

Measuring Border Delay and Crossing Times at the US – Mexico Border

Final Report on Automated Crossing and Wait Time Measurement

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16. Abstract A pilot test implemented a radio frequency identification (RFID) system to automatically measure travel times of US-bound commercial vehicles at a selected Port of Entry (POE) on the US– Mexico border under long-term, real-world conditions. The initiative began with a Part I technology trade-off study of potential detection technologies to measure travel times. A Part II initiative verified RFID as the most appropriate technology for the objectives and implemented a RFID-based reader system the selected POE: the Bridge of the Americas (BOTA) at El Paso, Texas/Ciudad Juarez, Mexico. The initial implementation measured crossing time, which is the average travel time completely through the POE starting at the end of the queue in Mexico. The project later added RFID reader stations at the U.S. Customs and Border Protection (CBP) Primary Inspection booths at BOTA and at the Pharr-Reynosa International Bridge POE in eastern Texas that allowed measurement of wait time. Wait time is the average travel time from the end of the queue in Mexico to the border and is a segment of crossing time. This report documents the technology system’s stakeholder involvement, planning, design, installation, integration, test and evaluation, and real-world operation as well as lessons learned. The project also developed stand-alone documents to assist future implementers of similar automated RFID-based travel time measurement systems.					
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TABLE OF CONTENTS

LIST OF ACRONYMS	vi
NOTICE.....	viii
QUALITY ASSURANCE STATEMENT	ix
FOREWORD.....	x
EXECUTIVE SUMMARY	xi
Acknowledgements.....	xi
Project Tasks and Accomplishments	xi
General Concept of the System.....	xii
Implementation at BOTA and Pharr-Reynosa.....	xiii
CHAPTER 1: BACKGROUND AND OVERVIEW	1
Background.....	1
Part I – Technology Identification and Selection	1
Discussion of Border Wait Times and Crossing Times.....	3
Part II - Pilot Implementation at BOTA and Pharr-Reynosa.....	5
CHAPTER 2: BRIDGE OF THE AMERICAS	9
Value and Significance of the El Paso Region Commercial Trucking Industry.....	9
El Paso – Juárez Port-of-Entry System.....	10
The Bridge of the Americas.....	11
US-bound Crossing Statistics	13
Operational Characteristics.....	14
CHAPTER 3: PHARR-REYNOSA INTERNATIONAL BRIDGE.....	17
Value and Significance of the Lower Rio Grande Region Commercial Trucking Industry	17
The Pharr-Reynosa International Bridge	19
US-bound Truck Crossing Statistics.....	20
Operational Characteristics.....	22
CHAPTER 4: TECHNOLOGY IDENTIFICATION, SELECTION, AND IMPLEMENTATION	25
Objectives and Approach.....	25
Part I – Technology Identification	25
Technology Trade-Off Analysis	25
Bench Test of RFID Technology.....	28
Part II - Technology Selection	30
Part II - Implementation at BOTA Border Crossing.....	32
Site Characterization and Identification of RFID Reader Locations	32
System Requirements for a Border Crossing Time Measurement System.....	35
System Engineering Methodology.....	37
Equipment Purchase and Bench Testing.....	40
Equipment Installation	41
System Test and Evaluation.....	46
Relocation of RFID Reader Station in Mexico.....	47
Installation of RFID Readers at CBP.....	49
Completed Installation of RFID Stations at BOTA	52

Part II – Implementation at Pharr-Reynosa Border Crossing	54
Site Characterization and Identification of RFID Reader Locations	54
Installation of RFID Readers at CBP	55
System Test and Evaluation.....	57
CHAPTER 5: DATA COLLECTION, PROCESSING, AND DISPLAY	59
Data Collection and Wireless Transmission	59
Filtering Raw Data.....	60
Automated Estimation of Current Wait and Crossing Times	61
Automated Archiving of Wait and Crossing Time Data	62
Dissemination and Accessibility of Data.....	65
Accessing Real-Time Information.....	66
Accessing Archived Information	69
CHAPTER 6: BOTA CROSSING AND WAIT TIME DATA ANALYSIS	73
Data Collection and Analysis Period	73
Unmatched Tag Reads	73
Matched Tag Reads.....	79
Monthly Performance of Border Crossing.....	79
Histogram of Crossing Times of Trucks.....	81
Hourly and Daily Variation of Average Crossing Times of Trucks.....	83
Histogram of Wait Times of Trucks	86
Hourly and Daily Variation of Average Wait Times of Trucks	88
CHAPTER 7: PHARR-REYNOSA WAIT TIME DATA ANALYSIS	93
Data Collection and Analysis Period	93
Unmatched Tag Reads	93
Matched Tag Reads.....	96
Monthly Performance of Border Crossing.....	96
Histogram of Wait Times of Trucks	98
Hourly and Daily Variation of Average Wait Times of Trucks	100
CHAPTER 8: EVALUATION OF CROSSING AND WAIT TIMES DATA.....	105
Evaluation Performed at BOTA in August 2009.....	105
Evaluation Performed at BOTA in January 2012.....	108
Evaluation Performed at PHARR-REYNOSA in May 2011	111
CHAPTER 9: LONG TERM OPERATION.....	113
Warrantees, Operations and Maintenance	113
Business Model for Progressing from Technology Exploration to Pilot Test to Adoption	113
Operations and Maintenance Cost	114
Data Security and Control.....	115
CHAPTER 10: SUMMARY AND CONCLUSIONS	117
General Conclusions	117
Reliability and Maintainability	118
Lessons Learned.....	118

LIST OF TABLES

Table 1. US-bound truck crossings in Texas ports of entry in 2011.....	13
Table 2. Summary of the advantages and disadvantages of potential technologies.	26
Table 3. Potential risks of RFID and GPS based systems	30
Table 4. Result of tag read reliability test by lane performed for each lane at BOTA.	52
Table 5. Single lane transponder readability test at Pharr-Reynosa border crossing.....	57
Table 6. Number of tags read over a five-hour period at different inspection lanes.	57
Table 7. Descriptions of tables used to store wait and crossing time data and definitions of fields in the data archive.	63
Table 8. Monthly performance of BOTA based on average crossing times of trucks.....	80
Table 9. Monthly performance of Pharr-Reynosa based on average crossing times of trucks.	96
Table 10. Percentage of total US-bound trucks identified by RFID readers at BOTA.	106
Table 11. Comparison of average crossing times measured in field and calculated by the RFID system.	108
Table 12. Differences between GPS and RFID measured wait times of US-bound trucks at BOTA.	110
Table 13. Differences between GPS and RFID measured crossing times of US-bound trucks at BOTA.	110
Table 14. Differences between GPS and RFID measured wait times of US-bound trucks at Pharr-Reynosa.	112
Table 15. Annual costs for operations and maintenance of BOTA system.	115

LIST OF FIGURES

Figure 1. Chart. Different scenarios of border crossing times for US-bound commercial vehicles.....	4
Figure 2. Equation. Travel time index subscript indx.....	4
Figure 3. Chart. Annual trend of US-bound truck movements through El Paso ports of entry.....	10
Figure 4. Map. El Paso area with commercial vehicle crossings.....	11
Figure 5. Image. Location of Bridge of the Americas.	12
Figure 6. Graph. Monthly US-bound truck volume through BOTA in 2011.	13
Figure 7. Image. Bridge of the Americas port of entry in El Paso–Ciudad Juárez region.	15
Figure 8. Map. Ports of entry allowing commercial vehicle crossings in the Lower Rio Grande Valley.	18
Figure 9. Graph. Distribution of truck volumes at different ports of entry in the Lower Rio Grande Valley region in 2011.	19
Figure 10. Map. Pharr-Reynosa (red circle) and McAllen-Hidalgo-Reynosa border crossings (blue circle).	20
Figure 11. Chart. Trend of US-bound truck volume through Pharr-Reynosa International Bridge.....	21

Figure 12. Graph. Monthly US-bound truck crossings at Pharr-Reynosa International Bridge in 2011.....	22
Figure 13. Photo. Aerial view of Pharr-Reynosa International Bridge looking south from US 281.....	23
Figure 14. Illustration. Demonstration of travel time data collection using RFID technology.....	29
Figure 15. Map. BOTA showing Federal and State inspection facilities and initial RFID reader locations.	33
Figure 16. Map. Final location of first RFID reader station in Mexico.....	34
Figure 17. Map. Location of RFID reader station at the exit of the State inspection facility on the US side of the border.....	35
Figure 18. Illustration. Organization of various subsystems.	38
Figure 19. Illustration. Hardware configuration required for a RFID reader station.....	39
Figure 20. Photo. Back panel with communication hardware installed inside a cabinet as part of the RFID reader station.	41
Figure 21. Photo. Contractors installing RFID antennae on a mast arm.	42
Figure 22. Photo. RFID antennae at the convergence of Boulevard Cuatro Siglos and MX45.	43
Figure 23. Photo. Contractors installing cabinets on a pole in Ciudad Juárez, Mexico.	43
Figure 24. Photo. Solar panel installed at Ciudad Juárez, Mexico.	44
Figure 25. Photo. Pole-mounted batteries installed at Ciudad Juárez, Mexico.	44
Figure 26. Photo. Truck leaving the State inspection facility on the US side of the border and passing under the RFID reader station.	45
Figure 27. Photo. Power cabinet and in-ground battery installed at El Paso, US.....	46
Figure 28. Photo. Original RFID reader station and new signage for relocation of original RFID equipment on the MX side of the BOTA.....	47
Figure 29. Photo. Relocated RFID equipment on the new signage.....	48
Figure 30. Chart. Improvement of transponder reads and sample size after relocation of RFID equipment to the new signage.....	48
Figure 31. Photo. RFID equipment being installed at CBP primary booth at BOTA.	50
Figure 32. Photo. Completed installation of RFID equipment at CBP primary booth at BOTA.....	51
Figure 33. Photo. Present Location of Three RFID reader stations at BOTA.....	53
Figure 34. Map. Pharr and Reynosa showing RFID reader locations.	54
Figure 35. Photo. Contractors installing RFID equipment at CBP’s primary inspection facility at Pharr-Reynosa border crossing.....	55
Figure 36. Photo. Installed RFID equipment at CBP’s primary inspection facility at Pharr-Reynosa border crossing.	56
Figure 37. Illustration. Data collection, communication, and archiving process.	60
Figure 38. Image showing snapshot of the prototype Web tool page to view real-time information.....	67
Figure 39. Image of RSS feed of wait and crossing time at Bridge of the Americas.....	69
Figure 40. Image of RSS feed of wait and crossing time at Pharr-Reynosa border crossing.	69
Figure 41. Image. Representative archived information web page	71

Figure 42. Chart. Daily transponder reads by first (R1) and last stations (R3) at BOTA in 2009.....	75
Figure 43. Chart. Daily transponder reads by first (R1) and last stations (R3) at BOTA in 2010.....	76
Figure 44. Chart. Daily transponder reads by all three stations at BOTA in 2011.....	77
Figure 45. Chart. Daily transponder reads by all three stations at BOTA in 2012.....	78
Figure 46. Chart. Monthly performance of BOTA based on average crossing times of trucks.....	81
Figure 47. Chart. Histogram of raw truck crossing times for a month February 2012 at BOTA.....	82
Figure 48. Chart. Histogram of raw truck crossing times on Wednesday, February 15, 2012 at BOTA.....	83
Figure 49. Charts. Hourly and daily variation of average crossing times of trucks during the week of February 13, 2012 at BOTA.....	86
Figure 50. Chart. Histogram of raw wait times for a month February 2012 at BOTA.....	87
Figure 51. Chart. Histogram of raw truck wait times on Wednesday, February 15, 2012 at BOTA.....	88
Figure 52. Charts. Hourly and daily variation of average wait times of trucks on the Week of February 13, 2012 at BOTA.....	91
Figure 53. Chart. Daily transponder reads by reader at CBP at Pharr-Reynosa in 2011.....	94
Figure 54. Chart. Daily transponder reads by reader at CBP at Pharr-Reynosa in 2012.....	95
Figure 55. Chart. Monthly performance of Pharr-Reynosa based on average crossing times of trucks.....	98
Figure 56. Chart. Histogram of raw truck wait Times for a month of February, 2012 in Pharr-Reynosa.....	99
Figure 57. Chart. Histogram of raw truck wait times for a weekday at Pharr-Reynosa.....	100
Figure 58. Charts. Hourly and daily variation of average wait times of trucks during the week of February 13, 2012 at Pharr-Reynosa.....	103
Figure 59. Chart. Comparison of total number of tags read hourly by RFID readers on the US and Mexican side of the border.....	107
Figure 60. Image. Overlaid truck GPS points, and virtual zones surrounding RFID stations.....	109

LIST OF ACRONYMS

ACE	Automated Cargo Environment
ALPR	Automatic License Plate Recognition
AMAC	Asociación de Maquiladoras de Ciudad Juárez
ATA	American Trucking Association
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
BOTA	Bridge of the Americas
BSIF	Border Safety Inspection Facility
BTS	Bureau of Transportation Statistics
CAPUFE	Caminos y Puentes Federales de Ingresos y Servicios Conexos
CBP	Customs and Border Protection
DMS	Dynamic Message Sign
DPS	Department of Public Safety
FAST	Free and Secure Trade
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GIS	Geographic Information System
GPS	Global Positioning System
GSA	General Services Administration
HAR	Highway Advisory Radio
IAVE	Identificación Automática Vehicular
IMIP	Instituto Municipal de Investigación y Planeación
INDABIN	Instituto de Administración y Avalúos de Bienes Nacionales
ITS	Intelligent Transportation System
MPO	Metropolitan Planning Organization
MX	Mexico
NAFTA	North American Free Trade Agreement
NMDOT	New Mexico Department of Transportation
POE	Port of Entry
RFID	Radio Frequency Identification
RGV	Rio Grande Valley
RSS	Real Simple Syndicate
SCT	Secretaría de Comunicaciones y Transportes
SRE	Secretaría de Relaciones Exteriores
TAMU	Texas A&M University
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation
UDP	User Datagram Protocol
URL	Universal Record Locator
US	United States

VPN	Virtual Private Network
XML	Extensible Markup Language

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QUALITY ASSURANCE STATEMENT

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FOREWORD

In December 2007, FHWA initiated a pilot project to assess, select, and implement technology appropriate for the measurement of travel times for US-bound trucks crossing into the United States from Mexico. The technology selected was radio frequency identification (RFID) and the international land border crossing chosen for this implementation was the Bridge of the Americas (BOTA) Port of Entry (POE) at El Paso, Texas/Juarez, Mexico.

The specific objectives of the project were to:

- Assess the effectiveness of RFID technology for automated measurement of travel time for vehicles crossing the border.
- Gather historical travel time data.

The project expanded to include included another POE, the Pharr-Reynosa International Bridge in the Lower Rio Grande Valley, and additional RFID installations both at BOTA and Pharr-Reynosa that enabled measurement of a different type of travel time. The results of the work summarized in this Final Report constitute Part II of a two-part effort. Part I, which this report builds upon, was a task conducted in 2006-2007 that focused on an initial technology trade-off study that identified detection technologies for measuring border travel times. Electronic copies of the Part I and Part II reports are available from FHWA.

EXECUTIVE SUMMARY

ACKNOWLEDGEMENTS

FHWA would like to thank the project's stakeholders, without whose support and cooperation this pilot technology implementation would not have been possible. There were many stakeholders representing associations and governmental organizations in the cities of El Paso, Pharr and Ciudad Juárez, the States of Texas and Chihuahua, and United States (US) and Mexican regional and national entities. In particular we would like to recognize the personnel of the U.S. Customs and Border Protection (CBP), both its Headquarters, Field Operations and field offices in El Paso and Laredo as well as CBP personnel at the Bridge of the Americas and Pharr-Reynosa International Bridge; Texas Department of Public Safety (DPS); Texas Department of Transportation (TxDOT); City of El Paso, Texas; El Paso Metropolitan Planning Organization (MPO); Aduana (Mexican Customs); Instituto Municipal de Investigacion y Planeacion (IMIP, the Juárez MPO); Ciudad Juárez, Chihuahua; the Maquila Association; City of El Paso and Ciudad Juárez bridge operations; and participating Mexican motor carriers. Personnel from each of these organizations and other stakeholders freely provided their time, perspectives, and other assistance in support of this implementation.

PROJECT TASKS AND ACCOMPLISHMENTS

This report portrays the process followed and the results obtained in implementing a radio frequency identification (RFID)-based system to automatically measure commercial vehicle travel times in real-world operation on the US–Mexico border. It documents attainment of a key milestone in Part II of a two-part project, in which total results from nearly 33 months of real-world system operation are captured. It is important to note that this Final Report is not meant to serve as a comprehensive document outlining each task conducted as part of this project, though pertinent extracts of prior project deliverables are included. Rather, it is meant to highlight the most important steps in implementing an automated border wait and crossing time measurement system as experienced with the implementation of such systems at Bridge of the Americas (BOTA) and Pharr-Reynosa International Bridge implementation (Pharr-Reynosa) in El Paso, Texas/Ciudad Juárez and Pharr, Texas respectively.

In Part I of this project (reported separately), an in-depth analysis was conducted to determine the most appropriate technologies that could be applied in a system for automatically measuring travel time of commercial vehicles that transit across land border crossings on the US–Mexico border. Automatic Vehicle Identification (AVI) using RFID was one of two technologies selected as most appropriate to the application, along with Global Positioning System (GPS). Passive RFID technology requires a reader and transponders (“tags”) and was already being used at some southern border crossings for other purposes. (NOTE: the terms “transponder” and “tag” are used interchangeably in this report.)

In Part II, the results of the Part I technology trade-off analysis were revisited and the recommended technologies verified to be still applicable. Land border crossings in the vicinity of El Paso–Ciudad Juárez were considered for the RFID system implementation. RFID was an

attractive technology in the El Paso–Ciudad Juárez region due to the relatively high percentage of commercial vehicles that already had RFID transponders. For example, passive RFID tags were widely used by trucks enrolled in CBP’s Free and Secure Trade, or “FAST” Program. Also, the Texas DPS installed RFID reader stations to provide identifying information that can be used to retrieve information needed to facilitate the passage of commercial vehicles through its Border Safety Inspection Facility (BSIF). (NOTE: “Border Safety Inspection Facility” is the term the Texas DPS uses for its State commercial vehicle safety inspection. Neither the term for the facility nor the identity of the State organization that operates it are universal, but the acronym BISF is used throughout this document for convenience.

Following an extensive stakeholder involvement in 2009 an RFID based system was implemented at BOTA that had capabilities to collect crossing times of US-bound trucks. Subsequently, a third reader at the CPB’s primary inspection facility in 2011 to measure wait times of trucks. Around the same time, RFID readers were installed at CBP’s primary inspection facility at Pharr-Reynosa to measure wait times of trucks. TxDOT had earlier implemented a similar system at Pharr-Reynosa with capabilities to measure crossing time only.

In addition to field implementation, the project also included developed of a Prototype Web Tool to disseminate and archive wait and crossing time data. Using the Web tool, stakeholders can view the most recent wait and crossing times at both POEs, retrieve historical data for planning, and decision-making purposes.

GENERAL CONCEPT OF THE SYSTEM

The general concept of the RFID technology based wait time and crossing time measurement system is that during its trip across the border at a POE, a US-bound truck passes under RFID tag reader antennae. These antennae are mounted above its lane in the roadway. Each tag reader detects the truck’s tag identification (ID) number and time-stamps and records the location of the detection. The first RFID reader station is located on the Mexican side of the POE at a site that is at the “upstream” end of the queue of US-bound trucks that backs up from the border at the POE. The length of the queue at any given time will vary depending on factors such as truck volume, number of customs primary inspection booths manned and open, time of day, and incidents or accidents at the POE. The first RFID reader station is at a static location that must be at or slightly upstream from the end of the historical queue that will develop on the majority of days. The second RFID reader station is located at CBP’s primary inspection booth on the US side. The third RFID reader station is located at the exit of the State’s inspection facility. Travel times between first and second readers are identified as wait times of trucks. Similarly, travel times between first and third reader are identified as crossing times of trucks.

Data from the RFID reader stations are sent to a central remote server via wireless modem. In the server, data from reader stations are compared, looking for the match of the truck’s ID as recorded at the two reader stations. If a match is found, that determines the wait or crossing time for that truck. The data – whether raw or processed – are stored and archived in a centralized repository implemented in a database server. The system calculates the most recent average wait and crossing time, which can be accessed using publicly available. Real Simple Syndication (RSS) and a Web site, described later in the report. These average wait and crossing times are

sufficiently current that they can be used for making informing decisions. Examples of these decisions are CBP staff deciding whether to open one or more additional inspection booths or trucking carriers that are dispatching trucks deciding which POE to route their trucks through.

IMPLEMENTATION AT BOTA AND PHARR-REYNOSA

An initial full meeting of stakeholders resulted in their approval of the BOTA POE in El Paso as the planned site and an RFID tag reader system using wireless data communication as the planned technology to be implemented. Prior to proceeding with implementation, a second full stakeholder meeting was conducted to present the key system requirements, explain the technology implementation intended to meet those requirements, and present plans for implementation at selected locations at the BOTA POE.

Subsequently, in July 2009 installation was completed for two RFID reader stations at the BOTA port of entry to measure crossing times of US-bound trucks. Furthermore, FHWA initiated discussions with CBP about the feasibility of RFID installations at its primary inspection facilities at international land border crossings on the US–Mexico Border. Such an installation enables the same system to also measure wait time of US-bound commercial vehicles. That discussion resulted in CBP approval of RFID installations at the Primary Inspection facility locations at two Texas POEs: BOTA and Pharr-Reynosa International Bridge. A compatibility test was conducted in August 2010 at the Pharr-Reynosa International Bridge that successfully demonstrated the planned RFID configuration at CBP Primary Inspection booths do not interfere electronically with CBP systems in the area. In January 2011, CBP recommended approval of – and the U.S. General Services Administration approved – the permit for RFID installation at the CBP facility at Bridge of the Americas. In October of the same year, installation of a third reader at the CPB’s primary inspection facility was completed.

Around the same time, RFID readers were installed at CBP’s primary inspection facility at Pharr-Reynosa. TxDOT had earlier implemented a similar system at Pharr-Reynosa with capabilities to measure crossing time only

The research team also initiated tasks to develop a Prototype Web Tool in February 2011. The objective of the prototype web tool was to provide an effective and efficient web-based platform for dissemination of real-time traveler information and archived border-crossing related data to stakeholders on the US-Mexico border. Real-time traveler information includes current border wait and crossing times. Archived data includes historic wait times and crossing times. Presentation of historic data includes trends shown in different temporal and spatial granularities, summarized and aggregated data, and simple summary statistics.

Subsequently, the research team also developed step-by-step guidelines for installing RFID-based systems at land POEs to measure crossing and wait times of trucks. These guidelines are not POE specific and hence can be used to deploy similar systems at other border crossings. Guidelines described in this document are based on experiences gathered while deploying RFID-based systems to measure crossing times and wait times at various land border crossings in Texas on the US–Mexico border.

A second document was developed to provide guidance to stakeholders regarding analysis that can be performed with the data collected by the RFID-based border crossing time and wait time measurement system. The guidance assists agencies implementing the system to develop meaningful output from the data analysis, in the form of charts/graphs/data subsets, which then can be used by stakeholders for planning and decision-making. The guidance also describes different techniques for relaying real-time crossing and wait time data to stakeholders.

CHAPTER 1: BACKGROUND AND OVERVIEW

BACKGROUND

This project is the culmination of years of planning, assessing, testing, and preparing for implementation of an automated travel time measurement technology system. In 2001, FHWA conducted the task Assessment of Automated Data Collection Technologies for Calculation of Commercial Motor Vehicle Border Crossing Travel Time Delay. That task involved manual wait time measurements on commercial vehicles transiting four northern and three southern border crossings.

Included in that effort was an assessment published in 2002 of vehicle detection technologies that were evaluated as candidates to automate the collection of border delay and crossing time data. There were 22 vehicle-sensing technologies that were initially screened against factors such as availability of appropriate software, volume count flexibility, minimization of privacy invasiveness, ruggedness/all-weather operation, low infrastructure cost, and positive identification capability. To be a candidate for the short list of that study's trade-off study, a sensing technology had to be able to:

- Make positive identification of both inbound and outbound trucks at a matched pair of two points (upstream and downstream in the traffic flow) that corresponded to where data collectors were stationed for manual readings.
- Time-stamp each vehicle that was positively identified at its detected location so as to enable travel time calculations.
- Operate in all weather conditions found at a (land) border crossing.

Subsequently, 11 of the 22 screened candidate sensing technologies met those three basic criteria and were assessed against the criteria of: geo-location/travel time accuracy, percent of vehicles recorded, requirement for cross-border installation, maturity of technology for application, infrastructure cost, and ability to count every vehicle crossing. A trade-off comparison involving advantages and disadvantages of each and commentary also was included.

PART I – TECHNOLOGY IDENTIFICATION AND SELECTION

FHWA has undertaken several freight performance initiatives aimed at measuring travel times on freight-significant corridors and crossing and delay times at major US land border crossings. For the US– Mexico border, FHWA sought to identify appropriate Intelligent Transportation Systems (ITS) or other commercial technologies that enable border crossing times to be easily and precisely measured. In 2006, FHWA initiated Part I of Measuring Border Delay and Crossing Times at the US–Mexico Border. This project was among the first steps in the current process to automate measurement of crossing times. The objective of the work detailed in the Part I report was to examine technologies that could be used to support automated measurement

of border crossing and delay times for US-bound commercial motor vehicles at US–Mexico land Ports of Entry (POEs. (The term POE is used interchangeably with border crossing in this document.) Delay time for commercial motor vehicles at US–Mexico POEs is a key indicator of transportation and international supply-chain performance.

Technology advancements had been developed and adopted by the market over the five years since the 2001 study and the Part I study. For example, Global Positioning System (GPS)-based locating and geo-fencing systems experienced rapid proliferation among motor carriers during that period. Technology candidates were screened for their applicability to automate the crossing time measurement process. 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 POEs. Technologies identified as meeting these criteria were: automated 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.

Of these, the three technologies considered the best candidates for the POE application were AVI, GPS, and ALPR. There were six technology variations of AVI identified and discussed. The one considered most appropriate for the intended purpose among the six AVI variations was passive RFID technology, which requires a reader and transponders. Passive RFID was already being used at some southern border crossings. For example, passive RFID was being used at the Bridge of the Americas POE by the US Customs and Border Protection (CBP) for lanes dedicated to trucks participating in CBP’s Free and Secure Trade (FAST) Program and also by the Texas’ Border Safety Inspection Facility (BSIF). FAST expedites processing of cargo through CBP Primary inspection for commercial carriers that have completed background checks and fulfill certain other eligibility requirements. Upon further consideration, the Part I effort narrowed the technology choices for pilot programs to two passive RFID and GPS. RFID was chosen as the technology for the pilot implementation in Texas. Chapter 4 covers additional details on this technology selection process. The POE chosen for the RFID pilot was the Bridge of the Americas in El Paso, Texas/Juarez, Mexico.

A demonstration of passive RFID transponder (i.e., “tag”) reading was conducted using a portable setup in Austin, Texas. This bench test-level demonstration was conducted to evaluate the functional effectiveness of the system’s tag detection and matching and travel time measurement capabilities prior to implementation in a real-world setting. Within the preceding years, several toll facilities became operational in the Austin area, which put a reasonable population of RFID toll tags (i.e., “TxTags”) on the area roadways. To prove the design concept, RFID antennas were mounted on overpasses. The RFID system successfully read and time-stamped identification (ID) numbers of tags in cars with TxTags under their windshields, passing at freeway speeds, and matched the transponder ID numbers read at the upstream and downstream locations. More details of this testing are found in the Chapter 4 *Part I Technology Identification* under “Bench Test of RFID Technologies.”

DISCUSSION OF BORDER WAIT TIMES AND CROSSING TIMES

While the collective term “travel time” is often used, it is useful to distinguish between the two main types of travel time provided in the prototype web tool. Wait time is defined as “the time it takes, in minutes, for a vehicle to reach the CBP’s 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. Typically, that last compound in the crossing process on the US–Mexico border is the State safety inspection facility, past which trucks exit onto the roadway system.

Border wait time is a segment of border crossing time, and such segmentation can be advantageous in determining the locations where delays are originating. As a metric, wait time is of greater significance than crossing time to CBP operations, whereas crossing time is of greater interest to FHWA and private sector stakeholders such as shippers and carriers.

Regarding definition of delay, the following is an excerpt from the Part I Final Report:

“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 1 illustrates these definitions.

¹ Border Wait Time Working Group presentation, April 2009, http://www.thetbwg.org/meetings/200904/1_-_border%20wait%20times%20update.ppt

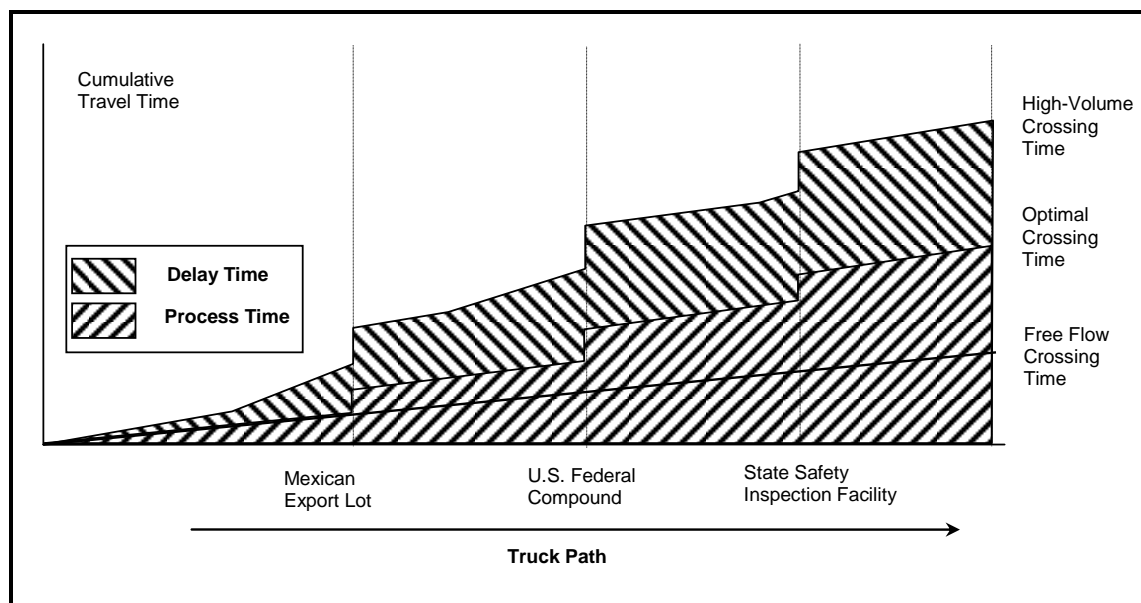


Figure 1. Chart. Different scenarios of border crossing times for US-bound commercial vehicles.

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 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.

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 in figure 2:

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

Figure 2. Equation. Travel time index subscript indx.

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 (and later, also 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 except later for the wait time component.

PART II - PILOT IMPLEMENTATION AT BOTA AND PHARR-REYNOSA

In 2007, FHWA began Part II of *Measuring Border Delay and Crossing Times at the US–Mexico Border*. For this part of the process toward an optimal solution, FHWA initiated two projects, one of which became the deployment of RFID at the BOTA land border crossing at El Paso and Ciudad Juárez. FHWA’s measure of success for this part of the work was to conduct it in a manner that would lead to adoption at the end of the process. A key element of achieving this goal was to utilize a consultative process. To this end, the project initiation included two stakeholder sessions. El Paso and Ciudad Juárez-area stakeholders participated in discussions that led to confirmation of the specific land border crossing and associated technology system (RFID at BOTA) that would be implemented as a pilot demonstration. An overview of the stakeholder sessions including the process and planned actions is described in this report.

This project initially implemented two RFID reader stations with an algorithm designed to measure crossing time only. However, border wait times and delays are an important concern for travelers and those involved with, or affected by, international trade. FHWA, sharing a common goal with CBP of facilitating the legitimate flow of travelers and trade across land border crossings, began working closely with CBP to determine whether existing RFID crossing time measurement implementations could be enhanced to measure border wait time in addition to border crossing time. CBP gave approval of RFID installations at the primary inspection facility locations at two Texas land border crossings: BOTA and the Pharr-Reynosa International Bridge (Pharr-Reynosa). FHWA subsequently allocated resources and initiated actions to install RFID equipment at BOTA and Pharr-Reynosa that enabled the measurement of border wait time

and complemented the border crossing time measurement already in progress at those POEs.

In addition to incorporating the two additional RFID reader stations at BOTA and Pharr-Reynosa, the actions included (among other tasking) development of:

- A guidebook for analysis and dissemination of border crossing time and wait time data.
- Step-by-step guidelines for implementing RFID to measure border wait and crossing times.
- A prototype web tool with design documentation and specifications and supporting user guidance and demonstration.

On May 6, 2010, FHWA held initial discussions on working with CBP and other stakeholders (e.g., U.S. General Services Administration, or GSA) on installing RFID readers at CBP primary inspection to enable automatic measurement of border wait times. At the initial discussion, CBP and FHWA/TxDOT agreed that a field test be conducted to demonstrate that installation of RFID equipment for border wait time measurement would not interfere with CBP equipment and operations. Based on this agreement, FHWA conducted a compatibility test at the Pharr primary inspection facility on August 17, 2010. The test concluded that RFID reader equipment can be installed on the exit side of each primary inspection lane in a manner that causes no interference with CBP operations and equipment. Because border wait times derived from this configuration would include the increment of time experienced in primary processing, the report also detailed a mitigation strategy for extracting that time if deemed necessary.

This final report is not meant to serve as a comprehensive document outlining each task conducted as part of this project, though pertinent extracts of prior project deliverables are included. Rather, it is meant to highlight the most important steps in implementing an automated border crossing and wait time measurement system as experienced with the BOTA and Pharr-Reynosa RFID implementations. These steps include lessons learned as well as observations and analysis of the border crossing Times at BOTA and wait times both at BOTA and at the Pharr-Reynosa International Bridge. Prior deliverables for this project are engineering records that can be found by contacting FHWA at FreightFeedback@dot.gov. Those other written deliverables for this project include the following documents:

- Prototype Web Tool Design Document.
- Prototype Web Tool User Guide.
- Slides: Webinar to Discuss Design and Specification for a Prototype Web Tool.
- Test and Evaluation Reports for BOTA and Pharr-Reynosa CBP Primary RFID Installations.
- BOTA and Pharr-Reynosa Installation After-Action Reports.
- Test and Evaluation Plan for BOTA and Pharr-Reynosa CBP Primary RFID Installations.
- Test and Evaluation Report for BOTA Crossing Time.
- Test and Evaluation Plan for BOTA Crossing Time.
- Implementation Plan (Post-installation Update).
- Approved GSA Installation Permit Applications for BOTA and Pharr-Reynosa CBP Primary RFID Installations.
- Implementation Plan for BOTA and Pharr-Reynosa CBP Primary RFID Installations.

- Report on RFID Compatibility Testing at Pharr-Reynosa.
- Design Document with Architecture Appendix.
- Plan for Collecting Baseline Data.
- Technology Assessment.
- Current State Analysis.
- El Paso Stakeholder Meetings –Agendas, Slides, Notes, and Minutes.

CHAPTER 2: BRIDGE OF THE AMERICAS

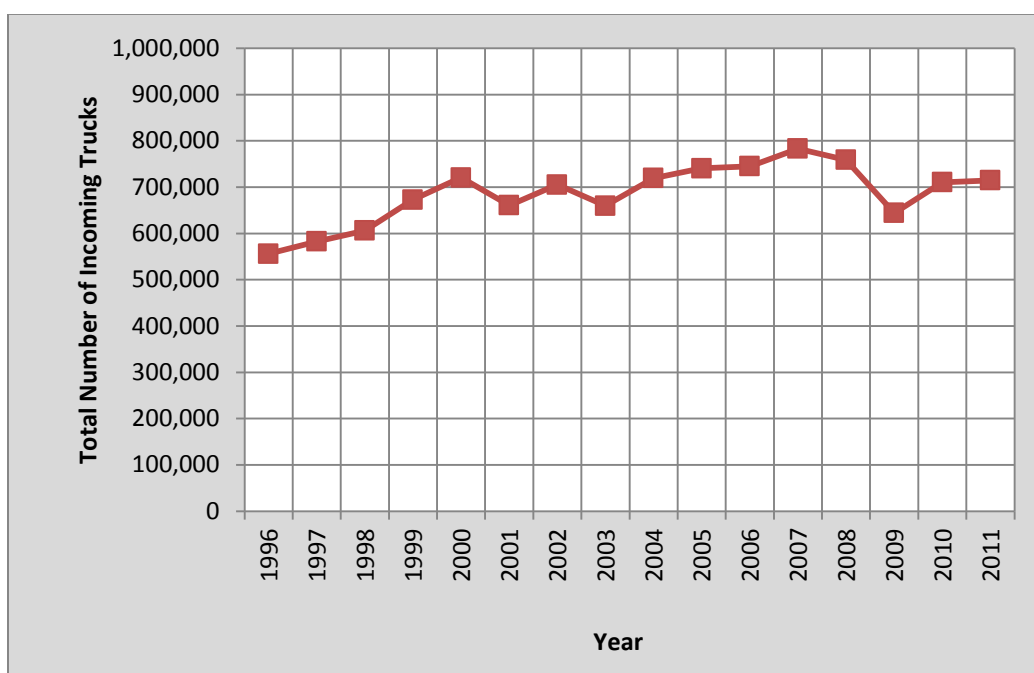
VALUE AND SIGNIFICANCE OF THE EL PASO REGION COMMERCIAL TRUCKING INDUSTRY

El Paso, Texas is currently the sixth largest city in the State of Texas and the 22nd largest city in the United States. Ciudad Juárez, El Paso's sister city across the border, is the largest city in the State of Chihuahua and the fifth largest city in all of Mexico. The metropolitan area comprised of Ciudad Juárez and El Paso consists of more than 2.6 million people, making it the second largest community on the US–Mexico border.⁽²⁾ This large population is largely supported by the number of jobs that the local manufacturing industry in the region produces. These manufacturing facilities – often referred to as “maquiladoras” or “maquilas” on the Mexico side – not only produce jobs but also are responsible for the flow of raw materials and goods that are shipped to and from the United States in significant volumes. A maquiladora is a manufacturing facility located in Mexico that temporarily imports materials for assembly on a duty-free basis, provided the product is re-exported. This arrangement has evolved into a system of transfer stations, distribution centers, and warehouses on the US side of the border and manufacturing plants in Mexico. The majority of freight shipped through the El Paso–Ciudad Juárez POE system is maquiladora trade.

Following the implementation of the North American Free Trade Agreement (NAFTA), trade between the United States and Mexico increased substantially. Northbound commercial movements through El Paso–Ciudad Juárez gateways peaked at 782,000 trucks in the year 2007. While a slowdown in the US economy in 2008 (particularly in the automotive and housing segments) and international trade has reduced the number of US-bound trucks, the El Paso–Juárez metropolitan area remains one of North America's largest manufacturing hubs. An estimated 6 percent of the US national economy crosses the border in the El Paso region.⁽³⁾ Over the past decade, the overall growth of US-bound commercial movements between Ciudad Juárez and El Paso increased by more than 85,000 crossings during the first eight years but decreased over the last two years, so that there is a slight net decrease. These numbers are shown in figure 3.

² http://www.elpasotexas.gov/city_manager/_documents/Presentation%20-%20Joyce%20AHMO%20Vitality%20of%20Border%20Regions%2010-26-06.pdf

³ America.Gov Online, “US–Mexico Border Officials Balance Security, Commerce Needs,” September 24, 2007, <http://www.america.gov/st/washfile-english/2007/September/20070924141658ajesrom0.7344171.html>



Source: U.S. Department of Transportation, Bureau of Transportation Statistics
http://www.bts.gov/programs/international/transborder/TBDR_BC/TBDR_BC_Index.html⁴

Figure 3. Chart. Annual trend of US-bound truck movements through El Paso ports of entry.

EL PASO – JUÁREZ PORT-OF-ENTRY SYSTEM

The El Paso–Ciudad Juárez metropolitan area is served by three international commercial vehicle crossings. The Santa Teresa/San Jeronimo, New Mexico POE is a land border crossing 11 miles west of El Paso. The other two commercial crossings, which are physically in the vicinity of El Paso–Ciudad Juárez, are the BOTA and Zaragoza–Ysleta POEs; both are international bridges over the Rio Grande River. No tolls are collected at the Santa Teresa or BOTA crossings; a toll is collected at the Zaragoza–Ysleta crossing.

The locations of these three ports are illustrated in figure 4.

⁴ U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Border Crossing/Entry Data; based on data from US Department of Homeland Security, Customs and Border Protection, OMR database.



Source: TTI using Bing Maps

Figure 4. Map. El Paso area with commercial vehicle crossings.

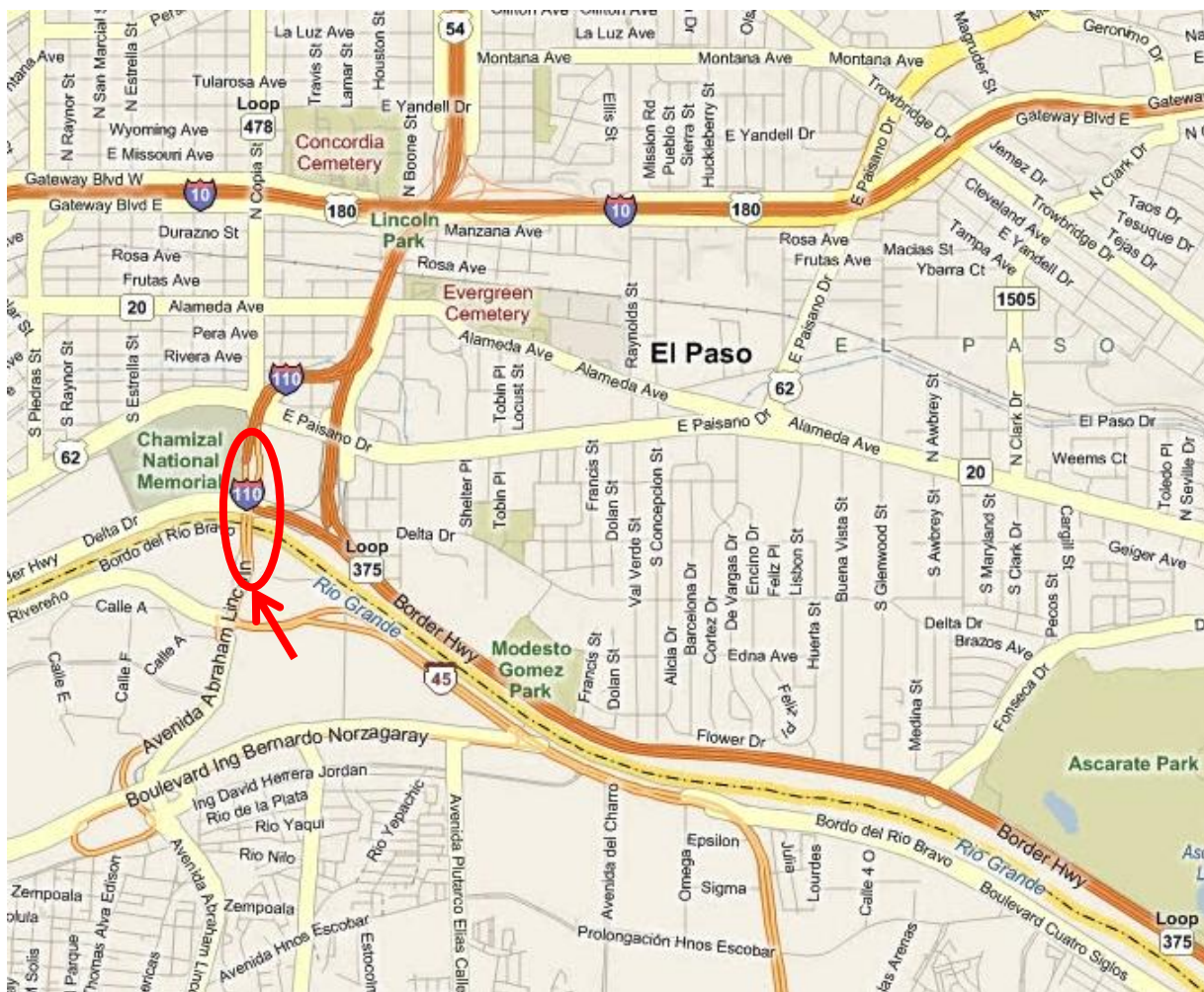
Overall US-bound truck traffic at both commercial crossings in El Paso–Ciudad Juárez peaks between 10:00 AM and noon. During the early hours of the day, empty trucks cross US-bound through BOTA to pick up loads for maquiladora assembly plants. Even before BOTA closes for operation, some traffic voluntarily diverts to Ysleta, causing a period of high demand around 5:00 PM. Around 7:00 PM, loaded vehicles create another period of high demand at the Zaragoza–Ysleta crossing. These afternoon peaks result from shipments that leave Mexican maquiladora plants at the end of the second manufacturing production shift. There is significantly less crossing activity at the Santa Teresa POE throughout the day than at either the BOTA or Zaragoza–Ysleta POEs.

THE BRIDGE OF THE AMERICAS

The BOTA facility is located in the center of the El Paso–Ciudad Juárez metropolitan area, as illustrated in figure 5. The bridge is used for both commercial truck and passenger vehicle movements, and it has two separate structures—one for US-bound traffic and one for southbound traffic. Passenger vehicles and commercial trucks access the bridge via Cuatro Siglos (a street on the Mexican side of the border) and are directed to specific lanes by road signs in order to separate the two types of vehicular traffic using the bridge. Once on the physical bridge, trucks and passenger vehicles are separated by a concrete barrier. Truck traffic is handled by two

dedicated outside lanes on each bridge structure. Local transportation companies funded the construction of a replacement bridge capable of handling commercial traffic in 1998.

Commercial freight accesses BOTA shortly after Boulevard Cuatro Siglos and Mexican Highway 45 merge, approximately ½ mile southeast of the physical bridge. Passenger traffic is diverted to Boulevard Ing. Bernardo Norzagaray at this point. Passenger traffic accesses BOTA from Avenida Abraham Lincoln, which runs north-south in Ciudad Juárez. After crossing the bridge, passenger vehicles have direct access to I-110, which links up with US Highway 54, I-10, and Loop 375. Commercial vehicles, after clearing the CBP and/or BSIF compound exit onto Gateway Boulevard North and enter the El Paso road system on East Paisano Drive, which provides access to US Highway 54.



Source: TTI using Bing Maps
Figure 5. Image. Location of Bridge of the Americas.

US-BOUND CROSSING STATISTICS

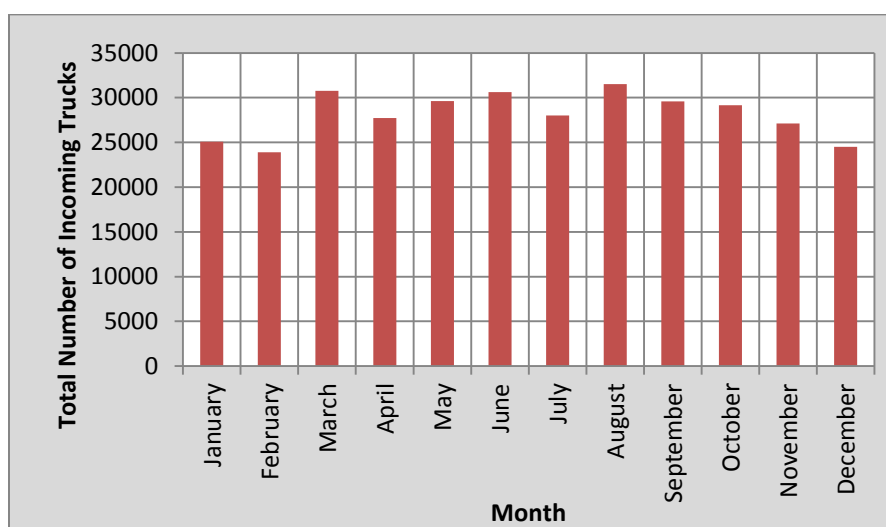
BOTA is the fifth largest commercial POE in the State of Texas in terms of number of US-bound trucks crossing. A list of the top ten POEs in the State of Texas for 2011 along with the number of US-bound trucks crossing at each POE is presented in table 1.

Table 1. US-bound truck crossings in Texas ports of entry in 2011.

Bridge	Number of US-bound Truck Crossings
World Trade Bridge	1,327,479
Pharr – Reynosa International Bridge	452,821
Ysleta – Zaragoza Bridge	379,508
Laredo – Colombia Solidarity Bridge	374,781
Bridge of the Americas	337,609
Veterans International Bridge	177,986
Camino Real International Bridge	106,423
Del Rio – Ciudad Acuna International Bridge	62,966
Progreso International Bridge	42,605
Free Trade Bridge	30,773

Source: CBP

Figure 6 shows the numbers of US-bound crossings at BOTA in 2011, broken down by month.



Source: CBP

Figure 6. Graph. Monthly US-bound truck volume through BOTA in 2011.

OPERATIONAL CHARACTERISTICS

There are several key agencies involved in the border crossing process for US-bound commercial trucks at BOTA. These agencies include:

- US Federal Agencies - Customs and Border Protection, Federal Motor Carrier Safety Administration (FMCSA), U.S. Department of Agriculture, Drug Enforcement Agency.
- US State Level Agencies - Texas Department of Public Safety (DPS).
- Mexican Federal Agencies - Aduana (Mexican Customs).

The following describes the three principal facilities through which a US-bound truck will pass at BOTA:

- Mexican Export Lot – A facility operated by Aduana (Mexican Customs) that is responsible for inspecting export materials leaving Mexico. Only a small percentage of freight is physically inspected at this facility for audit purposes.
- US Federal Inspection Compound – This facility is operated by CBP. Its primary function is to make sure no harmful or illegal freight is permitted to enter into the United States. Secondary inspections can occur here if CBP feels it necessary to examine further the driver, freight, or conveyance. These secondary inspections can include intrusive measures (physically unloading the trailer to examine its cargo) or non-intrusive measures (x-ray or gamma ray imaging).
- Border State Inspection Facility – The BSIF (a designation used by the State of Texas for this type of facility) is operated by the DPS. Its primary function is to ensure that tractors and trailers entering the United States from Mexico are safe enough to operate on US roadways. Secondary inspections of the vehicles can occur here if deficiencies are revealed through a preliminary review of the conveyance by the BSIF. The FMCSA also has onsite representatives dedicated to ensuring the safety of trucks and trailers that would enter the United States.

The US-bound commercial freight border crossing process begins at the Mexican Export Lot on the south side of the border (also known as the Aduana facility). After clearing customs on the Mexican side, a truck crosses the physical bridge structure. Immediately upon entering the United States, the truck proceeds to the Federal Inspection Compound. Entrance to the Federal Inspection Compound is through one of six primary inspection booths. At these primary inspection booths, a CBP officer determines whether the truck requires any secondary inspection and if so directs the driver to it, or otherwise instructs the driver to proceed to the exit. The CBP officer will give final clearance to exit the Federal Inspection Compound at one of two booths at the exit of the premises, at which point the truck proceeds on to the BSIF.

A one-lane access road that passes under US Highway 54 connects the Federal and State Inspection Facilities. 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. Drivers of trucks departing the inspection shed are instructed by two

overhead signs immediately after the inspection to either proceed to the exit of the facility (East Paisano Drive) or to secondary State inspection. If they are selected for secondary inspection, trucks will bear right after the inspection shed and loop back into the middle of the premises for further examination.

Figure 7 is an aerial view of BOTA, looking south across the Rio Grande river from El Paso, Texas.



Figure 7. Image. Bridge of the Americas port of entry in El Paso–Ciudad Juárez region.

BOTA operates from 6:00 AM to 6:00 PM Monday through Friday and from 6:00 AM to 2:00 PM on Saturdays. Empty truck traffic prefers using this free bridge to avoid paying the toll at the Ysleta–Zaragoza Bridge. Only trucks with empty trailers are permitted to cross between the hours of 6:00 AM and 8:00 AM. In 2003, one of BOTA’s two northbound lanes was converted to a designated lane for trucks whose carriers participate in the FAST Program. The FAST lane occupies the outside lane (the farthest right lane for US-bound traffic) on the physical bridge structure at BOTA.

CHAPTER 3: PHARR-REYNOSA INTERNATIONAL BRIDGE

VALUE AND SIGNIFICANCE OF THE LOWER RIO GRANDE REGION COMMERCIAL TRUCKING INDUSTRY

The Lower Rio Grande Valley is located in the southernmost tip of Texas, bordering 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 a 26 percent increase since the year 2000. Among the Councils of Governments' population estimates, the Lower Rio Grande Valley has Texas' second largest growth rate, exceeded only by after the Capital Area (Austin). The largest city in the region 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 the United States, the majority of which is grown in the Rio Grande Valley. This and other agribusiness and the emergence of the maquiladora industry have caused a surge of industrial development along the border. International POEs 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 valley. Figure 8 illustrates these six bridges extending from Veterans International Bridge in Brownsville, Texas at the eastern end to the Roma-Ciudad Miguel Alemán International Bridge in Roma, Texas at the western end.

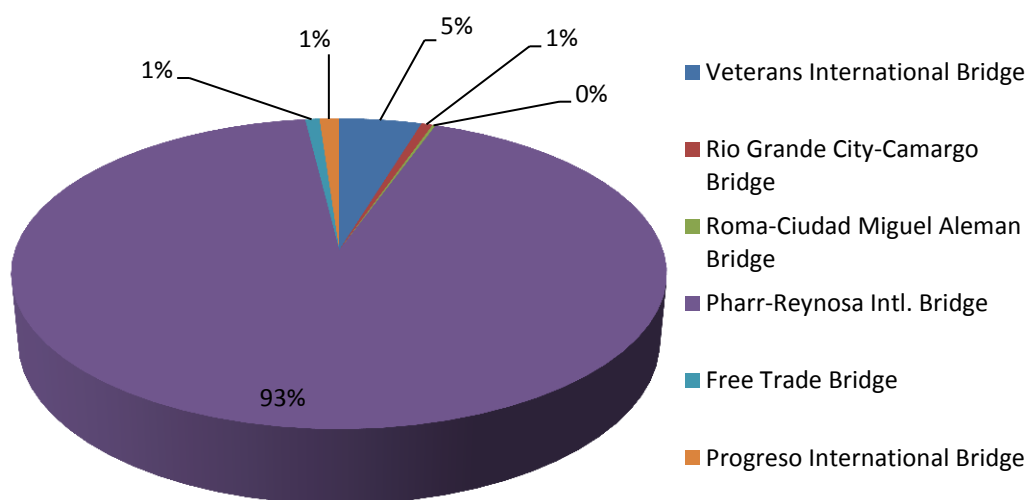
The FAST program allows pre-certified shipments to use a special lane and receive expedited inspection at the CBP FAST lane primary inspection booth. There are three POEs where a FAST lane exists: Veteran's International Bridge, Free Trade International Bridge, and the Pharr-Reynosa International Bridge.



Source: TTI using Google Maps

Figure 8. Map. Ports of entry allowing commercial vehicle crossings in the Lower Rio Grande Valley.

Figure 9 shows the distribution of 2011 US-bound truck crossing volume for the Lower Rio Grande Valley POEs. The Pharr-Reynosa International Bridge handled 93 percent of the total trucks in the region, followed by Veterans International Bridge, in Brownsville, Texas, with 5 percent.

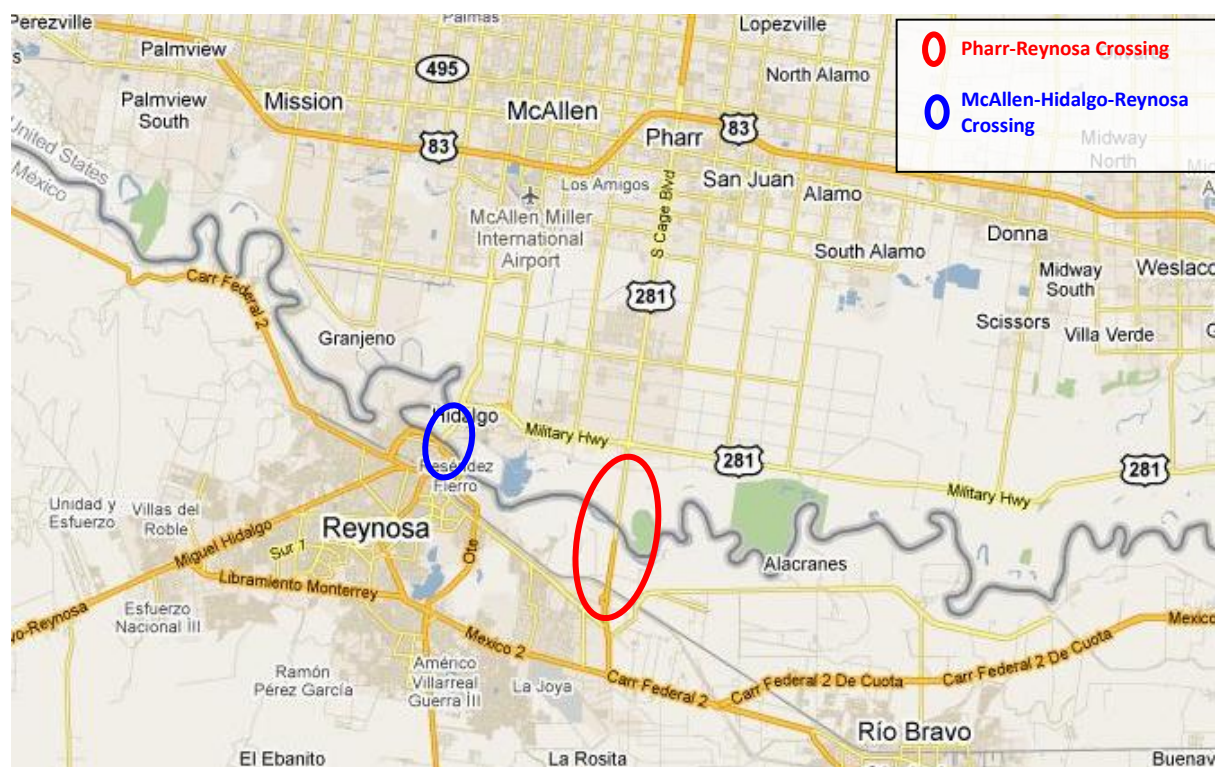


Source: CBP

Figure 9. Graph. Distribution of truck volumes at different ports of entry in the Lower Rio Grande Valley region in 2011.

THE PHARR-REYNOSA INTERNATIONAL BRIDGE

Pharr-Reynosa International Bridge is located in Hidalgo County, in the 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 Pharr-Reynosa International 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 around the McAllen-Hidalgo-Reynosa Bridge. The Pharr-Reynosa Bridge is 3.1 miles long and elevated to protect surrounding wetlands and farmlands. Figure 10 shows the location of the Pharr-Reynosa International Bridge and the McAllen-Hidalgo-Reynosa Bridge with major highway connections.

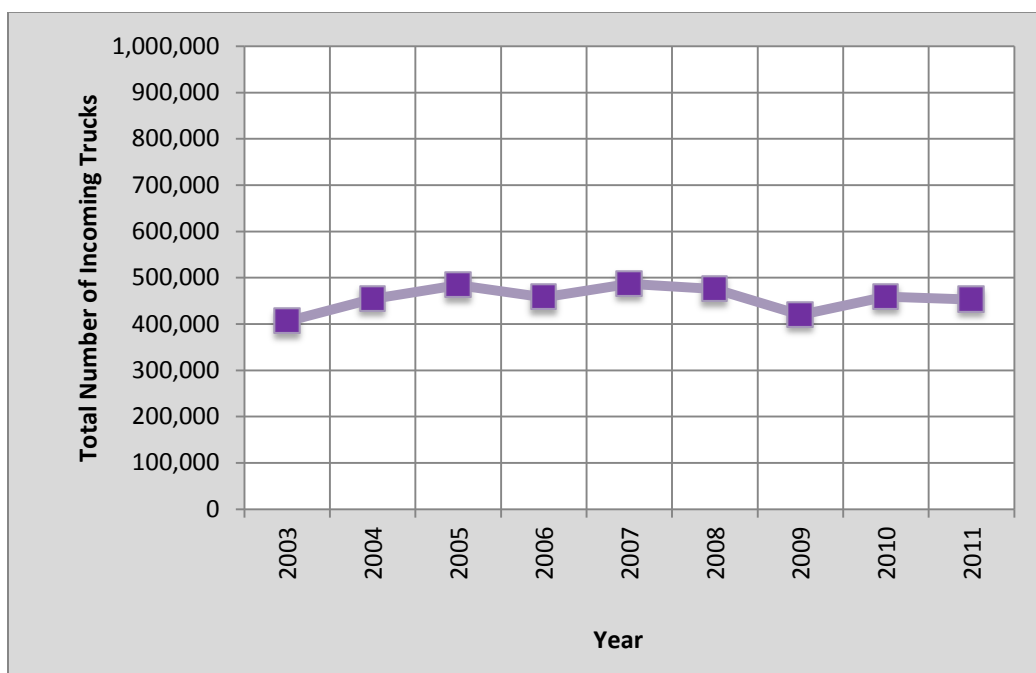


Source: TTI using Google Maps

Figure 10. Map. Pharr-Reynosa (red circle) and McAllen-Hidalgo-Reynosa border crossings (blue circle).

US-BOUND TRUCK CROSSING STATISTICS

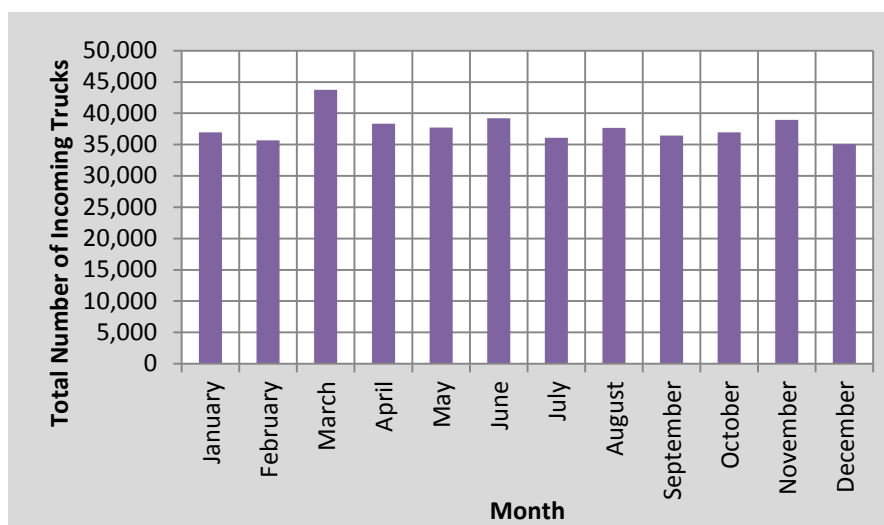
The Pharr-Reynosa International Bridge has a four-lane cross section, with three US-bound lanes and one southbound lane, on the US portion of the bridge. This crossing serves passenger as well as commercial vehicles. Truck crossings at the Pharr-Reynosa International Bridge reached a peak in 2007 with close to 500,000 crossings that year. International truck volumes started to decline in 2008 due to the economic downturn, as shown in figure 11.



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

Figure 11. Chart. Trend of US-bound truck volume through Pharr-Reynosa International Bridge.

In 2011, 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 452,821 trucks from Reynosa into Pharr, with an average of 37,735 trucks per month. Figure 12 shows that March, June, and November were the months of highest volume in 2011, while December registered the lowest truck volume.



Source: Texas Center for Border Economic and Enterprise Development

Figure 12. Graph. Monthly US-bound truck crossings at Pharr-Reynosa International Bridge in 2011.

OPERATIONAL CHARACTERISTICS

The border crossing process for commercial vehicles entering the United States requires that vehicles stop at several points. The time it takes a truck to cross depends 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 US-bound commercial border crossing process begins at the Mexican Export Lot on the southern side of the border. After clearing export customs on the Mexican side, a truck proceeds to the tollbooth operated by Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE). Once the driver of a truck pays tolls through an electronic toll-collection system or manually, the truck then crosses the 3.1-mile long bridge. Immediately upon entering the United States, the truck continues to the Federal Inspection Compound. Entrance to the Federal Inspection Compound is through the primary inspection booths. At these primary inspection booths, a CBP officer determines whether the truck requires any secondary inspection and if so directs the driver to it, or otherwise instructs the driver to proceed to the exit. CBP gives final clearance to exit the Federal Inspection Compound at booths at the exit of the premises. After leaving the Federal compound, the truck proceeds to the BSIF.

The BSIF is located at the north side of the Federal Inspection Compound and is 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. Drivers of trucks departing the inspection shed are instructed by the DPS officials to proceed either to the exit of the facility or to a secondary safety inspection. Figure 13 shows an aerial view of the Pharr-Reynosa International Bridge.



Source: TTI using Google Earth

Figure 13. Photo. Aerial view of Pharr-Reynosa International Bridge looking south from US 281.

The 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 City of Pharr owns the US side of the bridge 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 re-stripped the northbound lanes to dedicate FAST lanes on the bridge. CBP has designated the two right-most lanes to process FAST shipments. However, the booths for all the other lanes are also capable of processing FAST shipments. Depending on approaching truck volume, CBP may instruct FAST trucks to go to non-FAST booths or non-FAST trucks to the booths of the two right-most lanes to lower the wait time.

CHAPTER 4: TECHNOLOGY IDENTIFICATION, SELECTION, AND IMPLEMENTATION

OBJECTIVES AND APPROACH

The overall goal of the Part II project initially was to implement a system that would automatically and accurately collect data, measure, and disseminate wait and crossing times for US-bound commercial freight at BOTA. Additionally, the proposed system had to be designed to sustain long-term data collection in real-world operations and be easily transferable (as a design concept) to other POEs desiring it along the northern and southern borders of the United States.

As stated in the Background and Overview section of this report, FHWA has sponsored several other initiatives aimed at identifying technologies that could be used to calculate crossing times for US-bound commercial freight at the US–Mexico border. These previous efforts were used to aid in the technology selection for the BOTA technology implementation project.

The technology selection for this project consisted of two parts. The Part I initiative that preceded the activity that this report is based on was a technology assessment that identified technologies that were best suited to achieve the overall goal of this project. Part II involved two specific objectives: 1) selecting a final technology for the BOTA border crossing time measurement system, and 2) implementing the system itself. (It should be noted that during the project, the objective expanded to include a system of comparable configuration to obtain wait time at Pharr-Reynosa, where crossing time was already being measured.) The outcomes of Part I and Part II are described below.

PART I – TECHNOLOGY IDENTIFICATION

Technology Trade-Off Analysis

For the Part I study, six different technologies that could potentially facilitate the automatic measurement of border crossing times for commercial freight vehicles were identified and analyzed. This study, also entitled “Measuring Border Delay and Crossing Times at the US–Mexico Border,” provided a comparative analysis of the six selected technologies in its Part I–Tasks 1 and 2 Report. The full report can be found at <http://tti.tamu.edu/documents/TTI-2007-1.pdf>. The six technologies examined in the study’s Part I Report were:

- Automatic Vehicle Identification (AVI).
 - AVI using Laser Frequency.
 - AVI using Radio Frequency (Radio Frequency Identification – RFID).
 - AVI using Infrared Frequency.
- Automatic License Plate Recognition (ALPR).
- Vehicle Matching.
- Automatic Vehicle Location (AVL).

- Global Positioning Systems (GPS).
- Mobile Phone Location.
- Inductive Loop Detectors.

Factors such as cost, accuracy of readings, availability, and reliability were analyzed for each of the technologies listed above. Table 2 summarizes the results of the initial analysis from the Part I study by listing the advantages and disadvantages of the six technologies below.

Table 2. Summary of the advantages and disadvantages of potential technologies.

Technology	Advantages	Disadvantages
AVI	<ul style="list-style-type: none"> • Can send and/or receive information. • Commonly used in POEs for toll collection. • Available readers could be used for expanded purpose. • Low operating cost. • Broad application in metro areas. 	<ul style="list-style-type: none"> • Requires investment for roadside infrastructure (transponders and signal readers). • Requires operational agreements between the participating countries. • Card readers have to be installed in many locations to be able to have a good estimate of the border crossing travel time.
AVL	<ul style="list-style-type: none"> • Can track vehicle location and speed over the predetermined area with very good accuracy. • No need of installing any fixed roadside equipment. 	<ul style="list-style-type: none"> • Requires some investment on infrastructure (GPS devices). • Privacy issues with the vehicle owner. • Obtaining truck tracking data from truckers might be difficult.
Mobile Phone Location	<ul style="list-style-type: none"> • No infrastructure required. • Can track vehicle location and speed. 	<ul style="list-style-type: none"> • Relies on the size of the cell. • Especially affected in rural areas. • Not as accurate as other in-site technologies.
ALPR	<ul style="list-style-type: none"> • Good identification rate. • No on-board equipment is needed. 	<ul style="list-style-type: none"> • Negatively affected by slow-moving or turning vehicles (might not be suitable for border crossings). • Could require a high investment for infrastructure, especially for equipment. • Readers have to be installed in many locations to be able to have a good estimate of the border crossing travel time.

Table 3. Summary of the advantages and disadvantages of potential technologies (continued).

Technology	Advantages	Disadvantages
Vehicle Matching	<ul style="list-style-type: none"> • No on-board equipment is needed. 	<ul style="list-style-type: none"> • Could require a high investment for infrastructure, especially equipment. • Readers must be installed in many locations to be able to obtain a good estimated of the border crossing travel time.
Loop Detectors	<ul style="list-style-type: none"> • Relatively low installation cost on a per detector basis. 	<ul style="list-style-type: none"> • Detector subject to density of traffic. • In order to have a general sense of traffic patterns, a large amount of detectors are needed and therefore a large investment is required. • Border crossing scenarios are not suitable for this type of technology.

From the initial analysis, it was concluded that three of these six technologies were most appropriate to support a system that would sustain long-term data collection and be easily transferable to other POEs along the southern and northern borders of the United States. AVI (specifically with RFID), AVL (specifically with GPS), and ALPR all appeared to have the requisite characteristics to be considered for a crossing time measurement system.

After reviewing the initial assessment, the FHWA determined that the benefits of using RFID and GPS to measure commercial freight border crossing times outweighed the concerns associated with each technology. The ALPR generation available at the time was viewed as good technology, just not as cost-effective overall for crossing time calculation as RFID and GPS (NOTE: ALPR was not tested as were RFID and GPS). Some of the important benefits of the RFID and GPS technologies are described as follows.

Benefits of using RFID:

- CBP was currently using RFID transponders in commercial vehicles that could be used to capture data by this proposed system.
- Data collected for the border wait times can easily be shared with CBP and the DPS.
- DPS was planning to install RFID readers at several of their BSIFs.

Benefits of using GPS:

- The data collected are very precise
- The information received could be used to measure border wait times and locate exactly where delays are occurring.
- Real-time information is provided.

It should also be noted that not every truck need have a tag for an RFID system to produce beneficial results. RFID and GPS were subsequently chosen as the two technologies considered

best suited to support a system that automatically measures commercial freight border crossing times.

Bench Test of RFID Technology

Based on the results of the analysis performed during Part I activity, a bench test of RFID technology was conducted in a real world setting. In July 2008, a demonstration of passive RFID tag reading was coordinated using a portable setup in Austin, Texas. Within the last few years, several toll facilities had become operational in the Austin area, which put a reasonable population of RFID toll transponders (TxTags) on the area roadways. Additionally, the large number of overpasses in Austin provided an opportunity to gain easy access above the travel lanes. The bench test had two specific objectives: 1) measure the reliability of tag reads, and 2) demonstrate that tag reads between two points can be used to calculate the travel time between those two points. The results of the bench test by objective are documented below.

Objective 1 – Measure the Reliability of Tag Reads

The panel antennas were each mounted over a single lane, and tag read data were captured to a laptop using a Transcore model 2210 reader. The tag count gathered during this period was used as the baseline. This count was done by visually inspecting cars for TxTags under their windshields from overhead as they passed underneath the overpass. Electronic tags were read until the visual count reached 100 tags. The portable tag reading system reported 95 tags in one test and 103 in another compared to the visual count of 100. The differentials are small and errors easily could have arisen from visually misjudging a tag as well as traffic weaving near the reader location. In general, the portable system proved to be a reliable way to interrogate toll tags from an overhead structure. Further testing revealed that a single antenna mounted over the stripe between two lanes did a very good job of acquiring tags in both lanes, even though it is designed for reading only a single lane.

Objective 2 – Calculating Travel Times

A demonstration of travel time measurement with portable equipment was conducted on a small portion of Loop 1 northbound between the Braker Street and Duval Street overpasses in Austin. Testing occurred during off-peak hours with traffic speeds averaging 65 miles per hour (mph). The goal was to show that enough toll tag identification numbers (IDs) could be acquired at each location to provide a reasonable number of tag ID matches per minute, resulting in a travel time estimate between the two locations. One station was located on the Braker Street overpass at Loop 1. A single panel antenna was positioned over the center stripe between the center and median lane. An identical setup was deployed at Duval Street. The setup for this demonstration is illustrated in figure 14. The single antenna solution gathered data both from the center and median lanes; however, since the antenna was not optimally placed for either lane, it likely missed a small fraction of tags in those lanes. Vehicles in the shoulder lane were not read at either location. The exit ramp for Duval Street offered the only alternate travel path between the two reader locations.

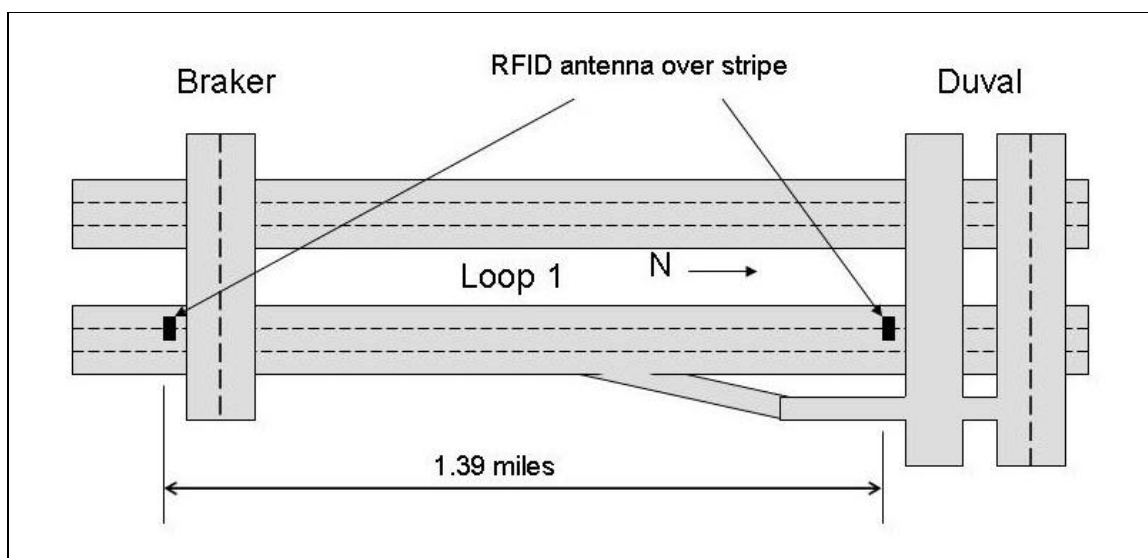


Figure 14. Illustration. Demonstration of travel time data collection using RFID technology.

The demonstration logged tags from both sites for approximately 30 minutes in the noon hour (off-peak) on July 24, 2008. The clocks on the recording equipment (i.e., laptop) at both locations were manually synchronized prior to collecting data. Note that this experiment was a rather simple deployment, which approached the limits of the RFID system capabilities. A normal deployment would place a single antenna over every lane at each site. It was impossible to match any vehicles in the shoulder lane and any vehicles that may have moved into the shoulder lane between Braker and Duval Streets such as vehicles taking the exit. A full deployment would not have this limitation and thus the results should be better (i.e., more tag matches between Braker and Duval Streets) than those in this experiment.

The total tags acquired at each site varied by approximately 90 tags, which is a significant amount. These numbers either reflected a poor reliability performance by the reader at Braker Street or could have been an indication of the traffic pattern near the Duval Street site. Vehicles may have had a tendency to choose the median and center lane for their upcoming entrance onto the tolled portion of Loop 1.

The results of this bench test exercise demonstrated that a system using RFID technology could be implemented to automatically capture the travel times of vehicles traveling between two points. Also, this test proved that the data collected by the system can be used to calculate average travel times of the vehicles passing through the system on an interval basis. Finally, testing two different RFID tag types (the TxTag and the DPS tag) demonstrated that the RFID equipment to be used for the proposed system could be configured to read different types of tags.

PART II - TECHNOLOGY SELECTION

The Part II project had a technology selection component, which focused more on the risks associated with using the two candidate technologies identified in the Part I analysis (i.e., RFID and GPS). The findings of the risks associated with using both RFID and GPS technologies are summarized in table 3.

Table 4. Potential risks of RFID and GPS based systems

Technology	Potential Risks
RFID	<ul style="list-style-type: none"> • Susceptibility to damage. • Equipment / component theft. • Limited power sources for RFID equipment. • Complexity of data transfer (especially from Mexican readers). • Agreements must be reached between public stakeholders.
GPS	<ul style="list-style-type: none"> • Privacy issues (installing tracking devices in each truck). • Agreements between private stakeholders must be reached. • Long term participation from carriers cannot be guaranteed.

After analyzing the advantages and disadvantages of both RFID and GPS technologies, RFID was selected as the recommended technology for the border crossing time measurement system at BOTA. The final portion of the Part II Technology Assessment included a stakeholder meeting in El Paso, TX. This first stakeholder meeting was held on February 20, 2008 in El Paso, TX. Stakeholders invited to this meeting included representatives from the following organizations:

- Mexican Public Stakeholders.
 - Customs (Aduana).
 - Department of Transportation (SCT).
 - General Services Administration (INDABIN).
 - State Department (SRE).
 - Ciudad Juárez Metropolitan Planning Organization (IMIP).
 - Ciudad Juárez.
- Mexican Private Stakeholders.
 - Maquila Association (AMAC).
 - Local Transportation Service Providers.
- US Public Stakeholders.
 - CBP.
 - Texas DPS.
 - FHWA.
 - FMCSA.
 - TxDOT.
 - New Mexico Dept. of Transportation (NMDOT).

- El Paso Metropolitan Planning Organization (MPO).
- City of El Paso.
- County of El Paso.
- Camino Real Regional Mobility Authority.
- GSA.
- Local University Representatives.

There were two main goals for this stakeholder meeting. The first was to validate with stakeholders the selection of RFID as the technology that would be used to measure border crossing times at BOTA. The second was to solicit ongoing stakeholder participation for the duration of the project, particularly from those stakeholders more involved in the commercial freight crossing process.

In order to meet the first goal of identifying the technology to be used, background information on the Part II project and the results of the Part I analysis of six different technologies that could support border crossing time measurements were considered. A discussion aimed at addressing any stakeholder questions and/or concerns about RFID technology and the proposed system was facilitated. This discussion also stressed that the project's interest was in aggregated transportation data. It was made clear that the intended implementation did not seek to determine the identity of any driver, vehicle, or motor carrier, and the envisioned RFID system would not reveal identity anyway. There were no objections to the proposed RFID system by the local stakeholders, which validated the initial assessment that RFID was the best-suited technology to measure border crossing times at BOTA.

However, some stakeholders did express an interest in collecting more detailed data for each US-Mexico border crossing. The original proposed system established two measuring locations (one before the queue on the Mexican side of the border and one after the BSIF on the US side) where RFID equipment would be installed in order to calculate the total crossing time for a US-bound trip. In order to collect more detailed data, additional measuring locations could be set up between each inspection facility in the US-bound border crossing process to segment the trip and measure the time a truck spends in each facility. (Segmentation would eventually be accomplished by installation of the additional reader station at the CBP primary inspection booths and modification of the algorithm to also measure wait times.)

Based on the Part I and Part II analyses and an assessment of BOTA's operational characteristics, RFID was confirmed as the technology that would be used to measure commercial vehicle border crossing times at BOTA. Both GPS and RFID technologies were considered highly capable of sustaining this particular system; however, several factors at BOTA contributed to RFID's selection. These factors included:

- Both CBP and DPS were currently using RFID in their facilities at BOTA. DPS installed several RFID stations inside its BSIF compound and distributed transponders to shippers and carriers on a voluntary basis.
- A high percentage of carriers were outfitted with RFID tags in order to comply with CBP and DPS initiatives at BOTA and the El Paso–Ciudad Juárez region.

- Because of substantial infrastructure investments by CBP and DPS, it appeared that RFID would continue to be utilized in the long run at other land border crossings along the US–Mexico border.
- Both DPS and TxDOT were willing to cooperate with the project team, and CBP expressed interest in the project.
- Local private stakeholders during the stakeholder meeting in El Paso favored RFID because of its “non-intrusive” capabilities .

After receiving final approval from the FHWA for the selection of RFID as the technology to be used, the RFID-based system was implemented. The design and installation of the system are summarized in subsequent sections of this report.

PART II - IMPLEMENTATION AT BOTA BORDER CROSSING

In Part II, the results of the Part I technology trade-off analysis were revisited and the recommended technologies verified to be still applicable. Bridge of the Americas in the vicinity of El Paso–Ciudad Juárez was considered for the RFID system implementation. Subsequently, in 2009 two RFID reader stations were installed at the port of entry to measure crossing times of US-bound trucks, followed by installation of a third reader at the CPB’s primary inspection facility in 2011. Around the same time, RFID readers were installed at CBP’s primary inspection facility at Pharr-Reynosa. TxDOT had earlier implemented a similar system at Pharr-Reynosa with capabilities to measure crossing time only.

This section of the report deals with systems engineering process utilized by the research team leading to a successful implementation of the system at both BOTA and Pharr-Reynosa. It also provides information regarding design and installation of equipment in the field as well as aggregation of data, archival and dissemination processes. Evaluation of both systems were also conducted, results of which are described in the following chapter.

Site Characterization and Identification of RFID Reader Locations

The pilot implementation conducted did not endeavor to install the optimal system for all users; rather the implementation was designed in a way that can be reconfigured. For example, in view of the above discussion of border delay and crossing times, it would be possible to discriminate shipments among FAST, non-FAST that go through primary inspection only, and non-FAST that go through secondary inspection. At BOTA, there was initially a concept for where five reader stations could be located to provide the greatest segmentation benefit. As shown in figure 15, the five reader locations that were identified would provide segmentation of the commercial vehicle crossing and allow identification of what steps in the crossing process were introducing delays.



Figure 15. Map. BOTA showing Federal and State inspection facilities and initial RFID reader locations.

Red lines outline the three distinct facility compounds at BOTA, designated by boxes with red letters:

(A) Mexican Export Lot, (B) US Federal compound, and (C) BSIF,

Orange line indicates basic direction of flow for all US-bound trucks crossing the border

Yellow line indicates internal route within a compound taken by trucks selected for secondary inspection

Green dots indicate the location of originally proposed reader sites, whose numbering is indicated by the adjacent boxes with green “R” and number

(Note that the time for a vehicle to progress from R1 to R3 as shown generally corresponds to wait time, although it can be seen in figure 15 that R3 is somewhat “upstream” from CBP primary and thus technically did not fully meet the wait time definition.)

While there was interest in the five reader locations and the benefits that would accrue from different combinations of reader locations, ultimately there were two readers initially

implemented, corresponding to R1 and R5 in figure 15.

The initial intended location for RFID reader station R1 shown in Figure 15 had to be moved upstream to the convergence of Boulevard Cuatro Siglos and Mexican Highway 45 approximately ½ mile southeast of BOTA due to construction on the approach roadways on the Ciudad Juárez side during this project. (The yellow line in figure 16 is the international border along the Rio Grande).



Figure 16. Map. Final location of first RFID reader station in Mexico.

Station R5 in figure 15 was later re-designated as R2, although its location did not change. Figure 16 shows the location of the R2 RFID reader station on the US side at the exit of the State's inspection facility. The yellow line in figure 17 is the generally counter-clockwise direction of flow of trucks that have left the CBP facility and are cleared to depart without secondary inspection).

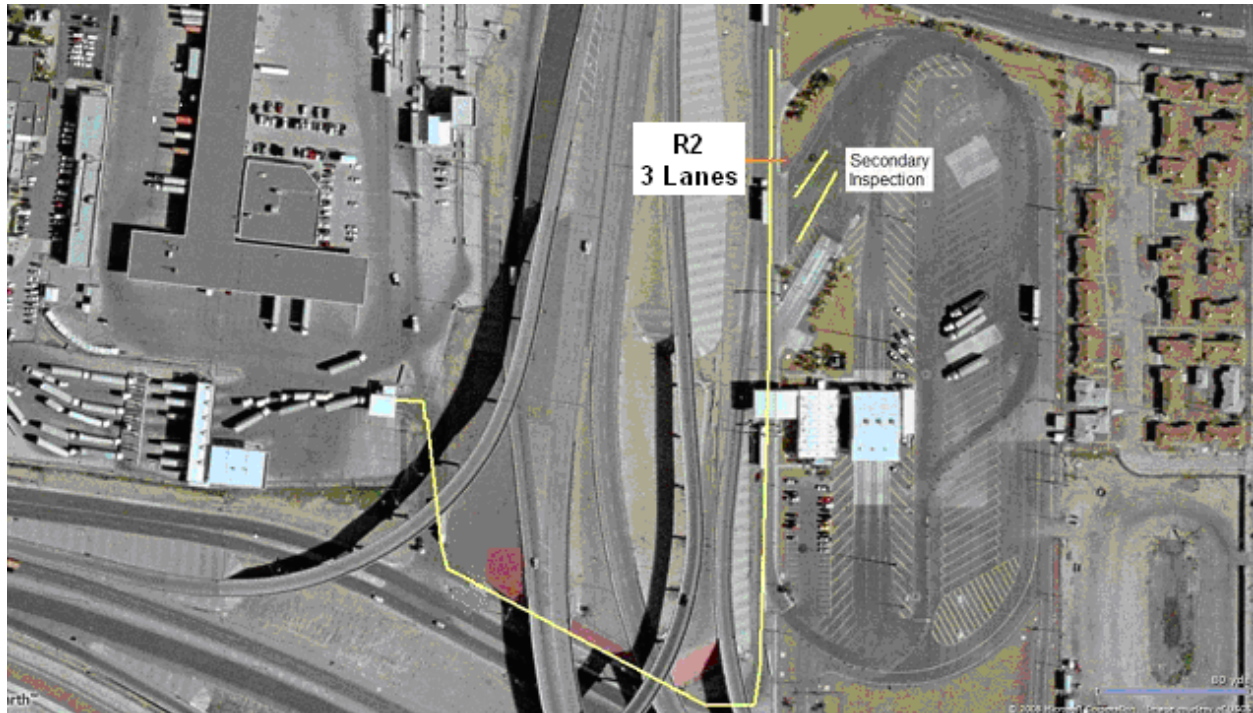


Figure 17. Map. Location of RFID reader station at the exit of the State inspection facility on the US side of the border.

System Requirements for a Border Crossing Time Measurement System

A second stakeholder meeting which took place on April 16, 2009 was coordinated as part of this project. The second stakeholder meeting was meant to provide stakeholders in the El Paso–Ciudad Juárez region with an update on progress toward implementation of the RFID-based border crossing time measurement system. The second stakeholder meeting included a project overview, reviewed current progress toward implementation, examined planned RFID reader sites, discussed the system design and installation plans, described the October 2008 limited field test and results at BOTA, presented the concept for the prototype automated crossing time measurement system, and discussed next steps. The attendees were essentially the same as the previous (first) stakeholder meeting.

The response from stakeholders who attended this meeting was overwhelmingly positive, as substantial progress had been made on the system’s implementation since the first stakeholder meeting in February 2008. From this meeting, as well as from previous tasks in this project, a group of stakeholder needs for the border crossing time measurement system were confirmed. The following is a list of the system users’ high-level needs:

- The system should not interfere in any way with day-to-day operations at BOTA. The process of vehicle detection shall not impact the speed or path of vehicles through the facilities.
- The system should be focused on analysis of aggregated data rather than the identity of drivers, shipments, and trucks in order to maintain anonymity. The goal is to generate average crossing times from individual vehicle data and not to specifically track and store crossing times of individual vehicles.
- Processed travel time data should be available to authorized subscribers through Web viewing.
- Access to archived crossing time information would be beneficial.
- Obtaining segmented trip data would be desirable but not absolutely essential to the success of the project.

In order to meet the needs of the public and private stakeholders, the project team confirmed the following list of system requirements. These system requirements were formulated through analyses of BOTA operations, RFID technology, and stakeholder meetings/interviews.

- The system needs to automatically measure the time required for a US-bound truck to cross from a pre-determined point upstream of the typical queue on the Mexican side to the exit of the BOTA POE on the US side.
- The system must not require the interaction of either drivers or employees of agencies manning the POE on either side of the border during normal operation, other than to report on a visible anomaly such as damaged system hardware (e.g., a tag reader antenna).
- System failure must not affect operations at the POE.
- The system will not require an interface to any current equipment or data streams in use at the POE. The system will not rely on data from other parties to be effective, although data from these parties may be incorporated at some point to increase the overall value of the project.
- The commercial vehicles are expected to have RFID tags using either the TransCore eGo or American Trucking Associations (ATA) tag protocol (based on information received from TxDOT). The field tag reader equipment shall be able to read tags of either protocol.
- For an RFID tag-reading system of this type to be operationally useful, it is not necessary for all or even a high percentage of the trucks to have tags. Similarly, the reader stations are not required to read and record every tag as in a tolling application. There is room for misreads. The match rate of readable tags (i.e., a percentage representing the capability of the system to detect and pair the ID of a tag when it passes readers at different field stations) is expected to be a lower percentage than the percentage of tags detected by the initial tag reader compared to total truck volume. That reality is due to trucks that pass the first reader but divert and do not cross the border, trucks that cross the border but are not allowed to exit, and trucks that are sent to secondary inspection and are “timed out” of the crossing time calculation. (It should be noted that the number of tags matched in this process is referred to in this report as the sample size.)

- The field station design must also include a solar powered option to support deployment in a more remote area or an area with unreliable electrical service.
- The field stations shall be capable of maintaining an accurate time clock, at least accurate to the minute, for use in time-stamping tag reads. Other approaches that can maintain time synchronization are also acceptable.
- The field tag reading stations should be physically compact as components may need to be installed on current traffic signal or new light weight pole installations.
- All field equipment should exhibit sufficient environmental specifications to ensure proper operation in the El Paso area climate.
- The field station design should incorporate a method to detect malfunctioning equipment and attempt to self-correct or otherwise compensate for the problem. This is particularly necessary for the communication link.
- The design shall utilize off-the-shelf components, which can readily be purchased in case a repair is required.
- The field station design shall be such that little ongoing maintenance is required since the sites may be difficult to access without prior authorization.
- The field station should be designed to remain operational after the term of this project. It is anticipated that another agency will assume responsibility for the operation and maintenance of the system at the end of the project.
- The project's Central System will reside at the Texas Transportation Institute's El Paso, Texas, office.
- All data created during the course of the project shall be stored in an archive for potential future use.
- The project will calculate current average border crossing times for US-bound commercial vehicles utilizing BOTAs.
- Project output data shall follow accepted Internet standards for data subscription/syndication.
- Processed travel time data need to be available to authorized subscribers having password protection (e.g., CBP, City of El Paso and Ciudad Juárez bridge operations, Texas DPS, TxDOT) through Web viewing.

System Engineering Methodology

With a system requirements list in place, a concept of operations (ConOps) for the border crossing time measurement system was developed. The ConOps describes the organization and operation of the system. Following is a summary of the project's design (the project's *Final System Design with Architecture Appendix* documents the following in greater detail).

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

- 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 18 shows the subsystem's organization.

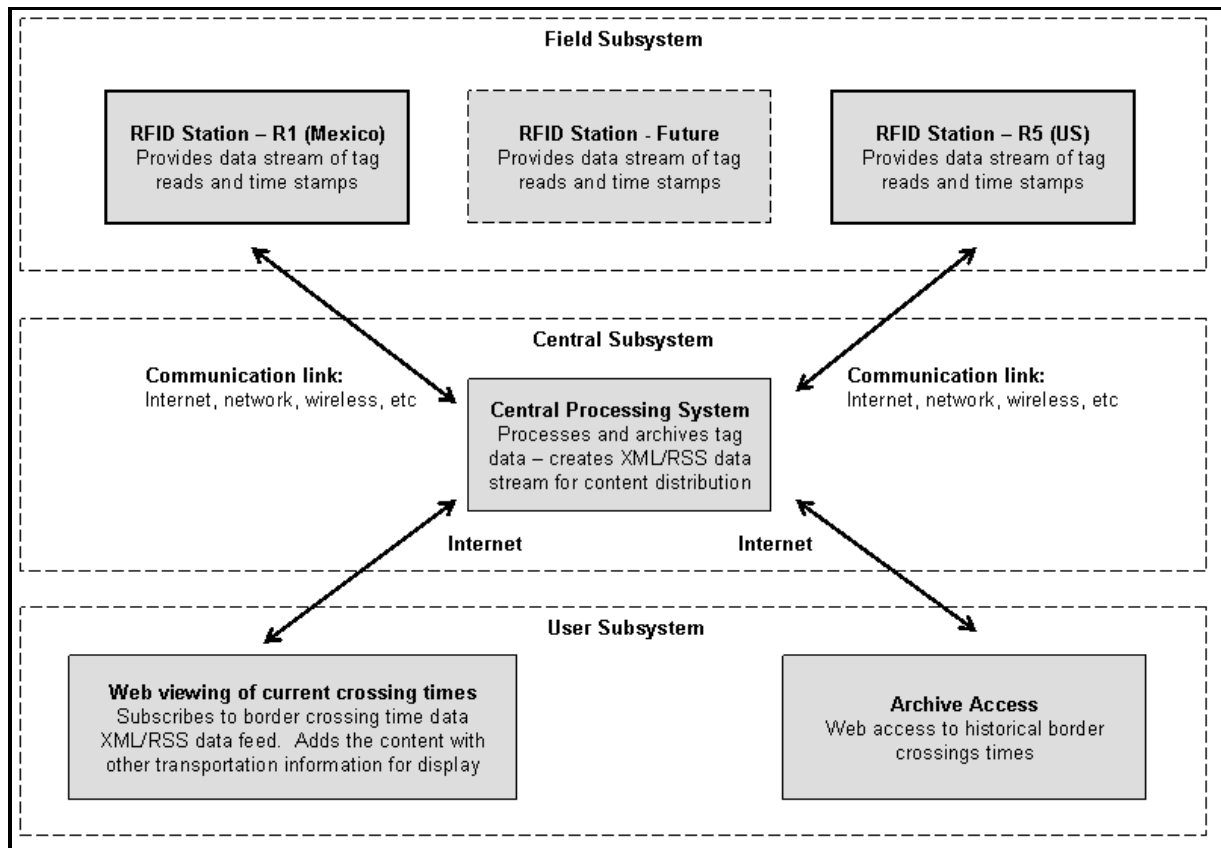


Figure 18. Illustration. Organization of various subsystems.

Northbound commercial vehicles (trucks in Mexico intending 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. RFID tags on the trucks are read as they pass the reader station. The tag query process recovers a unique identifier for each vehicle similar to a serial number. The reader station 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. A similar tag reading station is installed at the exit of the BSIF. This

station also time-stamps tag reads and forwards the data record to the central facility. There are several options for a communication link including public and private wireless and wire line. The data bandwidth requirements for each station are not excessive and could easily be met by each of these alternatives. An example detection station is shown below in figure 19.

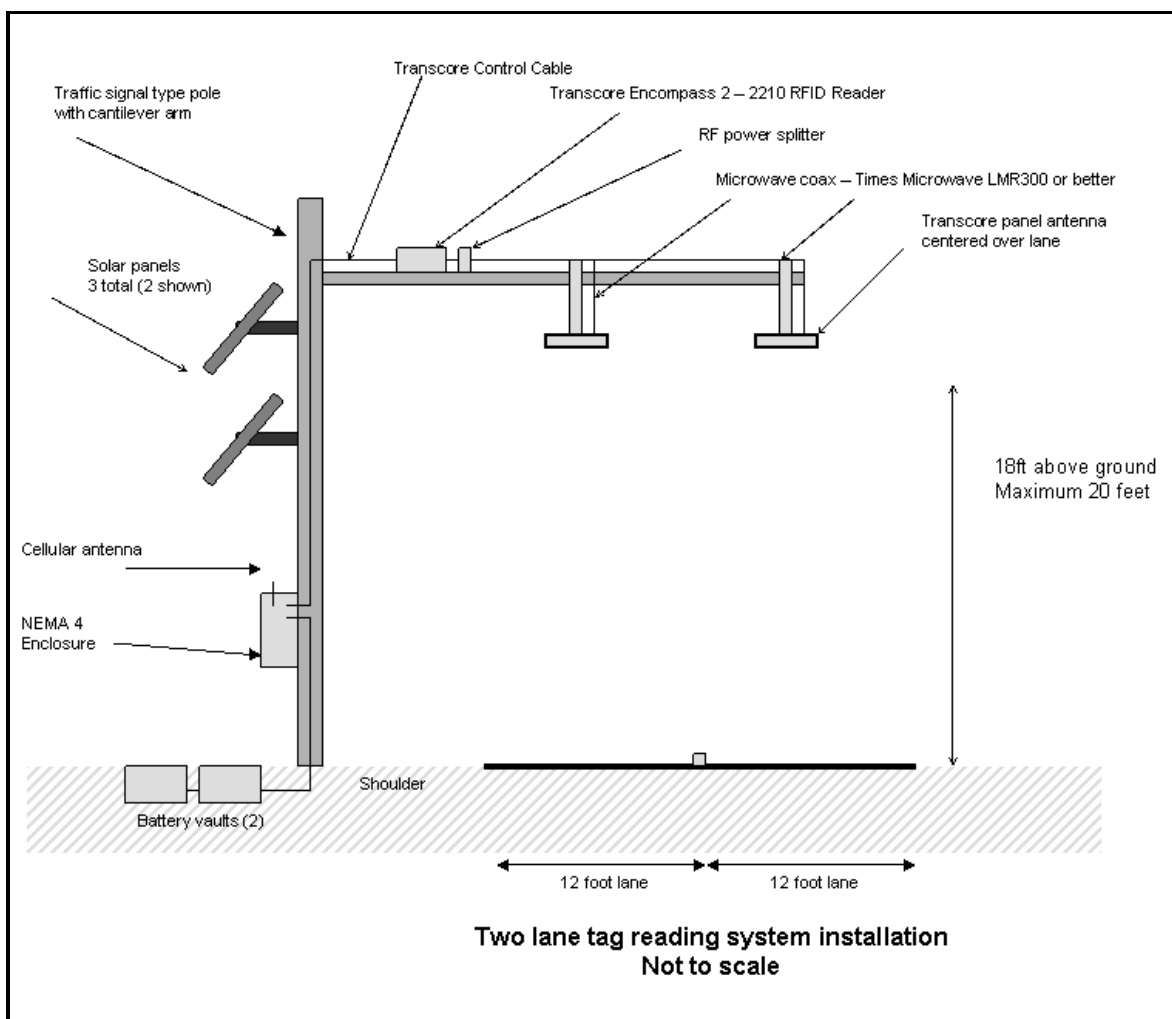


Figure 19. Illustration. Hardware configuration required for a RFID reader station.

The central facility receives data from all tag reading stations associated with the project (there were two stations installed initially at BOTA). The facility stores all inbound raw reader station data and subsequent processed data in an archive for future access and use by regional transportation agencies and other authorized stakeholders. In essence, the central facility acts as a data center for the project and therefore should be located in a reasonably secure building with reliable electric service and with personnel available to provide technical support as needed.

The raw data are processed to match tag reads of individual trucks at the entrance point on the

Mexican side and the exit point on the US side. The difference in time-stamps yields a single truck's progression as a function of time through the POE. It should be noted that the border crossing time is the sum of the time incurred on the Mexican side (Aduana, or Mexican Customs), the CBP facility, and the BSIF. If more reader stations are incorporated, producing trip segmentation, a better picture of the progression can be obtained using the same technique. The tag matching process is executed periodically to obtain a reasonable sample of trucks to produce an average.

The average US-bound 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. Archived data may also be available through the project's prototype web tool website (discussed later).

Equipment Purchase and Bench Testing

An equipment list was generated from the Final Design Document, and all identified products were procured in quantities to build two complete field detection stations. Transcore was selected as the vendor for all the RFID equipment (tag readers, antennas, cabling, etc.) to ensure compatibility with the FAST and TxDOT/DPS eGo technology windshield tags in use at BOTA. Various other vendors (B&B Electronics, Verizon Wireless, Digi International, etc.) were selected for the other, more generic, items required to construct the field detection stations.

Each field detection site back panel was assembled, configured, and tested in a project facility. Figure 20 shows an example of the back panel, which holds all the equipment for the station and is designed to be installed in the actual field cabinet as a single item. This method allowed the full suite of equipment for each detection site to be tested before it was permanently installed.



Figure 20. Photo. Back panel with communication hardware installed inside a cabinet as part of the RFID reader station.

Each detection site was fully bench tested which included (but was not limited to):

- RFID reader testing using sample tags to insure proper operation.
- Wireless communication link characteristics (bandwidth, addressing, stability, etc.).
- System watchdog (auto rebooting of wireless router) operation.
- Manual rebooting of the wireless system via web commands.
- Time-stamping and logging of sample tag data.
- Remote access to logged data.
- Timely wireless transmission of tag read data to a remote facility.
- RFID reader shutdown during a defined period of time (turn off when bridge operation is closed to reduce energy consumption).

Each detection site cabinet was subject to a 48-hour burn-in process in an attempt to uncover any design flaws or product defects prior to installation in the field. The two detection sites were specified to be solar powered which required the purchase of solar modules (solar panels), storage batteries, and power regulation equipment. This equipment was purchased and delivered to a project office in El Paso, Texas. The solar products were transferred to the construction contractor for field installation.

Equipment Installation

In February 2009, approval to break ground at the BSIF was granted by the TxDOT El Paso District, and approval to break ground at the Ciudad Juárez site was granted by IMIP, as the

cognizant agencies. The detection site equipment was assembled and tested at another project facility and shipped to El Paso for final installation by the designated construction contractors. Contracts for the installation were signed in April 2009. Installation on the US side began on April 15, 2009 and completed on May 13, 2009. Installation on the Mexico side began on May 10, 2009 and completed on July 7, 2009. The contractors were tasked with providing all field hardware needed to install an RFID tag detection station similar to ones previously installed by TxDOT at the BSIF. The contractors installed a traffic signal style steel pole and cantilever arm, ground boxes to house solar storage batteries, solar panels, and a pole cabinet large enough to house the equipment back panels. The contractors also installed the RFID antennas over the lanes as directed. Figure 21 shows antennas being installed on the US side just past where the trucks depart from the BSIF.



Figure 21. Photo. Contractors installing RFID antennae on a mast arm.

Figures 22 through 25 show different aspects of hardware installed on the Ciudad Juárez side. Note that in figure 22, roadway construction is in progress at the site of the RFID station.



Figure 22. Photo. RFID antennae at the convergence of Boulevard Cuatro Siglos and MX45.



Figure 23. Photo. Contractors installing cabinets on a pole in Ciudad Juárez, Mexico.



Figure 24. Photo. Solar panel installed at Ciudad Juárez, Mexico.



Figure 25. Photo. Pole-mounted batteries installed at Ciudad Juárez, Mexico.

Figure 26 and figure 27 show hardware installed on the El Paso side. Trucks are northbound on Gateway Boulevard North, which after a short distance intersects with East Paisano Drive providing access to the El Paso roadway system.



Figure 26. Photo. Truck leaving the State inspection facility on the US side of the border and passing under the RFID reader station.



Figure 27. Photo. Power cabinet and in-ground battery installed at El Paso, US.

Before performing the installation at the CBP primary inspection booths, a compatibility test was conducted on August 17, 2010 at the Pharr-Reynosa POE that successfully demonstrated the planned RFID configuration at CBP primary inspection booths does not interfere electronically with CBP systems at both POEs. In January 2011, CBP recommended approval of—and the GSA approved—the permit for RFID installation at primary inspection booths at the BOTA and Pharr-Reynosa POEs.

System Test and Evaluation

The system went online for its first full day of tag data matching on July 8, 2009. Northbound commercial freight crossing time data started to be received, measured, and archived by the central server at a project office in El Paso, several miles away. The *Test & Evaluation Plan* was then executed. The resulting *Test and Evaluation Report* describes various system level (i.e., field subsystem, central subsystem, and full system) tests performed to verify the proper operation of the RFID system and its hardware and software components. The tests were intended to establish the high-level working nature of the system and not to test individual system components for specification compliance. Tests were performed for each subsystem and its hardware and software components. All the tests were successful, and no errors were found in the way individual components of various subsystems were operating.

The system evaluation consisted of comparing average crossing times measured by the RFID and license plate data collected in the field to evaluate the efficiency and accuracy of the system. Evaluation of crossing time data and later wait time data is described in detail in Chapter 8

Relocation of RFID Reader Station in Mexico

When the RFID reader station in Mexico was originally deployed there were four northbound lanes. Months later, after re-construction of the roadway by the Mexican government, the number of lanes was expanded to seven. In addition, a new display sign was put in place that directed trucks to move to the right-most lanes to proceed to the BOTA POE. This diverted trucks from passing under the RFID antennas and eventually resulted in the RFID reader station identifying a less-than-desirable number of transponders.. Eventually a decision was made to remove the RFID reader station and mount the antenna on to a new sign gantry farther downstream as shown in figure 28.

Figure 28 shows a photograph from the site with the original RFID reader station, additional lanes, the new signage that directs truck to stay on right most lane, and the new location of the RFID reader station. Figure 29 shows a photograph of relocated RFID equipment into the new signage.



Figure 28. Photo. Original RFID reader station and new signage for relocation of original RFID equipment on the MX side of the BOTA.

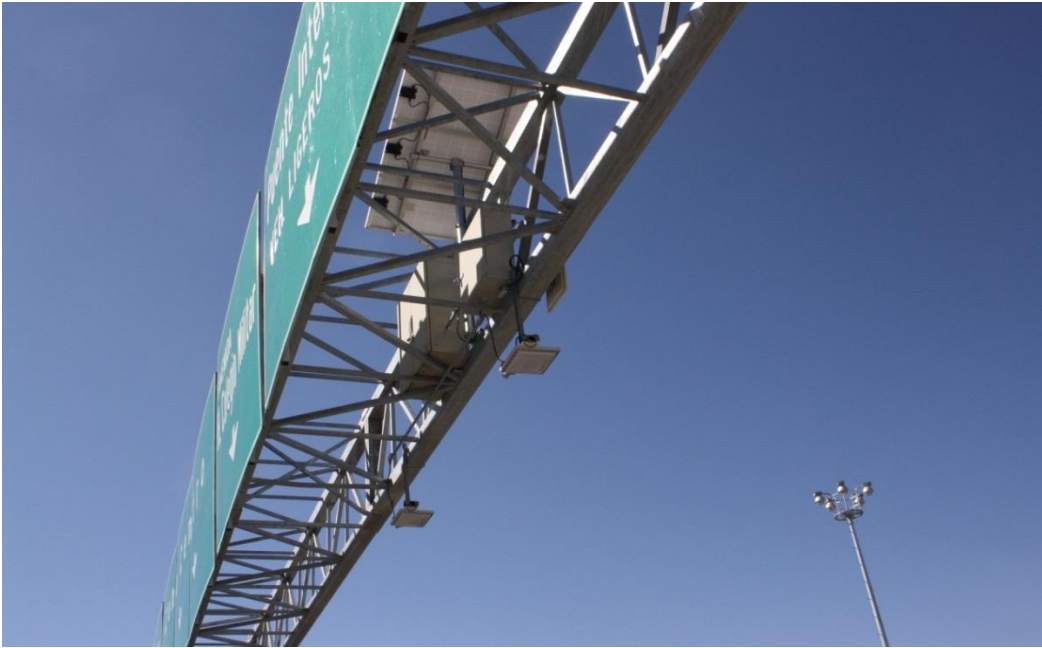


Figure 29. Photo. Relocated RFID equipment on the new signage.

The relocation of the RFID equipment was conducted on October 15-20, 2011. Subsequent to the relocation, the number of transponder reads from the station and the sample size increased substantially, as shown in figure 30.

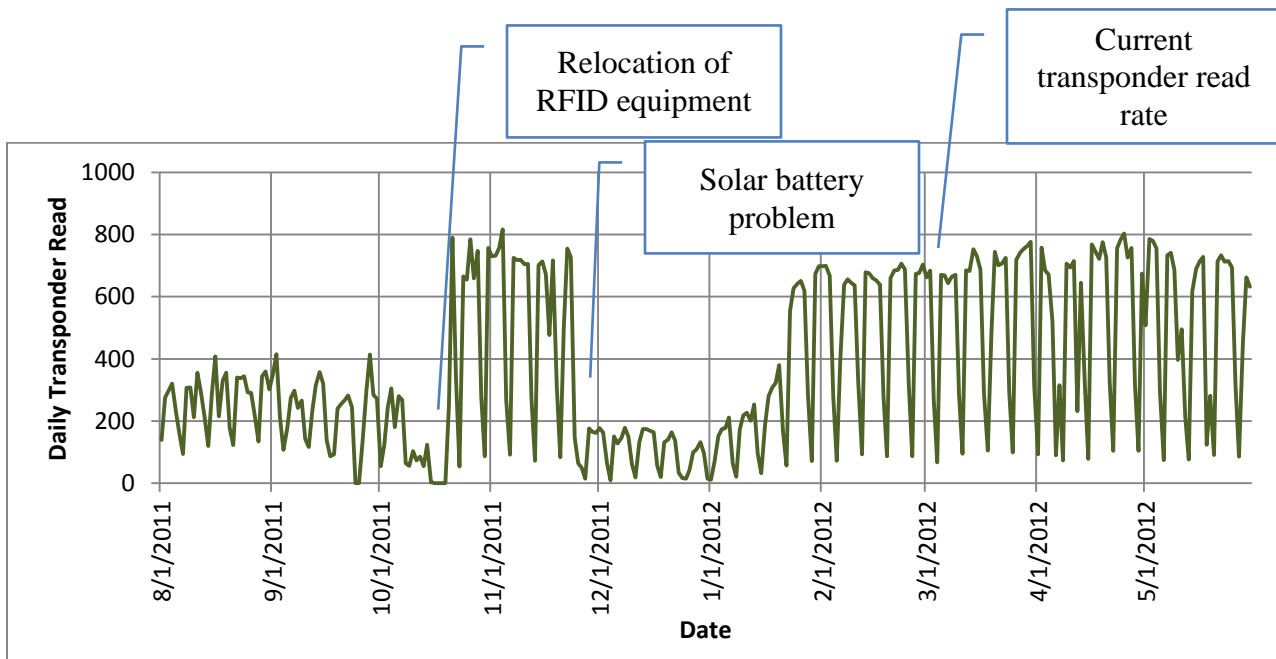


Figure 30. Chart. Improvement of transponder reads and sample size after relocation of RFID equipment to the new signage.

Installation of RFID Readers at CBP

In addition to crossing times, wait times are also important factors for shippers, carriers, and other stakeholders. Consequently, in November 2009 FHWA initiated discussions with CBP about the feasibility of RFID installations at its primary inspection facilities at international land border crossings on the US–Mexico border. Such an installation where there is already a crossing time measurement system enables the same system to also measure wait time of US-bound commercial vehicles. That discussion resulted in CBP approval of RFID installations at the primary inspection facility locations at two Texas POEs: BOTA and the Pharr-Reynosa International Bridge.

Installation of RFID readers at the CBP primary inspection lanes started on April 11, 2011. At BOTA, there are six lanes for primary inspection of trucks. Out of six lanes, two are designated for FAST trucks. However, depending on wait time and truck volume, FAST and regular lanes are interchanged since all lanes can process FAST as well as non-FAST trucks. Coordination with GSA and CBP was conducted to determine details such as installation procedure, timing, and running conduits.

Installation in all six lanes was completed on April 13, 2011. Panel antennas were mounted over each lane and a reader for every two lanes was installed in between the two lanes. Figure 31 shows RFID equipment being installed at CBP primary inspection booths at BOTA. The control cable from each reader to the control panel was run inside the conduit. The antennas were mounted slightly to the driver's side of the middle of the lane to increase the probability of detection for worn, damaged, or improperly applied tags.



Figure 31. Photo. RFID equipment being installed at CBP primary booth at BOTA.

Figure 32 shows installed RFID antennas and readers on the canopy of CBP inspection booth at BOTA. The RFID equipment was installed at the exit side of the canopy rather than at the entry side to avoid interference with the existing RFID equipment used by CBP.



Figure 32. Photo. Completed installation of RFID equipment at CBP primary booth at BOTA.

Following installation of RFID equipment, a tests of the installed equipment was performed. The most significant test was the lane-by-lane measurements of vehicle windshield tag acquisition. The test was conducted by connecting and collecting data from one RFID reader at a time. A single reader gathers tag IDs from two lanes. For instance, Reader R3A collects tag IDs from lanes one and two, Reader R3B collects tag IDs from lanes three and four, and Reader R3C collects tag IDs from lanes five and size. Both the incoming data and the vehicles in the two corresponding lanes were monitored while test equipment was connected to a reader. Each vehicle that passed through either of the two lanes was classified as one of the following:

- Had a tag and was read by the reader.
- Had what appeared to be a valid, readable tag but was not read.
- Did not have a tag, or had an improperly applied or physically damaged tag.

Table 4 displays the test results for each lane.

Table 5. Result of tag read reliability test by lane performed for each lane at BOTA.

Lane Number	Trucks with Readable Tags	Trucks With Unidentifiable Tags	Read Rate (in percent)
1	24	1	96
2	15	4	79
3	19	3	86
4	22	2	92
5	23	1	96
6	17	0	100

Note: Read rate =

$$\frac{\text{Number of trucks with readable tags}}{\text{Number of trucks with readable tags} + \text{Number of trucks with unidentifiable tags}}$$

Number of trucks with readable tags + Number of trucks with unidentifiable tags

Each reader and associated lanes were monitored for a period of approximately 1.5 hours. The number of vehicles without tags had no influence on the test results and was included strictly for completeness. The “no tag data” do indicate that a large percentage of the vehicles had some type of tag applied.

The determination of a readable tag was done by remote visual inspection. There will almost assuredly be errors made as this is strictly a judgment call made by a team member inspecting a vehicle. Most vehicles have some type of windshield sticker, but many are not RFID tags and some are difficult to tell with a high degree of accuracy. Additionally, sometimes tags have been removed and reapplied which negatively affects their performance.

Finally, a significant number of trucks in the El Paso region have the RFID windshield tag applied in the curved portion of the truck’s windshield. This bending of the windshield tag also impacts its performance. Many of the vehicles catalogued as a “miss” were trucks with the tag in the sharp radius area of the windshield.

When looking at the read percentage results, only lane 2 fell short of the target number of 85 percent. A single mistake in visually identifying an RFID tag or defining a misapplied tag was enough to make a 3 percent point difference. Both lane 1 and lane 2 are connected to Reader R3A. If an overall, calculation is made on all the lanes using the same methodology, the resulting all lanes read percentage is 92 percent, which is well above 85 percent.

Completed Installation of RFID Stations at BOTA

To date, the border wait time measurement system at BOTA includes three RFID reader stations – one on the Mexican side on the approach leading to Mexican Customs, one at the CBP primary inspection booth, and one at the exit of the State’s inspection facility. Figure 33 shows locations of RFID reader stations installed at BOTA.



Figure 33. Photo. Present Location of Three RFID reader stations at BOTA.

PART II – IMPLEMENTATION AT PHARR-REYNOSA BORDER CROSSING

Site Characterization and Identification of RFID Reader Locations

This section covers the work performed for FHWA only, which included the system development and deployment of RFID readers at CBP to allow measurement of wait times of US-bound trucks. Deployment of RFID reader stations in Mexico and at the exit of the State facility was performed as a separate initiative with TxDOT.

The system installed at Pharr-Reynosa is similar in design to BOTA. However, there is one difference: at the Pharr-Reynosa International Bridge POE there are two RFID reader stations in Mexico (R1 and R2) whereas there is only one RFID reader station in Mexico at BOTA. Through the TxDOT initiative, two RFID reader stations were installed in Mexico, one at the end of the Bridge on the US side of the border before the entrance to the CBP compound (R3), and one at the exit of the State inspection facility (R4). Because of the long length of the border crossing, a decision was made early on to add a RFID reader station at CAPUFE just north of Aduana (R2). The reader station before the entrance to CBP was uninstalled and a new set of readers were installed at CBP. Figure 34 shows the location of the RFID reader stations at the Pharr Reynosa International Bridge

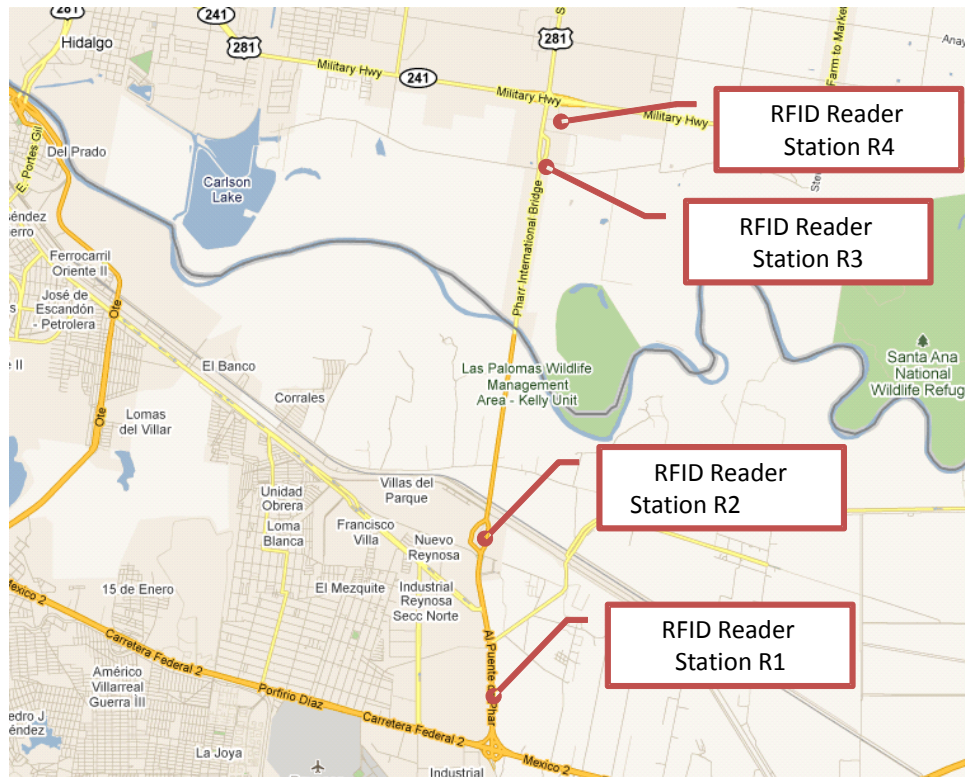


Figure 34. Map. Pharr and Reynosa showing RFID reader locations.

Installation of RFID Readers at CBP

In January 2011, CBP recommended approval of—and the GSA approved—the permit for RFID installation at the Pharr-Reynosa POE based on their implementation plans. RFID equipment was subsequently installed and tested at the Pharr-Reynosa CBP primary inspection booths, and measurement of wait time was confirmed at Pharr-Reynosa.

Installation of RFID reader stations at the Pharr-Reynosa POE primary inspection booths began on March 22, 2011 and completed on March 25, 2011. CBP has six inspection lanes at primary inspection facility. During installation, coordination with CBP operations staff was able to close one lane at a time to allow for the overhead installation work. Figure 35 shows installation of the RFID equipment at the primary inspection facility. The installation used a combination of a scissors lift and a bucket truck to quickly install in each lane. Adjacent lanes remained active and operation continued smoothly throughout the day.



Figure 35. Photo. Contractors installing RFID equipment at CBP’s primary inspection facility at Pharr-Reynosa border crossing.

Figure 36 shows completed installation of RFID equipment at the primary inspection booths. A panel antenna was mounted over each lane and a reader was installed in between two lanes.

Radio frequency coaxial cable was run from the antenna to reader. The control cable from the reader to the control panel was run inside the conduit. The antennas were mounted slightly to the driver's side of the middle of the lane to increase the probability of detection for worn, damaged, or improperly applied tags. The antennas are slightly canted toward the driver's windshield as per manufacturer's recommendations



Figure 36. Photo. Installed RFID equipment at CBP's primary inspection facility at Pharr-Reynosa border crossing.

System Test and Evaluation

The final day onsite at Pharr-Reynosa was used for system configuration, testing and any final adjustments and cleanup. On test day CBP had lane 6 closed. This meant that the third reader installed over (lanes 5 and 6) would only sense tags from lane 5. A test established the read reliability of a single lane, lane 5. During the test time interval, 36 vehicles passed under the lane five antenna. Table 5 shows the test results.

Table 6. Single lane transponder readability test at Pharr-Reynosa border crossing.

Test Parameter	Number Observed
Total Vehicles	36
Vehicles with a visible tag	30
Vehicles with an improper tag (application)	1
Vehicles read	28
Vehicles missed (assuming the tag was readable)	1
Percentage of read tags from readable tags	96.6%

Similar testing was desired for the other lanes but this would have required CBP to close lanes which was not desired. There was an attempt to measure tag reads from the other lanes, but it became clear that there was no precise way of doing a test without impacting CBP operations. Vehicles pull up and wait at the booths and tags can be read anytime during the arrival or departure. Vehicles arrive and depart independently in adjacent lanes and there is no way of determining which antenna (vehicle) the tag was read from.

An alternate option was chosen. The total tag reads would be compared from each of the three readers to determine whether there was a significant trend of lower readings from a reader. Since the queues at each lane are essentially the same (assuming no lane closures), the tag read counts should be similar given a long enough time interval.

The following data are from a test interval beginning at opening time for the Pharr facility to 12:12 p.m. on the same day. The tag read volumes as shown in table 6.

Table 7. Number of tags read over a five-hour period at different inspection lanes.

Test Parameter	Number Observed
Total tags read lanes 1 and 2	337
Total tags read lanes 3 and 4	440
Total tags read lanes 5 and 6	334

The volume on the outermost lanes (1 and 2, 5 and 6) are nearly identical with a greater volume in the middle lanes (3 and 4). The results are reasonable in that the middle lanes do not require trucks to veer into an alternate lane as they approach the primary booths. During times of minimal queuing, the middle lanes would be expected to handle more volume than the outer lanes. The relative closeness of the total tag reads from the outer lanes indicates a similar read rate (for a similar vehicle volume, which could not be verified cannot absolutely verify). It should be noted that most of the vehicles carry multiple readable tags, thus the tag volume in Table 6 does not reflect vehicle volume.

For the last measure, CBP officers working the booths were asked whether their FAST/Automated Commercial Environment (ACE) system was still operational and whether they were seeing any issues with its operation. Each officer reported the FAST/ACE system in their booth was operational and they were not seeing any service quality degradation. This indicates that the new travel time readers were not impacting the read reliability of the legacy system in operation at the inspection booths.

The system evaluation was performed by comparing average border wait times measured by the RFID and by GPS attached with a small sample of trucks. Results of evaluation of wait time data are described in detail in Chapter 8.

CHAPTER 5: DATA COLLECTION, PROCESSING, AND DISPLAY

This chapter highlights some of the key findings of the data collection and analysis portion of the project. This includes crossing time data at BOTA for the period of July 8, 2009, through March 30, 2012 and wait time data for the period of April 15, 2011 through March 30, 2012. The chapter also highlights wait time data collected at Pharr-Reynosa border crossing for the period of March 25, 2011 through March 30, 2012.

DATA COLLECTION AND WIRELESS TRANSMISSION

Each RFID reader station has an antenna located over each lane at the location. The antenna positioning is such that 85 percent or more of the vehicles passing underneath that have readable tags and pass under both reader stations should receive a tag match. The location of each reader was chosen to limit the number of antennas required for site coverage. The antenna connects with a traditional tolling-quality RFID tag reader (although these readers are not used for tolling) that can reliably read the protocol of a variety of tags carried by trucks crossing the border. The tag reader continually scans for a passing tag. (It should be noted that it is important for the tag to be correctly positioned under the truck's windshield glass for best readability results.)

As a tag passes the reader's antenna, a unique code is recovered from the tag via an exchange of radio frequency energy. The code is converted into a digital message and forwarded to the RFID station's onsite data logging component. The reader's data communication protocol is such that few or no "handshakes" and additional transactions are required during normal operation (tag read mode). The conceptual design does not currently include any additional processor or computer platform to manage the RFID reader at the local level.

The onsite logger is used to capture, time-stamp, and store all tag messages (tag reads with vehicle identification code) from the reader and can also be accessed either remotely or locally if a problem in communication interrupts data flow from the site. The logger can be considered a backup to secure the vital data needed to accomplish the main goals of the project in the event of communication failure. The logger then passes data moving both from the RFID reader and toward the reader. All data coming from the reader (tag data) are time-stamped and logged.

The tag read messages are routed out of the field site and toward a central server at an office in El Paso, Texas in near real-time. A communication solution was implemented for each field location. The communication setup included data transmission between the RFID station and the central server via cellular data.

RFID readers send data to the fixed Internet Protocol (IP) address on a fixed User Datagram Protocol (UDP) port number using a cell modem. The UDP listener on the central server monitors the UDP port for any incoming data packets. When the UDP listener detects any data packets on the incoming port, it reads the data packets, associates a time-stamp with the data read, and invokes a stored procedure on the database. This stored procedure then inserts the data read into the raw data table. A trigger fires whenever any new data are inserted into the raw data table. This trigger verifies whether the data are coming from a valid combination of reader ID

and IP address. If a valid combination is detected, then the tag number is parsed out of raw data, and the tag number and associated time-stamp are inserted in the processed data table. If the combination is not valid, then the raw data and time-stamp are inserted into the error data table.

The entire data transmission and archiving process is illustrated in figure 37.

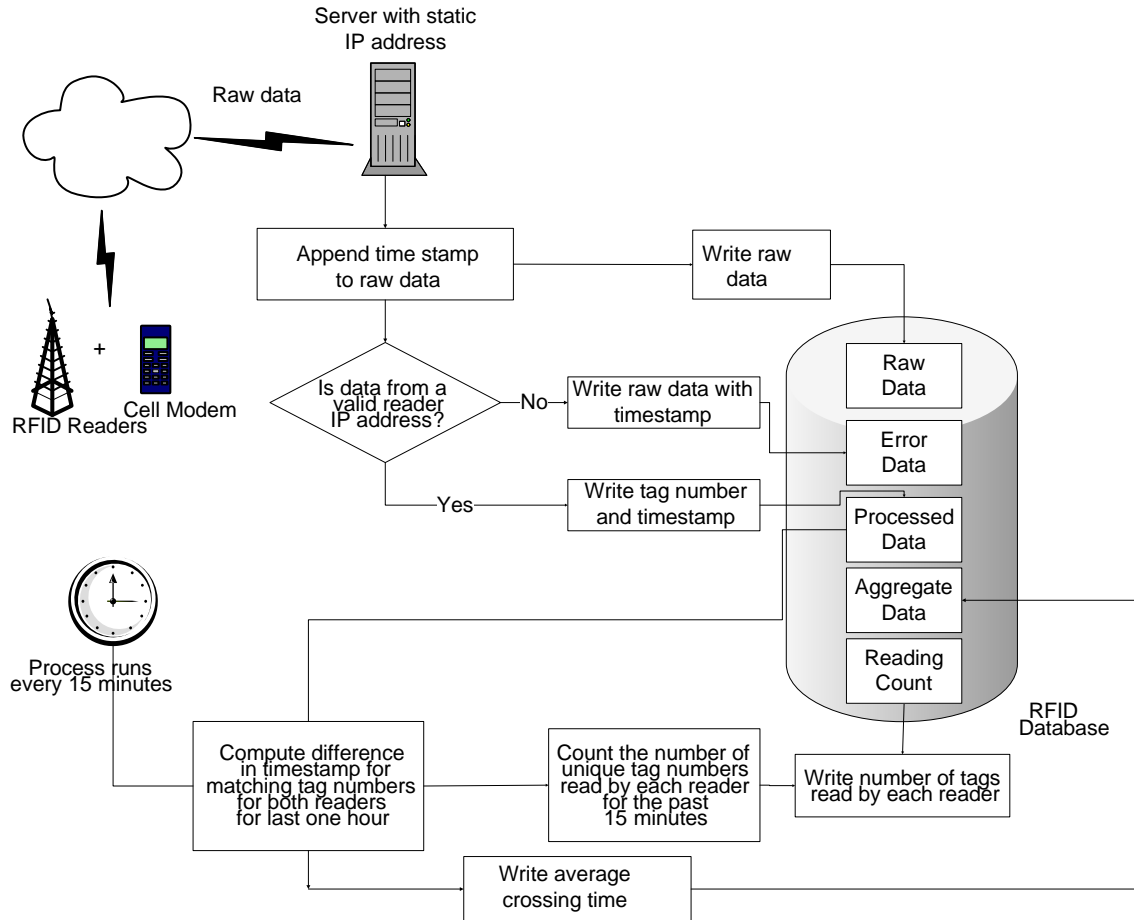


Figure 37. Illustration. Data collection, communication, and archiving process.

FILTERING RAW DATA

Depending on the characteristics of border crossings, a significant number of trucks could be part of drayage or other operations that result in their crossing the border several times in a day. Hence, it is imperative that a process to filter raw data be able to distinguish individual one-way trips inbound to the United States. This can be achieved by using a fixed time window. This is the minimum value a truck needs before the truck can join the queue again for making subsequent trips across the border. For example, if this time window is 120 minutes, it is assumed that a truck typically takes more than that amount before returning to join the queue to

cross the border again. However, this value needs to be reflective of the crossing time at the POE and thus needs to be much higher than crossing time of trucks even if some of them go through secondary inspection. It should be noted that the current filtering technique most likely filters out secondary inspection. Also, the value must not be so high that it is possible that trucks can cross the border again within that time period.

The individual transponder data are matched between RFID stations to obtain wait and crossing times. Prior to matching transponders, following filtering is performed:

- To avoid multiple tag reads from stalled vehicles.
 - Once the transponder tags are read by a RFID reader, the same tag cannot be read again by the same station for the next one hour.
- To filter tags that were missed by one of the RFID readers.
 - If a transponder tag is missed by next reader in the trip, then its excluded by the system from average crossing time and wait time calculations for that particular time interval.
- To filter trucks with multiple tags.
 - If the multiple tags read by the system have similar time timestamps (separated by a couple of seconds) for a couple of readers, then only one of those tags is used for average travel time computations.

AUTOMATED ESTIMATION OF CURRENT WAIT AND CROSSING TIMES

Following the filtering process described in earlier section, individual wait and crossing times of trucks are determined. Individual wait and crossing times that are over 120 minutes are discarded. Then after, using automated processes in the database individual wait and crossing times are aggregated in different temporal granularities.

First, average wait and crossing times are determined at a predefined frequency (e.g., every 15 minutes). For example, determine average crossing and wait times at 7:00 AM, 7:15 AM, and so on. This technique requires using a block of raw data, the span of which could be a fixed time window (e.g., 120 minutes), to calculate the average crossing and wait times. In addition to average values, standard deviation can also be part of the calculation. Average values reported every 15 minutes can be used to monitor trends within a day or week or within a predefined time period. They can also be used to identify peak and off-peak periods.

Second, average wait and crossing times data for aggregated for an hour, entire day, week, and month. This technique is useful in monitoring long-term trends of border crossing performance but dampens the peaks and off-peak values of crossing and wait times. The average truck wait and crossing time determined by the above-mentioned procedure is also used to update XML data files, which are shared via the RSS process. Using RSS, external users can obtain the most recent truck wait and crossing time via the Internet.

Toward the end of the project, discussions between CBP and FHWA led to general agreement that CBP would evaluate the wait time estimation algorithms implemented in this project so that it would make a determination to use wait times of trucks resulting from an RFID-based system.

Because of the on-going evaluation process, a separate initiative is modifying the algorithm to fulfill CBP's requirements. The initiative is also addressing CBP's concerns regarding overestimation of wait time at certain POEs during low volume conditions and providing the wait time more frequently than 15 minutes (e.g., measure every 10 minutes but display information every 5 minutes).

AUTOMATED ARCHIVING OF WAIT AND CROSSING TIME DATA

The central database server maintained at an El Paso, Texas office includes several database tables where raw and processed data are archived. Raw data include data packets obtained from the RFID reader stations and includes transponder identification number and timestamp along with the name of the reader station. The database server includes built in programs that determine wait and crossing times of individual trucks with transponders and store them in different table. The individual wait and crossing time data are then aggregated into different parameters (e.g., 15 minute/60 minute/daily average wait and crossing time) and are stored in different tables. Archived data is available to stakeholders via prototype web tool described later in this chapter.

A copy of the archived RFID data in a compact disk (CD) has been provided to the FHWA along with this report. The archived data is in Microsoft Excel 2002-2003 format. The file includes individual truck crossing times data from July 2009 through March 2012 and April 2011 through March 2012 for BOTA. The file also includes wait times data from March 2011 through March 2012 for Pharr-Reynosa.

In the database server, raw and aggregated wait and crossing time data is stored in eight different tables, definitions of which are described in table 7.

Table 8. Descriptions of tables used to store wait and crossing time data and definitions of fields in the data archive.

Table Name	Description	Field Names
RawData	This table includes raw data received from the RFID readers.	<p>PD_UID= System produced index number.</p> <p>PD_TagNum= Unique identification number of a transponder.</p> <p>PD_Time-Stamp= Time-stamp when the transponder was identified by the reader.</p> <p>PD_ReaderID =Identification number of the RFID reader. “00” represents the reader on the MX side and “01” represents the reader on the US side.</p>
TransponderCount15Minutes	This table includes total number of transponders read by individual readers at 15 minute time intervals.	<p>RC_ReaderID= Identification number of the RFID reader.</p> <p>RC_FromTime= Starting time period.</p> <p>RC_ToTime= Ending time period.</p> <p>RC_ReadingCount= Total number of transponders read by the reader in the given time period.</p>
TransponderCount60Minutes	This table includes total number of transponders read by individual readers at 60 minute time intervals.	<p>RC_ReaderID = Identification number of the RFID reader.</p> <p>RC_FromTime = Starting time period.</p> <p>RC_ToTime = Ending time period.</p> <p>RC_ReadingCount = Total number of transponders read by the reader in the given time period.</p>
RawTravelTimeData	This table includes travel times of individual transponders re-identified by both RFID readers.	<p>TagNum= Unique identification number of a transponder.</p> <p>From_Reader_ID = Identification number of the Entry RFID reader.</p> <p>To_Reader_ID = Identification number of the Exit RFID reader.</p> <p>EntryTime= Time when the transponder was identified by the RFID reader on the MX side.</p> <p>ExitTime = Time when the transponder was identified by the RFID reader on the US side.</p>

Table 9. Descriptions of tables used to store wait and crossing time data and definitions of fields in the data archive (Continued).

Table Name	Description	Field Names
AvgTravelTimeData15Min	This table includes average travel times calculated every 15 minute using 120 minutes as the time window.	AD_FromReaderID= Identification number of the upstream reader. AD_ToReaderID= Identification number of the downstream reader. AD_AvgCrossingTime= Average crossing time in Seconds. AD_Time-Stamp= Time of day when the average crossing time was calculated.
AvgTravelTimeData60Min	This table includes average travel times calculated every 60 minute using 120 minutes as the time window.	AD_FromReaderID= Identification number of the upstream reader. AD_ToReaderID= Identification number of the downstream reader. AD_AvgCrossingTime = Average crossing time in Seconds. AD_Time-Stamp=Time of day when the average crossing time was calculated.
DailyDelayStatistics	This table stores delay statistics on a daily basis	DTD_Day= Stores Day part of the date. DTD_Month =Stores Month part of the date. DTD_Year =Stores Year part of the date. DTD_TimeType =Identifies the segment type (Wait Time or Crossing Time). DTD_TotalDelay=Stores Total Delay in minutes for a time type(Wait or crossing time) for that day. DTD_SampleSize=Stores the total number of tags matches for a time type (Wait or crossing time) for that day. DTD_NumTrucksDelayed=Stores the number of trucks that had a travel time greater than the average travel time for a time type (Wait or crossing time) for that day. DTD_DelayPerTruck Stores the delay in minutes per truck for a time type(Wait or crossing time) for that day. DTD_PercentageTrucksCongested Stores the percentage of trucks that had a travel time higher than the average travel time for a time type(Wait or crossing time) for that day.

Table 10. Descriptions of tables used to store wait and crossing time data and definitions of fields in the data archive (Continued).

Table Name	Description	Field Names
MonthlyDelay Statistics	This table stores delay statistics on a monthly basis	<p>MTD_Month =Stores Month part of the date.</p> <p>MTD_Year=Stores Year part of the date.</p> <p>MTD_TimeType=Identifies the segment type (Wait Time or Crossing Time).</p> <p>MTD_TotalDelay =Stores Total Delay in minutes for a time type(WAIT or CROSS) for that month.</p> <p>MTD_SampleSize = Stores the total number of tags matches for a time type (WAIT or CROSS) for that month.</p> <p>MTD_NumTrucksDelayed=Stores the number of trucks that had a travel time greater than the average travel time for a time type (WAIT or CROSS) for that month.</p> <p>MTD_DelayPerTruck =Stores the delay in minutes per truck for a time type(WAIT or CROSS) for that month.</p> <p>MTD_PercentageTrucksCongested=Stores the percentage of trucks that had a travel time higher than the average travel time for a time type(WAIT or CROSS) for that month.</p>

DISSEMINATION AND ACCESSIBILITY OF DATA

A prototype web tool was developed to provide an effective and efficient web-based platform for dissemination of real-time traveler information and archived border-crossing related data to stakeholders on the US–Mexico border. Real-time traveler information includes current border wait times and crossing times obtained from the RFID deployments. Archived data include historic wait times and crossing times of trucks. Presentation of historic data includes trends shown in different temporal and spatial granularities, summarized and aggregated data, and simple summary statistics.

RFID systems deployed at the BOTA and Pharr-Reynosa International Bridge POEs are the focal points/sites; however the prototype web tool was developed to be scalable to accommodate other ports of entry on the US–Mexico border.

The prototype web tool was designed so that it acts as a “human interface” and “single window” to access border crossing-related archived data and real-time traveler information on the US–Mexico border. The tool is fully web-based in a client server architecture in which all data processing requests from the clients or users are performed in one or more servers. This allows faster transfer of results to the users and does not force the users to have extremely high-speed, powerful computers or mobile devices.

The prototype web tool is fully web-based and available to users via the Internet. At a minimum, a user should have access to the Internet and have a web browser such as Microsoft Internet Explorer®, Google Chrome®, Apple Safari®, and Mozilla Firefox®. The prototype web tool does not require third party software to be downloaded and installed in the computer or the mobile phone.

Accessing Real-Time Information

Stakeholders specifically indicated a need for efficient methods to access and retrieve traveler information as crossing and wait times of trucks at international land border crossings. There are several methods through which travel information can be pushed to travelers, upon their request, before leaving their point of origin and while en route to a destination. This provides travelers with capabilities to choose between border crossings, where possible, to reduce their overall trip time. While en route, travelers typically obtain information regarding travel condition at border crossings from local radio stations and, in the case of freight carriers, from their own dispatchers.

The prototype web tool includes methods by which traveler information can be “pushed” to freight carriers through personal mobile devices, or alternatively the carriers can “pull” the information from the web tool at their convenience. While this report recognizes the potential of mobile devices for expanding traveler information, it is emphasized that motorists must abide by current and future rules and regulations and safety recommendations regarding distracted driving; i.e., driver inattention due to use of cell phones or other electronic devices.

In terms of real-time information, the prototype web tool has following capabilities:

- Disseminates border crossing times and wait times of US-bound trucks.
- Provides a capability to support requests from the local media for real-time border travel time data (as long as data are from a public source that does not require any external agreements).
- Provides access to real-time data, which are used by external applications developers (e.g., for mobile devices or in-vehicle navigation devices) to access current border travel time information.
- Provides an alternate traveler information page compliant with Section 508 of the Rehabilitation Act and the Access Board Standards.
- Disseminates customized crossing and wait time information to travelers upon request.
- Provides the capability to exchange information with another traveler information service, such as State- and city-managed traffic management centers and 511 systems.

Stakeholder agencies can incorporate the real-time information into their website either by integrating the web page into a separate frame in the agency website and/or could use the RSS feed to read the data and present the data in appropriate format. Similarly, regional traffic management centers (TMCs) can use the RSS feed provided by whoever maintains the RFID system and display the crossing time information to their Dynamic Message Signs (DMS), Highway Advisory Radio (HAR), and the Internet.

Another option for the TMCs would be to use an autonomous/standalone application that receives period data from the RFID stations. The application would calculate the average crossing time periodically, and the TMC's core application can read the average crossing time and display over field devices such as DMS and HAR. This application could be distributed to regional TMCs wanting access to the crossing time information. However, there may be limitations as to how many TMCs can concurrently receive the RFID data.

The web address or uniform record locator (URL) to access the main page of the prototype web tool using a desktop web browser is <http://bordercrossing-dev.tamu.edu/index.html>. The main page (home page) of the prototype web tool shows the real-time information (most recent truck wait and crossing times) in map background, as shown in figure 38.



Figure 38. Image showing snapshot of the prototype Web tool page to view real-time information.

Users can receive real-time information consisting of most recent average crossing times and wait times of US-bound trucks via Real Simple Syndicate (RSS) feeds in XML file format. Using RSS feeds, individual users can receive the most up-to-date information automatically in their web browsers, e-mail client (e.g., Microsoft Outlook), and mobile devices. With RSS, users do not have to visit the prototype web tool website to obtain the latest real-time

information; with RSS, real-time information is delivered to the users. System users such as 511 systems, TMCs, traffic information providers, and navigation data providers can also receive the information, since RSS feeds are stored in non-proprietary XML format.

The RSS feeds also include geographical (e.g., latitude, longitude) data of lines representing the truck path between RFID stations, along with color-coding of the lines depending on the pre-determined value range. Users can also incorporate the real-time information into their Internet and Intranet sites by integrating the prototype web page into a separate frame in the agency website where the data can be presented in appropriate format. Another option for TMCs is to use an autonomous/stand-alone application that receives periodic data from the RSS feeds. This application is distributed to regional TMCs wanting access to the crossing time and wait time information.

One of the advantages of subscribing to an RSS Feed versus signing up for an e-mail newsletter or mailing list is that the subscriber does not provide name, e-mail address, or other personal information. The prototype web tool has no way of knowing the user's personal information.

Internet browsers such as the latest versions of Microsoft Internet Explorer®, Google Chrome®, Apple Safari®, and Mozilla Firefox® have RSS readers built in. If a user has a browser that does not currently support RSS, there is a variety of RSS readers available online. In addition, search engines such as Google and Yahoo! allow users to add RSS feed information to their e-mail client and personalized home pages. Users can also subscribe to RSS feeds on mobile devices using the appropriate software.

The prototype web tool currently includes two RSS feeds to relay average crossing times and wait times of US-bound trucks, one each for the BOTA and Pharr-Reynosa International Bridge POEs.

The prototype web tool currently includes two RSS feeds to relay average crossing times and wait times of US-bound trucks, one each for the Bridge of the Americas and Pharr-Reynosa International Bridge.


The URL for the RSS feed for the Bridge of the Americas is <http://bordercrossing-dev.tamu.edu/rss/trucktraveltimebota.xml>

The URL for the RSS feed for Pharr-Reynosa is <http://bordercrossing-dev.tamu.edu/rss/trucktraveltimepharr.xml>

Figure 39 and figure 40 show snapshots of RSS feeds in XML file format used at the BOTA and Pharr-Reynosa International Bridge POEs, respectively.

BOTA

You are viewing a feed that contains frequently updated content. When you subscribe to a feed, it is added to the Common Feed List. Updated information from the feed is automatically downloaded to your computer and can be viewed in Internet Explorer and other programs. [Learn more about feeds.](#)

 [Subscribe to this feed](#)

Wait Time : 25 min(s).

Wait Time for Bridge of The Americas at Dec 13 2011 1:32PM is 25 min(s).


Crossing Time : 41 min(s).

Crossing Time for Bridge of The Americas at Dec 13 2011 1:32PM is 41 min(s).

Figure 39. Image of RSS feed of wait and crossing time at Bridge of the Americas.

PHARR

You are viewing a feed that contains frequently updated content. When you subscribe to a feed, it is added to the Common Feed List. Updated information from the feed is automatically downloaded to your computer and can be viewed in Internet Explorer and other programs. [Learn more about feeds.](#)

 [Subscribe to this feed](#)

Wait Time : 37 min(s).

Wait Time for Pharr-Reynosa International Bridge, Pharr, TX at Dec 13 2011 2:32PM is 37 min(s).

Crossing Time : 47 min(s).

Crossing Time for Pharr-Reynosa International Bridge, Pharr, TX at Dec 13 2011 2:32PM is 47 min(s).

Figure 40. Image of RSS feed of wait and crossing time at Pharr-Reynosa border crossing.

Accessing Archived Information

Archived border crossing data are used by private and public agencies that have responsibilities to plan, operate, and manage border crossing infrastructure. Archived data are used by agencies

such as MPOs, city agencies, CBP, and GSA to plan future infrastructure improvements and manage resources in order to operate border crossings efficiently.

There is a strong need for a centralized repository of archived data and an efficient web-based interface to access the data. Hence, the objective of this prototype web tool is to provide user-friendly access to the archived freight border crossing and wait time data resulting from various ITS and non-ITS data sources. Through the prototype web tool, stakeholders will be able to not only access the data, but also to take action such as retrieve data, perform queries on data, and monitor trends and performance involving border-crossing flows.

Data are received from multiple RFID readers filtered, aggregated, summarized, and fed into a centralized database. Archived data not only provide a granular view of the border crossing data but also a single view of the system in the form of summarized or aggregated data. The data warehouse concept is built upon the need to provide a granular as well as a single view or image of the data, typically by using data extracted from disparate and potentially incompatible sources.

Data archived in the data warehouse are time-variant, which means that every record in the data warehouse represents a moment in time. In the prototype web tool, every record in a table is time-stamped. For example, raw data records are stamped with the time when the data were generated. Aggregated or summarized data are stamped with the time-period the data represent.

In terms of archived information, the prototype web tool has following capabilities:

- Collect and maintain data and data catalogs from one or more data sources and include quality checks, error notification, and archive coordination.
- Provide advanced data analysis and mining features to support discovery of information, patterns, and correlations in large archives.
- Provide ways for users to retrieve data and information through the Internet and mass media storage devices (consistent with Distracted Driver rules and regulations and related safety information).
- Provide pre-coded or standardized queries.
- Provide ad hoc queries and data searches.
- Provide data structured so they are readily available in ways that typical users may want to review, such as by time periods, geographic and political boundaries.
- Provide a catalog of the data and other information that are available, with the ability to request the desired format and data.
- Provide capability to execute summarizations, aggregations, and statistical analysis on the archive data.

To retrieve archived information, enter <http://bordercrossing-dev.tamu.edu/query.html> in a web browser, which brings up an archived information page as shown in figure 41. The webpage has been divided into five sections labeled 1 through 5 in figure 41 are as following:

- Crossing time-related information for user-selected POE and date range.
- Wait time-related information for user-selected POE and date range.
- Transponder count at user-selected RFID station, POE, and date range
- Monthly performance indicators for user-selected POE and date range.
- Monthly truck volume from the Bureau of Transportation Statistics (BTS).

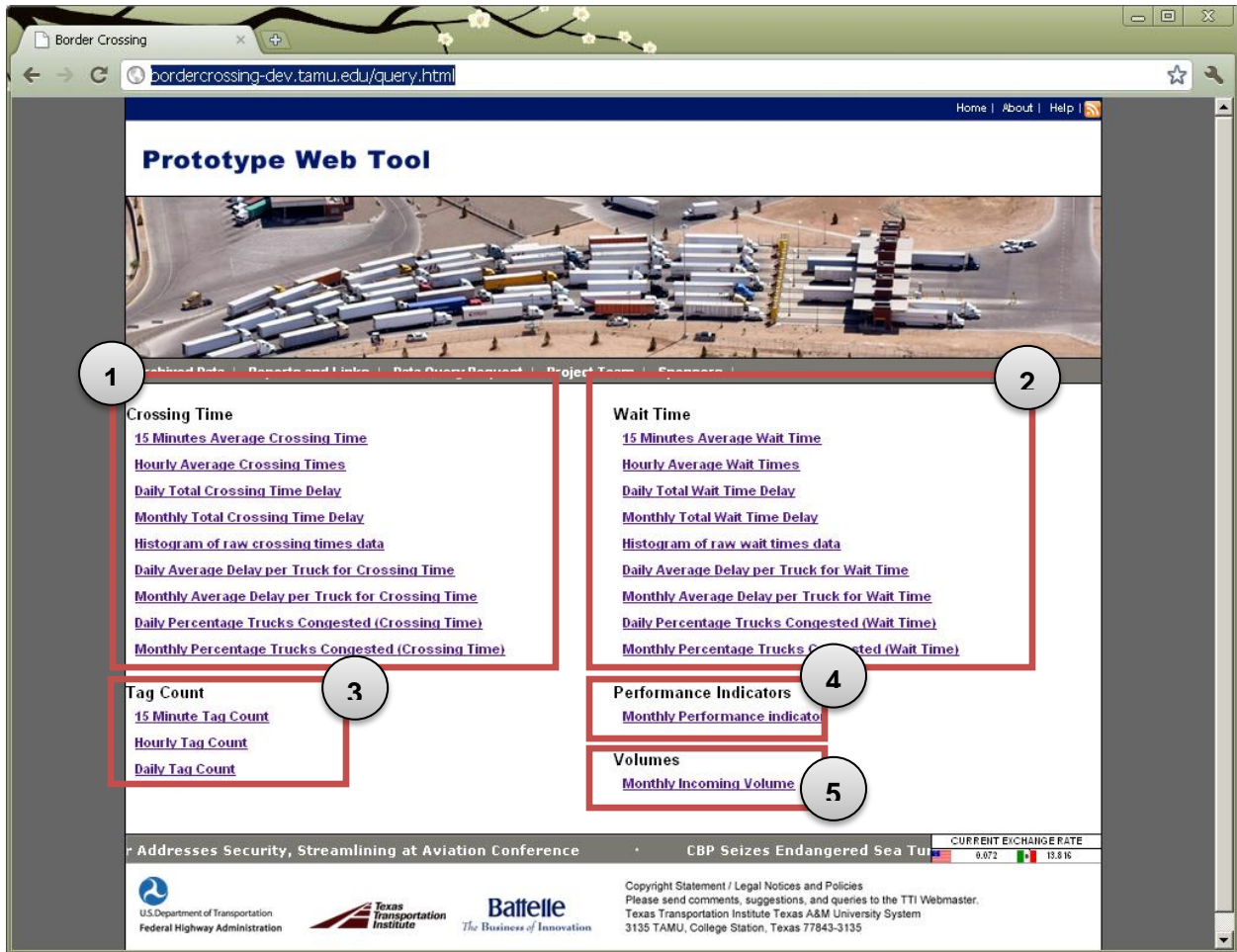


Figure 41. Image. Representative archived information web page.

CHAPTER 6: BOTA CROSSING AND WAIT TIME DATA ANALYSIS

DATA COLLECTION AND ANALYSIS PERIOD

This information will be presented in two sections: (1) unmatched tag reads with analysis, and (2) matched tag reads with analysis. Unmatched tag reads are the total number of tag IDs detected by a RFID reader station within a certain period (e.g., a day or month of operation), regardless of whether they were detected by other reader stations in the system during that same period. For measuring US-bound truck crossing time on this project, there were two reader stations initially: R1 on the Mexico side and R3 on the US side. On April 13, 2012, installation of three additional RFID readers (designated as R2A, R2B, and R2C) was completed to collect wait time data from readings at the CBP primary inspection lanes. Graphs for data collected by each reader location are portrayed as Mexico side or US side. Some tags were not readable for various reasons, which resulted in a smaller number of unmatched tag readings for either side of the border compared to the total volume of truck crossings for the same period reported by government POE operators..

For crossing time measurement, matched tag reads for the system at BOTA are the total number of tag IDs that were detected at R3 after having been previously detected at R1 within a certain buffer period. This period, which was generally set at 120 minutes, is adjustable. The buffer period is necessary so that trucks detained in secondary inspection for a long time and trucks that make multiple trips in which they are missed by a reader during a trip, do not cause the average crossing time to be longer than is representative of the operation. The matched tag read numbers are also known as the sample size.

The number of matched tag reads during a certain period will typically be lower than the unmatched tag reads for either side of the border. That is because of factors such as trucks that divert and do not cross the border after crossing R1 and trucks held in the Mexican Export Lot or CBP secondary inspection or BSIF for long periods before crossing R3. The capture rate in this report is a term expressed as a percentage in two different ways. In the data it is based on the following: (1) the number of matched tags divided by the total number of tags read on the US side, and (2) the number of matched tags divided by the total US-bound traffic volume as reported by a government source.

Events both external and internal to the system occurred during this pilot implementation that affected the tag reads. The analysis includes an explanation of what root causes were known to have brought about an anomaly, or if not conclusively proven, speculation as to the root cause.

UNMATCHED TAG READS

A central database server housed at an El Paso office receives tag identification data from the field RFID readers. In addition to the algorithms used to measure crossing times, the database contains a separate table to store highly detailed information from which the number of transponders read each day on both sides of the border can be retrieved.

One key objective in analyzing the daily transponder count is to understand the trend of commercial vehicle traffic flow during normal times, planned, and unplanned events that might impact the demand at the port of entry. Another key objective is to keep a log of when hardware failure occurred, for how long, and why.

A series of graphs has been developed that are based on the daily count of transponders, read per calendar month by RFID readers on both the Mexican and US sides of the border, that are not matched. These graphs are shown by figure 42 through figure 45. These data are meant to complement the project's information that is based on data from transponder reads that are matched (i.e., the same transponder identification number is detected passing the reader upon exiting the BSIF on the US side shortly after it was detected passing the initial reader on the Mexico side). Along with the graphs, explanations for observed discrepancies or speculation as to their causes are included. The discrepancy is numbered in the chart sequentially and then explained in following sections.

The graphs in figures 42 through figure 45 show the unmatched transponder read information by calendar year from July 2009 through March 2012. The figures are also annotated to explain or speculate on the cause of any anomalies experienced during a month. The labels on the charts represent specific anomalies, which are described as follows:

- 1 = Number of tags ready by the RFID station on the US side dropped, possibly due to frequency interference from the nearby RFID equipment deployed by TxDOT/DPS.
- 2 = Frequency of the RFID station on the US side was changed on February 19, 2009. The new frequency was set to 902.5 MHz while the original setting was 915 MHz. This change increased the number tags read by that RFID reader station.
- 3 = Roadway construction on the Mexico side started closing several lanes near the RFID station. The exact date of the road closure and number of lanes closed is not available. This reduced the number of tags read by the RFID reader on the Mexico side, while the number of tags read by the reader on the US side maintained its original level.
- 4 = Virtual private network (VPN) connection to the project's server at an El Paso office went down due to unknown reasons. Hence, data were lost for one week in March 2010.
- 5 = CBP closed several northbound commercial lanes at BOTA between May 10, 2010 and June 6, 2010 for construction.
- 6 = RFID reader installed at the CBP primary inspection booths to measure wait times of US-bound trucks.
- 7 = Due to Internet failure at El Paso office, several days of data were lost.
- 8 = RFID equipment on the Mexican side was relocated, which resulted in increase in transponder reads.

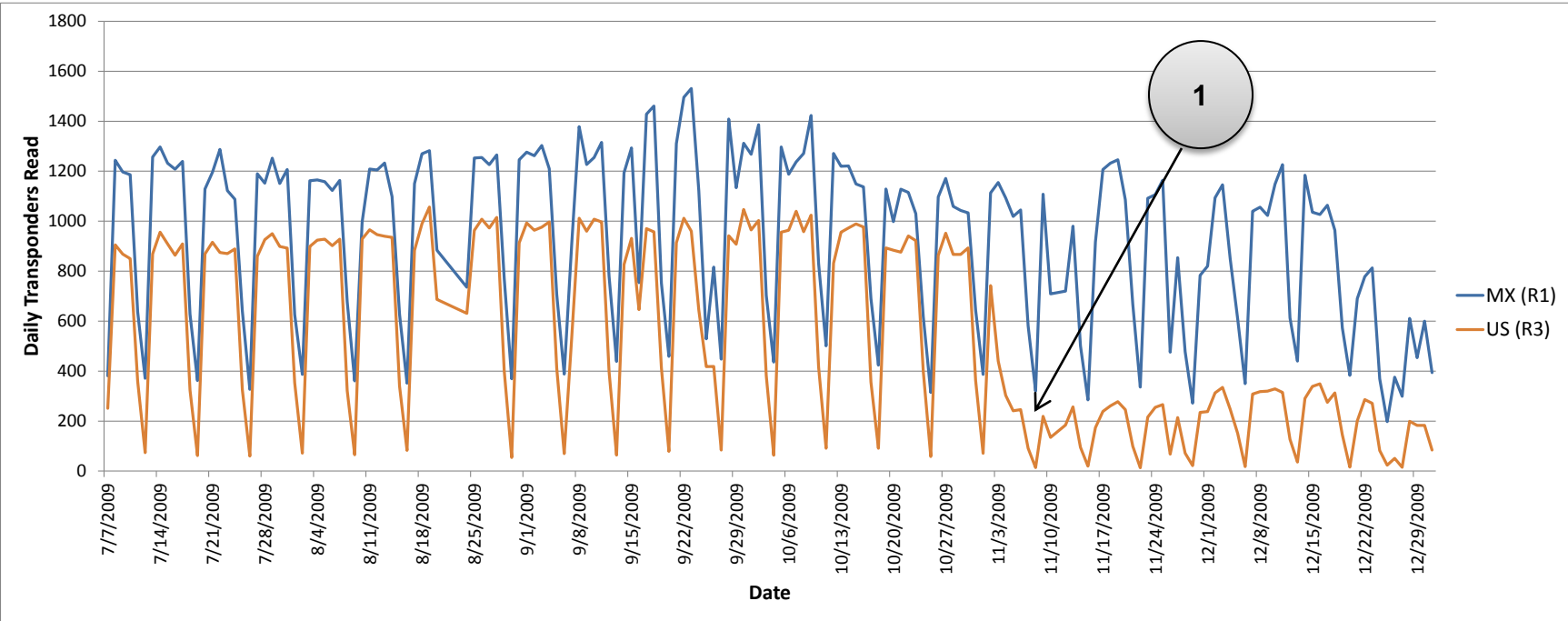


Figure 42. Chart. Daily transponder reads by first (R1) and last stations (R3) at BOTA in 2009.

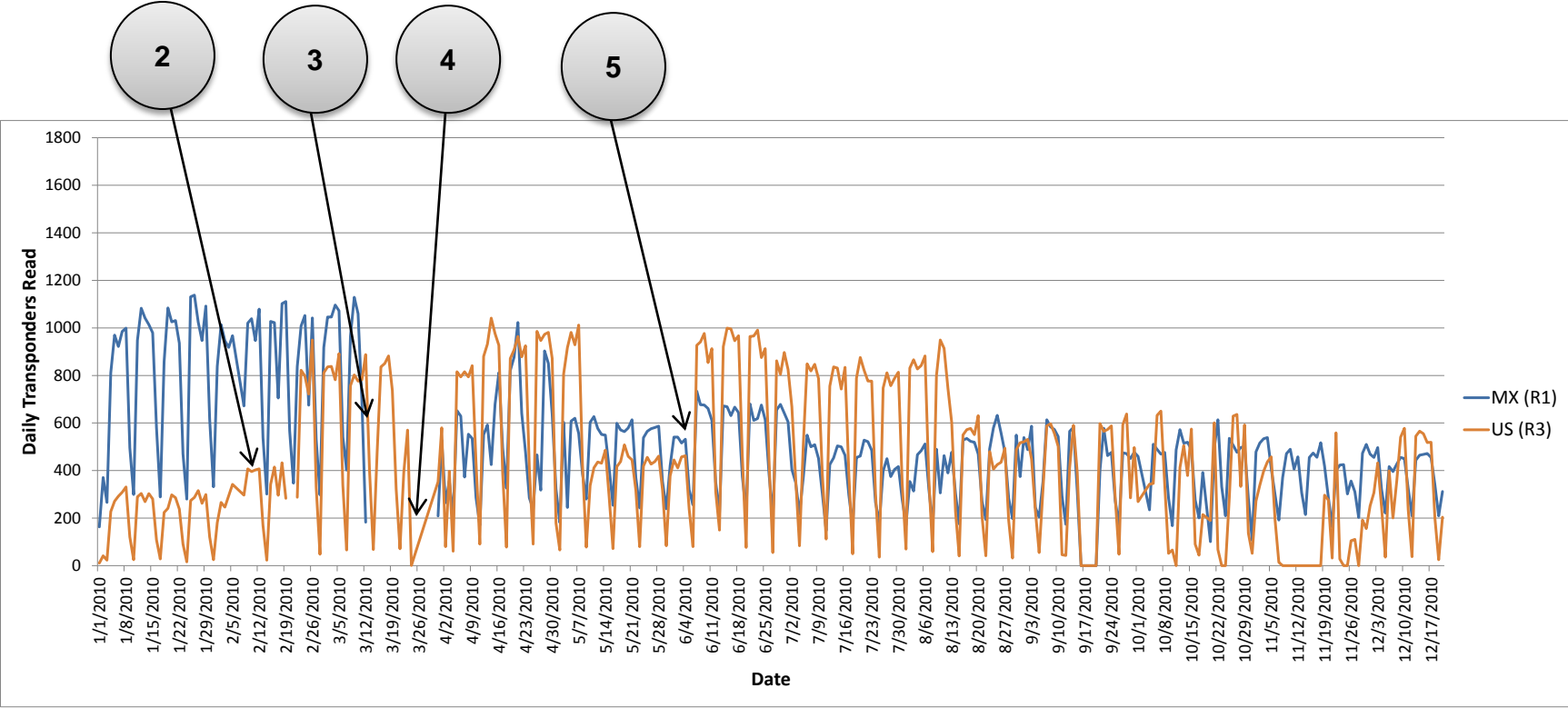


Figure 43. Chart. Daily transponder reads by first (R1) and last stations (R3) at BOTA in 2010.

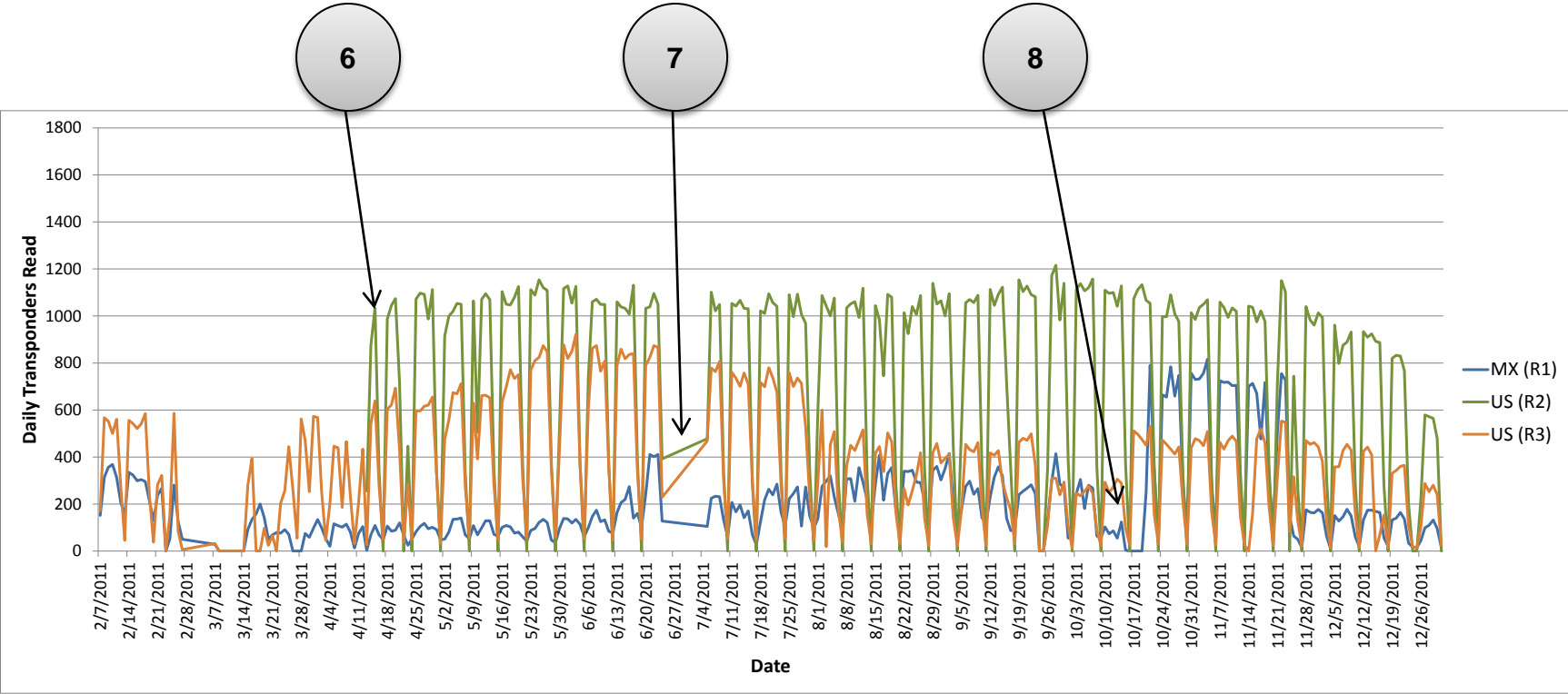


Figure 44. Chart. Daily transponder reads by all three stations at BOTA in 2011.

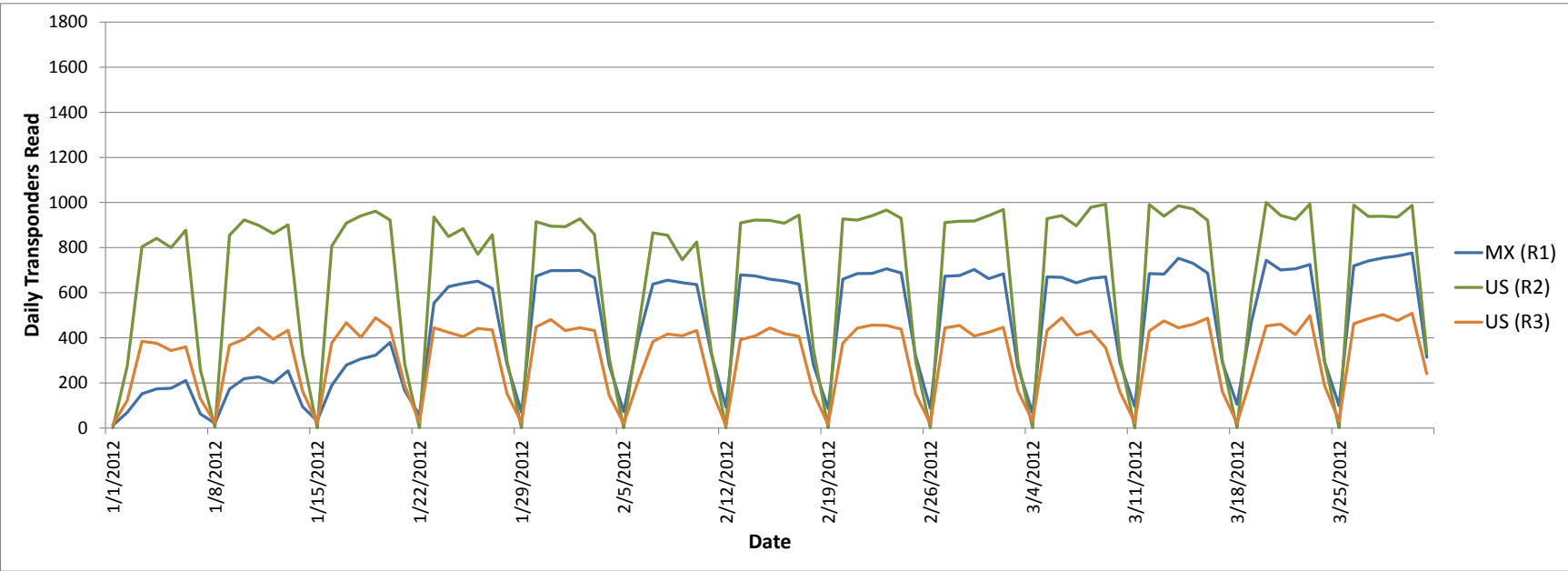


Figure 45. Chart. Daily transponder reads by all three stations at BOTA in 2012.

MATCHED TAG READS

Monthly Performance of Border Crossing

Monthly performance of the BOTA border crossing includes average crossing times of trucks observed in that month, buffer index, and sample size (total number of individual crossing times). Table 8 portrays in different ways the monthly average US-bound truck crossing times of trucks. 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.

The sample size (last column in table 8) after November 2009 dropped significantly. The number of tags read on the Mexico side appear to have continued at a consistent level (not shown in table 8), but the number of tags read on the US side dropped off. It was suspected (though not proven) that the RFID reader on the US side was reading significantly fewer tags due to frequency interference from another RFID reader installed nearby. The frequency of the project’s reader was lowered, and the numbers of its readings subsequently returned to previous rates at the later months.

The highly variable crossing times seen on this project were due to factors such as the reality that some trucks go through secondary inspection, some are part of the expedited FAST program, and some have trailers that are empty; those have very different crossing times from trucks not in those categories. When the mean crossing time was calculated, it did not distinguish among the crossing times of these trucks; all crossing times are used in calculating the mean. This results in a very high standard deviation and thus high co-efficient of variation, which is the ratio of standard deviation and the mean.

Table 11. Monthly performance of BOTA based on average crossing times of trucks.

	Average Crossing Time	95th Percentile Crossing Time	95th - Average	Buffer Index	Median	Sample Size
Month-Year	(1)	(2)	(3) = (2)- (1)	(4)=(3)/(1)	(5)	(6)
July-09	47.29	97.65	50.36	106.49%	40.71	4768
August-09	47.94	98.85	50.91	106.20%	41.78	4821
September-09	49.56	100.46	50.90	102.69%	43.24	5244
October-09	47.75	104.75	57.00	119.35%	41.03	5146
November-09	40.21	97.19	56.98	141.71%	31.08	1791
December-09	45.07	101.68	56.61	125.60%	37.35	1814
January-10	47.78	104.69	56.91	119.11%	40.43	1842
February-10	49.36	104.42	55.07	111.57%	42.77	2282
March-10	54.41	108.90	54.49	100.13%	47.88	1741
April-10	56.48	110.19	53.71	95.10%	51.59	2658
May-10	54.90	103.67	48.77	88.83%	49.65	440
June-10	52.59	107.25	54.66	103.95%	48.07	2201
July-10	50.81	103.42	52.61	103.54%	44.93	1881
August-10	50.63	105.53	54.90	108.45%	44.33	1324
September-10	54.32	106.82	52.50	96.66%	48.48	969
October-10	50.39	107.47	57.08	113.27%	43.23	622
November-10	53.14	107.75	54.60	102.75%	48.01	222
December-10	57.54	107.04	49.49	86.01%	52.42	147
January-11	54.60	102.02	47.43	86.87%	45.18	99
February-11	47.93	90.41	42.47	88.62%	46.82	109
March-11	64.30	103.81	39.51	61.45%	47.03	10
April-11	60.43	103.26	42.83	70.87%	46.88	13
May-11	57.21	107.51	50.30	87.92%	48.13	34
June-11	45.47	103.43	57.96	127.48%	38.67	375
July-11	40.83	97.00	56.17	137.59%	33.00	779
August-11	41.02	94.00	52.98	129.17%	33.00	636
September-11	46.82	105.00	58.18	124.28%	38.00	438
October-11	48.37	103.00	54.63	112.95%	42.00	1513
November-11	45.69	99.00	53.31	116.66%	39.00	3600
December-11	48.36	101.75	53.39	110.41%	41.50	1346
January-12	50.42	104.52	54.10	107.28%	44.93	2541
February-12	53.33	105.40	52.07	97.64%	49.27	3616
March-12	46.85	100.62	53.77	114.78%	40.67	4437

In figure 46, the information in Table 8 is graphed. The vertical axis on the left represents crossing time in minutes, and the axis on the right represents the buffer index (as a percent). Also included in the chart are the 95th percentile crossing time, average crossing time, total US-bound truck volume, and RFID sample size.

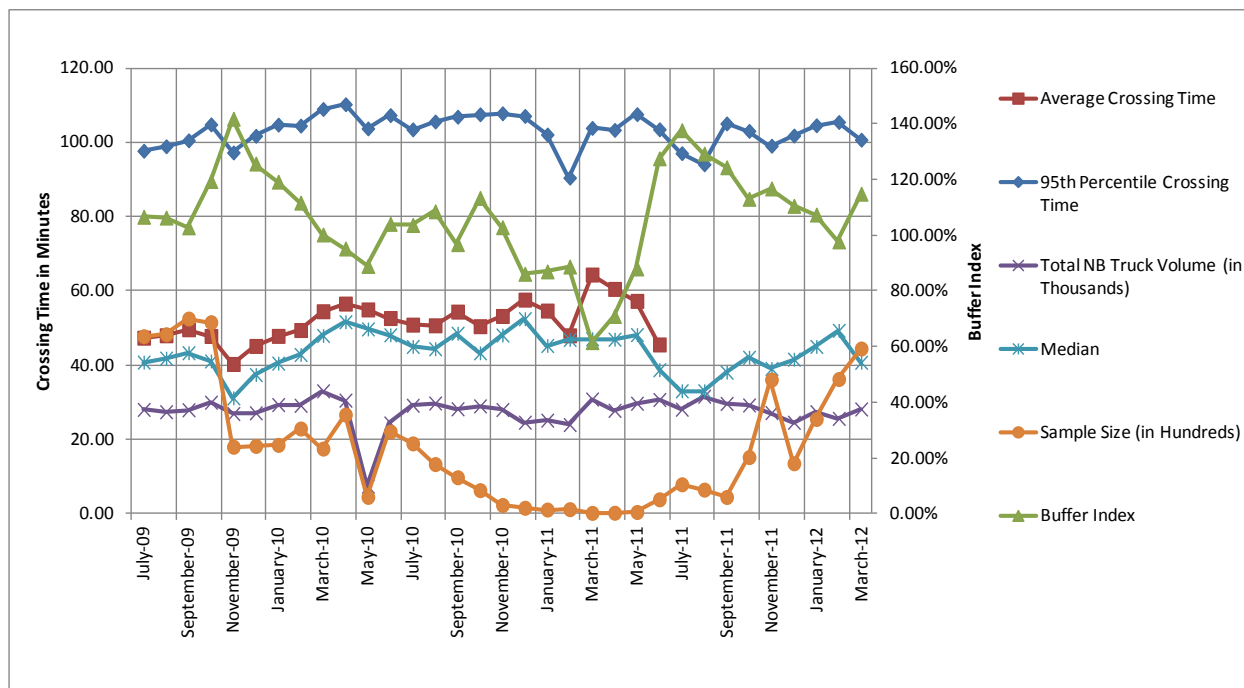


Figure 46. Chart. Monthly performance of BOTAs based on average crossing times of trucks.

Histogram of Crossing Times of Trucks

Figure 47 is a histogram of raw crossing times over a 29-day period (February 2012). It shows 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 should be noted that this histogram is based on the crossing time records with less than 120 threshold minutes to exclude outliers such as from the secondary inspection or mismatched RFID tags due to the random reader errors.

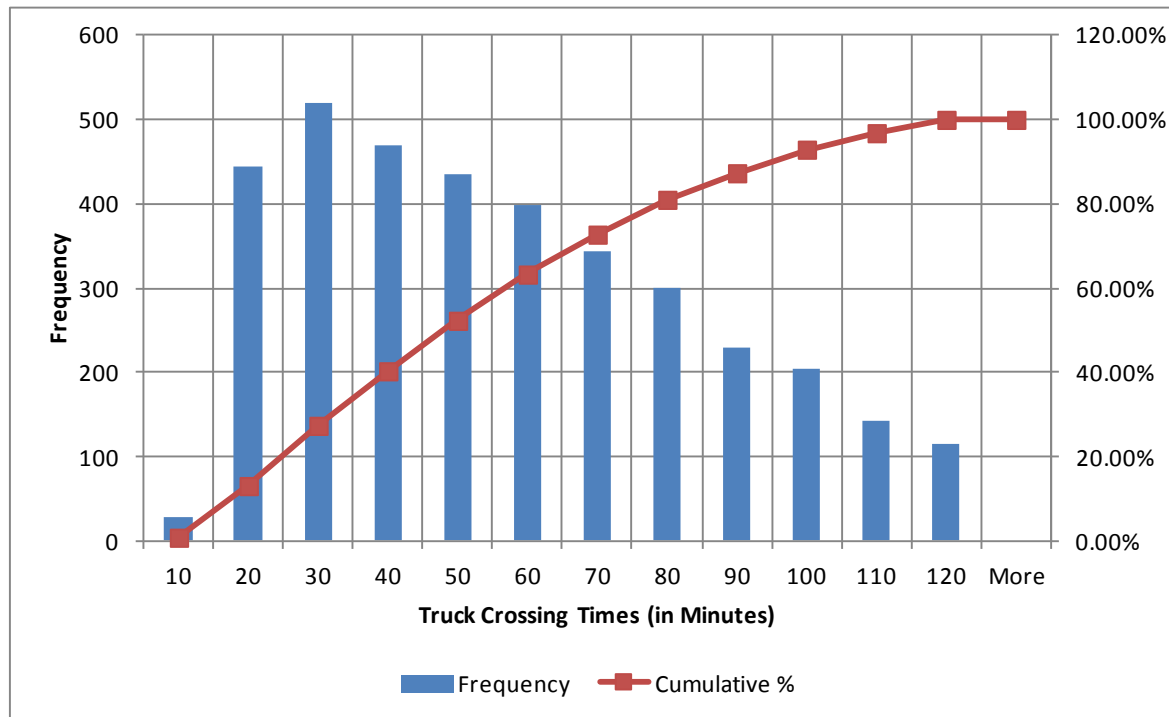


Figure 47. Chart. Histogram of raw truck crossing times for a month February 2012 at BOTA.

From the figure 47 histogram of raw truck crossing time for the month of February 2012, a histogram for a single weekday (February 15, 2012) was prepared and appears as figure 48. That histogram shows 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. As previously noted, 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 FAST 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.

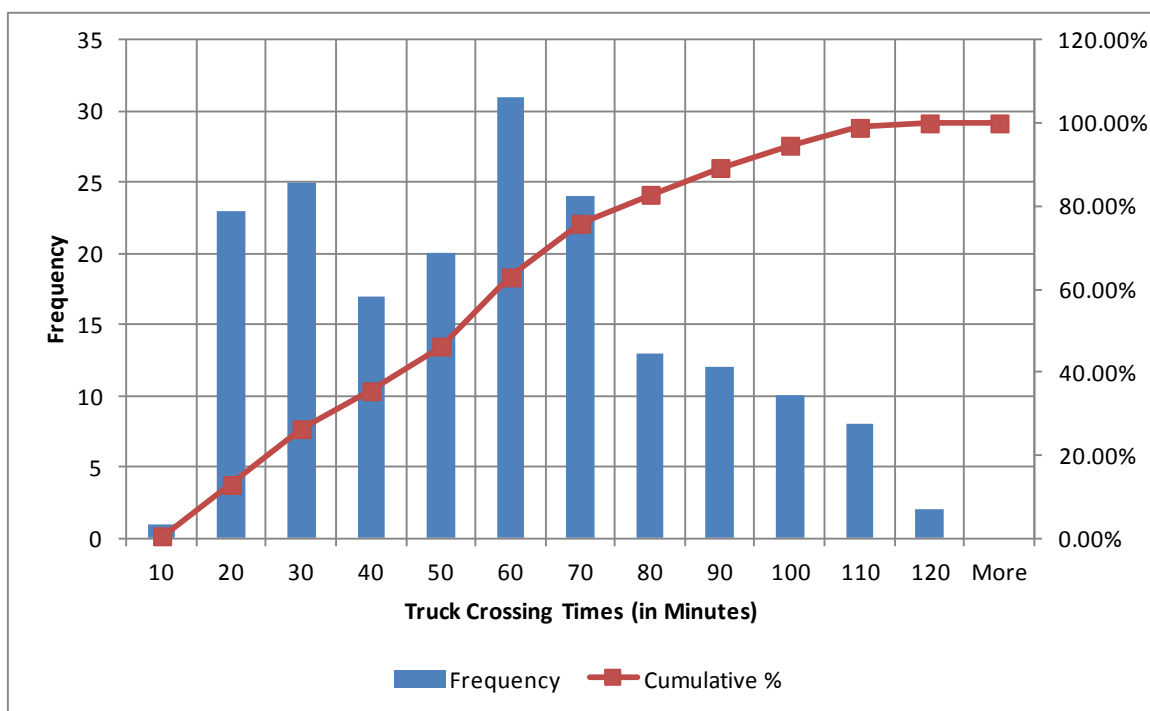
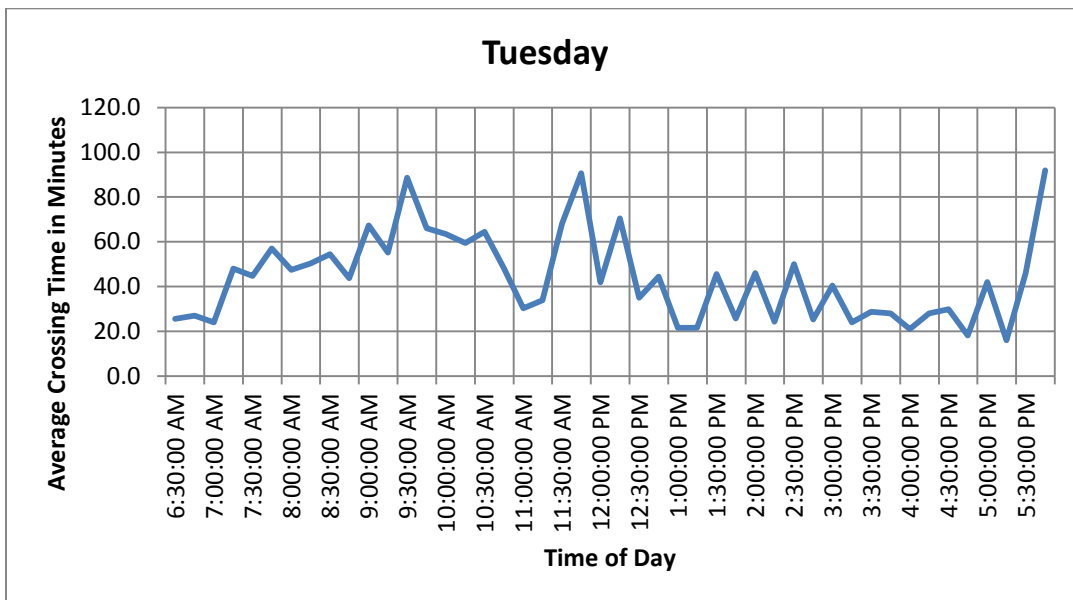
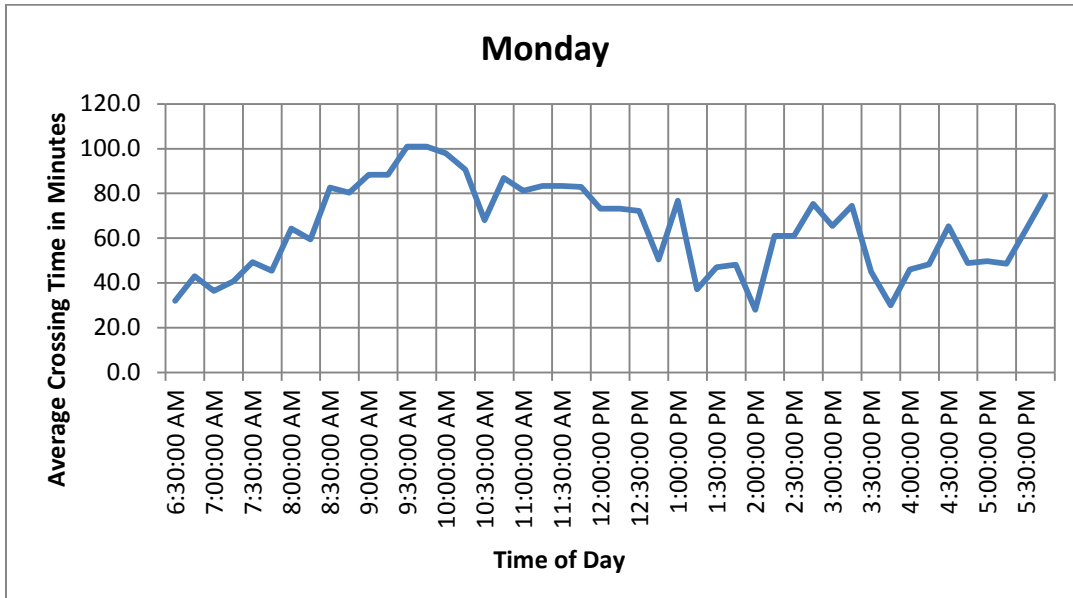
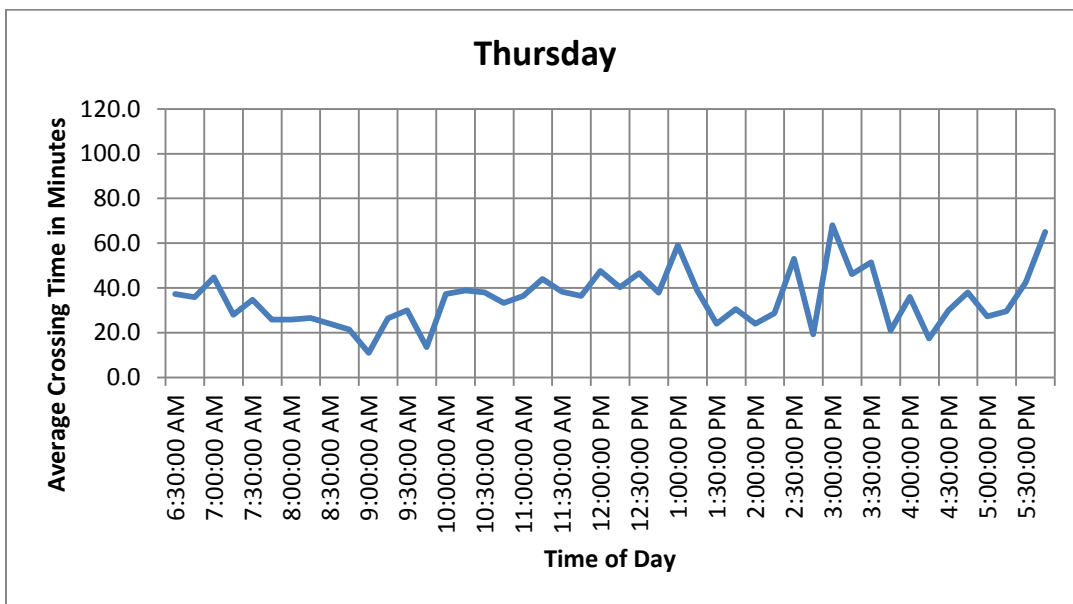
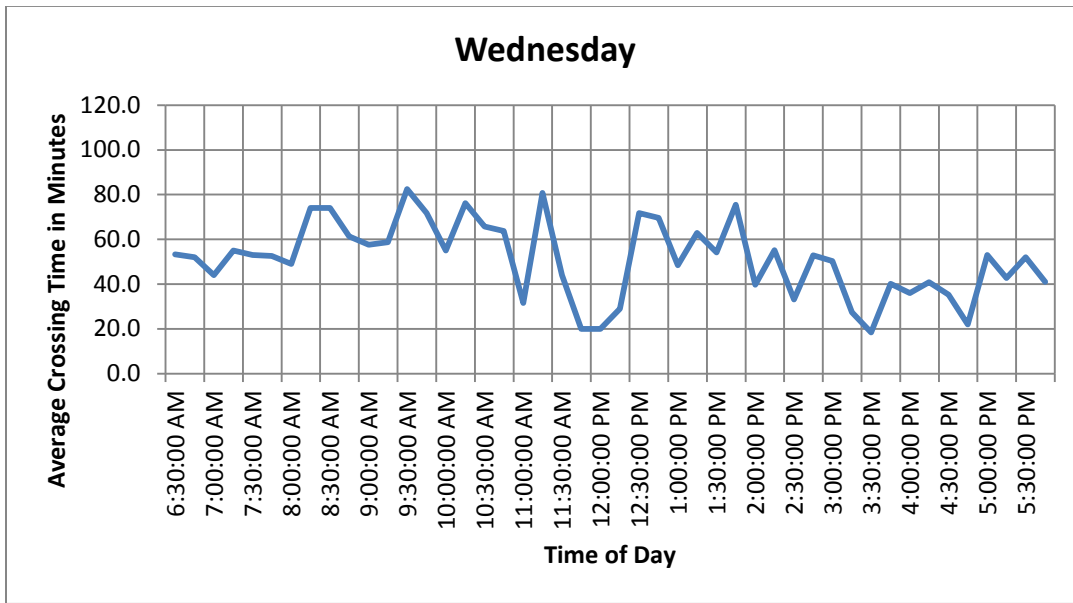


Figure 48. Chart. Histogram of raw truck crossing times on Wednesday, February 15, 2012 at BOTA.

Hourly and Daily Variation of Average Crossing Times of Trucks

Individual crossing times of trucks were aggregated into hourly and daily averages to understand the temporal variations of crossing times. Figure 49 is a snapshot of hourly and daily variation of average crossing times of US-bound commercial vehicles at BOTA for Monday through Saturday, the week of February 13, 2012. Since the bridge remains closed for commercial traffic during Sundays, there is no chart available for that day. Also, the bridge closes at 3:00 PM on Saturdays, after which there would be no data (and on the Saturday shown, there are no data after approximately 1:40 PM). These graphs show that average crossing times are lower on Thursday and Saturdays. Crossing times on Monday and Friday are higher, as Friday is normally the busiest day at the bridge. This increase in crossing times on Fridays most likely occurs because shippers rush to close out the week's sales by getting as many orders off their docks as possible, which causes US-bound truck traffic at BOTA to increase. Monday and Tuesday peak crossing times occur during the mid-morning hours, while Friday peak crossing times occur during the late-morning/early afternoon hours. Since the graphs only capture one week of February, the patterns could be different on the other weeks or months and need to be analyzed further for any possible seasonal or month-to-month trends.





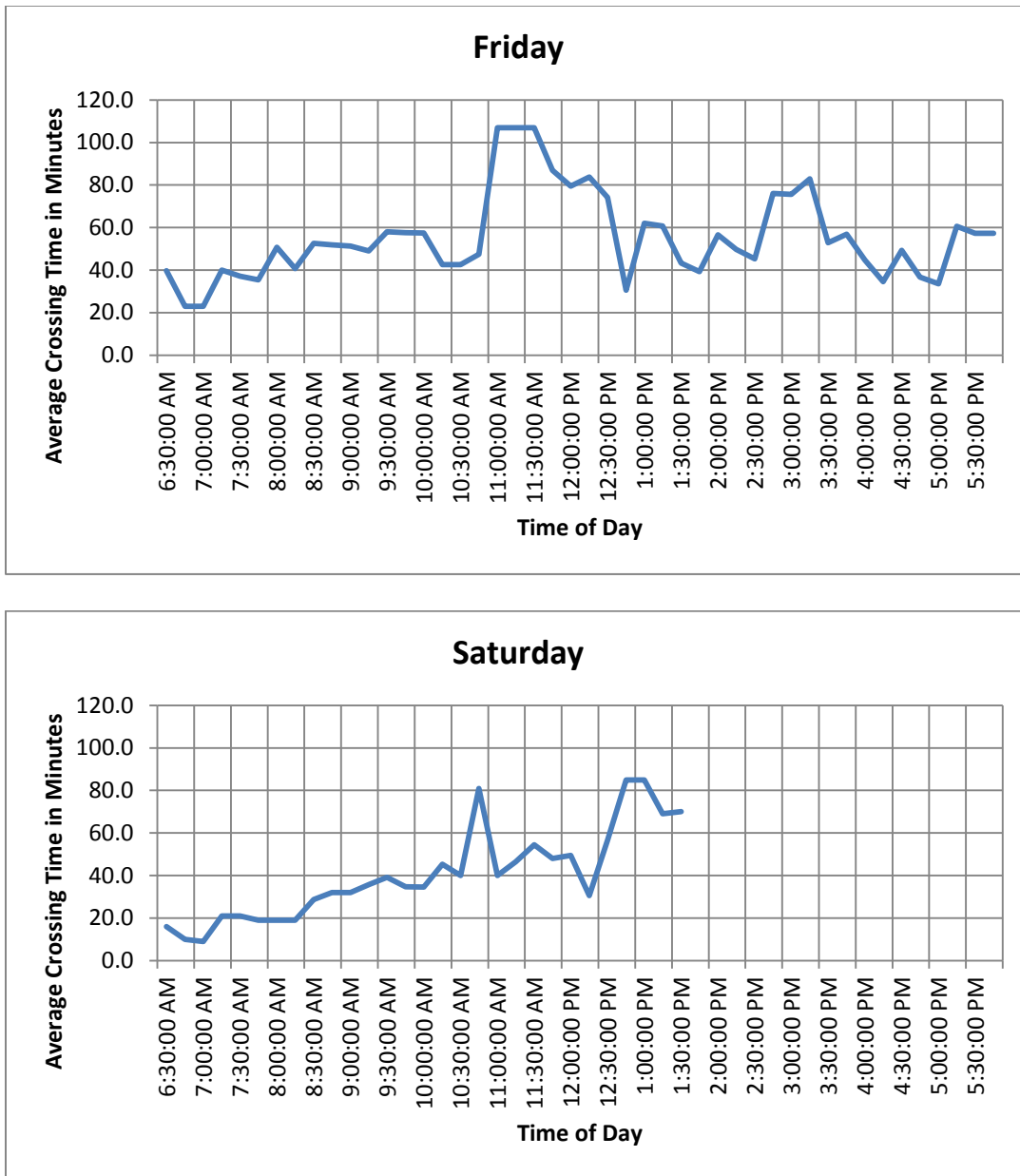


Figure 49. Charts. Hourly and daily variation of average crossing times of trucks during the week of February 13, 2012 at BOTA.

Histogram of Wait Times of Trucks

Figure 50 is a histogram of raw wait times over a 29-day period (February 2012). It shows that the 95th percentile of trucks takes approximately 80 minutes or less to wait at the border, and the 50th percentile of trucks requires approximately 40 minutes or less to cross the border. Notice that this histogram is based on the wait time records with less than 120 threshold minutes to

exclude outliers such as from the secondary inspection or miss matched RFID tags due to the random reader errors.

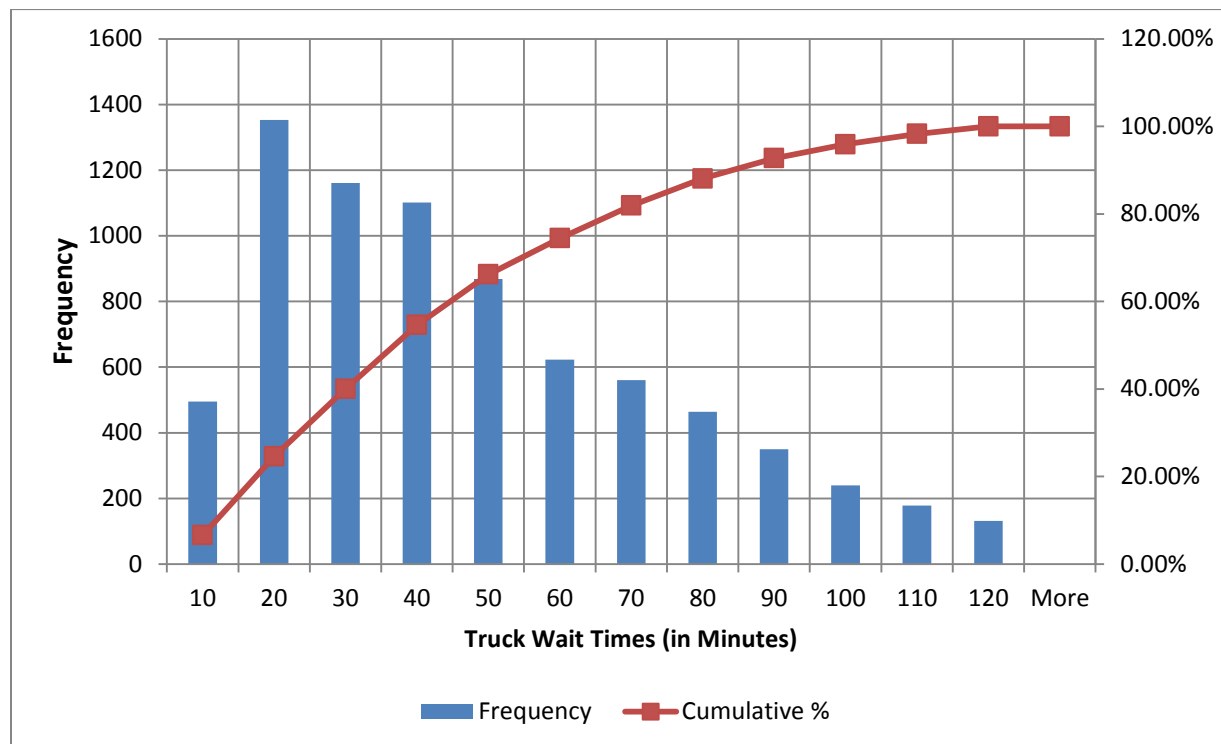


Figure 50. Chart. Histogram of raw wait times for a month February 2012 at BOTA.

Figure 51 shows histogram of raw truck wait time for the a single weekday (February 15, 2012). It shows that the 95th percentile of trucks requires approximately 90 minutes or less to wait at the border, and the 50th percentile of trucks requires approximately 50 minutes or less to wait at the border.

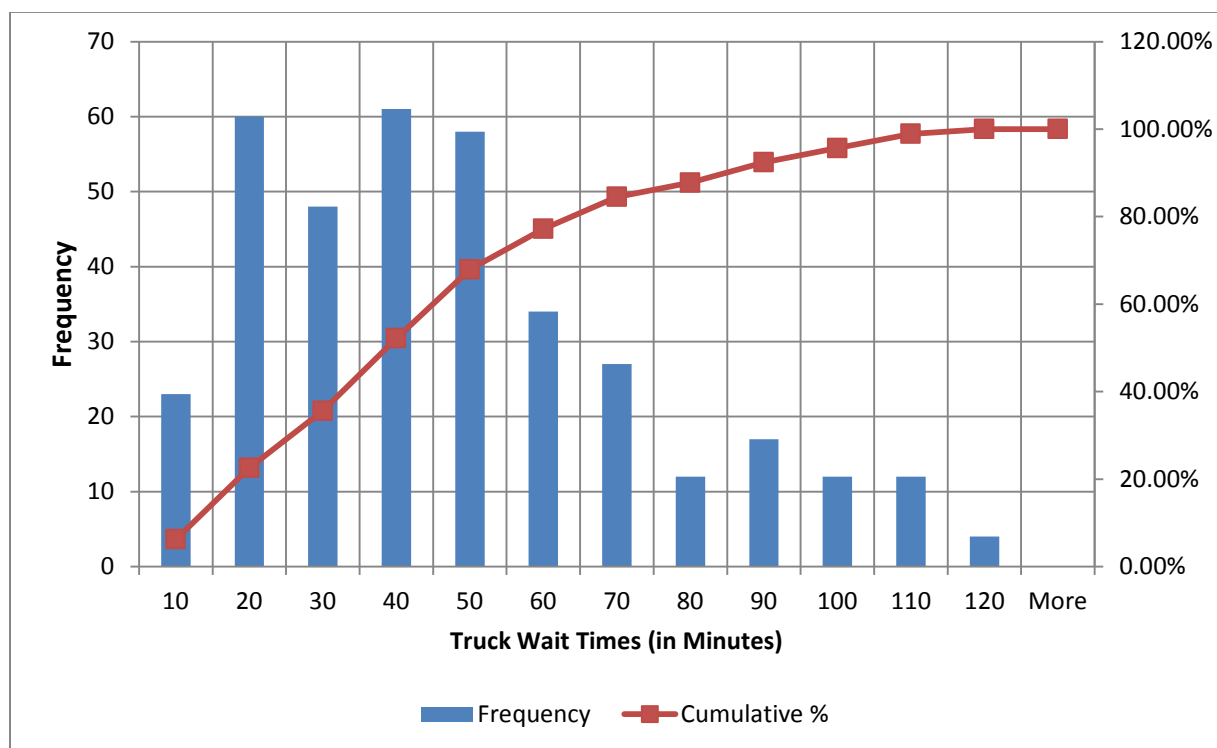
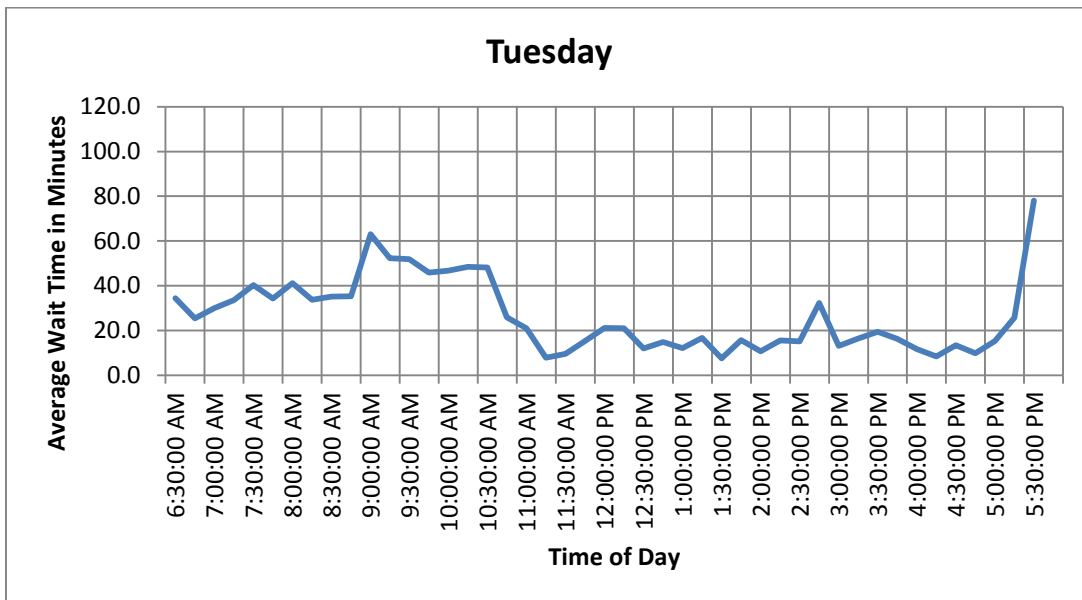
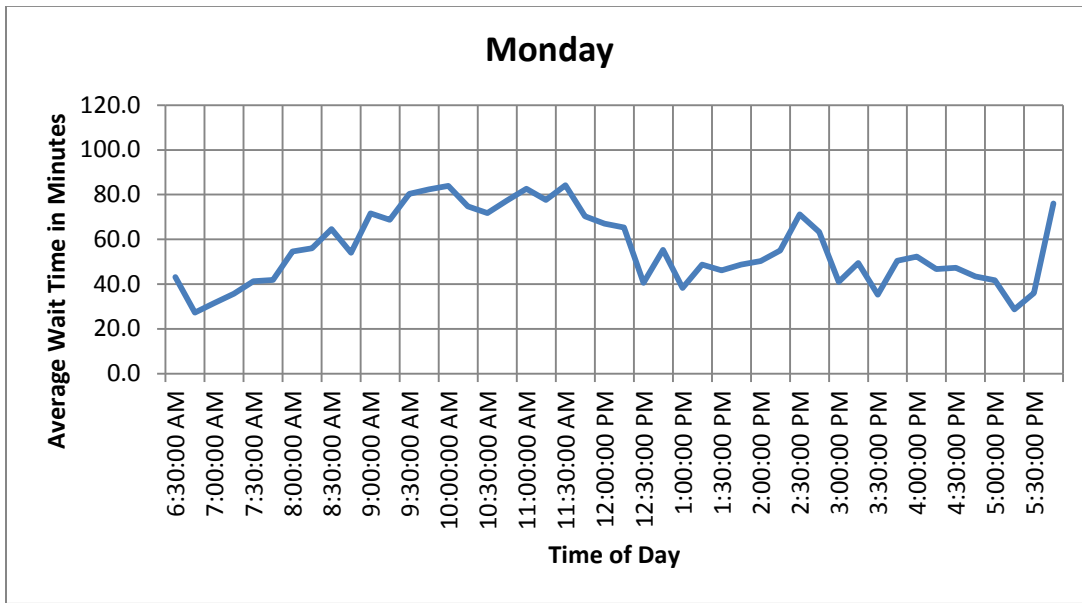
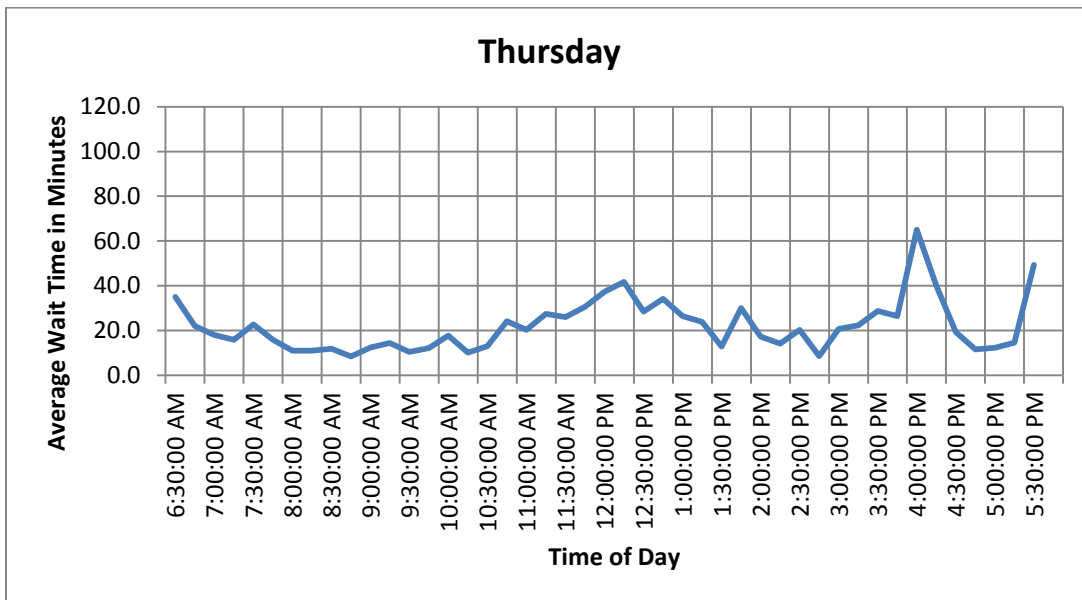
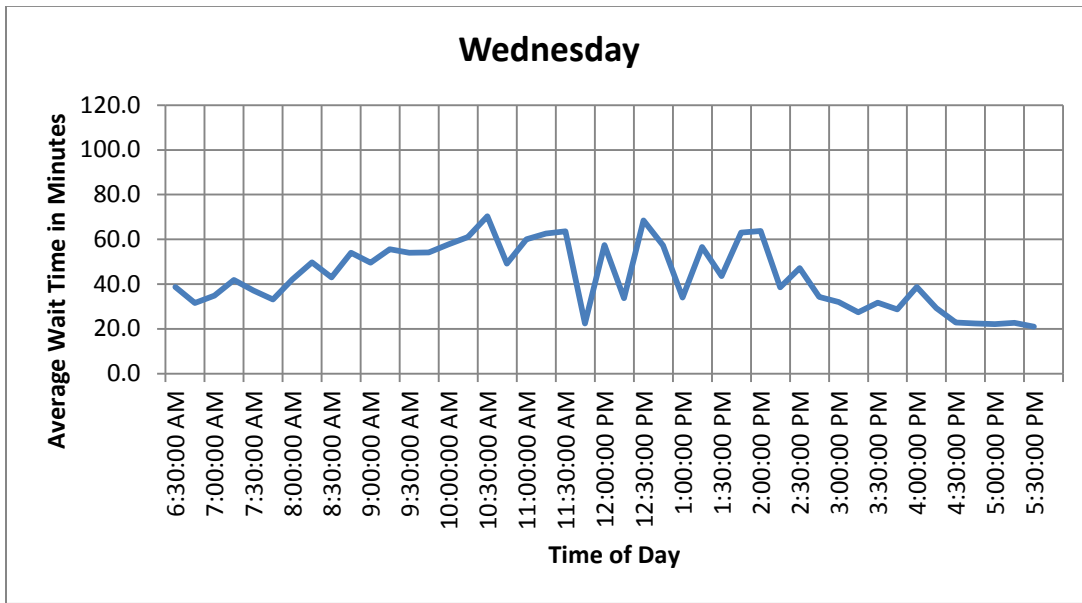


Figure 51. Chart. Histogram of raw truck wait times on Wednesday, February 15, 2012 at BOTA.

Hourly and Daily Variation of Average Wait Times of Trucks

Figure 52 illustrates the average crossing times for US-bound commercial vehicles at BOTA by day during the week of February 13, 2009. The wait time is calculated from the matched RFID tags between the reader in Mexico and at the CBP primary inspection facility. The average wait times are lower on Tuesday, Thursday, and Saturdays while Monday and Friday have overall higher wait times. Monday wait times are steadily increased to the peak time around 10:00 AM and maintain the plateau until 11:30 AM. Friday shows multiple peaks between 10:30 AM and 12:30 PM.





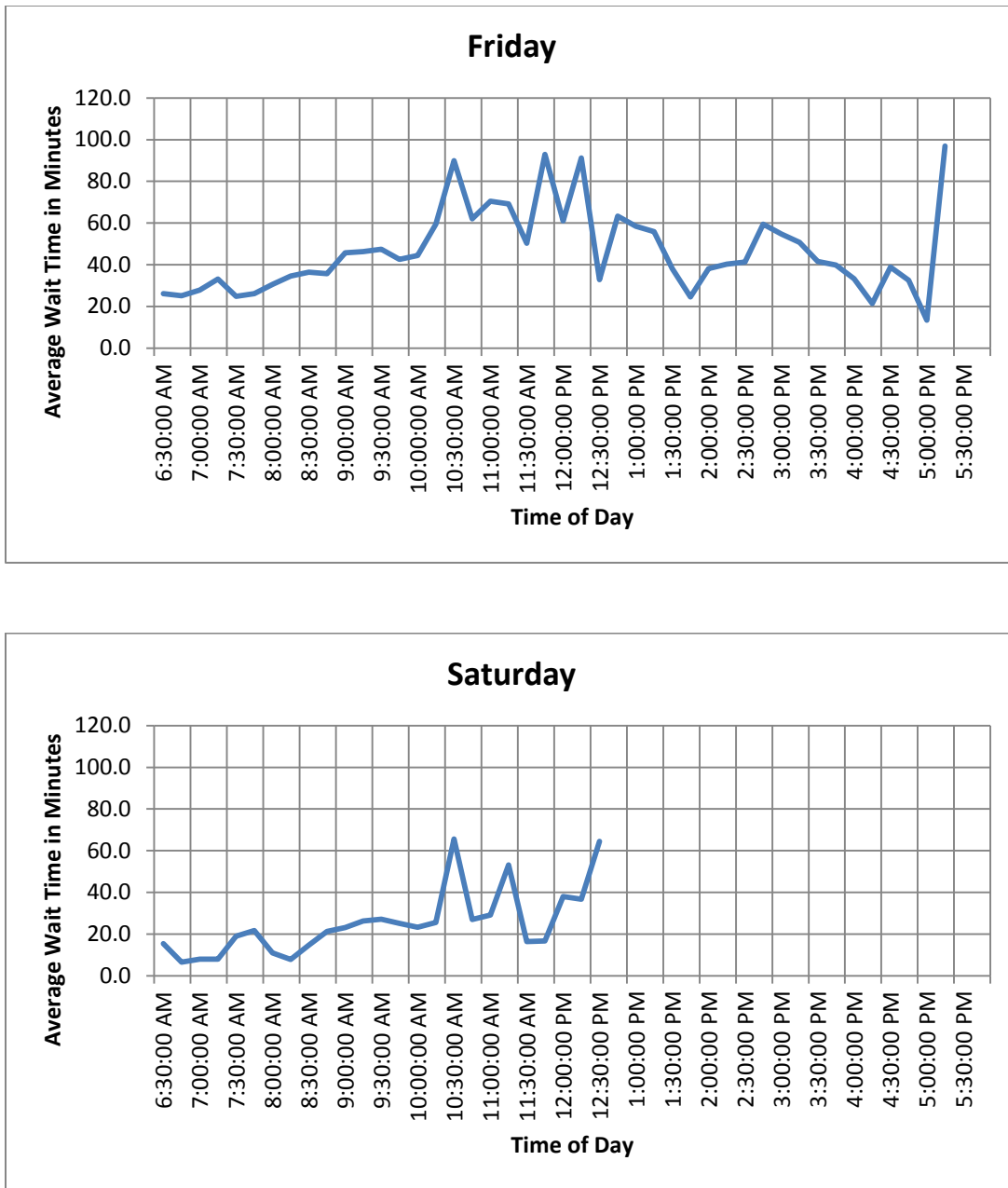


Figure 52. Charts. Hourly and daily variation of average wait times of trucks on the Week of February 13, 2012 at BOTA.

CHAPTER 7: PHARR-REYNOSA WAIT TIME DATA ANALYSIS

DATA COLLECTION AND ANALYSIS PERIOD

Pharr has two RFID reader stations in Mexico (R1 and R2) and two RFID reader stations in the United States (R3 and R4) to collect commercial vehicle travel times for segments of the trip. Tag reads have been recorded since October 2009 from three of the four stations, and the fourth station at CBP that enabled wait time measurement has been recoding tag reads since March 25, 2011. Pharr wait time analysis will be presented in two sections: (1) unmatched tag reads with analysis, and (2) matched tag reads with analysis. Graphs for data collected by each reader location are portrayed as being on the Mexico side or US side. Like BOTA, some tags were not readable for various reasons, which resulted in a smaller number of unmatched tag readings for either side of the border compared to the total volume of truck crossings for the same period reported by government border crossing operators.

Matched tag reads for the system at Pharr are the total number of tag IDs that were detected at US reader stations after having been previously detected at Mexico reader stations within a certain buffer period. This period, which was generally set at 120 minutes, is adjustable. The buffer period is necessary to exclude records not showing regular behaviors.

Events both external and internal to the system occurred during this about two and half year period that affected the tag reads. The analysis includes an explanation of what root causes were known to have brought about an anomaly, or if not conclusively proven, speculation as to the root cause.

UNMATCHED TAG READS

A central database server housed at El Paso office receives transponder (tag) identification data from the field RFID readers. One key objective in analyzing the daily transponder count is to understand the trend of commercial vehicle traffic flow during normal times, planned, and unplanned events that might impact the demand at the port of entry. Another key objective is to keep a log of when hardware failure occurred, for how long, and why. A series of graphs has been developed that are based on the daily count of transponders, read per calendar month by RFID readers on CBP primary inspection facility. These graphs are shown by figure 53 and figure 54.

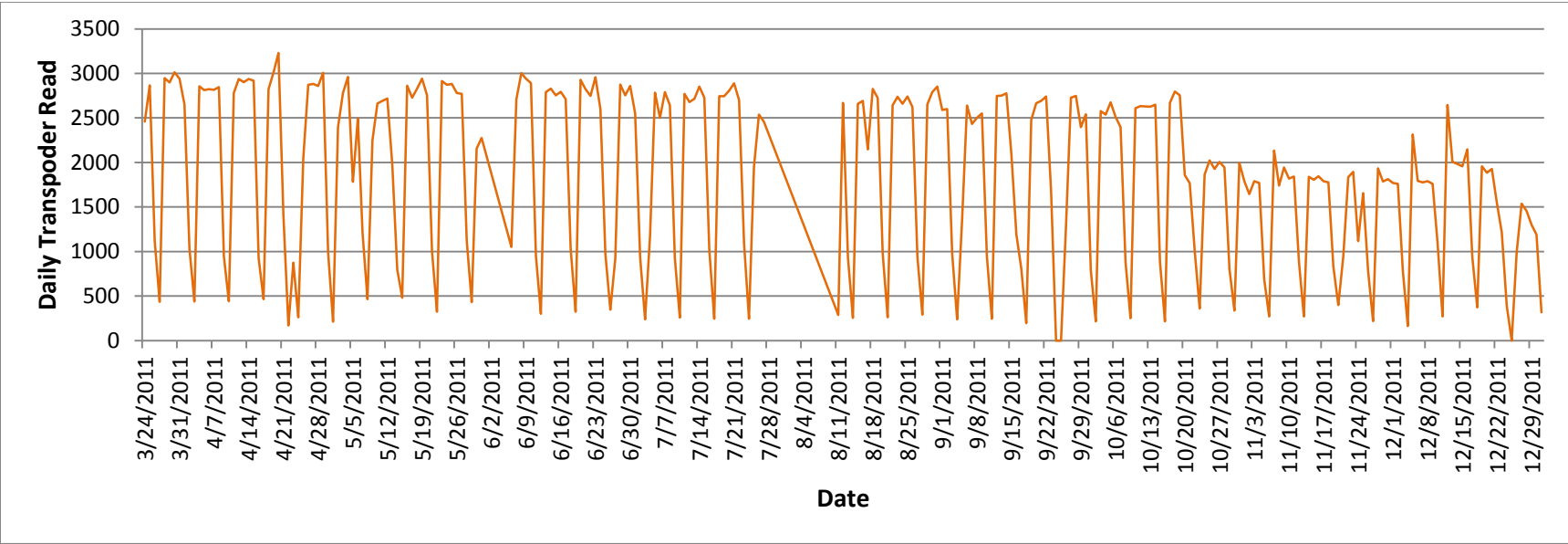


Figure 53. Chart. Daily transponder reads by reader at CBP at Pharr-Reynosa in 2011.

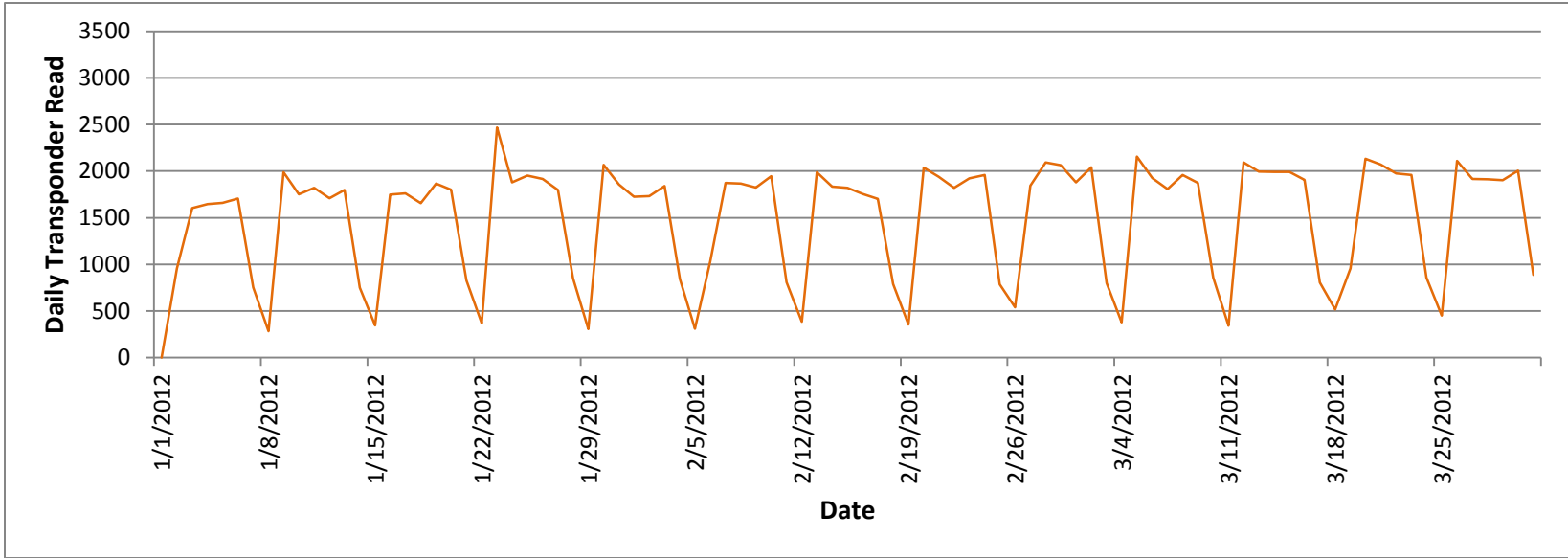


Figure 54. Chart. Daily transponder reads by reader at CBP at Pharr-Reynosa in 2012.

MATCHED TAG READS

Monthly Performance of Border Crossing

Table 9 shows the monthly average US-bound truck crossing time with various indices at the Pharr-Reynosa POE. The highly variable crossing times seen on this project were due to factors such as the reality that some trucks go through secondary inspection, some are part of the expedited FAST program, and some have trailers that are empty; those have very different crossing times from trucks not in those categories. When the mean crossing time was calculated, it did not distinguish among the crossing times of these trucks; all crossing times are used in calculating the mean. This results in a very high standard deviation and thus high co-efficient of variation.

Table 12. Monthly performance of Pharr-Reynosa based on average crossing times of trucks.

	Average Crossing Time (Minutes)	95th Percentile Crossing Time (Minutes)	95th - Average	Buffer Index (%)	Median Crossing Time (Minutes)	Sample Size
Month-Year	(1)	(2)	(3) = (2) - (1)	(4) = (3)/(1)	(5)	(6)
October-09	43.9	95.0	51.0	116.2%	37.9	14811
November-09	52.2	106.8	54.6	104.6%	45.7	11383
December-09	50.7	103.5	52.8	104.2%	44.3	4974
January-10	51.3	106.6	55.3	107.9%	44.3	3040
February-10	57.4	105.9	48.5	84.5%	54.9	3677
March-10	54.6	109.1	54.5	99.7%	48.4	5728
April-10	48.8	102.9	54.1	110.7%	41.9	5003
May-10	51.5	103.9	52.3	101.5%	45.7	5565
June-10	51.0	106.1	55.2	108.2%	44.3	3198
July-10	61.2	112.4	51.3	83.8%	57.5	3878
August-10	59.2	111.3	52.1	88.0%	55.2	6233
September-10	57.0	110.2	53.2	93.2%	51.1	9669
October-10	46.25	99.0	52.8	114.1%	39.0	13845
November-10	55.48	108.0	52.5	94.7%	50.0	12344
December-10	48.68	103.0	54.3	111.6%	41.0	14196
January-11	57.18	107.0	49.8	87.1%	55	10957
February-11	66.10	113.0	46.9	71.0%	65	8765
March-11	73.06	115.0	41.9	57.4%	76	5945
April-11	64.61	113.0	48.4	74.9%	64	5103

Table 13. Monthly performance of Pharr-Reynosa based on average crossing times of trucks (Continued).

	Average Crossing Time (Minutes)	95th Percentile Crossing Time (Minutes)	95th - Average	Buffer Index (%)	Median Crossing Time (Minutes)	Sample Size
Month-Year	(1)	(2)	(3) = (2) - (1)	(4) = (3) / (1)	(5)	(6)
May-11	63.17	112.0	48.8	77.3%	61	8347
June-11	59.91	108.0	48.1	80.3%	56	10950
July-11	51.31	105.0	53.7	104.6%	45	15895
August-11	53.64	105.0	51.4	95.7%	50	9250
September-11	55.06	99.0	43.9	79.8%	48	13059
October-11	55.10	125.00	69.9	126.9%	45	11629
November-11	63.60	127.00	63.4	99.7%	57	6610
December-11	56.48	121.00	64.5	114.2%	48	7767
January-12	67.20	134.00	66.8	99.4%	60.0	6815
February-12	66.23	132.00	65.8	99.3%	60.0	5620
March-12	71.40	135.10	63.7	89.2%	69.0	6719

In figure 55, the information in table 9 is graphed. The vertical axis on the left represents crossing time in minutes and the axis on the right represents the buffer index (as a percent). Also included in the chart are the 95th percentile crossing time, average crossing time, total US-bound truck volume, and RFID sample size.

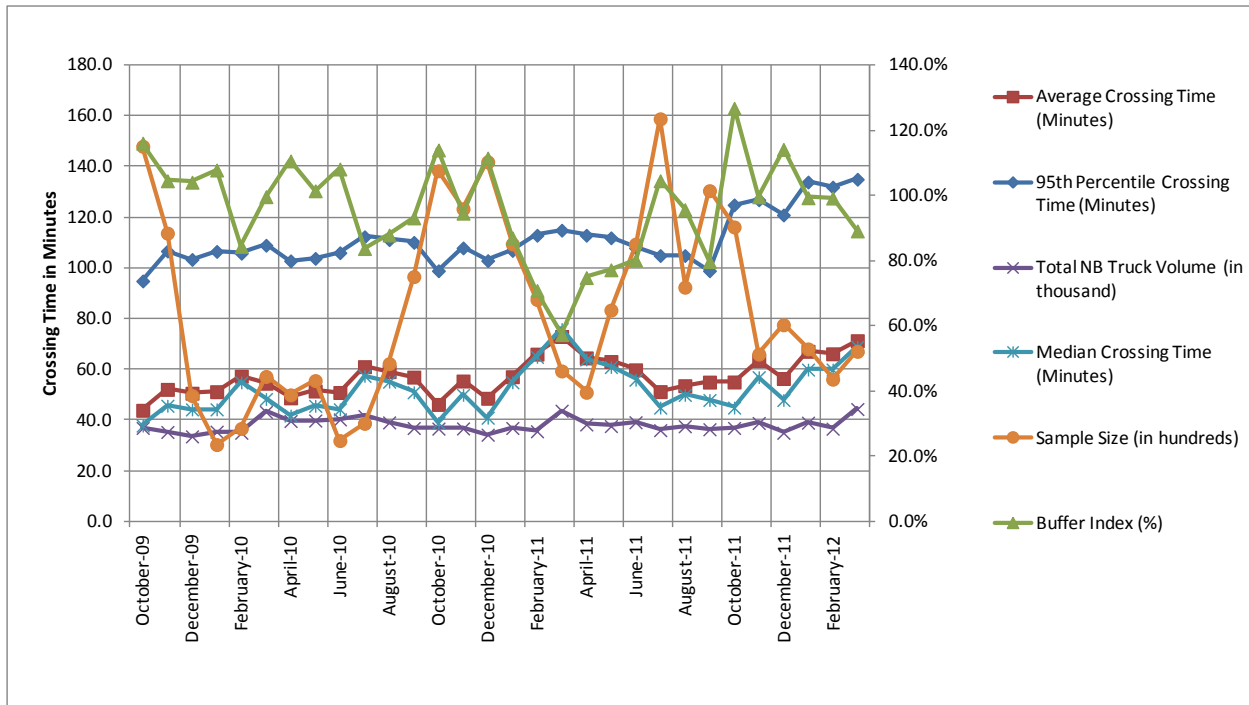


Figure 55. Chart. Monthly performance of Pharr-Reynosa based on average crossing times of trucks.

Histogram of Wait Times of Trucks

Figure 56 is a histogram of raw wait times over a 29-day period (February 2012). It shows that the 95th percentile of trucks requires approximately 110 minutes or less to wait at the border, and the 50th percentile of trucks requires approximately 45 minutes or less to wait at the border. It should be noted that this histogram is based on the wait time records with less than 120 threshold minutes to exclude outliers such as from the secondary inspection or mismatched RFID tags due to the random reader errors.

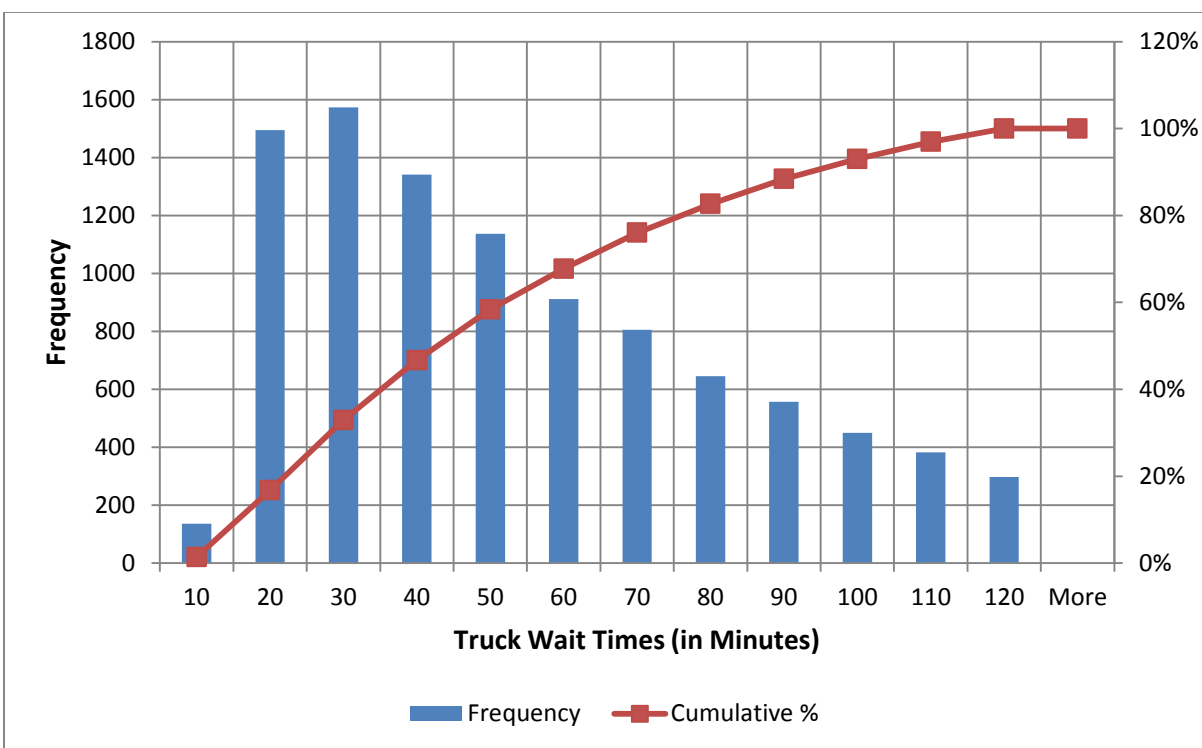


Figure 56. Chart. Histogram of raw truck wait Times for a month of February, 2012 in Pharr-Reynosa.

From the figure 56 histogram of raw truck wait time for the month of February 2012, a histogram for a single weekday (February 15, 2012) was prepared, which is shown in figure 57. It shows that the 95th percentile of trucks takes approximately 90 minutes or less to wait at the border, and the 50th percentile of trucks requires approximately 37 minutes or less to wait at the border.

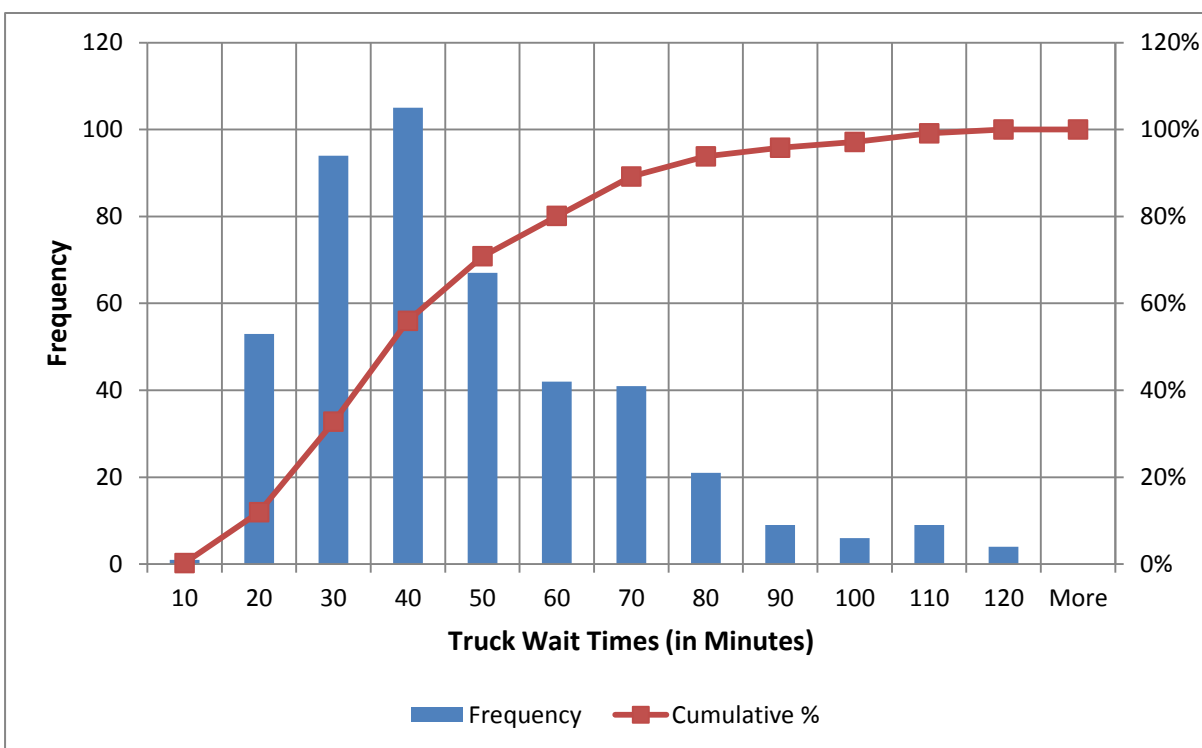
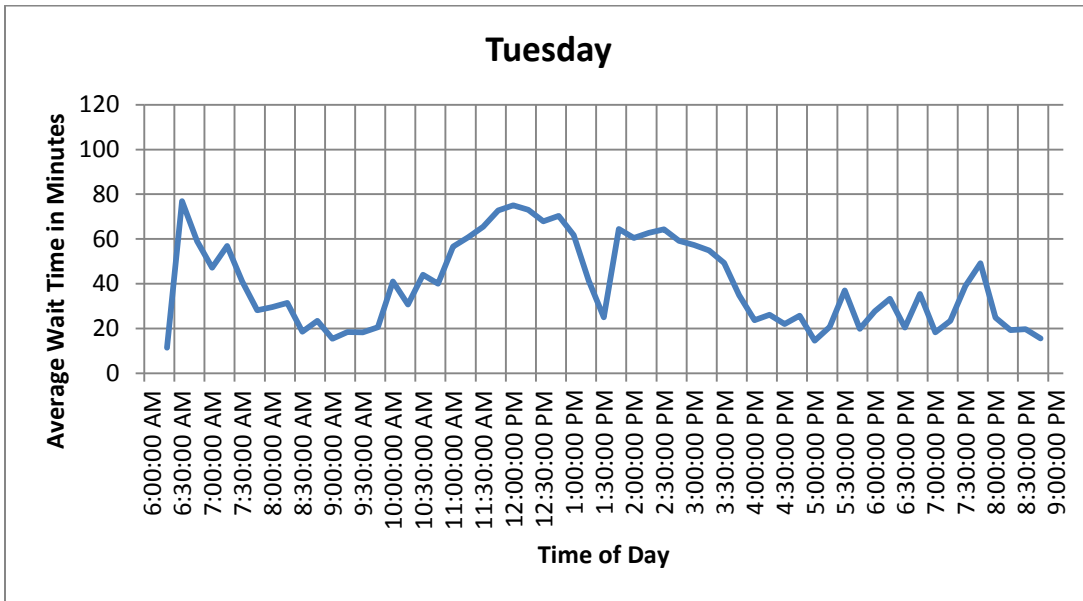
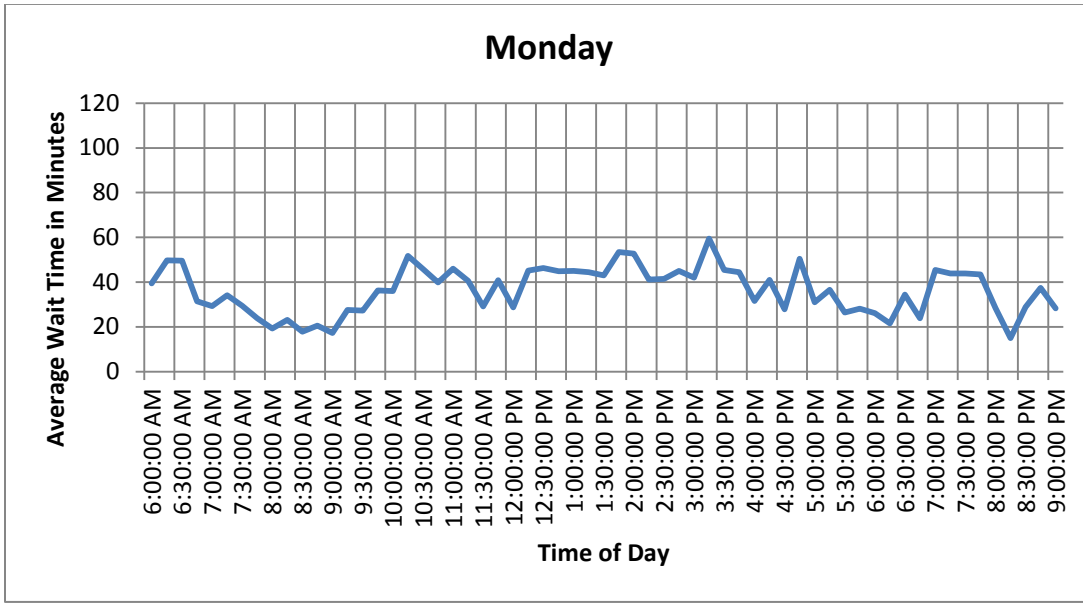
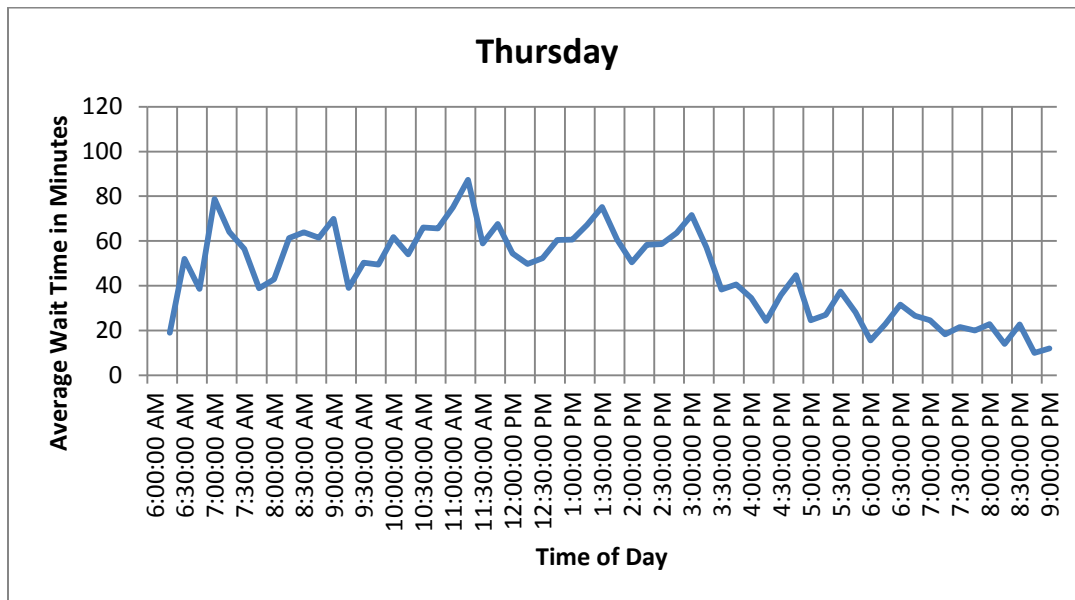
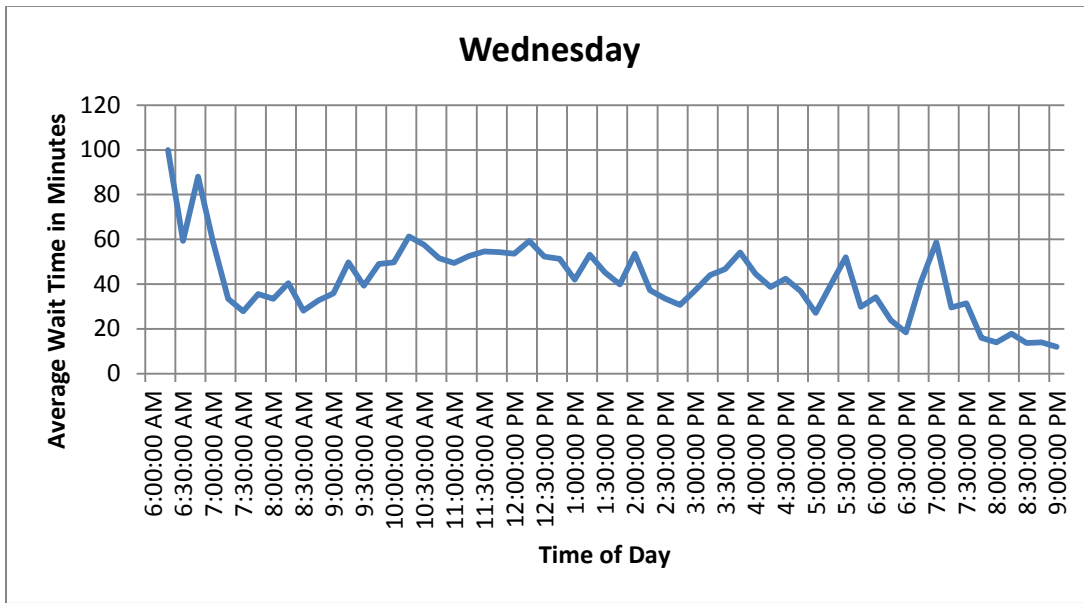


Figure 57. Chart. Histogram of raw truck wait times for a weekday at Pharr-Reynosa.

Hourly and Daily Variation of Average Wait Times of Trucks

Figure 58 is a snapshot of hourly and daily variation of average wait times of US-bound commercial vehicles at Pharr for Monday through Saturday, the week of February 13, 2012. The 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. These graphs show that average wait times are lower on Monday and Wednesdays. Wait times on Thursday and Friday are higher. Friday peak wait times occur during the early afternoon hours. Since the graphs only captures one week of February, the patterns could be different on the other weeks or months and need to be analyzed further for any possible seasonal or month-to-month trends.





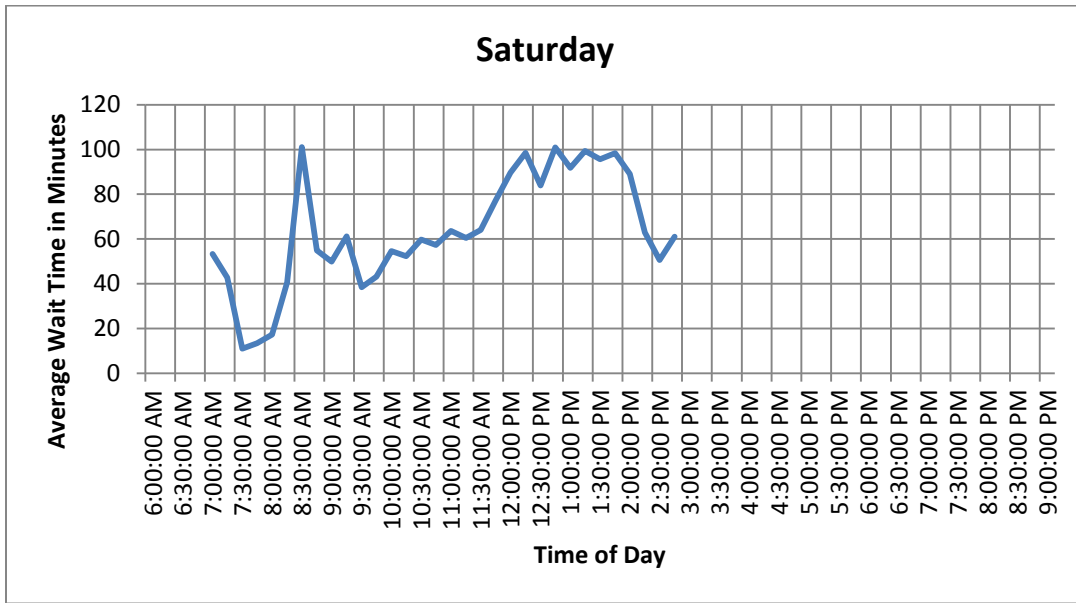
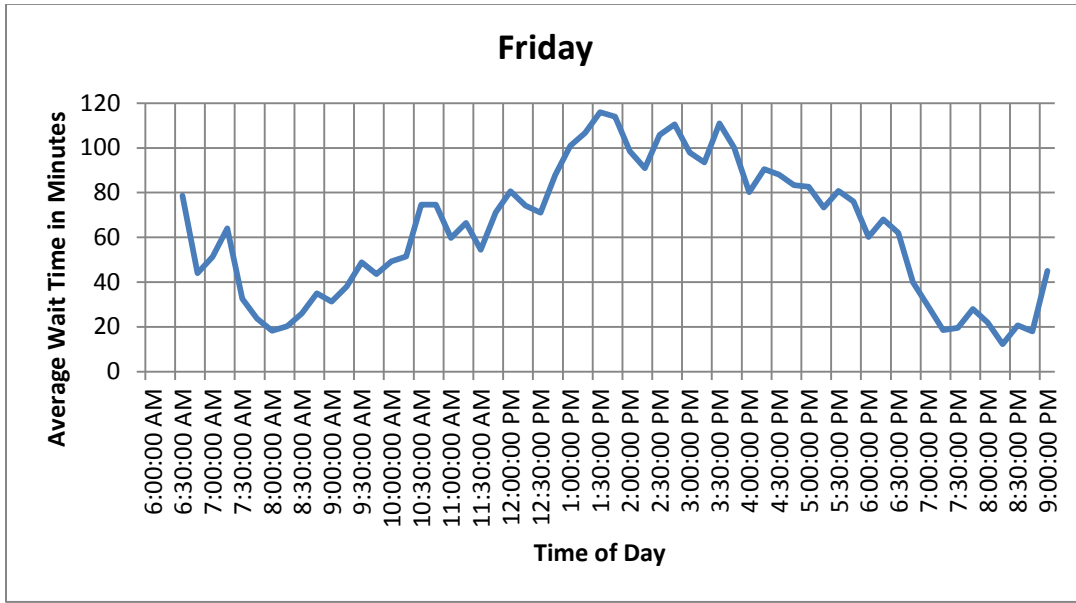


Figure 58. Charts. Hourly and daily variation of average wait times of trucks during the week of February 13, 2012 at Pharr-Reynosa.

CHAPTER 8: EVALUATION OF CROSSING AND WAIT TIMES DATA

This chapter highlights key findings from tests performed to evaluate the accuracy of wait time and crossing time data measured by the system. Evaluation tests were performed at different times using techniques such as manual license plate reading and GPS probes. The following evaluation tests were performed, and results from the tests are described in subsequent sections:

- Evaluation tests performed at BOTA in August 2009 by comparing RFID data with manual license plate data collection at BOTA immediately following installation of crossing time measurement system.
- Evaluation tests performed at BOTA in January 2012 by comparing RFID-measured wait times and crossing times with data measured by GPS installed inside US-bound trucks heading into the United States.
- Evaluation tests performed at Pharr-Reynosa in May 2011 by comparing RFID-measured wait times with data measured by GPS installed inside US-bound trucks heading into the United States.

EVALUATION PERFORMED AT BOTA IN AUGUST 2009

In August 2009, the first round of evaluation tests was performed immediately after installation of the initial two RFID reader stations at BOTA. The objective of the evaluation was to determine accuracy of crossing times determined by the RFID system, by comparing them with crossing time measured in the field using video data collection of truck license plates.

Portable and digital video cameras were installed at several locations along the truck path at BOTA. Using video recordings and manual observation, the presence of tags were noted and license plates of the trucks that had the tags were read. Based on these two observations, the volume of trucks and number of tags read at RFID stations were analyzed. Two handheld cameras were installed at pre-defined locations close to RFID reader sites.

The following tests were conducted to measure the accuracy of crossing time of US-bound trucks at BOTA:

- Compare the total number of tags read by RFID system to total tags observed in the field.
- Identify the cause of disparity between number of tags read by RFID stations on the Mexico and US sides of the border.
- Compare average truck crossing times observed in the field and determined by the RFID system.

Using video recording of trucks going under both RFID stations on the US side, tags affixed to the windshield were identified and counted and that number compared with the total number of tags read by the RFID. Trucks carry tags issued by several agencies and carry stickers related to

the permitting process. Since some of these stickers have a similar appearance to RFID tags, there are instances of overestimating the number of RFID tags carried by trucks. Thus, even though there is no guarantee that the tags observed in the field can be called “readable tags” or just stickers, field evaluation still indicated the capability of the RFID system to read an adequate number of tags. From video recordings, the number of tags attached to windshield of trucks going under the RFID stations were counted and the total tags read were compared with the total read by the RFID system, which were obtained from the central database. A detailed (15-minute) breakdown of the number of tags visually counted and read by the RFID reader was determined for the Mexico and the US side. An average 81percent of total tags were read by the RFID readers on the US side and 95 percent of the total tags were read by the reader on the Mexico side.

In addition, the total number of tags read by readers against the total number of trucks passing both RFID stations was obtained. Table 10 shows the penetration rates or percentage of total US-bound trucks successfully identify by the readers at both stations. The results show that the penetration rate is above 90 percent on the Mexico side and above 75 percent on the US side.

Table 14. Percentage of total US-bound trucks identified by RFID readers at BOTA.

Date	Time Period	Location	Total Number Trucks Counted at RFID Station on the MX Side	Total Number Tags Read By the RFID Reader	Penetration Rate (in percent)
08/19/09	7:00-9:00AM	MX	230	206	90
08/19/09	3:00-5:00PM	MX	161	148	92
08/20/09	7:00-9:00AM	MX	231	218	94
08/18/09	4:30-5:30PM	US	153	109	71
08/19/09	7:30-9:30AM	US	224	180	80
08/19/09	4:30-5:30PM	US	229	166	72
08/20/09	7:30-9:30AM	US	217	161	74

Analysis of archived RFID data at BOTA showed that a significant number of tags read by the RFID station on the Mexico side are not read by the station installed at the exit of the DPS facility on the US side. The total number of tags read by the RFID reader on the Mexico side is on an average 30 percent higher than the total number of tags read by the reader on the US side. This disparity is illustrated in figure 59.

This discrepancy was considered most likely because there are several driveways and at least one major roadway between the RFID station and the entrance to the Mexican Customs. Thus, trucks go under the Mexican RFID station, but instead of going to the Mexican Customs compound they go into side roadways and not under the reader on the US side. The researchers believe that this discrepancy does not hamper collection of sample size and estimation of average crossing times. In fact, there is an adequate sample size to estimate the average crossing times of trucks

reliably.

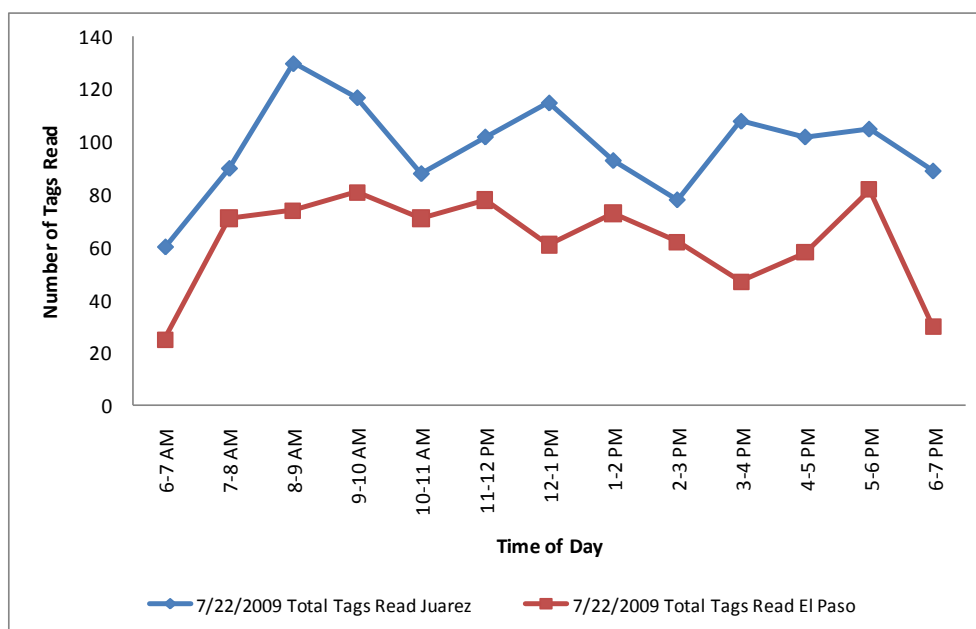


Figure 59. Chart. Comparison of total number of tags read hourly by RFID readers on the US and Mexican side of the border.

Finally, using video recordings of trucks over several hours at RFID stations and matching the license plate numbers of trucks manually collected at both stations, average crossing times of trucks observed in the field were compared to those calculated by the RFID system. The average truck crossing times were calculated at 15-minute intervals using the last two hours of data (referenced from the time when the tag was first read by the reader on the US side). Table 11 shows a comparison of average crossing time determined by license plate readings and by the RFID system. The results show that the average crossing time relayed by the RFID system is quite comparable to the ones computed in the field for most of the periods.

On average, the difference in crossing time estimated by the RFID system and the manual license plate reading method was 4.7 minutes for all time periods listed in table 11. The original minimum value was set at 3 minutes, which was based on a method of comparing crossing times of trucks carrying both GPS devices and RFID tags. In this case the trucks, whose license plates were identified on both sides of the border, may or may not have RFID tags. Hence, while calculating the average crossing time using license plate reads and the RFID system, there is no guarantee that the same trucks are being used in the calculation. Due to this reason, average crossing times estimated by the RFID system may differ with that estimated using manual license plate reads.

Table 15. Comparison of average crossing times measured in field and calculated by the RFID system.

Date	Time of Calculation on the US Side	Time Window Used to Calculate Average Crossing Time	Average Crossing Time from the RFID System	Average Crossing Time from the Field Data Collection
08/19/09	9:00AM	8:00 – 9:00	33.67	32.79
	9:15AM	8:15 – 9:15	31.35	34.50
	9:30AM	8:30 – 9:30	34.90	44.33
	5:00PM	4:00 – 5:00	43.00	48.07
	5:15PM	4:15 – 5:15	41.08	48.02
	5:30PM	4:30 – 5:30	37.02	49.07
08/20/09	9:00AM	8:00 – 9:00	49.28	47.10
	9:15AM	8:15 – 9:15	47.33	45.79
	9:30AM	8:30 – 9:30	46.83	45.71

EVALUATION PERFORMED AT BOTA IN JANUARY 2012

In January 2012, an evaluation of wait time and crossing time from the BOTA system was performed using three GPS devices installed on trucks operated by STIL Inc., a drayage carrier based in Ciudad Juarez. The GPS units provide longitude, latitude, and timestamp at 30-second intervals and stored the data in the unit. The carrier was not asked to run its trucks on a particular schedule. The GPS units were attached to the carrier’s trucks for two weeks. However, wait time and crossing time data collected were not continuous, since trucks were running on their own schedule.

The data obtained from GPS units were plotted in GIS software and overlaid over local roadway network and RFID zones, which are polygons surrounding RFID stations as illustrated in figure 60. Wait times and crossing times of trucks were measured by taking the time differences between when trucks exited starting zones and entered ending zones. Median value of wait times and crossing times of trucks measured by RFID was obtained approximately at the same time trucks exited the zone surrounding the first RFID reader station in Mexico. Table 12 and table 13 show the comparison of GPS- and RFID-measured wait and crossing times.

The absolute average difference for wait time was 5.5 minutes (11 percent) and for crossing time was 7.6 minutes (15 percent). This minor discrepancy was because GPS points do not always appear exactly at the location of the RFID station location, and also because it was not known whether the trucks carrying GPS devices also had RFID transponders that could have been read by the RFID system.

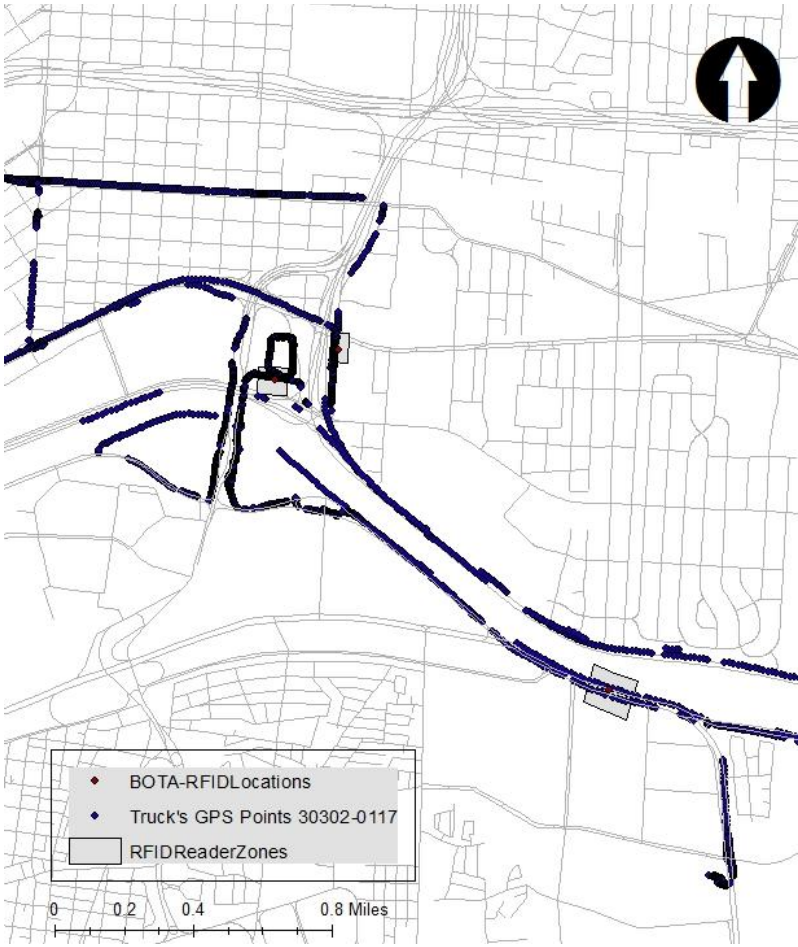


Figure 60. Image. Overlaid truck GPS points, and virtual zones surrounding RFID stations.

Table 16. Differences between GPS and RFID measured wait times of US-bound trucks at BOTA.

Trip Date	GPS Unit	Time Truck Crossed R1	Time Truck Crossed R2	GPS Wait Time (in minutes)	Median RFID Wait Time (in minutes)	Absolute Difference (in minutes)	Difference (in percent)
1/16/2012	10401	9:16:12	9:27:43	12	12	0.0	0
1/16/2012	10401	16:17:12	16:43:15	26	28	2.0	8
1/17/2012	10401	10:16:29	11:25:38	71	73.5	2.5	4
1/17/2012	10401	15:38:34	16:11:08	33	27.5	5.5	17
1/19/2012	10401	12:04:40	12:29:20	25	23	2.0	8
1/21/2012	10401	10:31:00	11:16:00	45	36.5	8.5	19
1/23/2012	10401	11:21:19	12:02:00	25	21.5	3.5	14
1/24/2012	10401	11:26:00	13:06:00	102	127	25.0	25
1/26/2012	10401	9:30:40	10:51:00	80	88	8.0	10
1/16/2012	30302	7:43:30	8:15:24	32	27	5.0	16
1/17/2012	30302	14:05:35	14:59:15	54	50.5	3.5	6
1/16/2012	30369	7:57:45	8:21:10	24	23	1.0	4

Table 17. Differences between GPS and RFID measured crossing times of US-bound trucks at BOTA.

Trip Date	GPS Unit	Time Truck Crossed R1	Time Truck Crossed R3	GPS Crossing Time (in minutes)	Median RFID Crossing Time (in minutes)	Absolute Difference (in minutes)	Difference (in percent)
1/16/2012	10401	9:16:12	9:42:33	26	18	8.0	31
1/16/2012	10401	16:17:12	16:45:25	28	31	3.0	11
1/17/2012	10401	10:16:29	11:24:43	68	72.5	4.5	7
1/18/2012	10401	9:55:35	11:01:46	66	74	8.0	12
1/18/2012	10401	15:59:58	16:31:00	31	40	9.0	29
1/19/2012	10401	12:04:40	12:30:13	26	29.5	3.5	13
1/21/2012	10401	10:31:00	11:49:00	78	65	13.0	17
1/23/2012	10401	11:21:19	12:10:51	34	27	7.0	21
1/24/2012	10401	11:26:00	13:11:25	105	106	1.0	1
1/26/2012	10401	9:30:40	11:50:00	139	118	21.0	15
1/16/2012	30302	7:43:30	8:23:30	40	33	7.0	18
1/17/2012	30302	14:05:35	15:20:00	74	81	7.0	9
1/16/2012	30369	7:57:45	8:36:00	48	41	7.0	15

EVALUATION PERFORMED AT PHARR-REYNOSA IN MAY 2011

In May 2011, an evaluation of wait time of trucks from the Pharr-Reynosa system was performed using three GPS devices installed on trucks operated by a drayage carrier based in the region. The carrier was not provided the GPS units; rather they were installed by the carrier for its internal purposes. The carrier provided archived GPS log data which include longitude, latitude, and timestamps at sporadic intervals. The carrier was not asked to run trucks on a particular schedule. Hence, wait time data collected were not continuous since trucks were running on their own schedule.

The data obtained from the carrier were plotted in a GIS software and overlaid over local roadway network and RFID zones, which are polygons surrounding RFID stations. Wait times of trucks were measured by taking the time difference between when trucks exited starting zones and entered ending zones. Median value of wait times of trucks measured by RFID was obtained approximately at the same time trucks exited the zone surrounding the first RFID reader station in Mexico. Table 14 shows the comparison of GPS and RFID measured wait times of US-bound trucks.

The absolute average difference for wait time was 3.6 minutes (8 percent). This minor discrepancy is because GPS points do not always appear exactly at the location of the RFID station location, and also because it was not known whether the trucks carrying GPS devices also had RFID transponders that could have been read by the RFID system.

Table 18. Differences between GPS and RFID measured wait times of US-bound trucks at Pharr-Reynosa.

Trip Date	Trip No.	Time Truck Crossed R1	Time Truck Crossed R3*	GPS Wait Time (in minutes)	Median RFID Wait Time (in minutes)	Absolute Difference (in minutes)	Difference (in percent)
17-May-11	1	12:01:01	13:16:49	75.9	76	0.10	0
17-May-11	2	14:48:00	15:38:01	50	53	3.00	6
17-May-11	3	16:20:28	16:37:24	17	19	2.00	12
17-May-11	4	17:54:07	18:19:27	25.3	27	1.70	7
17-May-11	5	19:01:22	19:21:45	20.4	18	2.40	12
17-May-11	6	20:30:02	20:50:23	20.4	18	2.40	12
17-May-11	7	20:37:59	20:53:11	15.2	15	0.20	1
18-May-11	1	13:56:50	16:16:51	140	123	17.00	12
18-May-11	2	14:12:46	16:09:16	116.6	117	0.40	0
18-May-11	3	14:14:55	16:18:16	123.4	121	2.40	2
18-May-11	5	14:55:27	17:02:12	126.7	139	12.30	10
18-May-11	6	16:02:45	17:03:34	60.9	64	3.10	5
18-May-11	7	16:47:22	17:27:21	40	40	0.00	0
18-May-11	8	17:22:44	18:03:39	40.9	43	2.10	5
18-May-11	9	19:01:33	19:19:09	17.6	16	1.60	9
18-May-11	10	19:43:04	20:08:28	25.5	30	4.50	18
18-May-11	11	19:47:37	20:09:15	21.7	19	2.70	12
20-May-11	4	14:29:40	14:59:27	29.8	34	4.20	14
20-May-11	5	15:06:54	15:42:31	35.6	37	1.40	4
20-May-11	6	16:47:37	17:13:00	25.4	31	5.60	22
20-May-11	7	16:47:37	17:14:28	26.9	31	4.10	15
20-May-11	8	17:00:19	17:26:01	25.7	30	4.30	17
21-May-11	1	9:21:08	10:36:59	75.9	81	5.10	7
21-May-11	4	11:54:48	13:15:59	81.2	89	7.80	10
21-May-11	5	12:17:15	14:02:16	105	106	1.00	1

* = Pharr-Reynosa international border crossing has one additional RFID reader station prior to CBP primary. Hence, the reader station at CBP is numbered R3 instead of R2.

CHAPTER 9: LONG TERM OPERATION

WARRANTIES, OPERATIONS AND MAINTENANCE

There is no programmed maintenance required with the system components. The RFID system carries a one-year warranty. The system as designed should operate on its own without any attention until a component ceases to function and will then need to be replaced.

The solar batteries carry a one-year warranty. They will need to be replaced every few years. It is a considerable advantage if circumstances allow the location of an RFID reader station to have access to reliable hardwired power for the readers and antennas (as in the BOTA and Pharr POEs at the CBP primary inspection booth installations). The batteries will still be needed, but the procurement, installation, and eventual replacement cost of the solar panels will be avoided.

Airtime costs for the cellular communications are captured in Table 15 below. This is the only significant recurring expense that has been experienced since the equipment has been installed.

The server and logger are key components of the data communication and archiving process. Like any computer equipment, they will need to be occasionally updated and eventually will have to be replaced. These are components that are mobile, in the sense that they can be transferred to another office and their functions resume. They require a secure, cool location with reliable power and backup power. Wireless communications connectivity to the reader system at a new location must be tested and not assumed to exist.

There is also a significant value in implementing an automated warning module within the back office component and integrated with the process that receives and stores the RFID data. This will allow the system administrator to proactively check for errors and fix any malfunctions quickly without losing significant amount of data. The automated warning module should generate alarm or some kind of notification to the system administrator when:

- The server or a computer loses connection with the field device for a long period of time (thresholds can be defined).
- The server or a computer does not receive RFID data packets from the field on days and times of day when POEs are supposed to remain open. The module could be pre-programmed with a list of days and times of day when the POEs will close.

BUSINESS MODEL FOR PROGRESSING FROM TECHNOLOGY EXPLORATION TO PILOT TEST TO ADOPTION

Once the border crossing/delay/wait time system is in place and the technology has been tested, the next step would be the adoption and use of the technology by all stakeholders. This could be achieved by developing close to real-time and archived information reports that are useful to all stakeholders. The operation of the system to provide close to real-time information needs to have staff dedicated to regularly monitor the system and make sure that is working properly.

The analysis of archived data and report development also requires staff dedicated to these activities.

It is intended that some set of this project's stakeholders accept ownership from FHWA and continue the operation and maintenance of the system. Transfer of the mobile components (i.e., wireless receiver and server) would be made to the agency, association, or other organization that will continue operation of the system. In that way, benefits to the region's stakeholders, FHWA, and CBP from having access to near real-time wait and crossing time information will continue to accrue.

Funding for the implementation and/or operation and maintenance costs could come from the border States, Federal agencies involved in cross-border transportation, and even private sector stakeholders that use the information generated on a close to real-time basis as well as the archived information.

OPERATIONS AND MAINTENANCE COST

A detailed cost of operation and maintenance of two RFID stations at BOTA that was experienced over the first year of operation is shown in table 15. This first year annual cost includes operation and maintenance of the website, RSS feeds, and the data archive. It does not include replacement of major hardware such as RFID readers, RFID antenna, utility poles, etc. It is meant to be illustrative, as circumstances at the site of another border crossing RFID tag reader system could be quite different. Costs do not include certain contractual loadings that would be applied.

Table 19. Annual costs for operations and maintenance of BOTA system.

Item	Description	Cost	Remark
1	Labor Cost to Maintain Processing and Real-Time Information Dissemination	\$5,100	Does not include first time setup of website, database, and other algorithms. This cost will decrease in subsequent years of operation. To get monthly cost, divide Item 1 cost by 12.
2	Hardware Maintenance Cost (2 visits in the event of major system failure)	\$6,400	Includes travel expense to verify and fix system failures. Does not include replacement of hardware such as readers, antennas etc. It is assumed the vendor will provide replacement warranty.
3	Other Accidental Hardware Purchase and Replacement Cost	\$900	Includes replacement of minor components – batteries, antennas, wirings etc. but not the reader, antennas, and poles.
4	One Year Subscription of Cellular Modem Data Plan for 2 Modems	\$1,200	Monthly data subscription of \$50.00 per modem and assumes 2 modems for this location.

DATA SECURITY AND CONTROL

While the nature of this topic depends on the organizations involved, it must be considered. FHWA, CBP, and their Mexican counterparts will desire access to border wait time and crossing time information, both the near real-time travel data as well as archived data. State DOTs and DPSs, MPOs, and bridge authorities are examples of stakeholders that may also desire this information. Decisions must be made on who owns and controls the data and who has access to what parts of the data.

CHAPTER 10: SUMMARY AND CONCLUSIONS

GENERAL CONCLUSIONS

An RFID technology based system using passive transponders was put into real-world operation in the vicinity of the BOTA at El Paso, Texas–Ciudad Juárez, Mexico and Pharr-Reynosa International Bridge, Pharr.. The RFID system was designed to automatically measure, display, and archive information on wait and crossing times of US-bound commercial vehicles transiting the POE. This pilot system was the result of years of FHWA efforts that laid the groundwork for its implementation. Development of the system followed a systems engineering process with significant upfront and continuing stakeholder involvement. Stakeholders were informed that there was neither intent nor capability for collecting information on identification of driver, vehicle, or carrier as part of the system design. The only information to be collected by the system was the ID number for the windshield transponder, a timestamp for when it was detected passing a RFID read above its lane, and the designation of the reader location. The presence of the equipment and its operation appear to have been fully accepted by the motor carriers, their drivers, and all other stakeholders.

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Following system design, development, equipment procurement, bench testing, installation, integration and checkout, and test and evaluation, the RFID system became operational in a real-world environment on July 8, 2009. Its two initial reader stations utilized solar panels with batteries, as reliable hardwired power was not available at either of the two RFID reader stations. The reader stations communicated with a server via wireless (cellular) communications. The system was programmed to cease data collection during days and periods of days when there were no crossing operations. Crossing time data were collected and archived over a nearly 33-month period and were analyzed for trends and anomalies. That analysis is contained within this report.

While the system was originally envisioned and developed for automatically measuring crossing times, it was subsequently desired that wait time data also be collected. To enable that, meetings and agreements between FHWA and CBP were conducted that resulted in CBP and GSA approval for a RFID reader station at the CBP Primary Inspection for both BOTA and the Pharr-Reynosa POEs. A comparability test was successfully conducted to ensure the RFID wait time RFID installation at CBP primary inspection booths would not interfere with CBP equipment. Installation of RFID reader stations for wait time measurement was conducted in March 2011 for the Pharr-Reynosa POE and April 2011 for the BOTA. Operations at the BOTA and Pharr-Reynosa POEs demonstrated that crossing times and wait times can be automatically and accurately measured using RFID technology. Experience from the engineering process followed

and lesson learned were used to prepare a number of guidance and instructional documents for use by future deployers of these systems.

Wait and crossing time of US-bound trucks at both ports of entry are being continuously collected and archived by TTI. The data collected from the field are filtered and converted into individual wait and crossing times and subsequently aggregated into 15-minute, hourly, daily, and monthly averages. The research team was also tasked to develop a prototype web tool to disseminate most recent wait and crossing times of trucks at both ports of entry. Methods of dissemination include publicly available Web site and RSS feeds. The research team also developed an application, which monitors the RFID system's health and fidelity in near real-time. This has helped the team to identify problems within a small window of time and fix them quickly.

Lastly, a November 21, 2011, article in the publication *RFID Journal* (<http://www.rfidjournal.com/article/print/8984>) titled "RFID Readers Installed at US-Mexican Bridges to Help Ease Traffic Congestion" described the travel time measurement system at BOTA. The article noted that since the BOTA implementation, a number of other POEs along the US– Mexico border in Texas and Arizona have implemented RFID-based travel time measurement systems or were in the process of doing so (currently a total of 6 POEs in addition to BOTA).

RELIABILITY AND MAINTAINABILITY

During the nearly 33-month period of this report when the system collected and measured crossing time data under real-world conditions, the RFID equipment operated without damage, interruption, or the need for any equipment replacement, recurring or non-recurring maintenance. It operated in hot, arid, dusty conditions with vibration from passing trucks. Connectivity through the wireless modem was good.

LESSONS LEARNED

- The RFID system is a successful implementation. It was developed using a systems engineering process. Its test and evaluation following installation showed the system performs to expectations and its data are accurate. The system has performed reliably since being placed into real-world operation without damage or major maintenance.
- The processed data showing near real-time average wait and crossing time measurements have been made available to stakeholders through web access. The display is both user-friendly and useful.
- It is essential to have a skilled bi-lingual, bi-cultural facilitator to conduct stakeholder meetings and to contact Mexican stakeholders for projects on the southern border. A bi-cultural facilitator would also be helpful on the northern border.
- Stakeholder involvement is very important. It not only informs all interested parties as to what is intended and when, it explains why and gets their buy-in and continuing support.

This can help in a number of ways such as a vehicle operator reporting damaged equipment, notification to system operators of pending events (such as construction) that will affect operation of the system, and greater use of the system for logistics efficiencies.

- Construction or traffic diversion can have a profound effect on the performance of the system. Through early stakeholder involvement, it was discovered that roadway construction was planned at a site that was originally intended for the first (R1) reader just upstream from the queue on the Mexico side. Without that advance knowledge, equipment might have been installed where it would have risked being damaged by ongoing roadway construction and even might have had to be moved – an unplanned and expensive development.
- It is critical to make sure that there is adequate signal strength for cellular modem to transmit data from field devices to a server. This should be done well in advance to the actual deployment and can be accomplished simply by reading the signal strength from a mobile phone.
- RSS has proven to be an extremely cost-effective method to share near real-time data with individual users, news media, traffic management centers, etc. RSS includes a standardized XML file format containing information to be published once and viewed by many different programs. The user subscribes to a feed by entering into the reader the feed's URL or by clicking an RSS icon in a web browser that initiates the subscription process. The RSS reader checks the user's subscribed feeds regularly for new work, downloads any updates that it finds, and provides a user interface to monitor and read the feeds. RSS formats are specified using XML, a generic specification for the creation of data formats. RSS feeds can be read using software called an "RSS reader," "feed reader," or "aggregator," or even the latest versions of commercially available web browsers, which can be web-based, desktop-based, or mobile-device-based.
- Even though there was knowledge of local construction plans that allowed the R1 reader station to be located in an undisturbed location, there was a subsequent expansion of lanes abreast of the R1 station (from four to seven lanes), coupled with signage redirecting trucks to the far side of the road from where the active antennas were located. These combined factors had the effect of decreasing the number of tag reads on the Mexico side for the last half of the nearly 14-month initial data collection period. That decrease affected the sample size (i.e., the number of matched tags) for the crossing time measurement. The problem was solved by relocating the RFID reader station to a gantry a short distance downstream from the original location where trucks were exiting to cross BOTA.
- There was a set of RFID antennae installed by the DPS for a different need on a crossbar in close proximity to this project's R2 reader station crossbar at the BSIF exit on the US side. In November 2009, around the time of that close-by installation, it was noted that the number of tags read by the R2 reader dropped dramatically. While it was never demonstrated that there was frequency interference, remote adjustments were made that changed the R2 station from the original setting of 915 MHz to new frequency 902.5 MHz. This increased the sample size compared to previous months. Thus, a lesson learned is that RFID frequencies can be adjusted without decrease in performance. In

retrospect, (1) closer stakeholder coordination might have been able to result in greater spacing between the two crossbars, and (2) when the problem occurred, an onsite spectrum analysis might have conclusively determined that frequency interference was the cause.

- Having additional reader stations to segment the vehicle crossing path is desirable. By having more segments, border crossing operators and other stakeholders are better able to see where delays are occurring that affect the entire crossing. The more reader stations, the better delays can be isolated and dealt with in a timely manner.
- Import duties may have to be paid on equipment brought into Mexico.
- Stakeholder input in development of information dissemination techniques is important. Different stakeholders have different perspectives in how and what kind of information they would like to receive. For example, carriers see more value in real-time information (e.g., most recent wait and crossing times), while MPOs and trade groups value historic information.

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