Commercial Border Crossing and Wait Time Measurement at the Pharr-Reynosa International Bridge

Final Report

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1. BACKGROUND AND OVERVIEW

The objective of the research described in this report is to install and implement radio frequency identification (RFID) technology to measure border crossing time and travel delay for commercial trucks crossing from Mexico into Texas at the Pharr-Reynosa border crossing.

The Texas Department of Transportation (TxDOT) is working with the Federal Highway Administration (FHWA) and other members of the U.S./Mexico Joint Working Committee (JWC) to implement automated border crossing and delay time measuring systems. Delay time for commercial motor vehicles is a key indicator of transportation and international supply-chain performance. The information collected with the RFID readers will establish a baseline and on-going measurement of border crossing times and delay, and will be processed and disseminated to stakeholders.

The Texas Transportation Institute (TTI) started working for the FHWA on identifying appropriate technologies that can be used to support automated measurement of border delay and crossing time at U.S./Mexico land ports of entry in 2006. In order to measure travel time and the associated delay, the chosen technology needed to be flexible enough to cover the complete trip and be applicable at all ports of entry (POEs). Technologies identified as meeting these criteria were: automatic vehicle identification (AVI), automatic license plate recognition (ALPR), vehicle matching, automatic vehicle location (AVL, including GPS), mobile phone location, and inductive loop detectors. The advantages/disadvantages of these technologies were also assessed by TTI.

Three technologies considered the best candidates for the POE application were identified: AVI, GPS, and ALPR. RFID was the AVI technology that was selected for the Pharr border crossing. Passive RFID technology requires a reader and a transponder. Initial research indicated that RFID transponders were already being used at this border crossing by U.S. Customs and Border Protection (CBP) for lanes dedicated to trucks participating in the Free and Secure Trade – "FAST" Program and also by toll bridge operators at both sides of the border.

In 2007, the FHWA funded Part II of *Measuring Border Delay and Crossing Times at the U.S.–Mexico Border*, which included the deployment of RFID at the Bridge of the Americas (BOTA) land border crossing between El Paso and Ciudad Juárez. In February 2008, TxDOT and TTI started this project under an Interagency Cooperation Contract (IAC). The original scope of work for the implementation of the technology at the Pharr-Reynosa International Bridge called for two RFID reader stations (1 in Mexico and 1 in the U.S. side of the border). After analyzing the layout of the crossing and meeting with stakeholders in the region, it was decided to add 2 more reading locations, for a total of 4 (2 in Mexico and 2 in the U.S.). The IAC was amended in March 2009 to include the 4 reading stations.

FHWA, TxDOT, and other members of the JWC began working closely with CBP to determine whether projects could be enhanced to measure border wait time in addition to total crossing time. Wait and crossing time are defined as:

- Wait time: "the time it takes, in minutes, for a vehicle to reach the (CBP) primary inspection booth after arriving at the end of the queue."[1] This queue length is variable and depends on traffic volumes and processing times at each of the inspection facilities throughout the border crossing process.

- Crossing time: has the same beginning point in the flow as wait time, but its terminus is the departure point from the last compound that a vehicle transits in the border crossing process. As a metric, wait time is of greater significance than crossing time to CBP operations, whereas crossing time is of relatively greater interest to FHWA. (A more detailed discussion of travel time elements is found in Appendix A.)

Following these definitions, in order to measure wait time, RFID readers need to be installed at the CBP primary inspection booths. In January 2010, CBP internally sent forward a recommendation for approval of RFID installation at the primary inspection facility locations at Pharr-Reynosa and BOTA. FHWA subsequently allocated the resources to install RFID equipment at both Texas Crossings (BOTA and Pharr-Reynosa) that will enable the measurement of border wait time.

This report covers the work that TTI developed under the contract with TxDOT, which includes the system development and deployment of RFID readers at two locations in Mexico and two in the U.S., and does not include implementation of the technology at the CBP primary inspection booths.

Organization of the Report

After this initial section that describes the project background, Section 2 presents a description of the characteristics of the Pharr-Reynosa International Bridge, including the Lower Rio Grande Valley port of entry system. Section 3 of the report describes the technology implementation process, including the technology selection and reader station locations processes.

Section 4 presents a description of the equipment procurement, installation and testing. Section 5 describes the data collection and analysis process that was conducted with the information that has been collected, and Section 6 presents activities that are being considered for the future operation and data dissemination of the border crossing time system at the Pharr-Reynosa International Bridge.

The report includes 6 appendices with a discussion of border and crossing time elements; the list of stakeholder meeting participants; a report of a site visit that was performed prior to the installation of the equipment; sample letters of equipment installation authorization; the equipment installation manual; and sample data reports.

[1] Border Wait Time Working Group presentation, April 2009

2. PHARR- REYNOSA INTERNATIONAL LAND BORDER CROSSING SITE DESCRIPTION

The Lower Rio Grande Valley Port-of-Entry System

The Lower Rio Grande Valley or the Rio Grande Valley (RGV) is located in the southernmost tip of Texas, bordered with the Mexican State of Tamaulipas. The region is made up of four counties: Starr County, Hidalgo County, Willacy County, and Cameron County. As of January 1, 2010, the Texas State Data Center estimated the population of the Lower Rio Grande Valley at 1,167,121 with 26% increases since the year 2000. It is the second largest growth rate after Capital Area among the Councils of Governments' population estimates. The largest city is Brownsville, followed by McAllen and Harlingen. Pharr is located in McAllen-Edinburg-Mission Metropolitan Statistical Area.

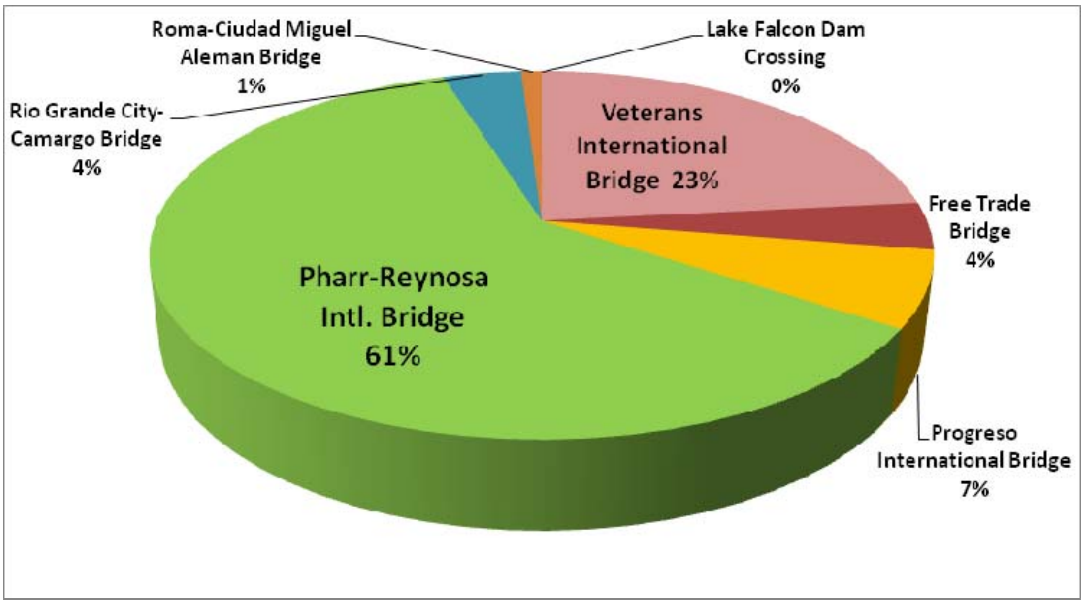
Texas is the third largest producer of citrus fruit in U.S., the majority of which is grown in the Rio Grande Valley. This industry and other agribusiness and the emergence of "maquiladoras" have caused a surge of industrial development along the border. International ports of entry are crucial for the development of the region and day-to-day operations of the bi-national region. Six operating international bridges handle freight in the RGV. Figure 1 illustrates these six bridges from the Veterans International Bridge in Brownsville, Texas, to the Roma-Ciudad Miguel Alemán International Bridge in Roma, Texas.

The FAST program allows pre-certified shipments to use a special lane and receive expedited inspection at the U.S. CBP booth. There are three POEs where a FAST lane exists: Veteran's International Bridge, Free Trade International Bridge, and Pharr-Reynosa International Bridge.

Source: TTI using Google Maps

Figure 1. Map of Lower Rio Grande Valley Commercial Vehicle Crossings.

Figure 2 shows 2009 northbound truck crossing in the Lower Rio Grande Valley POEs. The Pharr-Reynosa International Bridge handled 61% of the total trucks in the region, followed by Veterans International Bridge, in Brownsville, Texas, with 23%.

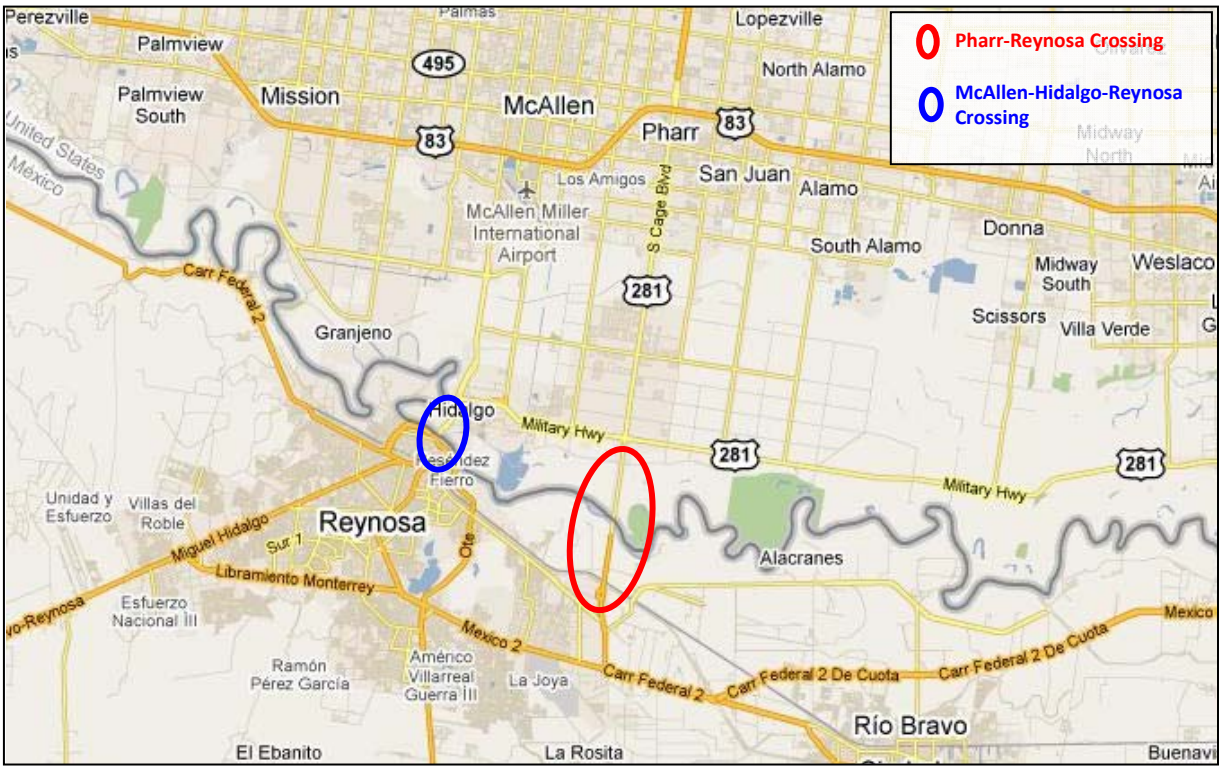


Source: U.S. CBP

Figure 2. Lower Rio Grande Valley POEs' Truck Traffic Volume (2009).

The Pharr-Reynosa International Bridge

Pharr-Reynosa International Bridge is located in Hidalgo County, middle of the Lower Rio Grande Valley. It was constructed to relieve congestion on the McAllen-Hidalgo-Reynosa Bridge due to commercial traffic demand. The bridge connects US 281 in Pharr, Texas, to the city of Reynosa, Tamaulipas, which is an important industrial city in northeastern Mexico. In Mexico, there is a direct connector road from the Pharr-Reynosa International Bridge to Mexico's highway 2, which connects Reynosa to Matamoros and provides access to the Reynosa airport. These roads allow traffic using the Pharr-Reynosa International Bridge to bypass the heavily urbanized areas of McAllen-Hidalgo-Reynosa Bridge. The Pharr-Reynosa Bridge is 3.1 miles long and elevated to protect surrounding wetlands and farmlands. Figure 3 shows the location of Pharr-Reynosa International Bridge and the McAllen-Hidalgo-Reynosa Bridge with major highway connections.



Source: TTI using Google Maps

Figure 3. Pharr-Reynosa and McAllen-Hidalgo-Reynosa Vehicle Crossings.

The Pharr-Reynosa International Bridge is the second largest commercial POE in the state of Texas in terms of number of northbound truck crossings. A list of the top 10 POEs in the state of Texas for 2009 along with the number of northbound trucks crossing at each POE is presented in Table 1. From January through November of 2010, the total import/export value through the Hidalgo/Pharr POE was about $22.7 billion while all Lower Rio Grande Valley POEs reached more than $35.6 billion.

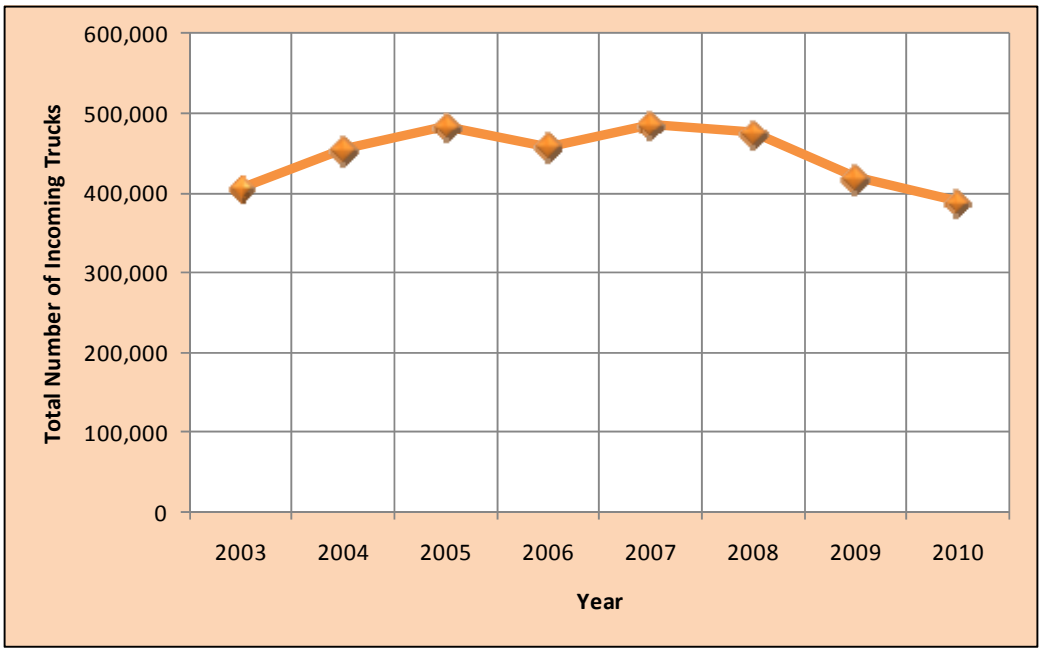
Table 1. Northbound Truck Crossings in Texas (2009).

Bridge	# of Northbound Crossings
World Trade Bridge	1,091,035
Pharr-Reynosa International Bridge	**419,426**
Bridge of the Americas	316,731
Laredo-Colombia Solidarity Bridge	291,284
Ysleta-Zaragoza Bridge	315,947
Veterans International Bridge	160,827
Camino Real International Bridge	83,254
Del Rio-Ciudad Acuna International Bridge	49,600
Progreso International Bridge	45,980
Free Trade Bridge	28,761

Source: U.S. Customs and Border Protection

Operational Characteristics of Pharr-Reynosa International Bridge

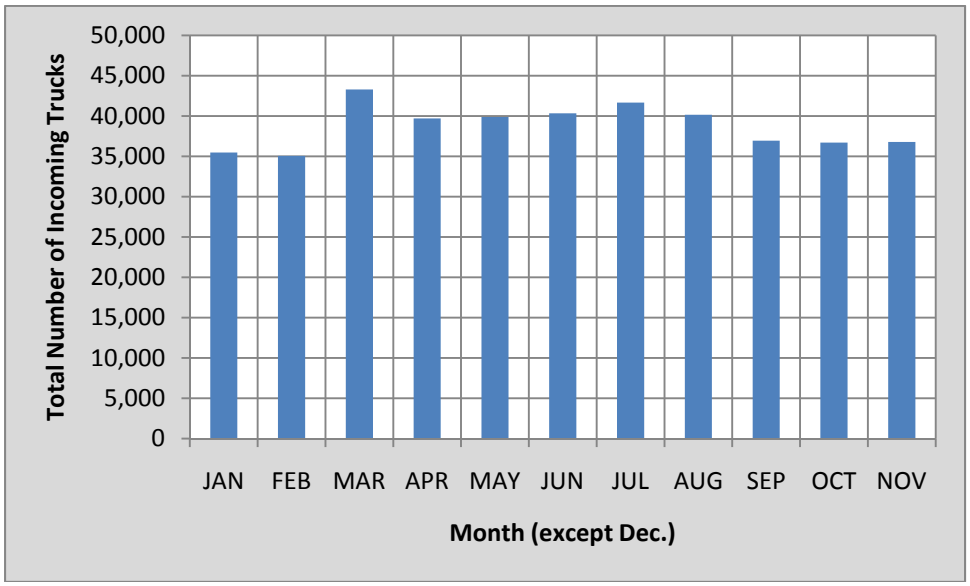
The Pharr-Reynosa International Bridge on the Rise has a four-lane cross section, with three northbound lanes and one southbound lane, on the U.S. portion of the bridge. This crossing serves passenger as well as commercial vehicles. Truck crossings at the Pharr-Reynosa International Bridge reached a pick in 2007, with close to 500,000 crossings in 2007. International truck volumes started to decline in 2008 due to the economy downturn (Figure 4).



Source: U.S. Department of Transportation, Bureau of Transportation Statistics

Figure 4. Northbound Truck Movements through Pharr-Reynosa International Bridge.

In 2009, the Pharr-Reynosa International Bridge was the second most important commercial crossing in Texas, after Laredo's World Trade Bridge. It handled a total of 419,426 trucks from Reynosa into Pharr, with an average of 34,952 trucks per month. March and July were the months of highest demand in 2010, while February registered the lowest truck volume (Figure 5).



Source: Texas Center for Border Economic and Enterprise Development

Figure 5. Monthly Northbound Truck Crossings at Pharr-Reynosa International Bridge (2010).

The border crossing process for commercial vehicles entering the U.S. requires several steps in which the vehicles need to stop. The time it takes a truck to cross would depend on the time spent at each of these points of inspection, toll collection, and the time it takes to move from one station to the next, which is a function of traffic volume and number of available booths.

The northbound commercial border crossing process begins at the Mexican Export Lot on the Mexican side of the border. After clearing export customs on the Mexican side, a truck proceeds to the toll booth operated by Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE). Once truck pays tolls through an electronic toll-collection system (Sistema IAVE) or manually, then crosses the bridge. Immediately upon entering the United States, the truck continues to the U.S. Federal Compound. Entrance to the Federal Inspection Compound is accessed through the primary inspection booths. At these primary inspection booths, a CBP agent determines whether the truck requires any secondary inspection and directs the driver to it, or otherwise instructs the driver to simply proceed to the exit. Final clearance to exit the Federal Inspection Compound is given at booths at the exit of the premises. After leaving the Federal premises, the truck proceeds to the State Border Safety Inspection Facility (BSIF).

The BSIF is located at the north side of the Federal inspection complex and connected by an access road. Weigh-in-Motion sensors measure the weight of every truck that travels on this access road. Upon leaving the access road and entering the BSIF, trucks continue moving

toward an inspection shed. Trucks departing the inspection shed are instructed by the DPS officials to either proceed to the exit of the facility or to a secondary safety inspection. An aerial view of the Pharr Reynosa International Bridge is presented in Figure 6.

Source: TTI using Google Earth

Figure 6. Aerial View of Phar-Reynosa International Bridge, Looking South from US 281.

Pharr-Reynosa International Bridge commercial crossing operates from 7:00 AM to 10:00 PM Monday through Friday and from 7:00 AM to 4:00 PM on Saturday and Sunday. The U.S. side of the bridge is owned by City of Pharr and the Mexican side is owned by the Government of Mexico and operated by CAPUFE. In January 2009, the City of Pharr widened the northbound approaches from the bridge to the truck and vehicle booths and restriped the northbound lanes to dedicate a FAST lane on the bridge.

3. TECHNOLOGY IMPLEMENTATION

Technology Selection

As mentioned in the initial section of this report, TTI performed an analysis sponsored by FHWA aimed at identifying technologies that could be used to calculate crossing times for northbound commercial freight at the U.S.-Mexico border. The study, entitled "Measuring Border Delay and Crossing Times at the U.S.-Mexico Border," provided a comparative analysis of the six selected technologies in its Part I–Tasks 1 and 2 Report.[2]

The recommendation for the Pharr-Reynosa International Bridge was to use RFID technology. This technology requires at least two reading stations, where a time stamp and vehicle identification are recorded. Time stamps for a particular vehicle are compared to determine the period of time elapsed between the two recording stations.

A preliminary analysis of the characteristics of the Pharr crossing and vehicles that operate in the region was performed before developing the final implementation plan. TTI developed the preliminary implementation plan that was presented to the stakeholders in the region to obtain feedback.

Stakeholder Input

The U.S./Mexico commercial border crossing process involves participants from both the public and private sectors in Mexico and the U.S. The most relevant stakeholders with an interest in the facilitation of commercial border crossing process include:

- U.S. & Mexican private sector stakeholders:
    - Carriers.
    - Customs Brokers.
    - Freight Forwarders.
- U.S. Federal Agencies:
    - U.S. Customs and Border Protection (CBP).
    - Federal Motor Carrier Safety Administration (FMSCA).
- State Agencies:
    - Texas Department of Transportation (TxDOT).
    - Department of Public Safety (DPS).
- Mexican Federal Agencies:
    - Secretaría de Comunicaciones y Transportes - SCT (Mexican Ministry of Communications and Transportation).
    - Aduanas (Mexican Customs).
    - Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE).
- Local Agencies:
    - City of Pharr Bridge Operator.

[2] The full report can be found at http://tti.tamu.edu/documents/TTI-2007-1.pdf

TTI organized a meeting to receive feedback on the project from the various stakeholders. The meeting was held on June 19, 2008, at the TxDOT facilities in Pharr. More than 30 people participated in the meeting from public and private sectors, Mexico and the U.S. (Participants list is presented in Appendix B).

Some of the relevant points that were discussed during the stakeholder meeting included the following:

- CBP was interested in whether or not the proposed system would be able to capture specific shipment data off of their system, or interfere in any way with their system.
  It was clarified that the only information that the RFID equipment collects is a time stamp and the transponder ID would be no interference to any of the CBP's systems.

- Stakeholders mentioned that given the length of the Bridge and operations, trips would need to be segmented to identify where delays are occurring.
  TTI proposed four reading stations to segment the trip in at least three segments.

- The SCT mentioned that the detailed, systematic data collected through this project will justify improvements on the Mexican side. Because SCT in Mexico is implementing an ITS system in the region, they are very interested in the success of this program.

- Stakeholders mentioned that if public funds are being used for the project, the information being collected should be made public to everyone, preferably via the internet.

- CBP mentioned that most of the trucks have a "User-Fee Tag."
  TTI mentioned that research would be performed to define if these tags are readable by the proposed system.

Reader Station Location and Characteristics

In October 2008, the TTI team with TxDOT representatives traveled to Pharr/Reynosa to survey the potential locations for the RFID readers and also to discuss the proposed installation plan with stakeholders. A full report of the visit is presented in Appendix C. During the visit, the team analyzed potential locations for the readers, identifying existing structures and power supplies. The visit also provided information on potential contractors that could perform the installation. CAPUFE was helpful in providing access to their facilities and contact information of contractors who worked for CAPUFE.

Based on the results from the site visits and discussions with stakeholders, TTI developed needs and specifications for the installation of RFID equipment at the Pharr-Reynosa International Bridge on all commercial northbound lanes.

During the initial assessment of the Pharr-Reynosa International Bridge, TTI staff identified five potential locations to install RFID readers (Figure 7).

PRx = Preliminary Reader location number

Figure 7. Pharr-Reynosa International Bridge Preliminary Reader Location.

The preliminary reader location description included:[3]

PR1. To be installed at the farthest south location where trucks would be detected as they approach the International Bridge. There is no structure at this location and it has two lanes.

PR2. To be installed passed the "Camino al Ejido El Guerreño," which is located halfway between the Reynosa-Rio Bravo highway and the toll booth. There are two sign structures that could potentially be used to install the RFID readers. There are two traffic lanes at this location.

PR3. The third reader location could be installed at the CAPUFE toll booth, just before trucks enter the actual Bridge and after they have cleared Mexican Customs (Aduanas). CAPUFE offered to provide power at this location as well as at the use of the toll booth canopy. There are four booths where trucks can circulate at this location.

PR4. On the U.S. side of the border, the first reader could be installed at a point where commercial traffic is segregated from passenger vehicles. This land belongs to the U.S. Bridge Operator. This location is two lanes wide.

PR5. The second reader location on the U.S. side could be installed at the exit of the DPS BSIF. There is one lane at the exit of the facility

After a detailed analysis of the preliminary reader location and traffic flow characteristics, it was determined that PR2 did not provide valuable information as there are some commercial vehicles that stop before entering the Mexican Customs Export Lot. Therefore this reader location was eliminated, and the proposed structure includes two readers in the Mexican side of the border and two in the U.S. side of the border, as shown in Figure 8.

[3] PR = Preliminary Reader.
R = Reader

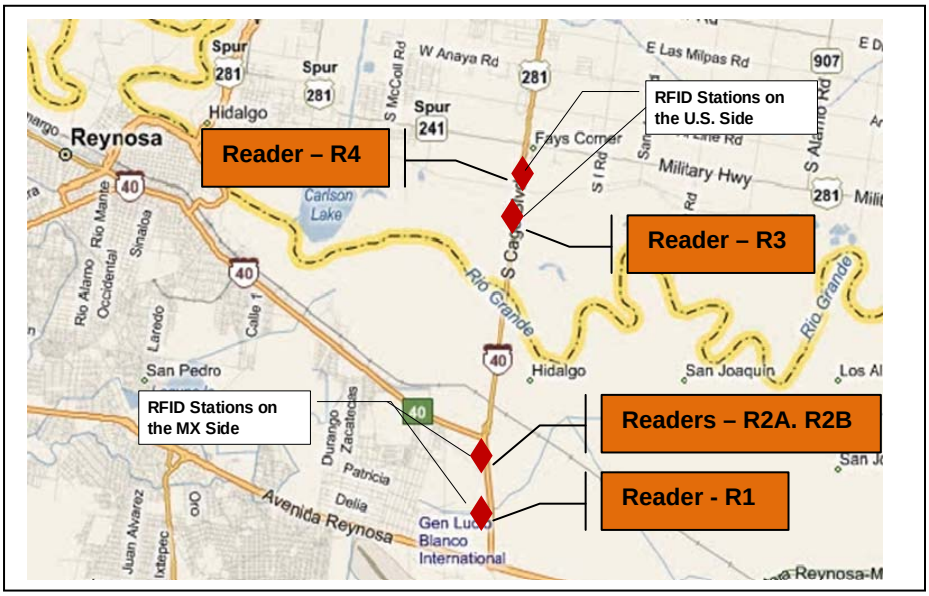


Figure 8. RFID Reading Stations Installed at the Pharr-Reynosa International Bridge.

Table 2 illustrates the location, installation characteristics, and number of lanes for each reader station. The original contract and budget called for the installation of two readers, one on the Mexican side and one on the U.S. side of the border. Based on an alternative analysis prepared by TTI, the contract was amended in March 2009 to include the four sites described in the following table.

Table 2. Description of Location of RFID Readers at the Pharr-Reynosa International Bridge.

Reader	Description of Location	Approximate Location of Readers
R1	Located approximately 1.88 miles to the south of the border on the Mexican side and approximately 1.45 miles south of the Mexican toll collection booth. Pole installed on the side of the road with solar power.	
R2A, R2B	On the booth of the Mexican toll collection booth that is managed by CAPUFE. Power provided by CAPUFE.	
R3	Approximately, 3.2 miles north of R2A/R2B on the U.S. side of the border. The reader is a few hundred feet before the CBP primary inspection. Gantry structure to support antennas and reader. Power provided by the Bridge Authority taken from a luminary.	
R4	Located at the exit of the DPS commercial vehicle inspection station. Using existing wooden pole to support structure for antenna. Power provided by DPS.	

Concept of Operations

Based on feedback from the stakeholder meeting and the definition of the number and location of RFID reading stations, the concept of operations (ConOps) that was previously developed under the FHWA BOTA project was modified to meet the Pharr-Reynosa border crossing time measurement requirements. A detailed description of the ConOps is available in the BOTA's *Final System Design with Architecture Appendix*. A summary of the ConOps that describes the organization and operation of the system for the Pharr-Reynosa project is described in this section.

The border crossing measurement system is organized into three subsystems representative of each component's function:

- Field Subsystem.
- Central Subsystem.
- User Subsystem.

The Field Subsystem is comprised of the tag detection stations including the communication equipment. A minimum of two detection stations are required, one in Mexico and one in the United States. The detection station reads RFID tags and passes the data to the Central Subsystem via the communication equipment. The Central Subsystem receives tag reads from the field detection stations and performs all processing to derive and archive the aggregate travel times between the stations. The User Subsystem interacts with the Central Subsystem to provide an Internet web portal for data users (stakeholders, the public, etc.) to access current border crossing times and, if given proper credentials, to access archived crossing time data. Figure 9 shows the system's organization.

Northbound commercial vehicles (trucks in Mexico destined to cross the border into the United States) pass an RFID tag reader installed at a point sufficiently ahead of the end of any queue on the Mexican Export Lot. This reader station is defined as R1 (as shown in Figure 8 and Table 2). Given the characteristics of the Pharr-Reynosa border crossing, a second reader was installed at the toll booth before commercial vehicles enter the international bridge (R2). The RFID tags on the trucks are read as they pass the reader stations. The tag query process recovers a unique identifier for each vehicle similar to a serial number. The reader stations applies a time stamp to the tag read and forwards the resulting data record to a central location for further processing via a data communication link. On the U.S. side of the border, two tag reading stations were installed, before the entrance to the CBP compound (R3) and at the exit of the BSIF (R4). This station also time stamps tag reads and forwards the data record to the central facility. An example detection station is shown in Figure 10.

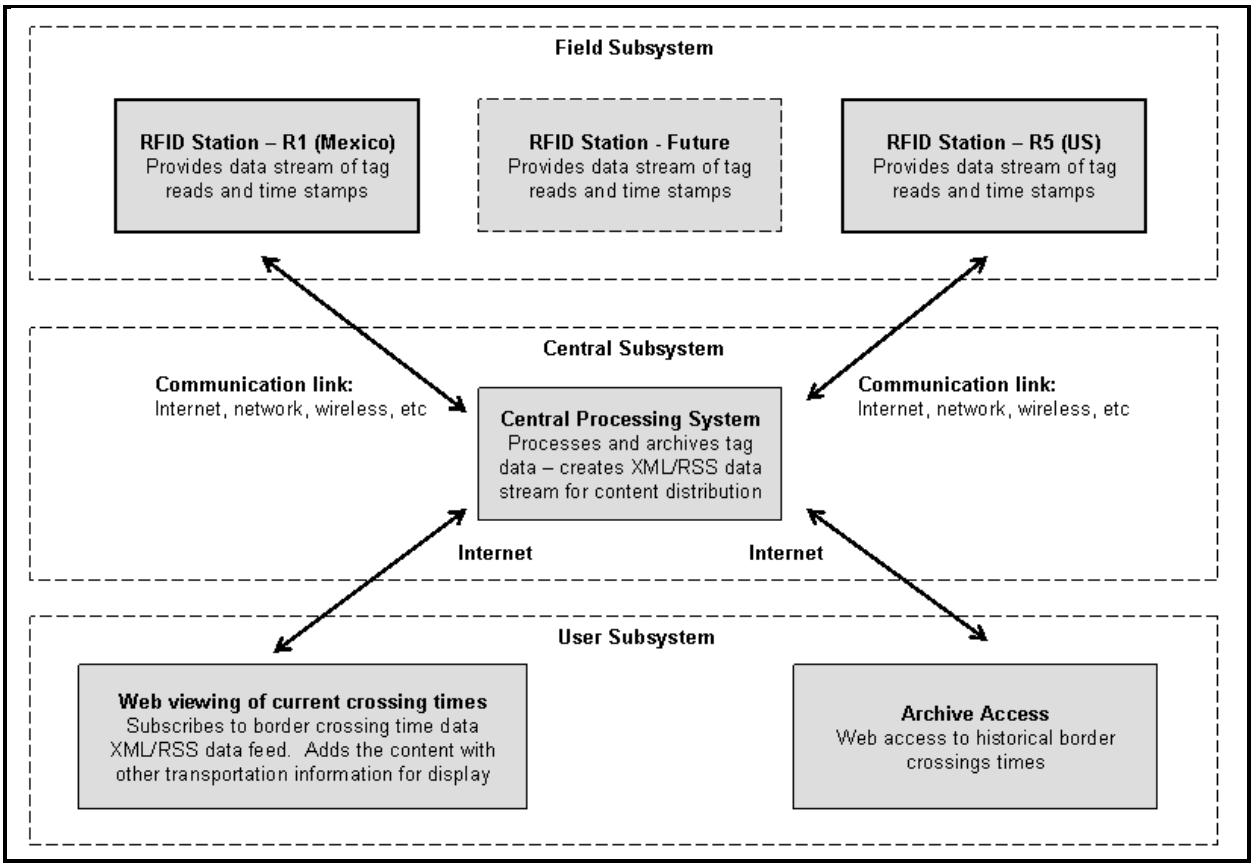


Figure 9. Subsystem Organization Diagram.

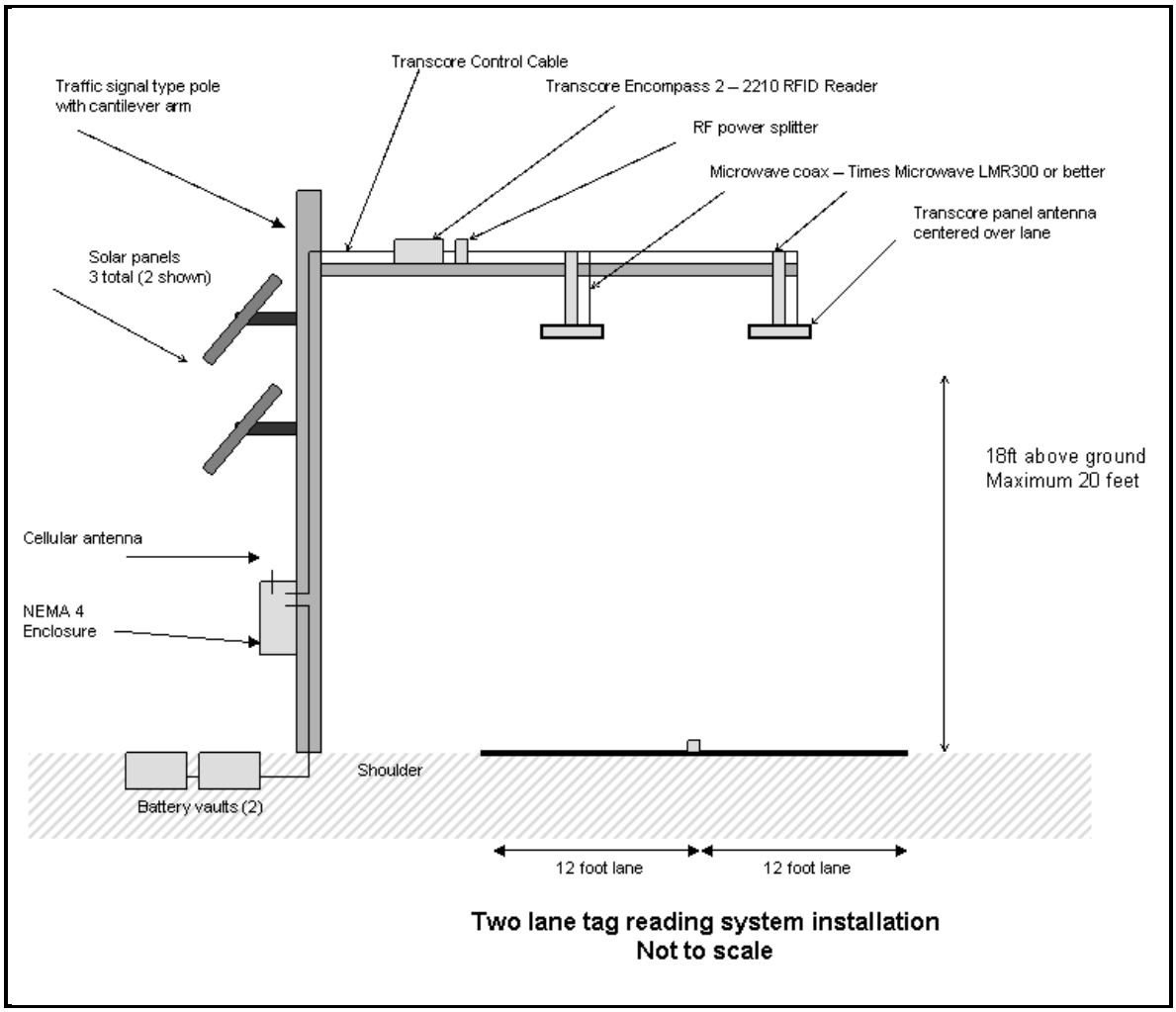


Figure 10. Example Field Detection Station.

The central facility receives data from all tag reading stations associated with the project. The facility stores all inbound raw reader station data and subsequent processed data in an archive for future access and use.

The raw data are processed to match tag reads of individual trucks at the entrance point on the Mexican side, through the two additional reading stations and the exit point on the U.S. side. The difference in time stamps between each station yields a single truck's progression as a function of time through the POE.

The average northbound crossing time was made a shareable resource. The User Subsystem manages access and creates web displays using the border crossing time data. The crossing time data are available via a simple subscription service as well as accessing a project related webpage (under development). Archived data may also be available.

Number of Valid RFID Tags

Part of TTI's scope of work was to identify the population of commercial vehicles with RFID tags that could be read to determine if the sample was large enough to provide an accurate estimate of border crossing time. Previous technology assessment determined that "egotag" was the RFID transponder with the most potential for measuring border crossing time at commercial border crossings at the U.S./Mexican border. This type of tag is the same one used by CBP's FAST program and other tolling operations.

TTI identified that there were several systems in the region that used tags. Other than the CBP FAST program, it was determined that CAPUFE's IAVE toll collection program was also using the same type of tag. At the time of this task (February 2009), the Pharr International Bridge toll collection system was being changed, installing readers and antennas similar to the ones that the border crossing time uses, and egotags were being distributed.

TTI obtained information from CAPUFE on the number of trucks that cross into the U.S. that have IAVE toll tags. CAPUFE's information was for November 2008, and the analysis showed that close to 50% of the commercial vehicles that cross into the U.S. have IAVE tags (Figure 11).

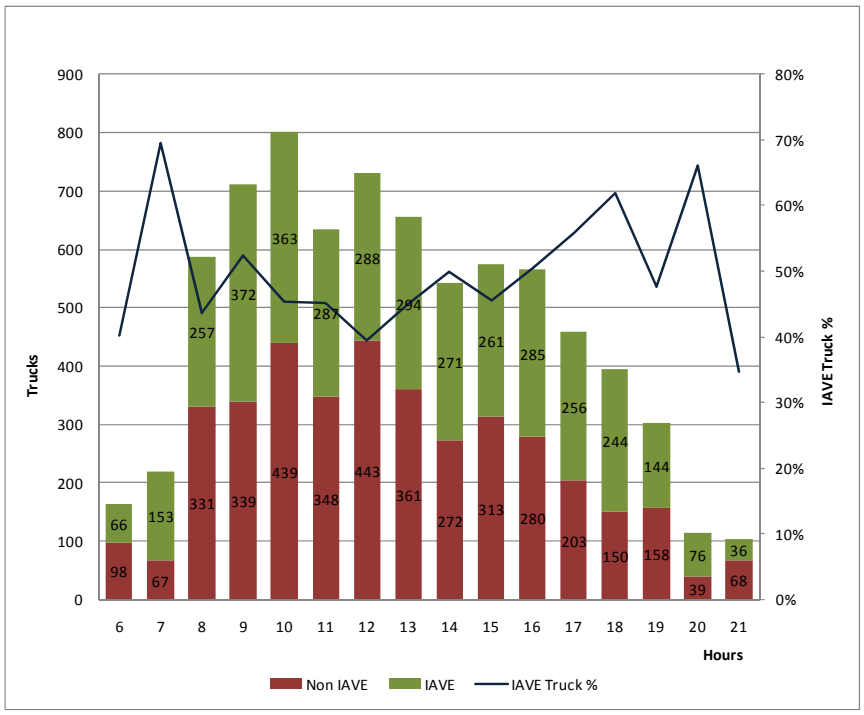


Figure 11. IAVE Trucks 11/03/2008 – 11/07/2008.

Results of the analysis proved that additional tags were not needed. As mentioned before, the IAVE tags are only one of the three sources of tags at the Pharr-Reynosa International Bridge. The 50% that was detected did not include trucks with FAST or Pharr Bridge tags.

4. EQUIPMENT PROCUREMENT, INSTALLATION, AND TESTING

Equipment Procurement and Installation

Once the implementation plan was finalized, TTI through TxDOT requested authorization to install equipment on the CAPUFE premises (R1 and R2), on the Pharr International Bridge premises (R3) and at the DPS BSIF (R4). Appendix D presents communications between TxDOT, the Pharr Bridge, CAPUFE, and TTI.

As mentioned in Table 2, R2, R3, and R4 required a power supply since these sites did not have solar power and 110 Volt power was readily available. A 110 Volt power source was obtained from CAPUFE at R2, from the Pharr Bridge at R3, and from DPS at R4. TTI developed the final list of equipment and it is presented in Table 3.

Table 3. Equipment List for Four Reading Stations.

Item	Model	Vendor	Quan
Border Crossing Travel Time Measurement - Detection Station - 2 lane - R1 - solar			
Beacon 915MHz antenna	AA-3153 P/N 12-3153-001	TransCore	2
RF power splitter (multi-lane site)	SCW02N	Hyperlink	1
Coaxial cable	LMR 300 (or better)	Times Microwave	3
RF Surge Protection	LABH2400NN	B&B Electronics	1
RFID Reader	Encompass 2 - Model 2210 P/N: 10-2210-100	Transcore	1
Cable, 35 foot, with connector	P/N: 58-1620-006	Transcore	1
Pole cabinet w/ (fuse/breaker, AC outlet, power strip)	Minimum 24x24x8	supplied by pole contractor	0
12-24v DC/DC adjustable output converter	PST-SR700 adj	Powerstream	1
RS-422 converter - DIN rail mount	485LDRC9	B&B Electronics	1
Programmable Logic Relay	SG2-12HT-D	B&B Electronics	1
Logger	SDR-CF	Databridge	1
Cellular wireless router	ConnectPort WAN	Digi International	1
External cellular antenna		Digi International	1
Remote Reboot	iBoot DC	DataProbe	1
Solar Panel	3115 BP Solar module 115 watt 12Vdc	SW Photovoltaic - Tomball	3
Charge Controller	Morningstar ProStar 30M	SW Photovoltaic - Tomball	1
Solar Batteries	MK8G31 Gel battery 96AH with cable kit	SW Photovoltaic - Tomball	8
Battery Cabinet	In ground vault or extra cabinet per quote	supplied by pole contractor	1
misc solar install parts	brackets, mounts,shipping, etc	SW Photovoltaic - Tomball	1
Border Crossing Travel Time Measurement - Detection Station - 4 lanes - R2 - power provided by others			
Beacon 915MHz antenna	AA-3153 P/N 12-3153-001	TransCore	4
RF power splitter (multi-lane site)		Hyperlink	1
Coaxial cable	LMR 300 (or better)	Times Microwave	5
RF Surge Protection	LABH2400NN	B&B Electronics	1
RFID Reader	Encompass 2 - Model 2210 P/N: 10-2210-100	Transcore	1
Cable, 35 foot, with connector	P/N: 58-1620-006	Transcore	1
Pole cabinet w/ (fuse/breaker, AC outlet, power strip)	Minimum 24x24x8	supplied by pole contractor	0
RS-422 converter - DIN rail mount	485LDRC9	B&B Electronics	1
Programmable Logic Relay	SG2-12HT-D	B&B Electronics	1
Logger	SDR-CF	Databridge	1
Cellular wireless router	ConnectPort WAN	Digi International	1
External cellular antenna		Digi International	1
Remote Reboot	iBoot AC	DataProbe	1
Border Crossing Travel Time Measurement - Detection Station - 2 lanes - R3 - power provided by others			
Beacon 915MHz antenna	AA-3153 P/N 12-3153-001	TransCore	2
RF power splitter (multi-lane site)	SCW02N	Hyperlink	1
Coaxial cable	LMR 300 (or better)	Times Microwave	3
RF Surge Protection	LABH2400NN	B&B Electronics	1
RFID Reader	Encompass 2 - Model 2210 P/N: 10-2210-100	Transcore	1
Cable, 35 foot, with connector	P/N: 58-1620-006	Transcore	1
Pole cabinet w/ (fuse/breaker, AC outlet, power strip)	Minimum 24x24x8	supplied by pole contractor	0
RS-422 converter - DIN rail mount	485LDRC9	B&B Electronics	1
Programmable Logic Relay	SG2-12HT-D	B&B Electronics	1
Logger	SDR-CF	Databridge	1
Cellular wireless router	ConnectPort WAN	Digi International	1
External cellular antenna		Digi International	1
Remote Reboot	iBoot AC	DataProbe	1
Border Crossing Travel Time Measurement - Detection Station - 1 lanes - R4 - power provided by others			
Beacon 915MHz antenna	AA-3153 P/N 12-3153-001	TransCore	1
RF power splitter (multi-lane site)	SCW02N	Hyperlink	0
Coaxial cable	LMR 300 (or better)	Times Microwave	2
RF Surge Protection	LABH2400NN	B&B Electronics	1
RFID Reader	Encompass 2 - Model 2210 P/N: 10-2210-100	Transcore	1
Cable, 35 foot, with connector	P/N: 58-1620-006	Transcore	1
Pole cabinet w/ (fuse/breaker, AC outlet, power strip)	Minimum 24x24x8	supplied by pole contractor	0
RS-422 converter - DIN rail mount	485LDRC9	B&B Electronics	1
Programmable Logic Relay	SG2-12HT-D	B&B Electronics	1
Logger	SDR-CF	Databridge	1
Cellular wireless router	ConnectPort WAN	Digi International	1
External cellular antenna		Digi International	1

Equipment was procured and assembled in College Station, Texas, where TTI's headquarters are located. Communication panels were prepared, and readers and antennas were tested using RFID tags that DPS provided. Figure 12 presents the field detection equipment back panel.

Figure 12. Field Detection Equipment Back Panel.

TTI identified a contractor that was able to install equipment on both sides of the border. Through coordination with the SCT, Aduanas, CAPUFE, DPS and Bridge Operators, the contractor installed equipment at the four pre-identified locations. When feasible, the equipment installation was performed at night, so that it would not interfere with the POE operations. TTI prepared a manual describing the detailed installation process (Appendix E). The manual was sent to the contractor and discussed via the phone to clarify the installation process. Once the equipment was installed, TTI staff traveled to Pharr/Reynosa to fine tune and test the equipment. The following figures (Figures 13–25) illustrate the installation and testing of the RFID equipment at all four locations.

Installation at R1 – CAUFE Access Road

Figure 13. Installation of Pole at R1.

Figure 14. Installation of Solar Panel at R1.

Figure 15. Installation of Transmission Equipment at R1.

Figure 16. R1 2 Antennas 1 Reader with Solar Power.

Installation at R2 – CAPUFE's Toll Booth Canopy

Figure 17. R2 CAPUFE's Toll Booth Canopy before Installation.

Figure 18. R2 Equipment Installation at CAPUFE's Toll Booth.

Figure 19. R2 Readers at CAPUFE's Toll Booth.

Figure 20. R2 Four Antennas at CAPUFE's Toll Booth.

Installation at R3 – Pharr International Bridge

Figure 21. R3 Gantry Installation.

Figure 22. R3 Antenna Installation.

Figure 23. R3 Equipment in Operation.

Installation at R4 – DPS Border Safety Station

Figure 24. R4 Single Antenna and Reader on Existing Pole.

Figure 25. R4 Equipment in Operation.

Equipment Testing

Once the equipment was installed, two types of tests were performed. The initial test was performed at four readers by checking that tags were read properly. Communication by telephone with TTI's headquarters was established, and the number of trucks that were visually observed at each reader location was compared with tag reads. During this test, it was discovered that some trucks had more than one tag installed. The algorithm of the border calculation routine was modified to discard multiple tags on one truck.

The second test was performed to verify that all readers were capturing information from the field and it was being sent as planned through the wireless modem to the server. The test indicated that all stations were sending appropriate tag reads, except for R2 –B. These are two antennas (one on each lane) at the CAPUFE toll booth on the far right lanes. After investigation, it was established that these two lanes are used by passenger vehicles and almost no trucks travel in those lanes.

5. DATA COLLECTION AND ANALYSIS

The deployment of the RFID readers and other communication equipment was completed in October 2009. Since then, the system has been collecting tag identification data from northbound trucks (entering the U.S.) and sending them to a central server at the TTI's El Paso office. The tag identification data (also referred as RFID data) includes unique identification of tags (also called transponders) and a time stamp when the tag was read by the RFID reader.

Processing and Archiving of Tag Identification Data

A database server at the TTI's El Paso office communicates with individual RFID readers, which directly sends tag identification data to the server. The server then processes the raw data to determine current average crossing times of commercial vehicles and also archives the raw data (individual tags and timestamps read by individual readers) as well as aggregated data (average crossing times) between the stations. None of the data collected by the system is discarded. It is archived for retrieval. Figure 26 shows data retrieval and archival of the tag identification data.

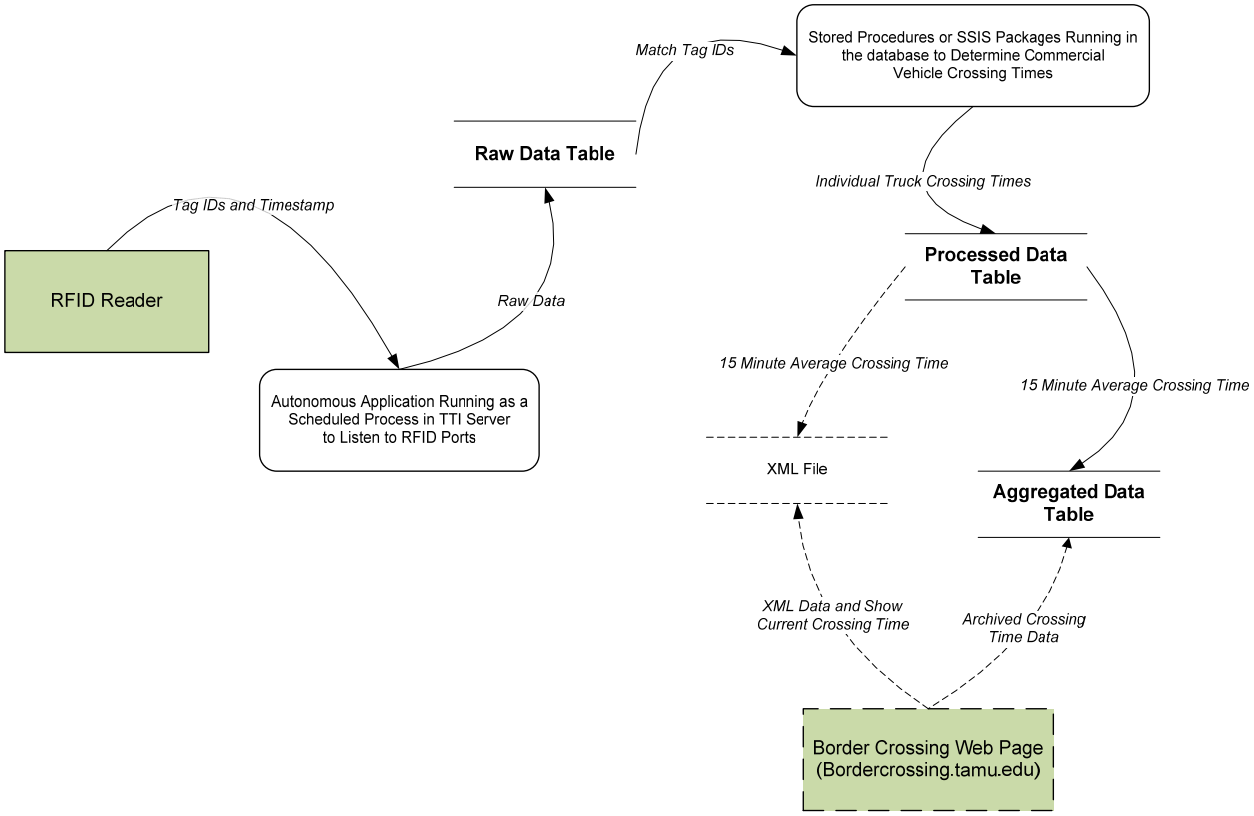


Figure 26. Flow Chart of Tag Identification Data Retrieval and Archival Process.

Calculation of Average Crossing Times of Commercial Vehicles

Relaying current average truck crossing time is valuable to shippers and freight carriers to plan for trips. The server after receiving the raw tag identification data calculates the average crossing times of trucks every 15 minutes using two-hour time window. The average travel times between the readers are determined using the following procedure:

- The average travel times are calculated every 15 minutes (e.g., 9:00 AM, 9:15 AM, 9:30 AM, etc.)
- The procedure uses 120 minutes as time window, meaning this value is used as a maximum crossing time that could possibly occur at any given segment. However, if there are many instances of crossing times exceeding 120 minutes, this threshold can be changed accordingly.
- For example, to calculate average travel time between R1 and R2 at 9 AM, all the tags that were read between 7 AM–9 AM are matched, and travel times of matched tags are averaged (simple mean).

Website to Access Real-Time and Archived Truck Crossing Times Data

TTI is developing a website to relay the most recent average truck crossing times between the stations and query archived crossing times data. The URL for the website is http://bordercrossing.tamu.edu. **The website is not fully operational yet**. Users will be able to select the border crossing and access the information. A snapshot of the website is shown below.

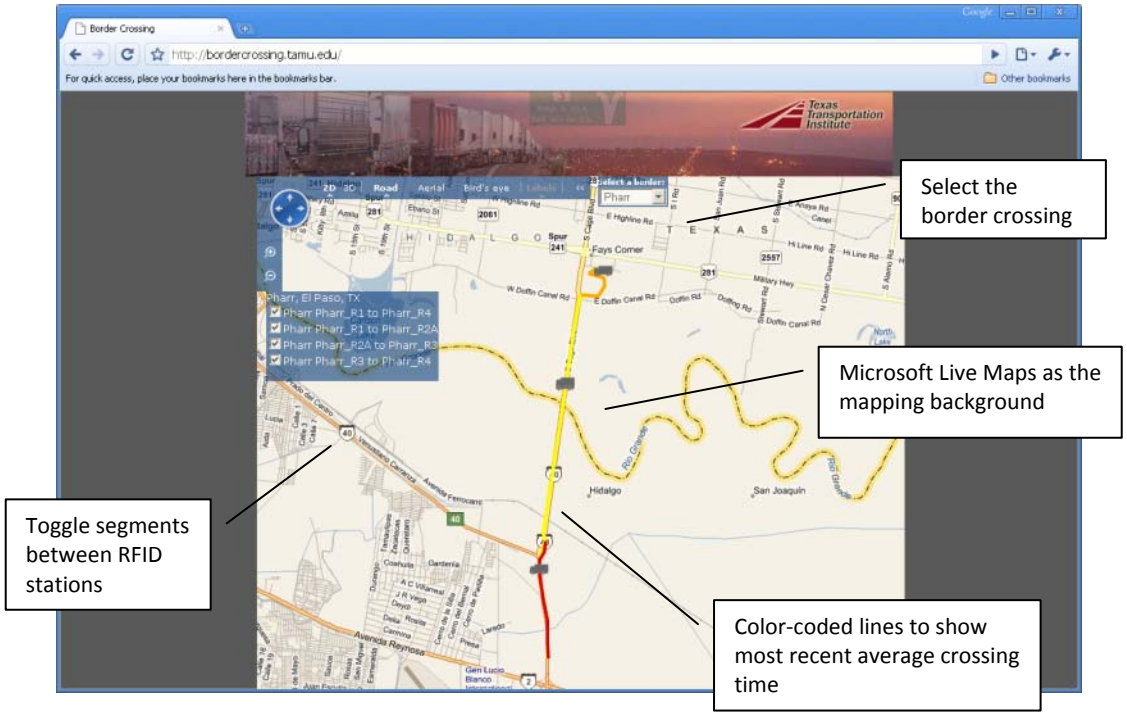


Figure 27. Snapshot of a Website Being Developed by TTI to Access Crossing Times Data.

Analysis of Commercial Vehicle Crossing Time Data

Table 4 contains the calculation of monthly capture rates, which are the percentage of matched tags read by the system. One column expresses the capture rate of matched tags as a percentage of tags read on the U.S. side, while another column expresses capture rate of matched tags as a percentage of total northbound truck volume as reported by TxDOT. The table also demonstrates a fairly high percentage of northbound trucks that cross have readable tags, as demonstrated by readings during the months not affected by anomalies.[4]

Table 4. Monthly Capture Rate Calculation.

Month-Year	Total NB Truck Volume	Total NB Truck Volume in 1000	No. of Tags Read by RFID on U.S. Side	% of Truck Volume Identified by RFID on the U.S. Side	Sample Size (i.e. Tags Matched that Made a Border Crossing Trip)	Capture Rate (Based on No. of Tags Read on U.S. Side)	Capture Rate (Based on Total NB Truck Volume)
(1)	(2)		(3)	(4) = (3) x 100/(2)	(5)	(6) = (5) x 100/(3)	(7) = (5) x 100/(2)
Oct-09	36969	36.969	31253	85%	14811	47.4%	40.1%
Nov-09	35383	35.383	22721	64%	11383	50.1%	32.2%
Dec-09	33657	33.657	12599	37%	4974	39.5%	14.8%
Jan-10	35473	35.473	17251	49%	3040	17.6%	8.6%
Feb-10	35068	35.068	17777	51%	3677	20.7%	10.5%
Mar-10	43292	43.292	17819	41%	5728	32.1%	13.2%
Apr-10	39711	39.711	25046	63%	5003	20.0%	12.6%
May-10	39891	39.891	21805	55%	5565	25.5%	14.0%
Jun-10	40347	40.347	17918	44%	3198	17.8%	7.9%
Jul-10		0	20386	-	3878	19.0%	-
Aug-10		0	32668	-	6233	19.1%	-

The system is able to relay and archive travel times of trucks on segments between individual RFID readers. The travel time between segments can be summed to estimate the total truck crossing times. The travel time estimated by matching the tags read by the readers R1 and R4 is a much more reliable account of the truck crossing times, since reader R4 reads only the tags carried by the trucks. Other readers read tags carried by trucks as well as passenger vehicles. The following histogram of truck crossing times (travel times of trucks between R1 and R4) shows the highly variable crossing time during the different times of day. Obviously, empty trucks require less crossing time than non-empty trucks and trucks enrolled in the FAST program require less crossing time than trucks not enrolled in the program. Being able to distinguish the type of trucks (empty versus non-empty) and FAST versus non-FAST by the RFID readers would provide a better way of distinguishing crossing times of different types of trucks; however, the system as designed does not do this[5]. The histogram shows that the 95th percentile

[4] It was detected that the system was not reading tags during some times of the day due to lack of power. This was a random failure difficult to identify the reason. TTI sent the installer to verify the equipment on site and humidity was detected inside the equipment box. The box was sealed and terminals cleaned. A system has been developed to detect any failure so that actions could be taken.

[5] In order to identify FAST and non-FAST trucks, readers at the CBP FAST primary inspection booths will be installed during the next phase of the project. Empty and loaded trucks could be identified by accessing the Weigh

of trucks take approximately 100 minutes or less to cross the border and 50th percentile of trucks require approximately 50 minutes or less to cross the border.

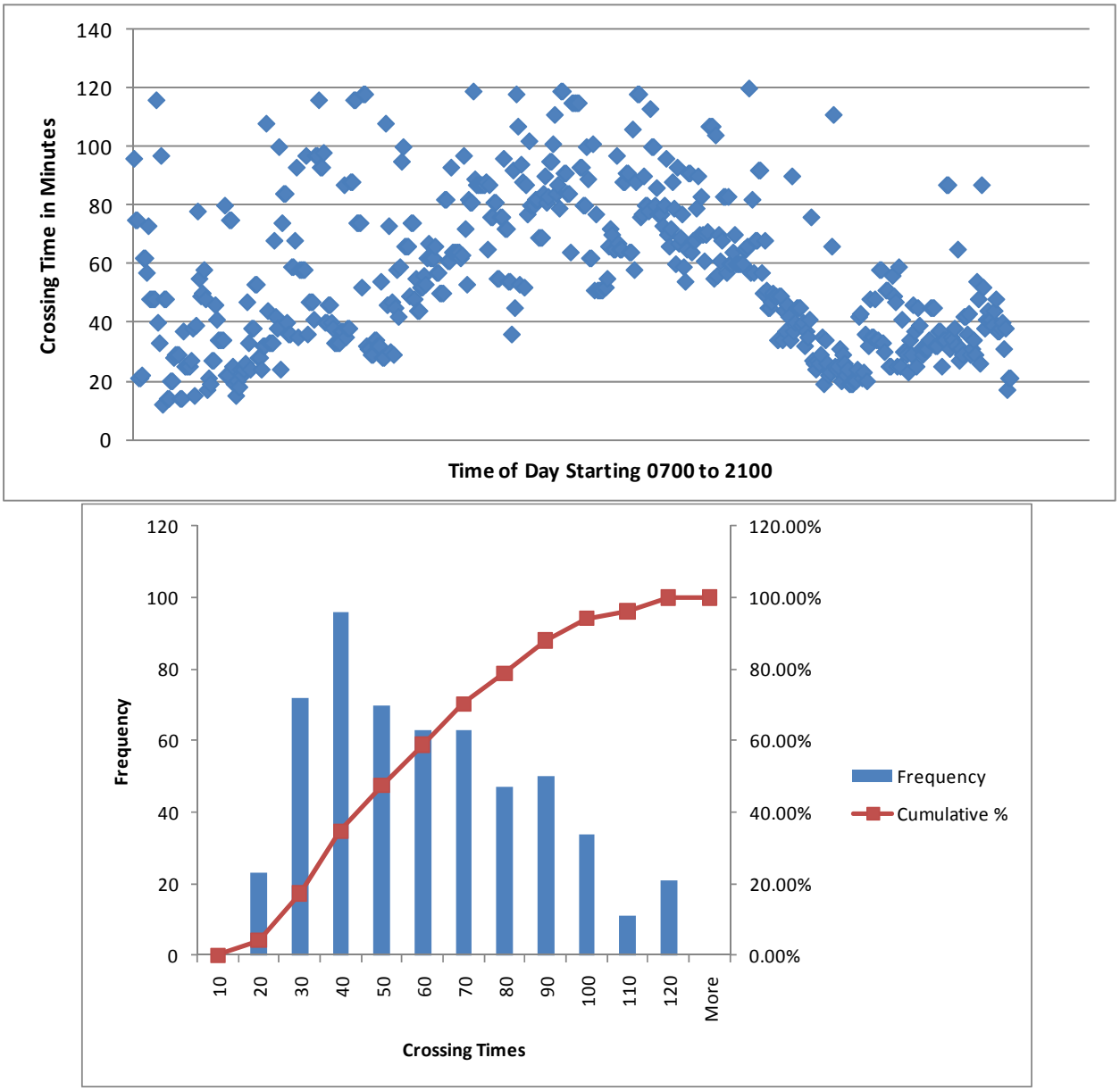


Figure 28. Histogram of Total Truck Crossing Times on a Typical Weekday.

Analysis of Travel Time on Segments between RFID Stations

The analysis of travel time on segments between the first and the last RFID stations is presented. Figure 29 shows the temporal variation of average travel times on individual segments during an entire week starting November 23, 2009.

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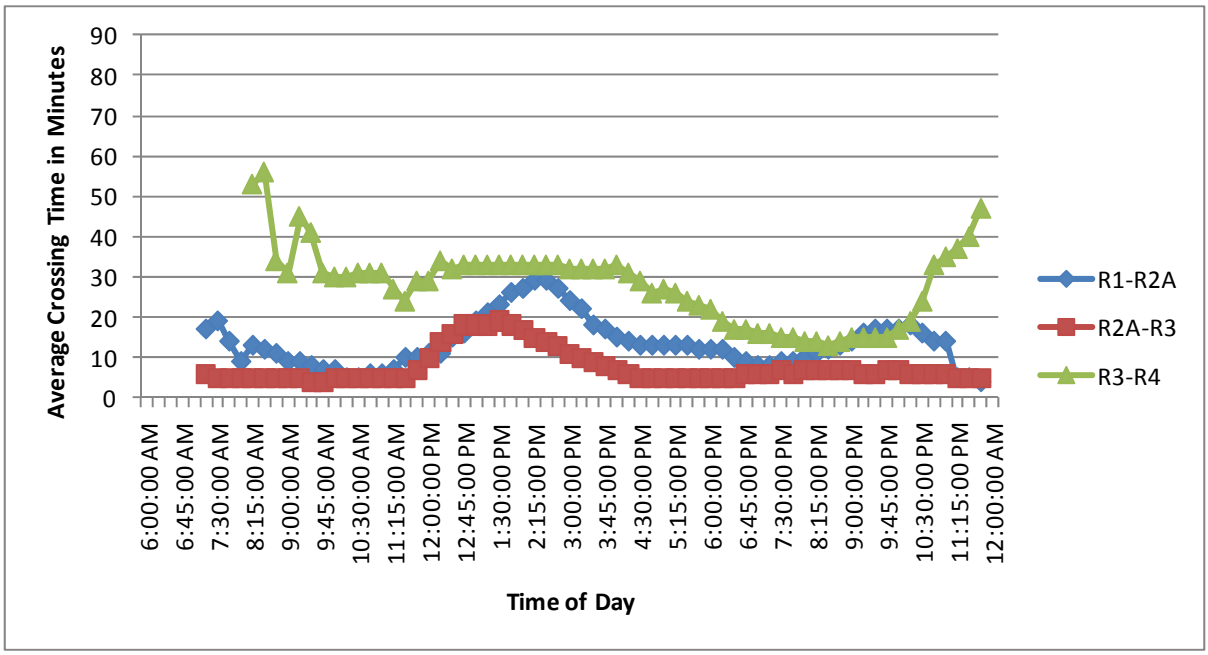
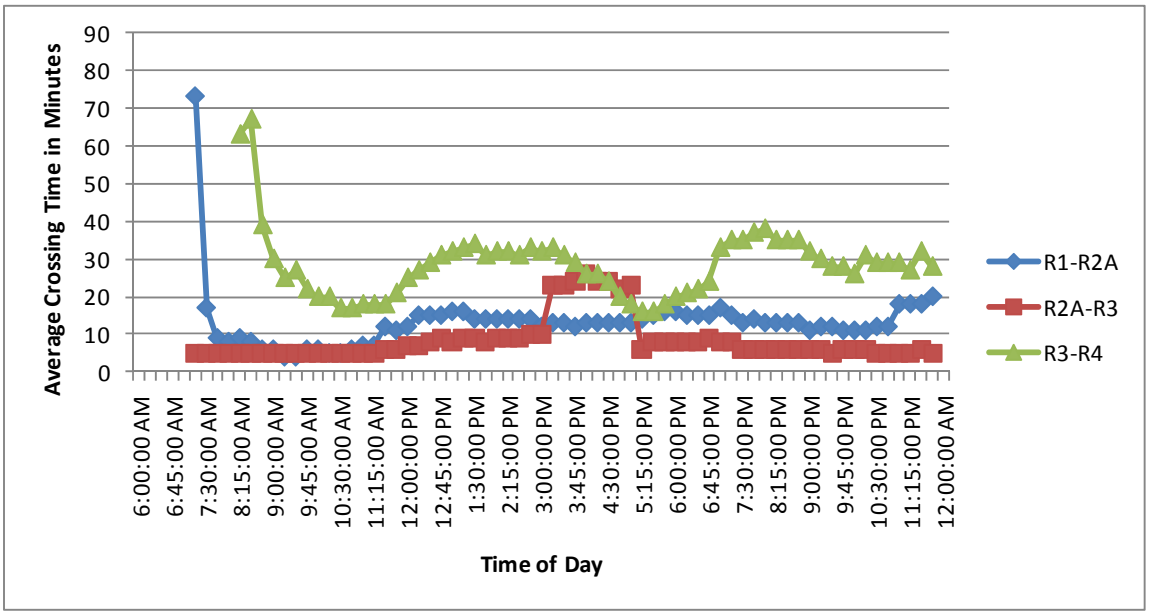
in Motion (WIM) equipment that DPS operates. WIMs are installed at the connection road between the CBP and DPS facilities.

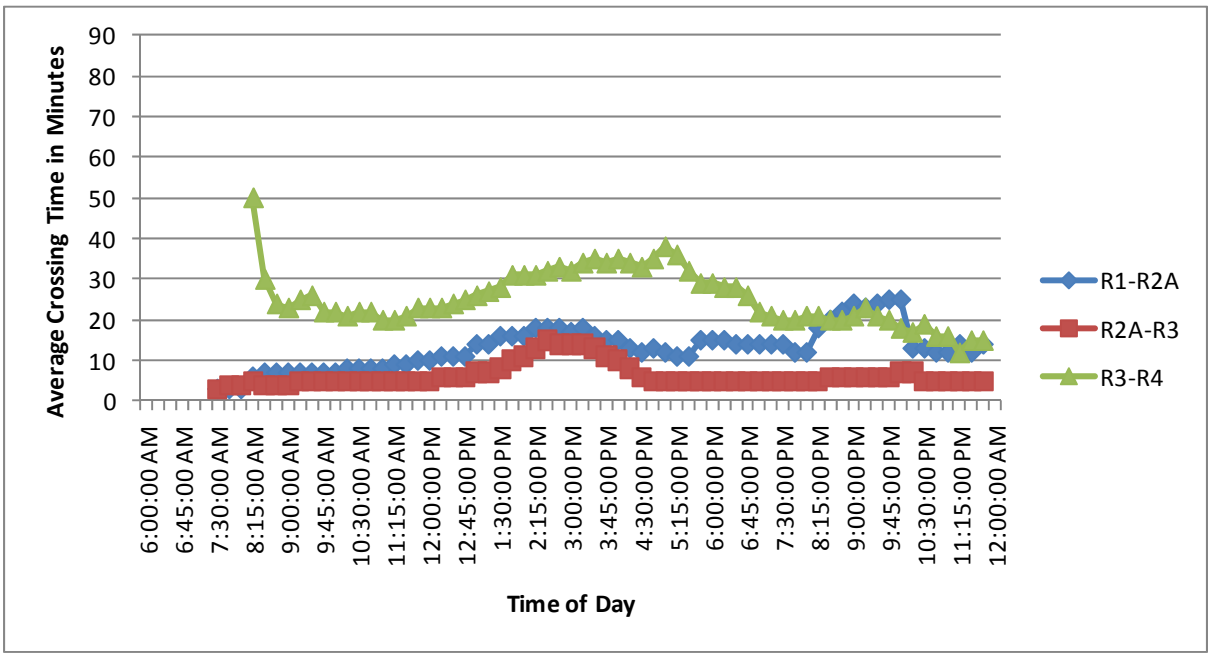
Variation of average travel time on the segment R2A-R3 is comparatively much smaller than the rest of the segments, since this segment does not experience queues or congestion and the trucks are able to move in a uniform speed. Graphs of remaining segments clearly show a queue built up during the early morning period and dissipates later in the day. In a way, segment R2-R3 (the bridge span) (because of its long length) is helping to reduce congestion and high wait time at the U.S. primary inspection. These charts clearly show where the biggest bottleneck is in this entire chain is—R3-R4, before the U.S. primary inspection.



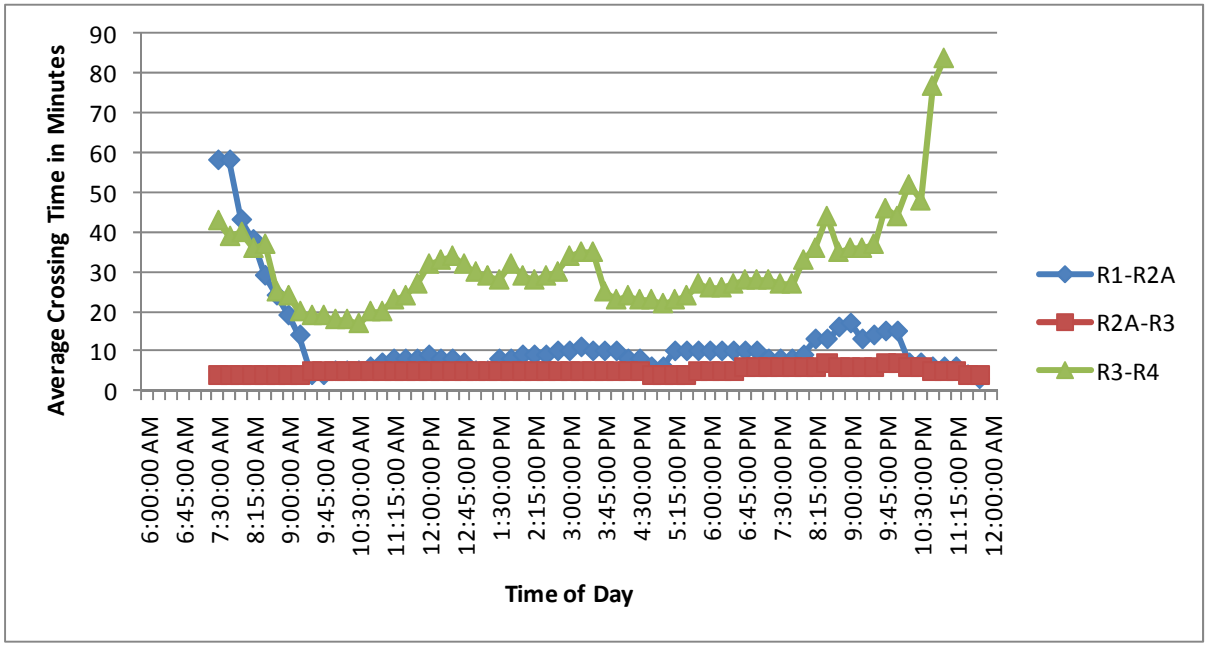
Monday



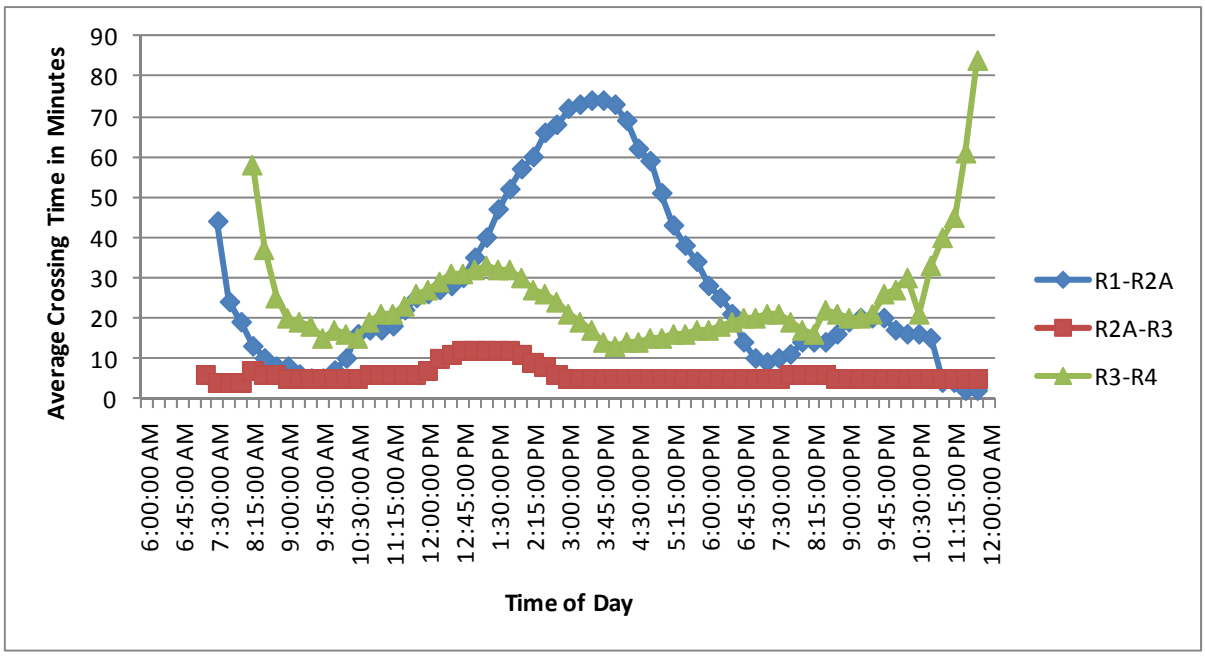
Tuesday



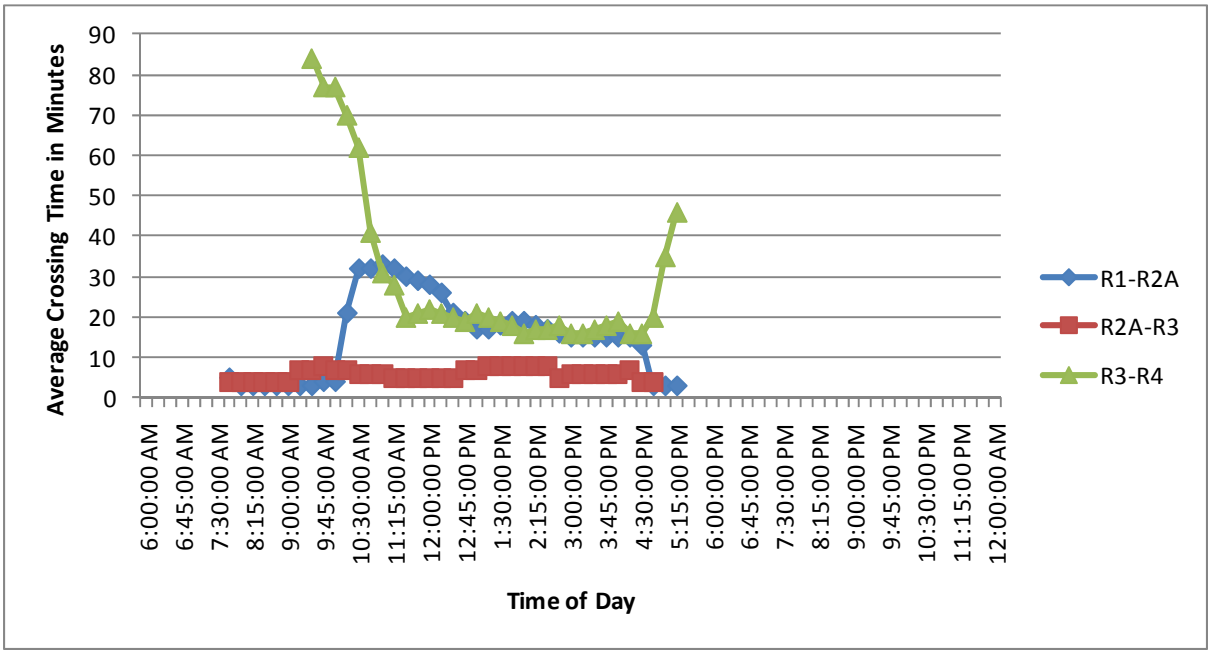
Wednesday



Thursday



Friday



Saturday

Figure 29. Graph Showing Travel Times through Three Different Segments.

The RFID based ITS solution such as the one described in this report opens up the possibility of creating border-crossing related performance measures and ultimately a performance management process for evaluating and improving international border-crossings for freight as well as passenger movement. Border-crossing performance measures provide stakeholder agencies and users with information to assist in various travel related decisions, establishes a common denominator to estimate the effect of improvements and modifications in operation, and

establishes indices that can be easily communicated with a non-technical audience and still find the information relevant.

Table 5 portrays in different ways the monthly average northbound truck crossing time. A buffer index measures the reliability of travel service and is calculated as the ratio between the difference of the 95th percentile travel time and the average travel time divided by the average travel time. The buffer index is the extra time required to cross the border above the usual (average) time and indicates reliability of the service. From an operational perspective, it would be interesting to understand why the reliability of truck crossing time increased so much during the month of November. An increase in the volume of trucks crossing the border during the month of November might explain the high buffer index.

Table 5. Monthly Variation of Truck Crossing Times at the Pharr-Reynosa International Bridge.

Month-Year	Average Crossing Time (R1-R4)	95th Percentile Crossing Time	95th - Average	Buffer Index	Median	Sample Size
	(1)	(2)	(3) = (2)-(1)	(4)=(3)/(1)	(5)	(6)
Oct-09	43.9	95.0	51.0	116%	37.9	14811
Nov-09	52.2	106.8	54.6	105%	45.7	11383
Dec-09	50.7	103.5	52.8	104%	44.3	4974
Jan-10	51.3	106.6	55.3	108%	44.3	3040
Feb-10	57.4	105.9	48.5	84%	54.9	3677
Mar-10	54.6	109.1	54.5	100%	48.4	5728
Apr-10	48.8	102.9	54.1	111%	41.9	5003
May-10	51.5	103.9	52.3	102%	45.7	5565
Jun-10	51.0	106.1	55.2	108%	44.3	3198
Jul-10	61.2	112.4	51.3	84%	57.5	3878
Aug-10	59.2	111.3	52.1	88%	55.2	6233

Note: Units are in Minutes except for Buffer Index and Sample Size.

Based on the understanding of variation in travel time on segments, the following recommendations can be drawn:

1. If R3 could be moved to U.S. primary, it would show the actual travel time from the exit of the Mexican toll booth to the U.S. CBP primary inspection. The overall crossing times would not change, but the data would reflect more closely the definition that has been established by CBP and U.S. DOT (United States Department of Transportation) for crossing times.

2. Installing a fifth reader at the exit of the federal compound would show the actual travel time through the BSIF operated by the Texas Department of Public Safety; although, as in number 1, it would not change the overall crossing time.

6. FUTURE OPERATION PLAN

During the initial phases of the project, TTI discussed long-term operation plans with various stakeholders. The majority of the stakeholders agreed that the system should be implemented and operated on a constant basis. Some private sector stakeholders expressed interest in operating the system. Apparently this was a good alternative as the private sector mentioned that operation costs could be absorbed by them. However, after discussion with public sector stakeholders at the federal and state level, it was decided that the system should be operated by a public-sector agency. This would maintain the integrity of the information and all stakeholders would feel that the information presented is valid.

Data Dissemination Plan

As part of the effort to identify the future operation of the system and the data dissemination plan, FHWA awarded a contract to Battelle and TTI to perform additional work in the Pharr-Reynosa International Bridge. The contract included two main areas. First is the installation of additional RFID readers at the CBP primary inspection booths and the second main part of the scope is preparing a guidebook for analysis and dissemination of Border Crossing Time and Border Wait Time Data.

For the first set of activities, TTI performed an interference test at the Pharr CBP facility to identify potential issues between the study RFID system and the various systems initialized by CBP. The test was successful and as of November 2010, TTI and Battelle are preparing an installation permit to be filed with the General Service Administration (GSA). Once the readers are installed at the primary inspection booths, R3 readers currently at the Pharr International Bridge property will be removed and used at CBP Primary.

For the second main area of activity, TTI has prepared four sample reports so that information could be disseminated to the different stakeholders. Appendix F presents the detailed information for each of these sample reports.

The first report is a “Monthly Average Northbound Crossing Time of Trucks.” This report includes the average of crossing times over a 30-day period, the 95th percentile, the median, the sample size, and the buffer index. This report could be prepared in tabular and column chart forms. The report could be published on the website, with users querying month and year ranges and view/download the table and the accompanying chart.

The second sample report is the “Monthly Performance of Northbound Truck Crossing.” It contains the simple average of crossing times over a 30-day period, the 95th percentile, the median, the sample size, the buffer index, and the northbound truck volume. The report could be prepared for tabular as well as a column chart view. It could be accessed through the Internet, where users can query month and year ranges and view/download the table and the accompanying chart.

The third report is the "Histogram of Truck Crossing Times." It presents a histogram of raw crossing times over a 30-day period on a column chart. The report could be accessed on the website where users can define the month or the week for which the histogram will be produced.

The fourth sample report that was prepared is the "Daily Variation of Average Crossing Time of Northbound Trucks." This report presents average crossing time of trucks calculated every 15 minutes. It is a line chart that could be accessed at the website where users can define the date.

Next Steps

The operation of the Border Crossing Time measuring system at the Pharr-Reynosa International Bridge will be covered under the new FHWA contract with Battelle and TTI. For the duration of this contract, the research team working with TxDOT and FHWA would identify the long-term operation strategy for this and other systems that are being implemented. The preliminary data dissemination tools (website and reports) have already been developed. However, it is important to identify funding sources and the agency that will be responsible for the long-term operation of the system. The FHWA contract is in effect until January 30, 2012.

APPENDIX A – DISCUSSION OF BORDER AND CROSSING TIME ELEMENTS

The following is an excerpt from the Part I Final Report of the "Measuring Border Delay and Crossing Times at the U.S.-Mexico Border" project. The study was conducted by TTI for the Federal Highway Administration.[6]

> The delay associated with the border crossing…can…be described in different ways. In 2002… a study (was conducted) 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. The following graph describes the differences between the free flow travel time, the optimal crossing time, and the high volume crossing time.
>
> Figure A-1 illustrates these definitions.

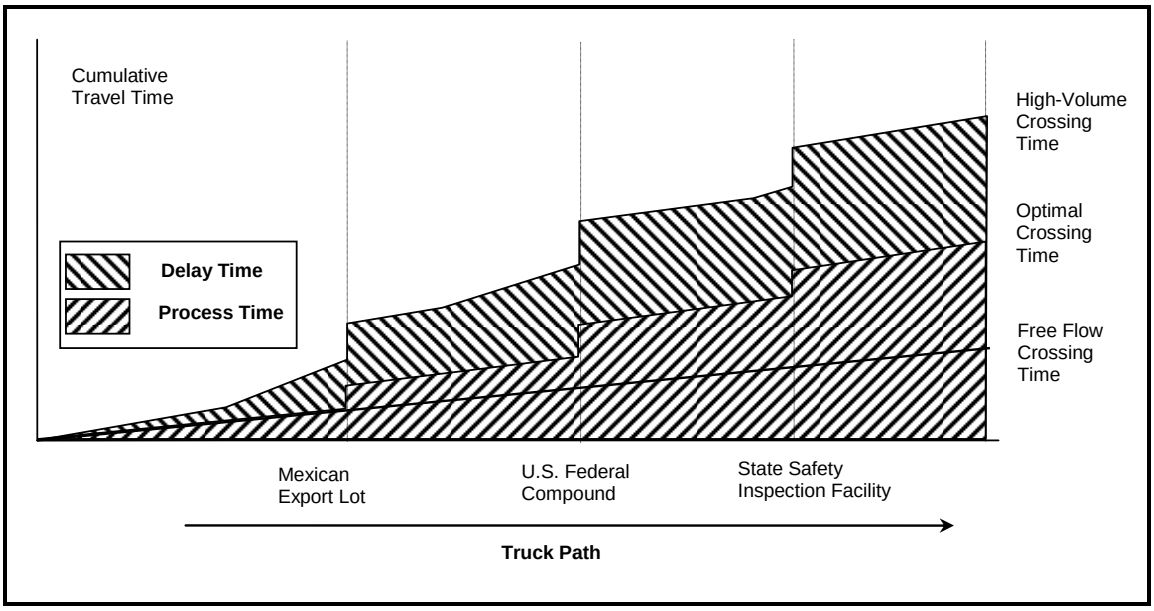


Figure A-1. Border Crossing Times under Different Scenarios.

> As shown on the graph, the free-flow crossing time would be that where the truck would not 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

[6] The full report can be found at http://tti.tamu.edu/documents/TTI-2007-1.pdf

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, or:

Border Crossing Delay = (observed truck crossing time) – (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 follows:

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

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 FAST expedites processing for commercial carriers who have completed background checks and fulfill certain eligibility requirements.

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.

In practice, the algorithms developed for crossing time measurement in this project did not measure delay but rather total crossing time (in a later stage they will also measure wait time). FAST lanes were included in the calculation for all lanes, as the more complete segmentation discussed in the following section was not implemented.

APPENDIX B – STAKEHOLDER MEETING PARTICIPANT LIST

Name	Organization
Manuel Beltran	AA. Francisco Almanza
Maricarmen Castillo	AV Cargo
Luis Rosales	Cal y Mayor
Luis Manuel Lastra	CAPUFE
Jorge Luis Lopez	Canacar Rio Bravo
Ernesto de la Torre	Canacar Rio Bravo
Alfredo Perez S.	Canacar Rio Bravo
Leonardo Varela	Canacar Rio Bravo
Alberto Gonzalez Karam	CAPUFE
Lauro Garza	CBP
Dianne Vlasik	CBP
Teclo J Garcia	City of McAllen
Damazo Villafranca	CONATRAM
Oscar Garza Herrera	CONATRAM
Manuel Quilantan	DPS Pharr
Elizardo Gonzalez	Elgo S.A.
Lupita Zuniga	Fletes y Cruces Front.
Jaime Garcia	FMCSA
Javier Rios	FYASA
Humberto Herrera	FYASA
E. Sustaita P.	Grupo Aduanal Sustaita
George Ramon	Hidalgo Bridge
Maria Champine	Hidalgo County MPO
Yadira Chavez	Hidalgo County MPO
Pat Townsend	Mission EcoDev
Jessie Medina	Pharr Bridge
Manuel Cuan	SCT
William Knight	SCT Reynosa
Jose Rodriguez III	Texas DPS
Juan Villa	TTI
Dave Winterich	TTI
Jesus S. Leal	TxDOT
Esther Hitzfelder	TxDOT
Gus de la Rosa	TxDOT
Mario Jorge	TxDOT

APPENDIX C – PHARR/REYNOSA SITE VISIT REPORT

October 6, 2008

Participants:

Juan Carlos Villa, TTI
Joseph Leal, TxDOT Pharr District
Roberto Fina, J.E. Saenz & Associates –City of Pharr Engineer

1. Meeting with CAPUFE (Caminos y Puentes Federales de Ingresos y Servicios Conexos)

Met with Lic. Alberto González Karam, Subdelegado de CAPUFE in Reynosa. CAPUFE operates the Bridge toll collection plazas and the 1.5 mile roadway between the toll collection plaza and the Reynosa-Rio Bravo highway. Mr. Gonzalez explained that the SCT recently published an RFP for the eventual concession of the Northeast Road Package that includes the construction of several roadways in Mexico's Northeast and the Bridge in Pharr is part of the package. The winner of the concession will have the option to choose to operate the International Bridge or contract CAPUFE to perform the toll collection and operation of the Bridge and connecting roadway. The SCT expects to award the concession at the end of July 2009. CAPUFE mentioned that the Border Wait Time project will add value to the concession, therefore, the installation and operation of the system needs to be accelerated.

2. Potential Location of RFID Readers

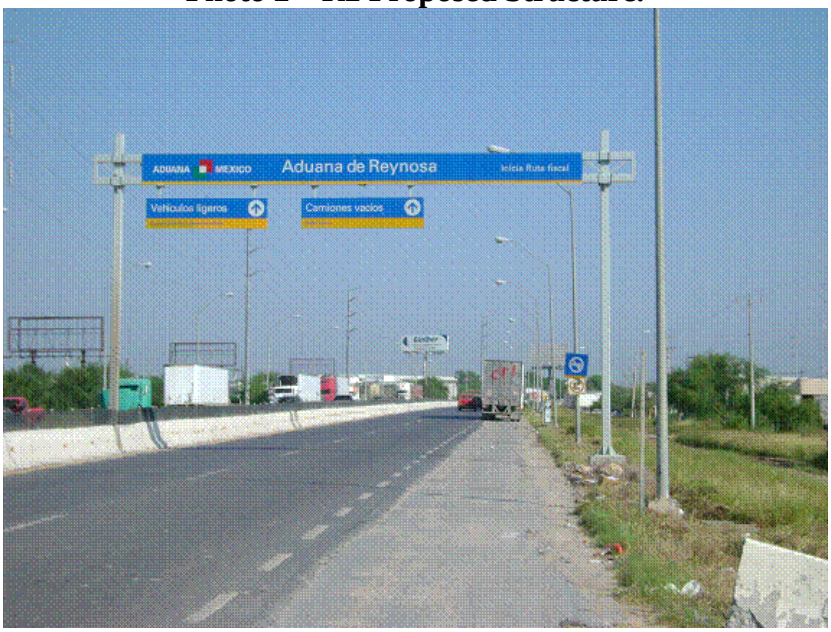
In order to collect sufficient information to define travel time for northbound commercial traffic, three readers would be required on the Mexican side of the border. The first reader should be installed at the farthest south location where trucks would be detected as approaching the International Bridge (R1). This is the only access to the bridge for commercial vehicles. A second reader could be installed before trucks have the option to turn into the "Camino al Ejido El Guerreño," which is located halfway between the Reynosa-Rio Bravo highway and the toll booth (R2). This road leads to a container depot and some trucks can drop containers there. The third reader would be installed at the CAPUFE toll booth, just before trucks enter the actual Bridge and after they have cleared Mexican Customs (Aduanas).

With Mr. Gonzalez, the team visited the roadway that leads to the toll booths and the Aduana inspection. The location of the first reader could be done approximately ¼ of a mile south of the Reynosa-Rio Bravo highway. Since there is no structure at this location, a new structure is required. The structure should be wide enough to cover not only the two existing lanes, but with sufficient span for the proposed additional lanes that could be built in the future (Photo 1).

Photo 1 – Potential Location of Reader 1.

The second reader (R2) could be installed on an existing structure that could hold the equipment and antennas (Photo2).

Photo 2 – R2 Proposed Structure.



The third set of readers on the Mexican side of the border could be mounted on the existing booths, where two readers are already installed for CAPUFE's toll collection use (Photo 3). There are currently four booths that serve commercial vehicles with power available for the equipment at this location (R3).

Photo 3 – CAPUFE's Toll Booths.

On the U.S. side of the border, the first reader could be installed at a point where commercial traffic is segregated from passenger vehicles. This location on bridge property and before the Customs and Border protection compound. This location is two lanes wide (R4).

Photo 4 – U.S. Side Bridge Location.

The second reader on the U.S. side would be installed at the exit of the DPS Temporary Inspection Facility. There is one lane at the exit of the facility and there is a post that could potentially be used to install the equipment (R5).

Photo 5 – DPS Safety Inspection Station Exit.

3. Next Steps

In order to expedite the installation of the equipment, Mr. Gonzales provided us with information of a local company that installed the readers at the CAPUFE toll collection booths. The project team will contact the contractor to request cost estimates for building and installing the required structures as well as the installation of the equipment. The company has the capability to work on both the U.S. and the Mexican side of the border.

APPENDIX D – EQUIPMENT INSTALLATION AUTHORIZATION LETTERS

March 21, 2009

Jesse J. Medina
Pharr-Reynosa International Bridge Director

Re: Commercial Border Crossing and Wait Time Measurement at Pharr-Reynosa International Bridge

Dear Jesse,

TxDOT and the Texas Transportation Institute have continued to work on the referenced project identifying location to install RFID readers. After meeting with stakeholders and CAPUFE, TTI is recommending to install 2 readers in the Mexican side of the border and 2 in the U.S. side of the border, as shown in Figure D-1.

Figure D-1. Pharr-Reynosa International Bridge Reader Location.

Reader R3 is located within the Pharr-Reynosa International Bridge property. The proposed location of the pole where the reader will be placed in shown on Figure D-2.

Figure D-2. R3 Location and Characteristics.

We are finalizing the contracts with the installation company that will perform the installation of the poles and would like to obtain an official permission from the Pharr-Reynosa International Bridge to erect the pole in the proposed location. In order to reduce costs of this project, we would also like to obtain 110 Volts power at this location. Site visits have shown that there is power supply in the area for lighting.

Please let me know when would be a good time we have a conference call to coordinate a visit from the company that is quoting the pole erection work so they can visit with you the site and define the final location for the pole.

Once the final location is selected, we would like to obtain from the Bridge an official authorization to perform the installation of the pole and providing the energy.

Sincerely

Agustin "Gus" De La Rosa
International Relations Office
Government & Public Affairs Division
Texas Department of Transportation

From: Jesse Medina [mailto:jjmedina@cityofpharr.com]
Sent: Wednesday, September 30, 2009 12:08 PM
To: Villa, Juan
Subject: Traffic overhead tower at the Pharr POE

Mr. Villa, I writing to confirm the approval of the elevated tower cross mounts at the Pharr POE. Mr. Hugo Gonzalez came be and presented himself as well as provided me with the design of the overhead system. This letter confirms my approval.
Thank you for your work in this matter, J. Medina

Caminos y Puentes Federales de Ingresos y Servicios Conexos
Delegación Regional VIII-Zona Noreste
Subdelegación de Operación

DNE/SRO/0329/2009/

Asunto: Seguimiento a la Autorización de instalación de equipo del Sistema de Medición del Tiempo de Cruce Fronterizo en el Puente Internacional Reynosa-Pharr

Cd. Reynosa, Tam., a 28 de Febrero del 2009

Ing. Juan Carlos Villa
Instituto de Transporte de Texas (TTI)
P r e s e n t e

Por este conducto me permito enviar anexo al presente el **Oficio DNE/SRO/0198/2009/** de fecha **9 de Febrero del 2009**, remitido al **Lic. Guillermo Castillo Caballero**, Director de Operación de Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE), mediante el cual se hace de su conocimiento que los **Estados Unidos**, **Canadá** y **México** por conducto de sus **Titulares de Transporte**, acordaron continuar los trabajos para implementar iniciativas que les permitan armonizar las regulaciones sobre seguridad vehicular e identificar las áreas específicas de cooperación para reducir o prevenir accidentes en las carreteras, así como establecer proyectos piloto para la aplicación de tecnologías en puntos prioritarios para reducir el congestionamiento vehicular en los cruces fronterizos, con el compromiso de fortalecer el flujo eficiente y seguro de bienes y personas, lo que constituye un factor para maximizar los beneficios del **Tratado de Libre Comercio de América del Norte** (**TLCAN**).

Es importante destacar que se dará atención continua a las políticas y enfoques estratégicos dentro del sistema de transporte regional, con el propósito de facilitar el comercio y el crecimiento económico, mediante la realización de los estudios de análisis costo-beneficio que identifiquen áreas específicas de cooperación regulatoria para reducir y prevenir accidentes.

Dentro de las medidas acordadas, se encuentran: establecer proyectos piloto para implementar tecnologías del **Sistema Inteligente del Trasporte** o **Intelligent Transport Systems** (**ITS**) en puntos prioritarios, para reducir la congestión en los puentes internacionales, así como aplicar iniciativas de planeación de infraestructura para promover y apoyar proyectos estratégicos, en estrecha cooperación y coordinación con las partes involucradas.

El **Departamento de Transporte de Texas** (**TxDOT**), en conjunto con la **Administración Federal de Autopistas** del **Departamento de Transporte de Estados Unidos** (**FHWA**) y la **Alianza de Comercio Fronterizo** (**BTA**) están desarrollando un proyecto para la implementación de tecnologías en puntos prioritarios para reducir el congestionamiento vial en cruces fronterizos y medir el tiempo de cruce de vehículos comerciales en el **Puente Internacional de Pharr-Reynosa**.

La meta de este programa es implementar un sistema usando **Tecnología de Identificación de Radiofrecuencia** (**RFID**) que puede automáticamente y con precisión medir el tiempo de cruce de frontera para transporte de carga cruzando de **México** a **Estados Unidos**.

El Tiempo de espera para los vehículos de motor comerciales que entran y salen de los **Estados Unidos** en los puertos de entrada con **México** es un indicador clave de transporte

internacional y la cadena de suministro.

Los datos recopilados serán difundidos a través de un sistema que se desarrolló con un proyecto independiente realizado por el **Instituto de Transporte de Texas** (**TTI**) para la **Administración Federal de Carreteras** (**FHWA**).

En función de los antecedentes y avances anteriores, me permití solicitar el valioso apoyo y colaboración de la **Dirección de Operación**, a fin de autorizar en la parte mexicana la realización del **Sistema de Medición del Tiempo de Cruce Fronterizo** en el **Puente Internacional Reynosa-Pharr**, así como aprobar la instalación de **Equipos de Identificación de Radiofrecuencia** (**RFID**) por parte del **Instituto de Transporte de Texas** (**TTI**) en las siguientes dos posiciones:

1. En el centro de la estructura del señalamiento horizontal que se ubica en el camino de acceso al Puente Internacional Reynosa-Pharr, mismo que se localiza a 200 metros al norte del distribuidor vial, a fin de cubrir dos carriles de circulación en el sentido México-Estados Unidos, siendo colocados paneles solares para la energía necesaria de los lectores de RFID.

2. Instalación de 4 lectores de RFID en la techumbre de las casetas de cobro del Puente Internacional Reynosa-Pharr, a fin de cubrir los 4 carriles de circulación del transporte de carga de exportación, mismos que estarán ubicados en el extremo norte para evitar cualquier interferencia y se estaría utilizando el servicio de energía eléctrica del edificio de la Plaza de Cobro PC-75, contando con sus respectivas baterías de emergencia.

Lo anterior se remite para su conocimiento y todos aquellos efectos que sean procedentes en lo particular, en el entendido que se ha solicitado el valioso apoyo y colaboración de la **Dirección de Operación** de **Caminos y Puentes Federales de Ingresos y Servicios Conexos** (**CAPUFE**), para contribuir con la implementación de la iniciativa trilateral del **Sistema de Medición del Tiempo de Cruce Fronterizo** en el **Puente Internacional Reynosa-Pharr** de la **Red del Fondo Nacional de Infraestructura** (**FONADIN**), le reitero la seguridad de mi atenta y distinguida consideración.

A t e n t a m e n t e

El Subdelegado de Operación

Lic. José Alberto González Káram

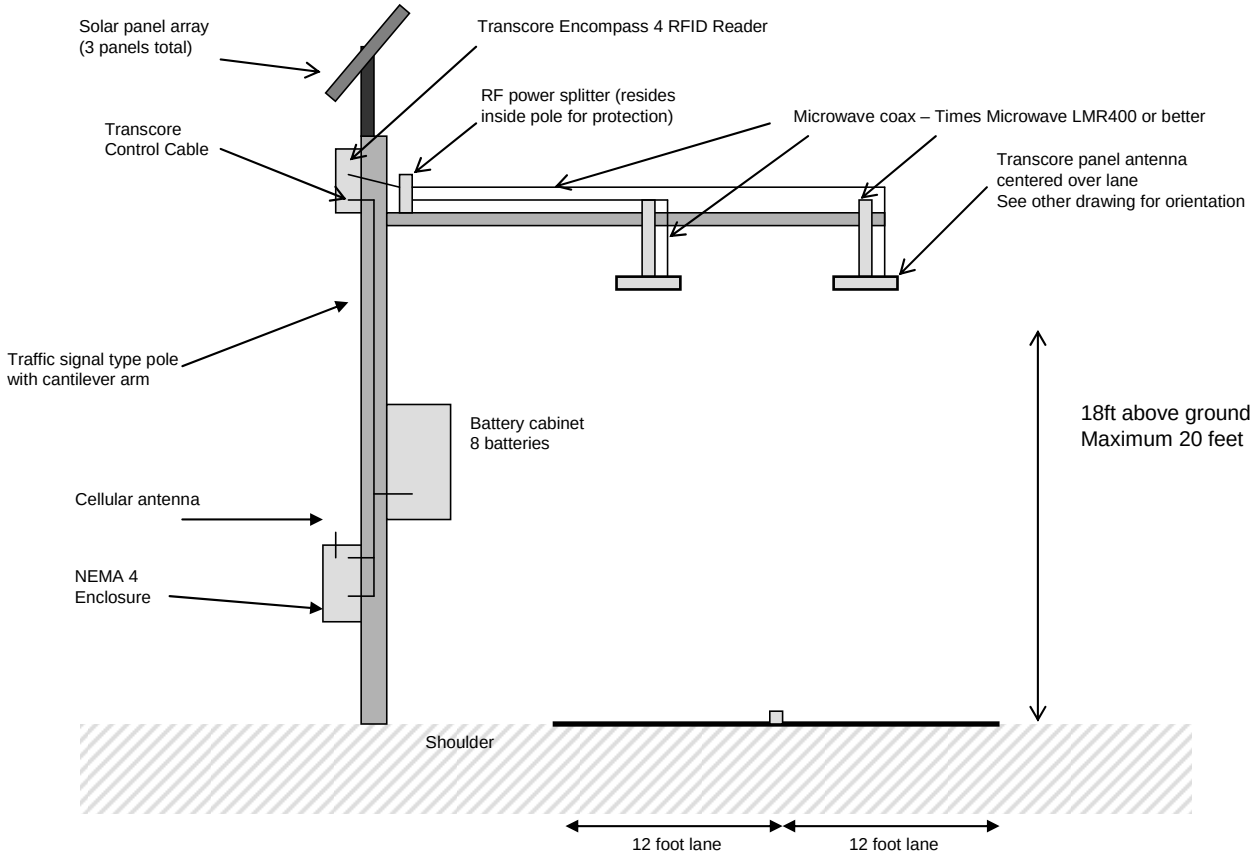
c.c.p.- **Lic. Guillermo Castillo Caballero**.- Director de Operación
c.c.p.- **Lic. Mariem Liliana Andrade Trejo**.- Subdirectora de Control de la Red Concesionada y Contratada.
c.c.p.- **Ing. Ángel Ricardo Zamora Tejeda**.- Subdirector de Supervisión de Operación.
c.c.p.- **Ing. Antonio Navarro Alejos**.- Subdirector de Normas de Operación.
c.c.p.- **Lic. José Luis Hernández Garza**.- Encargado del Despacho de la Delegación Regional VIII-Zona Noreste y Subdelegado Jurídico.
c.c.p.- **Esther Hitzfelder**.- Departamento de Transporte de Texas (TxDOT).
c.c.p.- **Archivo.**

APPENDIX E – EQUIPMENT INSTALLATION MANUAL

Back Panel Assignment

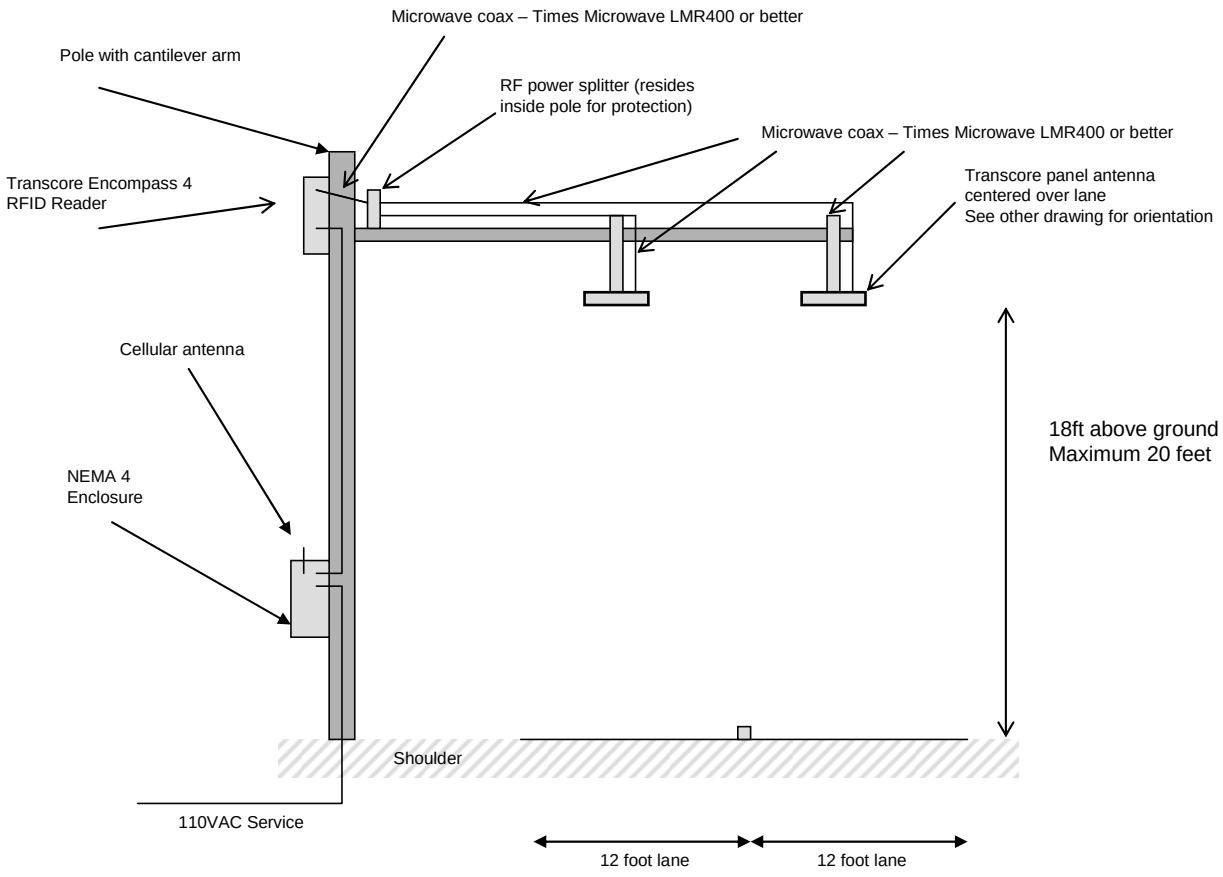
- Site R1 [MX] (Solar) – Back panel 04
  - The only DC powered panel
- Site R2 [MX] (Toll Plaza) – Back panel 01
  - The only panel with 2 reader connections
- Site R3 [US] (Split) – Back panel 02
  - A/C powered panel
- Site R4 [US] (DPS) – Back panel 03
  - A/C powered panel

Solar Site – Field Diagram



Two lane tag reading system installation - Not to scale

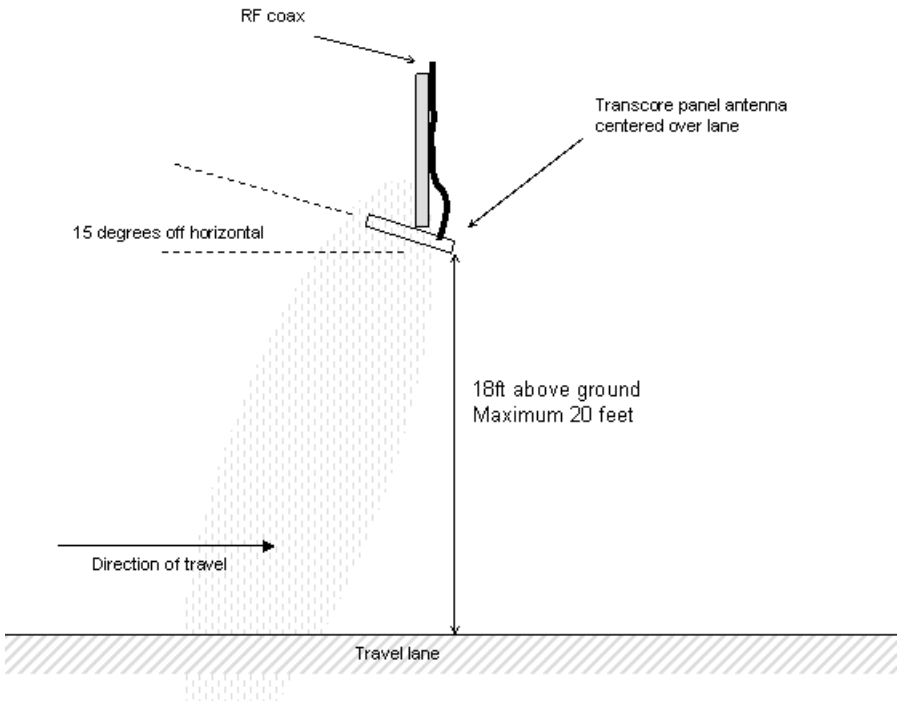
A/C Power Site – Field Diagram



INSPECTION BAYS
PASILLO DE INSPECCIÓN
INSPECTION BAYS ONLY
HC
HC

RFID Reader Mounting Example

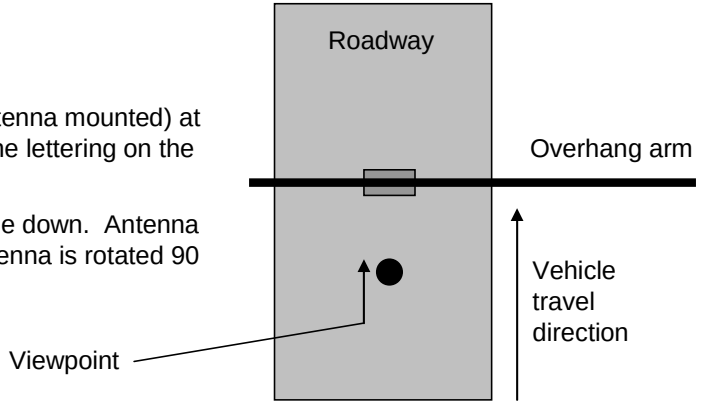
Antenna Orientation

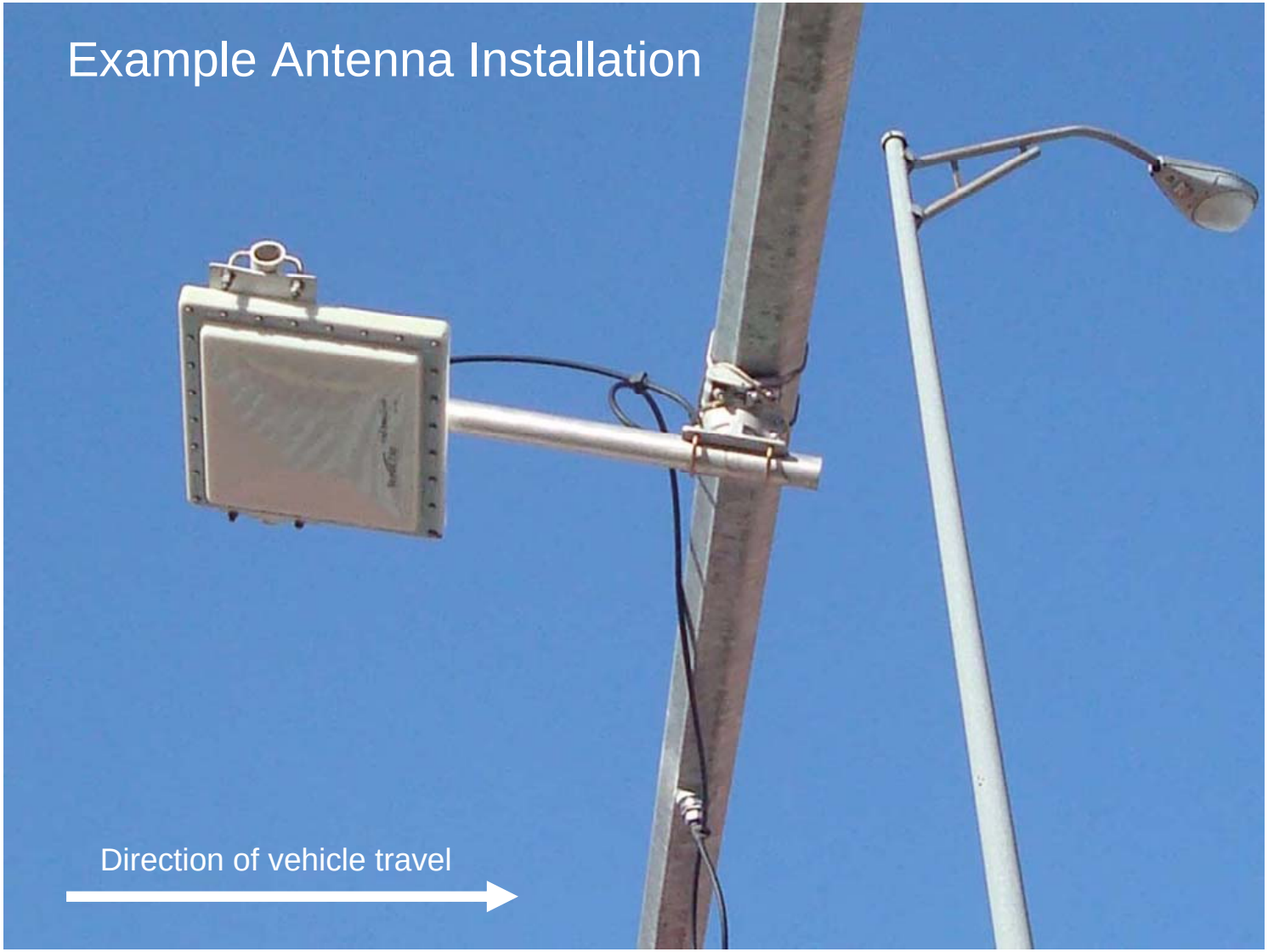


Antenna orientation on the pole:

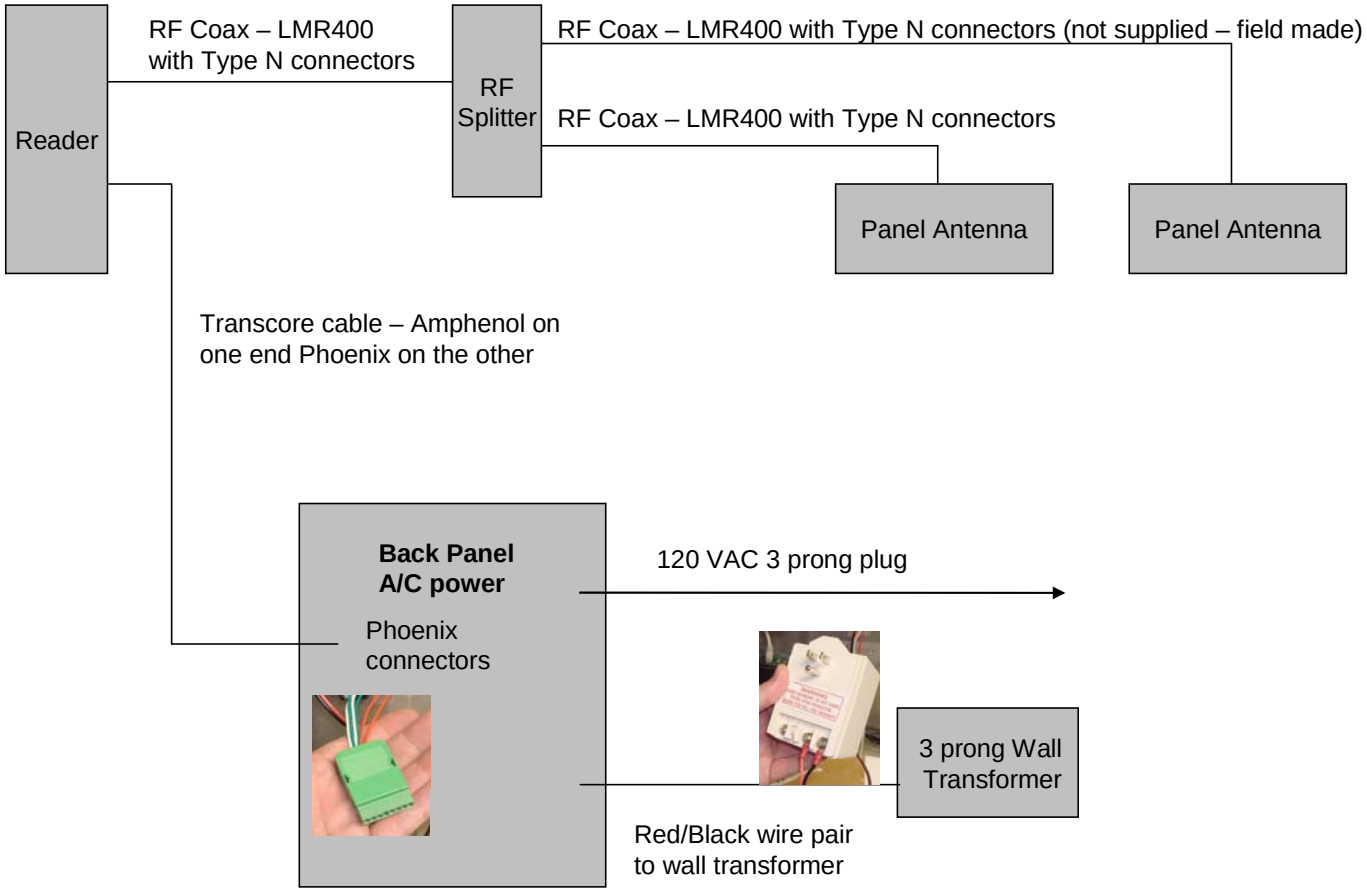
If a person stands in front of the overhanging pole (with the antenna mounted) at the black dot and looks up the person should be able to read the lettering on the panel ("Transcore")

The lettering **MUST BE** horizontal (NOT vertical) and not upside down. Antenna orientation is critical. The system **WILL NOT WORK** if the antenna is rotated 90 or 180 degrees from what is described.

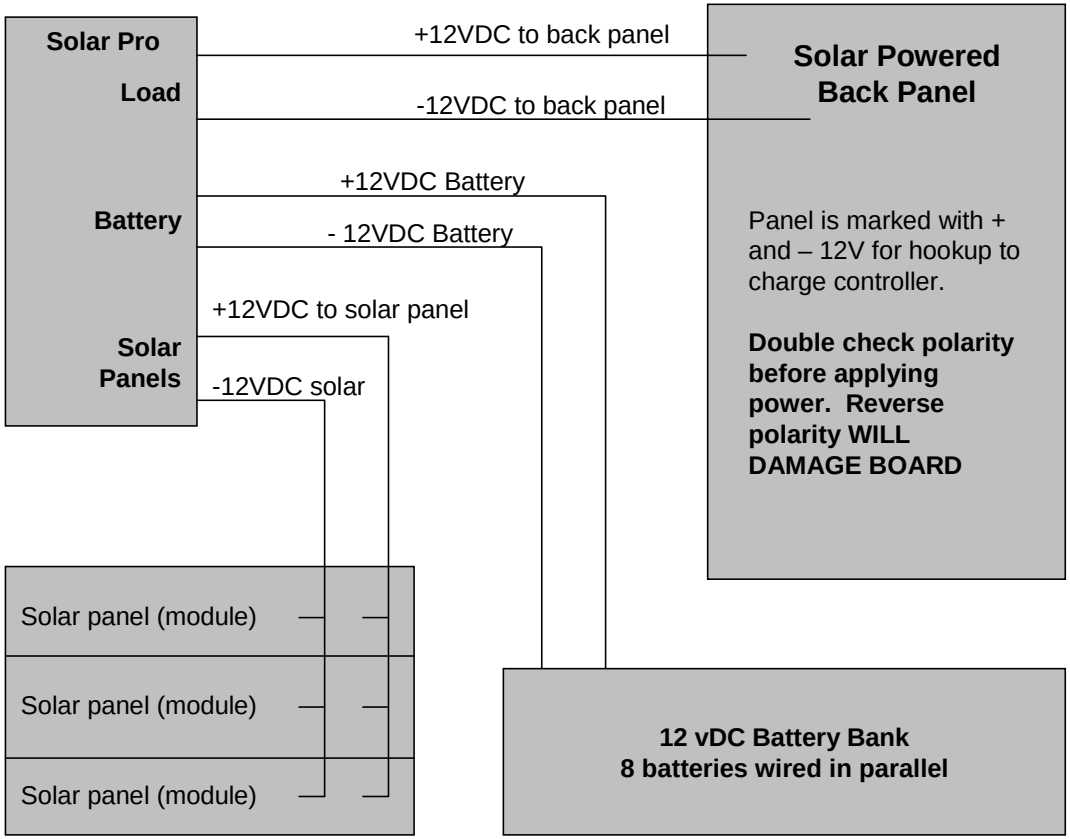



Example Antenna Installation
Direction of vehicle travel

Site Connection Diagram



Solar Pro Charge Controller
Hook up batteries first, then solar, then load.
Controller has a volt / amp meter which measures battery voltage, solar charging current and load draw current.
Load should draw about 2 amps when all working



Back Panel Mounting Example

APPENDIX F – QUICK LOOK REPORTS FOR THE PHARR-REYNOSA INTERNATIONAL BRIDGE

Report Type ID: BCT-1

Report Name: Monthly Average Northbound Crossing Time of Trucks

Parameters: Simple average of crossing times over a 30 day period, 95th percentile, median, sample size, buffer index

95th Percentile crossing time represents a value below which 95% of the samples may be found.

A median is defined as a numeric value separating the higher half of a sample, a population, or a probability distribution, from the lower half. The median value can be found by arranging all the observations from lowest value to highest value and picking the middle one. If there is an even number of observations, then there is no single middle value; the median is then usually defined to be the mean of the two middle values.

Buffer Index: Freight shippers and manufacturers are also concerned about travel time variability (the variation in travel time) and reliability (which relates to reaching destinations at expected times). Longer travel times are an important issue, but the assembly process can be adjusted to accommodate them; it is more difficult to accommodate variable travel times. These impacts may be more varied and require automated data collection mechanisms. As more extensive operating and monitoring mechanisms are deployed, reliability and variability statistics should be collected to assist local operators and shippers. The Buffer Index is a measure of trip reliability that expresses the amount of extra “buffer” time needed to be “on time” for 95% of the trips (e.g., a late shipment on one day per month). The Buffer Index can be calculated for each segment or particular system element.

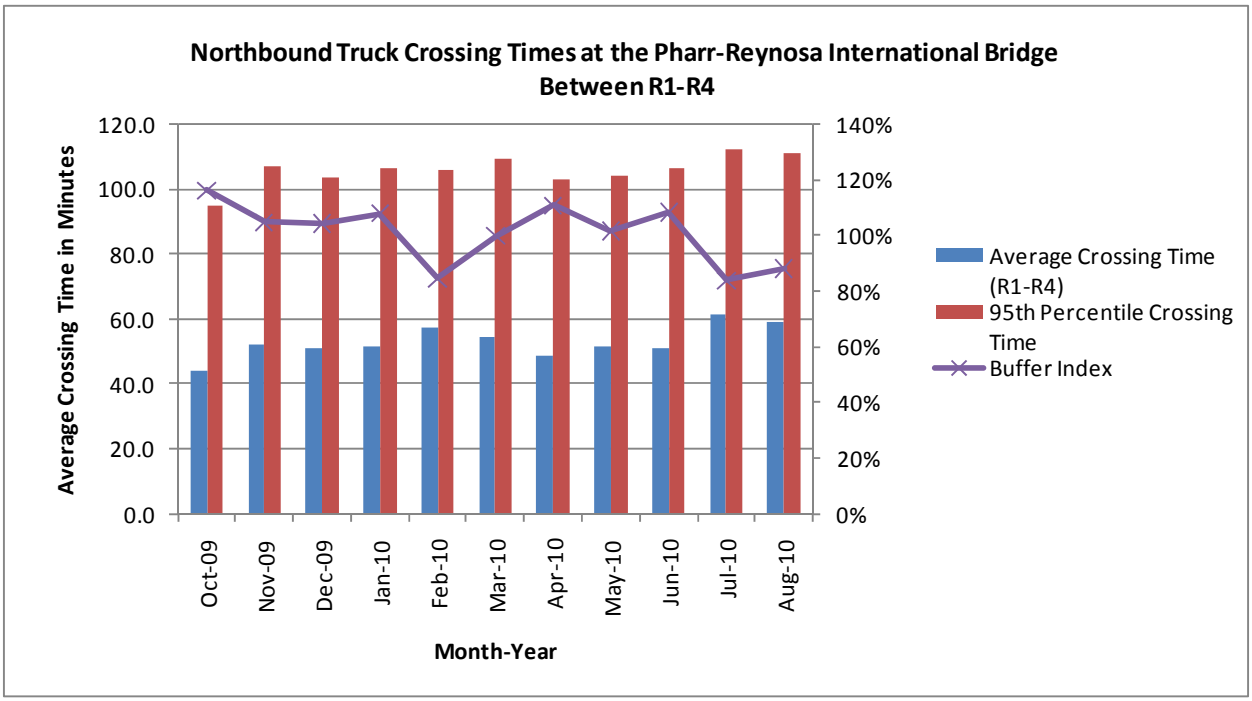
Presentation: Tabular and column chart

Publishing Medium: Website (Users can query month and year range and view/download the table and the accompanying chart)

Sample (all the units except the sample size and the buffer index are in Minutes):

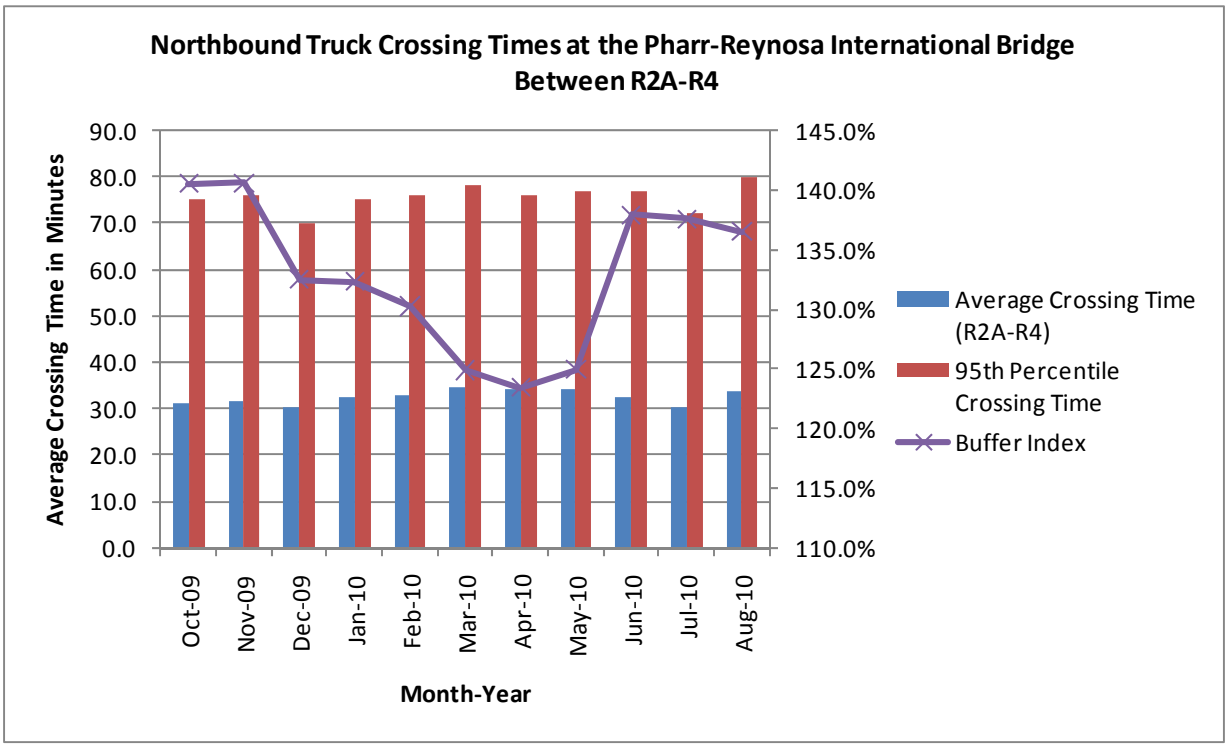
Month-Year	Average Crossing Time (R1 to R4)	95th Percentile Crossing Time	95th - Average	Buffer Index	Median Crossing Time	Sample Size*
	(1)	(2)	(3) = (2)-(1)	(4)=(3)/(1)	(5)	(6)
Oct-09	43.9	95.0	51.0	116%	37.9	14811
Nov-09	52.2	106.8	54.6	105%	45.7	11383
Dec-09	50.7	103.5	52.8	104%	44.3	4974
Jan-10	51.3	106.6	55.3	108%	44.3	3040
Feb-10	57.4	105.9	48.5	84%	54.9	3677
Mar-10	54.6	109.1	54.5	100%	48.4	5728
Apr-10	48.8	102.9	54.1	111%	41.9	5003
May-10	51.5	103.9	52.3	102%	45.7	5565
Jun-10	51.0	106.1	55.2	108%	44.3	3198
Jul-10	61.2	112.4	51.3	84%	57.5	3878
Aug-10	59.2	111.3	52.1	88%	55.2	6233

*Sample size refers the number of transponders that were matched by both RFID reader stations referred as R1 and R4 representing crossing time of trucks
TxDOT = Texas Department of Transportation



Month-Year	Average Crossing Time (R2A-R4)	95th Percentile	95th - Average	Buffer Index	Median	Sample Size*
	(1)	(2)	(3) = (2)-(1)	(4)=(3)/(1)	(5)	(6)
Oct-09	31.2	75.0	43.8	140.5%	24.00	17200
Nov-09	31.6	76.0	44.4	140.6%	24.00	14969
Dec-09	30.1	70.0	39.9	132.5%	24.00	9394
Jan-10	32.3	75.0	42.7	132.3%	26.00	11114
Feb-10	33.0	76.0	43.0	130.2%	27.00	11718
Mar-10	34.7	78.0	43.3	124.9%	29.00	12442
Apr-10	34.0	76.0	42.0	123.5%	28.00	15513
May-10	34.2	77.0	42.8	125.0%	28.00	14337
Jun-10	32.4	77.0	44.6	137.9%	26.00	12560
Jul-10	30.3	72.0	41.7	137.6%	24.00	14714
Aug-10	33.8	80.0	46.2	136.5%	26.00	21070

*Sample size refers the number of transponders that were matched by both RFID reader stations referred as R2A and R4.



Report Type ID: BCT-2

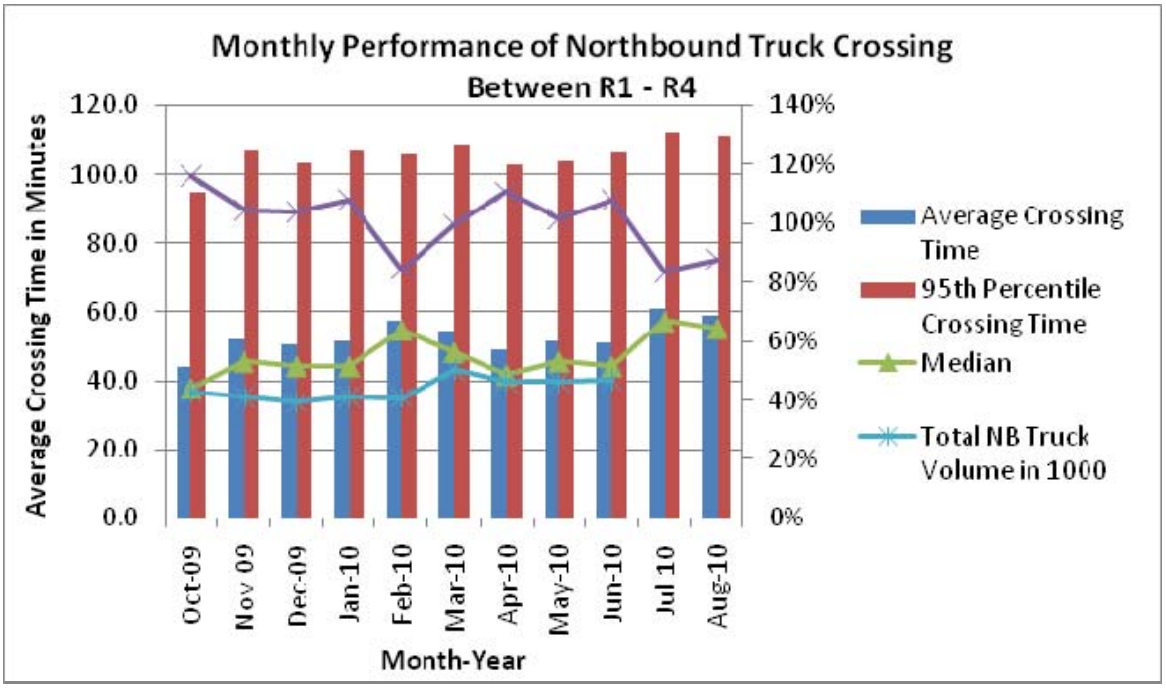
Report Name: Monthly Performance of Northbound Truck Crossing

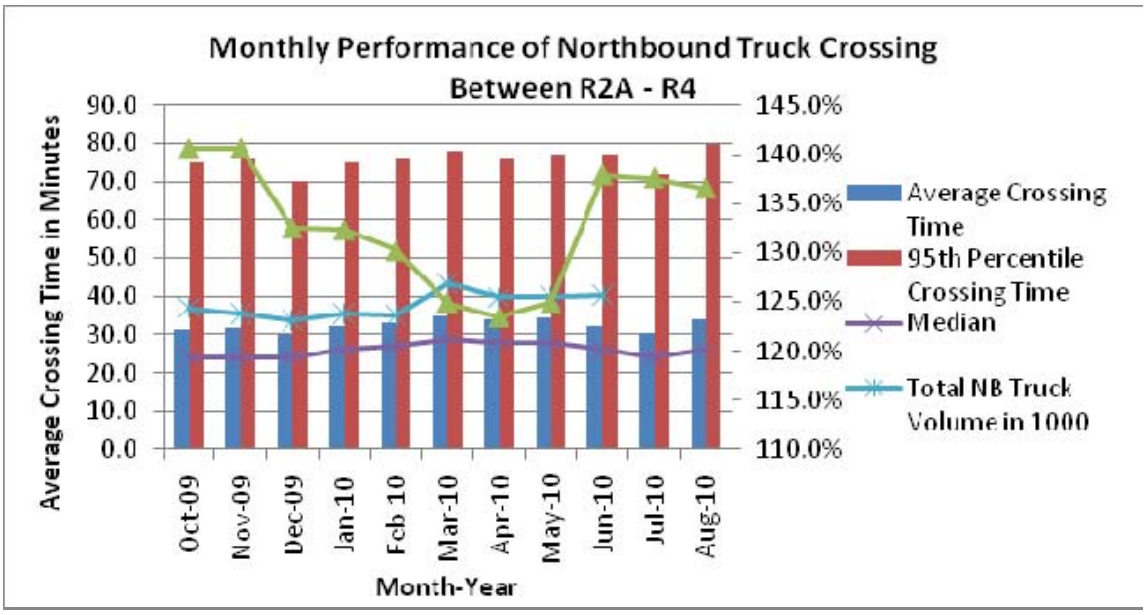
Parameters: Simple average of crossing times over a 30-day period, 95th percentile, median, sample size, buffer index, northbound truck volume

Presentation: Tabular and column chart

Publishing Medium: Website (Users can query month and year range and view/download the table and the accompanying chart)

Sample:





Report Type ID: BCT-3

Report Name: Histogram of Truck Crossing Times

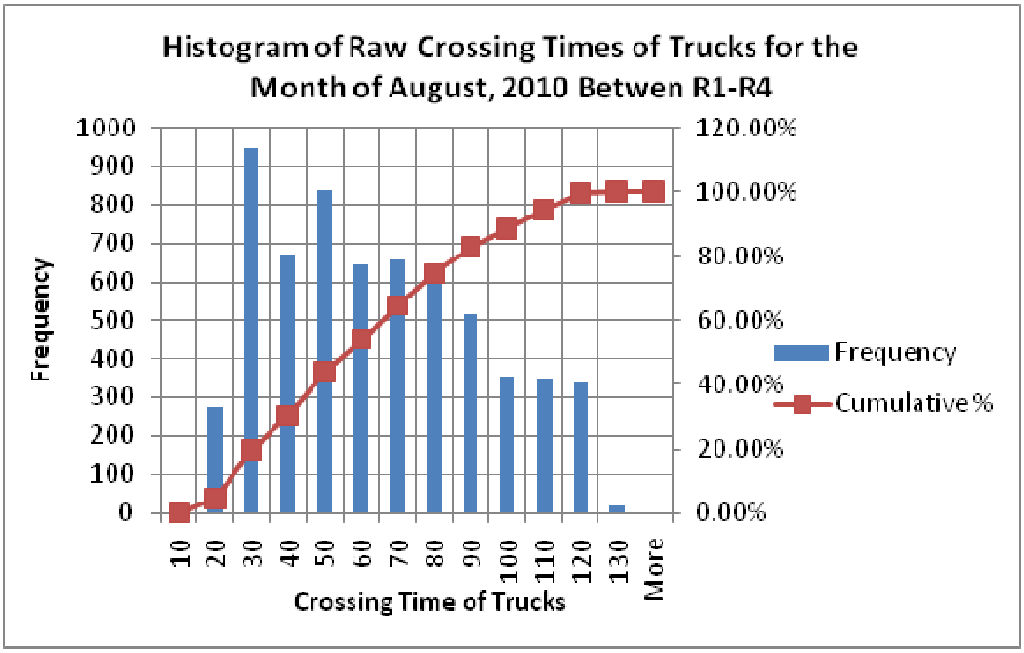
Parameters: Histogram of raw crossing times over a 30-day period

Histogram is a graphical representation, showing a visual impression of the distribution of the data.

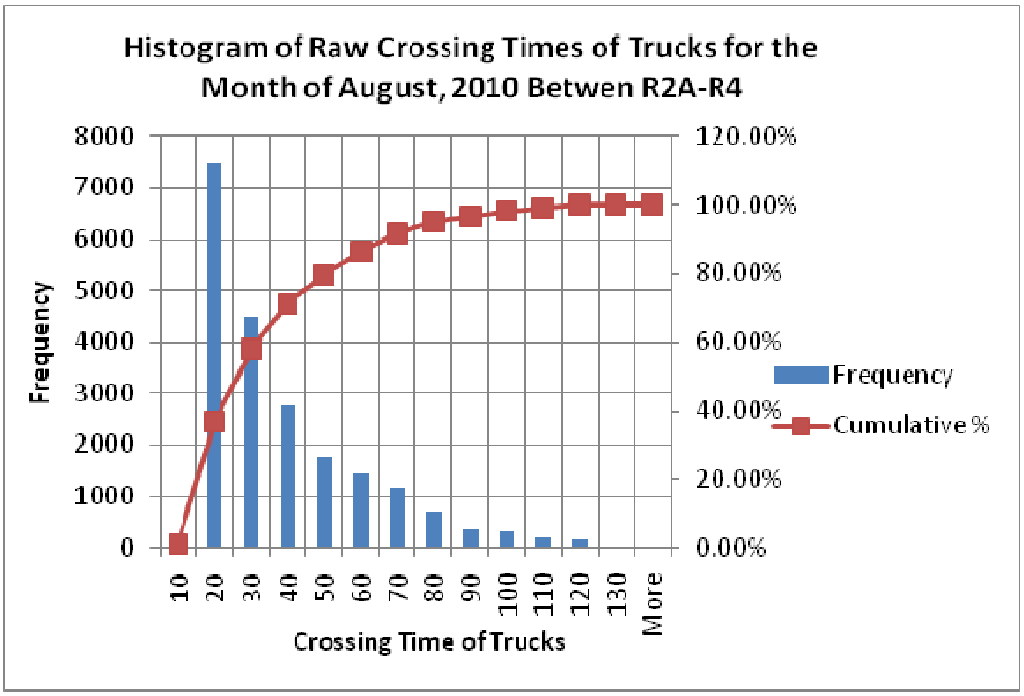
The following histogram show that the 95th percentile of trucks takes approximately 100 minutes or less to cross the border and the 50th percentile of trucks requires approximately 50 minutes or less to cross the border. It also illustrates highly variable crossing times during different times of day. Obviously, empty trucks require less crossing time than non-empty trucks, and trucks enrolled in the FAST program require less crossing time than trucks not enrolled in the program. Being able to distinguish the type of trucks (empty versus loaded) and FAST versus non-FAST by additional RFID readers will provide a better way of distinguishing crossing times of different types of trucks.

Presentation: Column chart

Publishing Medium: Website (Users can define the month or the week for which the histogram will be produced)



The following histogram show that the 95th percentile of trucks takes approximately 80 minutes or less to traverse between reader R2A, which is just north of the Mexican Aduana to the exit of the DPS facility, and 50th percentile of trucks requires approximately 30 minutes or less on the same segment.



Report Type ID: BCT-4

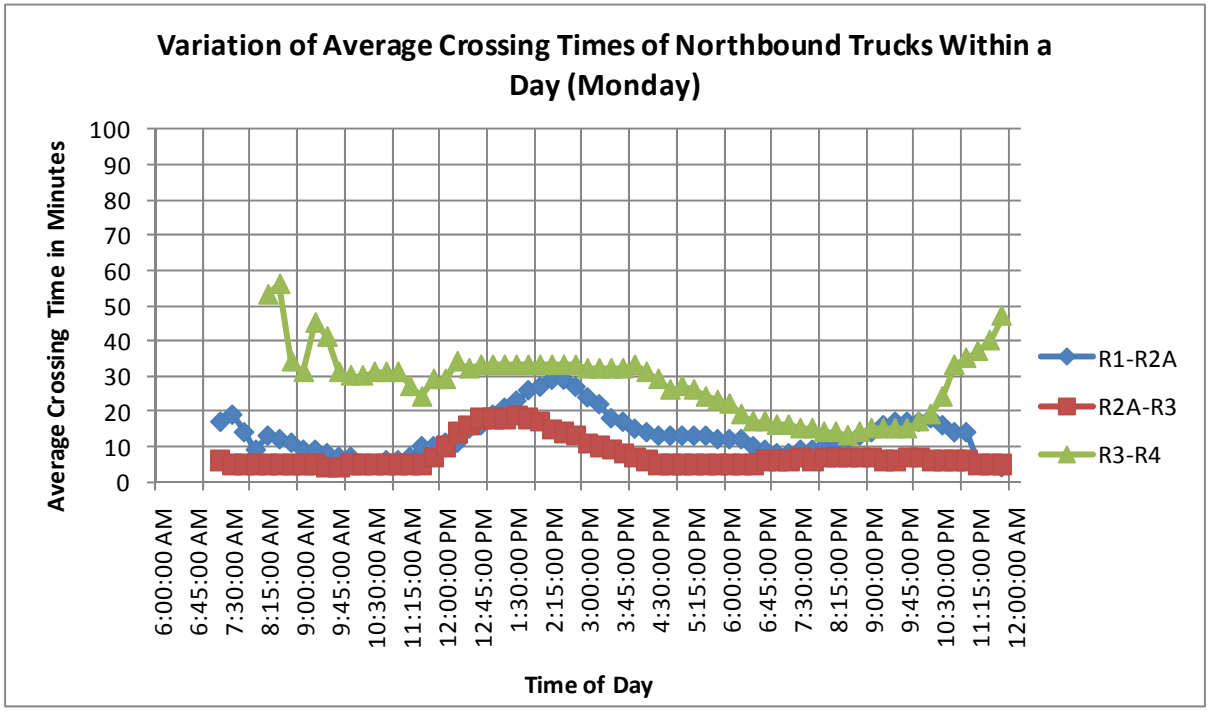
Report Name: Daily Variation of Average Crossing Time of Northbound Trucks

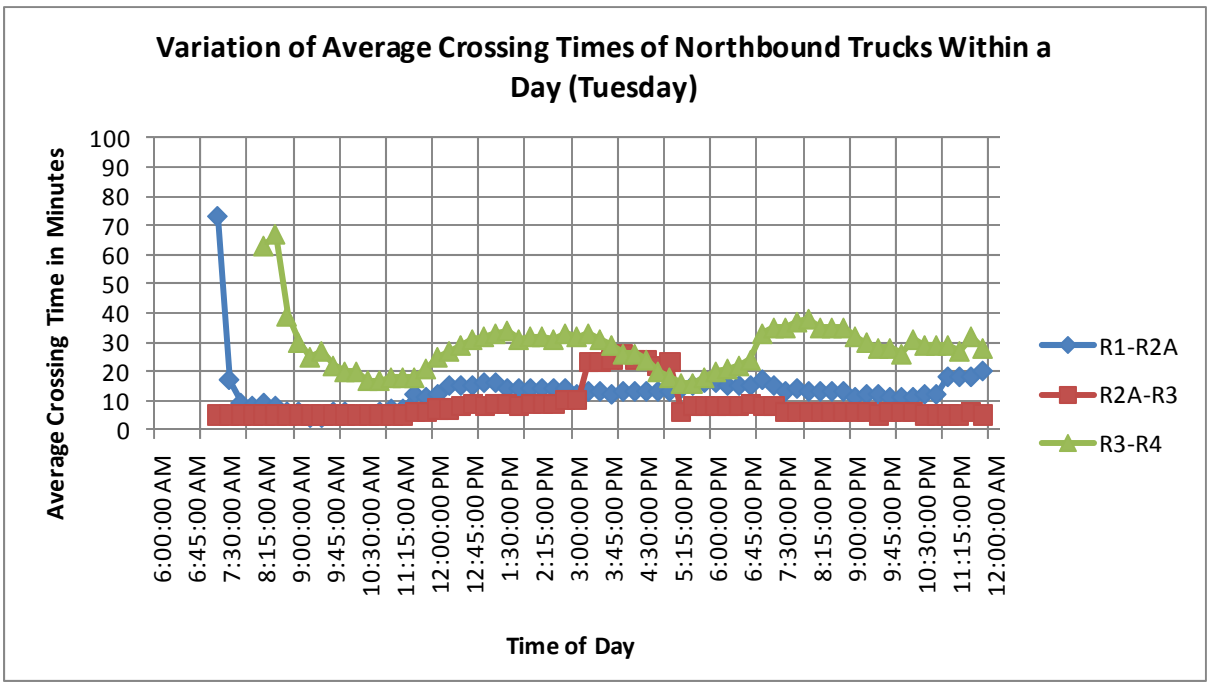
Parameters: Average crossing time of trucks calculated every 15 minutes. (NOTE: The graph below is based on the 15 minute crossing time interval but is labeled as a 45 minute time interval to reduce the clutter of labels on the horizontal axis.

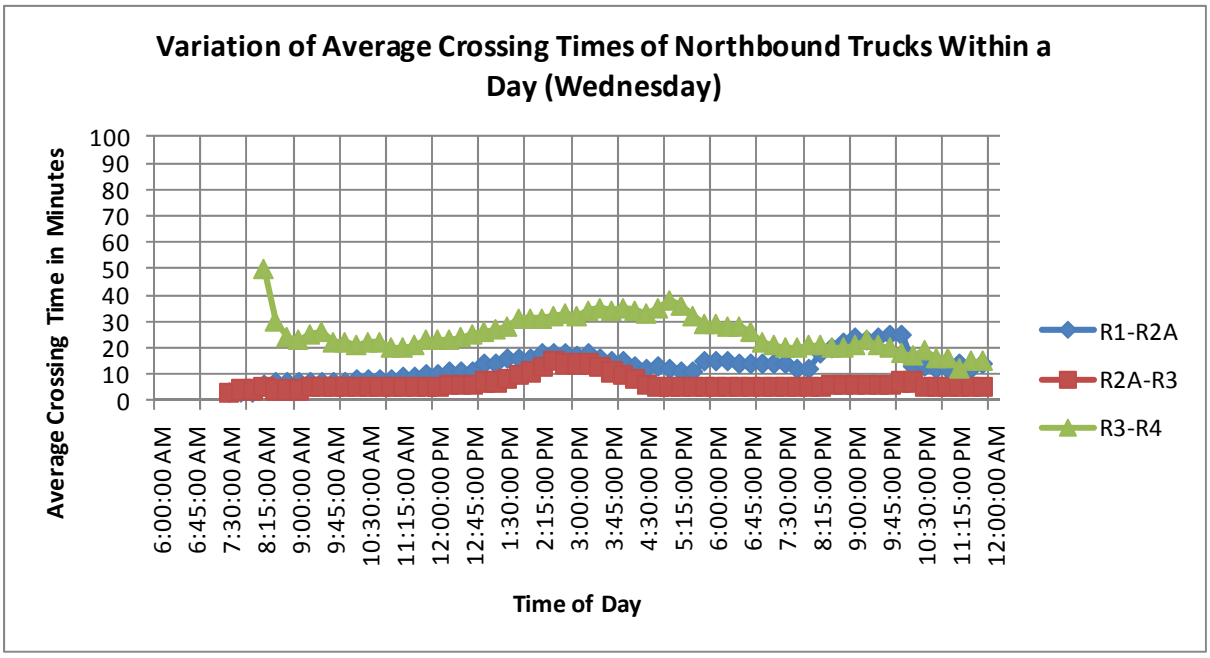
Presentation: Line chart

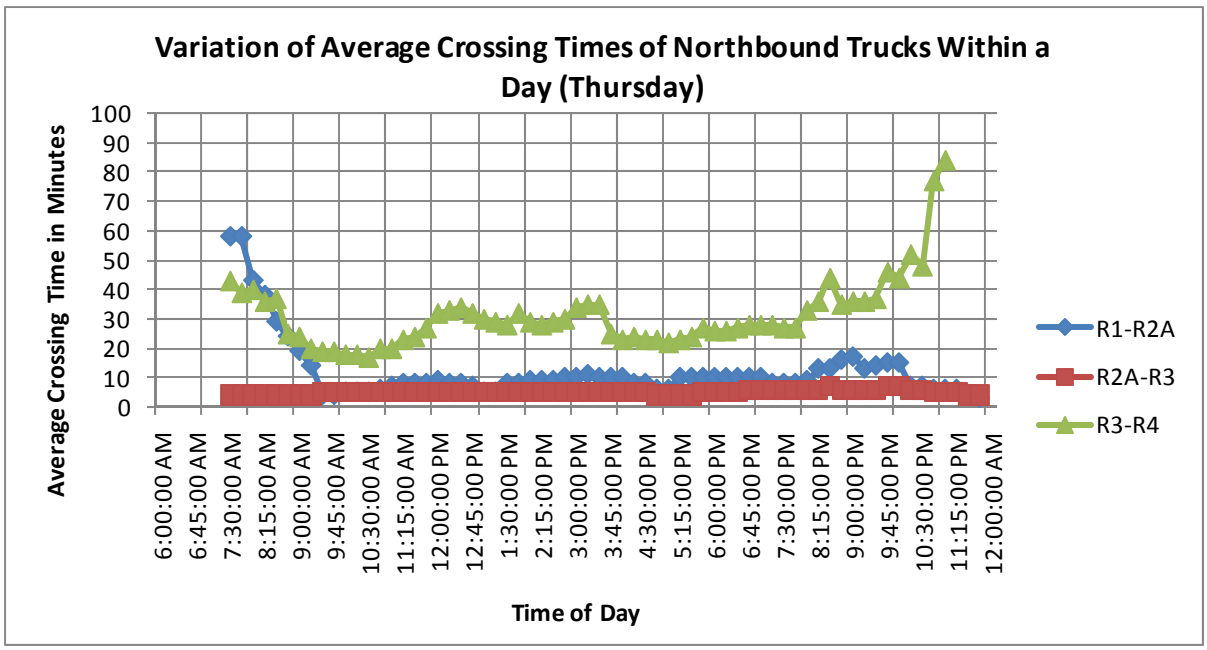
Publishing Medium: Website (Users can define the date)

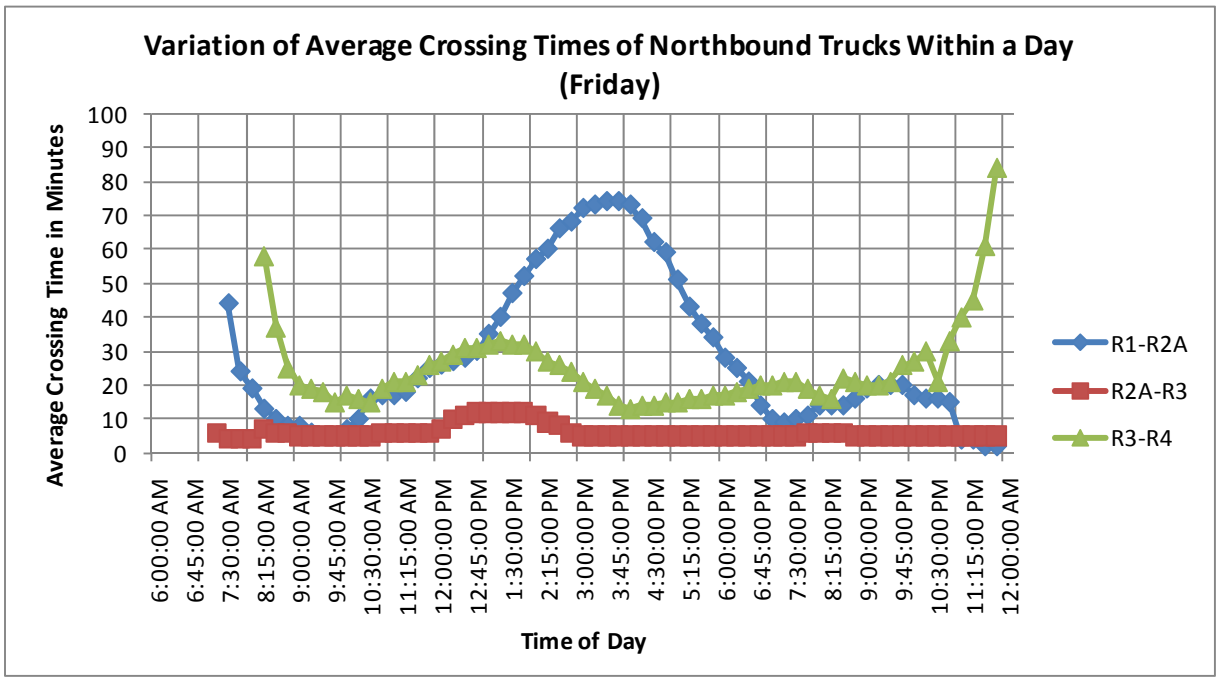
Sample:




Variation of Average Crossing Times of Northbound Trucks Within a Day (Tuesday)
Average Crossing Time in Minutes
100
90
80
70
60
50
40
30
20
10
0
6:00:00 AM
6:45:00 AM
7:30:00 AM
8:15:00 AM
9:00:00 AM
9:45:00 AM
10:30:00 AM
11:15:00 AM
12:00:00 PM
12:45:00 PM
1:30:00 PM
2:15:00 PM
3:00:00 PM
3:45:00 PM
4:30:00 PM
5:15:00 PM
6:00:00 PM
6:45:00 PM
7:30:00 PM
8:15:00 PM
9:00:00 PM
9:45:00 PM
10:30:00 PM
11:15:00 PM
12:00:00 AM
Time of Day
R1-R2A
R2A-R3
R3-R4


Variation of Average Crossing Times of Northbound Trucks Within a Day (Wednesday)
Average Crossing Time in Minutes
100
90
80
70
60
50
40
30
20
10
0
6:00:00 AM
6:45:00 AM
7:30:00 AM
8:15:00 AM
9:00:00 AM
9:45:00 AM
10:30:00 AM
11:15:00 AM
12:00:00 PM
12:45:00 PM
1:30:00 PM
2:15:00 PM
3:00:00 PM
3:45:00 PM
4:30:00 PM
5:15:00 PM
6:00:00 PM
6:45:00 PM
7:30:00 PM
8:15:00 PM
9:00:00 PM
9:45:00 PM
10:30:00 PM
11:15:00 PM
12:00:00 AM
Time of Day
R1-R2A
R2A-R3
R3-R4


Variation of Average Crossing Times of Northbound Trucks Within a Day (Thursday)
Average Crossing Time in Minutes
100
90
80
70
60
50
40
30
20
10
0
6:00:00 AM
6:45:00 AM
7:30:00 AM
8:15:00 AM
9:00:00 AM
9:45:00 AM
10:30:00 AM
11:15:00 AM
12:00:00 PM
12:45:00 PM
1:30:00 PM
2:15:00 PM
3:00:00 PM
3:45:00 PM
4:30:00 PM
5:15:00 PM
6:00:00 PM
6:45:00 PM
7:30:00 PM
8:15:00 PM
9:00:00 PM
9:45:00 PM
10:30:00 PM
11:15:00 PM
12:00:00 AM
Time of Day
R1-R2A
R2A-R3
R3-R4


Variation of Average Crossing Times of Northbound Trucks Within a Day (Friday)
Average Crossing Time in Minutes
100
90
80
70
60
50
40
30
20
10
0
6:00:00 AM
6:45:00 AM
7:30:00 AM
8:15:00 AM
9:00:00 AM
9:45:00 AM
10:30:00 AM
11:15:00 AM
12:00:00 PM
12:45:00 PM
1:30:00 PM
2:15:00 PM
3:00:00 PM
3:45:00 PM
4:30:00 PM
5:15:00 PM
6:00:00 PM
6:45:00 PM
7:30:00 PM
8:15:00 PM
9:00:00 PM
9:45:00 PM
10:30:00 PM
11:15:00 PM
12:00:00 AM
Time of Day
R1-R2A
R2A-R3
R3-R4