already out of date by the time the vehicle reaches Primary Inspection. As with the vehicle re-identification method, it is possible to include predictive components to the data analysis algorithm that allow the provision of a forecast delay. Additional flexibility to measure wait times along individual segments of the crossing process can be achieved by "geofencing" (defining virtual geographic zones), specific regions at each crossing.

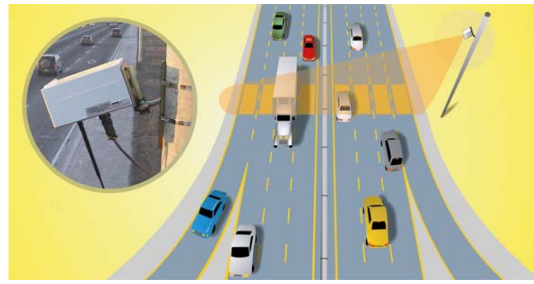
Within each of these approaches, there is a wide range of technologies that can be used. The technologies available, as well as their advantages and disadvantages, are outlined below.

1. Queue Length Measurement

INDUCTIVE LOOP DETECTORS

<table>
<tr><td>How it works:
Loops of cable embedded in the roadway measure the number of inspection booths open, the average inspection time, the length of the queue, and the arrival rate of vehicles at the end of the queue. Software uses this data to estimate the number of vehicles in the queue, and the wait time for the next arriving vehicle.</td><td rowspan="2"></td></tr>
<tr><td>Equipment Required:
A loop of cable embedded in each lane of the approach road, spaced every couple of hundred meters; equipment cabinet and field controllers; communications link to a Traffic Management Center.</td></tr>
<tr><td>Advantages:
• Estimates the wait time for the next vehicle entering the queue (future-oriented), rather than recording the wait time for a vehicle that has already passed through the queue.
• Minimal maintenance or operating costs.
• Used throughout the world for a variety of transportation applications. Technology well understood.
• Relatively low installation cost on a per detector basis.
• No on-board equipment required.
• Aesthetics—no overhead equipment required.
• Can provide separate measures for trusted carrier programs such as FAST by putting loops in the approach lane to the FAST inspection booth.</td><td>Disadvantages:
• Improper installation or pavement deterioration can reduce reliability of the detectors.[4]
• Large number of detectors needed.
• Proper calibration of algorithms is important.
• System is interrupted by changes in the road dynamics or booths due to construction.
• Maintenance requires lane closures.</td></tr>
<tr><td colspan="2">Other: Measurement can be improved by positioning the last loop detector at the exit of the customs Primary Inspection booth, rather than at the entrance to the booth.</td></tr>
</table>

RANGING RADAR DETECTORS

How it works: A RADAR gun mounted on a pole on the side of the road detects the passage of vehicles across multiple lanes. The detector can classify vehicles by size (trucks or cars) and measure speed. It can be used as a substitute for loop detectors for Queue Length Measurement. **Equipment Required:** RADAR guns spaced every 500 meters; equipment cabinet and field controllers; communications link to Traffic Management Center.	
Advantages: • Estimates the wait time for the *next* vehicle entering the queue (future-oriented), rather than recording the wait time for a vehicle that has already left the queue. • Can be used as a substitute for loop detectors in environments such as bridge decks where loop detectors are unsuitable. • No on-board equipment required. • Maintenance does not require lane closures.	**Disadvantages:** • Multiple detectors needed along the length of potential queuing. • Proper calibration of algorithms is important. • Occlusion (large vehicles blocking the next lane so that the detector cannot “see” some vehicles). • Maintenance may require lane closures to allow bucket trucks to access equipment. • Permanent installations can be higher cost than loops.
Other:	

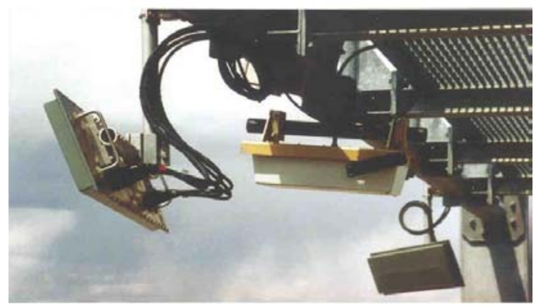
VIDEO IMAGE PROCESSING

How it works: A video camera monitors queuing traffic. Consecutive images are analyzed to track the movement of individual vehicles in the queue. Can be used as loop detector substitute, or to detect the end of the queue. **Equipment Required:** Cameras; image processing software; equipment cabinet and field controllers; communications link to Traffic Management Center.	
Advantages: • Estimates the wait time for the *next* vehicle entering the queue (future-oriented), rather than recording the wait time for a vehicle that has already left the queue.	**Disadvantages:** • Occlusion (large vehicles blocking the next lane so that the detector cannot “see” vehicles). • High equipment costs.

• Can be used as a substitute for loop detectors in environments such as bridge decks where loop detectors are unsuitable. • Image can be viewed for confirmation. • No on-board equipment required. • Maintenance does not require lane closures.	• Cameras need to be cleaned generally twice per year.
Other:	

2. Fixed Point Vehicle Re-identification

RADIO FEQUENCY IDENTIFICATION

How it works: A Radio Frequency Identification (RFID) transponder or "tag" is mounted on the windshield of participating vehicles. Readers located upstream of the queue and at customs Primary Inspection read the tags. The time elapsed between the two readings of each transponder represents the travel time between the two readers.	
Equipment Required: A large population of transponders in vehicles crossing the border; readers mounted on overhead gantries; equipment cabinet and field controllers; communications link to Traffic Management Center.	
Advantages: • Provides measures of actual time taken for a vehicle to cross the border. • Commonly used for toll collection or electronic commercial vehicle safety screening—i.e., a large population of transponders in vehicles already exists in some areas. • Readers can be placed at any point in the crossing process to measure transit times for selected zones within the plaza.	**Disadvantages:** • Requires large installed base of RFID transponders. • Requires installation of RFID readers in the customs plaza, unless recording travel times to a point beyond the Secondary Inspection area.

Other: CBP is currently using RFID transponders in their FAST cards that can be read by readers mounted on overhead gantries. Toll collection and commercial vehicle safety enforcement programs use an active RFID technology that allows for longer distance reading at high speeds.
Any wireless signal can be used to determine location–one potential alternative is to install antennae that will identify the passage of Bluetooth-enabled devices in vehicles.

LICENSE PLATE RECOGNITION

How it works:
A video camera takes pictures of license plates of vehicles passing by. Using Optical Character Recognition (OCR) software, a computer calculates an estimation of the letters and numbers on the plate. The transit time between the two cameras can be calculated by comparing the time stamps on matching pictures of license plates taken upstream of the queue and at Primary Inspection

Equipment Required:
Cameras; image processing software; equipment cabinet and field controllers; communications link to Traffic Management Center.

Advantages:

- Provides measures of actual time taken for a vehicle to cross the border.
- License Plate Recognition systems are already widely used by customs agencies at the Primary Inspection booth.
- No additional on-board equipment required.
- Can provide separate measures for trusted carrier programs such as FAST by putting a camera at the FAST inspection booth.
- Cameras can be placed at any point in the crossing process to measure transit times for selected zones within the plaza.

Disadvantages:

- Accuracy varies.
- Public perception of privacy concerns.
- Dirt, rust and damage on plates can reduce accuracy.
- Potential for vandalism if installed outside of secured areas.
- May not be able to get a clear picture of the plate if trucks are queued nose-to-tail

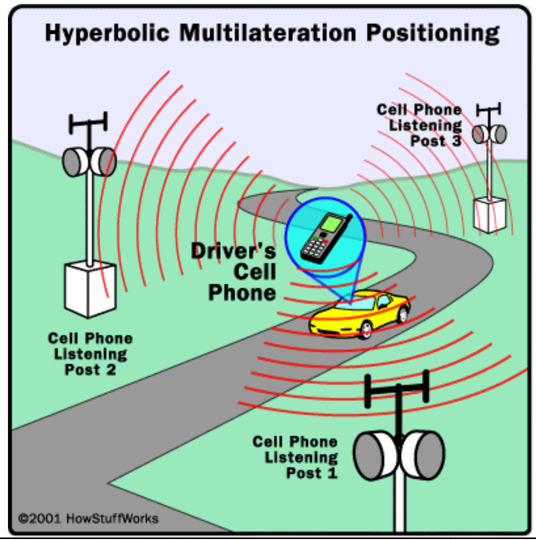
Other: To alleviate privacy concerns and improve recognition rate, the two images can be compared and matched without the need to interpret the actual letters and numbers on the plate.
The combination of license plate readers and side-fired cameras used to read the U.S. Department of Transportation (DOT) number on the door of truck cabs can increase the overall successful read rate.
An additional alternative is to use a laser scanner to read barcodes affixed to shipping containers.

3. Dynamic Vehicle Tracking

CELL PHONE TRACKING

How it works:
There are a number of techniques for tracking cell phones, including triangulation between nearby cell phone towers, or the detection of the hand-off of a call between towers. The cell phone's location can be determined at a number of points along its route, which can be analyzed to calculate the amount of time the vehicle was waiting in the queue.

Equipment Required:
A sufficiently large population of vehicles carrying cell phones; an adequate density of towers in the border region; agreements with cell phone service provider.



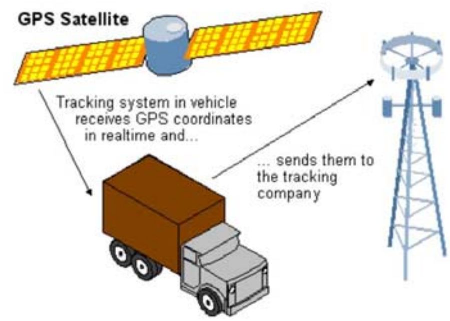
Advantages:
- Provides measures of actual time taken for a vehicle to reach Primary Inspection.
- Does not require the installation of any new equipment at the border.
- Can collect data on full regional roadway network, including segments before or after the border.
- Provides average speeds for entire length of queue and when coupled with appropriate algorithms, can provide estimated delays for approaching vehicles with no lag time.

Disadvantages:
- Requires agreements with cell phone service providers on BOTH sides of the border and includes ongoing fees.
- May require that cell phones are turned on to take readings.
- May incur roaming charges.
- May give multiple readings of a single vehicle if it is carrying multiple cell phones (e.g. a bus).
- May be insufficient number of cell phones crossing the border at various times throughout the day to provide any readings.

Other: In general, the volume of data that can be collected is higher when cell phones are active.
Most cell phones today are also embedded with a Global Positioning System (GPS) receiver. It is possible to use the device's GPS coordinates to record its location and calculate border wait time. However, there is a significant telecommunications cost related to the applications that ping the phones for GPS location.

GLOBAL POSITIONING SYSTEMS

How it works:
A Global Positioning System (GPS) receiver in a vehicle determines its latitude and longitude coordinates at multiple locations along its route. Tracking data can either be immediately transmitted to the service provider via the cell phone network or a two-way satellite link, or logged for later download. For logged data, the data is transmitted via a wireless antenna to the tracking service company when the truck returns to its depot. The data is analyzed to calculate the vehicle's position at regular time intervals in order to calculate the border wait time.



Equipment Required:
A sufficiently large population of vehicles subscribing to a fleet management service using GPS; agreement with a tracking service provider.

Advantages:
- Provides measures of actual time taken for a vehicle to reach Primary Inspection.
- Piggybacks on installed base of vehicles with GPS receivers.
- Through "geofencing", portions of the trip through the border region can be segmented to provide transit times of selected zones within the customs plaza.
- Can collect data on full regional roadway network, including segments before or after the border.

Disadvantages:
- Requires agreement with a tracking service provider and includes ongoing fees. Alternatively, data is simply purchased from the provider.
- May be insufficient number of GPS-equipped vehicles crossing the border at various times throughout the day to provide any readings.
- Signal may be hampered by tall buildings, tunnels or dense foliage.
- Carriers may have privacy concerns, although this has become less of an issue as safeguards have been implemented to scrub the data.
- Generally, GPS provides insufficient accuracy to calculate lane-by-lane travel times.

Other: For systems using GPS logs to calculate the wait time, a reader can be installed at the border to immediately transmit the data back to the tracking service provider to reduce the time lag between the truck's arrival at Primary Inspection and the calculation of the wait time. To improve the granularity of the data in the border region, the ping rate can be increased in the border region (that is, the frequency with which the coordinates are recorded).

EXISTING BORDER WAIT TIME PROGRAMS

This section provides a short description of the existing border wait time programs at the U.S.-Canada and U.S.-Mexico land border crossings. A summary table of these programs is presented in Table 2.

Blaine-Pacific Highway and Douglas (Peace Arch), B.C.-Washington

In 2003, both the British Columbia Ministry of Transportation (B.C. MOT) and the Washington State Department of Transportation (WSDOT) installed Advanced Traveler Information Systems (ATIS) for passenger cars at the Blaine-Pacific Highway and Douglas (Peace Arch) border crossings. The systems use loop detectors to estimate the wait times for cars crossing the border in both directions. Dedicated NEXUS approach lanes at the Douglas (Peace Arch) crossing enable the collection of separate wait times for NEXUS users in both directions. Data is output every 20 seconds. Temporary License Plate Readers have been installed on the northbound approach to the Douglas (Peace Arch) crossing to enable a continuous flow of wait time data during construction of the CBP facility. The new CBSA facility will include a set of loops at the *exit* of each Primary Inspection lane, which will provide improved accuracy of the wait time estimates.

Real-time system outputs can be viewed on the internet at http://www.wsdot.wa.gov/traffic/border/ for the WSDOT (northbound traffic) system and at http://www.th.gov.bc.ca/ATIS/index.htm for the B.C. MOT (southbound traffic) system. Wait times are also displayed on electronic signs on the approach to the crossings so that drivers can easily divert to the least congested crossing. Signs are updated every two minutes. An Integrated Voice Recording System enables drivers to phone in for wait time information.

The collected data is archived and available online at http://www.cascadegatewaydata.com/. Measures of delay, queue length, number of vehicles in the queue, traffic volumes, and the number of vehicles departing the queue per five minutes can be viewed online or downloaded for further analysis. The data management system is able to send an alert email to registered users when the wait time exceeds some user-defined limit.

WSDOT is in the process of installing loops in the new truck approach lanes at the northbound Blaine crossing. Loops in a dedicated FAST lane may enable separate measures for FAST and non-FAST trucks. Data for trucks is expected to begin by the summer of 2008.

Sarnia-Port Huron (Blue Water Bridge)

The Ontario Ministry of Transportation (MTO), working with Delcan, is installing a U.S.-bound border wait time system at the Blue Water Bridge in Sarnia, Ontario-Port Huron, Michigan. The system is able to build upon an existing queue-end warning system using loop detectors. Additional loops will be installed at approximately 300m intervals. Dedicated approach lanes for trucks and cars will enable the system to provide separate measures for each. Expansion of the system is also planned for other highway approach crossings in Ontario such as the Peace Bridge, Queenston-Lewiston Bridge and the 1000 Islands Bridge. The basic structure of the system depends on the ability to measure a queue on a controlled access freeway.

Lacolle, Quebec – Champlain, New York

The Ministère des Transports du Québec (MTQ) is installing a southbound border wait time system at the Saint-Bernard-de-Lacolle, Quebec crossing in cooperation with Tecsult using RADAR detectors to locate the end of the queue. Detectors are located every 500 meters along the last eight kilometers on the approach to the border. Variable Message Signs display the current distance to the end of the queue ahead as well as the estimated time it will take to reach customs Primary Inspection. The equipment is installed and undergoing final calibration.

Buffalo, NY-Niagara Falls, Ontario (3 locations)

The TRANSMIT traffic management system, developed by TRANSCOM, can re-identify vehicles that are equipped with RFID transponders already in use for the E-Z Pass electronic toll collection system on the New York State Thruway and the Peace Bridge. Readers have been installed throughout the Buffalo region and additional readers will be installed this summer to collect local traffic and average speed information for the northbound approaches to three land border crossings in the Buffalo region—the Queenston-Lewiston Bridge, the Rainbow Bridge, and the Peace Bridge. MTO, working with IBI Group, will install readers on the southbound approaches to the three crossings by October 2008.

The speed data will be transferred to the Niagara International Transportation Technology Coalition (NITTEC) Traffic Operations Center in Buffalo, New York, where it will be disseminated to the traveling public and border agencies. The system will provide link travel times between the RFID readers, rather than a standard border wait time measure. The TRANSMIT system does not provide a predictive algorithm. While the system will not distinguish between cars and trucks, the supplier has stated that this functionality will be implemented in the future.

El Paso, Texas-Mexico

The Federal Highway Administration (FHWA) has teamed with Battelle and the Texas Transportation Institute (TTI) to implement a system to collect truck border crossing data in El Paso, Texas. The proposed system will be designed to:

- Sustain long-term data collection;
- Be easily transferable for installation at other ports of entry along the U.S. northern and southern borders; and
- Use a technology that also may be applicable to supporting the measurement of passenger vehicle crossing times.

The team evaluated technologies based on cost, accuracy, availability and reliability, and chose to implement RFID technology to measure border crossing times at the Bridge of the Americas (BOTA). The next step is to install RFID readers at the beginning of the queue on the Mexico side of the border and at the exit of the Border Safety Inspection Facility (BSIF) on the U.S. side. Additional readers may be installed between these locations to collect more detailed data about the amount of time a truck spends along each segment of the crossing process. Data collection is scheduled to begin by the end of 2008. The Mexican Secretaría de Comunicaciones y Transportes (SCT) has expressed an interest in deploying a matching southbound system.

The system will read passive RFID tags embedded in FAST cards as well as tags issued to trucks by the Texas Department of Public Safety (DPS). The two tags share the same frequency.

Pharr, Texas-Reynosa, Mexico

The Texas Department of Transportation (TxDOT) is working with TTI to implement a high-tech system to measure how long it takes for commercial truckers to travel north across the Pharr-Reynosa International Bridge. The system will use RFID tags and readers and should be able to start collecting data by the end of 2008. The project is being funded by TxDOT, FHWA and the city of Pharr.[5] This system is similar to the one being implemented at the BOTA in El Paso, Texas.

Lynden and Sumas, Washington

WSDOT has installed License Plate Readers on the northbound approach to the Lynden and Sumas crossings in Washington State. One camera is located upstream of the queue, while the other camera is mounted at the actual border, 100-200 feet from the CBSA inspection booths. A 5-minute time factor is added to the wait time to account for the last 100-200 feet. One set of loop detectors right at the border is used to count vehicles.

San Ysidro, California-Tijuana, Mexico

Premier Wireless deployed a Queue Measurement and Vehicle Recognition System (QMVRS) at the San Ysidro, California crossing to give port personnel the ability to better gauge the traffic wait times. It employed a camera on a sixty foot tower in the port of entry, and cameras on all 24 lanes of traffic that looked into Mexico. It was designed to lock onto a vehicle near the end of the line and measure the time it took to get to the Primary Inspection booth. The port also records processing rates for all 24 lanes of traffic. Unfortunately the QMVRS system did not function as well as anticipated and was discontinued about three years ago.

In 1999, a study[6] was conducted by San Diego Dialogue under a contract with the U.S. Immigration and Naturalization Service (INS) to develop and test techniques for measuring queuing delays. Two indirect methods for measuring or estimating border wait times were evaluated by comparing their results with direct measurement of wait times. One method was used to monitor compliance while the other was used to produce real-time estimates of delay to be disseminated as part of a traveler information service. The latter uses estimates of both the number of vehicles in the queue and the vehicle-processing rate.

The study concluded that wait time estimates used for traveler information purposes must employ indirect measurements of both queue densities and vehicle-processing rates, but the levels of random variation in these measurements are so high that the resulting estimates are too uncertain to be of much value to individual travelers. Consequently, they recommended that the emphasis in measuring queuing delays at border crossings should be on monitoring rather than on traveler information.

This study used visual inspection of queue lengths using video cameras. It was hampered by a number of institutional and geographic issues that limited the ability to directly measure the various inputs into their wait time formula. No other technology was deployed for this study.

Douglas, Arizona-Mexico

A border wait time system was installed at the Douglas, Arizona crossing using digital video streaming and Video Image Processing. The system attempted to track vehicles as they moved through the queue by identifying vehicles or "objects" on successive images. New Technology Management Inc. and Sentrillion were involved. There was some difficulty maintaining a direct line of sight in the complex approach road network, and the need for multiple cameras made the system unworkable. The system is no longer in operation.

Bluetooth Functionality Test

Base Station readers deployed at five Southern Ontario border crossings in support of Transport Canada (TC) – Ontario region's wait time measurement project are Bluetooth-enabled devices. These Bluetooth readers are equipped to read/record digital signals emitted within a ten meter range and transmit the acquired data records via the Internet at no cost. All Bluetooth-enabled cell phones, handsfree headsets, car in-dash units, etc., when turned on will continuously emit a unique Bluetooth Identification (ID) signal that is hardwired into each device. As such, a Bluetooth-enabled reader will read/record and time stamp the unique ID emitted by every Bluetooth device that comes within its specified range.

Readers located at entry and exit points of the Detroit-Windsor Tunnel for both Canada and U.S.-bound traffic have recorded transit time intervals for 103,000 largely non-commercial/passenger vehicles over the past 18 months. A series of Bluetooth readers aligned in sequence along more distant intervals may be able to measure queue time as well as crossing times for both Canada and U.S.-bound traffic. It should be noted that the Bluetooth ID is a completely anonymous signal that only contains the manufacturer's unique serial code, or product number, and has no connectivity beyond any particular border crossing.

Otay Mesa, California-Tijuana, Mexico

The FHWA is conducting a test program at the Otay Mesa, California-Tijuana, Mexico land border crossing. The program will deploy technology to gather data that will accurately measure the time required for trucks to travel from the end of the queue to the exit of the California Highway Patrol (CHP) State Inspection Facility (i.e., U.S.-bound trucks only).

The initiative, led by Delcan, has identified project stakeholders and conducted an evaluation of two candidate technologies–Automatic License Plate Recognition (ALPR) and GPS. The GPS method was recommended as the preferred method for test deployment, based on the following summary considerations:

- Carriers support GPS deployment and have agreed to provide data.
- GPS deployment is non-intrusive and does not require infrastructure to be purchased, deployed, or maintained by the FHWA.

- GPS data, using geofencing and statistical analysis, can provide multiple measurement points along the border crossing as well as some movement-specific information. This additional information is of great interest to stakeholders.

FHWA is expected to begin collecting GPS data from cross-border motor carriers in Spring/Summer 2008. The system will be able to differentiate between FAST, empty and laden truck movements using fleet characteristics and geo-fencing.

The system could easily be expanded to include Mexico-bound trucks, although there are no plans to do so. The system could use the same trucks and simply expand the geographic study area. Analysis costs would increase incrementally, but data costs would remain the same.

GPS project at seven locations in Ontario and Quebec

Transport Canada's Ontario region, in collaboration with Turnpike Global Technologies (TGT), has developed a system to estimate commercial vehicle wait times at Southern Ontario border crossings using data elements derived from a carrier's GPS-based digital tractor logs. TGT's data logging system has been programmed to record vehicle movement, stop times and delays, both throughout predefined border crossing perimeter zones and at specified locations/facilities of interest within each crossing plaza. With Base Station readers located at Canada and U.S.-bound exit points, the data logs can be downloaded as soon as a vehicle completes the crossing. The data is transmitted immediately, processed within minutes, then posted to a dedicated Web-portal (www.borderinformation.com userID:peaceb; password: peaceb123) and otherwise stored for subsequent time-series and trend analysis. Crossing records posted to the website are stripped of all corporate identifiers; however, each observation is simultaneously routed to the individual carrier's proprietary records, giving every partner carrier a "one-view" display of their own wait-times relative to the total number of posted observations. Wait times are now routinely reporting at five crossings: the Peace Bridge (Buffalo, New York-Fort Erie, Ontario) the Lewiston-Queenston Bridge (Buffalo, New York-Niagara Falls, Ontario), the Ambassador Bridge (Detroit, Michigan-Windsor, Ontario), the Detroit-Windsor Tunnel, and the Blue Water Bridge (Sarnia, Ontario-Port Huron, Michigan). Some 240,000 wait time observations have been compiled to date, the carrier mix has grown from 15 to more than 50 fleets, and with minor exceptions, observations have increased continuously since the project's inception in mid-2006.

The Eastern Border Transportation Coalition (EBTC) is also working with TGT to install readers at two crossings in Quebec—Saint-Bernard-de-Lacolle, Quebec-Champlain, New York and Stanstead, Quebec-Derby Line, Vermont.

ATRI Study

The FHWA has been working the American Transportation Research Institute (ATRI) to measure border crossing times (not wait times) at several of the busiest crossings along the U.S. northern and southern borders. Archived data is purchased from fleet management services suppliers who have equipped trucks with GPS devices. The data is analyzed to provide a measure of the average time taken to travel through the border region—that is, from a point well before the border congestion to a point well after the truck leaves the border inspection facilities. FHWA favors the use of a reliability index, which calculates the difference between the average travel time and the travel time at the 95th percentile. That is, if the average crossing time through the region is twenty minutes, and 95% of the truck crossings take less than thirty-five minutes, then the delay time is fifteen minutes (35-20=15). This is expressed as a percentage (in this case, 15/20=75%) to produce a Buffer Index that can be used as a standard comparison across all border crossings.

Table 2: Summary of existing border wait time programs

Location	Proponents	Technology	Direction	Vehicles	Trusted program	Status
Blaine-Pacific Highway and Douglas (Peace Arch) crossings at the Washington-B.C. border	B.C. MOT, WSDOT, IBI, WCOG, TC, WED	Loop Detectors + License Plate Reader	U.S.-bound and Canada-bound	Cars only. Extending to trucks at Northbound Blaine crossing.	Separate measures for NEXUS and FAST	Operational since 2003
Sarnia, Ontario-Port Huron, Michigan	MTO, Delcan, TC	Loop Detectors	U.S.-bound only	Separate measures for cars and trucks	No	End of 2008
Lacolle, Quebec-Champlain, New York	Tecsult, MTQ, SAAQ, TC	RADAR Detectors	U.S.-bound only	Mixed traffic	No	Spring 2008
Buffalo, NY-Niagara Falls, Ontario (3 locations)	NYSDOT, NYSTA, MTO, NITTEC	RFID	U.S.-bound and Canada-bound	Mixed traffic, but planning to separate cars and trucks	No	October 2008
El Paso, Texas-Mexico Bridge of the Americas	FHWA, TTI, Battelle	RFID	U.S.-bound only	Trucks only	Separate measures for FAST	End of 2008
Pharr-Reynosa International Bridge	TxDOT, TTI, City of Pharr	RFID	U.S.-bound only	Trucks only	No	End of 2008
Lynden and Sumas, Washington	WSDOT	License Plate Readers	Canada-bound only	Cars only	No	Summer 2008
San Ysidro, California	Premier Wireless	Video Image Processing	U.S.-bound only	Cars only	No	Discontinued in 2005
Douglas, Arizona-Mexico	Sentrillion, NTMI	Video Image Processing	U.S.-bound only	Cars only	No	No longer in operation
Bluetooth Functionality Test	TC (Ontario), TGT	Bluetooth Readers	U.S.-bound and Canada-bound	Largely non-commercial/ passenger vehicles	No	Data collected since late 2006
Otay Mesa, California-Mexico	FHWA, Delcan	GPS	U.S.-bound only	Trucks only	Separate measures for FAST, empty	Spring/Summer 2008
GPS project at 7 locations in Ontario and Quebec	TC (Ontario), TGT, EBTC	GPS logs	U.S.-bound and Canada-bound	Trucks only	No	Pilot ongoing since Spring 2006
16 locations at U.S.-Canada and U.S.-Mexico borders	FHWA, ATRI	GPS	U.S.-bound, Canada-bound, Mexico-bound	Trucks only	No	Data collected since May 2006

CONSIDERATIONS FOR DISCUSSION

1. What is the primary objective of the system?
   - If it is to provide information to drivers, then the queue length measurement technologies provide more current information for driver decision-making.
   - If it is for performance monitoring, then the fixed point vehicle re-identification and dynamic vehicle tracking technologies provide more accurate measures of actual vehicle crossings.
2. How much will the system cost, both in the long term and short term? Queue length measurement and fixed point vehicle re-identification technologies require some up-front capital costs but minimal ongoing maintenance costs. The public agency owns and operates the equipment. Dynamic vehicle tracking technologies require no up-front costs but include ongoing service fees. The private sector company owns and operates the equipment.
3. Is it necessary to implement the same system everywhere, or does it make sense to build upon existing technology at each site? For example, the following systems are already in place at some crossings, and can be used as a building block for a wait time system:
   - GPS devices installed in commercial vehicles for fleet management
   - RFID tags used for tolling
   - RFID tags used for commercial vehicle safety enforcement programs
   - RFID tags used for FAST
   - Loop detectors used for queue-end warning at border crossings
   - License Plate Readers used by customs agencies for vehicle queries
   - Cell phones carried by drivers
   - Bluetooth devices carried by drivers

   Indeed, some of these technologies *require* that some investment has already been made.
4. What is the ease and speed of implementation of the system? It varies by application. All systems require the development of back-end software and computing to analyse the data.
5. What quality of data is required (reliability, granularity)? All systems have techniques for improving the data quality. Additional costs may be incurred. What is good enough?
6. How are outliers in the data dealt with? This is both a hardware and software issue.
7. Who owns the wait time data? This can limit further analysis of the data.
8. How is the information going to be distributed? To whom?
9. Is there a requirement to distinguish between regular traffic and trusted traveler/carrier programs? A number of technologies are available:
   - The system at El Paso, Texas will read the RFID tags in FAST cards to measure times for FAST trucks, and can also read Texas DPS tags to measure wait times for all trucks, providing separate measures for each.
   - License Plate Readers installed at each customs Primary Inspection booth can distinguish between measures for trucks processed through the regular commercial inspection booths, and those processed through the FAST inspection

booths. The same technique can be used for passenger vehicles and trusted traveler programs.
- Where dedicated approach lanes exist, loop detectors and RADAR detectors can estimate wait times for vehicles in the lanes used for trusted traveler/carrier programs, independent of the measures for traffic in the regular approach lanes.

10. How well does the system cope with periods of low volume? In fact, none of the technologies handle periods of low volume very well. Loop detectors, RADAR detectors and License Plate Readers will get a proportionally higher number of readings during periods of low volume. RFID, cell phone and GPS technologies all depend on the sample size of vehicles within the population carrying on-board equipment.
11. Are aesthetics or vandalism considerations? If so, systems that require overhead detectors or readers are less appropriate. Loop detectors, cell phone tracking and GPS systems require no overhead equipment.
12. How does the system handle rolling queues? At some crossings, truck queues are not stop-and-go, but rather continuously inching ahead at a very slow speed. Queue length measurement technologies require wait time estimation algorithms that may not handle rolling queues very well. On the other hand, rolling queues are not an issue for fixed point vehicle re-identification and dynamic vehicle tracking technologies.
13. How does the system deal with variable booth designation, i.e. when a booth that normally processes all truck traffic is temporarily designated FAST-only when demand warrants. Also, some lanes with high-low booths can accommodate either cars or trucks, depending on current demand. Systems that depend on lane or booth designation may be disrupted by variable booth designations. Cell phone and GPS tracking technologies do not provide detail at the individual lane level and would not be affected.

GLOSSARY OF ACRONYMS

ALPR – Automatic License Plate Recognition
ATIS – Advanced Traveler Information System
ATRI – American Transportation Research Institute
B.C. – British Columbia, Canada
BOTA – Bridge of the Americas
BSIF – Border Safety Inspection Facility
CBP – U.S. Customs and Border Protection
CBSA – Canada Border Services Agency
CHP – California Highway Patrol
DOT – Department of Transportation
DPS – Texas Department of Public Safety
EBTC – Eastern Border Transportation Coalition
FAST – Free and Secure Trade
FHWA – Federal Highway Administration
GPS – Global Positioning System
IBI – IBI Group
ID – Identification
INS – U.S. Immigration and Naturalization Service
MOT – Ministry of Transportation
MTO – Ontario Ministry of Transportation
MTQ – Ministère des Transports du Québec
NEXUS – The name of a trusted traveler program at the Canada-U.S. border
NITTEC – Niagara International Transportation Technology Coalition
NYSDOT – New York State Department of Transportation
NYSTA – New York State Thruway Authority
OCR – Optical Character Recognition
PBA – Buffalo and Fort Erie Peace Bridge Authority
QMVRS – Queue Measurement and Vehicle Recognition System
RADAR – Radio Detection and Ranging
RFID – Radio Frequency Identification
SAAQ – Société de l'assurance automobile du Québec
SCT – Secretaría de Comunicaciones y Transportes
SENTRI – Secure Electronic Network for Travelers Rapid Inspection
TC – Transport Canada
TECS (SQPQ) – Treasury Enforcement Communications System license plate record of border crossing
TGT – Turnpike Global Technologies
TTI – Texas Transportation Institute
TxDOT – Texas Department of Transportation
VACIS – Vehicle and Cargo Inspection System
VMS – Variable Message Sign
WCOG – Whatcom County Council of Governments
WED – Western Economic Diversification
WSDOT – Washington State Department of Transportation

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