

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

Task 1 Report Preliminary Design Document

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Background

FHWA seeks to identify appropriate ITS or other commercial technologies that enable border travel delay and crossing times to be more easily and precisely measured. FHWA awarded the *Measuring Border Delay and Crossing Times at the U.S./Mexico Border* project to the Battelle/TTI team in September, 2006. This project consists of two phases; Phase 1 involved an analysis of technologies that could support the installation of a border crossing time measurement system, while Phase 2, which is currently taking place, involves the selection of a technology and the actual implementation of the system. Phase 1 of this project conducted an assessment of technologies that could be used to automate measurement of border delay and crossing times, and the two most promising technologies were determined to be radio frequency identification (RFID) and Global Positioning System (GPS) based locating. During Phase 2 of this project, results of Phase 1 were presented at a stakeholder meeting on February 20, 2008, and it was determined that for this project an RFID system will be the technology implemented and the Bridge of the Americas (BOTA) at El Paso, Texas / Ciudad Juarez, Mexico will be the port of entry (POE) at which the RFID pilot test will occur. The BOTA crosses the Rio Grande River, which marks the international border between the United States and Mexico. This project constitutes an effort that builds on results of the Phase 1 work conducted by TTI as well as on FHWA-supplied information on other border crossing technology implementations.

Goals / Objectives

The specific area of interest for this project is measuring border delay and crossing times for freight traffic inbound to the U.S. from Mexico and providing the information in near real-time to regional transportation agencies for dissemination to the public. Although northbound freight traffic volume data are gathered at BOTA by both Customs and Border Protection (CBP) and the City of El Paso, Texas, there is currently no systematic approach in place for measuring border delays and crossing times. Crossing time estimates at BOTA are obtained by surveying drivers on how long it took them to cross together with unaided visual observations of how long the queue is.

Being able to accurately and automatically determine crossing times will result in better immediate information with which stakeholders can take steps to help improve transportation flow or to conduct more effective routing of assets for higher logistics efficiencies. The results from the planned implementation and test of the RFID system may have a secondary role of informing certain public stakeholders who may use the information in order to help make decisions on capital investments aimed at improving commerce at ports of entry. When this system is installed, the support requirements are expected to be very limited. Also, the system is intended to be operationally transparent to the border travel process, so any institutional, operational, and acceptance risks should result more from technical interfaces than from border crossing operational processes, which will not change.

Overview of Radio Frequency Identification (RFID)

RFID is a reliable, commercially-available technology that is being used in many applications to track the movement of shipments. An RFID system typically consists of four main components: tags, an encoder, readers and a central processing unit. An RFID system operates by transmitting

data using radio waves for communication between a tag and a reader, and also communication to a data base. An RFID tag is a device used for the purpose of identification using radio waves.

RFID tags come in three general types: passive, active, or semi-passive (also known as battery-assisted). Semi-passive and active tags require a power source, usually a small battery. Passive tags are the type planned for the BOTA implementation. Passive tags require no internal power source; they are only active when a reader is nearby to power them. The small amount of electrical current induced in the antenna by the incoming radio frequency signal provides just enough power for an integrated circuit in the tag to power up and transmit a response.

The RFID tags planned will have a practical read distance of a few feet within line of sight of the tag reader. The basic response of a passive RFID tag is an ID number. Passive RFID tags are a simple design, and since they lack an onboard power supply they can be conveniently small and inexpensive.

Layout and Operation of BOTA

Figure 1 shows the layout of the BOTA POE crossing geometry.

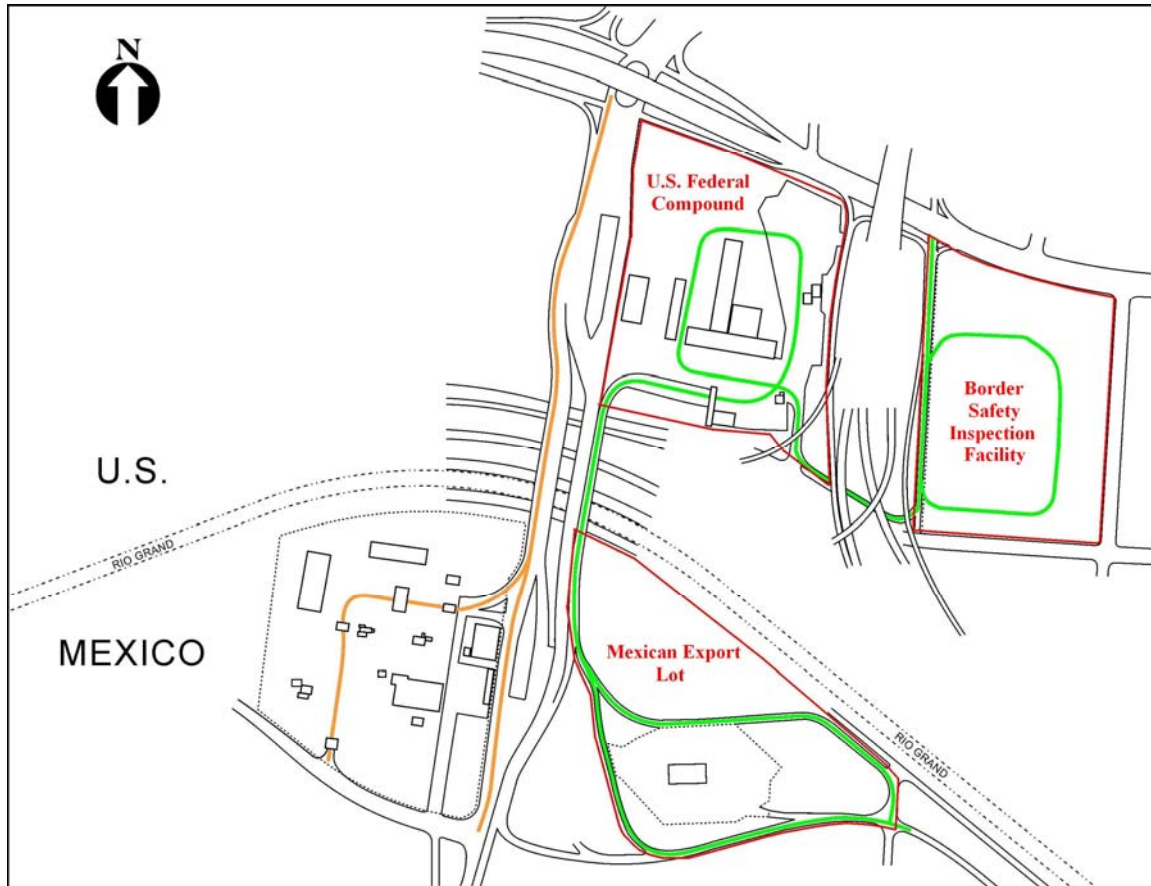


Figure 1: BOTA Layout

A full description of BOTA operations, as well as the northbound border crossing process can be found in the Task 1.5 Report (Current State Analysis). Building off of the Current State

Analysis, the project team has designed a system that uses RFID technology to quantify northbound border crossing times at BOTA. The basic design of this system is illustrated in Figure 2 below.

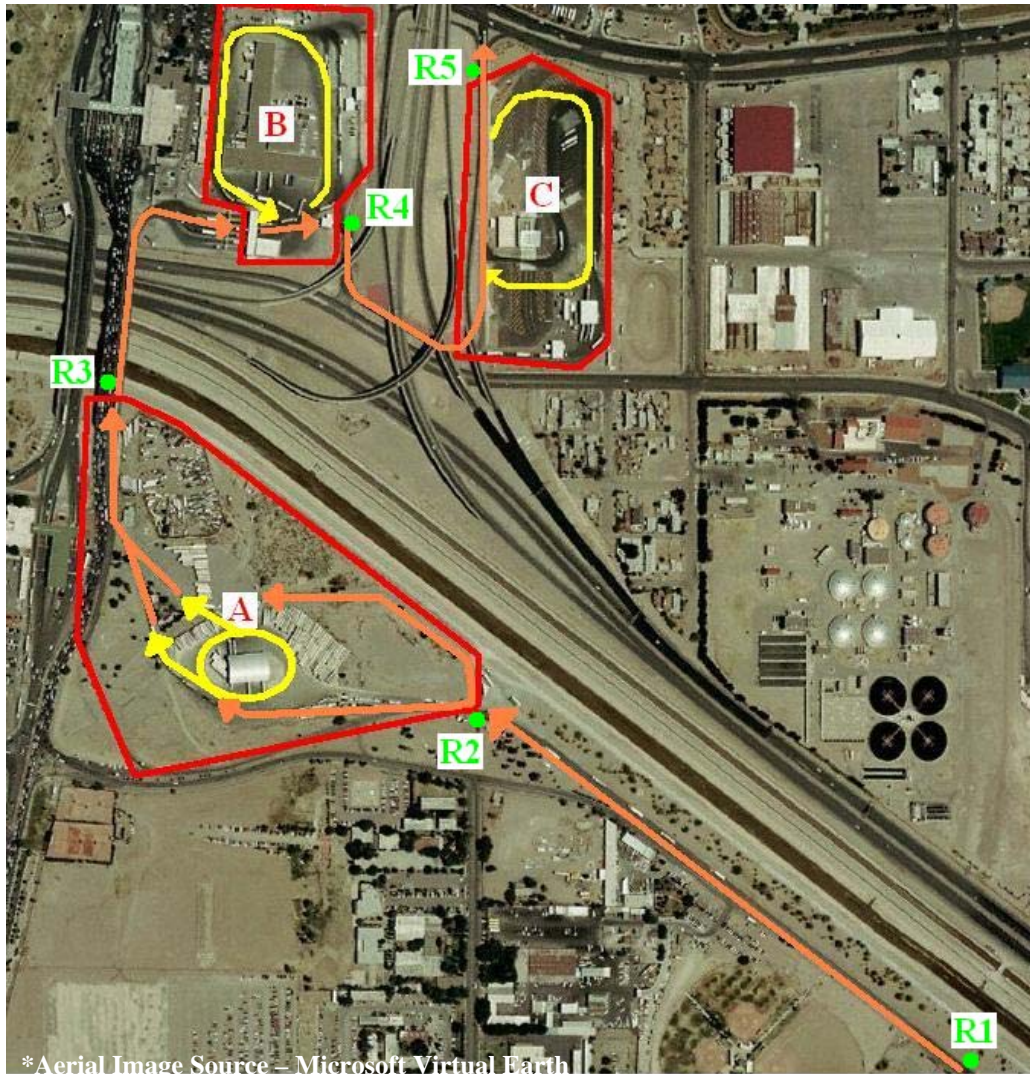


Figure 2: BOTA Northbound Flow and Possible Measuring Locations

In Figure 2, all physical inspection areas are outlined in red and labeled as the following:

- A – Mexican Export Lot
- B – U.S. Federal Compound
- C – Texas Department of Transportation (TxDOT)/Department of Public Safety (DPS) Border Safety Inspection Facility (BSIF)

Orange directional arrows illustrate the path that a northbound commercial vehicle will follow as it moves through the border crossing process. Yellow directional arrows show the path that a truck will take if it has been selected for secondary inspections in any of the border crossing facilities.

R1 through R5 show possible sites where RFID readers can be installed in order to measure crossing times. Approximate locations for each potential measuring site are outlined below:

- 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 - Immediately after the exit of the U.S. Federal Compound
- R5 - The end of the border crossing process after the exit of the BSIF

R1 and R5 are necessary to calculate total crossing times, however if additional detail are required, measuring locations could be installed at R2, R3, and R4 in order to segment each trip. The respective segments would measure 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 US Federal Compound and the amount of time the truck spends in the compound itself
- R4 to R5: the amount of time a truck spends in the BSIF

It is important to note that the project's initial budget includes funding to purchase and install RFID equipment at both R1 and R5. Installing measuring locations at R2, R3, and R4 would require additional equipment to be purchased or otherwise made available. The Texas DPS is currently installing RFID readers at the BSIF in the vicinity of R4 and R5. Both DPS and TxDOT at the stakeholder meeting mentioned the possibility of using these readers for this particular project. This possibility will be analyzed further by the project team, FHWA, DPS, and TxDOT as the project moves forward.

System Concept of Operation

The commercial vehicles (trucks) will pass an RFID tag reader at a point sufficiently ahead of the end of any queue on the Mexican Export Lot (R1 in Figure 2). The RFID tags on the trucks will be read as they pass the reader station. The tag query process will recover a unique identifier for each vehicle. The reader station will time stamp the tag read and forward the resulting data record to a central location for further processing via a data communication link. A similar tag reading station will be installed at the exit of the BSIF (R5 in Figure 2). This station will also time stamp tag reads and forward the data record to the central facility.

The central facility will receive data from all tag reading stations associated with the project (that number is currently projected as 2 stations but may increase if interest and budgets are expanded). The facility will store 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.

The raw data will be processed to match tag reads of individual trucks at the entrance point on the Mexican side to the exit point on the U.S. side. The difference in time stamps will yield a

single truck's progression as a function of time through the POE. Note: the border crossing time is the sum of the time incurred on the Mexican side (Mexican customs), the US Customs facility, and the BSIF. If more reader stations are incorporated, a better picture of the progression can be obtained using the same technique. The tag matching process will be executed periodically to obtain a reasonable sample of trucks to produce crossing times.

The northbound crossing time will be made a shareable resource with the objective of including the information on a regional transportation map or display. The data should be available via a simple subscription service as well as accessing a project related webpage. Archived data may also be available through the project website.

User Needs

As mentioned previously, part of the Current State Analysis consisted of coordinating a stakeholder meeting. This stakeholder meeting was designed to not only present a general outline of this project to local stakeholders, but also to obtain feedback from those stakeholders regarding potential uses of the proposed system for measuring and disseminating border crossing times. From this stakeholder meeting as well as other previous tasks in this project, the following list of user needs has been developed:

- The system should not interfere with day-to-day operations at the Bridge of the Americas.
- The system should be focused on analysis of aggregated data rather than the identity of drivers, shipments, and trucks in order to maintain anonymity.
- Processed travel time data should be available to authorized subscribers through Web viewing.
- Access to archived crossing time information would be beneficial.
- Obtaining segmented trip data would be desirable but not absolutely essential to the success of the project.

System Requirements

In order to meet the needs of the public and private stakeholders listed in the previous section of this report, the project team has developed the following list of System Requirements. These System Requirements have been formulated through analyses of BOTA operations, RFID technology, and stakeholder meetings/interviews.

- The system needs to automatically measure the time required for a northbound truck to cross from a pre-determined point upstream of the typical queue on the Mexican side to the exit of the BOTA POE on the U.S. side.
- The system must not require the interaction of either drivers or employees of agencies manning the POE on either side of the border during normal operation, other than to report on a visible anomaly such as damaged system hardware (e.g., a tag reader antenna).
- System failure must not affect operations at the POE.

- The system will not require an interface to any current equipment or data streams in use at the POE to be operational and effective. The system will not rely on data from other parties to be effective although data from these parties may be incorporated at some point to increase the overall value of the project.
- The commercial vehicles are expected to have RFID tags using either the TransCore eGo or ATA tag protocol (based on information received from TxDOT). The field tag reader equipment shall be able to read tags of either protocol.
- The reader stations are not required to read and record every tag as in a tolling application. There is room for misreads. The expected read rate should be approximately 85% of readable (i.e., correct protocol) tags from any field station.
- The field stations shall be capable of maintaining an accurate time clock, at least accurate to the minute, for use in time stamping tag reads.
- The field tag reading stations should be physically compact as components may need to be installed on current traffic signal or new light weight pole installations.
- All field equipment should exhibit sufficient environmental specifications to insure proper operation in the El Paso area climate.
- The field station design should incorporate a method(s) to detect malfunctioning equipment and attempt to self correct or otherwise compensate for the problem. This is particularly necessary for the communication link.
- The design shall utilize off-the-shelf components which can readily be purchased in case a repair is required.
- The field station design shall be such that little ongoing maintenance is required since the sites may be difficult to access without prior authorization.
- The field station should be designed to remain operational after the term of this research project. It is anticipated that another agency will assume responsibility for the operation and maintenance of the system at the end of the project.
- The project's Central System needs to reside at the Texas Transportation Institute El Paso office.
- All data created during the course of the project shall be stored in an archive for potential future use.
- The project will calculate current border crossing times for northbound commercial vehicles utilizing BOTAs.
- Project output data shall follow accepted Internet standards for data subscription / syndication.
- Processed travel time data need to be available to authorized subscribers having password protection (e.g., CBP, City of El Paso and Ciudad Juarez bridge operations, Texas DPS, TxDOT) through Web viewing.

System Conceptual Design

The conceptual design for the border crossing time measurement system shown in Figure 3 is organized into three broad task areas referenced as subsystems. The subsystems are: 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 stations. These measurement stations are responsible for accurately identifying and logging the passage of commercial vehicles past a point. The Field Subsystem will relay vehicle passage information via a telecommunication network to the Central Subsystem. The Central Subsystem logs the incoming vehicle information and processes it to produce border crossing time and other data. The crossing time is made available in a standard Internet sharing format for the User Subsystem which is various web sites that may choose to include the border crossing time as part of the web site's regional transportation information display.

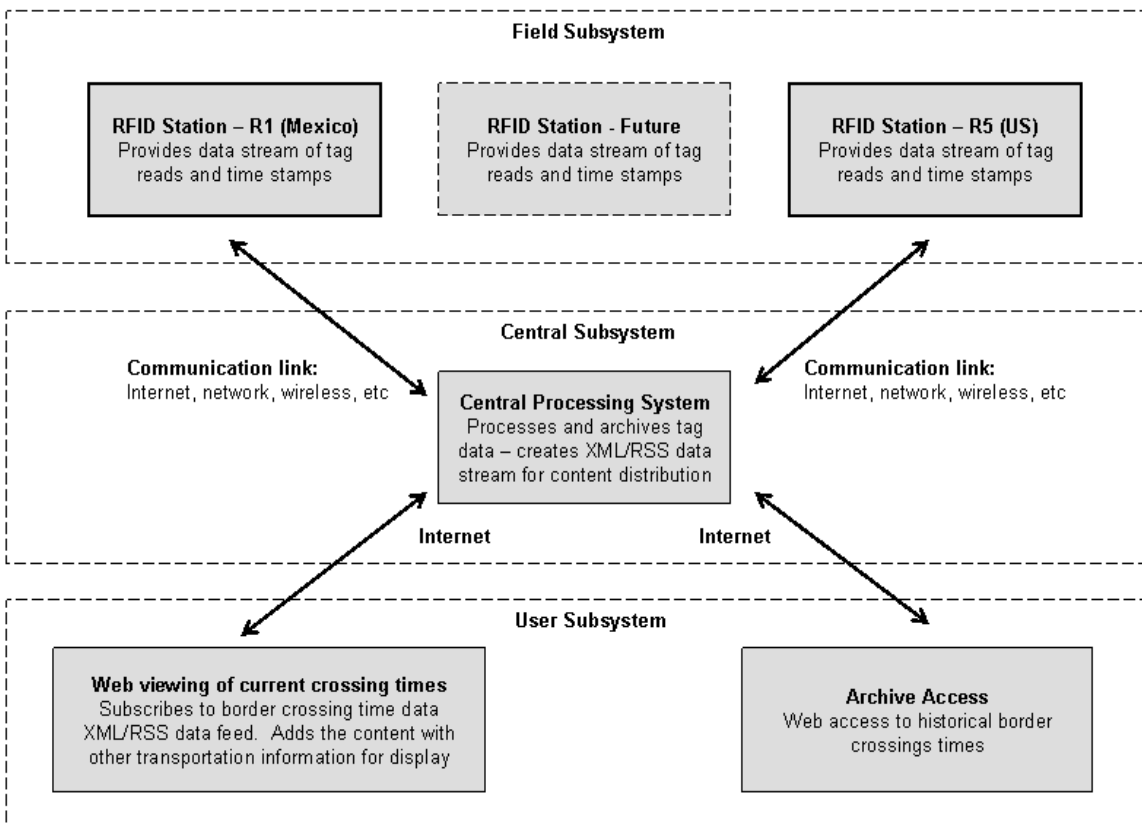


Figure 3: Conceptual Design Overview

Field Subsystem

The Field Subsystem shown in Figure 4 is the project's group of RFID detection stations.

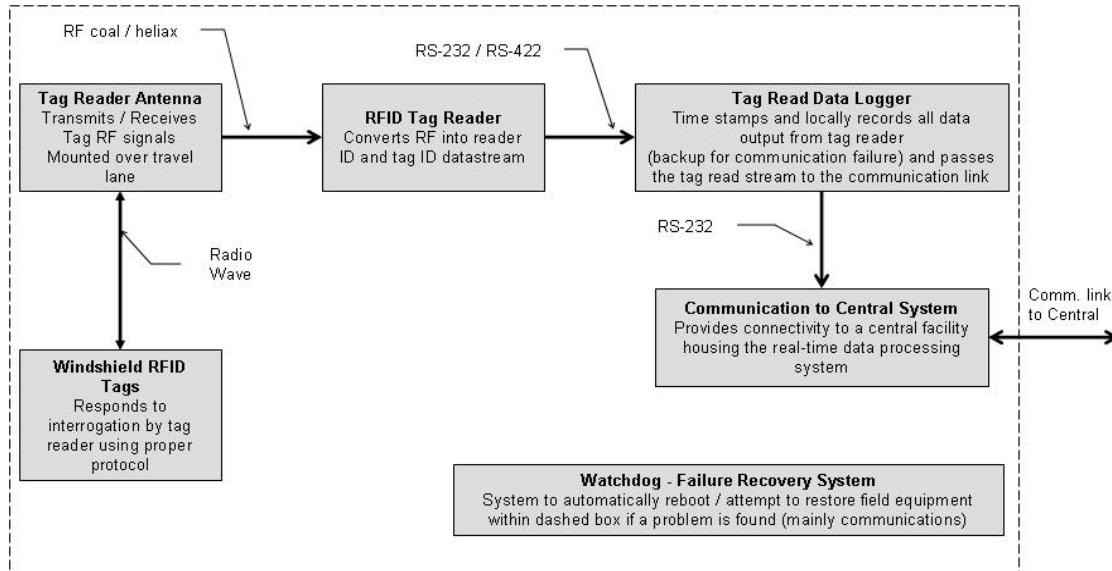


Figure 4: Field Subsystem Concept

At present, an RFID station is proposed for a location near the entrance to the Mexican customs area but outside the expected vehicle queuing zone. The remaining RFID station will be constructed near the exit of the BSIF. The detection technology will be RFID and will use the FAST program windshield sticker tag currently in operation. The tags will support the eGo and/or the ATA tag protocol.

Each RFID station will have an antenna located over each lane at the location. The antenna positioning must be such that a high percentage of the passing vehicles are accurately read. 100% read accuracy is not required. The location should be chosen to limit the number of antennas required for site coverage.

The antenna will connect with a traditional tolling quality RFID tag reader that can reliably read the FAST tag's protocol. TransCore is a popular vendor for such products. The tag reader continually scans for a passing tag. As a tag passes the reader's antenna, a unique code is recovered from the tag via an exchange of radio frequency energy. The code is converted into a digital message and forwarded to the RFID station's onsite data logging component. The reader's data communication protocol should be such that little or no "handshaking" and additional transactions are required during normal operation (tag read mode). The conceptual design does not currently include any additional processor or computer platform to manage the RFID reader at the local level.

The onsite logger is used to capture, time stamp and store all tag messages (tag reads with vehicle identification code) from the reader and can 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 advent of communication failure. The logger will need to pass through data moving both from the RFID reader and toward the reader. All data coming from the reader (tag data) will be time stamped and logged.

The tag read messages are routed out of the field site and toward the Central Subsystem in real-time. A communication solution will be required for each field location. Typical communication options include private wireless, public wireless, cellular data, traditional dialup, and a private ISP (Internet Service Provider). The requirement for a RFID station to be installed in Mexico will likely complicate and limit the telecommunication options.

Each field RFID station should include some form of system monitoring mechanism. A common issue for field deployment is occasional loss of communication or other system failure that requires nothing more than a system power cycle. A component should be included to, at minimum, monitor communication over the field-to-central link and cycle power when communication appears lost. Additionally, it would be advantageous to allow a central system management application to command a field site to cycle power in an effort to restart the tag reader.

Central Subsystem

The Central Subsystem shown in Figure 5 receives all inbound tag reads from the field RFID stations. The tag reads will be formulated into a data record containing the originating station, time stamp, and tag ID. Tag records will be routed to a Raw Tag Archive and introduced to a process utilizing a database to manage the real-time calculations for the project.

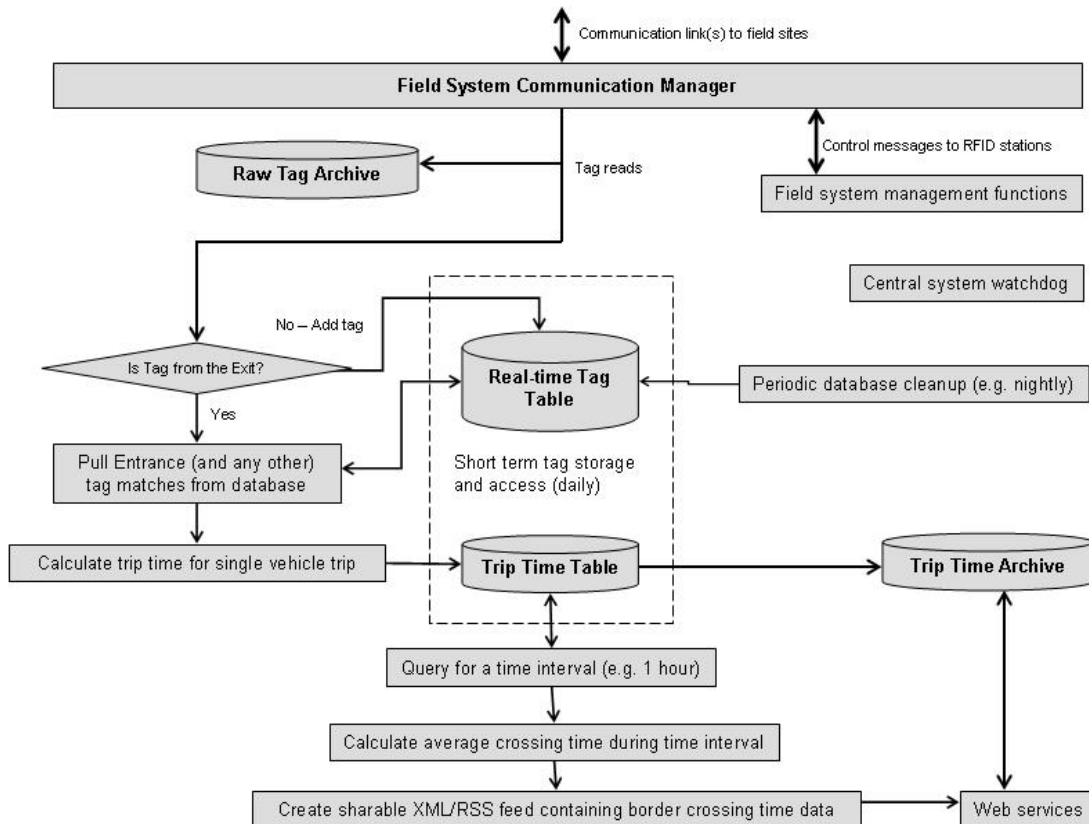


Figure 5: Central Subsystem Concept

The database will contain a Real-time Tag table to hold tag records for vehicles currently within the confines of the border crossing and a Trip Time table which holds individual travel times between the entrance and exit stations.

The process begins by determining the location from which an inbound tag originated. If the tag is from the entrance reader station, the tag record is added to the Real-time Tag table within the database and no further action is taken. If the tag is from the exit location, the Real-time Tag table is queried for all other tag records containing that tag ID. These records will indicate the tag's entrance (and possibly passage if additional RFID stations are deployed) through the border area. The tag's exit time on the U.S. side and entrance time in the Mexican side is compared and a single trip travel time is calculated and added to a Trip Time table within the database. The same measurement technique will be applied to multiple segments if one or more additional tag reader is added between R1 and R5. The records returned as part of the database query are then removed from the Real-time Tag table thus cleaning up the table as vehicles exit the system.

An external process will be periodically executed to completely clean old tag records which remain in the Real-time tag table. Records could get 'lost' if a vehicle remains within any of the inspection facilities for an extended period (e.g., more than a day). Data processing algorithms will allow a check to be placed on tag matches that return unrealistic numbers (both high and low), so that suspicious data can be tagged or eliminated to avoid skewing of crossing time measurements.

Single trip travel time records will be archived in another database. The archive can be opened for remote user access by project partners via an Internet interface which would support queries to return individual trip times and border crossing times. The information may be useful for future regional planning purposes.

The Trip Time table will be periodically queried to return all the single trip records for a time interval, for instance 30 minutes or 60 minutes. A border crossing time can be calculated as well as a measure of the variance (reliability) in the crossing time. This information will be packaged using the standard Internet information syndication scheme Real Simple Syndication (RSS). RSS is a common internet format for publishing frequently updating content such as news headlines. A web host will serve the RSS formatted border crossing time information and support access to the Trip Time Archive.

User Subsystem

The user subsystem is shown in Figure 6. All users of the border crossing information will access the shareable data (RSS border crossing information and Trip Time Archive) via the Internet.

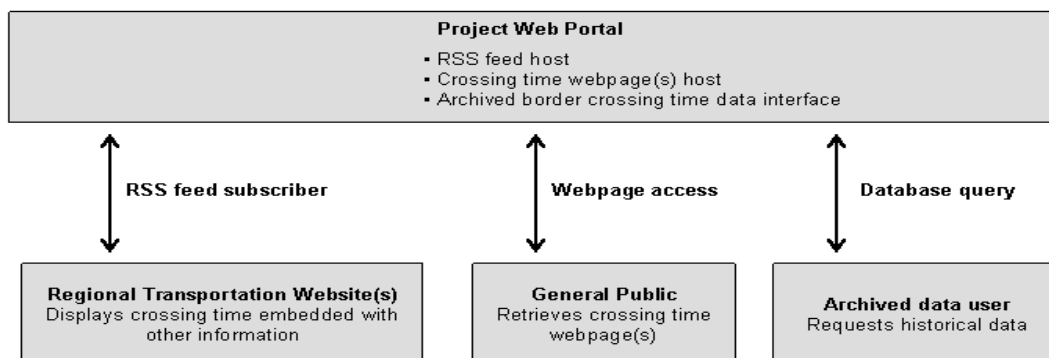


Figure 6: User Subsystem Concept

Real-time border crossing times will be distributed as an RSS feed which can be added to area transportation information providers' web pages. The RSS feed is designed to deliver raw, basic information. Each user who chooses to add the content to their site must define the graphical method for the data display. In general, the RSS provides only the data while the users (data consumers) must design and provide the display of the data. This project may choose to develop a simple display which utilizes the RSS feed as an example application for other web developers.

The Trip Time Archive will support an Internet interface. The interface should provide a group of tools to perform simple database queries and to display the results for users.

Relationship to National ITS Architecture

Per the National ITS Architecture, version 6.0: <http://itsarch.iteris.com/itsarch/index.htm> the elements that apply to the RFID implementation are the Commercial Vehicle Service Area, within which the most applicable Market Packages are CV003-Electronic Clearance and CVO05-International Border Electronic Clearance.

Relationship to El Paso Regional ITS Architecture

The El Paso Regional ITS Architecture home page is located at <http://www.consystem.com/texas/web/el Paso/el Pasointro.htm>. This regional ITS architecture was enacted in September 2003 and is a "roadmap" for transportation system integration in the El Paso Region for the next 20 years. The architecture represents a shared vision of how each agencies' systems will work together in the future, sharing information and resources to provide a safer, more efficient, and more effective transportation system for travelers in the Region."

In the El Paso Regional ITS Architecture:

- The Inventory by Stakeholder items that appear to be relevant to this project are:
 - El Paso MPO Data System Users future),
 - El Paso Transportation Hub (planned),
 - City of El Paso International Bridge Field Equipment (future),
 - Commercial Vehicle Operator Systems (existing),
 - Commercial Vehicles (existing),
 - IBWC BOTA Field Equipment (planned),
 - El Paso MPO Data System (future), and
 - Juarez IMIP (future)
- The applicable Function is On-board CV Electronic Data.

Technology Standards and Specifications

The following technology standards or specifications apply to the area of RFID and Internet formatting:

- ISO/IEC 18000-6: <http://www.hightechaid.com/standards/18000.htm> is the UHF (860-960 MHz) industry standard developed for the type of passive RFID system planned for the BOTA implementation.
- Really Simple Syndication (RSS) Specifications
- Extended Markup Language (XML): <http://www.w3.org/TR/xml11/>.