Measuring Border Delay and Crossing Times at the U.S.–Mexico Border—Part II

Step-by-Step Guidelines for Implementing a Radio Frequency Identification (RFID) System to Measure Border Crossing and Wait Times

June 29, 2012

U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

The purpose of these step-by-step guidelines is to assist in planning, designing, and deploying a system that uses radio frequency identification (RFID) technology to measure the time needed for commercial vehicles to complete the northbound border crossing process at the U.S.–Mexico border (i.e., crossing time) as well as time needed to reach the primary inspection station of the Customs and Border Protection facility from the end of a typical queue (i.e., wait time). Guidelines described in this document are based on experiences gathered while deploying RFID-based systems to measure crossing times and wait times at various U.S.–Mexico land border crossings in Texas. However, this document provides a step-by-step process that is not port of entry (POE) specific, so similar systems can be deployed at any POE, including those on the U.S.–Canada border.

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INTRODUCTION

Background

In 2001, the Federal Highway Administration (FHWA) conducted research that resulted in a report entitled *Evaluation of Travel Time Methods to Support Mobility Performance Monitoring*. That project involved manual wait time measurements on commercial vehicles transiting four northern and three southern border crossings [(1)]. The research also produced another report—*Assessment of Automated Data Collection Technologies for Calculation of Commercial Motor Vehicle Border Crossing Travel Time Delay*—which was published in 2002 and evaluated candidates to automate the collection of border delay and crossing time data [(2)]. 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. Of the 22 technologies initially screened, 11 were chosen for closer examination. These 11 technologies had a multitude of desirable attributes overall but in particular had the potential to meet the following three essential criteria:

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

Subsequently, 11 of the 22 screened candidate-sensing technologies that met those three basic criteria were assessed against the additional criteria of accuracy of geo-location/travel time, percent of vehicles recorded, requirement for cross-border installation, maturity of technology for application, cost of infrastructure, and ability to count every vehicle crossing.

As a follow up to the work described above, in 2006, the FHWA initiated Part I of a research effort entitled *Measuring Border Delay and Crossing Times at the U.S.–Mexico Border*. This project involved the first steps in the current process to automate measurement of crossing times. The Part I technology assessment identified two technologies that were best suited to achieve the overall goal of the project [(3)].

In 2007, FHWA began Part II of *Measuring Border Delay and Crossing Times at the U.S.–Mexico Border*. Part II involved two specific objectives: (1) selecting a final technology for the border crossing time measurement system at two ports of entry (POEs) on the U.S.–Mexico border, and (2) implementing the system itself. For this part of the research, FHWA initiated two projects, one of which became the deployment of radio frequency identification (RFID) technology at the Bridge of the Americas (BOTA), a land border crossing between El Paso, Texas, and Ciudad Juárez, Mexico. This project initially implemented two RFID reader stations at BOTA to measure crossing times of northbound commercial vehicles. The system at BOTA became operational in July 2009.

In February 2008, the Texas Department of Transportation (TxDOT) and Texas Transportation Institute (TTI) started a similar project under an interagency contract (IAC). The project implemented RFID technology at the Pharr-Reynosa International Bridge to measure crossing times of northbound commercial vehicles. The system includes four RFID reader stations—two in Mexico and two on the U.S. side of the border. The deployment of RFID reader stations and other communication equipment was completed and the system went online in October 2009.

The key reason RFID technology was selected at both the BOTA and Pharr POEs to measure wait time was due to the relatively high percentage of commercial vehicles crossing at those locations that already had RFID transponders. For example, passive RFID tags were widely used by trucks enrolled in the U.S. Customs and Border Protection's (CBP's) Free and Secure Trade (FAST) Program. Also, the Texas Department of Public Safety (DPS) installed RFID reader stations to provide identifying information that could be used to retrieve information needed to facilitate the passage of commercial vehicles through DPS's Border Safety Inspection Facilities (BSIFs).

Subsequently, the FHWA issued several supporting documents that provide guidance to local, regional, and State agencies to deploy similar RFID-based measurement systems on the U.S.–Mexico border. These documents include:

- Step-by-step guidelines for implementing RFID to measure border crossing and wait times.
- A guidebook for analysis and dissemination of border crossing and wait time data.

This document, the first in the above list, provides 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 U.S.–Mexico border.

The second document listed above provides guidance 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.

Purpose and Audience for the Guidelines

The purpose of this document is to provide step-by-step guidelines for planning, designing, and deploying a system that uses RFID technology to measure the time needed for commercial vehicles to complete the northbound border crossing process at the U.S.–Mexico border (i.e., crossing time) as well as time needed to reach the primary inspection station of the CBP facility from the end of a typical queue (i.e., wait time). This document provides a step-by-step process that is not POE specific, so similar systems can be deployed at any POE along the U.S.–Mexico border. The guidelines are also not direction specific, so a single system can be deployed to measure crossing and wait times of commercial vehicles heading both in northbound and/or southbound directions across the U.S.–Mexico border at a certain POE. It is also believed that RFID has potential for deployment at the U.S.–Canada border since POEs there need reliable and efficient systems to measure crossing and wait times. Thus, these guidelines can help agencies on the U.S.–Canada border plan, design, and deploy a wait time measurement system based on the RFID reader system technology.

The audience for these guidelines includes State departments of transportation (DOTs), metropolitan planning organizations (MPOs) and agencies, cities, and councils of governments that typically fund the design and deployment of the system. The document also consists of many technical details to facilitate private firms designing and implementing RFID-based systems at border crossings on behalf of the previously mentioned agencies. The process outlined by these guidelines is also beneficial for designing and deploying systems based on technologies other than RFID to measure wait times and crossing times at POEs.

For the purpose of this document, an agency (public or private) planning and procuring a project to deploy an RFID system is referred as an implementing agency, which may seek the services of consultants and contractors to design and deploy the system. The system to measure travel times of commercial vehicles is referred to in this document as the RFID-based border crossing time and wait time measurement system. This term presumes that RFID reader stations have been implemented in the configuration necessary to yield both crossing and wait time measurements.

Organization of the Guidelines

The Overview of the Border Crossing Process section describes a general overview of the border crossing process for commercial vehicles entering the United States from Mexico. A clear understanding of the commercial vehicle border crossing process is a must for any individual undertaking the design and deployment of the measurement system. The border crossing process, however, may vary depending on the POE.

The Project Planning section describes planning steps necessary to identify stakeholder needs, gain stakeholder support, obtain funding, select the appropriate project procurement method, and apply a systems engineering process to achieve desired goals and objectives of the RFID-based border crossing time and wait time measurement system.

The Feasibility Study, ConOPs and System Requirements describes the steps to perform feasibility studies and then develop the concept of operations (ConOps) and system requirements at both high and low levels.

The System Design section describes steps regarding design and deployment of an RFID-based border crossing time and wait time measurement system and its components.

The System Deployment section describes steps to procure, install, test, and evaluate the system.

Sections starting with Project Planning through System Deployment also include flow charts to illustrate key steps involved in planning, designing, and deploying the system. The charts are provided to demonstrate a simplistic flow of key steps since some of the key steps can be performed in parallel and under certain circumstances may not be necessary. Each section (except System Deployment) includes a self-evaluation checklist of questionnaire that needs to be considered prior to undertaking next steps. However, implementing agencies need to customize the checklist and the flow charts per their project needs, scope, and constraints.

OVERVIEW OF BORDER CROSSING PROCESS

Overview of the Commercial Vehicle Crossing Process at the U.S.–Mexico Border

The process for commercial freight to enter the United States from Mexico through border crossings begins at the Aduanas (i.e., Mexican customs) facility on the southern side of the border (also referred to as the Mexican export lot). After clearing customs on the Mexican side, a truck crosses a physical bridge or a short roadway segment to enter into the United States. Immediately upon entering the United States, the truck proceeds to the U.S. Federal inspection compound. Entrance to the compound is accessed through one or more primary inspection booths. At these primary inspection booths, CBP officers determine whether the truck requires secondary inspection and either direct the driver to it or instruct the driver to simply proceed to the exit of the inspection facility. For the FAST program, one or more lanes that allow cargo that meets specified security requirements to be expedited through the primary inspection process are provided. Final clearance to exit the inspection facility is given at one of the booths at the exit of the U.S. Federal inspection compound.

The Federal and State inspection facilities are usually connected by one or more lanes. After exiting the U.S. Federal inspection compound, trucks continue toward the State inspection facility. If present, weigh-in-motion sensors measure the weight of every truck that travels on this access road. Past the access road, trucks continue moving toward an inspection shed. Trucks continue moving through the inspection shed and are instructed to either proceed to the exit of the State facility or are told that they have been selected for secondary inspection. If they are selected for secondary inspection, trucks typically bear right after the inspection shed and loop back into the middle of the State inspection facility for further examination.

Basic Definitions of Border Crossing and Wait Times

While the collective term "travel time" has been used previously, it is useful to distinguish between the two main types of travel time to be measured through this project. 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. As a metric, wait time is of greater significance than crossing time to CBP operations, whereas crossing time is of relatively greater interest to FHWA.

The remainder of this section is excerpted from the Part I Final Report [(3)]. According to the 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

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

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.

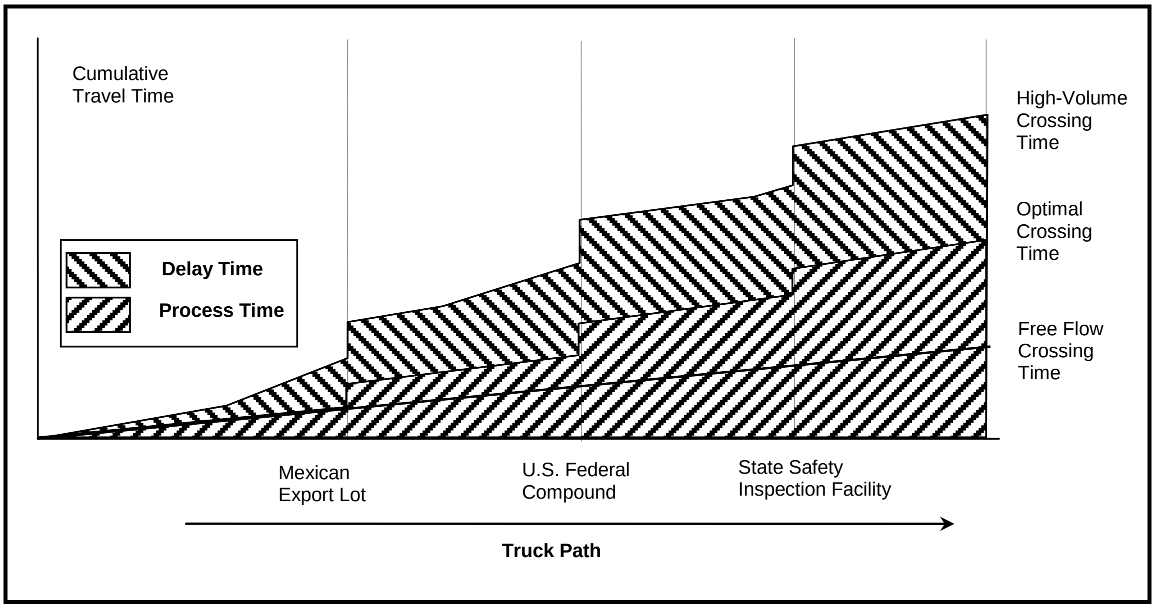

Figure 1. Chart describing border crossing times of U.S. bound trucks.

The Part I Final Report further states:

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, or:

Border-crossing Delay = (observed truck crossing time) – (optimal truck crossing time)

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

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

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

A very important fact that has to be taken in consideration is that not all trucks go through the same number of inspections. In most cases, a first inspection is enough to check the status of the shipment, the truck, and the driver. In some other instances, extra attention has to be given to a truck, its contents, or the driver. Moreover, most of the largest commercial border-crossings have dedicated FAST lanes, where crossing time might be significantly shorter since FAST expedites processing for commercial carriers who have completed background checks and fulfill certain eligibility requirements.

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

- FAST shipments.
- Shipments that go through Primary Inspection only.
- Shipments that go through secondary inspection.

Border-crossing delay and Border-crossing Time Index will have to be estimated for each one of these three categories since all of them have different optimal crossing times. Depending on the technology, a different number of readers will be needed to identify these three types of trips [(3)].

Factors That Influence Border Crossing and Wait Times

Crossing and wait times are influenced by a wide variety of factors. Some factors are related to operational changes related to Federal and State inspection processes, while others are external, such as approaching volume and major incidents around the border crossings. Influencing factors include the following:

- Time of day and day of week—Commercial vehicles crossing the border follow a temporal trend and show a distinct peak and off-peak volume. Intuitively, a temporal trend of crossing and wait times follows a similar trend for volumes.
- Approaching northbound volume—Volume of vehicles approaching the Federal inspection facility has a significant impact on crossing and wait times. Approaching volume of vehicles is also a function of time of day and week, special events and holidays, and other factors. The number of transponders read by the RFID readers on the Mexican side can be taken as a proxy to the approaching truck volume.
- Number of inspection lanes open—The number of inspection lanes open during any given time is correlated with crossing and wait times of vehicles. Vehicles that go through secondary inspection have much higher crossing times than the rest. However, it

is not clear what percentage of total vehicles go through secondary inspection in a day. Also, the number of lanes used at the DPS facility influences the crossing and wait times of trucks.

- Shipment type—Depending on the type of shipment, crossing and wait times could vary significantly, especially the shipments that are empty and are enrolled in the FAST program.
- Type of commodities—Many POEs experience significantly higher crossing and wait time during seasons when particular agricultural products are imported into the United States from Mexico. Also, agricultural commodities have to go through screening not only by the CBP but also the U.S. Department of Agriculture as they enter the United States.

PROJECT PLANNING

Key Steps in Planning a Project to Deploy the RFID-Based Border Crossing Time and Wait Time Measurement System

This section describes key planning-related steps to be undertaken by an implementing agency seeking to deploy an RFID-based border crossing time and wait time measurement system at U.S.–Mexico border crossings. The purpose of this section is not to guide the agency with detailed pre-procurement planning activities but rather to focus on key issues that need to be addressed before the agency decides to procure the project. Key steps in planning an RFID-based border crossing time and wait time measurement system project are illustrated in Figure 2.

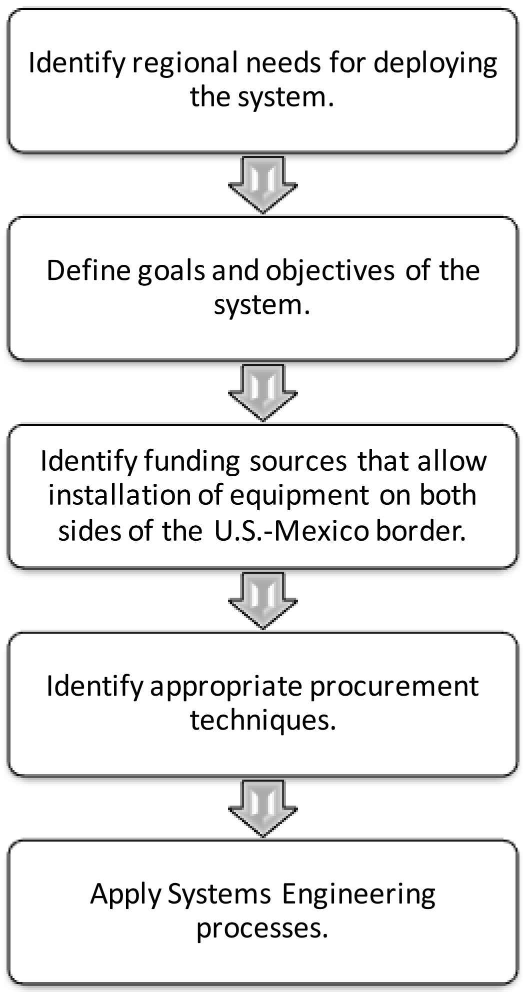

Figure 2. Key steps in planning an RFID-based border crossing time and wait time measurement system project.

Identifying Regional Needs

The success of any project is dependent on support from its stakeholders, who need to be convinced that there is a strong need for a system to measure border crossing and wait times. Even though the region may have already included such a project in its short- and long-term formal planning process, it is strongly recommended that the region obtain buy-in from key stakeholders to deploy such a system. A statement defining the needs of the stakeholders acts as a blueprint for subsequent activities related to procurement and deployment of the system.

The implementing agency can identify the need to measure performance of border crossings through the following:

- Ad-hoc and formal meetings with high-level decision makers.
- Discussions with key stakeholders, especially Federal and State agencies, trade groups, shipper and carrier trade associations, and industry.
- Past studies related to the impact of high crossing and wait times on the local, regional, and national economy.
- Observed trends such as growth in volume of northbound trucks and anecdotal values of wait times and delay at the border crossings.

By measuring performance of border crossings, the region can undertake the following:

- Quantify the impact of long crossing and wait times on local, regional, and national trade and economy.
- Plan, program, and develop border crossing and surrounding infrastructure that feeds into the border crossings to reduce long crossing and wait times.
- Provide traveler information to motorists, shippers, and freight carriers regarding current conditions at and around border crossings.

Using Regional Intelligent Transportation System and Border Information Flow Architecture

Many border regions have developed regional intelligent transportation system (ITS) architectures, which provide a framework to support planning and programming of ITS projects in the region. The architecture can also be used for a variety of border-crossing-related systems. Before using the regional ITS architecture, it is prudent to identify portions in the architecture that are relevant to the project. These include market packages, inventory elements, information flows, and functional requirements. In the absence of a regional ITS architecture, agencies can refer to concepts used in the border information flow architecture (BIFA) as a framework for identifying stakeholders, system requirements, and other key information [(4)].

Identifying Project Goals and Objectives

It is important to use a top-down approach along with successive refinement of the set of goals and objectives of the project, envisioned solutions, and stakeholder expectations, because the ultimate goal is to create a system widely accepted by the stakeholders. Thus, the goal of the project needs to be broad enough to allow successive refinement and allow future expansion based on changing needs of the stakeholders in the region.

For example, the project's goal could be something similar to the following: The goal of the project is to plan, design, deploy, operate, and maintain a system to measure, relay, and archive crossing and wait times of commercial vehicles crossing the international ports of entry on the U.S.–Mexico border. Objectives of the project would then include specifics that are derived from the project's goal. For example, objectives of the project would include the following:

- Plan, design and deploy an RFID-based border crossing time and wait time measurement system at key locations on both the U.S. and Mexico side of the border.
- Archive crossing and wait time data for applications related to planning, decisionmaking, and research.
- Relay current and predicted crossing and wait time information to the public, freight carriers, local media, shippers, and so forth.
- Measure performances of border crossings in terms of efficient and reliable movement of commercial vehicles.
- Operate, maintain, and expand the system for the benefit of regional stakeholders.

Identifying Sources of Funding

Several sources are available for border regions to obtain funds to deploy border wait time measurement systems. It is imperative that these funding sources allow installation of infrastructure on both sides of the U.S.–Mexico border by allowing the implementing agency to contract with counterpart agencies from the other side of the border. The objective of these guidelines is not to provide guidance on how to obtain funding but to point out various funding sources available. It is useful to refer to Web sites of these funding sources and have discussions with individuals (either within their organization or from outside) who have had prior experience obtaining funds from these sources. Also, it is important to be aware of the possibility that one or more funding sources may not be available in the future. Hence, this document is neither a definitive list nor a predictor of funding sources for undertaking ITS projects at international border crossings.

The Coordinated Border Infrastructure Program

The Coordinated Border Infrastructure (CBI) program is a formula grant program whose purpose is to improve the safe movement of motor vehicles at and across U.S. borders with Canada and Mexico [(5).] Under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) program, a total of $833 million is authorized to be distributed by formula to States.

States may use funds in a border region, defined as any portion of a border State within 100 mi of an international land border with Canada or Mexico, for the following types of improvements to facilitate/expedite cross-border motor vehicle and cargo movements:

- Improvements to existing transportation and supporting infrastructure.

- Construction of highways and related safety and safety enforcement facilities related to international trade.
- Improvements to operations, including those related to electronic data interchange and use of telecommunications.
- Modifications to regulatory procedures.
- International coordination of transportation planning, programming, and border operation with Canada and Mexico.

A border State may use these funds to construct a project in Canada or Mexico if the project directly and predominantly facilitates cross-border vehicle and cargo movement at an international POE in the border region of the State. Canada and Mexico must assure that the project is constructed to standards equivalent to those in the United States and is maintained and used over the useful life of the facility only for the purpose for which the funds are being allocated.

Regional Mobility Authorities

Regional mobility authorities (RMAs) are political subdivisions formed by one or more counties to finance, acquire, design, construct, operate, maintain, expand, or extend transportation projects [(6)]. RMAs were created and operate under the Texas Transportation Code Chapter 370 and are authorized under the State law to implement a wide range of transportation systems including roadways, airports, land ports, sea ports, and transit services. RMAs also have the authority to undertake projects in Mexico and enter into contracts with other governmental entities in the United States.

In essence, RMAs are not a direct source of funds but are institutions with the authority to request funds from various State and Federal sources to construct projects in Mexico. However, RMAs may acquire, construct, operate, maintain, expand, or extend a transportation project into another State or Mexico if:

- A city that borders Mexico has a population of 500,000 or more and has the same authority as a county to create an RMA.
- Political subdivisions where the project is to be located approve of the RMA action.
- The RMA member county/city receives significant transportation benefits.
- The county of another State/Mexico is adjacent to the RMA county/city where the project is being developed.
- The Texas governor approves project development.

By law, RMAs require authorization from the Texas Transportation Commission to enter into a contract with Mexico.

The North American Development Bank

The North American Development Bank (NADB) and its sister institution, the Border Environment Cooperation Commission (BECC), were created under the auspices of the North American Free Trade Agreement (NAFTA) to address environmental issues in the U.S.–Mexico border region. The two institutions initiated operations under the November 1993 Agreement Between the Government of the United States of America and the Government of the United

Mexican States Concerning the Establishment of a Border Environment Cooperation Commission and a North American Development Bank (the "Charter").

The purpose of the North American Development Bank is to provide financing endorsed by the United States and Mexico, as appropriate, for community adjustment and investment in support of the purposes of NAFTA.

The NADB provides financial assistance to public and private entities involved in developing environmental infrastructure projects in the border region. Potable water supply, wastewater treatment, and municipal solid waste management form the core sectors of the bank's activities and are its primary focus. However, assistance can also be provided in other areas—such as air quality, clean energy, and hazardous waste—where sponsors are able to demonstrate tangible health and/or environmental benefits for residents living in the area. Eligible communities must be located within 100 km (about 62 mi) north of the international boundary in the four U.S. States of Texas, New Mexico, Arizona, and California, and within 300 km (about 186 mi) south of the border in the six Mexican States of Tamaulipas, Nuevo Leon, Coahuila, Chihuahua, Sonora, and Baja California.

State Planning and Research Program

The State Planning and Research Program (SP&R) is authorized by Title 23, USC and is regulated under 23 CFR Part 420.[2] SAFETEA-LU requires that States set aside 2 percent of the apportionments they receive from the Interstate Maintenance, National Highway System, Surface Transportation, Highway Bridge, Congestion Mitigation and Air Quality Improvement, and Equity Bonus programs for the State's planning and research activities. Of this amount, States must allocate 25 percent for research, development, and technology. These activities involve researching new areas of knowledge, adapting findings to practical applications by developing new technologies, and transferring these technologies via the process of dissemination, demonstration, training, and adoption of innovations by users.

TxDOT has in the past funded deployment of RFID-based border crossing time and wait time measurement systems in Laredo and Brownsville through its SP&R funds. FHWA has allowed TxDOT to use the SP&R funds to deploy RFID-based border crossing time and wait time measurement systems in lieu of CBI program funds and reimburse 100 percent of the project cost. This has eliminated the need for TxDOT to seek a 20 percent match from a local funding source, which is a key requirement under the CBI program.

Identifying an Appropriate Procurement Method

The successful procurement of ITS is a challenging task for State and local transportation agencies. The procurement process must be flexible enough to accommodate the uncertainties of complex system acquisitions but at the same time structured enough to ensure that the responsibilities of the participants are fully defined and their interests are protected [(7)] Although there are several options for procuring ITS projects, some options are more appropriate than others. For more information on procuring ITS projects, the reader is encouraged to refer to the

[2] http://www.fhwa.dot.gov/publications/research/general/spr/legsregs.cfm

Guide to Contracting ITS Projects—NCHRP 560. [7] This guide presents a decision model that helps agencies identify the most appropriate procurement options depending on complexity and risks associate with the ITS project. The procurement process includes four dimensions: work distribution, method of award, contract form, and contract type, which are illustrated in Figure 3. A typical procurement process includes choosing an appropriate method of selecting a contractor and consultants, selecting a method of award, forming a contract, and selecting the type of contract. However, an agency needs to customize its procurement process based on its legal, technical, and institutional constraints.

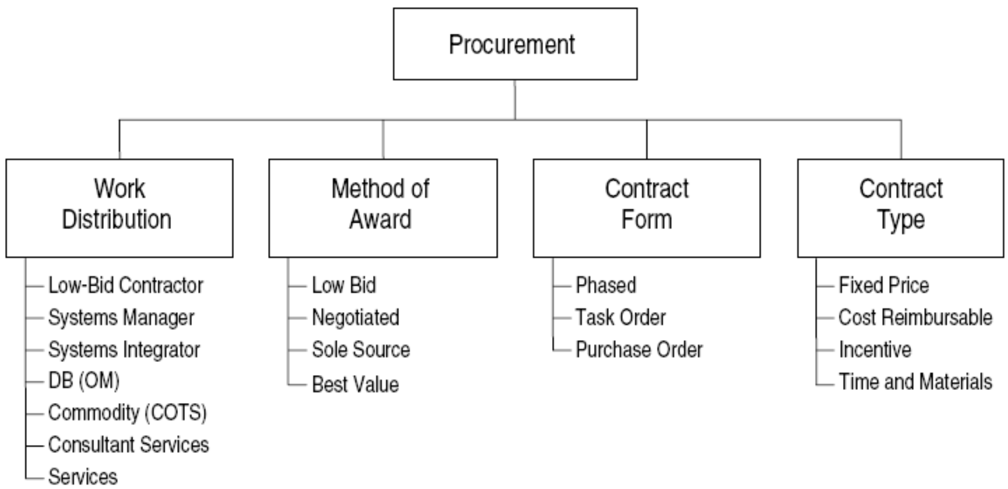

Figure 3. Four dimensions of a procurement process.

Applying the Systems Engineering Process

According to the International Council on Systems Engineering (INCOSE), systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem.

Systems engineering integrates all the disciplines and specialty groups into a team effort, forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

The primary benefit of systems engineering is that it reduces the risk of schedule and cost overruns. Other benefits include the following:

- Better system documentation.
- Higher level of stakeholder participation.
- System functionality that meets stakeholders’ expectations.
- Potential for shorter project cycles.
- Systems that can evolve with a minimum of redesign and cost.

- Higher level of system reuse.
- More predictable outcomes from projects.

The U.S. Department of Transportation (USDOT) recognized the potential benefit of the systems engineering approach for ITS projects and included requirements for a systems engineering analysis in the FHWA Rule/Federal Transit Administration (FTA) Policy that was enacted in 2001. The Rule/Policy requires systems engineering to be performed for ITS projects that use funds from the Highway Trust Fund [8] Many different process models have been developed over the years that specify a series of steps that make up the systems engineering approach. Among these models, the "V" model, shown in Figure 4, has emerged as a de facto standard way to represent systems engineering for ITS projects.

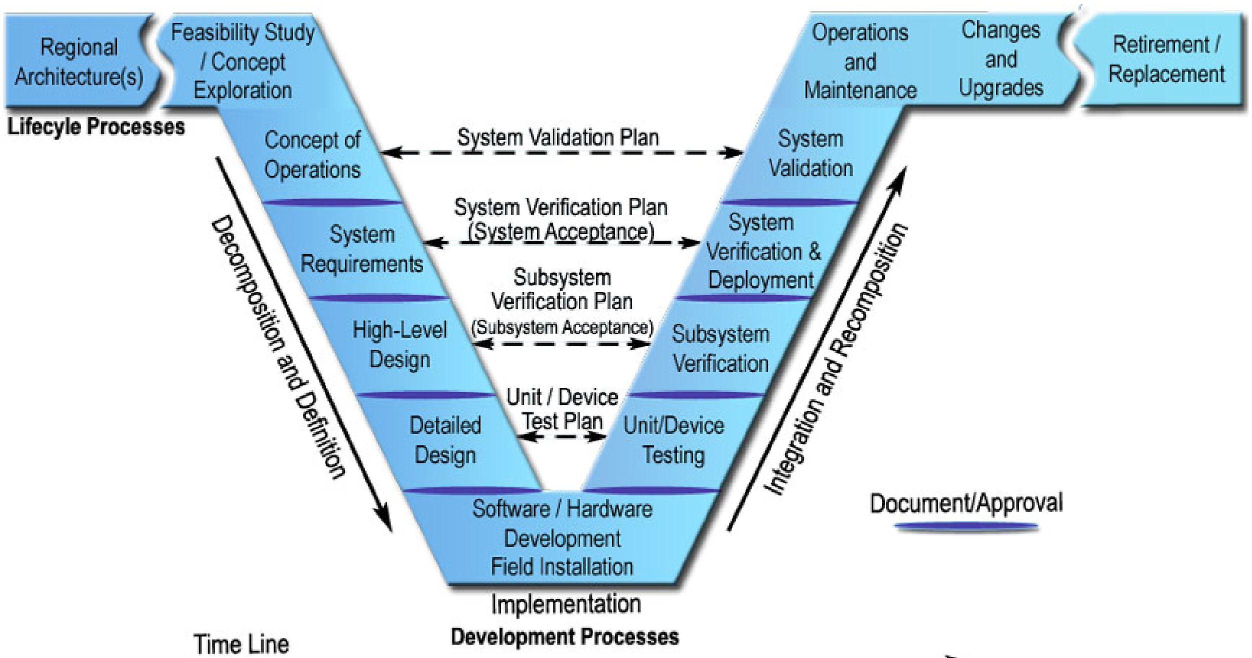

Figure 4. "V" model diagram.

Even when the project is not be funded by the Highway Trust Fund, it is strongly recommended that agencies use the systems engineering approach throughout the life of the project and also require its vendor/contractor/systems integrator to use the approach. Even though the intent of this document is not to provide detailed steps for using the systems engineering approach, subsequent sections describe key steps shown in the "V" diagram. Agencies have the flexibility to elongate left and right wing portions of the "V" diagram according to their unique conditions.

Evaluation Questionnaire

The implementing agency should prepare a list of questionnaire that should be considered prior to undertaking next steps for analyzing feasibility for an RFID based system to measure wait times and crossing times of trucks. A recommended list of evaluation questionnaire is as following:

- Is there a broad consensus among the stakeholders that long wait times at the border are a major concern?
- Have the stakeholders expressed need for a reliable system to measure crossing and wait times of vehicles at the border?
- Are the stakeholders aware of ITS deployment technologies at the border, especially which parameters can be collected using which technology?
- Have you identified funding sources? Is a funding source limited due to the fact that some field devices have to be installed in a different country?
- Have you identified how the system will be operated and maintained in the future?
- Have you assessed your agency's readiness in procuring and deploying ITS?
- Have you decided which strategy you will use to procure the system (e.g., request for proposal for a turnkey project or use of a system integrator)?

FEASIBILITY STUDY, CONOPS, AND SYSTEM REQUIREMENTS

Key Steps Prior to Designing the System

This section describes key planning-related steps to be undertaken by an implementing agency and/or the agency contracted by the implementing agency prior to developing high- and low-level designs of the system. These key steps identify alternative technologies and preliminary cost based on planning steps, identify stakeholder needs, and develop the concept of operations of the system. Eliciting stakeholder needs is probably the most important step and not only assists in defining the system but also in gaining support of the system. Key steps prior to designing the system are illustrated in Figure 5:

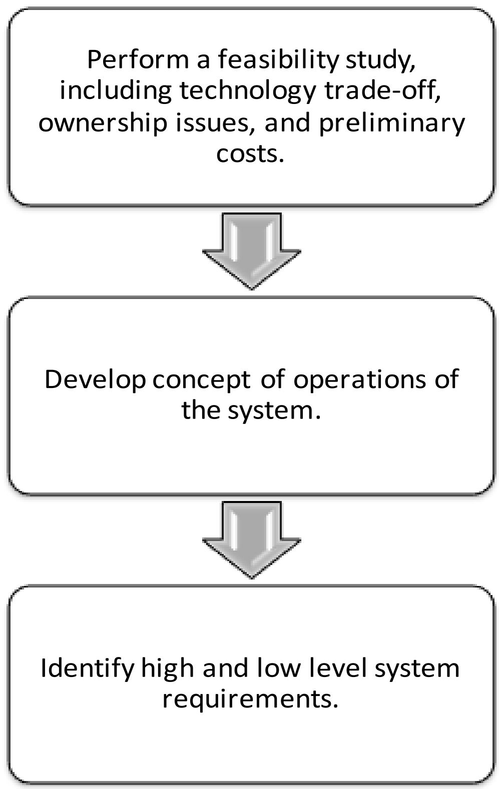

Figure 5. Key steps prior to designing the system.

Performing a Feasibility Study

A feasibility study needs to be performed after stakeholders agree on the higher-level system concept, which mostly focuses on how the system is to be used. The feasibility study identifies institutional and financial constraints, appropriate technology, approximate costs, and scope of the system. The feasibility study reduces risk of cost and schedule overruns by verifying and identifying risks early on. Project feasibility is established once the project scope and cost estimations have been validated and verified against available agency resources and external funding. The feasibility study identifies the following:

- Alternative methods and technologies to achieve the same goals and objectives, such as use of existing infrastructure such as masts or cross-arms, hardwired vs. solar power, wireless vs. wired communications, and local vs. remote server.
- Project risks and institutional and physical constraints.
- Project and system cost, affordability, and funding sources considering the short- and long-term operation of the system.

Performing Technology Trade-Off Analysis

The preferred technology (in this case RFID) has proven its capability to measure, relay, and archive crossing and wait times of commercial vehicles. However, if the stakeholders have concerns about the fundamentally different alternatives to the RFID-based border crossing time and wait time measurement system, then a technology trade-off analysis needs to be performed to identify alternative technologies that could be less expensive and more acceptable to stakeholders. Thus, it is recommended that the implementing agency perform a technology trade-off analysis against the requirements of the stakeholders, funding availability, and operational characteristics of the border crossing. A trade-off analysis also helps to ensure that stakeholders are well-informed about strengths and weaknesses of alternative and preferred technologies.

An earlier trade-off analysis performed for the FHWA prior to deployment of RFID is an example of how similar studies can be performed by agencies. In the FHWA study, the following technologies were analyzed prior to selection of the RFID technology:

- Automatic vehicle identification (AVI):
    - AVI using laser frequency.
    - AVI using radio frequency (i.e., RFID).
    - AVI using infrared frequency.
- Automatic vehicle location (AVL).
- Mobile phone location.
- Automatic license plate recognition (ALPR).
- Vehicle matching.
- Inductive loop detectors.

Factors such as cost, accuracy of readings, and maturity of technology, availability, and reliability were analyzed for each of the six main technologies listed above. Table 1 summarizes the results of the initial analysis from the study by listing the advantages and disadvantages of the six technologies.

Table 1. Summary of the advantages and disadvantages of potential vehicle identification technologies.

Technology	Advantages	Disadvantages
AVI	• Can send and/or receive information. • Is commonly used in POEs for toll collection. • Could use available readers for expanded purposes. • Has low operating cost. • Has broad application in metropolitan areas.	• System requires investment for roadside infrastructure (transponders and signal readers). • System 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	• Can track vehicle location and speed over the predetermined area with very good accuracy. • Does not need fixed roadside equipment installed.	• System requires some investment on infrastructure (geographical positioning system [GPS] devices). • System results in privacy issues with the vehicle owner. • Obtaining truck tracking data from trucking carriers might be difficult.
Mobile Phone Location	• Does not require infrastructure. • Can track vehicle location and speed.	• System relies on the size of the cell. • System is especially affected by fade zones in rural areas. • System is not as accurate as onsite technologies.
ALPR	• Has good identification rate. • Does not need on-board equipment.	• System is negatively affected by slow-moving or turning vehicles (might not be suitable for border crossings). • System 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.
Vehicle Matching	• Does not need on-board equipment.	• System 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	• Has relatively low installation cost on a per-detector basis.	• Detector is subject to density of traffic. • In order to have a general sense of traffic patterns, a large number of detectors are needed, and therefore a large investment is required. • Border crossing scenarios are not suitable for this type of technology. • Due to high operations & maintenance (O&M) cost, long-term cost is usually high.

Despite the advantages of the RFID technology, there are potential risks, which are as follows:

- Technology is susceptibility to damage.
- Equipment/components are susceptible to theft.
- Equipment has limited power sources.
- Data transfer is complex (especially from Mexican readers).
- Permits and agreements must be reached with public stakeholders.

Some other factors that can be considered while selecting RFID technology are as follows:

- CBP (and DPS in the case of Texas) currently use RFID technology in its facilities. DPS installed several RFID reader stations inside its compound and distributed transponders to shippers and carriers on a voluntary basis. A high percentage of carriers whose vehicles cross the U.S.–Mexico border in Texas are outfitted with RFID tags in order to comply with CBP (and DPS) initiatives.

- Because of substantial infrastructure investments by CBP (and DPS), it is understandable that RFID continues to be utilized in the long run at land border crossings along the U.S.–Mexico border.

- Due to business competitive sensitivities, local private stakeholders tend to prefer technologies that are non-intrusive and do not have to reveal their operational practices, especially the shippers and carriers.

- Prior to the pilot program for implementation of the RFID automated travel time measurement system at BOTA, it was emphasized to stakeholders that there was no intent for the RFID system to identify any carrier, truck, or driver. Rather, the interest was confined to gathering and manipulating aggregated data. The system was only intended to extract and time stamp the identification number of the transponder carried on a truck's windshield. While there are other data that reside on the transponders, use of data beyond transponder ID is not necessary for travel time measurement. However, the possibility exists that the transponder ID number could be used for other purposes. For example, if the transponder ID were read at a remote sensor, it could be used to give a heads-up to Federal Motor Carrier Safety Administration (FMCSA) and/or State vehicle inspectors that a certain truck was inbound because the transponder ID presumably is in their databases. Truck drivers are naturally curious about what data are being collected as they drive past RFID equipment some distance from the border. It needs to be made clear to stakeholders exactly what data are to be collected and for what purposes they are to be used.

Identifying Ownership Issues

There needs to be a clear distinction between who owns and who operates the RFID-based border crossing time and wait time measurement system after it is deployed. This may depend on the type of procurement method used, especially in the case of design-build type procurement in which the institution contracted to maintain the system may be designated as the owner of the system until the system has been transferred to a government agency as the owner. If the procurement method is not a design-build arrangement, then the implementing agency is the owner of the system but could contract with another institution for operating and maintaining the system.

Liability issues need to be identified, addressed, and completely understood early on. It is strongly recommended to pursue services of legal experts to assess the likely impact of liability.[5] It is also important in the case of a cross-border project, such as is being described in this document, to identify who is liable for damages due to equipment failures in Mexico.

Also, data ownership and redistribution might emerge as an issue for which adequate policies and procedures need to be in place. If the region already has other ITS deployments, then such policies can be borrowed from previous projects. In most situations, policies regarding distribution of data are governed by Federal, State, and city laws if the owner of the system is a public agency.

It must be clear who owns the intellectual property rights that might result from the deployment. Retaining intellectual property rights also depends on source of funding. Typically, Federal funding sources allow private entities contracted to implement the system to retain rights and patents generated by the system.

Data ownership, redistribution, and intellectual property rights issues also need to be specified in contractual documents developed prior to procurement of private entities and contractors to design and deploy the system.

Estimating Preliminary Costs

At this stage of the project planning, it is important to estimate the approximate cost of deploying an RFID-based border crossing time and wait time measurement system. However, the cost needs to reflect the following three key drivers of the project and the system: major hardware components, high-level capabilities, and O&M needs.

There are no formal sources whereby the implementing agency can reliably estimate the approximate cost. Studies have used the FHWA ITS Cost/Benefits Database to estimate ITS deployment cost, but the database has not had enough unit cost history to estimate the cost of components for an RFID-based border crossing time and wait time measurement. Hence, the ideal method of estimating preliminary project and system cost is by referring to past projects with similar scope and capabilities (i.e., analogous estimating). FHWA and TxDOT have procured similar projects and are deploying more at the U.S.–Mexico border. The actual cost of these projects is a reliable source with which to estimate preliminary project costs.

Table 2 includes the cost of RFID-based border crossing time and wait time measurement system projects deployed at various crossings at the U.S.–Mexico border. All project costs include cost of major hardware components, management labor, field device installation, and O&M.

Table 2. Project cost of RFID-based border crossing time and wait time measurement system projects deployed during 2009-2011.

Project Location	Project Sponsor	Project Cost	Equipment and Installation Direct Cost	RFID Configuration[a]
Bridge of the Americas, El Paso, Texas	FHWA	\$328K[b]	\$110,000	2 reader stations, 2 with solar power, 5 traffic lanes
Pharr-Reynosa Bridge, Pharr, Texas	TxDOT	\$213K[c]	\$70,000	4 reader stations, 1 with solar power, 9 traffic lanes
World Trade Bridge and Colombia Bridge, Laredo, Texas	TxDOT	\$408K[d]	\$170,000	6 reader stations, 2 with solar power, 21 traffic lanes
Veteran's Memorial Bridge, Brownsville, Texas	TxDOT	\$248K[e]	\$100,000	3 reader stations, 1 with solar power, 8 traffic lanes
Mariposa Port of Entry, Arizona	ADOT	\$180K[f]	\$56,000	2 reader stations with solar power, 4 traffic lanes

[a] Reader configuration includes reader stations, readers, and antennae. Reader stations are physical locations where there is infrastructure including one or more RFID readers, each connected to antennae on a mast or roadway cross-arm, equipment cabinet, batteries, wireless modem (typically), and solar power (if there is no reliable hardwire power available). Reader configuration in Table 2 includes total number of individual RFID reader stations located on both sides of the U.S.–Mexico border. A single RFID reader is capable of receiving information from multiple antennae located over passing vehicles. Each antenna typically reads transponders from a single lane, so the number of traffic lanes shown for a crossing in Table 2 corresponds to the number of antennae deployed.
[b] As a pilot deployment, along with installation and evaluation/assessment of results, this project included costs for:

- Coordinating stakeholders.
- Gathering baseline data.
- Identifying potential vehicle detection technologies and conducting a trade-off analysis.
- Developing requirements, specifications, and ConOps.
- Designing the project.
- Developing implementation plan.
- Demonstrating technology effectiveness.
- Reporting (including Section 508 compliance).

[c] This project included two reader stations in Mexico and two in the United States.
[d] This project included two crossings. Readers were installed at the CBP primary inspection booths and cover a total of 12 lanes—8 at the World Trade Bridge and 4 at Colombia.
[e] This project included installation of readers at CBP primary inspection booths, covering four lanes.
[f] While two reader stations (one on each side of the border) are in the original plan, two reader stations are now planned for the Mexican side of the border and one at CBP primary inspection booths due to stakeholder input and POE layout, which is expanding to eight lanes.

Based on the estimated and actual cost of past RFID-based border crossing time and wait time measurement system projects listed in table 2, the approximate cost of such a system ranges between \$70,000 to \$100,000 per RFID reader station. Per-station cost includes the following:

- The reader station includes a single utility pole with a mast arm, concrete foundation, and battery vault installed without acquiring the right-of-way.
- Accessories include a solar panel, signal cabinet, and necessary panel board to hold communication and power devices.
- RFID components include two antennae per reader and four antennae per mast arm.
- The central subsystem includes storage space on an existing database server and a relational database structure to archive and process the crossing and wait time data.
- The user subsystem includes storage space in a Web server to host a map-based Web site to relay current crossing and wait time using real simple syndication (RSS) and a set of predefined charts and graphs.

The bulk of the per-station cost includes installation of a separate utility pole and the mast arm, the cost of which is approximately $30,000. Note that the cost of installation both on the U.S. and Mexico side may not differ substantially. If an existing mast or gantry is available to install the RFID readers and antennae, then the per-station cost can be reduced by almost 50 percent. The aforementioned project cost also includes approximately $550 to $650 per month per reader station to operate and maintain the system for a 12-month period.

Developing a Concept of Operations

The ConOps sets a framework for the design and deployment of the system and a technical course for the project.[1] Its purpose is to clearly convey a high-level view of the system to be developed that each stakeholder can understand. The ConOps is not a document that lists the detailed requirements for the system, nor is it a design document that specifies the technical design or technologies to be used. The ConOps defines the following:

- What the stakeholder needs are and stakeholders' roles and responsibilities in the project.
- What the high-level capabilities of the system are and its basic elements.
- What the ideal locations of RFID reader stations are.
- How the system is to be evaluated and validated (key performance parameters [KPPs] or other measures).
- How the system is to be operated and maintained.

Defining Stakeholder Needs and Their Responsibilities

There are several stakeholder agencies involved in the border crossing process for commercial trucks crossing the U.S.–Mexico border. One or more stakeholder meetings need to be undertaken to (a) solicit stakeholder participation during the project, (b) identify stakeholder needs, and (c) identify responsibilities of individual stakeholders throughout the life cycle of the project. Active participation and support from these agencies depends on their immediate need for the border crossing and wait time data. It is important to note that not all agencies may play an active role in the project, but their involvement might be crucial in successful deployment of the system. Thus, discussions aimed at addressing any stakeholder questions and/or concerns about the technology and the system need to be encouraged and facilitated. For example, stakeholder agencies that have to issue permits to install equipment in their right-of-way may understandably have initial concerns about the technology and equipment being deployed so that it does not hinder their operations.

A list of stakeholder agencies, including their points of contact for the project, need to be developed early in the project. Typically, for a cross-border project of this type that involves components being deployed in two different countries, stakeholder agencies most likely include:

- U.S. Federal agencies:
    - CBP.
    - General Services Administration (GSA).
    - FHWA.
    - FMCSA.
    - U.S. Environmental Protection Agency (EPA).
- U.S. State-level agencies:
    - DPS, State Highway Patrol.
    - State DOTs.
- Mexican Federal agencies:
    - Aduanas.
    - Secretaría de Comunicaciones y Transportes (SCT).
    - General Services Administration.
- Mexican local and regional stakeholders:
    - MPOs.
    - Cities and States.
- Mexican private stakeholders:
    - Maquila associations.
    - Shippers and carriers.
    - Local transportation service providers.
- U.S. local and regional stakeholders:
    - MPOs, councils of government, associations of government.
    - Cities and counties.

Table 3 includes roles and responsibilities of key stakeholder agencies in successfully deploying an RFID-based border crossing and wait time measurement system on the U.S.–Mexico border.

Table 3. Stakeholder agency roles and responsibilities.

Stakeholder Agency	Roles and Responsibilities in Deploying a RFID-Based Border Crossing Time and Wait Time Measurement System
GSA	The Federal inspection facility on the U.S. side is owned by the GSA. Installation of RFID equipment under the auspices of FHWA requires approval of GSA form 1583: Permit for Use of Real Property by Federal Agency.
CBP	CBP coordinates with GSA to allow the installation of RFID equipment. In the past, CBP has shown interest in receiving most current wait times and crossing times.
FHWA, State DOTs, Cities, and MPOs	These agencies may play a major role as a funding and/or implementing agency and provide right-of-way and access to existing roadside infrastructure.
Freight Carriers and Shippers	These agencies help define requirements of the system for real-time information and archived data based on their needs.
Mexican Local, State, and Federal Agencies	Local and State agencies play a significant role in providing the necessary right-of-way, which may also belong to Federal agencies. They may also assist in lowering the equipment importation.

Based on experiences from similar projects, stakeholders particularly indicated a need for efficient and reliable traveler information related to border crossings. Also, 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.

Identifying the Ideal Location for RFID Reader Stations

All border crossings are different in their operational characteristics. Differences in features such as physical layout, hours of operation, provision of separate lanes for shipment types, and expedited processing arrangements influence system design. Thus, developing a geometric layout of a border crossing is essential. At large crossings and most other crossings, lanes for passenger vehicles and trucks typically separate prior to the crossing and converge after departure from the crossing.

A footprint of a border crossing typically needs to consist of the following:

- Physical boundaries of State and Federal inspection facilities.
- Path of trucks from start of queue to exit of the State facility.
- Separate paths for shipment types, primary and secondary inspections.
- Identification of access and egress for trucks to access facilities other than inspection facilities.
- Egress points that could allow trucks to depart the truck path after being detected by entry but not exit reader(s).
- Right-of-way along the truck path.
- Tentative location of RFID reader stations.

A typical footprint of U.S.–Mexico border crossings in terms of freight movement consists of the following:

- Mexican export lot—A facility operated by Mexican customs that is responsible for inspecting export materials leaving Mexico. Generally, only a small percentage of freight is physically inspected at this facility. Roads leading to the Mexican customs facility may be a Federal roadway or a city roadway. At many border crossings, roadways leading to the facility could be on the right-of-way of a city and Federal agency. Thus, permission from the city and SCT is essential to install field devices on the right-of-way.

- U.S. Federal inspection compound—This facility is operated by CBP. Its primary function is to make sure no illegal freight is permitted to enter the United States. Secondary inspections can occur here if CBP feels it necessary to further examine the driver, freight, or conveyance. These secondary inspections can include intrusive measures (e.g., physically unloading the trailer to examine its cargo) or non-intrusive measures (e.g., x-ray or gamma ray imaging). FMCSA might be co-located within the facility. CBP is the occupant of the facility, but GSA is responsible for all construction-related activities inside the compound. Hence, obtaining necessary permits from GSA is essential to install field devices inside the facility.

- State inspection facility—This facility is operated by the State’s Department of Public Safety. Its primary function is to ensure that tractors and trailers entering the United States from Mexico are safe enough to operate on U.S. roadways. Secondary inspections of the vehicles can occur here if deficiencies are revealed through a preliminarily review of the conveyance by DPS. In the State of Texas, the inspection facility is located on TxDOT’s property and right-of-way. Hence, obtaining TxDOT’s permission to install utility poles for the readers on the side of the road north of a facility in Texas is necessary. This may not be the case with other States.

The northbound commercial freight border crossing process begins at the Mexican export lot on the Mexican side of the border (also known as the Aduana facility). After clearing customs on the Mexican side, a truck crosses into the United States, typically across a physical bridge structure. Immediately upon entering the United States, the truck proceeds to the U.S. Federal inspection compound. Entrance to the Federal inspection compound is accessed through a primary inspection booth. At these primary inspection booths, a CBP agent determines whether the truck requires any secondary inspection. If so, the agent directs the driver to it; otherwise, the agent instructs the driver to simply proceed to the exit. Final clearance to depart the Federal inspection compound is given at a booth at the exit of the compound, at which point the truck enters a State inspection facility (in Texas, the BSIF).

In principle, the greater number of RFID reader stations that can be installed at a border crossing, the greater the ability to segment the truck path in a way that yields information on where delays are occurring. The more detailed information facilitates both a more effective response to alleviate congestion and better historical data about the causes of the congestion. However, more readers means more cost. The benefits of segmenting the truck path with more readers needs to be discussed with stakeholders so that they are clear on the trade-offs. In reality, it may be difficult to secure a budget for more than the basic two or three readers. As an illustration, the approximate locations for potential measuring sites identified for the BOTA border crossing site were as follows:

- R1—the farthest point from the entrance to the Mexican export lot, before the queue develops on the Mexican side of the border.
- R2—the entrance to the Mexican export lot.
- R3—the exit of the Mexican export lot.
- R4—primary inspection booth of the U.S. Federal compound.
- R5—the entrance to the State inspection facility.
- R6—the end of the border crossing process after the exit of the State inspection facility.

Based on these sites, the respective segments allow measurement of the following:

- R1 to R2—the amount of time a truck spends in the queue on the Mexican side of the border.
- R2 to R3—the amount of time a truck spends in the Mexican export lot.
- R3 to R4—the amount of time a truck spends on the physical bridge before entering the U.S. Federal compound.
- R4 to R5—the amount of time a truck spends inside the U.S. Federal compound.
- R5 to R6—the amount of time a truck spends inside the State inspection facility compound.
- R1 to R4—wait time of a truck, assuming the time spent to enter the Mexican facility is relatively small if the truck is a FAST one or zero in the case of a non-FAST truck.
- R1 to R6—crossing time of a truck to complete the border crossing process.

Two reader stations corresponding to R1 and R6 were initially implemented at BOTA to provide measurement of crossing time, and a third reader station corresponding to R4 was installed that provided measurement of wait time.

Defining High-Level Capabilities of the System

Through stakeholder meetings, high-level capabilities of the proposed system need to be defined. All the stakeholders need to be in agreement with these capabilities, which need to satisfy their individual needs. High-level capabilities of the system need to be short and concise. An example list of high-level capabilities for an RFID-based border crossing time and wait time measurement system includes the following:

- The system needs to automatically measure the wait time required for a northbound truck to move from a predetermined point upstream of the typical queue on the Mexican side to the CBP primary inspection facility on the U.S. side.
- The system needs to automatically measure the crossing time required for a northbound truck to move from a predetermined point upstream of the typical queue on the Mexican side to the exit of the POE on the U.S. side.
- The system needs to relay most recent crossing and wait times to local media and travelers through the Internet and other electronic delivery mechanisms.

- The system needs to systematically archive all the raw crossing and wait time data created during the course of the RFID implementation.
- Archived data need to be made available to authorized subscribers and stakeholders.

Defining Evaluation Performance Measures

The ConOps also needs to define the approach that is to be taken to evaluate and validate the system and the project. Key performance measures and a basic plan to evaluate and validate the system need to be included in the ConOps. All the stakeholders need to be in agreement with these key performance measures.

After the system has been installed, it needs to be tested and evaluated based on a test and evaluation (T&E) plan that is developed as part of a detailed design. The T&E plan is based on the performance measures identified in the ConOps.

Two key performance measures are recommended in order to ensure that the system accurately collects border crossing and wait times of trucks. These key performance measures are:

- **Tag Read Time Stamp Accuracy:** RFID readers send identification number of tags to a central server, which assigns a time stamp to each read. Internal clocks of both RFID readers and the central server must be the same most of the time. These two times must be within 1 minute of each other 95 percent of the time in order to ensure the accuracy of the system. If there is a significant time delay between the RFID reader station and the central server, the time stamps of transponders will not be consistent.

- **Accuracy of Crossing and Wait Times:** A side-by-side comparison of crossing and wait time measured by the RFID-based border crossing time and wait time measurement system and the one measured in the field (or baseline data) need to be performed to evaluate the system. The difference between crossing and wait times collected by an RFID-based border crossing time and wait time measurement system and the baseline data need to be within 3 minutes of each other 85 percent of the time to guarantee the RFID-based border crossing time and wait time measurement system's accuracy. There are several techniques by which baseline crossing and wait time data can be collected in the field.

The system evaluation may also consist of determining the ability of RFID readers to read a significant number of tags carried by the trucks crossing the border. Total tags read by the RFID readers can be compared with the total number of tags collected in the field by visually counting the tags carried by the trucks. However, as a word of caution, it is very difficult to accurately count the number of tags visually since trucks carry many decals that appear to look like tags. Also, there is no way to confirm whether the tag carried by a truck is active.

Identifying System Requirements

System requirements describe what the system needs to do to meet the stakeholder needs. Developing system requirements could be an iterative process in some projects and may involve going back and forth among the stakeholders to come up with a final list of requirements. It is important to involve stakeholders in requirement development. Stakeholders may not have experience in writing requirement statements, but they are the foremost experts concerning their own requirements.

The following is a sample list of system requirements:

- The system must not interfere in any way with day-to-day operations at the border crossings. The process of vehicle detection should not impact the speed or path of vehicles through the facilities.
- 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 must be focused on analysis of aggregated data rather than the identity of drivers, shipments, or trucks in order to maintain anonymity. The goal is to generate average crossing and wait times from individual vehicle data and not to specifically track and store crossing and wait times of individual vehicles.
- Processed crossing and wait time data need to be available to authorized subscribers through the Internet.
- If more than two RFID reader stations are installed, segmented data need to be obtained, measured, and archived.
- The system need not require an interface to any current equipment or data streams in use at the POE. The system need 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.
- Commercial vehicles are expected to have RFID tags using either the TransCore eGo or American Trucking Association's (ATA's) tag protocol. The field tag reader equipment is to be able to read tags of either protocol.
- The RFID reader station design needs to include a solar-powered option (including batteries) to support deployment in a more remote area or an area with unreliable electrical service.
- The RFID reader stations need to 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.
- All field equipment must exhibit sufficient environmental specifications to ensure proper operation in the area climate.
- The RFID reader station design needs to incorporate a method to detect malfunctioning equipment, send an alert, and attempt to self-correct or otherwise compensate for the problem. This is particularly necessary for the communication link.
- The design of the system needs to maximize the use of off-the-shelf components that can be readily purchased in case a repair is required.
- The RFID reader station design needs to be such that little ongoing maintenance is required since the sites may be difficult to access without prior authorization.

Evaluation Questionnaire

The implementing agency should prepare a list of questionnaire that should be considered prior to designing the system and ensure that the system is feasible. A recommended list of evaluation questionnaire is as following:

- Have you identified the stakeholders for the system?
- Have all the stakeholders agreed to support and participate in the project for a successful deployment?
- Have you identified and defined institutional issues of ownership and liabilities?
- Have you performed technology trade-off studies? Are there any other technologies that the stakeholders prefer?
- Have you determined approximate cost for installing and maintaining the system? Can you afford the system and obtain funding?
- Have you defined high-level capabilities of the system?
- Have you identified requirements for the system?
- Are there any requirements that cannot be met by the system? Are these requirements critical, or can they be met by incremental upgrades to the system in the future?
- Have you identified how the system will be evaluated and validated?

SYSTEM DESIGN

Key Steps for Designing the System

A general design concept of the RFID-based border crossing time and wait time measurement system is that during its trip across the border at the POE, a truck passes under two or more RFID reader stations, which include antennae. The RFID reader station detects the truck's tag identification number and makes a time stamp of the record. By calculating the difference in time stamps, a truck's crossing and wait times are recorded. Based on this simplistic concept, preliminary designs and detailed designs need to be prepared and need to include a description of subsystems and their functions. The detailed design includes the low-level hardware and software design for individual subsystems. The detailed cost estimate depends on the detailed design of the system. A detailed design document is also required to obtain necessary construction permits from concerned agencies, such as CBP and GSA. Key steps for designing the system are illustrated in Figure 6.

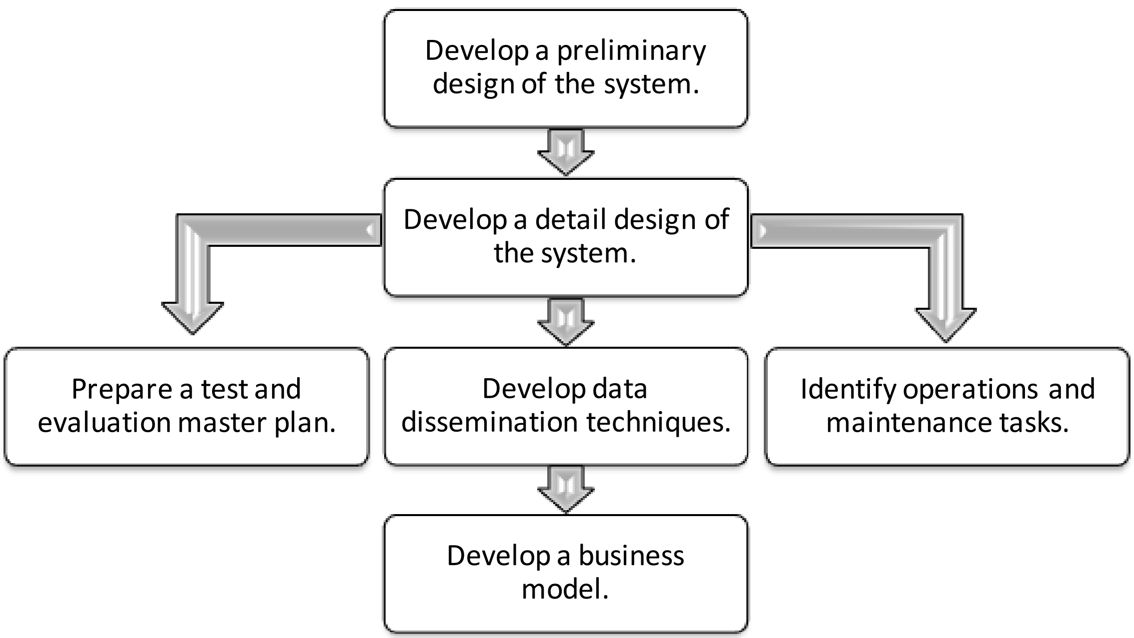

Figure 6. Key steps for designing the system.

Developing Preliminary Designs

A preliminary design document needs to identify specific details of the RFID-based border crossing time and wait time measurement system that is to be deployed at the border crossing. This document needs to include maps of the POE along with flow lines, key points, and locations at the crossing where RFID reader stations are to be installed. Drawing from stakeholder meetings, the needs of the stakeholders who are to use the system should be incorporated into this document. The preliminary design document needs to address high-level capabilities defined for the system. Once the preliminary design document is prepared, it needs to be reviewed by project coordinators to assess the feasibility of successfully implementing the system. The final element of this document is a subsystem level design in which the system is broken down into its core elements and each element is described in detail.

Subsystems of the RFID-based border crossing time and wait time measurement system typically consist of a field subsystem, central subsystem, and the user subsystem. Each subsystem is functionally and technology independent of the others.

The field subsystem consists of all the deployed field RFID reader stations. The field subsystem is comprised of the RFID reader stations including the communication equipment. These stations are responsible for accurately identifying and logging the passage of commercial vehicles past a point. The field subsystem relays vehicle passage information via a telecommunication network to the central subsystem. The central subsystem logs the incoming tag information, matches the identification, determines individual crossing and wait times of trucks, and archives the data. The user subsystem interacts with the central subsystem to provide an Internet Web portal for data users (e.g., stakeholders or the public) to access current border crossing times and, if given proper credentials, to access archived crossing time data.

Subsystems for a typical RFID-based border crossing time and wait time measurement system are illustrated in Figure 7.

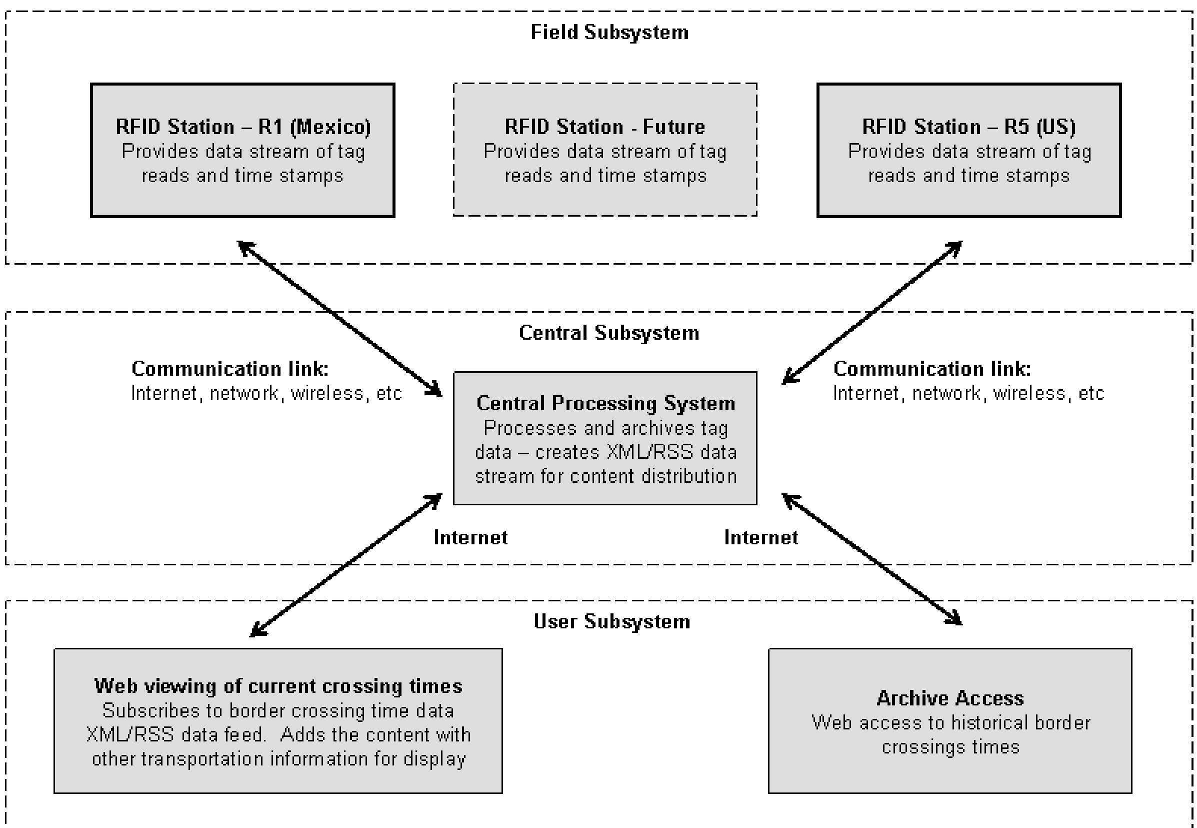

Figure 7. Sample conceptual design of an RFID-based border crossing time and wait time measurement system.

Developing a Detailed Design

The detailed design document builds on the preliminary design document. While the preliminary design document lays out the subsystem and conceptual design of the system, the detailed design document specifies the equipment that is needed in order to actually build the proposed system in a real-world setting. Equipment specifications for system hardware (i.e., measuring sites) and software need to be provided in this report, along with detailed diagrams of equipment that is to be installed onsite. Other considerations such as how to power the equipment need to be incorporated into this document as well.

It is important to note that before completing the detailed design document, it is essential to confirm whether the physical layout of the POE has been modified or whether there are plans to modify it. Stakeholder intent and commitments need to be reaffirmed at this point in the project, which is probably best accomplished via another stakeholder meeting. At that meeting, the interfaces between the implementation and the regional architecture (from the detailed design document) can also be validated.

Once a detailed final design document is prepared, it needs to be reviewed by project coordinators to assess whether all elements required to successfully implement the system have been identified and documented and all risks updated and addressed.

A detailed design of the RFID-based border crossing time and wait time measurement system needs to describe in hardware and software terms each subsystem identified in the preliminary design document. An example detailed design from the BOTA system included the following description about hardware assembly and installation.

> Northbound commercial vehicles (trucks in Mexico destined to cross the border into the United States) pass an RFID tag reader installed at a point sufficiently ahead of the end of any queue on the Mexican export lot. The 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. This reader 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 wireline. The data bandwidth requirements for each station are not excessive and could easily be met by each of these alternatives.

Figure 8 illustrates the configuration.

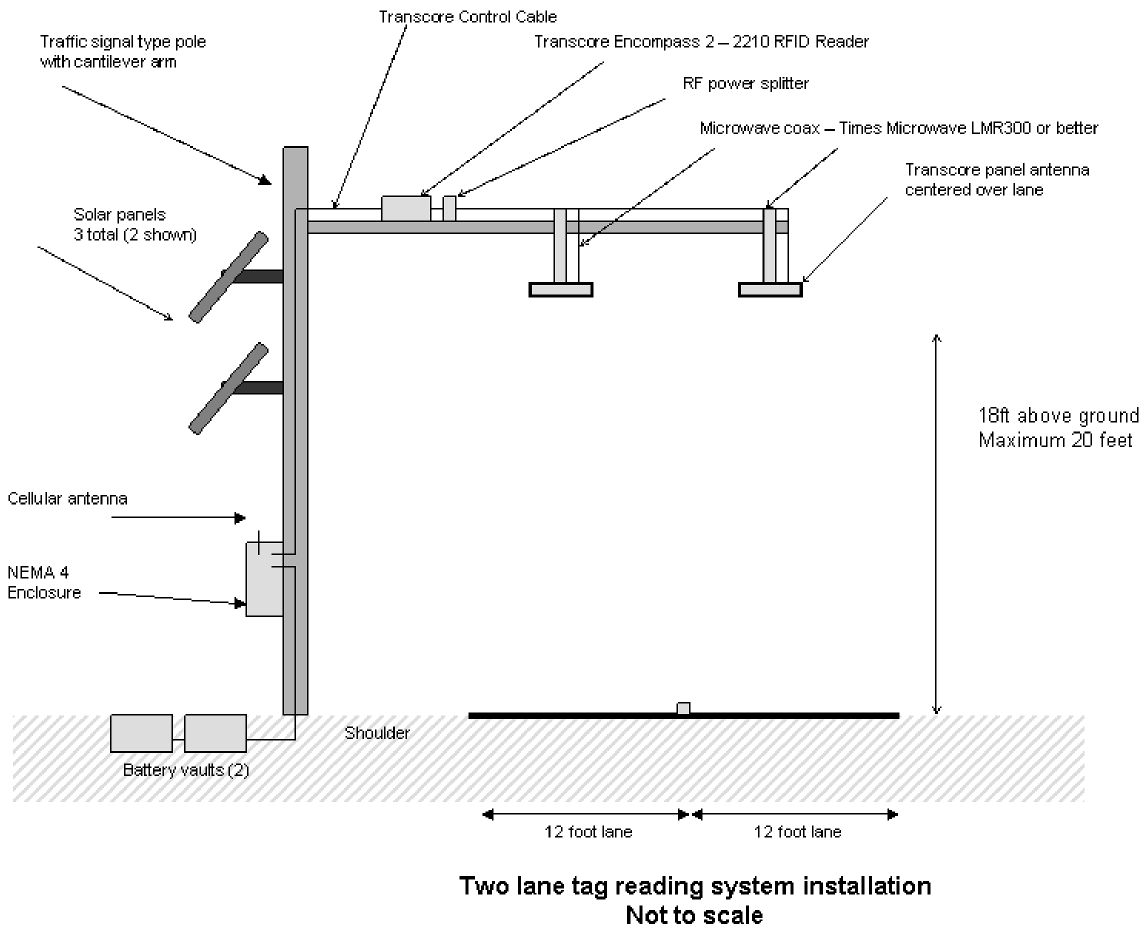

Figure 8. Sample RFID reader station.

Each RFID reader station has an antenna located over each lane at the location. The location of each reader needs to be chosen to limit the number of antennae required for site coverage. The antenna connects with a traditional tolling-quality RFID tag reader 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 is important for the tag to be correctly positioned and under the windshield's 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 reader station's onsite data logging component. The reader's data communication protocol needs to be such that few or no "handshakes" and additional transactions are required during normal operation (tag read mode).

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.

A communication solution needs to be implemented for each field location. The communication setup needs to include data transmission between the RFID reader 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.

The central facility receives data from all RFID reader stations. The raw crossing and wait time data are processed by matching tag identification of individual trucks at the entrance point on the Mexican side and the exit point on the U.S. side. The difference in time stamps yields a single truck's progression as a function of time through the POE. 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 current crossing and wait time data can be made available via Internet and mobile devices.

The central 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 needs to be located in a reasonably secure building with reliable electric service and with personnel available to provide technical support as needed.

Developing Data Dissemination Techniques

The RFID-based border crossing time and wait time measurement system works by reading unique identification numbers assigned to individual transponders. These unique identification numbers can be made anonymous by encrypting them using industry standard algorithms. Encrypting a transponder identification number before it leaves the wireless modem or other transmission devices that sends data to the central subsystem provides the highest level of security. This method also satisfies the need to make the transponder identification number anonymous before sending the data to the central subsystem. To achieve this, either a separate encrypting device has to be installed inside the cabinet or the readers themselves need to have a function to encrypt transponder identification numbers.

If ensuring data security and making the transponder identification anonymous are mandatory requirements, then the system design needs to explore these techniques. Also, appropriate steps need to be taken to safeguard the data once they have reached the central subsystem (server). This includes regular data backups to external media such as compact disks, magnetic tapes, or virtual storage facilities.

As part of the system design, techniques to provide access to raw data, aggregated data, and other charts and graphs to stakeholder agencies and the public need to be included. For example, access to near-real-time crossing and wait time data could be made available to motorists and the public in general through the Internet. Real-time information can be relayed using RSS technology, which essentially provides updated data in an extensible markup language (XML) format. Because of the open nature of the format, Web browsers and standalone applications can easily read the data. External agencies can obtain the information from the RSS site and add to their information Web sites. Similarly, regional traffic management centers or whoever else maintains the RFID-based border crossing time and wait time measurement system can use the RSS feed and display the crossing and wait time information to their field ITS devices.

Preparing a Test and Evaluation Master Plan

A test and evaluation master plan (TEMP) that describes various subsystem level and hardware/software-level tests to be performed to verify the proper operation of the RFID-based border crossing time and wait time measurement system and its components needs to be developed. These tests are intended to establish the high-level working nature of the system and also to test individual system components for specification compliance. Tests need to be performed for each subsystem and its hardware and software components. The TEMP also needs to describe techniques that are to be used to test individual devices and subsystems and the key parameters that are to be used to test against. The TEMP also needs to include how the system as a whole is to be evaluated. These key test and evaluation parameters need to be agreed upon by the stakeholders early on while preparing the concept of operations.

Identifying Operations and Maintenance Tasks

O&M of the system includes tasks required to run the system continuously to accomplish goals and objectives for which it was designed and implemented. O&M of the system needs to include tasks performed (a) daily, such as real-time monitoring of the system and data dissemination; (b) as needed, due to unexpected device failures; and (c) periodically, to repair and replace equipment.

Day-to-day tasks for operating the system include the following:

- Monitoring collection of raw data from RFID field devices and processing, aggregating, and disseminating real-time crossing and wait time data.
- Monitoring information relayed to end users through the Internet.
- Monitoring performance of the system components and troubleshooting critical system failures.

Periodic tasks to operate and maintain the system include the following:

- Repairing, replacing, and upgrading equipment, components, and modules.
- Diagnosing and resolving data inconsistencies and software glitches.
- Responding to requests from the users regarding information such as data accuracy and data query.
- Preparing reports related to information such as performance of the system and summary results.
- Performing preventive tasks such as backing up the data archive.

Maintenance tasks due to unexpected events include the following:

- Repairing and replacing field devices due to extreme weather conditions.
- Recovering archived data in the event of hardware failure and rebooting the system after power failures.

Developing a Business Model

It is important to develop a business model for the operation of the system after the implementation. During the stakeholder input phase of the project, is important to analyze willingness to develop a long-term commitment from 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 it is working properly. The analysis of archived data and report development also requires staff dedicated to these activities.

It seems that the best alternative for the operation of the system is to have an independent third party dedicated to running the system. Some stakeholders from the private sector have expressed their interest in operating the system. However, most of the private-sector stakeholders are interested in one particular POE and not in the overall system. Therefore, a better option is to have a group that has no particular interests and that could independently monitor and further develop the system.

Funding for the operation 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 near-real-time basis, as well as the archived information.

Data usage and access policies and procedures along with cost of data access need to be defined in order to identify the amount of funds that are required to operate and maintain the system. Funding for system expansion is another parameter that needs to be budgeted in the business model.

Evaluation Questionnaire

The implementing agency should prepare a list of questionnaire that should be considered prior to deploying the system and ensure that the system is deployable. A recommended list of evaluation questionnaire is as following:

- Have you collected and documented current state of operation at the border crossings? This includes criteria such as physical layout and operation times.
- Have you collected baseline data, which may include total crossing times for different types of vehicles, shipments, and daily volumes?
- Will the design meet all the requirements of the system?
- Have you estimated the detailed cost of the system and the components?
- Have you prepared a detailed T&E plan? Have the stakeholders agreed to it?
- Has a budget for ongoing operations been defined and funding sources identified?

SYSTEM DEPLOYMENT

Key Steps for Deploying the System

This section describes key steps necessary to deploy the system components. These key steps include procuring the hardware and software components and obtaining necessary permits from local, State, and Federal agencies. Implementing agencies need to plan and allocate enough time to obtain necessary permits from GSA if the RFID station is being installed inside a Federal compound. Also, the agencies need to be cognizant of a process to import hardware into Mexico and the cost associated with it. Key steps prior to designing the system are illustrated in Figure 9.

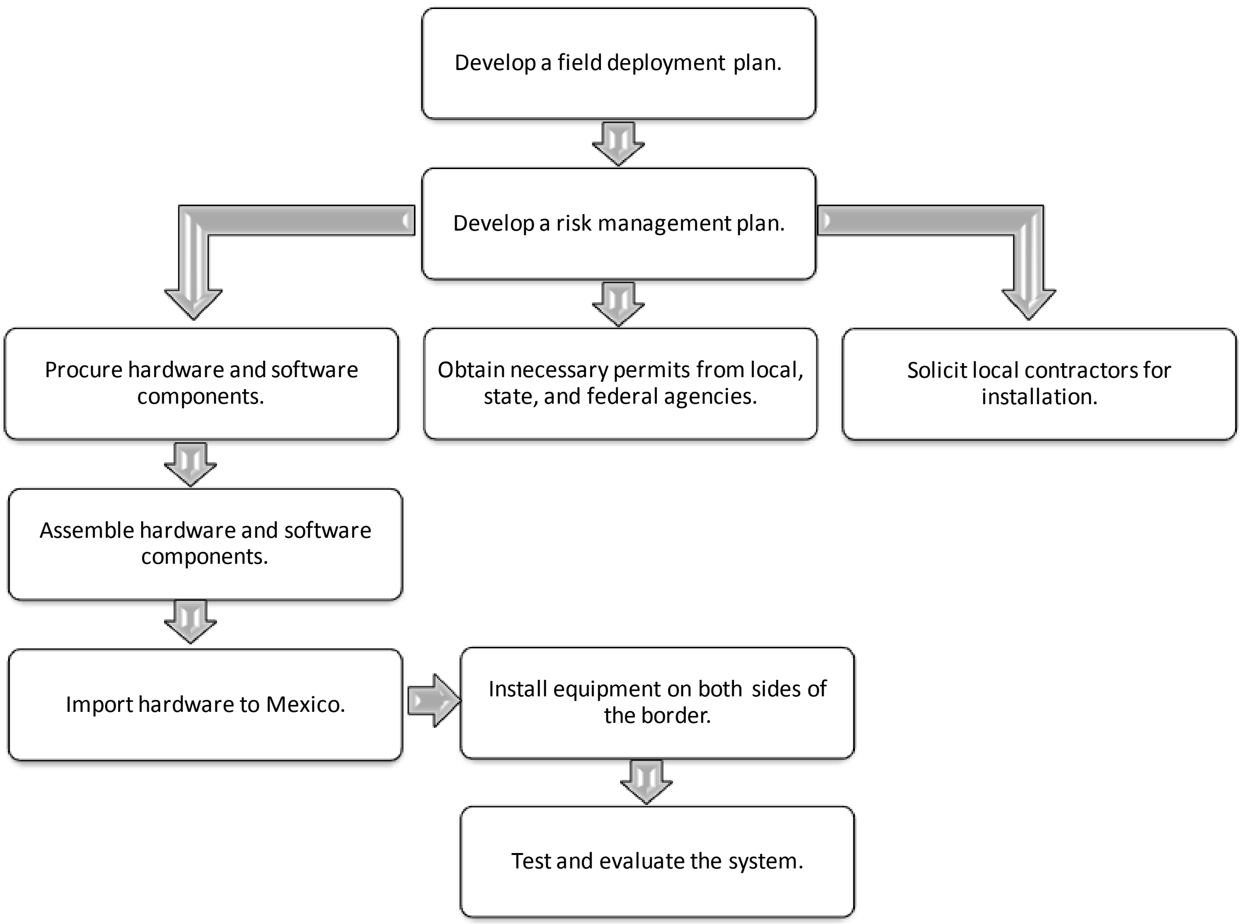

Figure 9. Key steps while deploying the system.

Developing a Field Deployment Plan

The implementation plan is meant to serve as a checklist for the activities that must take place after the detailed design is complete and before the procurement of equipment and software commences. This implementation plan could be amended if the specific characteristics of a POE necessitate it being changed. As noted previously, the implementation plan is not meant to replace the project management process or the systems engineering process.

Developing a Risk Management Plan

In following the project management process, risk management is addressed early in the project. However, risks need to be reevaluated prior to the major steps of equipment procurement and installation. Table 4 shows a sample risk management plan developed for the RFID implementations at BOTA and Pharr, Texas.

Table 4. Project risk, description of impact, and mitigation plans.

Risk Type	Description of Impact	Mitigation Plans
Technology system costs increase significantly.	Unplanned procurement expense.	Check on costs and explore alternate sources if needed.
Integration of data from multiple sources proves to be problematic.	Unplanned labor expense.	Integrate data as realistically as possible during equipment checkout and table-top testing.
Reviews by stakeholder organizations take longer than expected.	Deliverables cannot be presented within their planned period of performance.	Monitor progress of responses from stakeholders. Implement work-around tactics as needed.
Managing numerous stakeholders including two different languages and two different countries proves to be more difficult than expected.	Unplanned management time, delays in agreements.	Work closely with key Federal-level and other influential stakeholders to resolve impasses that may arise.
Running the evaluation takes more resources than envisioned.	Unplanned labor and/or maintenance expense.	Identify and assess any unplanned challenges when discovered.
A real-world event occurs that elevates security at border crossings in a way that affects the technology implementation.	Reaction to the event delays installation due to security concerns or causes more limited data to be collected and key findings to be missed, resulting in non-optimal project recommendations.	Should any such event occur, work closely with FHWA, CBP, and other stakeholders to fully understand the impacts any such event has on the program's technical integrity.
Vandalism takes installed equipment out of commission.	Interruption in data, delayed deliverables, and repair or replacement cost.	Maintain a security plan for the technology implementation, including stakeholder buy-in.

Procuring Equipment

This step may involve getting quotes for system components, which may take a considerable amount of time. If possible, it is recommended to obtain quotes on system components earlier in the project so that time can be saved during this phase of the implementation plan. Receipt of RFID equipment may require 6 to 8 weeks after ordering.

Obtaining Necessary Permits from Stakeholder Agencies

Obtaining necessary permits from stakeholder agencies is a crucial step in moving the project forward toward installation. To obtain permits from the agencies in time without significant delay to the project, it is important that these agencies have favorable views about the project and that they are involved in every step of the project as key stakeholders. Table 5 includes a list of agencies that may have to be contacted to obtain permits, purpose of requesting a permit, conditions the agencies may put forth before granting the permit, and necessary documents requested by the agencies to review the permitting process. There needs to be sufficient lead time built in prior to installing the field devices to obtain necessary permits from these agencies.

It is possible that CBP representatives at a particular POE may require a compatibility test to ensure that the planned RFID implementation does not interfere with CBP's equipment.

Soliciting Local Contractors for Installation

It is highly recommended that a local contractor that has experience with installation of utility poles and mast arms be used. Bringing in outside contractors requires more lead time and resources. Because the system has field devices in both the United States and Mexico, two separate contractors may be required to install the equipment—one on each side of the border. Local contractors from one country generally do not have permissions to go to another to install equipment in the field.

Assembling Equipment

Once the equipment is procured and in hand with the project team, all necessary preassembly can take place. All wiring between the readers, antennae, power sources, and cabinets (each of which need to be described in the final design document) needs to be performed at this point. In-house tests also need to be performed once the equipment is preassembled to ensure individual devices are working properly. This process helps reduce troubleshooting at the site.

An equipment list needs to have been generated in the final design document, and all identified products need to be procured in quantities to build the RFID reader stations with a central server. It is very unlikely that commercial-off-the-shelf (COTS) software is available to process the data inside the central server. Hence, custom application development needs to proceed at this point.

Table 5. Permitting agencies, purpose of permits, conditions for granting permits, and necessary documentation.

Permitting Agency	Purpose of Requesting Permit	Conditions for Granting Necessary Permit	Documents to be Submitted to Obtain Permits
City, County, or State DOT from Both Sides of the Border	To install mast arms and poles on the right-of-way of these agencies.	- The design and construction of utility poles and mast arms needs to satisfy agency specifications. - There are no utilities running underground where the foundation for the pole is to be dug. - Installation of mast arm and antennae on it must not obstruct traffic for too long.	- Exact location of utility poles in relation with the right-of-way. - Detailed design of utility poles and mast arms.
CBP	To allow operation and maintenance of RFID reader stations inside the U.S. Federal compound.	- Installation of the system must not interfere with day-to-day CBP operation (i.e., inspection). - The system must not interfere with any other system deployed by CBP.	- Exact location of utility poles in relation to right-of-way. - Location of antennae and readers in relation to inspection booths. - Detailed design of utility poles and mast arms. - Detailed sketch diagram of readers, antennae, wirings, and so forth. - Compatibility test report, which confirms non-interference (wireless signal) between RFID-based border crossing time and wait time measurement system and CBP systems.
GSA	To install RFID reader station inside the U.S. Federal compound.	- Installation of the system must not interfere with day-to-day CBP operation. - The system must not interfere with any other system deployed by CBP. - GSA seeks input from CBP before providing final approval.	- Exact location of utility poles in relation to right-of-way. - Location of antennae and readers in relation to inspection booths. - Detailed design of utility poles and mast arms. - Detailed sketch diagram of readers, antennas, wirings, and so forth. - Insurance-related documents to cover liabilities. - Completed GSA Form 1583 (see Appendix C for a completed form prepared for Pharr-Reynosa POE).

Importing Equipment to Mexico

Importing the equipment that is to be installed on the Mexican side of the border is a crucial element of the deployment process. Mexican laws require the use of a licensed Mexican customs broker to perform the importation into Mexico. The customs broker requires information on the make and model of the equipment and country of origin certificates in order to define the duties.

The approximate cost of importing the equipment is 15 percent of the total value. This could vary depending on the country of origin of the equipment. One possible option is to declare the sources of some equipment in Mexico, especially those that are also available in Mexico. This has to be verified from the manufacturer or retailer but reduces the cost of importing and the time it takes to prepare the paperwork.

Installing Equipment

Once the equipment is assembled and local contractors are selected by the project team, onsite equipment installation can begin. Acceptance criteria need to be defined and agreed upon with the contractors, and authority to accept the installation should be established beforehand. Warranty terms and conditions need to be clear. It is important to note that while local contractors perform the actual installation work, members of the project team generally need to be present to supervise the work taking place onsite. Since land border crossings have many large vehicles moving about, safety is a key consideration. The project team and the contractors need to meet with the facility operators to discuss onsite safety considerations. Figure 10 shows installation of RFID antennae on a mast arm on the U.S. side of the BOTA crossing.

Figure 10. Installing RFID antennae on a mast arm.

Testing and Evaluating the Installed System

After equipment installation, the tests documented in the T&E plan needs to be conducted. All the tests need to be successful, with no errors found in the way individual components of various subsystems operate.

Results of the tests and any problems completing the tests set forth in the T&E plan need to be documented and addressed at this point. If it becomes evident that the tests outlined in the T&E plan are not being met or exceeded, a process needs to be put in place to address and correct the problems with the system or redefine the key performance parameters if necessary.

The following sections briefly describe individual tests and evaluations recommended to ensure proper function of hardware and software components and the subsystems.

It is up to the implementing agency to decide whether to perform tests at all RFID reader stations or a selected few. If all the RFID reader stations are similar in terms of hardware and software used, it is not recommended to perform the tests at all stations.

Testing Field and Central Subsystems

Tests need to be performed to ensure that individual hardware and software devices are working properly. Also, tests need to be performed to ensure that software applications and communication links are taking place as intended.

Field subsystem tests include testing individual pieces of hardware installed in the field. Individual hardware pieces including RFID readers, antennae, solar power, and devices inside the cabinet have to be tested to ensure they are meeting their intended purpose. Many tests can be performed remotely, but some require actually opening the cabinet and reading display panels of the equipment. Table 6 includes a list of recommended tests to be performed with equipment installed as part of the field subsystem. Tests also depend on the configuration of hardware. For example, if the RFID reader station is being powered by a direct electricity source, then tests related to solar power and batteries are not necessary.

Appendix A includes steps to conduct the tests, parameters to be measured, and expected values (or ranges) to determine whether the hardware, software, and subsystems are functioning properly.

Table 6. Field subsystem tests.

Test	Purpose
Solar Power System Test	Verifies whether battery voltage, solar current, and load current readings are appropriate given the conditions at test time.
24 vDC Power System Test	Verifies whether a proper voltage is applied to the RFID reader and programmable relay with both units connected and drawing power.
Tag Read Test	Verifies whether the RFID readers can recover an identification ID from the RFID tags used by the vehicles (i.e., read the tag).
Tag Reading Reliability Test	Verifies RFID reader's ability to read at least 85% of the readable tags on trucks in lanes within the RFID unit's coverage zone.
System Latency Test	Shows that all components that make up the field subsystem, once turned on, properly function together.
Data Logger Test	Verifies that the data logger in the RFID reader station can time stamp incoming tag reads from the RFID unit and locally store a copy of each tag read.
Wireless Signal Strength Test	Verifies sufficiency of cellular wireless signal strength.
Static IP Address Test	Verifies that the RFID reader station has a static (non-changing) IP address so the station can be found on the wireless network.
RFID Reader Station Communication Accessibility Test	Tests wireless router to ensure it can be accessed over the cellular wireless infrastructure.
RFID Reader Station Auto-Power Cycle Test	Tests the reader station's ability to sense the loss of communication to the wireless network.
RFID Reader Shutdown Test	Tests whether the RFID reader can be automatically connected and disconnected to conserve power.

Central subsystem tests include testing to ensure wireless data transfer between the RFID reader station and the central computer, retrieval of data from a data logger remotely, and ability of the software application that resides inside the central computer to retrieve data from the data loggers inside the RFID reader station. Table 7 includes a list of recommended tests to be performed with equipment and software applications that are part of the central subsystem.

Table 7. Central subsystem test.

Test	Purpose
Wireless Data Transfer Test	The wireless router moves data from the output of the data logger (in pass-through mode) to a software application located at a central location. This test is designed to ensure that the data link between the logger and the central computer.
Remote Data Retrieval Test	The data logger can be accessed via the wireless network and Internet to retrieve data if a long-term communication outage has occurred. This test ensures that data can be retrieved from the data logger remotely.
Data Retrieval Application Test	RFID readers transmit the data through a wireless data modem to a central computer. A core application in the central computer retrieves data from data loggers at a predetermined time interval. This test is designed to ensure that the application does not fail completely in the event one or more RFID readers fail.

Evaluating the System

The most important system test that must take place in order to assess the functionality and accuracy of the system is the system evaluation. Two key performance parameters are recommended in order to ensure the system accurately collects border crossing and wait times of trucks. These key performance parameters are:

- **Tag Read Time Stamp Accuracy:** RFID readers send identification number of tags to a central server, which assigns a time stamp to each read. There are other RFID readers available on the market that assign a time stamp and send the data to a central server packaged with the identification of tags. In this case, there is no need for a central server to assign a time stamp. In any case, internal clocks of both RFID readers and the central server must be the same most of the time. These two times must be within 1 minute of each other 95 percent of the time in order to ensure the accuracy of the system. If there is a significant time delay between the RFID reader station and the central server, the time stamps of transponders will not be consistent. Thus, time difference between the readers and central processing system needs to be detected by pinging the router and recording the time delay (time required to send the data from the readers to the central server).

- **Accuracy of Crossing and Wait Times:** A side-by-side comparison of crossing and wait time measured by the RFID-based border crossing time and wait time measurement system and the ones measured in the field (or baseline data) needs to be performed to evaluate the system. The difference between crossing and wait times collected by the RFID and the baseline data needs to be within 3 minutes of each other 85 percent of the time to guarantee the RFID-based border crossing time and wait time measurement system's accuracy. There are several techniques by which baseline crossing and wait time data can be collected in the field. These techniques along with their pros and cons are described in Table 8.

The system evaluation may also consist of determining the ability of RFID readers to read a significant number of tags carried by the trucks crossing the border. Total tags read by the RFID readers can be compared with the total number of tags collected in the field by visually counting the tags carried by the trucks. However, as a word of caution, it is very difficult to accurately count the number of tags visually, since trucks carry many decals that appear to look like tags. Also, there is no way to confirm if the tag carried by a truck is active.

Appendix B includes steps to conduct an evaluation of the system and expected values (or ranges) to determine whether the system is accurately functioning.

Table 8. Techniques to collect baseline crossing time or wait time data in the field.

Technique	Pros	Cons
Recording video of trucks passing the RFID reader stations and manually re-identifying the license plate numbers.	Allows repeated post-processing of crossing and wait time data. Allows collection of other data such as volume, flow, type of trucks (with and without trailer) without requiring additional field personnel.	May be perceived negatively by truckers due to their movement being video-taped. Needs additional time and resources to obtain crossing and wait time data.
Manually collecting license plate numbers of trucks passing the RFID reader stations and re-identifying the license plate numbers.	Needs less time and resources to obtain crossing and wait time data.	May be perceived negatively by truckers due to their movement being recorded.
Collecting location and time data from trucks installed with GPS devices.	Provides much finer location data of trucks than any other method.	Needs active participation by trucking companies, which may not be easy. Restricts sample size of trucks to the number of trucks fitted with GPS devices. Requires development of software application to obtain crossing and wait time data from the GPS data.
Using travel logs archived by carriers and shippers.	Eliminates the need for deploying surveyors in the field or purchasing GPS devices or GPS data from trucking companies.	Needs active participation by trucking companies, which may not be easy. Restricts sample size of trucks to the number of trucking companies agreeing to provide the log data.

Monitoring and Troubleshooting the System

The system needs to be constantly monitored for proper operation using mechanisms that monitor the system at different time intervals. The system needs to be monitored to make sure all three subsystems are functioning properly and that communication between the subsystems is intact. System monitoring needs to be performed at predefined schedules and after special events such as extreme weather.

Monitoring of the system at predefined time intervals needs to be performed using a software application that checks for validity of the data stream and communication between subsystems and hardware devices. Automated monitoring using the software application can identify problems associated with communication failure due to hardware malfunction, inadequate wireless signal strength, or power failures. This application then needs to log all activities related to system checks and notify the system administrator immediately via e-mail or text message.

For example, an automated monitoring of systems in Pharr and El Paso is performed using a software application that runs periodically inside the central subsystem server. The software checks the status of communication between subsystems every 30 minutes. The software is pre-coded with bridge closing times. The software checks whether there have been any tags read in the last 30 minutes for each RFID station in the database; if so, then it is logged as a success. If the program does not find any tags when the bridge is supposed to be open, then the software performs a series of communication checks (e.g., by pinging the modem). If the software detects that the field subsystem is not online and/or if there are not enough tags being read, then an administrator is notified immediately via e-mail. The system design allows remote booting of the field devices, which may succeed in bringing the field devices online.

If power for the field devices or readers is being supplied by solar power, it is crucial to monitor the amount of electric charge the batteries are holding throughout the day. A software application cannot read the amount of charge the batteries are holding. One way to find out whether the system is getting enough power without actually visiting the field site is by analyzing the tag count. If there is not enough charge throughout the day, a graph of the number of tags read by the readers against the time of day needs to be created for several days, and trends need to be analyzed against the traffic pattern. If there is an inadequate power source, the number of tag counts might decrease significantly during evening hours, which might be contrary to the fact that large numbers of trucks are still crossing in the evening. In that case, voltage readings need to be confirmed by visiting the field site and reading the voltage off the battery controller.

It is also important to monitor the system after major weather events. Utility poles and mast arms are especially vulnerable to windy conditions. Readers, antennae, and communication devices are also vulnerable to extreme cold and hot temperatures. Flooding for a sustained period can damage batteries stored in an underground vault. The automated system can be programmed to monitor proper function of the system when extreme cold and hot temperatures are recorded by nearby weather stations, information that is released by the National Oceanic and Atmospheric Administration.

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APPENDIX A FIELD AND CENTRAL SUBSYSTEM TESTS

Field Subsystem Tests

Parameters Tested	Units	Expected Range (Value)
Solar Power System		
Date	-	-
Time of day	-	-
Sky conditions	-	-
Battery voltage (using charge controller meter for all readings in this section)	vDC	11.5-14
Solar charging current (panels illuminated in direct sun)	Amps	8-19
Load current	Amps	Less than 2.5
24 vDC Power System		
Power converter output voltage under expected load (reader)	vDC	24 (+/- 0.5)
Border Crossing Tag Read		
DPS tags read from test vehicle	Yes/No	Yes
Tag Reading Reliability		
Number of tags read from a 50 truck sample with readable tags	Reads	> 85%
System Latency		
Time required for RFID devices to become operational after turning the system off and on	Minutes	< 5
Data Logger		
Verify logger data light-emitting diode (LED) light flashes with a tag read	Yes/No	Yes
Verify logger passes data from the reader to a personal computer (PC) connected to the logger's configuration port	Yes/No	Yes
Extract sample data from logger memory card showing tag ID and proper time stamp	Samples	Yes

Note: "-"means data was not collected.

Central Subsystem Tests

Parameters Tested	Units	Expected Range (Value)
Wireless Signal Strength		
Once the router has been powered up and reaches a steady state, access the router's internal management Web pages and record the cellular signal strength.	dBm	Greater than -90
Static IP Address		
Cycle power, access the router via the local area network (LAN) side upon boot up, record the wide area network (WAN) side IP, and then wait 10 minutes.	IP Address	The same static IP needs to be read in each repetition.
Cycle power, access the router via the LAN side upon boot up, record the WAN side IP, and then wait 10 minutes.	IP Address	
Cycle power, access the router via the LAN side upon boot up, and record the WAN side IP.	IP Address	
Reader Station Communication Accessibility		
Record whether the router Web interface was accessible via the Internet.	Yes/No	Yes
Reader Station Auto-Power Cycle		
Confirm that the iBoot cycles the power on the router after the scheduled timeout period.	Yes/No	Yes
RFID Reader Shutdown		
Alter the real-time clock from the programmable relayer minutes before programmed shutoff is to occur.	Yes/No	Yes
Verify system has shut down.	Yes/No	Yes
Alter the real-time clock from the programmable relayer minutes before programmed startup occurs.	Yes/No	Yes
Verify system started up.	Yes/No	Yes
Wireless Data Transfer		
Confirm tag reads are immediately sent to the central system software from the field site.	Yes/No	Yes
Remote Data Retrieval		
Download data from the data logger.	Samples	Some sample data
Data Retrieval Application		
Test for resiliency of the application in the central subsystem.	Yes/No	Yes

APPENDIX B SYSTEM EVALUATION TESTS

System Evaluation Tests

Parameters Tested	Units	Expected Range (Value)
Tag Read Time Stamp Accuracy		
Determine the time difference between the readers and central processing system by pinging the router and recording the time delay (time required to send the data from the readers to the central server).	Milliseconds	Less than 60 seconds (1 minute)
Accuracy of Crossing and Wait Times		
Compare the total number of tags read by RFID system to total tags observed in the field (optional).	% of total readable tags	> 85%
Compare the difference in crossing and wait times of trucks using field measurements and the RFID system.	Minutes	If using GPS method to collect baseline data, difference between crossing/wait times obtained by RFID and GPS, for which the truck has both technologies, needs to be within 3 minutes for 85% of total trucks equipped with GPS and RFID tags.

APPENDIX C GSA FORM 1583 AND AMPLIFYING INFORMATION

GSA Form 1583

PERMIT FOR USE OF REAL PROPERTY BY FEDERAL AGENCY	1. PERMIT NUMBER

Permission, revocable at the will of the General Services Administration, is hereby granted the Permittee hereinafter named to use the property described below for the purpose designated, subject to the conditions, special and general, herein prescribed.

2. NAME OF PERMITTEE AGENCY	3. LOCAL REPRESENTATIVE *(Name and address)*
Federal Highway Administration	

4. PROJECT DESIGNATION AND ADDRESS	5. MAXIMUM PERIOD COVERED
Customs and Border Protection (CBP) primary cargo inspection booths at the Bridge of the Americas (BOTA) in El Paso, TX and Pharr-Reynosa International Bridge in Pharr, TX	A. FROM 02/01/2011 B. TO 01/07/2011

6. DESCRIPTION OF PROPERTY AFFECTED

(As shown on Exhibit 1 *, attached hereto and made a part hereof.)*

Radio Frequency Identification (RFID) reader system hardware will be installed at each of the northbound cargo lanes of the two land ports of entry (BOTA and Pharr) as shown in Exhibit 1

7. PURPOSE OF PERMIT

The permit is to install the equipment described in # 6 and to maintain the equipment that reads RFID tags that trucks already have attached to the windshield.

8. By the acceptance of this permit, the Permittee agrees to abide and be bound by the following conditions:

I. SPECIAL CONDITIONS

PERMIT FOR TEMPORARY CONSTRUCTION PURPOSES

A. Contractor Insurance. Each of Permitee's construction contractors who perform any work on the property shall obtain and maintain insurance policies which meet or exceed the following insurance terms, conditions, requirements and coverages. During the Term of this Permit, including renewals, if any, each of the Permitee's contractors shall obtain and maintain liability insurance in an amount of not less than $1,000,000.00 combined single limit for accidents or occurrences which cause bodily injury, death or property damage to any member of the public caused by or related to the construction, installation, operation, maintenance replacement, removal or other activity related to the property. The insurance policy shall name the General Services Administration, its employees and officials, as their interest may appear, as additional insureds. Any cancellation provision must provide that if the policy is canceled prior to the expiration date of the Permit, materially changed or not renewed, the issuing company will mail thirty (30) days written notice to the General Services Administration, Attention: Contracting Officer, Property Development Division (7PD), 819 Taylor Street, Fort Worth, Texas 76102.

B. Damages and Indemnity. The Permitee shall repair or pay for all actual damages done to the GSA Property and improvements, or to the improvements of the GSA's tenants caused by Permitee's Operations pursuant to any liability determined under the Federal tort Claims Act (28 U.S.C. §§2671 et seq.). Permitee agrees that is will be responsible for damages arising from personal injury or damage to persons or tangible property to the extent they result from Permitee's operations under this permit if liable under the Federal Tort Claims Act.

Permitee agrees to defend and remain responsible (financially and otherwise) for all claims, disputes, appeals and other legal actions arising out of actions of Permitee's personnel, contractors and other agents if liable under the Federal Tort Claims Act.

The liability of the Permitee shall be subject in all cases to the immunities and limitations set out in the Federal Tort Claims Act (28 U.S.C. 2671, et seq.) and shall be subject to available appropriations.

GENERAL SERVICES ADMINISTRATION **GSA** FORM **1583** (REV. 9-98)

C. Personal Injury or Personal Property Claims. The Permitee acknowledges that GSA will have not responsibility or liability, either directly or indirectly for any personal injury, and/or personal property damage claims against the Government that arise out of or relate to the performance of the work at the Facility under the terms of this permit. Permittee will be the lead federal agency responsible for the administrative handling of any tort claim(s) filed pursuant to the Federal Tort Claims Act.

D. Pre design and construction site surveys will be completed with GSA and local Permitee's Representatives

E. Preliminary construction documents will be furnished to GSA for Review.

F. Final signed and sealed construction documents will be furnished to GSA for review.

G. Construction schedules will be furnished to GSA and updated as milestones change.

H. Final Inspection notes and acceptance documents will be furnished to GSA.

I. Any work that does not meet applicable local and federal codes and/or does not meet GSA standards must be corrected.

J. Permitee is responsible for any interruption of services and must take corrective action immediately. GSA is to be notified if any service is interrupted.

K. Any damage to the existing site caused by the contractor is the responsibility of the Permitee to correct immediately pursuant to the immunities and limitations of the Federal Tort Claims Act. GSA must be notified of the damage and provided with a written plan of correction if Permitee is required to do so pursuant to liability under the Federal Tort Claims Act.

L. All work performed must conform to all applicable local, state and federal codes.

11. GENERAL CONDITIONS

a. The use and occupancy of the property shall be without cost or expense to the General Services Administration, and under the general supervision of the Regional Administrator, General Services Administration, or his/her authorized representative, and subject to such rules and regulations as he/she may prescribe from time to time.

b. The permittee shall at its own expense and without cost or expense to the General Services Administration, maintain and keep the property in good repair and condition.

c. The use to be made of the property shall be limited to that specified in this permit.

d. The permittee shall pay the cost, as determined by the Regional Administrator, General Services Administration, or his/her authorized representative, of producing and/or supplying any utilities and other services furnished by the General Services Administration for use of the permittee.

e. No additional to or alterations of the property shall be made without the prior consent of the Regional Administrator, General Services Administration, or his/her authorized representative.

f. On or before the date of expiration or termination of this permit, the permittee shall vacate the premises, remove its property therefrom and restore the premises to a condition satisfactory to the General Services Administration. If however, this permit is revoked, the permittee shall vacate the premises, remove its property therefrom and restore the premises as aforesaid within such time as the General Services Administration may designate.

DATED *(Day, Month, Year)*	DATED *(Day, Month, Year)*
BY *(Signature)*	BY *(Signature)*
NAME OF SIGNER	NAME OF SIGNER
TITLE	TITLE

GSA FORM **1583** (REV. 9-98) **BACK**

Amplifying Information for Submission of GSA Form 1583: Permit for Use of Real Property by Use of Government Agency for RFID System Installation at CBP Primary Inspection Booths at the Bridge of the Americas and Pharr-Reynosa Ports of Entry

(*Date*)

1. Description of the Border Wait Time Measurement System and why it is important.

The proposed installation of automatic vehicle identification systems using radio frequency identification (RFID) tag reader equipment will enable automated measurement of wait time for northbound commercial vehicles, both at the Bridge of the Americas (BOTA) and Pharr-Reynosa land Ports of Entry (POEs) between Texas and Mexico. Wait time is defined as “the time it takes, in minutes, for a vehicle to reach the U.S. Customs & Border Protection (CBP) Primary Inspection booth after arriving at the end of the queue.” Wait time is a travel time component that is of particular importance to CBP as a metric of border flow. Knowing the accurate wait time helps CBP make informed decisions about how many Primary Inspection booths need to be manned.

USDOT and CBP collaboration resulted in an agreement to conduct a limited initial installation of readers at CBP Primary Inspection booths at the BOTA and Pharr-Reynosa POEs. Wait time implementation at both POEs will capitalize on equipment and capability that is already in place to automatically measure crossing time of northbound commercial vehicles. Crossing time is a travel time component that is of particular importance to FHWA as a metric of border flow. The general concept of the current RFID crossing time measurement system is that during its trip across the border at the POE, a northbound truck passes two RFID tag reader stations, one on each side of the border. Their antennae are mounted above lanes in the roadway. Each tag reader detects the truck’s RFID tag identification (ID) number and time-stamps and records its ID with the location of the detection. Tags of several types compatible with this system are carried in the vast majority of trucks crossing at BOTA and Pharr.

The initial RFID reader station is located at a site that is at the “upstream” end of the queue of northbound 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 is slightly upstream from the end of the historical queue that will develop on the majority of days on the Mexican side of the border. At the BOTA and Pharr POEs, that site is outside of a government compound. The second RFID reader station used for crossing time measurement is located at a site at or close to the point at which trucks exit from the gate of the final compound associated with commercial vehicle crossings. At the BOTA and Pharr POEs, that final compound is the Border Safety Inspection Facility (BSIF) that is operated by the Texas Department of Public Safety.

[NOTE: the Pharr border crossing currently has two more RFID reader stations than BOTA, developed in response to requests by the sponsor to provide more travel time detail. These additional readers were installed at locations to mark when a truck exits Mexico and just prior to arriving at the CBP Primary Inspection facility. Project sponsors want to capture the total wait time (including DPS inspection), thus the reader site requirement for the Pharr border crossing is for stations at the Mexico queue, CBP Primary Inspection, and the DPS exit. Consequently, one of the current Pharr RFID reader stations (at the end of the Rio Grande bridge on the U.S. side) may be relocated to fill a need at BOTA, since the reader to be installed at the downstream Pharr CBP Primary Inspection will give a more accurate wait time measurement.]

The proposed installation would segment the crossing at both POEs to allow measurement of wait time, by adding an additional reader station at the CBP Primary Inspection facility. The algorithm that currently measures crossing time between the current two reader stations (i.e., at the head of the queue and departing BSIF) at each of the subject POEs will be modified to also measure the commercial vehicle's wait time (i.e., travel time from the head of the queue to reaching a Primary Inspection booth). The average wait time that is calculated will be shared with CBP. Without this scientifically measured information, wait times will only be anecdotal and thus imprecise.

2. Environment and conditions that must exist for the installation to be successful, and options – if any – that will enable accurate border wait time measurement other than installing on GSA property.

The equipment will be installed above the point where trucks depart the six Primary Inspection booths at each POE. Thus, the installation should take place either when the POE is closed to northbound commercial vehicle traffic or is experiencing low demand when lanes can remain closed. BOTA operates from 6:00 AM to 6:00 PM (Mountain Time) Monday through Friday and from 6:00 AM to 2:00 PM on Saturdays. BOTA is closed all day Sunday. The Pharr-Reynosa International Bridge Cargo Operations operates from 7:00 AM to 10:00 PM (Central Time) Monday through Friday and from 8:00 AM to 4:00 PM Saturdays and Sundays. The selected installation contractor has stated that he can conduct the installations on weekends. Since the Pharr POE is not closed Sundays, it is possible that certain lanes that are not open for the lower weekend traffic can be selectively instrumented.

In-depth analysis has been conducted by FHWA to determine the types of technology systems that are appropriate for automated travel time measurement at land border crossings. Only two types of current technology systems were considered viable and have been implemented for this purpose: AVI using RFID and GPS. RFID was considered best for measuring crossing times at Texas POEs, which resulted in the BOTA and Pharr implementations. The proposed RFID equipment installation to enable wait time capitalizes on existing RFID equipment and thus is the technology of choice both for BOTA and Pharr. Thus installation is required, and it must be located at the Primary Inspection booths to fulfill the goal of accurate wait time measurement. In fact, since the proposed system detects trucks as they leave the inspection booths, it is suggested that the wait time algorithm subtract the average time trucks spend in processing at the booths to have the most accurate average wait time.

3. Explanation of how the system will be operated and maintained and how any deficiency that occurs between installation and removal/completion will be addressed. Identification of any known threats or risk in this area that might happen, how they will be mitigated, and whether any safeguards are needed.

The RFID tag detection system is a self-contained independent system. The system will continually scan the area under the antenna and send any detected tag data to a Border Crossing Time central receiving application in El Paso, TX. There are no local users and no operators. The system uses open road tolling technology that is specifically manufactured for unmanned outdoor operation.

There is no programmed maintenance needed for the equipment (i.e., no devices that need scheduled local attention). In the event of system failure, maintenance will be coordinated with CBP by (*performing organization*). A representative of (*performing organization*) will travel to the location to perform repairs. Any activity planned onsite will be coordinated with GSA and CBP prior to staff arrival. Maintenance personnel will check with CBP upon arrival at the facility and provide a briefing on their task.

If the system were not working at all it would not affect the normal operation of the POE. The system in operation is innocuous. A compatibility test was run at the Pharr POE to determine whether there was interference with CBP systems, and there was no interference noted for the intended configuration. The nominal 915 MHz frequency of the RFID system can be remotely adjusted within narrow limits to improve performance. The system uses very little electricity. It will be programmed to turn off automatically at times when the POE is not in operation (primarily to save on wireless airtime costs). If the system is degraded or fails, there will be alert criteria that notify operators of the condition. Since the proposed system is not critical to port operations, a visit by a technician to repair or replace a failed component can simply be coordinated to occur during a time when the POE is not in operation.

There are no known threats or risks involving this technology system. RFID is a very familiar technology at the BOTA and Pharr POEs, and the sight of new reader stations should not arouse suspicion or animosity. For example, the BOTA RFID reader station at the head of the queue is located well back from the Mexican Export Lot. It includes pole, mast, solar power panel, battery platform and locked cabinets. It has not been subjected to any vandalism or other damage in the more than 18 months it has been in operation. Since the proposed system will be at the Primary Inspection booths, the risk of intentional damage is essentially nil.

4. Diagram with full description of all major components, operating frequencies, etc. with discussion of the appropriateness of the frequency for this use.

Major system components onsite include the following:

- RFID reader – Outdoor mounted unit containing all the electronics to interrogate passing windshield RFID tags and return tag data in a computer readable form. The RFID readers use the unlicensed ISM (Industrial, Scientific, and Medical) radio spectrum between 902MHz and 928MHz. The readers are compliant with the requirements of CFR Title 47, Part 15, which is part of the Federal Communications Commission rules and regulations that apply to unlicensed transmissions.

- RFID reader antenna – Rectangular panel type antenna (902-928MHz unlicensed ISM band) mounted over the booth travel lane and used to direct the radio signal from the reader onto the windshield area.
- Cellular wireless router – Receives tag data from the RFID reader as a serial stream and transmits these data to the central office application (El Paso) using a cellular wireless data connection.

Exhibit 1 shows the Primary Installation Diagram.

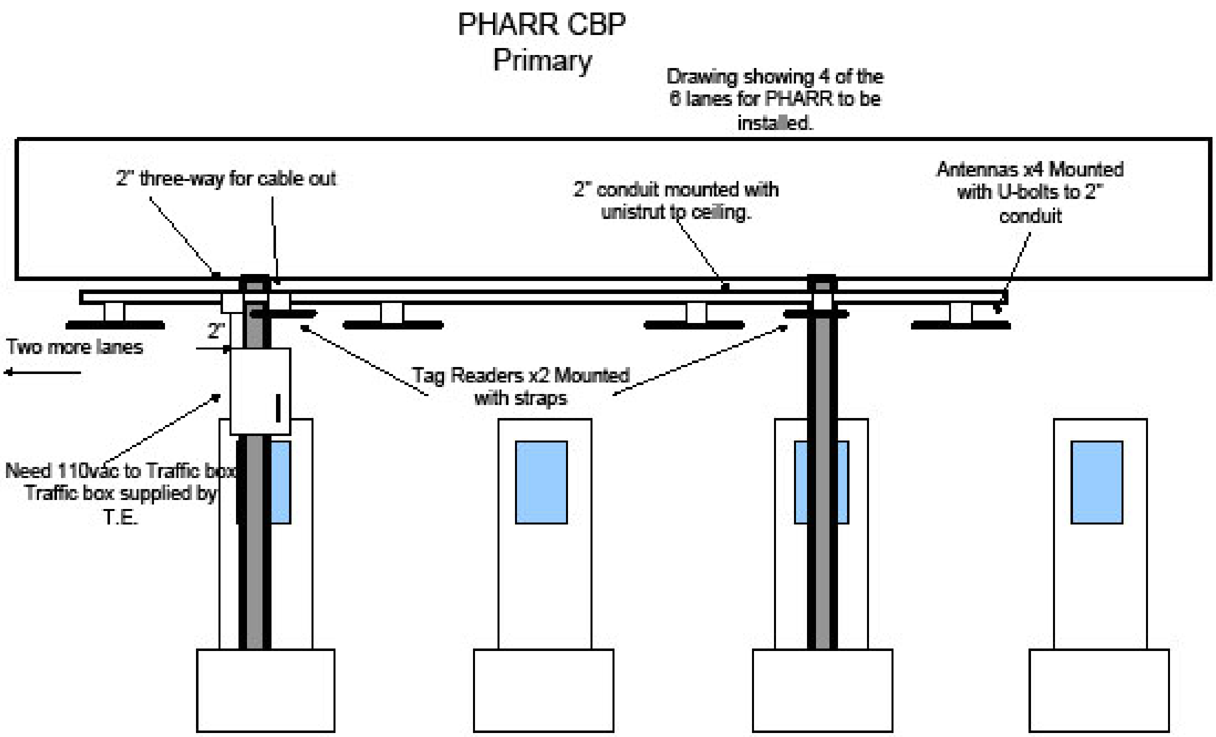

Exhibit 1. Primary Installation Diagram

Exhibit 2 shows a visualization of the installation.

Exhibit 2. Installation Visualization

Exhibit 3 shows a representative electronics cabinet.

Exhibit 3. Representative Electronics Cabinet

5. Contractor personnel who will be involved in the installation, their roles, and the frequency and nature of their activities during installation.

(*Person's and organization's name removed*) will be the lead installation technician and (*person's name removed*) will be the (*organization's name removed*) representative onsite during installation and test. (*Person's name removed*) will oversee (*person's name removed*) and insure that the installation is conducted as planned and presented to CBP.

Their contact information is:

- (*Information removed:* n*ame, organization, phone number, e-mail address*)

6. Constraints and Assumptions.

Constraints

- GSA and CBP approval of proposed installation and schedule (assume December).
- Equipment ordered and received (approximately two months lead time involved)
- Contractor availability for installation during a weekend or Mexican holiday when a POE is closed
- CBP authorization for the installation contractor and project personnel to be onsite
- Availability of standard 115V electrical power

Assumptions

- The subject installation has the support of CBP and USDOT for both BOTA and Pharr POEs
- CBP will have access to the wait time data measured at BOTA and Pharr, both real-time and archived data
- A plentiful supply of RFID tags compatible with the system to be installed is already carried by vehicles owned by Mexican carrier fleets that cross at the POEs
- Use of GSA facilities will be on a no-cost basis (i.e., no utility costs or rent).
- CBP personnel at BOTA and Pharr will provide all safety briefings necessary for team personnel while onsite at their respective facilities.
- Removal or continuation of equipment will be separately discussed at a scheduled point.
- CBP will notify project contacts if any known physical, operational, or perceptional problems with the equipment on its premises are discovered.
- Some type of separate data collection and measurement (i.e., manual collection or comparison with another technology) may be necessary to verify the results of the automated wait time measurement system.

7. **Comprehensive schedule, including opportunity for GSA Program Managers to inspect and approve the installation configuration and a decision point for continued operation and maintenance.**

Exhibit 4 is the Proposed Schedule.

Activity	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11
Submit GSA Permit													
Obtain Authorization to Install Equipment													
Order Equipment													
Assemble and Test Equipment													
Installation at Pharr and BOTA*													
Test and Evaluation													
Border Crossing and Wait Time Reading													
GSA Inspect Installation Configuration													
FHWA & CBP decides continue operation or removal													

* Installation will be performed over the weekend
and each site a week apart

Note: Blue arrows represent milestones for deliverables

Exhibit 4. Proposed Schedule

8. **Points of contacts for all major activities described in the SOW.**

- (*Information removed: name, role, organization, phone number, e-mail address*)

U.S. Department of Transportation
Federal Highway Administration
Office of Operations
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" (866) 367-7487
Fax: 202-366-3225

http://www.ops.fhwa.dot.gov

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FHWA-HOP-12-016

U.S. Department of Transportation
Federal Highway Administration