

***Measuring Border Delay and Crossing Times
at the U.S./Mexico Border***

Tasks 1 and 2 Report

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Measuring Border Delay and Crossing Times at the U.S./Mexico Border

Introduction

The Federal Highway Administration (FHWA) is undertaking a Freight Performance Measurement (FPM) initiative aimed at measuring travel times in freight-significant corridors, including border waiting times at major U.S. land border crossings. FHWA seeks to identify appropriate intelligent transportation systems (ITSs) or other commercial technologies that enable border travel and wait times to be more easily and precisely measured.

The objective of this project is to examine technologies that can be used to support automated measurement of border delay and crossing time at U.S./Mexico land ports of entry. The specific area of interest for this project is measuring border delay and crossing times for freight traffic. This work explores technologies that can also be used to support measurement of crossing times for passenger cars and have the capacity of being expanded to measure travel characteristics, not only at border crossings but throughout border metropolitan areas.

This report covers tasks 1 and 2 of the project work plan that comprise “Contact Project Stakeholders/Gather Baseline Data” and “Identify Technologies.” These two tasks were performed concurrently because of their interrelation and are therefore covered together in this report. The definition of a plan for collecting baseline data, which is the objective of the initial task, requires the analysis of potential technologies that could be used and this analysis leads directly to the objective of task 2.

The premises under which these initial tasks were developed include the definition of a system that is capable of collecting reliable and consistent information, that is permanent, that can easily share information, and that has potential to expand to other areas outside of the border crossings. The system must collect reliable data so that measures of border delay will be accurately represented and enable appropriate improvements to be made. Similarly, the information must be consistent across numerous border crossings.

If the measurements from all the crossings are accurate and consistent it will be possible to compare border crossing operations and identify potential improvements along the border. The system definition should take into consideration existing and planned ITS technologies that are being implemented at the border and throughout the U.S. and Mexico to incorporate any potential synergies. A permanent system is required so that the data can be collected frequently and so that results of changes to the border crossing process or infrastructure can be measured.

All data gathered should be easily shared with Federal, State, and local agencies so that informed decisions could be taken to improve transportation and reduce congestion. Additional benefits could be gained by sharing information with carriers and the public. Ideally, the measurement system should be expandable to areas outside of the border crossings, capitalizing on the other travel measurement activities in place. An expansion of the system could allow for a greater amount of data that can provide information of truck movements in the region.

This report includes an introduction to the research (this section) and a description of the border crossing process along the U.S./Mexico border (next section). Input gathered from stakeholders in the El Paso-Ciudad Juarez region is summarized in the third section. The fourth section of this report analyzes forms of measuring border crossing time and crossing delay and the variables that are needed for these measurements. A review of technologies that were identified as possible ways to measure border crossing time and delay is presented in the fifth section of the report, including analyses of advantages and disadvantages of each technology.

A more detailed analysis of three technologies that have the most potential to accurately and feasibly measure border crossing time and delay is presented in the sixth section. The seventh section presents proposed data collection plans for specific ports of entry at El Paso/Ciudad Juarez international bridge (Bridge of the Americas) and Zaragoza Bridge, showing the recommended locations of the measuring devices for the three selected technologies. The final section of this report presents conclusions and recommendations for next steps.

The North Bound Border Crossing Process

Over 5 million trucks crossed from Mexico into the United States in 2005. This represents 17 percent growth from 2001, and the number of crossings is expected to continue growing as trade between the two North American Free Trade Agreement (NAFTA) partners continues to grow.

NAFTA's original trucking provisions regarding opening the U.S. border to Mexican trucks were designed to improve transportation efficiency by enabling more seamless cross-border trucking operations. Generally, Mexican tractors are restricted to circulation on a narrow commercial zone extending 3 to 25 miles (or up to 75 miles in Arizona). On February 23, 2007, the U.S. and Mexican governments announced that they had reached a resolution to the cross-border trucking impasse. The agreement calls for a one-year pilot project involving up to 100 Mexican and 100 U.S. trucking firms that wish to engage in direct long-haul movements across the border and beyond the commercial zone. Mexican carriers must undergo safety audits by U.S. inspectors in Mexico; meet all safety, environmental, insurance, homeland security, and other regulations imposed on U.S. trucking firms; and pay all applicable U.S. state and federal taxes and registration fees. The pilot project will be evaluated after one year, at which time a decision regarding the future of the initiative will be made.

The restriction that limits safety inspections to those conducted in the U.S. is one of the fundamental reasons why Mexican truck shipments into the United States are required to use a drayage or transfer tractor that picks up a trailer at the Mexican side of the border and crosses it into the U.S., where it is dropped so a U.S. long-haul tractor can carry the trailer into U.S. territory.

The northbound border crossing process requires a shipper in Mexico to file shipment data with both Mexican and U.S. agencies, prepare both paper and electronic forms and, as mentioned earlier, use a drayage or transfer tractor to move the goods from one country to the other. Once the shipment is at the border with the drayage or transfer tractor and an authorized driver, the process flows through three main physical potential inspection areas:

- Mexican export lot.
- U.S. Federal compound.
- State safety inspection facility.

A description of the main activities that take place in the northbound border crossing process is presented in the following sections and illustrated in figure 1.

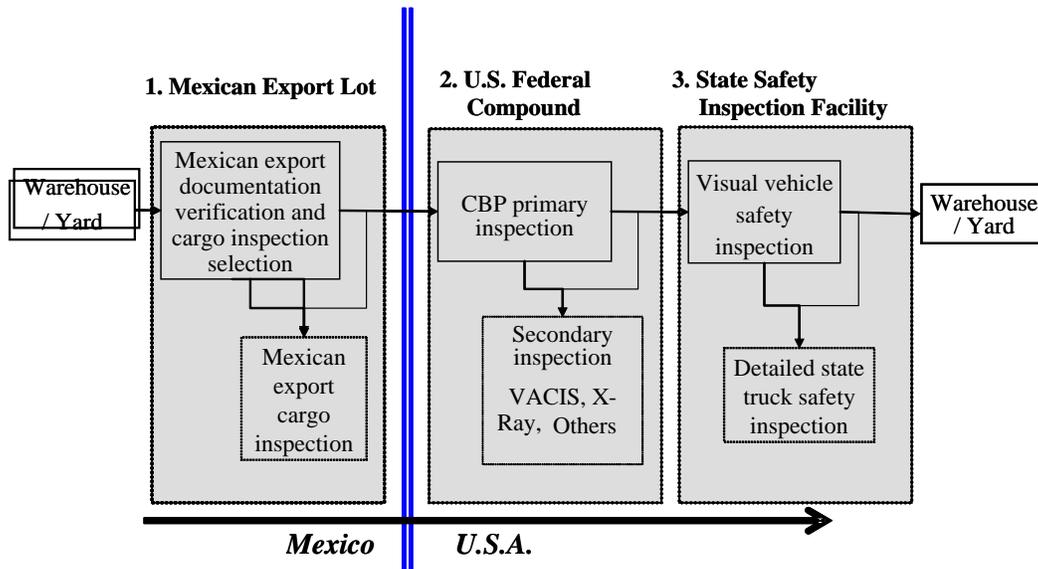


Figure 1. Diagram. Northbound commercial border crossing process.

Mexican Export Lot

The drayage driver with the required documentation proceeds into the Mexican Customs compound. For audit and interdiction purposes, Mexican Customs (Administración General de Aduana) conducts inspections consisting of a physical review of the cargo of randomly selected outbound freight prior to its export. Shipments that are not selected proceed to the exit gate, cross the border, and continue on to the U.S. port of entry (POE).

U.S. Federal Compound

At the primary inspection booth, the driver of the truck presents identification (proof of citizenship or a valid visa or laser card), a copy of the Inward Cargo Manifest, and the commercial invoice to the processing agent. The U.S. Customs and Border Protection (CBP) inspector at the primary inspection booth uses a computer terminal to cross-check the basic information about the driver, vehicle, and load with information sent previously by the U.S. Customs broker, then makes a decision to refer the truck, driver, or load for a more detailed secondary inspection of any or all of these elements or releases the truck to the exit gate.

The e-Manifest is replacing the Pre-Arrival Processing System. The e-Manifest is an electronic manifest that contains pertinent information concerning the truck, driver, and load. It will reduce processing time by allowing CBP to pre-screen the manifest before the trucks arrive at U.S. border crossings. This allows CBP to focus its efforts and inspections on high-risk commerce and minimize unnecessary delays for low-risk commerce. Beginning April 19, 2007, all carriers must electronically submit an e-Manifest before arriving at any southern U.S. land port. Any carriers who arrive without first submitting an e-Manifest will be denied permit to proceed beginning June 19, 2007.

A secondary inspection includes any inspection that the driver, freight, or conveyance undergoes between the primary inspection and the exit gate of the U.S. Federal Compound. Personnel from CBP usually conduct these inspections, which can be done by physically inspecting the conveyance and the cargo, or by using non-intrusive inspection equipment (such as x-ray). Within the compound, the U.S. Department of Transportation (USDOT), Federal Motor Carrier Safety Administration (FMCSA), and the Food and Drug Administration (FDA) have personnel and facilities to perform inspections when required. A vehicle audit could happen at the Federal Compound or the State Safety Inspection Facility depending on practice.

State Safety Inspection Facility

In the majority of the POEs, the stations are located adjacent to the Federal compounds. State police inspect conveyances to determine whether they are in compliance with U.S. safety standards and regulations. When the initial visual inspection finds any violation, the truck proceeds to a more detailed inspection at a special facility.

After leaving the State inspection facility, the driver typically drives to the freight forwarder or customs broker yard to drop off the trailer for later pickup by a long-haul tractor bound for the final destination.

Security

CBP has implemented several security programs at land ports of entry. The Free and Secure Trade (FAST) program is in operation at several crossings and its objective is to offer expedited clearance to carriers that have demonstrated supply chain security and are enrolled in the Customs Trade Partnership Against Terrorism (C-TPAT). FAST shipments use a special booth and a FAST-only lane at the international bridges. Non-FAST-enrolled commercial vehicles handle traditional paper documentation that takes longer to process, and they are more likely to experience secondary inspections that sometimes require unloading the truck for detailed inspection.

The time required for a shipment to make the complete trip from the yard or the manufacturing plant in Mexico to the exit of the State Inspection Facility is dependent on the number of secondary inspections required, as well as the number of inspection booths in service and traffic volume at that specific time of day—and if the shipment is eligible for FAST. There is

duplication on the vehicle safety inspection, as U.S. Federal and State agencies perform some level of inspection of every truck that crosses from Mexico into the U.S.

Stakeholder Input

The research team met with key border crossing stakeholders in the El Paso-Ciudad Juarez region. The objectives of the meetings were to identify the stakeholders' points of view and concerns on a crossing time measuring system. The key stakeholders that were contacted include drayage motor carriers, Texas Department of Public Safety (DPS), CBP, and the City of Ciudad Juarez.

Drayage Motor Carriers

Drayage or transfer is usually done by motor carriers established in the border region. In some instances there are hundreds of drayage companies in the El Paso-Ciudad Juarez region. Most of them are small carriers with a low number of tractors. The large drayage carriers have global positioning systems (GPS) to track their shipments for security reasons. Before entering the Mexican Customs compound, the large Mexican drayage carriers have inspection sites where loaded trucks receive a final security inspection with dogs to ensure that shipments are clean of any drugs or other illegal materials. These inspections are organized by the truckers and add little delay to the process.

The trucking companies would be willing to participate in the border crossing time measuring program, but they expect to gain something in return. Currently most of the drivers communicate back to the base via radio transmitters and a possible benefit identified by the drayage industry is receiving more information regarding crossing time that can be relayed back to the bases.

Texas Department of Public Safety

The Texas Department of Public Safety performs safety inspections of all trucks crossing into Texas. DPS is in the process of developing a safety express lane system. The system includes the use of radio frequency identification (RFID) tags on tractors that would allow DPS to verify the truck safety record electronically and define if the truck requires a safety inspection. The system is similar to the FAST program that has been implemented by CBP for vehicle safety purposes. The system will have RFID readers at the entrance of the safety inspection facility and will be tested at the Bridge of the Americas facility in El Paso. DPS has already purchased the RFID tags but has not distributed them among the local motor carriers as of this report.

U.S. Customs and Border Protection

CBP performs security inspection immediately after a commercial vehicle enters the United States. CBP has implemented the FAST program at most of the commercial border crossings. The FAST program uses RFID technology and CBP has RFID readers at each primary inspection

lane, and most of the tractors in the El Paso-Ciudad Juarez region have RFID tags in their trucks. During the development of the DPS express lane system, CPB was contacted to analyze the possibility of sharing information from its RFID readers, and information sharing was denied for security reasons.

City of Juarez

The Instituto Municipal de Investigación y Planeación (IMIP) performs planning activities in Ciudad Juarez. The IMIP has implemented a series of video cameras to monitor passenger-car congestion at the various border crossings in the region. An agreement has been reached between the City of Juarez and a local radio station so that the radio station could use the information from the camera system in exchange for maintaining the system in operation. This agreement has solved a problem that the City of Juarez had on how to secure funding for the operation of the system. IMIP is willing to work with Texas Transportation Institute (TTI), FHWA, and other stakeholders for the implementation of a commercial crossing time measuring system.

Measuring Border Crossing Time and Delay

Border crossing time can be described in many different ways. It can be as simple as the travel time required from the border line that divides both countries to the first U.S. customs inspection, or it can include the time elapsed during the secondary inspection. Even more complex, border crossing time could be measured as the time elapsed between the arrival of the vehicle at the Mexican Customs compound to the exit from the state safety inspection facility. In a regional context, border crossing time could be defined as the travel time between the origin and the destination of the trip.

For the purpose of this project, crossing time is defined as the time elapsed between a pre-established location on the Mexican side of the border and the exit from the state safety inspection facility on the U.S. side. The location of the first measuring point will be chosen in order to ensure that the truck queue never extends beyond that point. Since this definition depends on the physical and operational characteristics of the border crossing and on the traffic volume, the location of the initial point will vary from port of entry to port of entry, as each of them has different characteristics.

The delay associated with the border crossing time, can also be described in different ways. In 2002, Battelle and TTI conducted a study for the Office of Freight Management and Operations of FHWA titled *Evaluation of Travel Time Methods to Support Mobility Performance Monitoring*. In that project, border delay was defined as the difference between actual crossing time and low-traffic-volume crossing time. With this definition, the processing time that the inspection agencies need to accomplish their mission was removed from the description of delay. Moreover, the authors mention that the use of free-flow conditions is a standard that is not relevant at border crossings (1). The following graph describes the differences between the free flow travel time, the optimal crossing time, and the high volume crossing time.

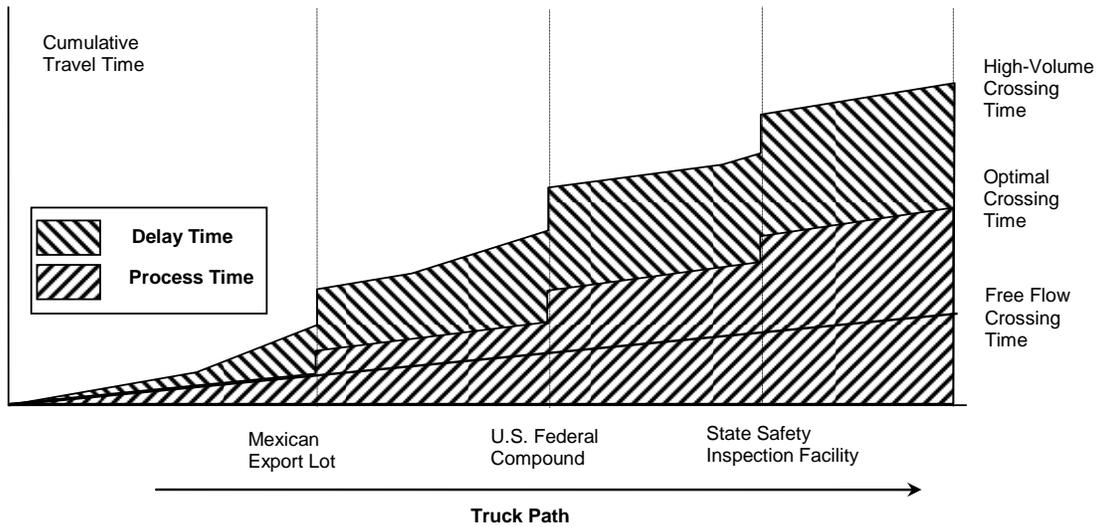


Figure 2. Diagram. Border crossing times under different scenarios.

As shown on the graph, the free-flow crossing time would be that where the truck wouldn't have to stop at any time during the border crossing trip. Obviously, this scenario is not realistic and therefore should not be set as a reference. The optimal crossing time is set as the base time, since it represents the case where there are no queues at any of the stops. This optimal crossing time is achieved under very low traffic volume conditions and takes into account the processing time at all inspection facilities. Finally, the high-volume crossing time accounts for all delays caused by high traffic volume that cause lower traffic speeds and queues.

Taking these factors into consideration, it can be concluded that the border crossing associated delay is determined by the difference between the observed crossing time and the optimal crossing time.

$$\text{Border Crossing Delay} = (\text{observed truck crossing time}) - (\text{optimal truck crossing time})$$

In order to have a better estimate of the status of the border crossing time, a similar concept as the travel time index (T_{indx}) can be used. The T_{indx} is defined as:

$$T_{\text{indx}} = \frac{\text{observed truck travel time}}{\text{truck free - flow travel time}}$$

For commercial border crossings, as previously discussed, instead of using free-flow travel time, the crossing time under optimal conditions will be used to define the Border Crossing Time Index.

A very important fact that has to be taken in consideration is that not all trucks go through the same number of inspections. In most cases, a first inspection is enough to check the status of the

shipment, the truck, and the driver. In some other instances, extra attention has to be given to a truck, its contents, or the driver. Moreover, most of the largest commercial border crossings have dedicated FAST lanes, where crossing time might be significantly shorter since the shipment has been pre-cleared.

Therefore the truck population has to be divided into three categories:

- FAST shipments.
- Shipments that go through primary inspection only.
- Shipments that go through secondary inspection.

Border crossing delay and Border Crossing Time Index will have to be estimated for each one of these three categories since all of them have different optimal crossing times. Depending on the technology, a different number of readers will be needed to identify these three types of trips. The following sections describe the proposed technologies and data collection plans.

Technology Assessment

In order to measure travel time and the associated delay, the chosen technology should be flexible enough to cover the complete trip and be applicable at all POEs. The technologies that were identified as meeting these criteria are:

- Automatic vehicle identification (AVI).
- Automatic license plate recognition (ALPR).
- Vehicle matching.
- Automatic vehicle location (AVL).
- Mobile phone location.
- Inductive loop detectors.

Automatic Vehicle Identification

AVI technology identifies a vehicle when it passes through a detection area. There are three means of identifying vehicles with this technology: laser, radio frequency, and infrared frequencies (see figure 2). In general terms these systems work following these steps (2):

- A roadside communication unit broadcasts an interrogation signal from its antenna.
- When a vehicle equipped with an AVI device enters the antenna's coverage range, the transponder or tag returns a signal to the roadside unit with the vehicle's identification.
- The information is retransmitted for further processing and storage.

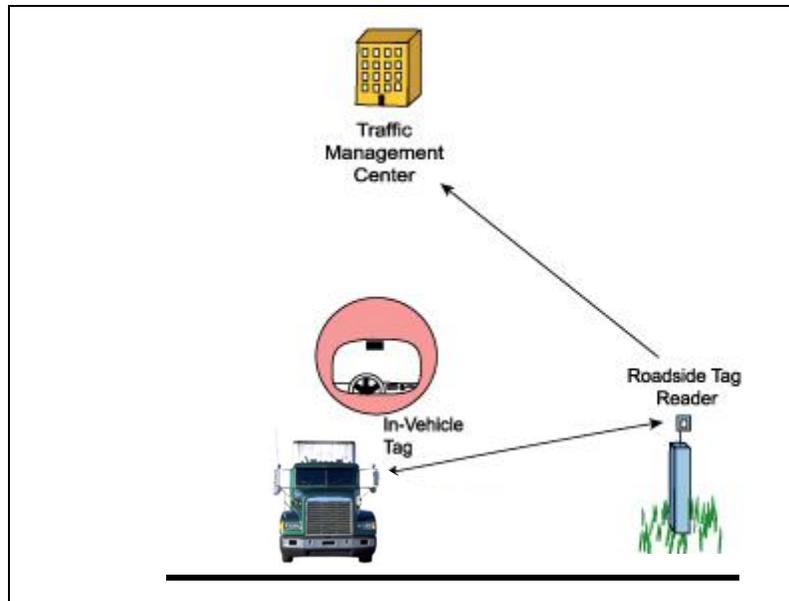


Figure 3. Diagram. Automatic vehicle identification. (3)

AVI Using Laser Frequency

The laser AVI system reads a barcode attached to the truck when the vehicle passes through the scanner. The truck needs only a simple barcode for this system, which is an advantage, but weather and dirt can make reading difficult and the distance between the scanner and the barcode has to be relatively small.

AVI Using Radio Frequency

The radio AVI technology is commonly known as radio frequency identification, and its capabilities depend on the characteristics of the tag located in the vehicle. There are two classification methods—one depends on the type of power source of the tag and the other depends on the capabilities of the tag (2).

Classification based on the power source of the tag:

- Active: The tag has its own power source. This allows the tag to broadcast its own signal when the device is activated by the interrogation signal.
- Passive: The tag does not have an internal power source and therefore it only reflects the signal sent by the interrogation signal.
- Semi-Active: This device does not generate its own signal but it boosts the original interrogation signal. It has its own power source.

Classification based on the tag capabilities:

- Type I: The tag has read-only function. It is able to transmit preset information such as vehicle identification.
- Type II: The tag has read and write functions. It contains preset information such as vehicle information plus reprogrammable capabilities that can be updated by interaction with the roadside antenna. This type of RFID is commonly used in toll roads and toll

bridges. A good example is the World Trade Bridge at Laredo, where tags are used for electronic toll collection (ETL).

- Type III: This tag is commonly known as a “smart card” and has full two-way communication capabilities. It can send, receive, or send and receive information at the same time. As an example, these devices can show weather, congestion, and incident conditions.

Roadways equipped with RFID technology allow estimation of a vehicle’s speed, location, and travel time. Installation cost of the necessary roadside infrastructure is high, but operation cost is fairly low. A big advantage of this system is that its operation is not impeded by adverse weather conditions.

AVI Using Infrared Frequency

AVI technology that uses infrared frequency is very similar to AVI using radio frequency. The most important difference is that AVI with infrared operation can be impeded by adverse weather conditions (i.e. fog, rain, clouds) and has inconsistent reliability under high-volume conditions.

Automatic License Plate Recognition

This system works by electronically recording the front and rear license plates of the vehicles using cameras. This technology has been used at POEs to identify stolen cars but has the potential to be used to identify vehicles like any AVI devices. It has a relatively high identification rate but it has problems identifying dirty, damaged, bent, or multiple license plates (4). In order to obtain travel times, one camera must be located at the end of the queue. This camera captures and decodes license plate images (see figure 3). A second camera generally located at or after the border crossing, also captures and decodes license plates. The information is matched and the travel time is calculated. This technique does not require identifying the entire vehicle population to estimate travel time. Only a sample is needed to have an accurate estimation.



Figure 4. Photo. License plate reader. (4)

Vehicle Matching

Vehicle matching uses the same principles to estimate travel time as ALPR technology. It captures images of the entire vehicle and creates identities that include date, time, and position. At another location, the system captures images of the vehicles and matches them. Since this system is independent of the license plate and its condition, it is more flexible. This technique also has a high rate of identification (4). The identification rate of this technology at commercial border crossings is affected negatively by the fact that all the vehicles are trucks.

Automatic Vehicle Location

AVL systems locate and track the position of a vehicle within the transportation network. There are many techniques used to locate vehicles. Some of them include:

- Dead-reckoning and map-matching.
- ground-based radio navigation.
- global positioning systems (GPS).

GPS use a network of 24 earth-orbiting satellites where real-time latitude and longitude information of the GPS receiver is collected (See figure 4). Coupled with use of a geographic information system (GIS), GPS is able to track the speed and location of the device, which can then be viewed on a road network map on a real-time basis. It can collect accurate travel times and variability across different days, weeks, or any time period (3). This technology is ideal for multi-jurisdictional areas because there is no need to install any fixed roadside equipment, and the information can be obtained regardless of the location of the vehicle. Since GPS technology is widely used, this project analyzed feasibilities of GPS in significant detail.

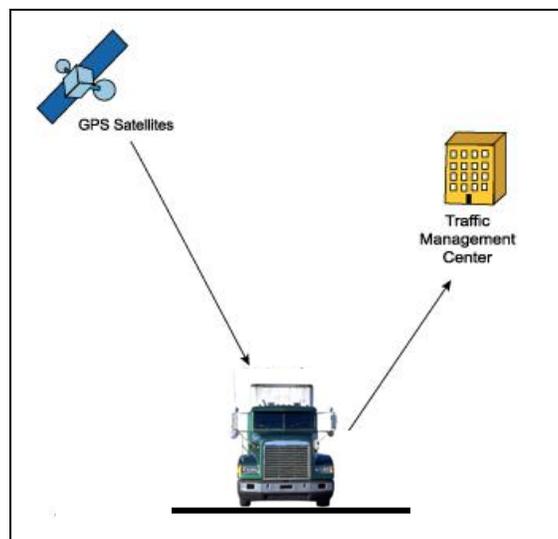


Figure 5. Diagram. Automatic vehicle location. (3)

The most important limitations with regard to the use of GPS are privacy issues of vehicle owners and the difficulty of establishing a connection with the satellite if the device is close to tall buildings, tunnels or under dense foliage (3). This disadvantage is observed in downtown areas, where tall buildings and tunnels can block the satellite signal.

Mobile Phone Location

There are two approaches to estimating travel times through the use of mobile phones.

The first approach uses equipment at the cell tower to determine when a mobile phone switches from one cell to the next. This location technique is good as long as the phone is turned on. The biggest disadvantage of this method is the cell size. Cell size varies widely depending on the location, and therefore the accuracy of the method suffers. Generally urban areas have smaller cell sizes than rural areas. Another disadvantage is that mobile phones systems are notoriously poor at the border because the signals are pulled from one system to the other (Mexico – U.S.) based on signal strength, tower location, and interference. There are some additional techniques that can improve accuracy, such as relative signal strength, time delay, or triangulation (5). With further refinement, this method can potentially provide a rich source of inexpensive and useful information.

Mobile phone location technology works this way (2):

- The time is registered when a vehicle enters a cell.
- The latitude and longitude are calculated.
- Location is checked to ensure it is within the interest boundaries.
- A confidence factor related to the location is calculated.
- The location of the mobile phone is continuously updated for a determined roadway segment, enabling the travel time and speed to be calculated.

The second approach uses mobile phones with GPS technology capabilities. The location of the identified mobile phone is achieved by using the GPS and is communicated via the telecommunication network. This method provides an excellent source of travel time but requires an agreement with the telecommunication service providers and relies on a considerable number of users with GPS technology in their mobile phones (5).

Inductive Loop Detectors

Inductive loop detectors consist of one or more turns of insulated wire embedded in a narrow cut in the road connected to a roadside control box. The loop is excited by an electric signal that usually ranges between 10 kHz and 200 KHz. When a vehicle passes over the loop, it creates a change in the electrical properties of the loop (reduction of its inductance) announcing the vehicle's presence. These loops can operate in two different modes, pulse or presence mode. The pulse mode is used for volume counts by sending a short signal from the loop to the detector. The presence mode is used to provide volume counts and occupancy. In presence mode, the loop sends a signal to the detector as long as the vehicle is in the detection area (4).

Loop detectors are capable of estimating speed if two loops in pulse mode are placed close to each other. The vehicle speed will be the distance between the loops divided by the vehicle travel time (see figure 5). This information can be used to calculate travel time through a section of the roadway, but only in an indirect way. The effectiveness of this technology can be poorly suited to a border crossing scenario since high volumes and low speeds are common, plus the speeds measured are spot speeds and may not be useful in estimating crossing time.

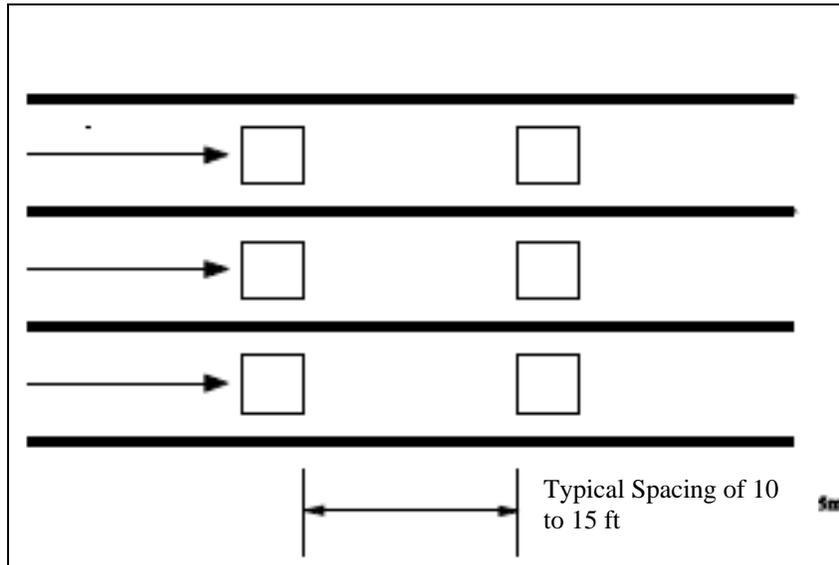


Figure 6. Diagram. Loop installation for measuring speed. (2)

Loop detectors are commonly used to actuate traffic control devices and to detect congestion and incidents. One of the biggest disadvantages is poor reliability, often caused by improper installation or pavement deterioration (2).

Recent advances give loop detectors the ability to produce a vehicle inductive signature through a serial port on the detector card. This signature is based on the unique net decrease in the detector inductance that the vehicle creates when it passes over the detection area. Using this special feature allows improved vehicle classification (4).

Comparative Analysis

In order to determine which technology would be the best choice in terms of cost, accuracy, availability, and reliability, the six technologies described in this section were compared. Each of the technologies has strengths and limitations that make it suitable for some applications. Table 1 shows a brief description of the advantages and disadvantages of all six technologies.

Three of the six options were discarded from further consideration based on disadvantages that outweighed advantages. The remaining three technologies that have potential to effectively measure travel time at border crossings are ALPR, RFID (AVI), and GPS (AVL). A more detailed analysis was conducted for these technologies, gathering additional information and contacting vendors to obtain cost estimates. The following section provides information on the equipment specifications, requirements, and costs for the three potential technologies.

Table 1. Summary of advantages and disadvantages of potential technologies.

Technology	Advantages	Disadvantages
AVI **	<p>Can send and/or receive information. Commonly used in POEs for toll collection.</p> <p>Available readers could be used for expanded purpose.</p> <p>Low operating cost.</p> <p>Broad application in metro areas.</p>	<p>Requires investment for roadside infrastructure (transponders and signal readers).</p> <p>Requires operational agreements between the participating countries.</p> <p>Card readers have to be installed in many locations to be able to have a good estimate of the border crossing travel time.</p>
AVL **	<p>Can track vehicle location and speed over the predetermined area with very good accuracy.</p> <p>No need to install fixed roadside equipment.</p>	<p>Requires some investment for infrastructure (GPS devices).</p> <p>Privacy issues with the vehicle owners.</p> <p>Obtaining truck tracking data from truckers might be difficult.</p>
Mobile phone location	<p>No infrastructure required.</p> <p>Can track vehicle location and speed.</p>	<p>Relies on the size of the cell.</p> <p>Especially affected in rural areas.</p> <p>Not as accurate as other technologies.</p>
Automatic License Plate Recognition **	<p>Good identification rate.</p> <p>No on-board equipment required.</p>	<p>Negatively affected by slow-moving or turning vehicles (might not suitable for border crossings).</p> <p>Could require a high investment for infrastructure, especially for equipment.</p> <p>Readers must be installed in many locations to be able to have a good estimate of the border crossing travel time.</p>
Vehicle Matching	<p>No on-board equipment required.</p>	<p>Could require a high investment for infrastructure, especially for equipment.</p> <p>Readers must be installed in many locations to be able to have a good estimate of the border crossing travel time.</p>
Loop Detectors	<p>Relatively low installation cost on a per detector basis.</p>	<p>Detector subject to density of traffic.</p> <p>In order to have a general sense of traffic patterns, a large amount of detectors are needed and therefore a large investment is required.</p> <p>Border crossing scenarios are not suitable for this type of technology.</p>
<p>** = Potential technologies following analysis of six candidate technologies.</p>		

Detailed Technology Evaluation

Automatic License Plate Recognition

(Candidate vendor - PIPS Technology)

ALPR technology requires cameras at the beginning of the queue and at the exit of the border crossing for each lane. The system works by electronically recording the front and rear license plates of vehicles. The recordings from the two ALPRs are matched and travel time is calculated. Dirty, damaged, or bent license plates can cause problems for the cameras. The PIPS Technology, Inc., cameras can detect license plates from many U.S. States, as well as bordering states in Mexico (i.e., Nuevo Leon, Chihuahua, Coahuila, Tamaulipas, Baja California, and others).

The requirements for installation are a power source and internet connection. Cameras can be operated by battery only on a temporary basis. Wireless local area network (LAN) connectivity is available. Individual camera processors need to feed into a common lane controller or server that is not included with the ALPR equipment (see figure 6).



Figure 7. Photo. ALPR camera and interface box. (6)

From PIPS Technology, Inc., the cost per camera is \$13,250. Installation will incur a \$9,800 cost per camera. The estimate for annual maintenance is \$1,600 per camera. A common lane controller also needs to be purchased.

The advantages of ALPR include:

- ALPR is fairly accurate and can work under most weather conditions and at night.
- The technology is not dependent upon carrier or passenger participation, therefore gathering sufficient data is not a concern.

The disadvantages include:

- Bent or dirty license plates can escape detection.
- Sufficient space between commercial vehicles may not exist for the camera to collect license plate images.

Radio Frequency Identification

(Candidate vendor – TransCore)

RFID technology requires a reader and a transponder or tag. The reader broadcasts an interrogation signal from its antenna. When a transponder comes within the antenna's coverage range, the transponder returns the signal to the roadside reader with the vehicle's identification. The information is then retransmitted for further processing and storage.

With a reader at the entrance to the border crossing and one at the exit, time-stamped data can be gathered on individual vehicles and used to calculate border crossing times. The RFID readers are not affected by adverse weather conditions, but transponders must be within six feet of the reader for data to be collected.

The requirements for installation include AC power, an internet source, and a place to mount the reader.

The main advantages of RFID readers are that a large population of tags or transponders is already installed in trucks crossing the border and that reader technology is widely deployed in metro areas. Currently CBP is using Transcore's eGo sticker tags that could be used to calculate border wait times (See figure 7). Each reader with installation costs between \$25,000 and \$50,000.

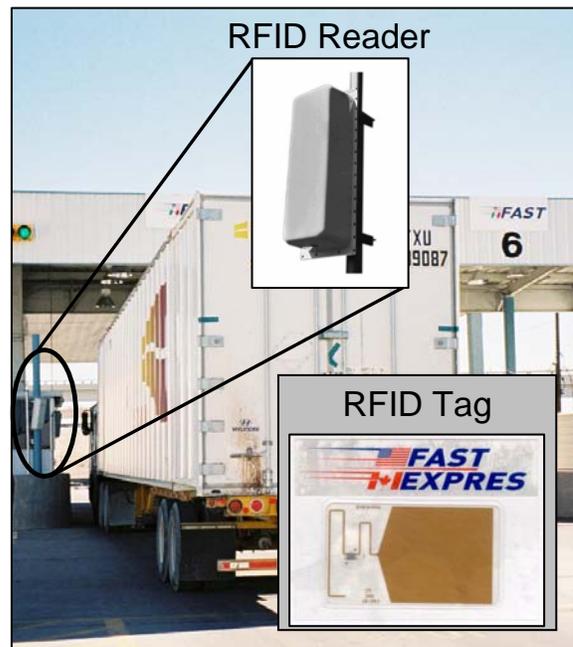


Figure 8. Photo with insets. RFID reader on a FAST lane.

The benefits of RFID technology are:

- CBP is currently using RFID transponders in vehicles, that could be used to measure border wait times.

- Data collected for the border wait times can easily be shared with CBP and DPS. This includes vehicle identifications recorded at the beginning of the queue that can be used to improve the speed of the e-manifest and inspection process.
- DPS is planning to install more RFID readers at the entrance of the inspector lot, decreasing the reader costs and increasing the number of measuring points.

The concerns of RFID technology include:

- The data will not be as detailed as GPS data,
- Identifying trucks that use FAST lanes would require at least one additional reader,
- The readers are expensive to install.

Global Positioning Systems

(Candidate Vendor – Turnpike Global Technologies)

Transport Canada is currently working with Turnpike Global Technologies to evaluate the use of GPS technology to measure border wait delay. The project began in March 2006 and will conclude around July 2008. Currently the GPS measuring technologies are employed on several crossings, including the Peace Bridge, Ambassador Bridge, and Detroit Windsor Tunnel. Probes are located in over 3,000 trucks, and carriers have provided very positive feedback. To date, the project has brought in statistical data that have allowed identification of transportation patterns and concerns. Transport Canada considers the program a great success.

GPS devices require both a probe and a reader. The probe is a small device that gathers information from GPS satellites and the reader extracts the information from the probes. The probe continually collects and stores information throughout the trip of the vehicle (see figure 8). When the probe comes within range of a reader, the data are wirelessly extracted and transmitted to the provider's headquarters via the internet. There the provider analyzes the data and posts it to the internet for viewing. The entire process of uploading the information and transmitting the data to the internet takes less than four minutes.



Figure 9. Photo. Turnpike Global Technologies probe. (7)

Because information on position and time is gathered constantly, detailed reports can be generated to determine how long delays are and the cause of delays. In addition, the probe is connected to the engine via a socket located in the cab of the tractor. The probe collects engine diagnostics, making it possible to calculate emissions and the environmental impact of border wait times. The readers use Bluetooth® technology to wirelessly collect the data. Because the readers read all Bluetooth identification codes, time-stamped data are gathered from all vehicles operating Bluetooth devices. In some cases this information can be used to gather data on passenger border crossing times.

Requirements for installing GPS readers are a power source and an internet connection. If a power source is not available, a solar panel can be installed as an alternative power source. However, most border crossings have a power source of some type. If an internet connection is not available then a cellular modem can be attached to the reader to transmit the collected data to the internet. There is an additional transmission charge for cellular internet service. The only requirement to install the tractor probe is a J-17-O-8 socket in the cab if engine diagnostics is needed.

Turnpike Global Technologies charges \$1,000 for each reader. One reader can collect data from several lanes of traffic, so there are typically two readers per border crossing. However, if border wait times are to be measured for only one direction of traffic then one reader may be sufficient. There are two different types of probes. The first probe, which collects engine diagnostics, is \$600 to buy one probe or \$35 per month to lease. The second is a trailer probe that does not collect any data from the engine. The trailer probe is \$400 to buy. The number of probes required depends on the sample size necessary to ensure accurate data.

There is a monthly data procurement fee of \$15 per tractor probe or \$5 per trailer probe. A monthly data management fee is charged per month. For a similar project in Canada the fee is \$2,500 per month. The end data are posted on the internet for the subscriber to view.

The benefits of using GPS include:

- The technology has been successfully tested in Canada for the U.S./Canada border.
- The data are very precise.
- The detailed information can be used to measure border wait times and to locate where delays exist.
- Specific detailed parameters for measurements can be created for each border crossing to adapt to differing needs (geofencing).
- Environmental impact of wait times can be estimated.
- Carriers benefit from near real-time information and automated fuel tax calculations.
- Passenger vehicle wait times could be measured using Bluetooth identifications to produce time-stamped passenger border wait times.

Some concerns about using GPS technology are:

- The continuing cost of operation is high.
- The gathered data cannot easily be shared with CBP or DPS because they are currently not using a GPS system, but the calculated crossing times would be almost immediately available.

- Carriers may resist having the data collected from their trucks unless the identities can be masked. Their cooperation is essential to this technology.

Carrier's GPS Informational Agreements

Currently along the U.S./Mexico border several trucking companies are using GPS technology to track their own vehicles. Information is gathered using GPS technology and sent back to the companies' dispatch or headquarters where the vehicle is monitored. While the companies collect this information for security and efficiency purposes, the data could be used to measure border wait times. The data would be shared daily, weekly, or bimonthly and analyzed to calculate border wait times.

If an agreement is reached with individual carriers to obtain their GPS data, data would need to be scrubbed of all identifiers and anonymous data used to calculate border crossing times. A server would be needed to collect and analyze the raw data provided by the carriers. The American Transportation Research Institute (ATRI) has reached a similar agreement with carriers traveling through the United States. However, ATRI receives snapshots of information in hourly increments. To measure border wait time data must be collected more frequently.

The benefits include:

- Little money is required.
- The information could be fairly precise.

The concerns for using informational agreements include:

- Agreements may be difficult to reach with carriers.
- The ability to gather data is completely dependent upon the willingness of carriers to share their information.
- GPS information received from carriers may not be collected frequently.

The following table shows a summary of the equipment purchase and installation costs for the selected technologies for the Bridge of the Americas and/or Zaragoza Bridge at El Paso, Texas.

Table 2. Cost estimates for each technology individually for the Bridge of the Americas and/or Zaragoza Bridge.

	Equipment & Installation						Data Transmission				Data Processing					Total Cost Per Bridge for Pilot Program			
	Equipment	Cost	Quantity	Total Equipment Cost	Installation Cost	Total Equipment and Installation Cost	Item	Cost Per Month	Months	Total Monthly Cost	Item	Cost (Per Month for GPS)	Months	Total Cost Per Item	Total Data Processing Cost				
GPS - Turnpike Global Technologies	Bluetooth Reader	\$ 1,500	1	\$ 1,500	\$ -	\$ 11,000	Internet Connection	\$ 50	1	\$ 50	Monthly Service Fee	\$ 1,500	1	\$ 1,500	\$ 4,000	\$ 15,050			
	Probe - Lease (per month)	\$ 35	100	\$ 3,500	\$ 6,000						Monthly Support Fee	\$ 2,500	1	\$ 2,500					
RFID - TransCore	Tag/Transponder Reader	\$ 13,000	4	\$ 52,000	\$ 48,000	\$ 125,000	Cellular Data Plan	\$ 50	1	\$ 85	Develop, Test, Install Software	\$ 14,000		\$ 14,000	\$ 14,000	\$ 139,085			
	Onsite Computer	\$ 3,500	2	\$ 7,000	\$ 15,000												Telephone Line	\$ 35	1
	Multiport Serial Port PC card	\$ 750	2	\$ 1,500															
	Misc. Electronics	\$ 500	1	\$ 500															
	Cellular Modem	\$ 1,000	1	\$ 1,000															
	Motorola Canopy Solution	\$ -	2	\$ -															
ALPR - PIPS Technology	Camera	\$ 13,250	3	\$ 39,750	\$ 29,400	\$ 96,150	Cellular Data Plan	\$ 50	1	\$ 85	Develop, Test, Install Software	\$ 14,000		\$ 14,000	\$ 14,000	\$ 110,235			
	Onsite Computer	\$ 3,500	2	\$ 7,000	\$ 15,000												Telephone Line	\$ 35	1
	Multiport Serial Port PC card	\$ 750	2	\$ 1,500															
	Small Cabinet	\$ 1,000	2	\$ 2,000															
	Misc. Electronics	\$ 500	1	\$ 500															
	Cellular Modem	\$ 1,000	1	\$ 1,000															
	Motorola Canopy Solution	\$ -	2	\$ -															

The GPS-Turnpike Global Technologies cost estimate is substantially less than the other two technologies because it is based on leasing the equipment for one month. The other two technologies require equipment to be purchased.

Assumes Telecomunicaciones y Servicios del Norte, S. A. de C. V. of Mexico will provide Motorola Canopy Solution with installation without charge. Each Canopy Solution costs \$10,810 to buy.

Assumes one month pilot test.

Assumes probes for GPS are leased and not purchased for the pilot program. Each probe costs \$650 to buy.

Assumes 100 probes are needed for the pilot test. The actual number required may be more or less which will affect costs. The pilot test should help determine how many probes are required for a permanent measurement system.

Assumes no additional RFID tags will be purchased.

Assumes two man months for development, testing, and installation of software and hardware for data transmission and processing.

Assumes data will not be collected in real time.

Assumes two lanes at the beginning of the queue and one lane at the exit of the DPS facility.

Proposed Data Collection Plan

Each of the technologies from the previous discussion is unique in its capabilities and requirements. The data collection plan provides information regarding which data are collected from the technologies and a detailed discussion of the placement of the technologies including aerial maps of the Bridge of the Americas and the Zaragoza Bridge.

How frequently data are gathered depends primarily on the purpose of the data. Calculating border delays and wait times can be done in near real-time, hourly, daily, weekly, or monthly. Each of the three candidate technologies collects different data elements. Data elements that will be collected for each technology are listed in Table 3.

Table 3. Measured Data Elements

Data Element	GPS	ALPR	RFID
Entry Date	X	X	X
Entry Time	X	X	X
Exit Date	X	X	X
Exit Time	X	X	X
Vehicle License Plate State/Country		X	
Vehicle Route	X		
Vehicle Speed	X		
Stop Times*	X		
Idle Time*	X		

* Requires probe to be installed in the tractor

Each of the three technologies requires installing equipment at the selected U.S./Mexico border crossing. The locations and requirements are unique for each technology. Because of the similarities between the Bridge of the Americas and the Zaragoza Bridge, one description will be given for each technology. Refer to figure 9 and figure 10 to locate the specific locations at each crossing. Locations are designated as R1 through R5 as indicated.

ALPR

One ALPR camera will be installed for each lane of traffic at R1 and one camera will be installed at the exit of the DPS inspection facility at R5. This will provide the total border crossing time.

Additional cameras can be installed at R2 and R3 to provide greater detail. One camera at R2 would make it possible to determine which vehicles used the FAST lanes and a camera at R3 would give data on how long it took for a vehicle to pass through the Federal inspection facility. With a camera located at R3, little benefit would be gained from adding another camera at R4.

RFID

One RFID reader will be installed for each lane at R1 to identify incoming vehicles before they reach the queue. In addition to two readers at R1, one reader will be installed at R5, the one-lane

exit of DPS. These three readers will provide enough information to calculate the total border crossing time.

To add greater detail to the data and provide a clearer picture of what is happening within the border crossing, optional readers can be installed at R2, R3, and R4. R2 is located at the entrance of the FAST lanes. Currently CBP has installed RFID readers at R2 and if the information from these readers is shared then it could be determined which trucks used the FAST lanes. If the information cannot be shared another option is to install a reader at this location. A reader at R2 would make it possible to determine which vehicles used FAST lanes and to calculate the time saved by using FAST lanes.

R3 is located at the one-lane exit of the Federal inspection facility. No readers currently exist at this location, but installing a reader would provide details on how long it took vehicles to reach the end of the Federal facility. The Texas DPS has plans to install a reader at R4 located at the entrance of the DPS facility. If the information was shared it could provide accurate data on how much time was spent in the DPS inspection facility when combined with reader R5. If DPS shares information from the R4 reader, little additional data would be gained by having a reader installed at R3. In other words, a reader should be used at R3 or R4 but not at both locations.

GPS

Because of the ability of GPS technology to retain detailed information from the vehicles trip, only one reader is required at R5. Throughout the border crossing the GPS probe will collect detailed data that will be extracted at the end of the border crossing. The extracted information will contain detailed data from the vehicle's trip. It will be possible to determine if FAST lanes were used, if any secondary inspections were required, and how much time was spent at each of the facilities at the border crossing.



Figure 10. Aerial photo hybrid map. Bridge of the Americas at El Paso, Texas.

- A: Mexican Export Lot. Trucks go through Mexican Export Customs (document inspection, cargo inspection selection)
- B: U.S. Federal Compound. Trucks go through U.S. Customs Primary Inspection (document inspection). If secondary inspection is required, truck(s) are sent to the U.S. Secondary Inspection (VACIS, X-Ray, INS, USCS, USDA, FDA, EPA, US DOT, K-9, others)
- C: State Safety Inspection Facility. Checks that trucks comply with all the safety requirements

	Description of Locations of Readers		Amount of Readers		
			RFID	ALPR	GPS
	R1	Upstream of queue	2	2	0
<i>Optional</i>	R2	Entrance to FAST lane	1	1	0
	R3	Exit of Federal inspection facility	1	1	0
	R4	Entrance to DPS inspection facility	1	0	0
	R5	Exit of DPS inspection facility	1	1	1



Figure 11. Aerial photo hybrid map. Zaragoza Bridge at El Paso, Texas.

- A: Mexican Export Lot. Trucks go through Mexican Export Customs (document inspection, cargo inspection selection)
- B: U.S. Federal Compound. Trucks go through U.S. Customs Primary Inspection (document inspection). If secondary inspection is required, truck(s) are sent to the U.S. Secondary Inspection (VACIS, X-Ray, INS, USCS, USDA, FDA, EPA, US DOT, K-9, others)
- C: State Safety Inspection Facility. Checks that trucks comply with all the safety requirements

	Description of Locations of Readers		Amount of Readers		
			RFID	ALPR	GPS
	R1	Upstream of queue	2	2	0
<i>Optional</i>	R2	Entrance to FAST lane	1	1	0
	R3	Exit of Federal inspection facility	1	1	0
	R4	Entrance to DPS inspection facility	1	0	0
	R5	Exit of DPS inspection facility	1	1	1

Next Steps

This report presents findings from the two initial tasks of the project work plan, which include the definition of a plan for collecting baseline data and the analysis of potential technologies that could be used to collect the information. The technology analysis resulted in three candidate technologies that could be used for measuring travel time at commercial border crossings. In order to make a final recommendation in relation to which of these three candidates should be implemented, it will be necessary to:

- Perform a field test of all three technologies to analyze the performance of each of them under real field conditions.
- Define in coordination with FHWA and other stakeholders the final use of the information that will be collected.

The research team has already made preliminary contact with several technology vendors, and all of them have expressed interest in participating in the field test. The next step is to identify a border crossing where the test can be carried out. This report presents a possible data collection plan for two commercial border crossings at the El Paso-Ciudad Juarez border. These two examples are representative of most of the commercial border crossings along the U.S./Mexico border, and once a crossing is identified for the field test, a final detailed plan could be developed.

The final use of the information collected at the border crossing needs to be defined. For example, the information could be shared with other stakeholders on a continuous basis through the internet or it could be stored and analyzed periodically (weeks, monthly, etc.) and could become part of a regional border data collection effort for transportation planning purposes. The definition of the final use of the information is important at this time because it will characterize the required output and influence the system integration constraints and analysis procedures of the information. FHWA's objectives and long-term plans on the Freight Performance Measurement initiative should be aligned with the definition of the border crossing time and delay system tested at the U.S./Mexico border.

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