Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-16/0-6879-1		

4. Title and Subtitle
CROSS-BORDER ITS SYSTEMS WITH TRAFFIC MANAGEMENT CENTERS: TECHNICAL REPORT

5. Report Date
Published: October 2016

6. Performing Organization Code

7. Author(s)
Roberto Macias, Juan Carlos Villa, Rafael Manuel Aldrete, David Salgado Manzano, Rajat Rajbhandari

8. Performing Organization Report No.
Report 0-6879

9. Performing Organization Name and Address
Texas A&M Transportation Institute
College Station, Texas 77843-3135

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
Project 0-6879

12. Sponsoring Agency Name and Address
Texas Department of Transportation
Research and Technology Implementation Office
125 E. 11th Street
Austin, Texas 78701-2483

13. Type of Report and Period Covered
Technical Report:
April 2015–July 2016

14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Cross Border ITS Systems with Traffic Management Centers
URL: http://tti.tamu.edu/documents/0-6879-1.pdf

16. Abstract
The Traffic Management Centers (TMCs) in Texas play a vital role in managing traffic operations in many of major metropolitan areas. TMCs have deployed extensive detection, monitoring, and communication infrastructure to allow TxDOT operators to manage incidents and reduce collisions; provide traveler information through roadside assets; provide traffic status to broadcast media; and support work zone monitoring and construction information. Currently there is no cross-border TMC or traveler data exchange along the Texas/Mexico border to inform the traveling public of the traffic conditions on the other side of the border, so travelers do not have information on traveling conditions between border sister-cities. Researchers evaluated the current state of the practice and future plans in Mexico to advance intelligent transportation systems, and developed a framework and an action plan for TxDOT to lead the deployment of cross-border TMCs and share data to improve the traffic conditions along the Texas/Mexico border and adjacent border cities.

17. Key Words
Traffic Management Center, TMC, Cross, Border, Traffic Operations, Wait Time, Data Exchange, Binational TMC

18. Distribution Statement
No restrictions. This document is available to the public through NTIS:
National Technical Information Service
Alexandria, Virginia
http://www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	164	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

CROSS-BORDER ITS SYSTEMS WITH TRAFFIC MANAGEMENT CENTERS: TECHNICAL REPORT

by

Roberto Macias
Associate Research Scientist
Texas A&M Transportation Institute

Juan Carlos Villa
Research Scientist
Texas A&M Transportation Institute

Rafael Manuel Aldrete
Senior Research Scientist
Texas A&M Transportation Institute

David Salgado Manzano
Associate Transportation Researcher
Texas A&M Transportation Institute

and

Rajat Rajbhandari
Associate Research Engineer
Texas A&M Transportation Institute

Report 0-6879-1
Project 0-6879
Project Title: Cross Border ITS Systems with Traffic Management Centers

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: October 2016

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT), Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Roberto Macias.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The authors thank Darrin Jensen, Edgar Fino, Alberto Aldape, Alesia Gamboa, Manuela Ortiz, Betty Farnham, and Gabriel Garcia.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

1. LITERATURE REVIEW

INTRODUCTION

Traffic management centers (TMCs) in Texas play a vital role in managing traffic operations in many of our major metropolitan areas. TMCs have deployed extensive detection, monitoring, and communication infrastructure to allow the Texas Department of Transportation (TxDOT) operators to:

- Manage incidents and reduce collisions.
- Provide traveler information through roadside assets.
- Provide traffic status to broadcast media.
- Support work zone monitoring and construction information.

Currently, there is no cross-border TMC or traveler data exchange along the Texas-Mexico border to inform the traveling public of the traffic conditions on the other side of the border; so travelers do not have information on traveling conditions between sister-cities along the border.

This chapter contains a comprehensive review of past research and studies performed of cross-border TMC and sharing data projects on the U.S.-Mexico and U.S.-Canada borders.

TECHNOLOGY AND DATA AT THE BORDER

Port of Entry Technologies

The United States has taken great steps in the past 25 years to implement relevant technology that makes cross-border travel more efficient. U.S. Customs and Border Protection (CBP) has financed new technology at most land ports of entry (POEs), including license plate readers (LPRs), smart cards, and radio frequency identification (RFID) readers that are used to manage POEs and to develop new strategies for traffic management and security screening.

License Plate Readers

One of the most-used pieces of technology that has been implemented at land POEs are LPRs. These machines capture the license plate of each vehicle that enters the POE, and they automatically register the vehicle in the CBP system. This simple task of registering a vehicle before it reaches the CBP officer shaves time off of travel by allowing the CBP officer to skip basic data collection. This also puts more emphasis on officer interviews of the vehicle passengers, creating a safer border.

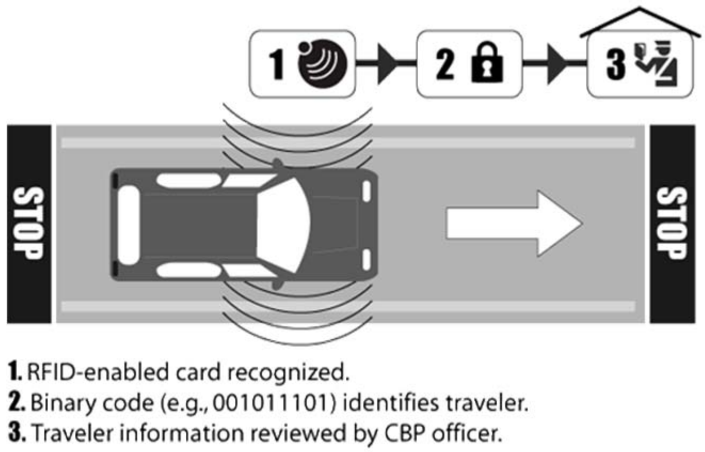
There are also commercial implications for the use of LPRs. When a commercial vehicle wishes to pass through a POE, the driver must furnish a cargo manifesto to the CBP at least one hour before crossing. When the cargo vehicle enters the POE, the cargo manifesto is automatically retrieved and made available to the officer working at that particular post. Having cargo manifestos automatically delivered to CBP officers instead of making them search for each individual cargo manifesto saves on the overall crossing time and alleviates wait times for all other crossers.

Concerns over the use of LPRs have surfaced recently, specifically on the government's sharing of the information collected. Recording the license plate and location of each vehicle that enters a POE is considered by some to be an invasion of privacy. Documents released in 2012 revealed that the federal government shares data collected by LPRs with the National Insurance Crime Bureau to help fight against vehicle theft and fraud. This information further fueled concerns over a person's right to privacy as they enter or leave the country. Aside from willful sharing of information, there are concerns over the government's ability to protect the data it collects from these LPRs.

Radio Frequency Identification

Another widely used border technology is RFID, which is a two-part technology that consists of an RFID reader and an RFID tag. The tag normally comes in the form of a sticker that is adhered to the vehicle's windshield, or a smart card that the driver possesses. Each RFID tag is embedded with a unique identification number that is associated with either a commercial vehicle or a commercial driver. As the driver and the vehicle approach a land POE, RFID readers placed near the POE receive the RFID signal from the tag and download the vehicle information.

Figure 1 shows a basic example of how RFID technology operates at the border. This process happens in a matter of seconds as the driver approaches the CBP officer at the POE. When the driver reaches the CBP officer, the RFID technology has already delivered all necessary data to the officer who can then interview the driver and choose whether to send the vehicle to secondary inspection, or waive the driver through. This automatic delivery of information is similar to the delivery of information produced from the LPRs. The RFID technology reduces crossing times by expediting the POE interview process.



Source: (1)

Figure 1. RFID Technology Example.

Automatic Vehicle Detection

There are many different types of technology that can be used at POEs to automatically detect a vehicle approaching. Most of these technologies are used at tolling stations, but they can also be used at other checkpoints along the POE. Two of the technologies used as automatic vehicle detection are LPRs and RFID tags/readers. Another technology frequently used to detect vehicles is the inductive loop detector. Loop detectors are metallic wires that are buried in the ground at the point of detection. The wires detect a vehicle's magnetic signature and register the vehicle's presence at the detection point. Loop detectors are able to maintain a relatively accurate traffic count, and when installed in pairs can determine the speed of passing cars. Inductive loops are difficult to install because they need to be placed under the road. The loops can also wear out over time depending on the climate, and repairs are costly and difficult (*2*).

Advanced Imaging

In order to make a more secure and efficient border, the U.S. CBP has invested in new advanced imaging systems. These advanced imaging systems include radiation portal monitors, backscatter imagers, and photonuclear gamma ray imagers. Each of these devices is intended to quickly and efficiently scan personal and commercial vehicles without the need for time-consuming intrusive searches. These machines allow the vehicles to pass through a scanner that can detect explosives, narcotics, organic heat signatures, and other contraband. If contraband is detected the CBP officer can switch to a manual intrusive search, but if no contraband is detected the CBP officer can waive the vehicle through the POE. While these devices primarily bolster the security at land POEs, they also contribute to a more efficient traffic flow as the need for long, intrusive searches is reduced.

Border Crossing Wait Times

To understand the process behind the measurement of border crossing wait times, it is important to first understand the border-crossing process itself. The border-crossing process for passenger and commercial vehicles at the U.S.-Mexico border is complicated due to the number of stakeholders that participate in the process.

Northbound Commercial Vehicle Crossing Process

Mexican tractors are restricted to circulation in a narrow commercial zone extending out to 25 miles from the border (or up to 75 miles in Arizona). Therefore, Mexican truck shipments into the United States are required to use a drayage or transfer tractor that picks up a trailer on the Mexican side of the border and then hauls it into the United States, where it is dropped off so a U.S. long-haul tractor can carry the trailer farther into U.S. territory.

The typical northbound border-crossing process requires a shipper in Mexico to file shipment data with both Mexican and U.S. federal agencies. The e-Manifest with shipment data is filed with U.S. authorities. The use of a drayage or transfer tractor to move the goods from one country to the other is the common practice at the U.S.-Mexico border, and once the shipment is at the border with the drayage or transfer tractor and an authorized driver, the process flows through three main potential physical inspection areas:

- Mexican export lot.
- U.S. federal compound.
- U.S. state safety inspection facility.

The Mexican Export Lot

A drayage driver with the required documentation proceeds into the Mexican Customs (Aduanas) compound. For audit and interdiction purposes, Aduanas conducts inspections consisting of a physical review of the cargo of randomly selected outbound freight prior to its export. Shipments that are not selected proceed to the exit gate, cross the border, and continue on to the U.S. POE. There are several international crossings along the U.S.-Mexico border that are tolled. Tolls are collected in Mexico for northbound traffic and in the United States for southbound traffic. Toll collection is manual (cash) and electronic using RFID technology. All of the crossings along the Texas-Mexico border are bridges that cross the Rio Grande River, and most of them are tolled. Before crossing into the United States, commercial vehicles pay tolls and proceed to the U.S. federal compound.

The U.S. Federal Compound

At the primary inspection booth, the driver of the truck presents identification and shipment documentation to the processing agent. The CBP inspector at the primary inspection booth uses a computer terminal to cross-check the basic information about the driver, vehicle, and cargo with information sent previously by the carrier via the e-Manifest. The CBP inspector then makes a decision to refer the truck, driver, or cargo for a more detailed secondary inspection of any or all of these elements or, alternatively, release the truck to the exit gate.

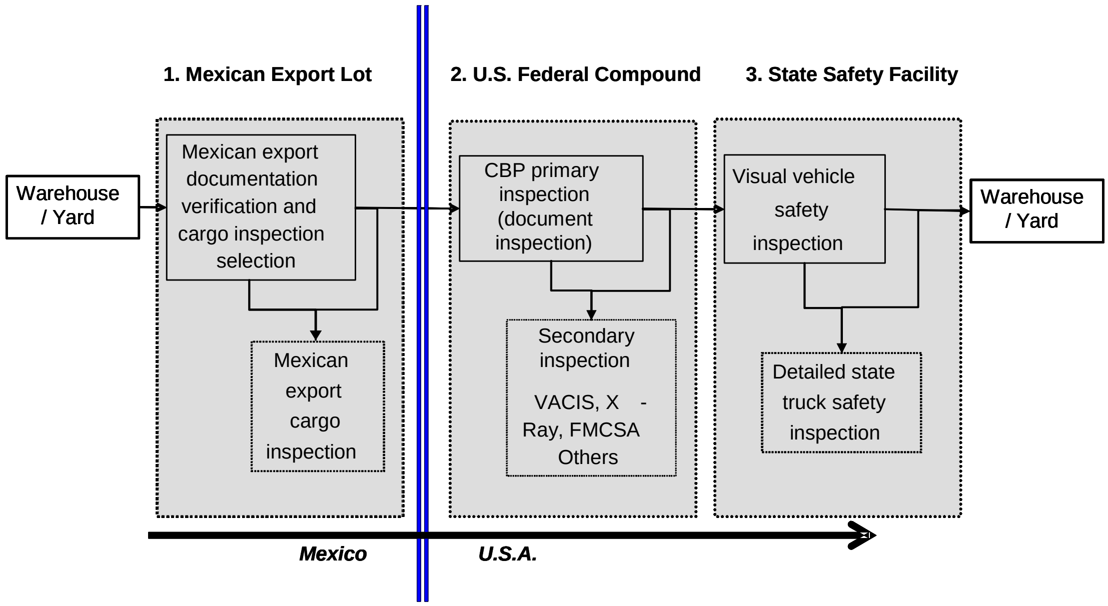
A secondary inspection includes any inspection that the driver, freight, or conveyance undergoes between the primary inspection and the exit gate of the U.S. federal compound. Personnel from CBP usually conduct these inspections, which can be done by physically inspecting the conveyance and the cargo or by using non-intrusive inspection equipment (such as x-rays).

Within the compound, the U.S. Department of Transportation (USDOT) Federal Motor Carrier Safety Administration (FMCSA) and U.S. Food and Drug Administration have personnel and facilities to perform other inspections when required. A vehicle audit could happen at the federal compound or the state safety inspection facility, depending on practice.

The State Safety Inspection Facility

In the majority of POEs, the state safety inspection facilities are located adjacent to the federal compound. State police (in Texas, the Texas Department of Public Safety [DPS]) inspect conveyances to determine whether they are in compliance with state vehicle safety standards and regulations. If their initial visual inspection finds any violation, they direct the truck to proceed to a more detailed inspection at a special facility.

After leaving the state safety inspection facility, the driver typically drives to the freight forwarder or customs broker yard to drop off the trailer for later pickup by a long-haul tractor bound for the final destination (Figure 2).



Source: (3)

Figure 2. Northbound U.S.-Mexico Commercial Border-Crossing Process.

Southbound Commercial Vehicle Crossing

The southbound commercial vehicle crossing process has only one inspection station by Aduanas. The process in Mexico is a red light/green light decision in which a loaded commercial vehicle is randomly selected for a secondary inspection if it gets a red light. Empty vehicles cross with no need to stop at the Aduanas' booths. Recently, CBP has started to perform random manual inspection on the U.S. side of the border for commercial vehicles crossing into Mexico, aiming to identify illegal shipments of money and weapons. The POEs are not designed for southbound commercial inspection on the U.S. side of the border, and this has consequently created congestion.

Passenger Vehicle Crossing Process

On the Mexican side of the border, passenger vehicles are required to pay tolls at most international bridge crossings. Tolls are paid manually or via electronic collection systems. Once passenger vehicles pay the toll, if necessary, they proceed to the U.S. federal compound primary inspection booths where a CBP officer must ask the individuals who want to enter the country to show proper documentation, such as proof of citizenship, and state the purpose of their visit to the United States. If necessary, the vehicle is sent to secondary inspection.

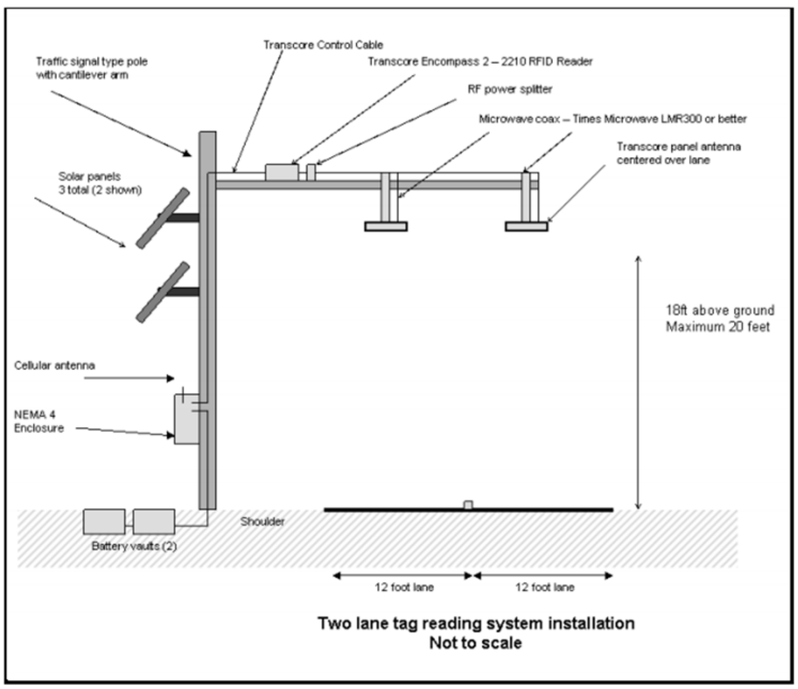
At the primary inspection booth, LPRs and computers perform queries of the vehicles against law enforcement databases that are continuously updated. A combination of electric gates, tire shredders, traffic control lights, fixed iron bollards, and pop-up pneumatic bollards ensure physical control of the border crossers and their vehicles.

At the secondary inspection station, officials conduct a much more thorough investigation of the identity of those wanting to enter the United States. During this step, individuals may also have to pay duties upon their declared items. Upon completion, access to the United States is either granted or denied.

Passenger vehicles traveling from Texas to Mexico pay a toll at most of the international bridges. Tolls are paid in cash or, at some border crossings, via electronic payment. Recently CBP has started performing southbound checks at the CBP facility, mainly looking for arms and cash. The process does not involve technology, just questioning at the check point. Once the vehicle crossed into Mexico, it goes through a random selection process to determine if the vehicle requires detailed inspection at a secondary inspection facility.

Measuring Border Crossing Wait Times

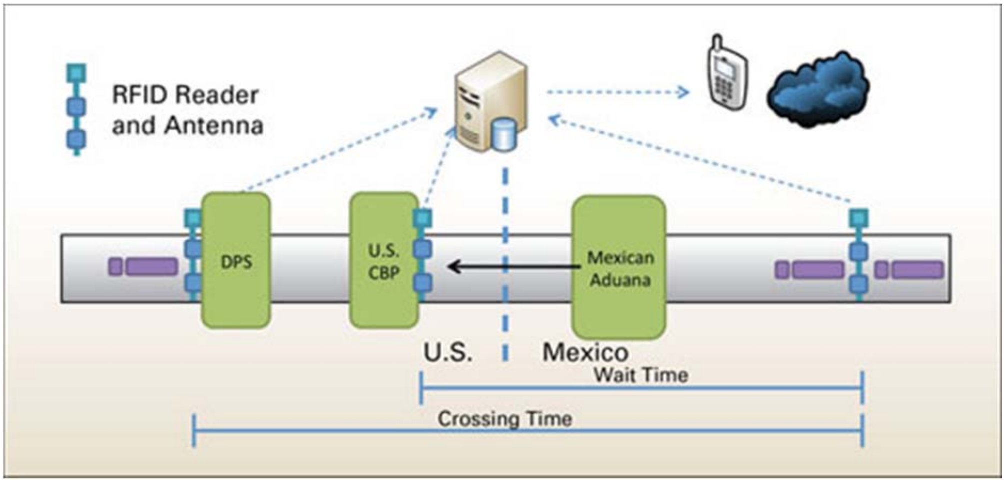
Actual wait times are being measured through a collaborative project that includes TxDOT and the Federal Highway Administration (FHWA). The commercial vehicle wait time measurement system uses data gathered by RFID readers like the one shown in Figure 3.



Source: (4)

Figure 3. Border RFID Wait Time Measuring Installation.

These RFID stations register each vehicle with a compatible RFID tag crossing under them with the raw data for the readers stored in a central location. The data reveal the time it takes a commercial vehicle to travel from Point A on the Mexican side—through Mexican, U.S., and state customs inspections—to Point B on the Texas side (Figure 4).



Source: (5).

Figure 4. RFID Reader Locations and Measured Times.

Seven of the most heavily traveled commercial border crossings, accounting for more than 90 percent of all truck traffic from Mexico into Texas, have been equipped with the technology.

Privately operated vehicle wait time measurement is being performed using Bluetooth® technology. The general concept of the system, which has been implemented at the Zaragoza-Ysleta POE in El Paso, is that during a vehicle's trip across the border at the POE, Bluetooth signals emitted from mobile devices carried by drivers and/or passengers are read by reading stations at multiple fixed locations (at least three). These stations include antennas and readers that constantly look for Bluetooth signals. These stations detect Bluetooth signals, read media access control addresses, and send the information to a server, which then adds a time stamp to the data. If matches are found, then wait times of individual vehicles are determined. Since many personally owned vehicles (POVs) are waiting at the same time, individual wait times are aggregated (e.g., averaged). The data—whether raw or processed—are stored and archived in a database server. Figure 5 shows an illustration of how the Bluetooth-based system works to measure wait times of U.S.-bound POVs. Similarly, Figure 6 shows an illustration of how the Bluetooth-based system works to measure wait times of Mexico-bound POVs.

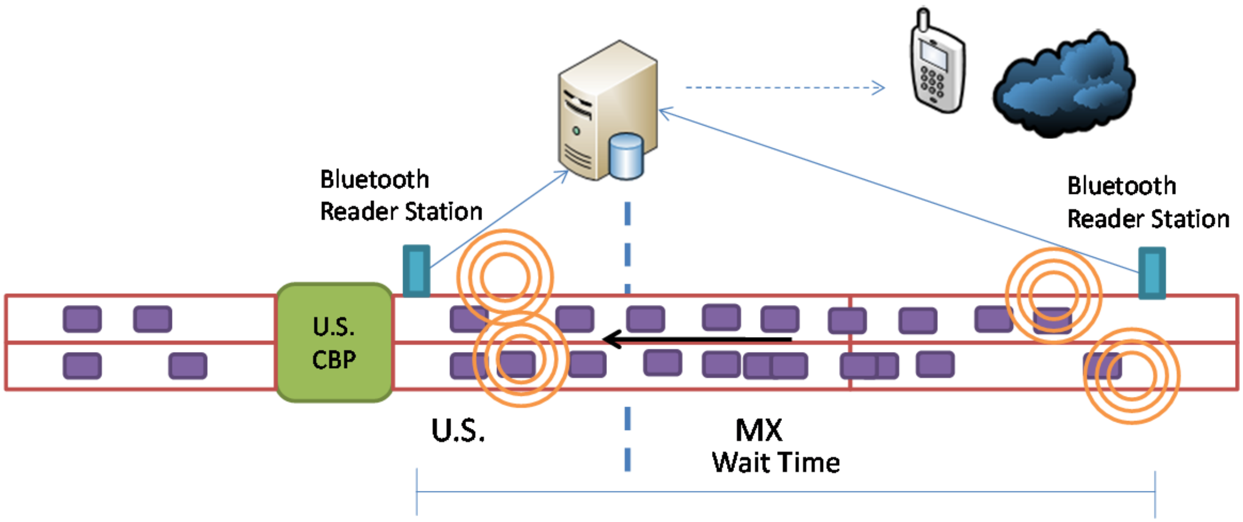


Figure 5. Design of the Bluetooth-Based Wait Time Measurement System for U.S.-Bound POVs.

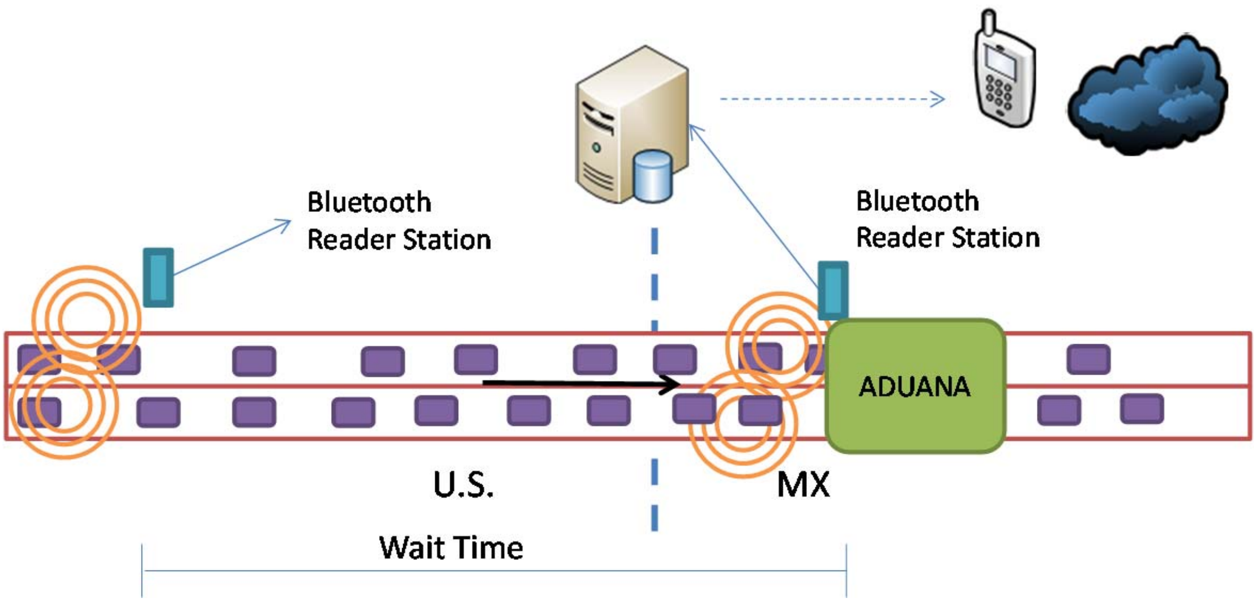


Figure 6. Design of the Bluetooth-Based Wait Time Measurement System for Mexico-Bound POVs.

Border Crossing Time Information Dissemination

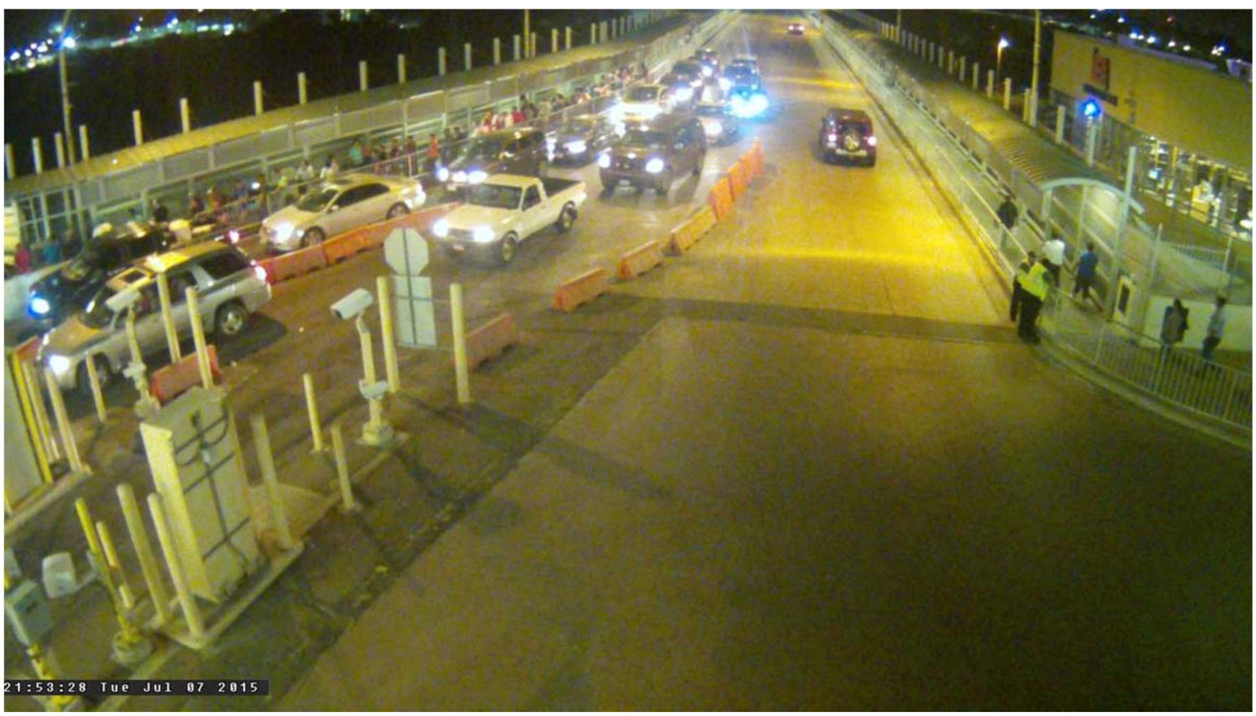
The information is being disseminated via the Border Crossing Information System (BCIS) (http://bcis.tamu.edu/). BCIS calculates the expected wait and crossing times, which motorists can access using the Real Simple Syndication feed or the BCIS web page. The system also provides archived or historical data through the website that is maintained and operated by the Texas A&M Transportation Institute (TTI).

Other Border Wait Times Measuring Systems

Mexican authorities enabled the filming and transmission of the international border crossings along the entire U.S.-Mexico border. These transmissions can be accessed via the Internet to determine the length of the queue at each crossing.

Authorities in the United States have laws on the surveillance of their citizens through video cameras that do not permit this type of video recording transmission in the southbound crossing direction, so there are only transmissions of the Mexican side of border crossings. Since these transmissions do not use any technological resources to report border crossing wait times, only wait time estimations can be inferred from these video feeds.

There are two types of video feeds: 1) government-regulated video feeds such as the ones found in Laredo (see Figure 7), and 2) some that are generated by private organizations or companies, which can be found all along the border (*6*). The difference between these two types of camera feeds is the location of the video cameras generating the information. In general, the government-authorized feeds are set up at international crossings, while others use feeds from cameras installed in the vicinity of the bridge.



Source: (6)

Figure 7. Border Crossing Live Video Feed.

Data Exchange between the United States and Mexico

Direct and peer-to-peer exchange of operational traffic data between TMCs in the United States and Mexico is limited and probably nonexistent. TMCs in both countries do not measure wait times; the wait and crossing times are measured and disseminated via the BCIS. Bridge operators may share daily, monthly, and annual volume data with their counterparts. For example, trucks are tolled in the United States going into Mexico, so they may have more accurate measurements of truck volume than Aduanas. Trucks entering United States have to go through both U.S. Customs and Aduanas. Hence, these agencies have the most up-to-date volume information. The researchers are not aware of TMCs on both sides of the border using aggregated volume data for day-to-day operations. Toll operators may use such data to plan resources at the booth. The City of El Paso's international bridge department collects such data and uses them to correlate toll revenue with the volume of trucks.

Registration information of commercial vehicle drivers is not shared on a database level between the two countries mainly due to privacy issues. However, carriers entering the United States must submit an electronic manifest of their shipping to CBP's Automated Commercial Environment within 24 hours prior to arrival. Hence, CBP has some information on which carrier and shipment will arrive at the port ahead of time. Recently, FMCSA performed a pilot study at three POEs, in Texas, Arizona, and New York. In this pilot study, CBP's Automated Commercial Environment system was integrated with FMCSA's system. This system allowed FMCSA inspectors to know in advance which trucks are arriving and had arrived at CBP's primary inspection facility and their safety history. This allowed the FMCSA and state inspectors to plan their resources to focus on high-risk carriers.

In Texas, this integrated truck screening system was piloted in El Paso. FMCSA gave access to the system to the Texas DPS officers. Similarly, in Arizona and New York state, officers were provided access to the system at selected POEs. However, this system was never intended to be integrated with TxDOT's TMC since TxDOT does not have the jurisdiction to screen cross-border trucks for safety.

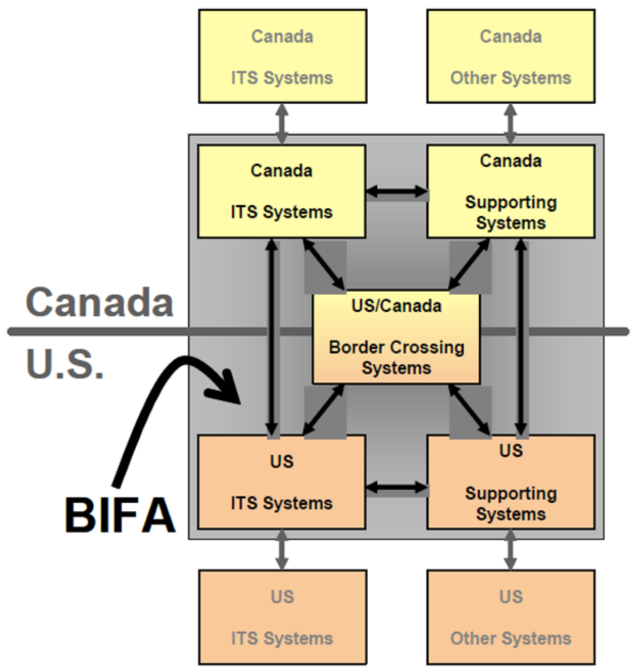
BORDER DATA SHARING

U.S.-Canada Border Data Sharing

In 2001, the United States and Canada signed the Smart Border Declaration (SBD), which outlined a long-term plan for increasing the security of the U.S.-Canada border, while not impeding the flow of people and goods. The SBD originally contained a 30-point action plan that outlined what the goals of the SBD were, and how the United States and Canada would reach those goals together. In order create a smarter and safer border, USDOT and Transport Canada work together through the U.S.-Canada Transportation Border Working Group (TBWG). TBWG is charged with bringing together multiple transportation and border agencies from both countries in order to coordinate transportation planning, policy, and the development of technology to enhance border infrastructure and operations (*7*).TBWG meets twice a year to discuss important topics concerning the U.S.-Canada border.

One of the first goals of the SBD that TBWG tackled was the implementation of Border Information Flow Architecture (BIFA). Although the BIFA does not contain any data itself, it is a framework intended to promote the implementation of interoperable technology. This means that BIFA facilitates technology to gather data that will be available to agencies on both sides of the border.

Figure 8 outlines the basic structure of the BIFA system. This infrastructure is critical for cross-border data sharing projects. Since the implementation of BIFA, the United States and Canada have been able to launch multiple data sharing projects.



Source: (8).

Figure 8. BIFA Scope.

British Columbia–Washington State Cross-Border Advanced Traveler Information System Data Management System

In 2004, the International Mobility and Trade Corridor Program approved funding for a cross-border project between British Columbia and Washington State. The funding was intended to go toward the creation of a database of the captured border crossing wait time information from the Washington State Department of Transportation (WSDOT) and the British Columbia Ministry of Transportation (*9*). In addition, the project aimed to provide more accurate wait times to travelers on both sides of the border. In order to achieve the goals of the cross-border advanced traveler information system, the International Mobility and Trade Corridor Program and the Whatcom Council of Governments had to establish a plan to collect data from the WSDOT and the British Columbia Ministry of Transportation sources at the border, convert the gathered data into a unified format, export the data to a unified database, and finally make the unified data publicly available. The British Columbia–Washington State joint project was one of the first projects that put the BIFA to use and demonstrated that the United States and Canada could effectively share border transportation data.

Entry/Exit Program

In 2011, President Obama and Prime Minister Harper renewed their commitment to strengthen and secure the U.S.-Canada border by signing the *Beyond the Border Action Plan for Perimeter Security and Economic Competitiveness*. This plan called for the gradual implementation of an entry/exit (E/E) program. The E/E program was designed to use one country's border entrance data as the border exit data for the other country. In order for this to be effective, both countries would have to openly share their entry information with the other. Ultimately, when a person enters Canada their basic biographical data are registered in Canada's entry system. Canada then sends their entry information to the United States, which uses the information to mark the traveler as exited from the United States. The program has been implemented in multiple phases. The first phase was a test to see how easily the two countries could exchange and reconcile E/E information. This first phase was implemented at four major POEs: British Columbia/ Washington State and Ontario/New York. The first phase only collected data for third-country nationals who were not American or Canadian citizens, or residents of either country. The second phase, which was implemented in June 2013, was a replication of the first phase, but expanded to include automated land border POEs (*10*). Future plans for the E/E program involve collecting information for all travelers, including citizens from both countries, and expanding the program to include Canadian airports and seaports as well.

Compilation Projects

The two projects outlined above show how the use of the BIFA can be used to directly share transportation information between the United States and Canada. Aside from direct country-to-country sharing projects, BIFA technology is used by each country individually to collect transportation data. These transportation data are, in most cases, made publicly available and used by the other country to compile important reports and statistics.

For example, USDOT's Bureau of Transportation Statistics uses commercial freight data released by the USDOT and Statistics Canada to release their reports on transborder freight. These reports include information over the type of cargo being transported, method of transportation, and logistical crossing details. While this use does not represent direct sharing of information, it is made possible by the data collected by BIFA technologies. Other data collected by individual countries includes traffic counts, border wait times, origin-destination information, and POE congestion statistics. Each of these variables is published online by the collecting agencies, and used by other agencies on both sides of the border to compile reports on the condition of the U.S.-Canada border.

U.S.-Mexico Border Data Sharing

While the United States has dedicated great time and money to the southern border, no concrete transportation data sharing programs have been established between the United States and Mexico. The U.S.-Mexico Joint Working Committee (JWC) included BIFA as part of their 2005–2007 Work Plan, but the BIFA development was largely one-sided. A recent report by FHWA cited that while most U.S. POEs were designed with BIFA technology, their Mexican counterparts did not have TMCs that included BIFA technology, so the sharing of data is nearly impossible (*10*). In response, the JWC has included capacity building in their 2013–2015 Work Plan (*11*). The capacity building will focus on evaluating and preparing Mexican states for the construction of intelligent transportation systems (ITS) in border regions. The JWC will work with the Mexican Transportation Institute, the Mexican Department of Communication and Transportation (SCT), and the Nuevo Leon Center for the Transfer of Transportation Technology on capacity building research and planning.

More recently, President Obama and President Peña Nieto declared their commitment to strengthen binational transportation data sharing in the High Level Economic Dialogue (HLED) of 2013. Both presidents agreed that in order to modernize the border and create safe and efficient POEs, the two countries must improve data sharing capabilities. Since the HLED of 2013, Vice President Biden has led two cabinet-level meetings between the two countries to continue working on the issues discussed in the HLED. After the most recent meeting in January 2015, the White House released a statement saying that both countries continue to work toward harmonizing data requirements at the U.S.-Mexico border in order to create a modern border (*12*). In light of all this rhetoric, the Mexican government, through SCT, drafted a national ITS architecture. The architecture is aimed at monitoring the highways and toll roads that lead to the U.S.-Mexican border (*13*). Data collected from these ITS will help provide an understanding of traffic and delay patterns on the Mexican side of the border and could one day be a source of binational data exchange. One area forecasted to be an issue for the sharing of information between the United States and Mexico is the adoption of different operating systems for the individual ITS. Without a common base for the information, it cannot be shared between ITS.

ITS ARCHITECTURE

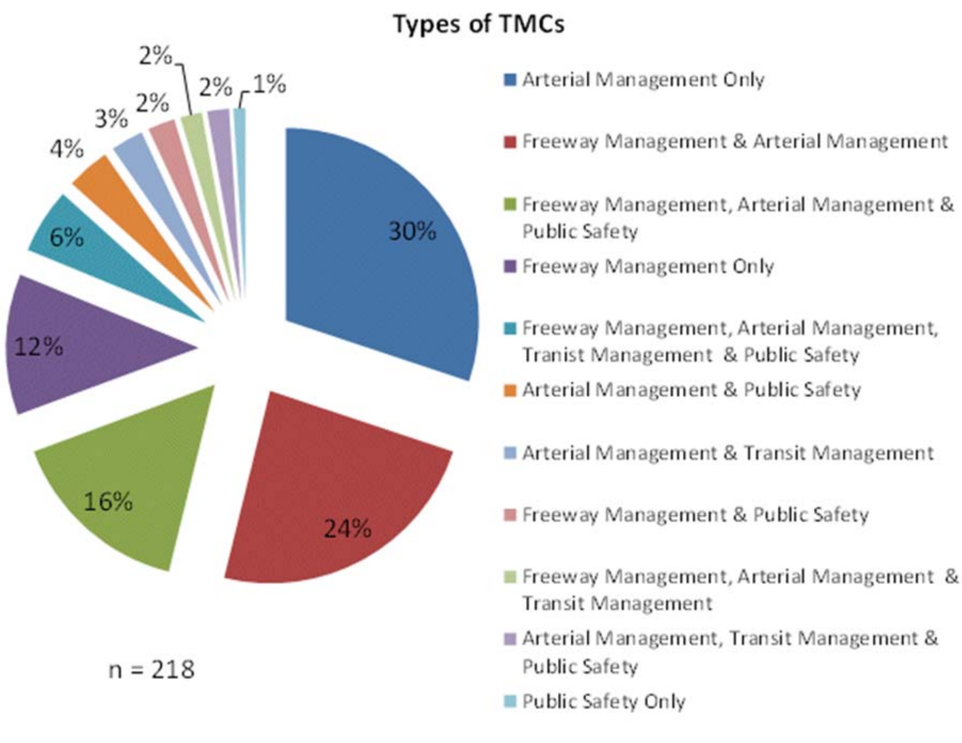
Researchers evaluated the available literature on ITS in the United States as it pertains to cross-border ITS. Specifically, the following was reviewed: the National ITS Architecture, regional ITS architectures, Texas' TxDOT ITS Strategic Plan, and connected vehicle technology.

Summary of Nationwide ITS Presence

TTI, working under a TxDOT contract, conducted an evaluation for the presence of ITS for all 50 states and 5 U.S. territories (*14*). Of the 55 locations studied, evidence of statewide ITS architecture was found in 36:

- 29 have ITS websites.
- 22 have branded ITS programs.
- 36 have a statewide map link for traffic information.
- 35 have a strategic ITS plan.

For over a decade, the Intelligent Transportation System Joint Program Office (ITS JPO) of the USDOT Research and Innovative Technology Administration has sponsored a project to track the metropolitan deployment of ITS. The most recent ITS deployment survey under this project was conducted in 2010, which surveyed seven types of agencies in 108 cities (*15*). Figure 9 presents a summary of ITS deployments across the country based on this survey.



Source: (15)

Figure 9. Breakout of TMCs by the Modes Supported.

National ITS Architecture

The national ITS architecture includes 97 service packages. A service package represents slices of the physical architecture that addresses specific services like the Traffic Incident Management

System. The only package that specifically addresses the border environment is service package CVO05-International Border Electronic Clearance. The USDOT provides the following description of this package on its website (*16*):

> This service package provides for automated clearance at international border crossings. It augments the Electronic Clearance service package by allowing interface with border administration and border inspection related functions. This service package processes the entry documentation for vehicle, cargo, and driver, checks compliance with import/export and immigration regulations, handles duty fee processing, and reports the results of the crossing event to manage release of commercial vehicle, cargo, and driver across an international border. It interfaces with administrative systems used by customs and border protection, immigration, carriers, and service providers (e.g., brokers) and inspection systems at international border crossings to generate, process, and store entry documentation.

Border Information Flow Architecture

In 2005, FHWA's Office of Freight Management and Operations, and Transport Canada's ITS Office spearheaded an effort in partnership with state and provincial departments of transportation (DOTs) and regional planning organizations to develop BIFA. The initiative involves numerous stakeholders and is intended to be a framework that depicts the flow of information between government (federal, state, and local) agencies and components of the transportation system, as they relate to border processes (e.g., the flow of advanced traveler information from inspection and enforcement agencies to transportation organizations). The objective is to develop an architecture to promote information sharing and coordination among agencies and stakeholders and increase interoperability of technologies used to support their operations.

While BIFA has been used limited in planning cross-border systems in the U.S.-Canada border, there is very little evidence to suggest that it has been used by public agencies on the U.S.-Mexico border for the same purpose. The BIFA was developed by a joint collaboration between the United States and Canada. However, it can be easily used to conceptualize systems on the U.S.-Mexico border.

Many southern border regions have developed regional ITS architectures, which provide a framework to support planning and programming of ITS projects in the region. Before using the regional ITS architecture, it is prudent to identify portions of 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 BIFA as a framework for identifying stakeholders, system requirements, and other key information.

BIFA does have components necessary to exchange information between regional and local TMCs in both countries in support of traveler information, incident management, tolling, etc. The most recent version of BIFA was released in 2012 with several refinements, including enhanced support for border wait time monitoring and dissemination and is available at http://www.iteris.com/itsarch/bifa/.

Snapshot of ITS Deployment in Various Texas Regions

As part of a TxDOT-sponsored report published in 2013, TTI researchers conducted a series of statewide interviews with stakeholders on their needs for ITS, the issues related to architecture on a statewide and regional level, specific goals for operations, and information about partnerships and expectations, especially in the future. In total, TTI researchers held 50 information-gathering sessions that included representatives from 84 stakeholder agencies, including all TxDOT district offices and some local area offices. Some participating cities included representatives from several departments (i.e., traffic operations, planning, fire, and police). The following section presents a summary of these interviews (*17*).

The researchers' goal was to provide a detailed inventory of ITS in various regions in Texas. The report notes that in many cases stakeholders were only asked to provide, or volunteered, this information to facilitate the regional issues and needs assessment process. The information that stakeholders provided, which is summarized here, is not a complete picture. It lacks information about ITS deployment and functions in larger urban areas (i.e., Houston and Dallas). The information received does provide a picture of the state of ITS deployment in Texas. The following list presents the ITS elements identified by stakeholders:

- Surveillance cameras of various types.
- Portable and permanent dynamic message signs (DMSs).
- Detectors (loops, microwave, video, Bluetooth, etc.).
- Weather stations.
- Flood, ice, and fog detection systems.
- Closed-loop, central, or adaptive signal control.
- Computer-aided dispatch for transit and emergency vehicles.
- Security cameras, automatic vehicle locator devices, data terminals, and global positioning system (GPS) on buses.
- Mobile data terminals and automatic vehicle locator on transit and emergency vehicles.
- Traffic signal preemption.
- Wired (including fiber) and wireless (Wi-Fi and radio-based) communications.
- Weigh-in-motion (WIM) stations.
- Highway advisory radio (HAR).

- Warning systems (signal ahead, speed on curves, and school zones).
- Technology for information dissemination to users, including email, text, and reverse-911.

TxDOT ITS Strategic Plan

The TxDOT ITS Strategic Plan published in 2013 provides a framework to guide the development and deployment of an integrated statewide ITS program (*18*). This section will discuss this plan as it pertains to cross-border ITS with TMC. The TxDOT ITS Strategic Plan for the fiscal years 2013–2017 has the same four goals as the TxDOT Strategic Plan: maintain a safe system, address congestion, connect Texas communities, and become a best-in-class state agency (*19*).

The TxDOT ITS Strategic Plan includes an objective and several strategies relevant to the border region:

- Objective – Deploy ITS and technologies that facilitate the efficient movement of freight and goods along strategic, high-volume freight corridors, including border crossings. Understand and address the freight community's needs for information.
- Strategies:
    - Deploy ITS to provide more seamless information to the freight community.
    - Implement and operate communications systems that can be shared with partner agencies and that meet the requirements of ITS services as the marketplace develops.
    - Fill in critical gaps in ITS in TxDOT districts and along strategic routes using TxDOT, partner, or private-sector resources.
    - Deploy and operate ITS services that provide pre-trip, en-route, and travel-demand management capabilities through public- and/or private-sector paths.
    - Provide active management of traffic and other progressive solutions services that can improve travel reliability and predictability.
    - Incorporate automated and semi-automated decision support systems into the ITS software and systems.

Candidate ITS Archetype

The main recommendation of the TxDOT ITS Strategic Plan is a proposed consolidation of the operations of core ITS functions into several primary TMCs located in strategic metropolitan areas (e.g., El Paso, Dallas, Houston, San Antonio, and Amarillo). The recommendation in the TxDOT ITS Strategic Plan describes in detail the role of the primary TMCs (*19*):

> These primary centers would assume responsibility for operating ITS devices on state-supported highway/freeway facilities and state-supported routes of significance in the major metropolitan areas, as well as the ITS devices in neighboring TxDOT districts. Operation of neighboring districts would primarily be after-hours or as preferred by the

districts. TxDOT would operate these primary centers 24 hours per day, seven days per week, and 365 days per year. These primary TMCs would support the following core ITS functions:

- The operation of permanent dynamic message sign (DMS) and other en-route traveler information systems.
- Freeway surveillance and traffic sensors systems.
- Traffic signal systems (if appropriate).
- Data archiving and performance measurement/reporting.
- Operation of dynamic traffic control devices, such as ramp meters and lane control signals.
- Operation of active transportation and demand management technologies.
- Work-zone and construction-related ITS.
- Weather-responsive traffic management (such as winter weather events, or hurricane evacuations).
- Coordination and potential sharing of assets (e.g., fiber).
- Implementation of pre-approved signal plans for local partners when appropriate.
- ITS performance monitoring and reporting.

The consolidation of TMCs is an important factor to take into consideration while evaluating the needs for cross-border TMCs since it may impact the functions of the current border TMCs. The TxDOT ITS Strategic Plan only includes a very high-level discussion related to the border regions and possible sharing/cooperation of ITS elements with Mexico. The discussion is centered on the needs presented by the stakeholders:

- Regional data needs –Local and cross-border sharing of data/information in the Laredo and San Angelo region.
- Border crossing needs:
  - Better tracking/recording of wait times at crossings.
  - Tracking of commercial vehicles into the United States.
  - Hazmat crossing information.

Texas Regional ITS Architectures

TxDOT developed its regional ITS architectures in the last 12 years. With the exception of Eagle Pass, which was completed in 2013, the rest of the ITS architectures have not been kept current. The following border cities have a regional ITS architecture: Laredo, El Paso, Del Rio, Eagle Pass, and Lower Rio Grande Valley (LRGV) (*20*).

Laredo, El Paso, Del Rio, and Eagle Pass

A scan of these cities' regional ITS architecture reveals little to no mention of cross-border ITS initiatives. Similar to the National ITS Architecture, service package CVO05 (International Border Electronic Clearance) is the only ITS package mentioned that is related to a cross-border environment. The deployment status of service package CVO05 varies by border city:

- Laredo: existing.
- Del Rio: planned.
- Eagle Pass: planned.
- El Paso: not planned.

Lower Rio Grande Valley

This city also includes service package CVO05 with a deployment status shown as future. However, unlike the other border cities, LRGV architecture also includes interfaces to SCT and Mexico Emergency Management Systems. These two Mexican agencies are shown interfacing cross-border data with the following LRGV agencies (Table 1).

Table 1. LRGV ITS Interfaces to Mexican Agencies.

Mexican Agency	U.S. Agency	Status
SCT	LRGV Regional Traffic Information Network	Future
	National Weather Service	Existing
	TxDOT Pharr District TMC	Future
Mexico Emergency Management Systems	• Brownsville Metropolitan Planning Organization (MPO) Traffic Management System	Future
	• Cameron County International Bridge Mgmt. Sys.	Future
	• City of Brownsville TMC	Future
	• City of Harlingen TMC	Future
	• City of McAllen TMC	Future
	• City of Pharr TMC	Future
	• Hidalgo/Reynosa Bridge Management System	Future
	• National Weather Service	Existing
	• Pharr/Reynosa Bridge Management System	Future
	• Private International Bridge Mgmt. Systems	Future
	• Tourism and Event Information Systems	Future
	• TxDOT Pharr District TMC	Future

With the exception of the interface to the National Weather Service that is already in place, all the other interfaces are shown as future.

Other Non-Texas Border Regional ITS Architectures

Vermont

CVO05 is the only ITS service package related to a cross-border environment that is mentioned on Vermont's regional ITS architecture. It shows status as planned. The architecture is from 2005.

In its ITS inventory, two cross-border elements are included, both with a planned status:

- IRP Clearinghouse: This is a registration reciprocity agreement among jurisdictions in the United States and Canada that provides for payment of license fees on the basis of fleet miles operated in various jurisdictions (21). IRP, Inc. is the corporation that administers the IRP Clearinghouse.
- Other States Credentials Admin and Safety Systems: Credentials and safety inspection systems in other states or Canada.

New York North Country Regional ITS Architecture

The North Country Regional ITS Architecture is comprised of five New York counties, some of them in the border with Canada. The architecture is from 2011.

CVO05 is the only ITS service package related to a cross-border environment that is mentioned on the New York North Country regional ITS architecture. It shows its status as planned.

This architecture does include multiple cross-border ITS elements focused on the international bridges, as shown in Table 2 (*22*).

Table 2. New York North Country Cross-Border ITS Elements.

ITS Element	Description	Status
International Bridge Authorities Traveler Information Systems	Represents the systems operated by international bridge authorities to distribute traveler information about the international bridge crossings to the general public. Maybe kiosks with 511 type information. Such information may include traffic conditions, roadway construction, and border clearance times.	Planned
International Bridge Authorities Operations Center	Operations centers for international bridge authorities in the region. Monitors and operates the approaches to and on the international bridges.	Planned
International Bridge Authorities Closed Circuit Television (CCTV) Cameras	Traffic monitoring CCTV cameras owned and operated by the International Bridge Authorities.	Existing
International Bridge Authorities CSC	Customer Service Centers for the International Bridge Authorities for servicing electronic payment instruments.	Planned
International Bridge Authorities Electronic Toll Equipment	Electronic toll collection equipment operated by the International Bridge Authorities.	Planned
International Bridge Authorities Infrastructure Monitoring Equipment	Infrastructure monitoring equipment, including security cameras.	Existing
International Bridge Authorities Maintenance Departments	Maintenance group for the International Bridge Authorities.	Planned
International Bridge Authorities Motorist Information Systems	Includes DMSs and HARs. HAR is planned.	Planned
International Bridge Authorities Payment Device	Electronic payment card or tag for paying electronic tolls.	Planned
International Bridge Authorities Toll Service Centers	Provides toll administration and customer service for each respective International Bridge Authority.	Planned

Buffalo-Niagara Binational Regional ITS Architecture

This region includes the metropolitan area of Buffalo, Niagara Falls, the surrounding municipalities in New York, and Region Niagara in Ontario, Canada. The architecture is from 2011. This architecture was specifically created for a border region and provides a detailed description of numerous cross-border ITS elements.

ITS service package CVO05 is thoroughly described in this architecture and proposed to be used by several U.S. and Canadian agencies as shown in Table 3. It shows its status as planned (*23*).

Table 3. Buffalo-Niagara ITS Elements.

ITS Element	Description
511 System - Canada	The 511 system for Canada, focusing on transportation and traveler information to the traveling public.
Canada Border Services Agency (CBSA)	This system supports screening and clearance of vehicles and persons entering Canada.
CBSA Border Inspection Administration	CBSA administration.
Automated Clearance System for U.S. Customs	This clearance system is operated by U.S. Customs at the international border.
Bridge Border Crossing Systems	Represents the electronic border crossing systems for pre-clearance credentials and information at the border crossings. The commercial traffic will electronically transmit the documentation prior to arrival to the border crossing so that an instantaneous clearance can be made. Includes The Niagara Falls Intelligent Transportation Border Crossing System and the similar system at the Peace Bridge.
U.S. Border Inspection Sensor Systems	Sensor systems (e.g., radiation portal monitors) used to sense threats in freight, vehicles, or travelers.

The architecture contains a comprehensive list of multinational stakeholders such as the ones shown in Table 4.

Table 4. Multinational Stakeholders.

Stakeholder	Description
Niagara Falls Bridge Commission	Operates the Whirlpool Rapids (Lower) and Lewiston-Queenston Bridges. Also operates and maintains facilities for Customs and Immigration functions on both sides of the border at the bridges.
Buffalo and Fort Erie Public Bridge Authority	Operates and maintains the Peace Bridge.
Niagara Falls Bridge Commission and Niagara Parks Commission	Represents the Niagara Falls Bridge Commission and the Niagara Parks Commission.
Niagara International Transportation Technology Coalition	Is an organization of 14 agencies in Western New York and Southern Ontario. The system includes four international transportation border crossings.

New Mexico

CVO05 is the only ITS service package related to a cross-border environment that is mentioned on New Mexico’s regional ITS architecture. It shows its status as planned. The architecture was updated in 2012. This architecture does include multiple cross-border ITS elements as shown in Table 5 (*24*).

Table 5. New Mexico Cross-Border ITS Elements.

ITS Element	Description	Status
Mexico Customs and Border Patrol	This element represents the border patrol agency in Chihuahua, Mexico, which also handles customs when entering into Mexico.	Planned
Mexico Public Safety	This element represents the public safety providers (police, fire, and EMS) in Chihuahua, Mexico, and the surrounding Mexican states.	Planned
Mexico Regional Maintenance Section	This element represents the maintenance function in Chihuahua, Mexico, that would coordinate with both New Mexico (District 1 and 2) and Texas.	Planned
Mexico Regional TMC	This element represents the regional TMC located in Chihuahua, Mexico, that would coordinate traffic information or operations with New Mexico and Texas.	Planned

Connected Vehicle Reference Implementation Architecture

The Connected Vehicle Reference Implementation Architecture is a comprehensive connected vehicle website sponsored by the USDOT's ITS JPO. The website is being developed as the basis for identifying the key interfaces across the connected vehicle environment that will support further analysis to identify and prioritize standards development activities. There are more than 80 connected vehicle applications described, including an application for Border Management Systems (*25*).

The Border Management Systems application is centered on international border registration, pre-processing, and border inspection capabilities. However, it also includes functionality applicable to border TMCs, such as collecting traffic conditions for vehicles operation near the border crossings and providing border status information to the traveling public. Table 6 shows the needs and requirements included for the Border Management Systems application.

Table 6. Connected Vehicle Needs and Requirements for Border Management Systems.

<table>
<tr><th>Needs</th><th>Requirements</th></tr>
<tr><td rowspan="3">Border Management Systems need to collect transportation-related data, including border crossing data to support planning and research activities that span the U.S. land border crossings.</td><td>Border Management shall collect traffic conditions data from vehicles acting as probes operating near a land border crossing.</td></tr>
<tr><td>Border Management shall collect border clearance data from systems at the border to support planning and research activities, including: number of people (passengers, drivers, and vehicle operators), number of vehicles, and types of goods.</td></tr>
<tr><td>Border Management shall provide the collected border activities statistics data to archived data and planning systems.</td></tr>
<tr><td rowspan="2">Border Management Systems need to be able to verify that people coming into the country are admissible and comply with federal laws and regulations.</td><td>Border Management shall collect traveler credentials information as travelers approach a land border crossing to support the determination that a traveler is in compliance with border crossing regulations.</td></tr>
<tr><td>Border Management shall notify travelers whether they are allowed to cross the border.</td></tr>
<tr><td rowspan="2">Border Management Systems need to be able to verify that vehicles coming into the country are admissible and comply with federal laws and regulations.</td><td>Border Management shall collect vehicle credentials information as vehicles approach a land border crossing to support the determination that a vehicle is in compliance with border crossing regulations.</td></tr>
<tr><td>Border Management shall send a notification to the vehicle whether the vehicle is allowed to cross the border.</td></tr>
</table>

Needs	Requirements
Border Management Systems need to be able to verify that goods and cargo coming into the country are admissible and comply with federal laws and regulations.	Border Management shall collect credentials information of cargo or freight equipment as its conveyance (e.g., truck, chassis, or other vehicle type) approaches a land border crossing to support the determination that that cargo or freight equipment is in compliance with border crossing regulations.
	Border Management shall send a notification to the conveyance (e.g., truck, chassis, other vehicle type) whether the cargo or freight equipment is allowed to cross the border.
Border Management Systems need to be able to provide border status and wait times to travelers approaching the border crossing or planning to cross.	Border Management shall provide border status information to travelers approaching or planning to cross a land border crossing, including: border open/closed status, border wait times, and expedited crossing lane availability.
	Border Management shall provide border status information to the traveling public using various means, including: traveler information service providers, traffic information signs, and in-vehicle signing.
Border Management Systems need to exchange commercial vehicle records with other agencies and stakeholders including credentials, status of the credentials, and records of fuel tax payments.	Border Management shall exchange commercial vehicle records with commercial vehicles, to support screening and expedited clearance at border crossings, including: credentials, credentials status, cargo manifests, tax payment reconciliation data, screening results, and inspection results.
Border Management Systems need to detect and identify the presence of hazardous materials (HAZMAT) on board commercial vehicles in order to support the quick effective response.	Border Management shall collect HAZMAT credentials data from vehicles and their cargo approaching a land border crossing.
	Border Management shall support verification that drivers and vehicles are authorized to carry HAZMAT across the border.
	Border Management shall collect electronic placard information as cargo or freight equipment approaches a land border crossing that indicates any and what type of hazardous materials are being carried.
Border Management Systems need to provide electronic communications with commercial vehicles to support security inspections and WIM detection.	Border Management shall provide pass or pull-in indicators to vehicles to go into or bypass secondary inspection stations at a land border crossing.
Border Management systems need to monitor traffic flow at or near a border crossing using data from vehicles and mobile devices acting as probes to provide information to the public, adjacent traffic centers, and other border stakeholders.	Border Management shall collect traffic and road conditions information from vehicles acting as probes at or near a land border crossing to support border operations and incident management, including: traffic data, road weather conditions, and maintenance and construction vehicle activities.

TMCS NEAR THE U.S.-MEXICO BORDER

This section describes the main characteristics and coverage of TMCs located at cities near the U.S.-Mexico border. Figure 10 shows the main U.S. cities located near the border with Mexico. Texas has seven major cities bordering Mexico: El Paso, Presidio, Del Rio, Eagle Pass, Laredo, McAllen, and Brownsville. However, only the Cities of El Paso, Laredo, and McAllen have TMCs established. In New Mexico, there is a statewide TMC, which is operated by New Mexico Department of Transportation (NMDOT) and is located in Albuquerque. In the state of Arizona, the closest city to the border that has a TMC is the City of Tucson. Finally, the California

Department of Transportation (Caltrans) operates a TMC in San Diego. The following paragraphs describe technology and capabilities of these TMCs.

Figure 10. U.S. Cities near the U.S.-Mexico Border.

Texas TMCs near the Border

TransVista

TransVista is the TMC operated by TxDOT El Paso district, and it is located in the City of El Paso. TransVista relies on the TxDOT Lonestar® traffic management software system, and provides three primary operations components: 1) traffic monitoring, 2) incident assessment and reporting, and 3) traffic management (*26*).

TransVista uses data from loop detectors, microwave detectors, and cameras. After this information is processed, TransVista informs travelers via DMSs, and/or lane control signals. Lane control signals instruct drivers which lane to avoid due to closure or incident. TransVista is synchronized with the City of El Paso TMC that is in charge of signal timing and coordination of approximately 650 traffic signals. Currently, TxDOT is installing new detectors that use Bluetooth technology and are able to capture traffic volume and speed.

The TMC operates Monday through Friday from 6 a.m. to 8 p.m. The official website for TransVista is http://its.txdot.gov/elp/elp.htm. This website is optimized for mobile devices, and includes the following information:

- Traffic Information:
  - Traffic map.
  - Travel times.
  - Incident map (detected by the Highway Emergency Report Operation program, police radio scanning, or communication with police department).
  - Lane closure information.
  - CCTV cameras.
  - DMSs.
  - Incident reports by El Paso Police Department.
  - Border wait times.
  - International bridge cameras.
- Emergency Information:
  - AMBER Alerts.
  - Weather information.
  - Homeland security.

TransVista covers a total of 121 miles of highways in the El Paso area (see Figure 11). Specifically, the corridors covered by TransVista are:

- 40 miles on I-10.
- 38 miles on Loop 375.
- 12 miles on US 54.
- 10 miles on SH 20.
- 9 miles on US 62/180.
- 7 miles on Spur 601.
- 3 miles on SH 178.
- 2 miles on Spur 16.

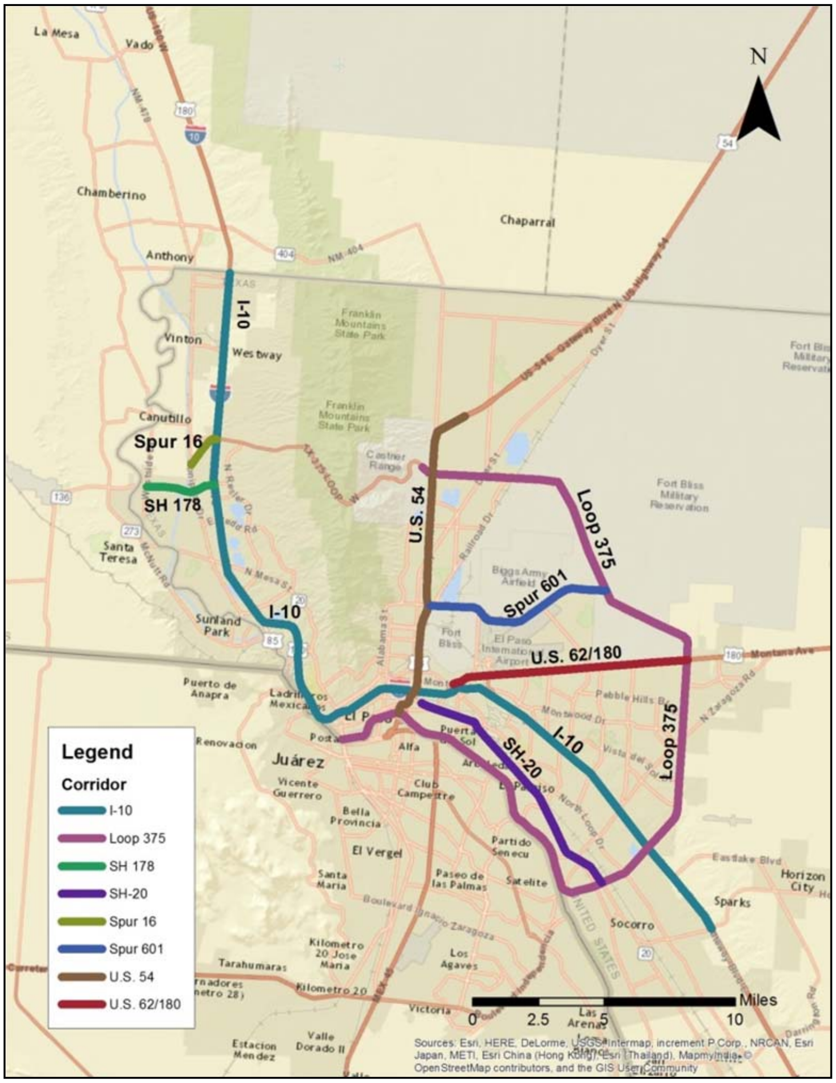
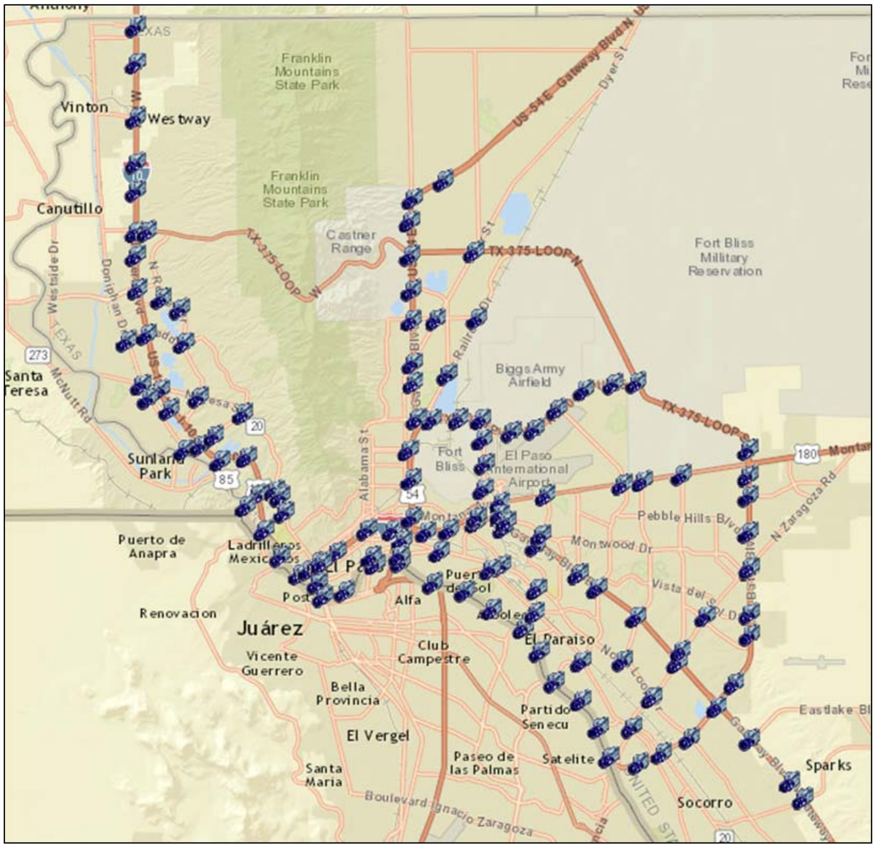


Figure 11. TransVista Coverage.

The following paragraphs provide information on TransVista ITS currently used and their locations.

Cameras

There are 159 cameras distributed along the 121 miles of highway covered. Figure 12 shows the location of the cameras.



Source: (27)

Figure 12. TransVista Camera Location.

Vehicle Detectors

There are 273 detectors in total, out of which 166 radar vehicle sensing devices are located on I-10, 37 on US 54, 47 on Loop 375, 17 on Spur 601, and 6 on SH 178.

Dynamic Message Signs

The TMC operates a total of 74 DMSs, out of which 25 are located on I-10, 17 on US 54, 23 on Loop 375, 2 on US 62/180, 3 on SH 178, and 4 on city streets.

Lane Control Signal Stations

Lane control signals are a specific type of lights used to manage traffic on a multi-way road or highway. The stations may consist of 2 to 6 heads, for a total of 237 heads. The TMC operates 82 signal stations in total. Currently, 34 stations are installed on I-10, 14 on US 54, 24 on Loop 375, and 10 on Spur 601.

Highway Advisory Radio

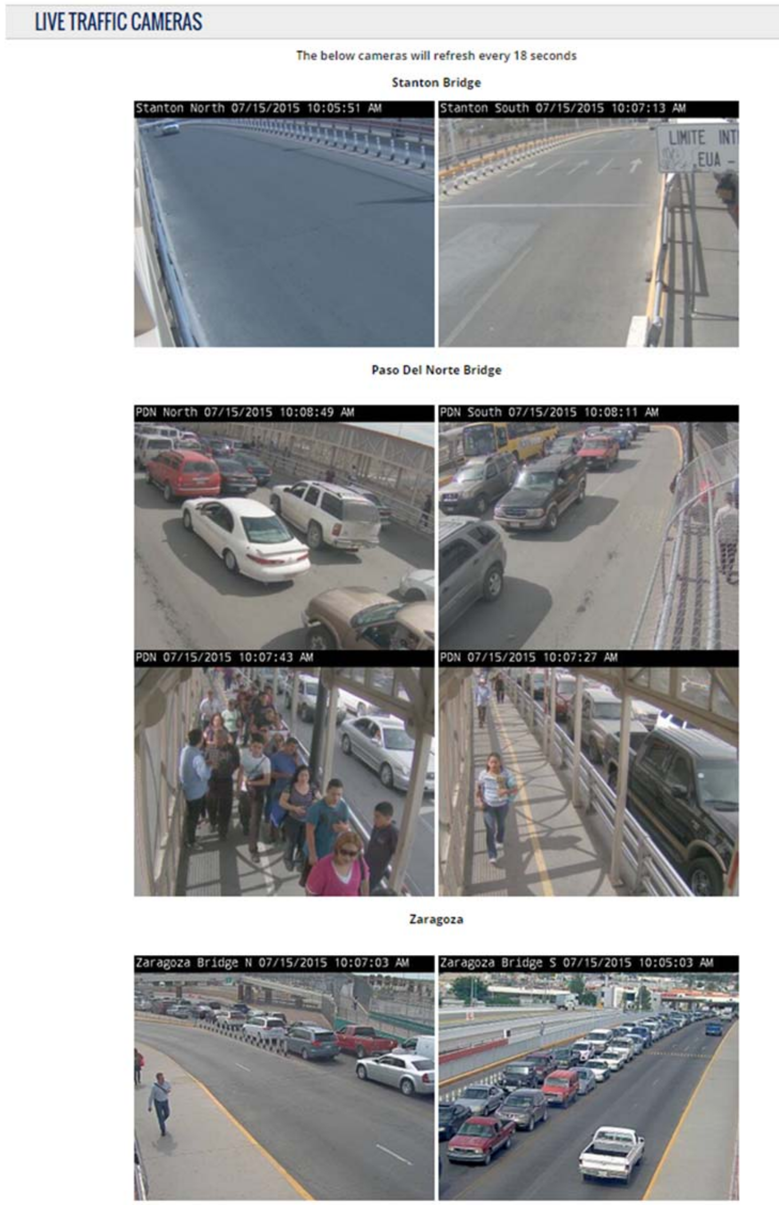
HAR is a traveler's information station to provide useful information for motorists about incidents, emergencies, dangers, etc. The TMC operates 13 radio controllers in total: nine on I-10, three on US 54, and one on Loop 375.

TransVista partners with four city agencies that help in the traffic management: El Paso Streets and Maintenance Department TMC, 911 Communication Center, Office of Emergency Management Communications Center, and University of Texas at El Paso Police Department. Media partners are KDBC-Channel 4, KFOX-Channel 14, KINT-Channel 26, KTSM-Channel 9, and KVIA-Channel 7.

City of El Paso TMC

The City of El Paso TMC is in charge of signal timing and coordination of approximately 650 traffic signals within the city limits, including those located on gateways and state highways. The signal timing is modified based on loop detectors installed at the entrance of intersections, so timing can be adjusted based on traffic volumes. Additionally, 350 CCTV detection cameras are installed in traffic signals to detect vehicles and optimize signal timings complementing loop detectors. The City of El Paso TMC and TransVista are in constant communication. However, the City of El Paso TMC decides which actions need to be taken based on traffic information provided by TxDOT.

The City of El Paso Bridge Department operates Stanton POE, Paso Del Norte POE, and Ysleta-Zaragoza POE; it also collects toll fees from passenger vehicles and commercial vehicles exiting the United States via these POEs. The City of El Paso also has cameras in every POE and posts snapshots of the bridges on a website (see Figure 13).



Source: (28)

Figure 13. Snapshot from Cameras Installed by City of El Paso on POEs.

City of McAllen Traffic Operations Center

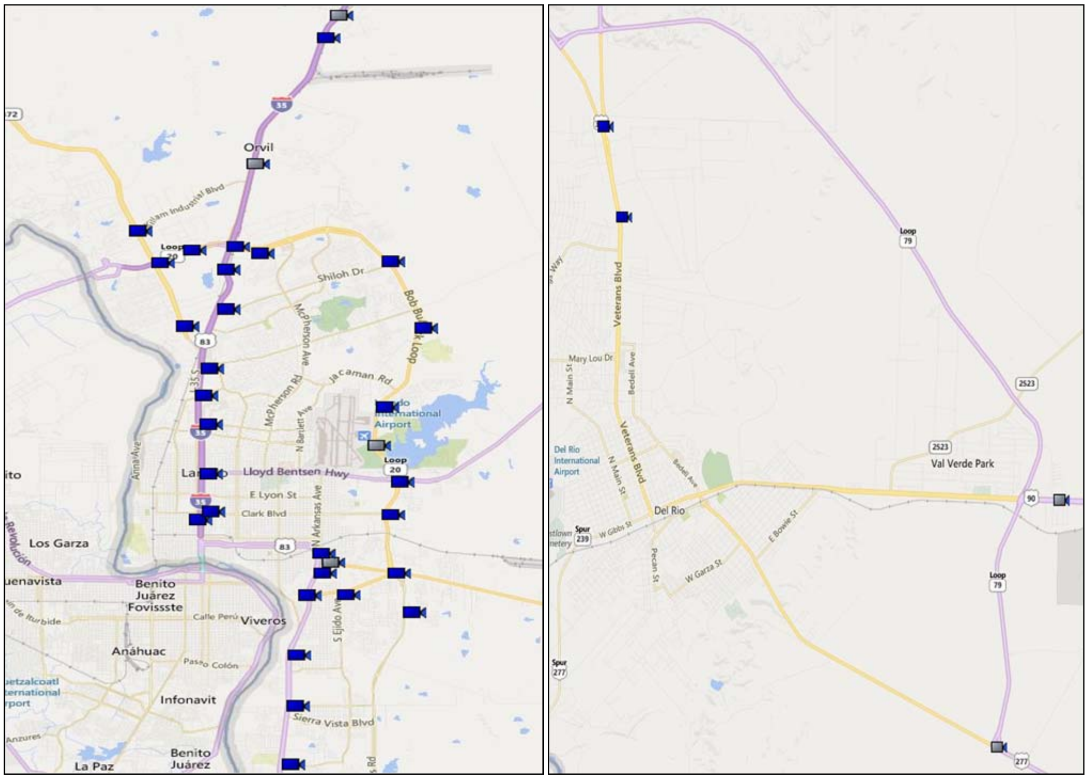
The City of McAllen TMC's primary operations components are traffic monitoring, incident assessment and reporting, and traffic management. This TMC includes four staff members who receive traffic emergency calls mainly related to traffic incidents. Two of these four staff members are 911 dispatchers, so they have direct communication with the McAllen Police Department and the Fire Department. The City of McAllen TMC has access to the McAllen Police Department CCTV cameras that cover the Downtown District, 6 miles of US 83, Bicentennial Blvd, and also 10th Street. Currently, the City of McAllen TMC can modify the signal timing of more than 50 traffic signals located in some of the most congested corridors in the city. The TMC reports any incident to the City of McAllen Public Information Department for its broadcast.

South Texas Regional Advanced Transportation Information System

South Texas Regional Advanced Transportation Information System (STRATIS) is located in the City of Laredo and operated by TxDOT. It was established in 2004 to support monitoring and management of the traffic operations. STRATIS monitors and manages traffic flows and detects highway incidents in the City of Laredo and the City of Del Rio; it relies on the TxDOT Lonestar® traffic management software system. The ITS currently used by this center are 21 DMSs, 37 CCTV cameras, 20 detectors, and 5 stations of flood detection located in the City of Del Rio. STRATIS hours of operation are Monday through Friday from 8:00 a.m. to 5:00 p.m. The San Antonio District TMC, TransGuide, operates DMSs after hours and during weekends. TxDOT is currently working on providing access to the STRATIS CCTV camera network to the City of Laredo Traffic Safety Department, Police Department, and Fire Department.

The TMC staff monitors the traffic on several corridors in Laredo and Del Rio with 37 CCTV cameras as shown in Figure 14. Cameras are placed as follows:

- 2 cameras on FM 1472, City of Laredo.
- 12 cameras on I-35, City of Laredo.
- 12 cameras on Loop 20, City of Laredo.
- 1 camera on US 59, City of Laredo.
- 6 cameras on US 83, City of Laredo.
- 2 cameras on Veterans Boulevard, City of Del Rio.
- 1 camera on US 90, City of Del Rio.
- 1 camera on Loop 79 with US 277, City of Del Rio.

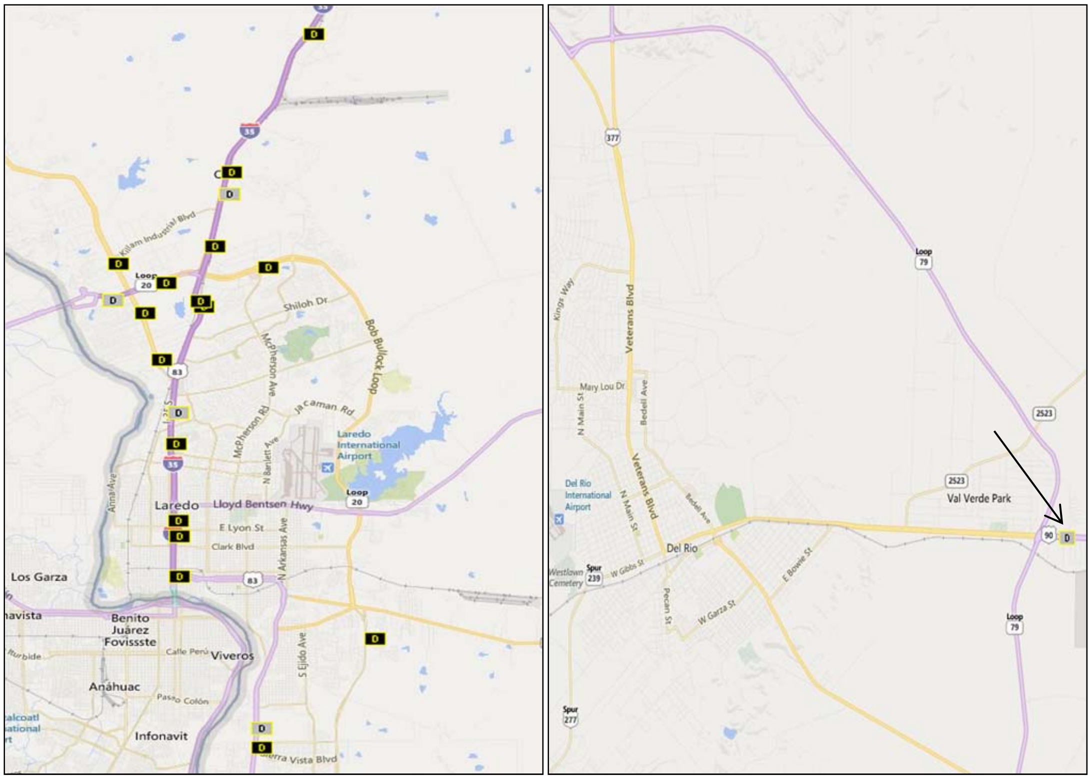


Source: (29)

Figure 14. Camera Positioning, City of Laredo and City of Del Rio.

Figure 15 shows DMS locations for Laredo and Del Rio, which are listed below with exact location:

- 1 sign on FM 1472 North, City of Laredo.
- 2 signs on FM 1472 South, City of Laredo.
- 5 signs on I-35 North, City of Laredo.
- 6 signs on I-35 South, City of Laredo.
- 2 signs on Loop 20 East, City of Laredo.
- 2 signs on Loop 20 West, City of Laredo.
- 1 sign on US 83 North, City of Laredo.
- 1 sign on US 83 South, City of Laredo.
- 1 sign on US 90 West, City of Del Rio.



Source: (29)

Figure 15. DMS Positioning, City of Laredo and City of Del Rio.

New Mexico TMCs near the Border

Traffic management in the state of New Mexico is centralized. The NMDOT ITS Operations, located in Santa Fe, oversees TMC operations. New Mexico has only one TMC located in Albuquerque. The center's hours of operation are Monday through Friday from 6 a.m. to 9 p.m., and weekends from 8 a.m. to 5 p.m. After hours, TMC operations are remotely administered. During adverse weather conditions, such as winter storms, the TMC operates 24/7.

The NMDOT TMC staff is responsible for monitoring and operating the systems on the state-managed roads statewide. The operators at the TMC dispatch the Highway Emergency Lending Patrol courtesy patrol vehicles in the Albuquerque Metropolitan Planning Area region, monitor traffic conditions using CCTV images and a congestion map, monitor the National Weather Service forecasts, and monitor and support the management of incidents on NMDOT facilities, including inputting information for broadcast to the public via DMS, the web, and phone 511.

Video control in the center is managed by Jupiter software, DMS/variable message sign (VMS) are managed by the Skyline software, HAR is managed by Platinum software, and traffic signal control is managed by Centracs (external, not managed by the TMC staff). Incident response and clearance times are reported by motorist assistance patrol units (*30*).

The NMDOT and Albuquerque TMC provide online interactive coverage and monitoring of the following:

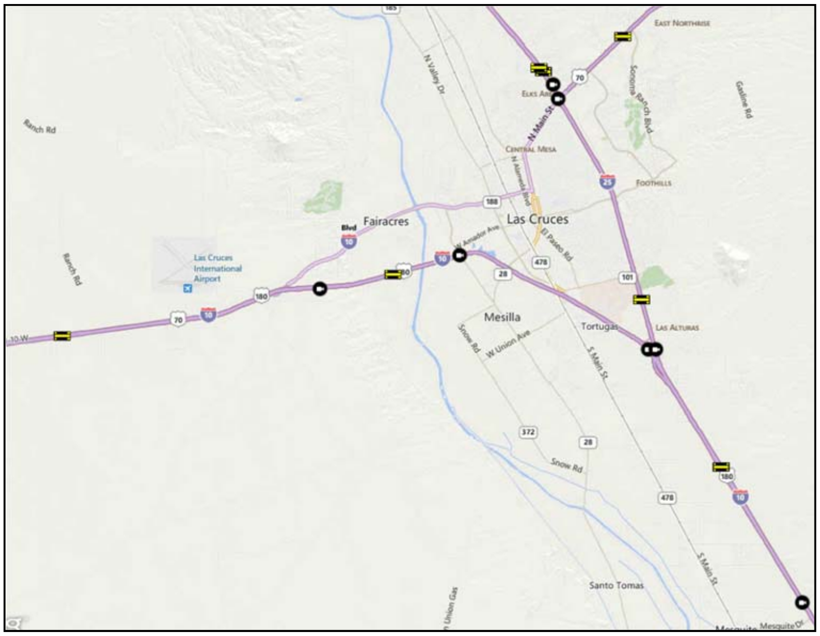
- Road conditions, which includes:
  - Road closures—Temporary closures due to weather events or incidents or seasonal closures.
  - Severe driving conditions.
  - Difficult driving conditions.
  - Fair driving conditions.
  - Seasonal closures.
  - Crashes (coordination with Albuquerque Police Department and state police).
  - Alerts.
  - Special event information.
  - 511 information from other states.
- Pan-tilt-zoom (PTZ) CCTV traffic cameras.
- VMS/DMS.
- Road construction information, which includes:
  - Construction closures (full and partial closures and minor roadwork where delays can be expected).
  - Lane closures.
  - Roadworks.
- Traffic conditions, which includes congestions and speeds statewide.
- Current weather conditions:
  - Weather advisories.
  - Current weather reports and radar loops.
- General transit and rest area:
  - Rest areas (locations, amenities, contact information, etc.).
  - Rail runner (station locations and schedules).
  - Park and ride locations.
  - Airports.
  - Bicycle routes.
  - Trucking restrictions.

The data can be accessed at http://nmroads.com/. It is also available as a mobile website and an application for iOS and Android platforms.

The following paragraphs describe the ITS located near the border in Las Cruces, Mesquite, Lordsburg, and Deming, which are controlled by the NMDOT TMC.

Las Cruces Area

In the Las Cruces area, there are six cameras monitoring traffic on I-10 and I-25. This area is also covered with eight DMSs on I-10, I-25, and US 70, as shown in Figure 16.

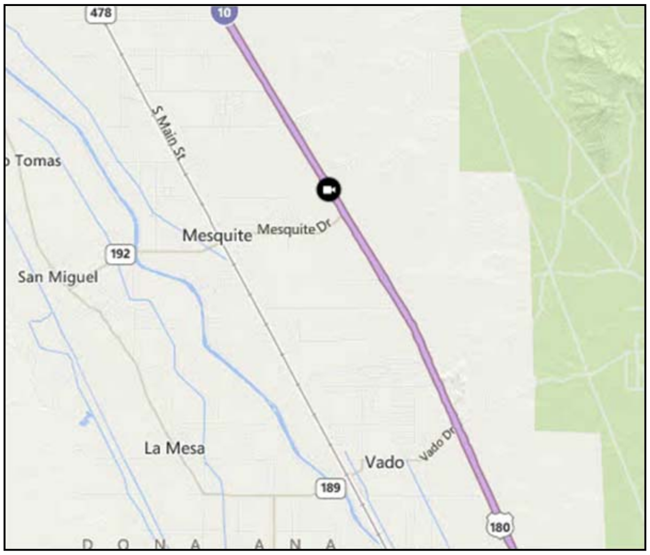


Source: (31)

Figure 16. Las Cruces DMS and Camera Positioning.

Mesquite Area

There is one camera location on I-10 next to Mesquite and no DMS, as shown in Figure 17.



Source: (31)

Figure 17. Mesquite Area DMS and Camera Positioning.

Lordsburg Area

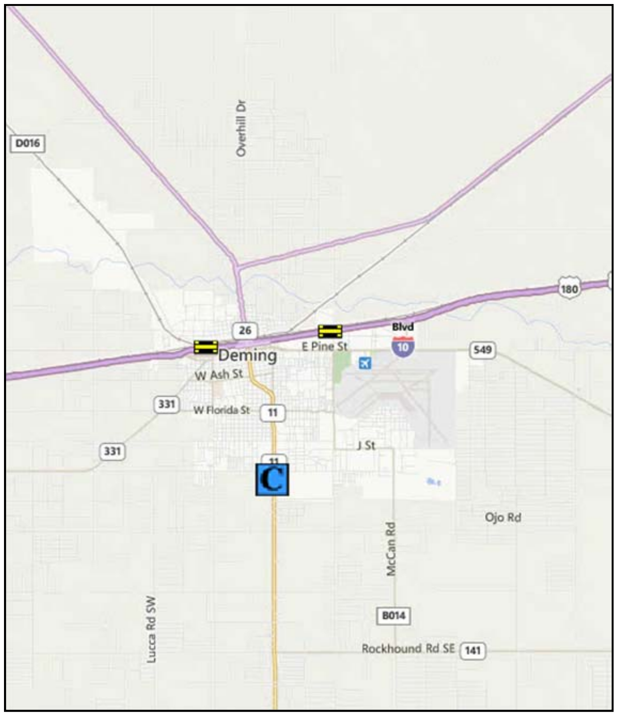
There are five cameras on I-10 monitoring the traffic next to Lordsburg and three DMSs, as shown in Figure 18.

Source: (31)

Figure 18. Lordsburg Area DMS and Camera Positioning.

Deming Area

There are two DMSs located on I-10 next to Deming, with no CCTV cameras installed, as presented in Figure 19.



Source: (31)

Figure 19. Deming Area DMS and Camera Positioning.

Arizona's TMCs near the Border

Arizona DOT (ADOT) has a statewide TMC. However, this TMC does not cover areas near the border. The main border cities of Arizona are Douglas, Nogales, and Yuma. However, none of these cities have a TMC. In fact, only the City of Nogales has traffic cameras, but the information collected is not used for traffic management purposes. The closest TMC to the U.S.-Mexico border in Arizona is the City of Tucson Regional Traffic Operations Center (RTOC).

City of Tucson Regional Traffic Operations Center

This RTOC monitors and controls all traffic signals in Pima County. The center partners with the State of Arizona, Pima County, City of Tucson (in charge of managing the RTOC), City of South Tucson, Town of Marana, Oro Valley, and the Pima Association of Governments.

The RTOC has a PC-based Windows® system that communicates with every intersection once per second, providing updates to the center. The RTOC is in charge of monitoring and managing arterial traffic signal systems, CCTV cameras, DMSs, and fiber optic communication. The monitoring is also provided to ADOT, the City's 911, and DPS. The staff also manages traffic volume and turning movement count programs for the city, along with warranting studies. They provide plans, specifications, and estimates for new signal and street light installations; assist consultants in the review and preparation of plans and specifications; and provide guidance and clarification during the construction phases (*32*, *33*, *34*).

California TMCs near the Border

California is separated into 12 independent TMCs. The San Diego TMC is responsible for all state operations south of San Clemente and as far east as the Arizona border. The San Diego, or District 11, TMC spans the entire California-Mexico border. The San Diego TMC is equipped with fiber optic cable, vehicle detection stations, CCTV monitoring systems, and various traffic operations field elements. Table 7 outlines the specific numbers for each technology.

Table 7. San Diego TMC Technology.

Technology	In Use	Under Construction	Planned	Future
Fiber Optic Cable	102.1 Miles	5 Miles	16.7 Miles	137.6 Miles
CCTV	154	9	554	
DMS	66	2		42
VMS	3			
Speed Feedback Sign	11			
Extinguishable Message Sign	17			
NCC HAR	2			22
HAR	4			
Loop Sensor	549			16
Radar Unit ID	295			
Sensys	2			
Ramp Meter	318			333

Although the District 11 TMC is well equipped overall, the lack of project funding has resulted in gaps in fiber optic coverage. Figure 20 show the gaps in fiber optic coverage in the District 11 TMC.

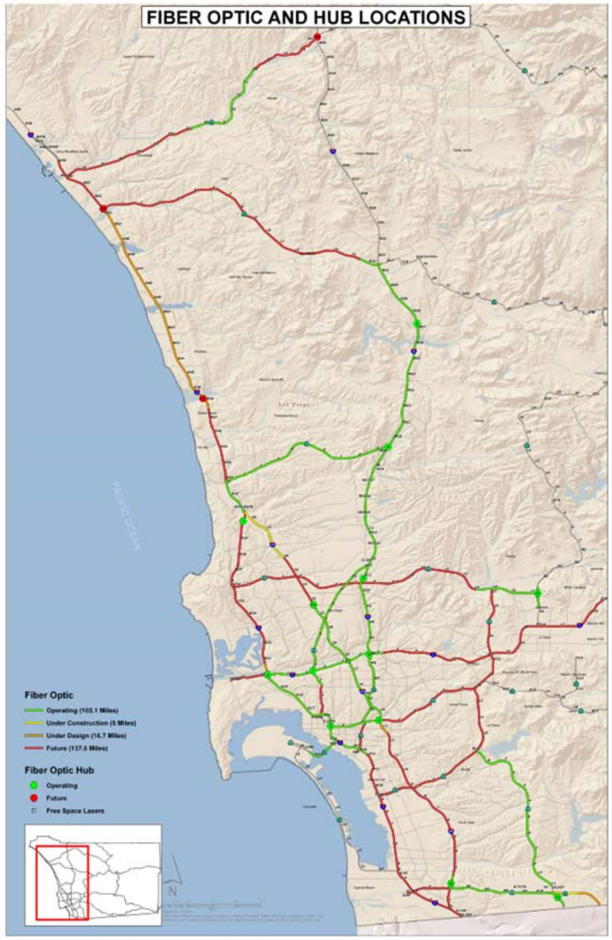


Figure 20. Fiber Optic and Hub Locations in District 11 TMC.

These gaps in fiber optic coverage are especially noticeable on major southbound roads leading to the California-Mexico border. These gaps in fiber optic cable mean that other services that rely on fiber optic, such as CCTV systems and vehicle detection stations are also scarcely available in the border region.

The District 11 TMC does not participate in any formal information sharing with the other TMCs in the state, but information from each TMC is gathered and made publicly available through the Caltrans' website. The website includes a feature called Quick Map, which allows the public to access current highway camera still shots, lane closure information, and up-to-date road signs across the state. Figure 21 shows the Quick Map website with the various options available to users.

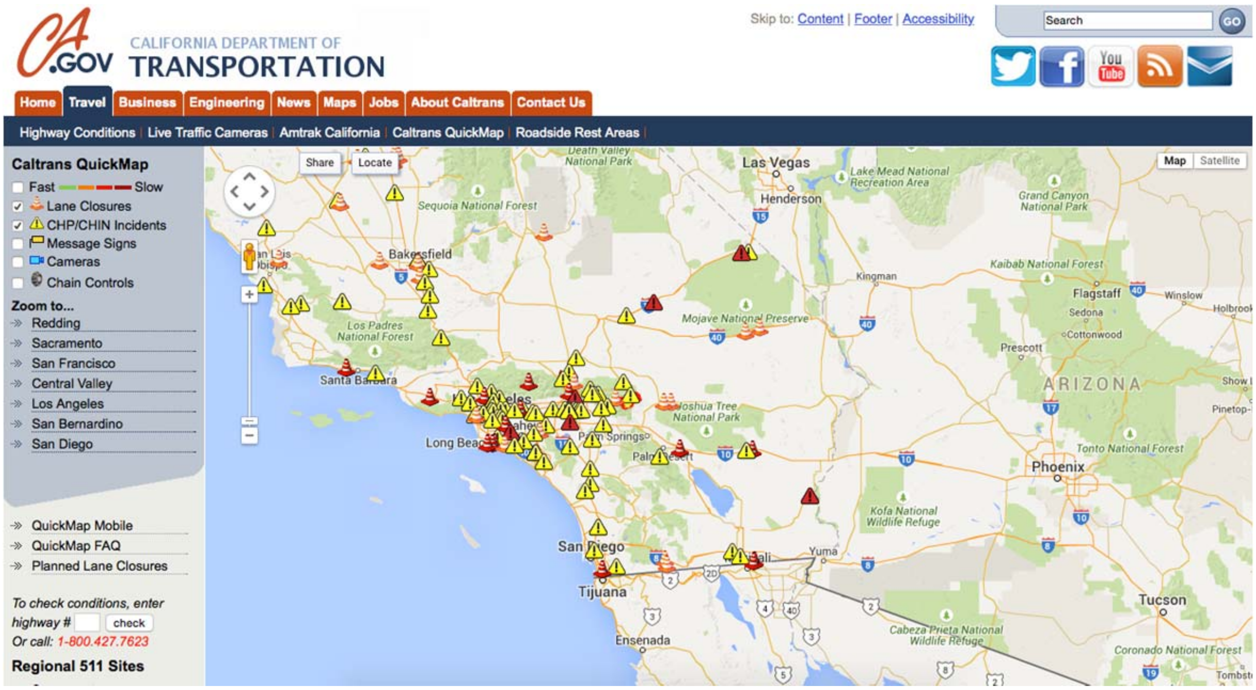


Figure 21. Caltrans Quick Map.

Aside from the limited information sharing conducted through the Quick Map website, there is no data sharing among the TMCs in California. The San Diego TMC has started exploring the possibility of sharing data between the San Diego TMC and a TMC under construction across the Mexico border. The biggest challenge to any future data sharing across the border is the format of the data collected on both sides of the border. Data formats would have to be compatible on both sides of the border, meaning there would have to be bilateral communication during the construction of the Mexican TMC in the Otay area.

TMCs and ITS in Mexico

Mexican authorities have not yet developed citywide systems to accurately and centrally control traffic. Most of the programs have been geared toward increasing security, which has a side effect of increasing information availability for traffic management. Some of the centralized existing or proposed centers in Mexican cities are:

- Command.
- Control.
- Communications.
- Computing.
- Intelligence.
- Integration.

- Information.
- Investigation (C4I4) Center in Mexico City.

The C4I4 center was established as a part of the Secure City program, which was created by the Emergency and Citizen Protection Center in Mexico City. The center started operating in July 2011 and provides information to authorities that manage emergency services in Mexico, supplying them with accurate information on transpiring incidents and guidance on how to handle them accordingly. This center's main goal is to use technology resources to reduce the time it takes for Mexican emergency services to respond to emergencies (*35*).

This C4I4 center was installed in the city to group the five previously existing Command and Control (C2) Centers. Currently the five centers continue to operate with the C4I4 focusing primarily on processes and information gathering. These centers use more than 20,000 cameras installed on main streets and areas with high pedestrian traffic, such as metro stations, as their main information-gathering tool (Figure 22) (*36*).

The cameras installed by this program are Samsung and Pelco PTZ IP 360° cameras, which use optic fiber to connect with the C4I4 system (*37*).

Source: (38)

Figure 22. PTZ IP Cameras Installed in Mexico City.

To increase the services provided to the citizens of Mexico City, the local government will invest $9.5 million to install 3,000 intersections with intelligent traffic lights, which will be controlled by the C4I4 center. The installation of these traffic lights will be during 2015, with a focus on reducing travel and wait times caused by traffic accidents and congestion (*39*).

Traffic Orientation Center in Mexico City

Mexico City's public safety department created the center for traffic orientation in 2011. The main goals for the new center were to generate traffic-related information and directly provide year-round information to the general public (*40*). This center provides information through social networks, such as Twitter and Facebook, on the state of traffic congestion throughout the city (*41*). To be able to accomplish this, it uses information gathered by 3,000 policemen, 230 police cars, 100 police motorcycles, and helicopters.

This center does not use technological resources in the data-gathering process. It primarily uses information reported by emergency service providers and by civilians, with additional information coming from other dependencies reporting to the Federal District's Government such as the Federal District's Police Department, the Proximity Police Department, the Department for Works and Services, the Waterworks system, and the C4I4 among others.

Traffic Light Centers in Various Mexican Cities

Because controlling traffic lights independently to manage traffic in a city became increasingly difficult as cities grew, a solution was developed in which cities centralize their traffic light controls to manage them appropriately (Figure 23). Adding to the development of this type of system was the addition of intelligent traffic lights.

Source: (42)

Figure 23. Example of Traffic Light Video Camera.

Centralized traffic light systems operate with the use of information generated from video cameras or sensors at the intersections. These can provide information on the velocity of vehicles approaching the intersection, the number of vehicles approaching from each direction, and a video feed of the intersection.

The cities in Mexico that include these types of centralized traffic light systems are Mexico City, Cancún, and Chihuahua.

Mexico City

As previously stated, the Government of Mexico City decided to install a monitoring system for the intelligent traffic lights as part of the C4I4 system (command, control communications, computing, intelligence, integration, information and investigation). This system will control 3,000 intersections, each fitted with intelligent traffic light systems using cameras designed to analyze vehicle speed and traffic direction. This system will be controlled by the Public Security Department, and is designed to reduce vehicle transit time, fuel consumption, and wait times while in high traffic.

Cancun

One of the centralized traffic light systems in Mexico is in the city of Cancún, Quintana Roo. This Centralized Traffic Light Center was developed to reduce wait and transit time for vehicles moving through the city. It uses cameras to detect the number of vehicles and their speed across the 162 intersections at which cameras are installed (*43*).To develop this multistage project, the city invested $2.7 million in the first stage of this center, which currently controls 162 road crossings throughout the city. Sixty-two of those crossings use an intelligent program developed to control these centralized or intelligent traffic lights, and the other 100 are just normal traffic lights that can be controlled by policemen working in the Centralized Traffic Light Center (*44*).

Chihuahua

This city has a Centralized Traffic Light System, which up to this point operates at 233 intersections along 10 main streets. This system includes several different types of intelligent and non-intelligent traffic lights (*45*).

Highway Alert from CAPUFE

The Highway Alert program was established by Mexico's Federal Highway and Bridges Administration (Caminos y Puentes Federales [CAPUFE], Mexican toll road operator). The alert system was designed to report information on the state of highways in the country and present highway alternatives for citizens with the end goal of reducing travel times and fuel consumption.

This administration uses reports from highway services and from an established emergency telephone line to report on incidents, high traffic areas, and road works from which a general report is made and presented through the Internet and in the affected areas. These reports include the location of the incident, the type and extent of the accident, and the precautions that should be undertaken while driving through the affected area.

The CAPUFE installed solar powered emergency telephones along the highways in the country for users who suffer accidents (Figure 24). These emergency telephones are connected directly to CAPUFE's emergency response service that generates new highway alerts.

Source: (46)

Figure 24. CAPUFE Highway Alert Program Information Screen.

Automatic Vehicle Identification from CAPUFE

Automatic Vehicle Identification (IAVE) from CAPUFE is a highway electronic toll collection mechanism used to facilitate the collection of tolls along the country's highways. This system started operating on August 1, 2014, using RFID technology to expedite toll collection processes throughout the highways in the country.

This system was built upon the existing electronic tolling system in the country, which was handled by two competing companies and needed two RFID tags for each car. The two companies that handled electronic tolling in the country, CAPUFE and Pinfra, signed a countrywide interoperability agreement, which produced this new countrywide IAVE system (Figure 25). To use this system a user needs to obtain an RFID tag from CAPUFE, such as the one shown in Figure 25, and register it using the vehicle's primary user's personal information.

Source: (47)

Figure 25. CAPUFE's IAVE Tag.

After the tag has been registered, the user must establish a payment method either by providing a valid credit card or adding funds to their RFID card online or at the CAPUFE's offices. Once the payment method has been established, the user can go ahead and use the RFID reader stations at the tollbooths located along the highway system. CAPUFE's system uses RFID readers at toll booths and at all highway exits (such as the one in Figure 26) to be able to calculate the charge each vehicle incurs.

The operation of these electronic tolling booths is heavily regulated by Mexican laws; there are three official Mexican laws, two international laws, and seven manuals designating the characteristics of the installation required for IAVE tag use.

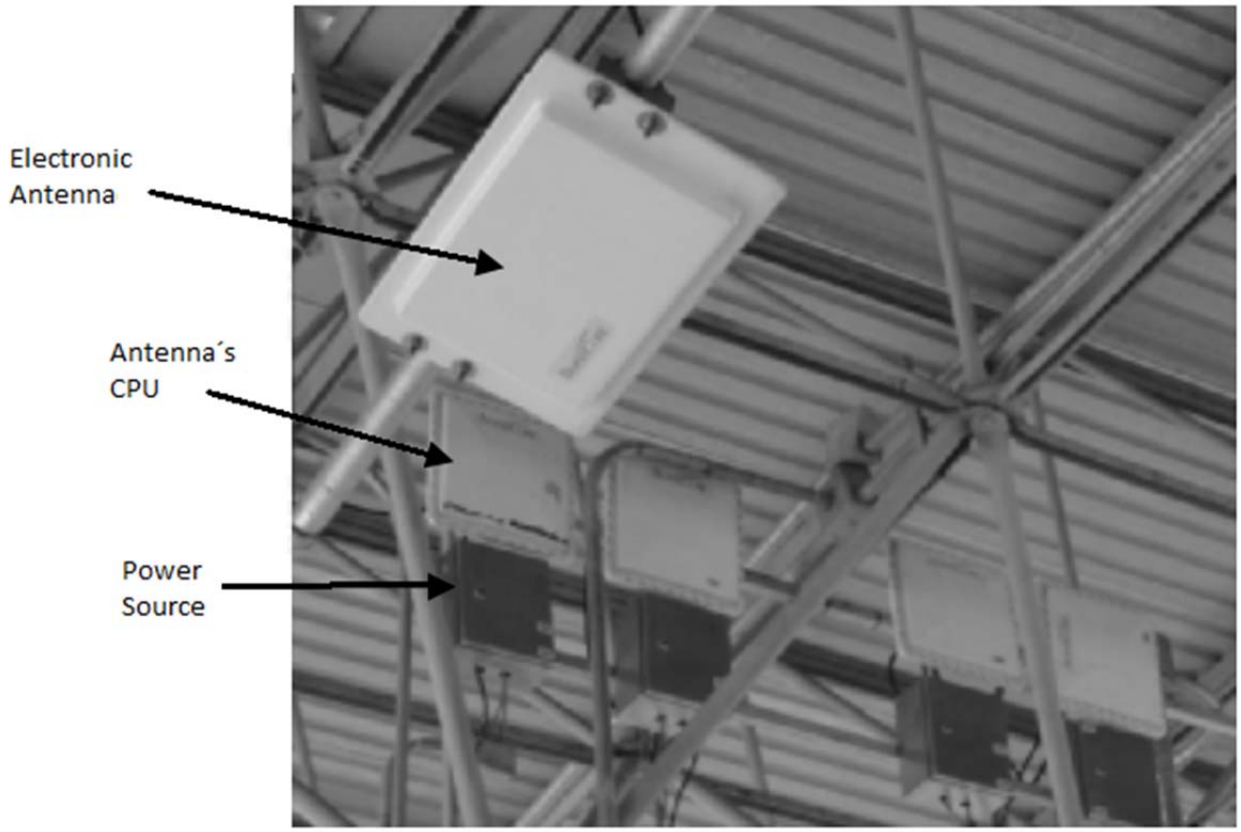
IAVE tags operate between the ranges from 902 MHz to 928 MHz with an operating distance of 9 meters. These tags have an expectation of operation period of at least 10 years, with an encryption standard Advanced Encryption Standard. Tags have a data reading rate of 512 bits per second (*48*).

The tag's memory is divided as follows:

- 500 bits for encrypted user data.
- 64 bits for global identifier.
- 32 bits for the tag´s identification.
- 32 bits for password accessing and erasing.

The IAVE readers need to meet operational restrictions similar to the ones the tags are set to and also need to comply with all the structural and construction laws of the country.

The IAVE readers operate in the same frequency, operating up to a distance of 5.5 m with a maximum operating power of 4 watts. The readers have to read tags up to a speed of 110 km/hr, with an error rate of no more than 0.05 percent (*49*).



Source: (49)

Figure 26. IAVE System RFID Readers.

TMC COST ESTIMATE

Based on experience in prior work at other TMCs, and cross checking with US Department of Transportation ITS Knowledge Resources (*50*), a rough order magnitude estimate was developed for a border TMC in the U.S. The estimates assume four international crossings to be covered by the TMC. It is important to note that prices might change in Mexico, particularly installation costs could be lower than in the U.S. The cost of the actual TMC building is not included in the estimate, as an existing space could be adapted to house the TMC.

Table 8 shows the cost estimate for field devices and TMC basic functions assuming four international crossings.

Table 8: Cost Estimate for a Basic TMC in U.S.

Basic TMC	Unit Cost	Qty	Subtotal
Basic Functions			
Advanced Traffic Management System Software	500,000	1	$500,000
Supporting Software	350,000	1	$350,000
Video Wall/Displays	250,000	1	$250,000
Workstations	20,000	4	$80,000
Furniture	25,000	4	$100,000
Backup Power/Filters	250,000	1	$250,000
Servers/Racks/Support	200,000	1	$200,000
Internal Comm	250,000	1	$250,000
External Interfaces	100,000	1	$100,000
Binational Comm/Connections	200,000	1	$200,000
Power/Building Improvements	400,000	1	$400,000
Subtotal			*$2,680,000*
Management/Procurement		0.15	$402,000
Design/Engineering		0.2	$536,000
Revised			$3,618,000
Contingency		0.2	$723,600
SUBTOTAL			**$4,341,600**
BASIC FIELD DEVICES (including basic enclosures/mounting)			
Dynamic Message Signs (Medium) - Comm Wireless/AC Power	175,000	8	1,400,000
Border Wait Time Detection - Comm Wireless/AC Power	12,000	32	384,000
Border Wait Time Detection - Comm Wireless/Solar Power	20,000	8	160,000
Travel Time Detection - Comm Wireless/AC Power	25,000	12	300,000
Basic Queue Cameras (Wireless/AC)- Fixed - Existing Structure	15,000	8	120,000
Traffic Surveillance Cameras (Wireless/AC) - PTZ w/Pole	40,000	8	320,000
			2,684,000
Management/Procurement		0.15	$402,600
Design/Engineering		0.15	$402,600
Install		0.15	$402,600
Revised Subtotal			$3,489,200
Contingency		0.2	$697,840
SUBTOTAL			**$4,187,040**
TOTAL ESTIMATE			**$8,528,640**

SUMMARY OF FINDINGS

Technology and Data at the Border

The most used technologies that are currently being used at land POEs are LPRs and RFID. LPR technology is used by CBP to identify vehicles entering the United States before they reach the primary inspection booth. RFID technology has a widespread use at land POEs. The RFID system is also used by CBP to gather information from tags that commercial vehicle have attached to windshields. This provides the CBP officer with information before the commercial vehicle approaches the booth. CBP trusted-traveler programs for passenger and commercial vehicles also have RFID devices. The toll authorities at international bridges also rely on RFID technology to collect tolls automatically. Commercial vehicle border wait time measurement systems use RFID devices to collect truck identification.

ITS Architecture

The national ITS architecture includes only one service package (CVO05) that addresses specifically the border environment. However, this service package is focused on automated clearance for commercial vehicles at international border crossings.

The Texas regional ITS architectures for the border cities of El Paso, Laredo, Eagle Pass, Del Rio, and the LRGV reveal little to no mention of cross-border ITS initiatives. All of these cities include also service package CVO05. The LRGV is the only architecture that includes interfaces to Mexican agencies.

Outside of Texas, the ITS architectures for other states or cities along the U.S. borders present a mixture of the level of integration of cross-border ITS elements. The New York North Country and Buffalo-Niagara binational regional ITS architectures include multiple cross-border ITS elements focused on the international bridges. In particular, the Buffalo-Niagara binational regional ITS architecture was specifically created for a border region. The Vermont and New Mexico regional ITS architectures are similar to the Texas regional ITS architectures containing only a few cross-border ITS elements.

The Connected Vehicle Reference Implementation Architecture includes the Border Management Systems application that is centered on international border registration, pre-processing, and border inspection capabilities. However, it also includes functionality applicable to border TMCs, such as collecting traffic conditions for vehicles operation near the border crossings and providing border status information to the traveling public.

TMCS near the U.S.-Mexico Border

Texas

There are four TMCs near the Texas border: 1) TransVista, El Paso; 2) City of El Paso TMC, El Paso; 3) City of McAllen Traffic Operations Center, McAllen; and 4) STRATIS, Laredo. TransVista and STRATIS are owned and operated by TxDOT. The City of El Paso TMC and the City of McAllen TMC are owned and operated by the cities of El Paso and McAllen, respectively. None of the four centers consider delay in border crossing operations or traffic congestion around the POEs in their decision-making process. Additionally, there are no communication channels established between these centers and CBP to improve congestion levels around POEs.

New Mexico

The NMDOT ITS Operations is the only TMC that monitors and manages traffic operations in this state. Currently, this center does not cover traffic operations in border cities.

Arizona

The City of Tucson RTOC is the closest TMC to the border of Arizona. However, this center only operates within the City of Tucson limits, which is located 70 miles away from the border.

California

The San Diego TMC is the largest TMC near the Mexican border in California. Currently this TMC does not interchange data with Mexican authorities; however, there are plans to build a TMC in Tijuana and eventually information will be exchanged between the two regions.

Mexico

There are no TMCs in Mexico that are dedicated to traffic activities. Most of the centers are used for security purposes. There is some traffic information that is collected and could be used for emergency responses or other activities, but not for traffic management purposes.

2. STATE OF THE PRACTICE AND BEST PRACTICES

This chapter:

- Investigates the existing and planned TMCs along the U.S.-Mexico border and capture the TMC and ITS inventory on the largest twin cities along the Texas border.
- Researches European and Asia practices, where the closeness of many countries over a small geographic area and a very active cross-border traffic flow has made Europe in particular a leader on this topic.
- Presents case studies of projects that showcase a coordinated binational effort.
- Evaluates existing and new ITS technologies that agencies can apply to the border to assist travelers.

TMC AND ITS INVENTORY ON THE LARGEST TWIN CITIES ALONG THE TEXAS BORDER

This section provides an inventory of TMCs and ITS that currently exist in the largest cities along the Texas border (i.e., El Paso and Laredo) that have Mexican twin cities. The Mexican cities of Ciudad Juárez and Nuevo Laredo are the twin cities of El Paso and Laredo, respectively. There are no TMCs in Ciudad Juárez and Nuevo Laredo.

El Paso TMC and ITS Inventory

There are two TMCs located in the City of El Paso. The first is TransVista, owned and operated by TxDOT, and the second is City of El Paso TMC, owned and operated by the City of El Paso. This section presents an ITS inventory of these two TMCs and the traffic-incident detection and response protocol currently used in the City of El Paso.

TransVista owns and operates 159 CCTV cameras, 273 vehicle detectors (of which 166 are radar-vehicle sensing devices), 74 DMSs, 82 lane-control signal stations, and 13 HAR controllers. These ITS are strategically distributed along the 121 miles of highway covered by TransVista. Table 9 provides specific information of manufacturers and models (if available) of TransVista ITS.

Table 9. TransVista ITS Manufacturer and Model.

ITS	Manufacturer	Model
CCTV Cameras	COHU	3855, 3955, 3960 & 3965
	WTI	SW720A
Vehicle Detectors	Image Sensing Systems	X2, X3 & G4
DMSs	Adaptive	VMSLED-L-3-18F-27x125-I & VMSLED-L-3-12F-27x125-I
	FDS	N/A
	Skyline	N/A
Lane Control Signal Stations	Micro Aide	N/A
	USA Signal Technology	N/A
	Southern Manufacturing	N/A
	SES America	Smart Lane Control Sign -4
HAR	MH Corbin Inc.	HAR 100

On the other hand, The City of El Paso TMC is in charge of signal timing and coordination of approximately 650 traffic signals within the city limits, including those located on frontage roads and state highways. The signal timing is modified based on loop detectors installed at the entrance of intersections, so timing can be adjusted based on traffic volumes. Additionally, 350 CCTV detection cameras are installed in traffic signals to detect vehicles and optimize signal timings that complement loop detectors. These CCTV detection cameras are not used for incident detection.

TransVista and the City of El Paso TMC are in constant communication to perform effective and efficient responses to traffic incidents. TransVista detects traffic incidents by means of CCTV cameras and vehicle detectors. The City of El Paso TMC also detects traffic incidents by accessing TransVista's CCTV cameras. TransVista responds to traffic incidents using DMS, Lane Control Signal Stations, HAR, and by releasing information reports; meanwhile, the City of El Paso TMC responds to traffic incidents by modifying signal timings. Figure 27 shows the protocol followed by these TMCs to detect and respond to traffic incidents in El Paso.

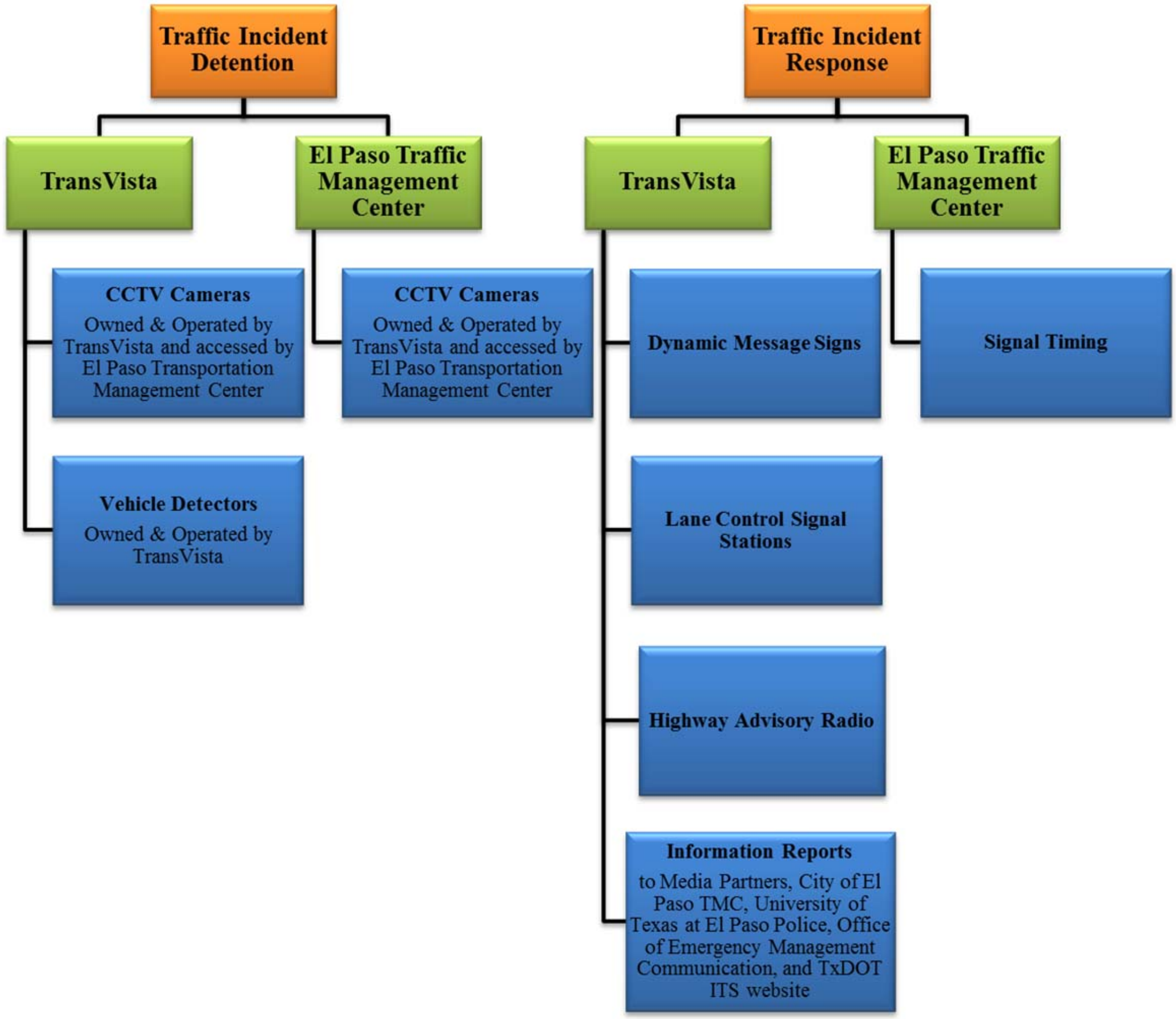


Figure 27. El Paso Traffic Incident Detection and Response Protocol.

Laredo TMC and ITS Inventory

STRATIS monitors and manages traffic flows and detects highway incidents in the City of Laredo and the City of Del Rio. The ITS currently used by this center in the City of Laredo are 20 DMSs, 33 CCTV cameras, and 20 detectors. STRATIS detects traffic incidents by means of CCTV cameras and vehicle detectors. On the other hand, STRATIS responds to traffic incidents by using DMSs and releasing information reports. Figure 28 shows the protocol followed by STRATIS to detect and respond to traffic incidents in Laredo.

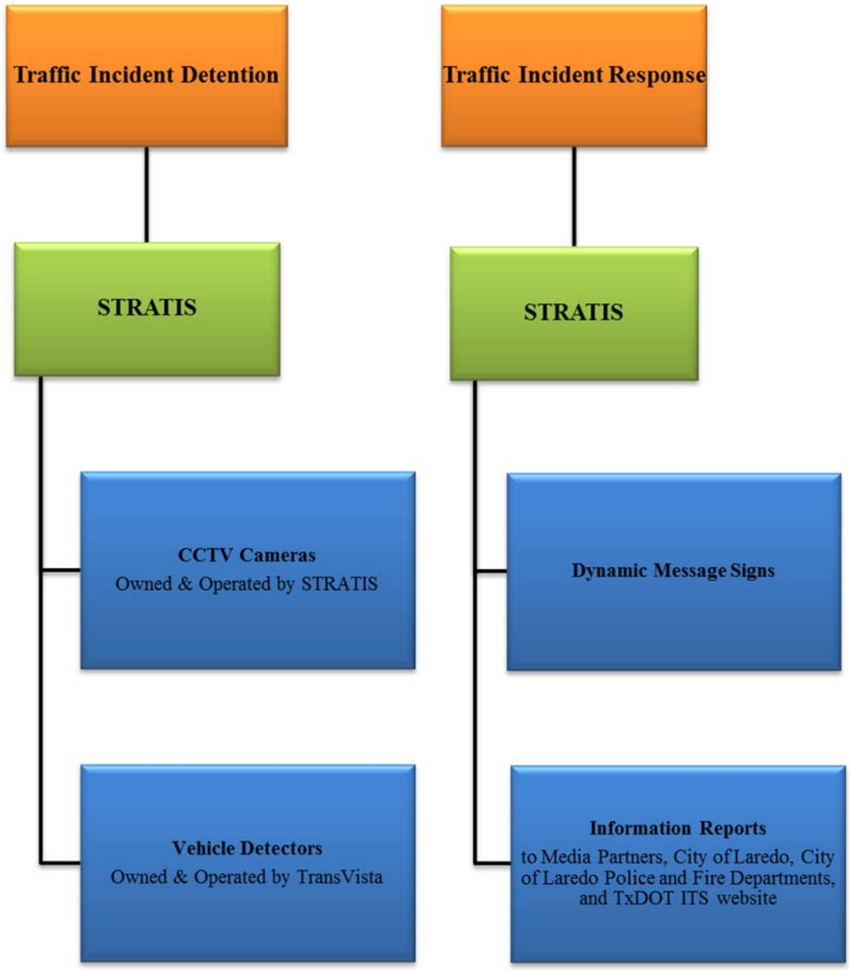


Figure 28. Laredo Traffic Incident Detection and Response Protocol.

PLANNED TMCS ALONG THE BORDER

The only planned TMC along the U.S.-Mexico border is in the San Diego-Tijuana region. The objective of this TMC is to manage traffic in Tijuana and especially to coordinate traffic operations at all the POEs in the area (Figure 29).

Figure 29. Tijuana-San Diego Region Border Crossings.

The Tijuana TMC will be collecting border-crossing times at all POEs and sharing that information with the San Diego TMC and with the border-crossing management system that is planned for the proposed POE at Otay Mesa East. The plan for Otay Mesa East is to have variable tolls that would be set as a function of the wait times and demand at all POEs in the region. The proposed TMC will monitor traffic on the access roads leading to the region's POEs, actual crossing times in both directions, and for passenger and commercial vehicles.

EXISTING AND NEW ITS TECHNOLOGIES APPLICABLE TO THE BORDER

In recent years, use of radio and wireless communication technologies such as Bluetooth, Wi-Fi, and RFID has increased at border crossings in order to identify travelers who will be allowed entry into the country and to measure wait times. Agencies deploy Bluetooth and Wi-Fi detection systems at border crossings all over the country mainly because of the proliferation of smart phones among travelers. On the other hand, RFID transponders are more common among truckers, who are provided with such devices by CBP in order to enroll the carriers in Free and Secure Trade (FAST) and User Fee programs.

More and more newly constructed or renovated border crossings are being fitted with dynamic lane management signs instead of fixed signs. Lane management signs are controlled by a central computer or by the officers in the individual lane. These signs direct travelers to move to or use appropriate lanes based on the type of vehicle and/or type of clearance program in which they are enrolled.

RFID and Wireless Communication to Measure Wait Times

Bluetooth and RFID technologies have become widely available to measure wait times at border crossings. TTI, with funding from TxDOT and FHWA, recently completed deployment of RFID technology at the seven largest border crossings on the Texas-Mexico border to measure border wait and crossing times of U.S.-bound commercial vehicles. ADOT also deployed a similar system at the Mariposa POE. San Diego is planning a similar system at its border crossings.

The RFID readers are deployed at several locations along the truck path both in the United States and Mexico in order to measure wait times of trucks. The wait-time measurement systems use multi-protocol readers to identify transponders issued by the CBP and tolling agencies in Mexico and border cities to motor carriers; the systems use that information along with time stamps to determine travel times between readers. The algorithms in the back office then estimate current and expected wait times.

Figure 30 shows RFID readers installed at the primary inspection facility at Ysleta-Zaragoza POE in El Paso. Figure 31 shows RFID readers installed at the primary inspection facility at Mariposa POE in Arizona.

Figure 30. RFID Readers Installed at CBP's Primary Inspection Facility at the Ysleta-Zaragoza POE.

Figure 31. RFID Readers Installed at CBP's Primary Inspection Facility at the Mariposa POE.

Because of the wide use of smartphones by motorists, sensing Bluetooth signals and identifying them to measure wait times has also gained popularity. TTI recently installed a Bluetooth technology–based, wait-time measurement system at the Ysleta-Zaragoza POE, as shown in Figure 32. Several Bluetooth readers were deployed on both sides of the border. These readers identify the unique identification of the Bluetooth device and send the information to a central service using cellular wireless. The server then computes current and expected wait times for passenger vehicles, and it is posted on a website developed by TTI. Similar systems have also been installed at the Detroit-Windsor Tunnel and the Ambassador Bridge connecting Windsor, Canada, and Detroit. There are plans to install the same detection devices in Sarnia, Canada, and Niagara Falls.

Figure 32. Bluetooth Reader Installed at CBP's Primary Inspection Facility at the Ysleta-Zaragoza POE.

Dynamic Signs for Lane Management

More and more POEs are being retrofitted with dynamic lane signs upstream and at the CBP's primary inspection facility. These signs have several objectives. They can direct traffic to a particular lane based on the type of vehicle or program in which the motorists/truckers are enrolled. As motorists/truckers approach the primary inspection facility, these signs can indicate if the lane is closed or open. One of the benefits of dynamic signs is that they allow flexible opening and closing of lanes and re-designation based on a queue of vehicles.

Figure 33 shows dynamic signs on a three-lane roadway leading to CBP's inspection facility at a POE on the U.S.-Canada border. Based on the queue of cars and trucks, sign operators can designate lanes accordingly. Figure 34 shows an image of CBP primary inspection facility at the Mariposa POE in Arizona. The image shows how CBP uses the dynamic lanes to inform travelers which ones are closed and open.

Source: (51)

Figure 33. Dynamic Sign Showing Lane Designation for Cars and Trucks at a POE on the U.S.-Canada Border.

Source: (52)

Figure 34. Dynamic Sign Showing Open and Closed Lanes at the CBP Facility at the Mariposa POE.

Connected Vehicles

The fundamental premise of the Connected Vehicle Environment lies in the power of wireless connectivity among vehicles, the infrastructure, and mobile devices to bring about transformative changes in highway safety, mobility, and in the environmental impacts of the transportation system. Over the past decade, wireless technologies and wireless data communications have fundamentally changed the way people live their lives.

The Connected Vehicle initiative was originally based on exclusive use of dedicated short-range communications (DSRC). DSRC is a fast, dedicated network that is particularly well suited to safety applications and was designed specifically for automotive applications. The DSRC standards and protocols are based on the Institute of Electrical and Electronics Engineers 802.11 standards for wireless local area networks like Wi-Fi. In the United States, DSRC operates over 75 MHz of spectrum in the 5.9 GHz band. In 2004, the Federal Communications Commission allocated this spectrum for use to protect the safety of the traveling public. DSRC can communicate directly between vehicles and infrastructure and has low latency, but it also has limited range.

Deployment of connected vehicle systems and application has the potential to reduce costs relative to deployment of older technologies. For example, DMS, HAR, or static signs may become unnecessary if vehicles receive traveler information directly from their connected onboard vehicle devices. Border crossings with high volumes have technology to measure wait times and provide traveler information. State or provincial agencies with federal involvement deployed the majority of these systems, while private concessionaires deployed others. Several border crossings already use Bluetooth, loops, and RFID technologies to measure wait times. It can be expected that agencies will migrate to connected vehicle technology only after there is a significant penetration of new devices and demonstrated capabilities for advanced data collection (e.g., position data to the lane-level) resulting in more precise wait-time information. Agencies will be able to relay geographically relevant, border-related information through in-vehicle displays rather than fixed devices such as DMS.

With adequate density of DSRC-equipped vehicles, wait times of different lane types can be estimated and subsequently directed to appropriate lanes. Roadside equipment to identify the vehicles could be fixed or portable, but backhaul to central location is optional since approach management can be done locally. Lane-level mapping support will be required to identify different approach lanes. Siting dependencies of the roadside units are not critical if vehicles can be read in any direction. Management of data collected by roadside units is not required and neither is the back-office service since a central server connected to all roadside units can evaluate approach lane management strategies and send messages to overhead signs and vehicles.

Smartphone Apps

Several smartphone applications share information to POE users. For example, CBP has an application that shows border wait times at every land POE, with the information refreshed frequently (http://apps.cbp.gov/bwt/mobile.asp). The app also provides information on the number of lanes open for each vehicle category.

Other apps use crowd sourcing from GPS. These apps are in operation at the U.S.-Canada border. Some apps, like "Best Time to Cross the Border," use a combination of the official CBP information and crowd-sourcing data from border-crossing users.

Inspection Technologies and Dynamic Lanes

Border authorities require inspections of passenger and commercial vehicles at land POEs. CBP has implemented several trusted-traveler programs to expedite inspection for enrolled users. The FAST program is for commercial vehicles, while the Secure Electronic Network for Travelers Rapid Inspection (SENTRI) program is for passenger vehicles. These programs use RFID technologies to detect the vehicle before it comes to the inspection booth, and the system verifies that it is enrolled in the program. As mentioned earlier, POEs have been equipped with signs that indicate the type of lane at that particular time of day. Traffic lanes at the POE could be designated as FAST or SENTRI based on demand at a particular time of the day.

Agencies have not fully implemented this idea of managed lanes at land POEs, but managed lanes are planned for Otay Mesa East POE in order to make more efficient use of the infrastructure.

CASE STUDIES

This chapter presents what is being done in the U.S.-Canada and U.S.-Mexico borders and in other countries around the world to integrate ITS technologies and cross-border TMCs. The research team focused primarily on European, Asian, and U.S. borders. Some of these regions currently have cross-border TMCs and exchange ITS data while others, such as Asia, only show informal initiates of ITS data sharing.

Cross-Border TMCs in Europe

The closeness of many countries located over a relatively small geographic area and a very active cross-border traffic flow has encouraged Europe to work together to deploy cross-border TMCs and exchange ITS data since the late 1990s. Although cross-border ITS cooperation has not become ubiquitous yet in Europe, it has been accelerating with the European Union (EU) open borders policy. Several key efforts are described below.

DATEX2

Data Exchange (DATEX) was created in the 1990s as a protocol that defines a methodology for traffic and travel data exchange in Europe. DATEX was developed under the sponsorship of the European Commission. In 2006, DATEX was upgraded to a better version named DATEX2. The vision of DATEX2 is "to enable exchange information in an unambiguous manner whereby it is represented in common structures and users are able to fully understand the semantics and context of the information being exchanged" (*53*).

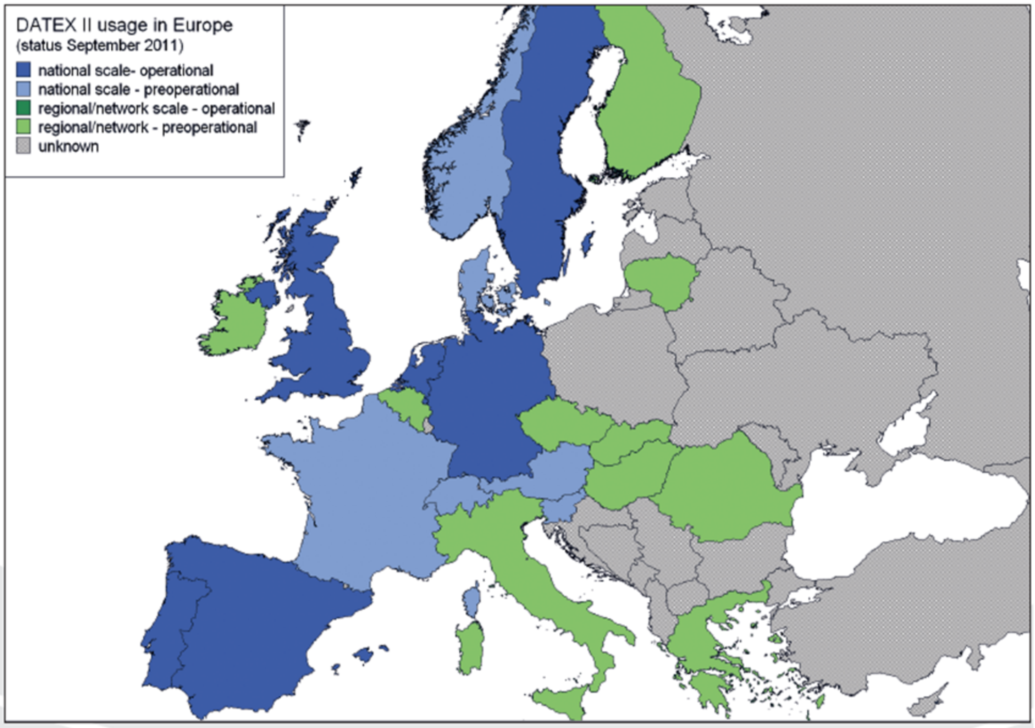
DATEX2 is a similar concept to the Center-to-Center data exchange software used by TxDOT statewide but on a multinational scale. The DATEX2 model provides:

- A data model that embraces the needs of the majority of road operators across Europe.
- An architecture for exchanging data between suppliers and clients.
- An architecture that supports the most recent technologies.
- A broader range of localization types.
- A guide to implementing solutions and products (*54*).

DATEX2 provides a common language to the various players in the traffic and travel information scene. These include not only TMC but also news broadcasters, incident-handling teams, and firefighters. DATEX2's main applications are:

- Linking traffic management and traffic information systems.
- Rerouting, network management, and traffic management planning.
- Applying lane-control systems and related applications such as ramp metering, dynamic speed limits, and overtaking control.
- Applying crucial information exchange between individual vehicles and traffic management, such as vehicle-to-infrastructure.
- Applying crucial information exchange between management systems for different modes, like multimodal information systems.

DATEX2 is a mature protocol that has been deployed all over Europe at various stages of development, as shown in Figure 35. DATEX2 success in Europe is in part due to the European ITS directive (2010/40/EU), which creates an international legal framework for the technical specifications of roadside ITS and telematics systems. It aims to establish interoperable and seamless ITS services while leaving member states the freedom to decide in which systems to invest. Under this directive, the European Commission has to adopt specifications within the next seven years (i.e., functional, technical, organizational, or service provisions) to address the compatibility, interoperability, and continuity of ITS solutions across the EU (*55*). Many of the priority areas and services included in this directive are already covered by DATEX2. The cross-border ITS integration among European countries is dependent on DATEX2.



Source: (53)

Figure 35. DATEX2 Applications in Europe.

The Project for the Management of European Traffic

The Project for the Management of European Traffic (PROMET) is a joint venture between Italy and Slovenia. PROMET started in 2007 with the goal to provide tactical management of a cross-border corridor linking both regions and to make their TMCs interoperable and compatible from the users' point of view. PROMET is one of the first true interoperable cross-border initiatives in Europe. One of the most relevant activities in this project is the implementation of an international data exchange link between the existing TMCs in Italy and Slovenia. Subsequently, Austria was added to PROMET.

PROMET's geographic area includes the southeast part of Europe, ranging from the Italian region, Friuli Venezia Giulia, west to Slovenia (see Figure 36). This corridor is a critical link within the EU Corridor V. The corridor has high traffic volume of passenger and freight vehicles, particularly during the summer peak season. The PROMET project uses the DATEX2 standard described earlier to achieve interoperability between TMCs.

Figure 36. PROMET Area.

Multiple organizations from both countries worked together in the project, including:

- National Ministries of Transport in Slovenia and Italy.
- Road operators: Družba za avtoceste v Republiki Sloveniji d.d.-DARS and Autovie Venete–AV.
- ITS companies: Traffic Design, Autostrade per l'Italia, MIZAR Automazione.
- A research institution: Politecnico di Milano.

PROMET is expected to produce immediate tangible results to the community and in particular to the cross-border commuters coming and going from Slovenia to Italy (both for work and for holidays) due to (*56*):

- The reduced congestion time.
- The increased information on traffic events and foreseen travel times.
- The establishment of higher cooperation between the cross-border TMCs and authorities to manage possible breakdown situations.

Some of the goals of PROMET are (*57*):

- Reinforce the traveler information service network with new services (e.g., TMC service in Slovenia) and enrich the already existing services with international cross-border contents.
- Improve the road monitoring quality level through sensor and communication technologies.

- Reduce the traffic peaks and increase the usability of the network for European drivers coming and going from Slovenia to Italy.
- Establish timely cross-border recovery actions by the different authorities and motorway operators, especially in cases of major difficulty for traffic flows.
- Support the efficiency of the network by harmonized information to the drivers.
- Enhance the continuity of the road network.
- Foster the interoperability of the systems through European Standard (e.g., DATEX).

Source: (55)

Figure 37. Bilingual Information on the DMS in Slovenia.

The project includes conducting a pre- and post-evaluation study to verify that the PROMET had the desired impact. The study will evaluate the following areas:

- Safety.
- Effectiveness.
- Environment.
- Acceptance by users.
- Integration.
- Accessibility.

The research team attempted to reach via email a PROMET contact to get an update on the project and request a copy of the pre- and post- evaluation study, but no response was received.

EasyWay

The EasyWay program was created in 2007 to foster European harmonization of ITS. EasyWay is the only program in Europe where member states, road operators, and stakeholders (public and private) cooperate intensively on the harmonized deployment of European ITS services (*58*).

The stakeholders from all over Europe are exchanging knowledge and best practice, defining and building consensus on harmonization and roadmaps, implementing harmonized ITS in a concerted way, and cooperating on actual cross-border projects (*59*). EasyWay incorporates eight Euro-Regions (CENTRICO, STREETWISE, ITHACA, SERTI, ARTS, CORVETTE, CONNECT, VIKING). More than 27 European member states are involved.

EasyWay is an umbrella of ITS services and projects with the goals of reducing congestion, improving road safety, and reducing emissions. One of the initiatives under the EasyWay umbrella is focused on cross-border TMCs (*60*). These initiatives cover two types of services:

- Traveler Information Services.
    - Seamless (local and cross-border).
    - Multimodal.
    - Language independent and with harmonized provision at European level.
- Traffic Management Services.
    - Management measures in regional, national, cross-border areas.
    - Conurbations, when necessary, deployed with traffic management plans in a coordinated way.

EasyWay has several projects currently active. Several of the EasyWay projects are related to cross-border TMC initiatives and are described below. These are ongoing projects in the early planning stages but clearly show how European countries are working together toward a common goal.

CROCODILE

The CROCODILE is comprised of public authorities, road administrations, and traffic information service providers of 13 European member states. Their main goal is to set up and operate a data exchange infrastructure based on DATEX2. That infrastructure will be used to exchange data and information between all involved stakeholders, including private partners, with the goal to provide harmonized cross-border traveler information services along the whole corridor (*61*). Participating member states include Austria, Cyprus, Czech Republic, Germany, Greece, Hungary, Italy, Poland, Romania, Slovenia, Bulgaria, Croatia, and Slovakia.

CROCODILE will mainly focus on the implementation of DATEX2 notes for data availability and exchange. To ensure data availability, additional data collection infrastructure, relevant for road-safety and truck-parking information services, will be deployed on specific road sections along the CROCODILE corridor for collecting data needed to detect events or identify conditions. The data exchange will be initially shared among TMCs, and eventually the exchanged data will be integrated in end-user services by CROCODILE partners and interested ITS associations.

Mediterranean Traveler Information Services

Mediterranean traveler information services' (MedTIS) objective is to implement traveler information services on the Trans-European Transport Network (TEN-T) Mediterranean corridor. MedTIS takes into account TEN-T priorities and EU policy objectives to deliver high-level travel time services and enhanced traveler information services, including road user awareness, to European travelers. The MedTIS corridor is 4,226 miles long involving four member states from the EU: France, Italy, Spain, and Portugal.

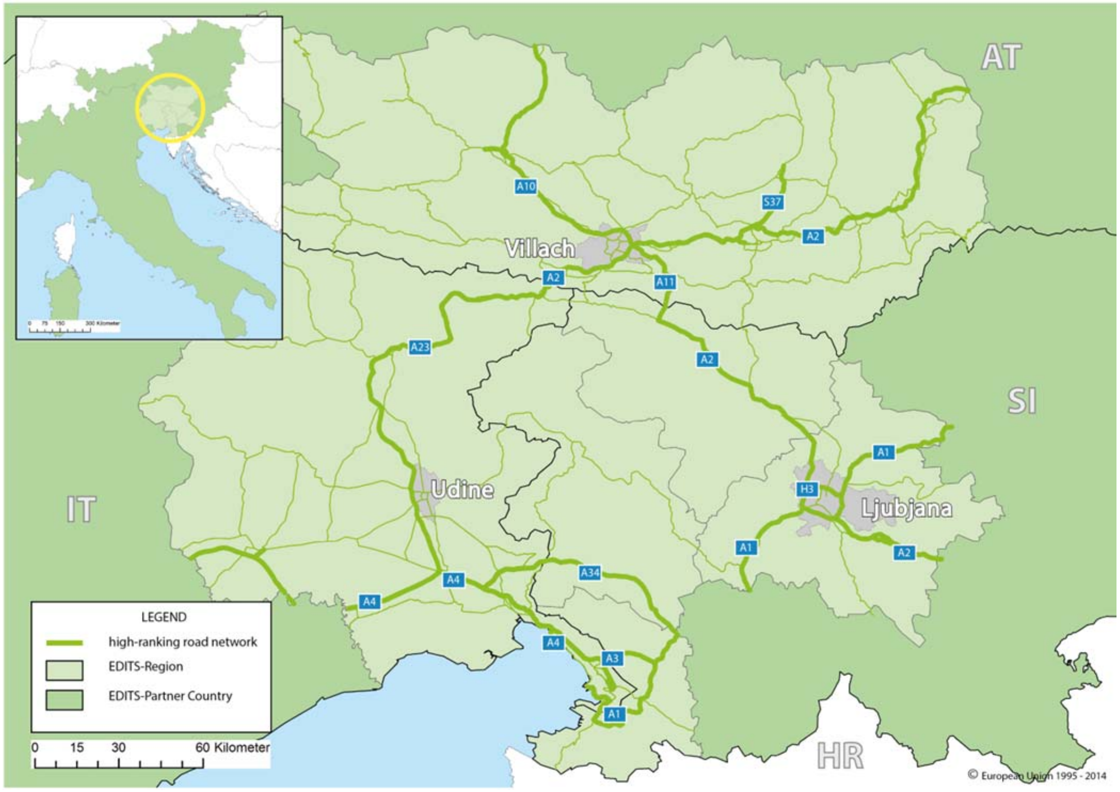
EDITS

European Digital Traffic Infrastructure Network for Intelligent Transport Systems (EDITS) is an EU co-funded project under the umbrella of the Central Europe program that aims at enabling cross-border, multimodal travel information based on harmonized traffic data and information gathered on a transnational level. Rather than creating a centralized system, EDITS focuses on improving, updating, and harmonizing existing services in the partner regions to ensure seamless cross-border services to the single traveler. The EDITS consortium consists of five countries: Austria, Italy, Slovakia, Hungary, and Czech Republic (*62*).

EDITS was conceived as a pilot project consisting of three demonstration regions including the Centrope region (Austria, Slovakia, Czech Republic, and Hungary), the triangle area covering Austria-Italy-Slovenia, and the Italian bordering provinces of Modena and Ferrara. Figure 38 shows the demonstration region of Austria-Italy-Slovenia that covers the cross-border triangular area linking the cities of Villach in Austria, Udine in Italy, and Ljubljana in Slovenia. Work started in 2012 with the goal of going live by 2014. After the go-live, EDITS' services will remain operational for the next five years. The work consisted of four steps:

- Analysis.
- Study and design.
- System set-up.
- Demonstration and testing (current stage).

EDITS' concept included two main components: 1) EDITS Graphic Integration Platform format, which provides the interface for the exchange of geographic information system (GIS) data between the EDITS source systems covering GIS data of the transportation infrastructure; and 2) the specification for commonly agreed data and information exchange based on existing European and national standards such as DATEX2 and DINO. EDITS consortium has deployed 10 different web- or app-based EDITS-related traveler information services covering different demonstration areas in Central Europe.



Source: (60)

Figure 38. EDITS Demonstration Region of Austria-Italy-Slovenia.

Cross-Border TMCs in Asia

The research team conducted an Internet search and literature review to identify major binational border locations in Asia located at or near an international border crossing and equipped with a TMC that included monitored border traffic. The search yielded two relevant examples for this research. These include the border crossings between Singapore and the State of Johor in Malaysia and between the Hong Kong Special Administrative Region (SAR) and the City of Shenzhen in China.

The review indicated that these two locations have TMCs on at least one side of the border monitoring crossing traffic conditions and relaying that information to the public over the Internet (via CCTV images and speed maps). The locations selected are highly relevant to the U.S.-Mexico border from an economic development and economic activity standpoint. In both cases, although one of the jurisdictions involved is significantly more economically developed than the other, their economic linkages and social bonds are also significantly strong.

Based on the analysis of the information available, neither location has a cross-border TMC or a formal mechanism to share or aggregate traffic information generated on either side of the border. The paragraphs that follow describe these two locations in more detail.

Singapore-Malaysia Border Crossings

The countries of Singapore and Malaysia in Southeast Asia share a maritime border and are linked by two border-crossing structures over the Straits of Johor. Similar to the United States and Mexico, the two countries have highly integrated economies and a very active shared border economy. Singapore is a small city-nation with an approximate gross domestic product (GDP) per capita of U.S. $82,800, and Malaysia has a GDP per capita of about $24,700.

The first crossing structure linking the two countries is the Johor-Singapore Causeway, which links the Woodlands district in Singapore with the City of Johor Bahru in Malaysia. This 0.7-mile long facility contains a road and a railroad; the road facility handles both freight and passenger traffic, while the railroad handles passengers only (*63*). Average daily traffic was estimated at 57,000 vehicles per day (vpd) in 2011 (*64*).

The second crossing is known as the Malaysia-Singapore Second Link and it links the Tuas district on the Singapore side with the town of Tanjung-Kupang (in the outskirts of Johor Bahru) on the Malaysian side. This crossing is about 1.2 miles long and includes a dual three-lane roadway and also handles both passenger and freight traffic. This crossing includes toll payment and has an average daily traffic estimated at around 66,000 vpd in 2011.

The Singapore Land Transport Authority (LTA) operates a TMC that monitors the island's road network, including the Singapore side of the two border crossings. The Singapore LTA's TMC operates an intelligent incident management system called the expressway monitoring and advisory system (EMAS) that monitors and manages traffic on the networks. EMAS provides real-time traffic information to motorists, including traffic maps and traffic cameras that include the Woodlands (Johor-Singapore Causeway) and Tuas (Second Link) border checkpoints (*65*, *66*).

EMAS does not include any portion of roadway outside Singapore and the LTA's website does not provide any information on traffic conditions on the Malaysian side of the border. In Malaysia, the roads accessing the crossings with Singapore are managed and monitored by the Malaysian Highway Authority, providing real-time information of travel conditions to the public through a combination of traffic cameras and maps on its website. Similar to Singapore, the information provided by the Malaysian Highway Authority is limited to the Malaysian side of the border.

The review did not yield any references to any formal mechanisms to integrate real-time border-crossing traffic information for public consumption. However, there are at least two seemingly informal private websites that aggregate the video feeds from both sides of the border (*67*, *68*, *69*).

Hong Kong–Shenzhen Border Crossings

China's Hong Kong SAR and the city of Shenzhen on mainland China are linked by six major land crossings (*70*). Although Hong Kong is today part of China, it still maintains its own currency, customs, immigration laws, and overall regulatory framework. The difference in economic development between the two sides of the border is also significant. While Hong Kong's GDP per capita was reported at U.S. $54,700 in 2014 by the Central Intelligence Agency Factbook, China's overall GDP per capita was reported at $12,900. When considering Shenzhen only, the city's GDP per capita was reported at U.S. $24,100 by the Taiwan-based China Times News Group (*71*).

Four of the six land crossings between Hong Kong and Shenzhen are roadway-based: 1) Shenzhen Bay Port–Shenzhen Bay Port; 2) Lok Ma Chau–Huanggang; 3) Man Kam–Wenjindu Port; and 4) Sha Tau Kok–Shatoujiao Port. The two other crossings serve railroad traffic. According to the Hong Kong Transport Department (HKTD), the annual volume of cross-border traffic on these crossings ranges from 24,762 vpd on the busiest (Lok Ma Chau) to 2,192 vpd on the least busy (Sha Tau Kok).

The research team contacted HKTD by email to request information about their ITS systems as they relate to their border crossings with Shenzhen. The response was brief, but it provided some useful insights. HKTD provides real-time traffic information through speed maps and traffic cameras at the Shenzhen Bay Port border crossing and the access road to the Lok Ma Chau (*72*). The other four border crossings do not seem to be covered based on the information reviewed, and no formal data sharing or joint ITS-based traffic management efforts exist between the two governments.

The set-up in Shenzhen is similar to Hong Kong and the other locations reviewed in that the extent of their TMC information is limited to roadways on its side of the border, but includes the roadways leading to the border crossings. The Shenzhen Traffic Bureau provides real-time traffic information to the public through a speed map on their website, but it does not seem to have traffic camera imagery available online.

Similar to the Singapore-Malaysia case, the information reviewed suggests that Hong Kong and Shenzhen do not have a formal mechanism to integrate real-time border-crossing traffic information. No references were found to any websites that attempted to aggregate this information in a single location.

Cross-Border TMCs at the U.S.-Mexico and U.S.-Canada Borders

Otay Mesa East Crossing at San Diego-Tijuana

The San Diego Association of Governments and Caltrans, along with a number of key local, state, and federal agencies in the United States and Mexico, are working to build an innovative

POE in the San Diego–Baja California region. The main objective of the project is to reduce border wait times in the region.

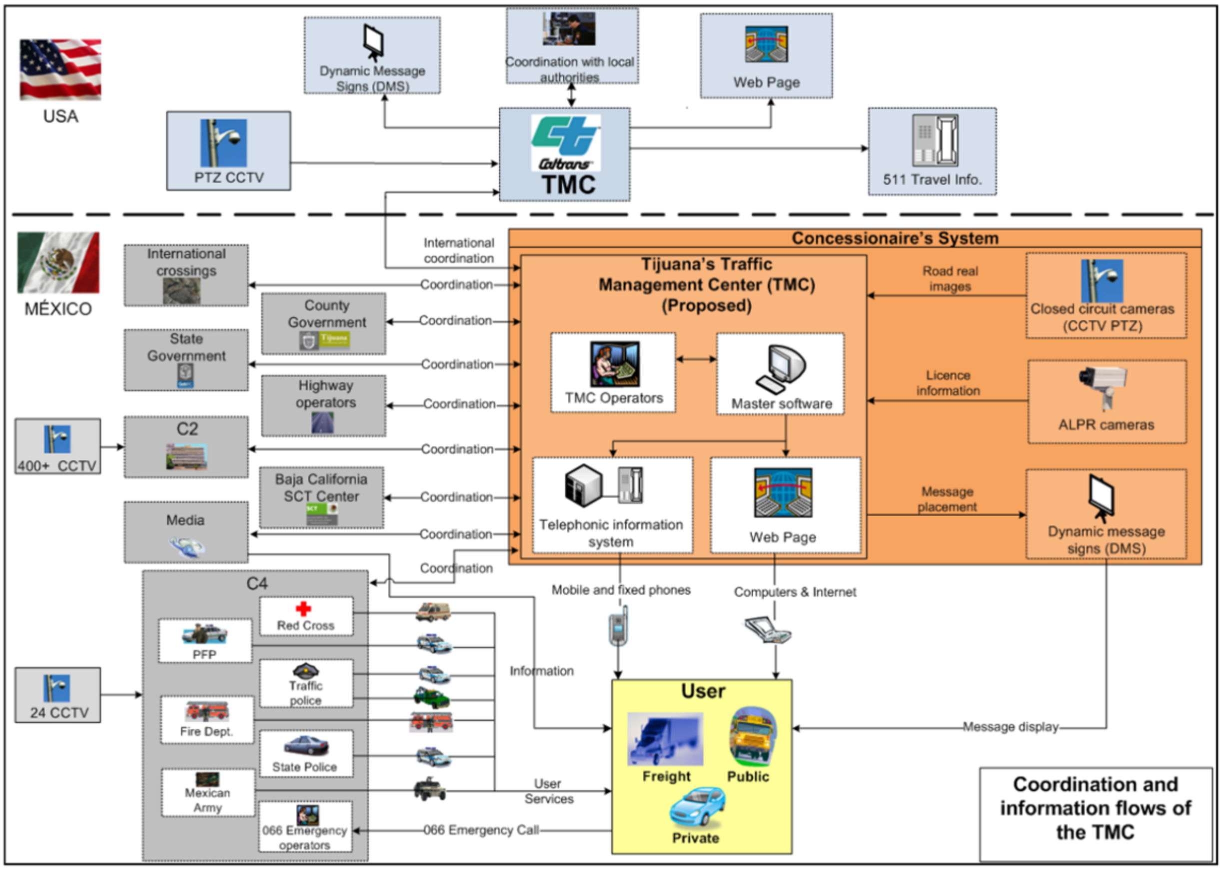
The State Route 11/Otay Mesa East POE Project will provide fast, predictable, and secure crossings via tolled approach roads that connect directly to a new state-of-the-art POE serving both personal and commercial vehicles. ITS is a key element of the project, and FHWA is funding the ITS pre-deployment study. The goal of the study is to assess innovative operating concepts and technologies to create a secure, state-of-the-art border crossing.

A major objective of the ITS study is to identify ways to manage the approach roads to the regional border crossings as a system. Through TMCs in the United States and Mexico, actual border wait times will be posted, traffic conditions will be available through multiple platforms (such as roadway signs and the 511 traveler information system), and approach lanes to the new POE will be segmented to better organize traffic prior to security inspections.

Once the ITS technology is deployed, it will collect and provide real-time information on border-crossing choices for both personal and commercial vehicles, including variable toll rates at the Otay Mesa East POE and wait-time patterns on both sides of the border for the entire San Diego–Baja California region. The technology also will collect tolls electronically. The data collection will work seamlessly with the region's established ITS architecture to enable travelers to make educated choices on when and how to travel.

Figure 39 presents the preliminary structure of the ITS operation at the Mexican side of the border. The system is planned to have DMS, CCTV, and automated license plate recognition systems feeding information to the Tijuana TMC, which is under construction. Information will be shared with the San Diego TMC.

The ITS study is still under development and the final concept of operations has not been released. This will be the first binational TMC implementation at the U.S.-Mexico border (*73*).



Source: (74)

Figure 39. Tijuana ITS Operation Diagram.

U.S.-Canada Border Experiences

The Michigan Department of Transportation (MDOT) and WSDOT have ITS systems implemented near the border with Canada. At the Detroit-Windsor border, the Southeast Michigan Transportation Operations Center is the hub of ITS technology applications at MDOT. The TMC staff oversees a traffic monitoring system composed of 400 freeway miles instrumented with:

- Over 241 CCTV cameras.
- Over 94 DMS.
- Over 144 microwave vehicle detection sensors in conjunction with probe traffic detectors.

The system is being continually expanded to include coverage along all metro Detroit area freeways. ITS devices have expanded, providing motorists with real-time information on conditions at the Blue Water Bridge, surrounding freeways, and border-crossing times, as seen in Figure 40.

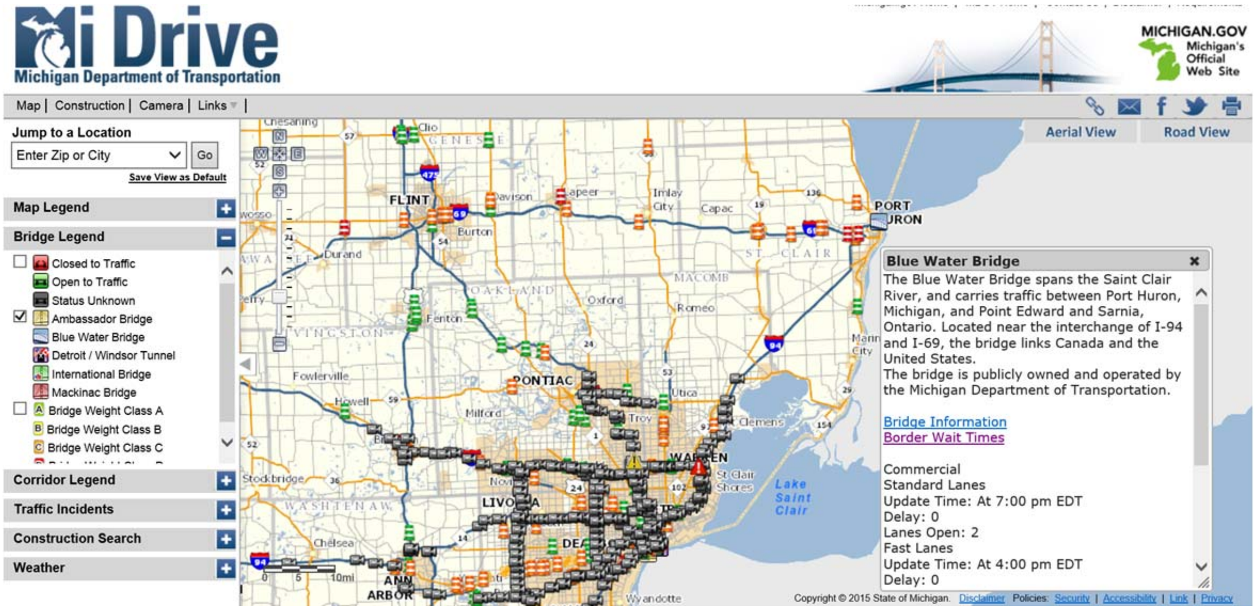
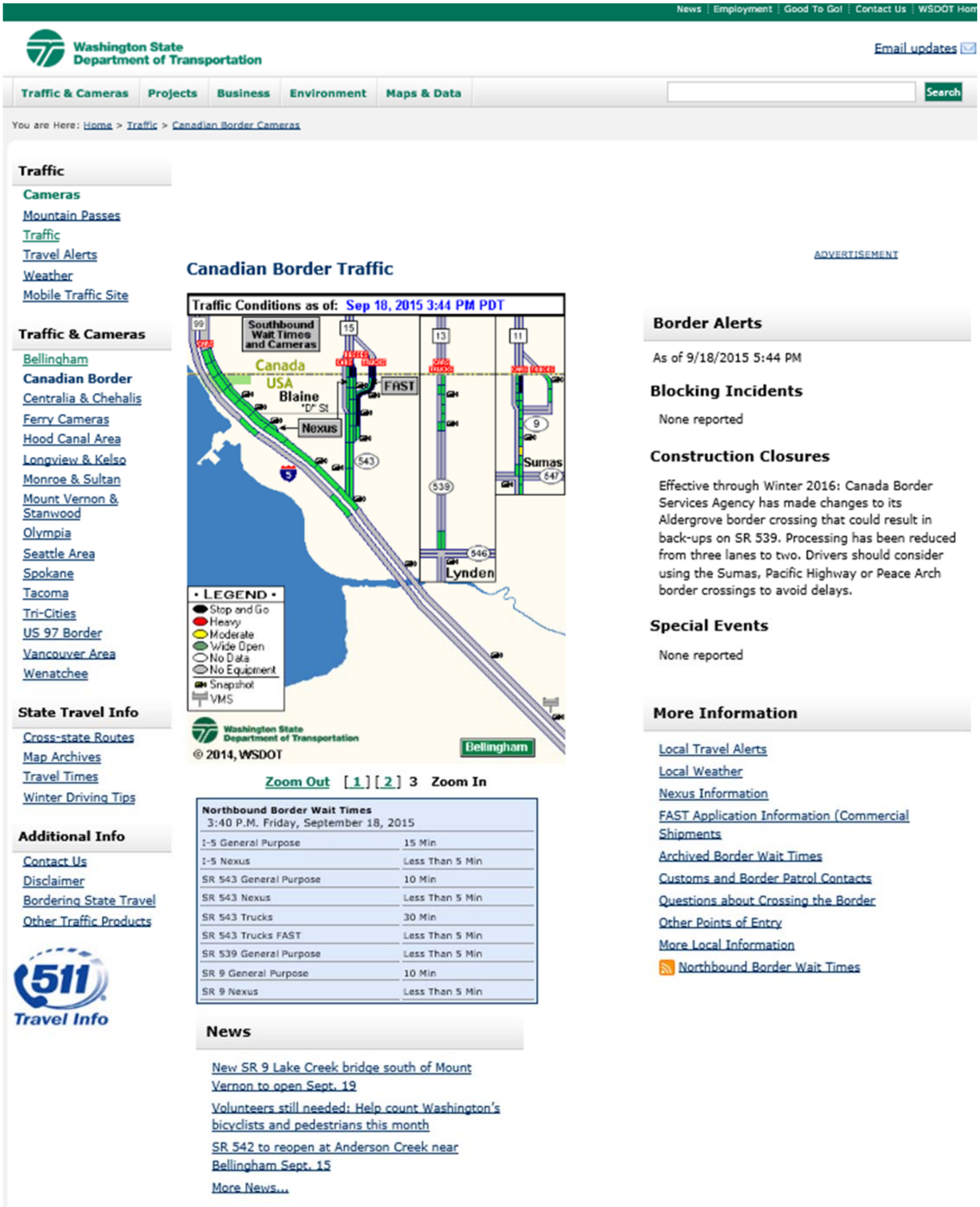


Figure 40. Detroit-Blue Water Bridge Traffic Information.

At the Washington State-British Columbia border, there is no TMC; however, the WSDOT provides traffic information for all border crossings in the state (Figure 41).



Source: (75)

Figure 41. Washington State-Canadian Border Traffic.

Cascade Gateway Border Data Warehouse Project

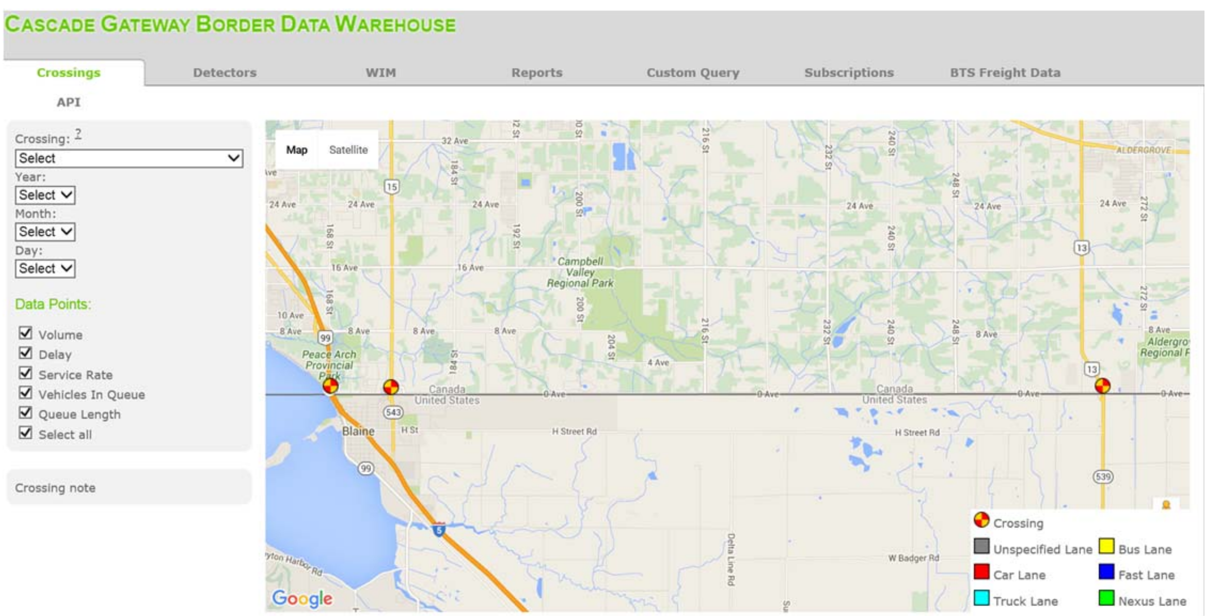
The Cascade Gateway Border Data Warehouse Upgrade and BIFA Integration project was funded by Transport Canada, FHWA, and WSDOT. The project developed an architecture based on BIFA, developed out of TBWG.

A full series of reports were developed to describe the process of using the BIFA template to develop a project architecture and to review and provide guidance to other regions considering the BIFA for their cross-border ITS projects.

The Cascade Gateway Data Warehouse provides traffic information at four POEs between the Lower Mainland, BC, and Whatcom County, WA. It also includes additional data collected from readers on I-5. The information elements include:

- Volume.
- Delay.
- Service rate.
- Vehicles in queue.
- Queue length.

The information can be queried by POE, direction, month, and day. Figure 42 shows a sample of the query screen.

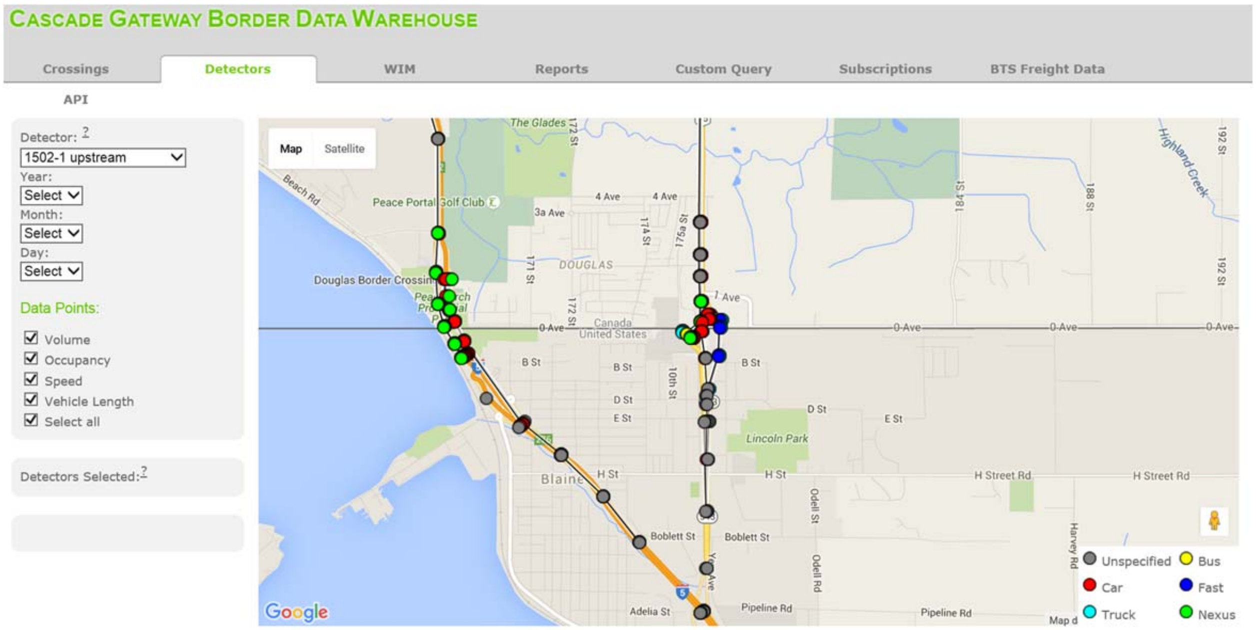


Source: (76)

Figure 42. Cascade Gateway Data Warehouse Crossings.

The site also provides information from various roadway-detecting points with vehicle information for different vehicles types at each location, such as (see Figure 43):

- Volume.
- Occupancy.
- Speed.
- Vehicle length.



Source: (77)

Figure 43. Cascade Gateway Data Warehouse Detectors.

Secure Border Trade Demonstration Project

The Secure Border Trade Demonstration Project (SBTDP) was a three-year demonstration effort funded with Coordinated Border Infrastructure funds administered by FHWA and implemented by the County of El Paso in El Paso, Texas. El Paso County contracted with TransCore, a technology firm, for the development and implementation of the project. TTI assisted El Paso County in complying with federal technology monitoring requirements throughout the project.

The main objectives of the SBTDP were to enhance security, increase participation in U.S. and Mexico trusted-shipper programs, promote economic development, and facilitate U.S.-Mexico border trade efficiency by enhancing collaboration between Maquiladoras, customs brokers, transporters, and border security personnel.[1] The project was aimed at increasing the efficiency and security of goods crossing the U.S.-Mexico border by providing visibility of the goods'

[1] A maquiladora is a manufacturing plant in Mexico that retains a permit from the Mexican government to import raw materials duty free into Mexico for manufacturing, assembly, repair, or other processing. The foreign company must agree to re-export a majority of its production.

movement throughout the entire supply chain, from the point of shipping in Mexico, through the POE, and on to the point of delivery in the United States. The demonstration phase of the project phase started in summer 2012 and concluded in spring 2014.

This project provided a framework for binational cooperation between U.S. and Mexican government agencies and the private sector on both sides of the border. This model can be applied to future cross-border ITS.

Project Technology Elements

More specifically, the SBTDP introduced new electronic tracking, reporting, and monitoring technology into the cross-border maquiladora supply chain elements. The technology expanded the capabilities of the private and public sectors to monitor the loading of tractor/trailers and track the movement of goods and the operation of vehicles from origin to destination. In addition, the technology allowed identity verification of truck drivers and other cross-border supply chain participants in real time.

The project used video surveillance cameras monitored from a SBTDP command center in El Paso, TX, to watch the maquiladora and warehouse facilities in Mexico and the United States, including loading/unloading areas and protected trailer parking. The command center monitored in real time the cargo movement, security, and integrity of the shipment. The project used biometric devices to verify the identification of a driver by using fingerprints, facial recognition, and/or a pin code. This was done at the point of origin and the point of destination. Additionally, the project included deploying, in participating trucks, 30 “ContainerSafe,” trailer-door-mounted GPS tracking and intrusion detection devices and 30 in-cab units for cab/trailer separation detection. PTZ camera units were mounted at selected locations in Ciudad Juárez, Mexico, to provide surveillance along selected routes from the maquiladora plant to the U.S.-Mexico border. The PTZ cameras were controlled from the SBTDP command center for rapid observation of detected events in sight of the camera.

Stakeholder Participation

The success of the SBTDP required the collaboration of multiple stakeholders from the public and private sector on both sides of the border involved in cross-border trade. The federal, state, and local agencies and private sector firms that participated in the TMC included:

- U.S. CBP.
- U.S. FHWA.
- U.S. FMCSA.
- Texas DPS.
- TxDOT.
- County of El Paso.

- El Paso MPO.
- City of El Paso.
- El Paso Fire Department.
- Motor carriers.

In addition to the organizations participating in the TMC, the SBTDP included a number of private sector companies involved in cross-border trade, including maquiladoras and motor carriers in the United States and Mexico, technology and software partners, and distribution centers in the United States. The project demonstrated the implementation of state-of-the-art technology, software, and processes to secure, track, and monitor freight from the maquilas in Mexico to the distribution centers in the United States. The technology used GPS/global system for mobile communications, CCTV, biometrics, and analytical software systems integrated into the process flow systems of the maquilas to provide critical data to the control center in the United States.

Outcomes

The implementation and performance monitoring of the SBTDP allowed participants to develop and document a better understanding of the unique dynamics that exist between maquiladoras in Mexico, freight carriers, government entities on both sides of the U.S.-Mexico border, and the distribution centers in the United States. The project had an initial goal to install one monitoring site at each of three participating maquiladoras and achieve 30 shipments per day, with10 shipments from each maquiladora. However, actual conditions on the ground made these goals impractical, and the project was forced to pursue a different approach. The final project set-up included fully equipping with the selected technology multiple maquila plant locations not initially planned for the project.

The project achieved 24,909 northbound and southbound commercial shipments and 413 HAZMAT shipments without a single security breach, and thousands of these shipments occurred without any significant incident. The project allowed better understanding of the full scope of securely moving freight across the international border between the United States and Mexico. As a demonstration project, it also allowed agencies and partners to attempt new concepts, experiment, and test against market demands of what is practical and needed in the real world.

CURRENT AND PROPOSED METHODS OF COMMUNICATION OF INFORMATION TO TRAVELERS

This section discusses how travelers currently receive information about wait times and bridge closures and some of the best practices of agencies that provide such information. It also describes methods that agencies on both sides of the border are exploring.

TxDOT primarily uses two methods to provide information to motorists. It uses DMS to provide motorists information about congestion, weather, and lane closures. TxDOT has deployed DMS in El Paso and Laredo. TxDOT also provides road condition information to motorists through a website called DriveTexas. In addition, it also provides access to its cameras to local television media, which then relay snapshots from the cameras during their regular news programming.

Dynamic Message Signs

DMSs are widely used in Texas highways. So far, TxDOT has not relayed wait times to cross into Mexico via DMSs, primarily because there are no systems to measure southbound wait times except at the Ysleta-Zaragoza POE in El Paso. That information is relayed strictly via the BCIS website developed by TTI with funding from FHWA and TxDOT. However, there is an opportunity to relay the southbound wait times through DMSs strategically placed on highways connecting the Ysleta-Zaragoza POE.

On the U.S.-Canada border, however, DMSs are widely used to relay wait times of passenger and commercial vehicles. Figure 44 and Figure 45 show DMSs installed on a highway in Canada. They relay wait times at various border crossings to go into the United States.

Source: (78)

Figure 44. DMS Installed on the Canadian Side of the Border with Washington State.

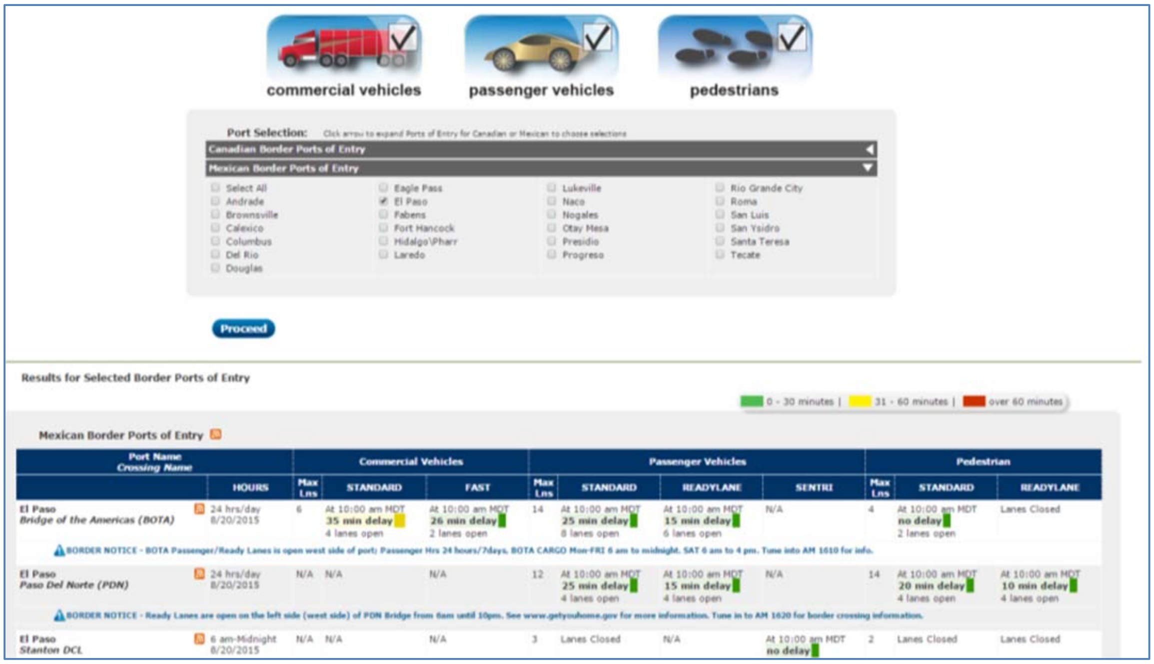
Source: (78)

Figure 45. Different Kind of DMS Installed on the Same Roadway Leading to the United States from Canada.

Websites

Websites are a great tool to provide information before starting a trip, but it is not an ideal tool while en route. Many transportation agencies measure and provide wait-time information via their websites, such as WSDOT and MDOT. TxDOT relies on a TTI-developed website to provide wait-time information to motorists and commercial-vehicle drivers.

One of the most widely used websites to get wait-time information is the CBP's website (https://bwt.cbp.gov). It provides wait-time information for U.S.-bound passenger and commercial vehicles and pedestrians at POEs. Figure 46 shows a snapshot of the CBP's website. Wait-times information on the website largely comes from user surveys and visual methods, the accuracy of which has been a subject of much discussion. Hence, CBP is developing ways to collect wait times from instrumented and automated systems deployed by local and state agencies. Figure 47 shows a snapshot of the Government of Canada's website, which shows wait times to enter Canada.



Source: (79)

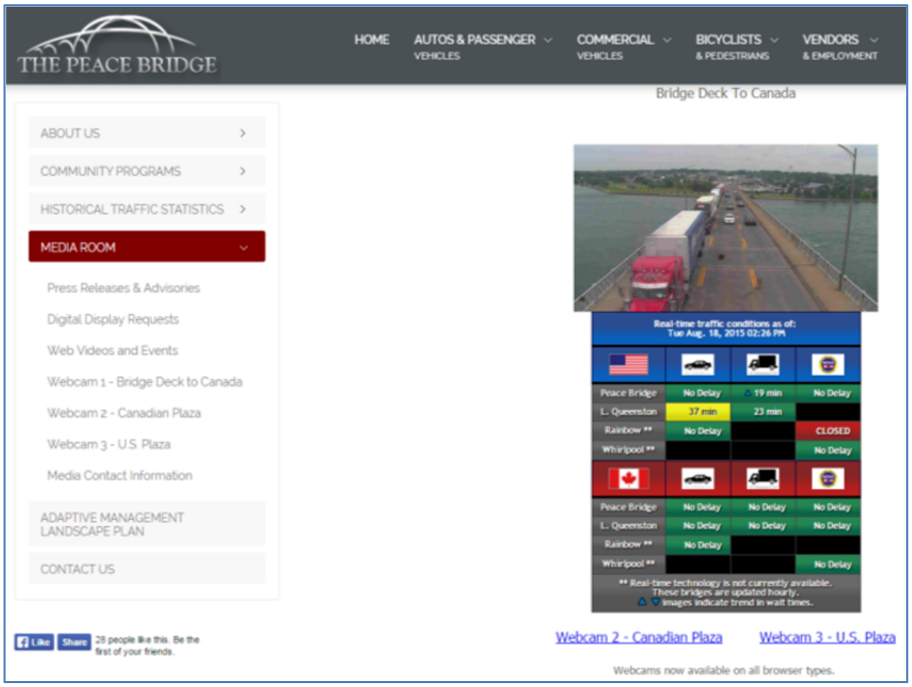
Figure 46. CBP Website Displaying Wait Times of U.S.-Bound Travelers.

Source: (80)

Figure 47. Government of Canada Website Displaying Wait Times of Canada-Bound Travelers.

Wait times provided by the CBP and the Canadian government are relayed by many other agencies such as media partners, private website owners, and transportation agencies at the border (tolling agencies, consortiums, cities, etc.) As an example, the Buffalo and Fort Erie

Public Bridge Authority is an international compact entity created pursuant to a compact entered into by the State of New York—with the consent of the U.S. Congress—and the Government of Canada. The authority is governed by members from both the United States and Canada. The Authority operates Peace Bridge, which is a major international toll crossing spanning the Niagara River between Fort Erie, Ontario, and Buffalo, New York. Figure 48 shows a snapshot of the authority's website, which overlays CBP wait times with snapshots of cameras deployed by the authority.



Source: (81)

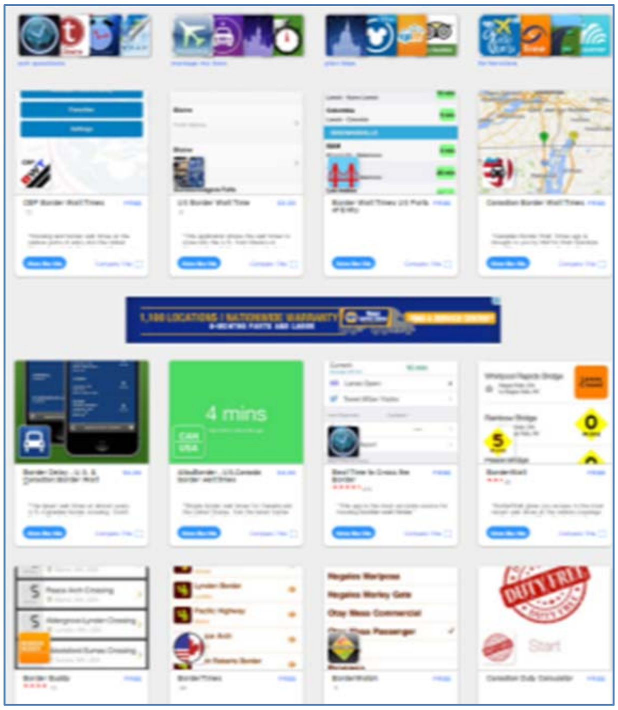
Figure 48. New York-Area Peace Bridge Website Displaying Wait Times of U.S.- and Canada-Bound Travelers.

Traditional Television and FM Radio

Traditional media such as television and radio operating at the border relay wait times of passenger vehicles during their regular programming. Most of these radio and television stations are reachable by audiences in both countries. Hence, radio and television are effective media to relay both north- and southbound wait-time information.

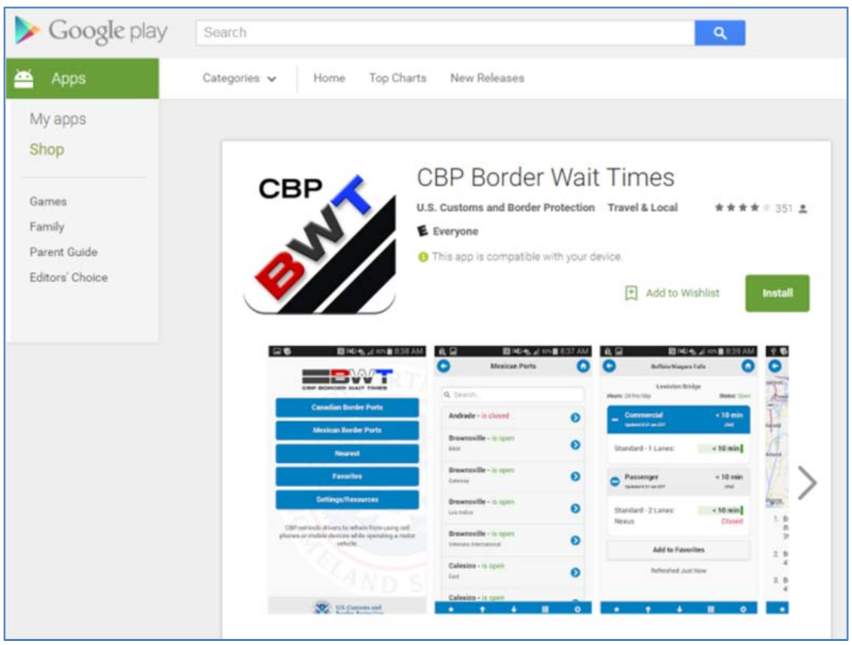
Smartphone Apps

Smartphone apps for Android and Apple devices are available for motorists. Almost all of those apps scrape information from CBP's website and provide them in easily accessible form. Figure 49 shows a snapshot from Google's Play Store for a list of apps that provide border wait-times information. Figure 50 shows a snapshot of CBP's border wait-time app in the Google Play Store.



Source: (82)

Figure 49. List of Applications in the Google Play Store App.



Source: (82)

Figure 50. CBP's Wait Time App in the Google Play Store App.

511 System

Established in July 2000 by the Federal Communications Commission, 511 is the nationally designated three-digit number for traveler information. Referred to as an N11 number, 511 was created to provide an easy-to-remember, three-digit number that travelers could use to access road and traffic information from within the jurisdiction they were traveling.

Several states such as New York, California, Washington, and Michigan provide border condition information through their statewide 511 system. For example, the ADOT deployed the statewide 511 telephone system in March 2002 and has continued to enhance the system ever since. What started out as a system that only covered freeways and airports in Phoenix and Tucson now provides border wait times. Arizona travelers can access the 511 traveler information line simply by dialing 511 from any landline and most mobile phones anywhere in the state. Most of the information is also available on the web (www.AZ511.gov).

Dispatchers and Fellow Drivers

Drivers also get wait information from their dispatchers at the carrier's control center. Dispatchers in turn get the information mostly from CBP's website and through conversations with drivers who have already made the trip. Some shippers keep logs of wait times to validate claims by drivers/carriers for longer than usual wait times, since some drivers/carriers are paid by the hour.

BEST PRACTICES FOR WAIT TIMES ON THE LARGEST TWIN CITIES ALONG THE TEXAS BORDER (LAREDO AND EL PASO)

TTI, with funding from TxDOT and FHWA, has implemented wait-times measurement systems in El Paso, Laredo, and other POEs. The overall goal of the system is to automatically and accurately collect border-crossing times for commercial freight at the U.S.-Mexico border.

Prior to designing the system, TTI conducted a technology assessment to identify the best solution for the U.S.-Mexico border. In order to measure travel time and the associated delay, the chosen technology needed to be flexible enough to cover the complete trip and be applicable at all POEs. The technologies that were identified as meeting these criteria are:

- Automatic vehicle identification.
- Automatic license plate recognition.
- Vehicle matching.
- Automatic vehicle location.
- Mobile phone location.
- Inductive loop detectors.

RFID emerged as the best candidate for supporting the system, and TTI developed the system with input from stakeholder agencies from both sides of the border. The stakeholder agencies included CBP, Aduanas, Texas DPS, and cities on both sides of the border. With the help of these agencies, TTI was able to identify the queueing patterns, length of queue, peak periods, and appropriate locations for sensors in both the United States and Mexico.

TTI then designed and deployed RFID technology-based systems to measure wait times of U.S.-bound commercial vehicles and Bluetooth technology-based systems to measure wait times of passenger vehicles. These systems have been measuring, relaying, and archiving wait times and crossing times of commercial vehicles. Wait times are relayed to users by methods such as CBP and to drivers via a publicly accessible website. TTI is improving the RFID-based system in Laredo to develop capability to differentiate between wait times of FAST and non-FAST trucks.

Archived data are also available via public website. Archived data include wait and crossing times aggregated at different periods such as hourly, daily, and annual averages. The information has been utilized by planning agencies, Government Accountability Office, FHWA, TxDOT, and congressional staffers to discuss the current status of delay and methods to improve operation of border crossings.

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

- Field subsystem.
- Central subsystem.
- User subsystem.

The field subsystem is comprised of the RFID tag detection or reading stations and includes the communication equipment. A minimum of two detection stations are required, one in Mexico and one in the United States. The detection station reads RFID tags and passes the data to the central subsystem via the communication equipment. The central subsystem receives tag reads from the field detection stations and performs all processing to derive and archive the aggregate travel times between the stations. The user subsystem interacts with the central subsystem to provide an web portal for data users (stakeholders, the public, etc.) to access current border-crossing times and to access archived crossing-time data. Figure 51 shows the system's organization.

Northbound commercial vehicles (trucks in Mexico destined to cross the border into the United States) pass an RFID tag reader installed at a point sufficiently ahead of the end of any queue on the Mexican Export Lot. This reader station is defined as R1.The RFID tags on the trucks are read as they pass the reader stations. The tag query process recovers a unique identifier for each vehicle similar to a serial number. The reader 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. On the U.S. side of the border, two tag-reading stations are installed, one at the CBP primary inspection booths (R2) and one at the exit of the DPS border safety inspection facility (R4).

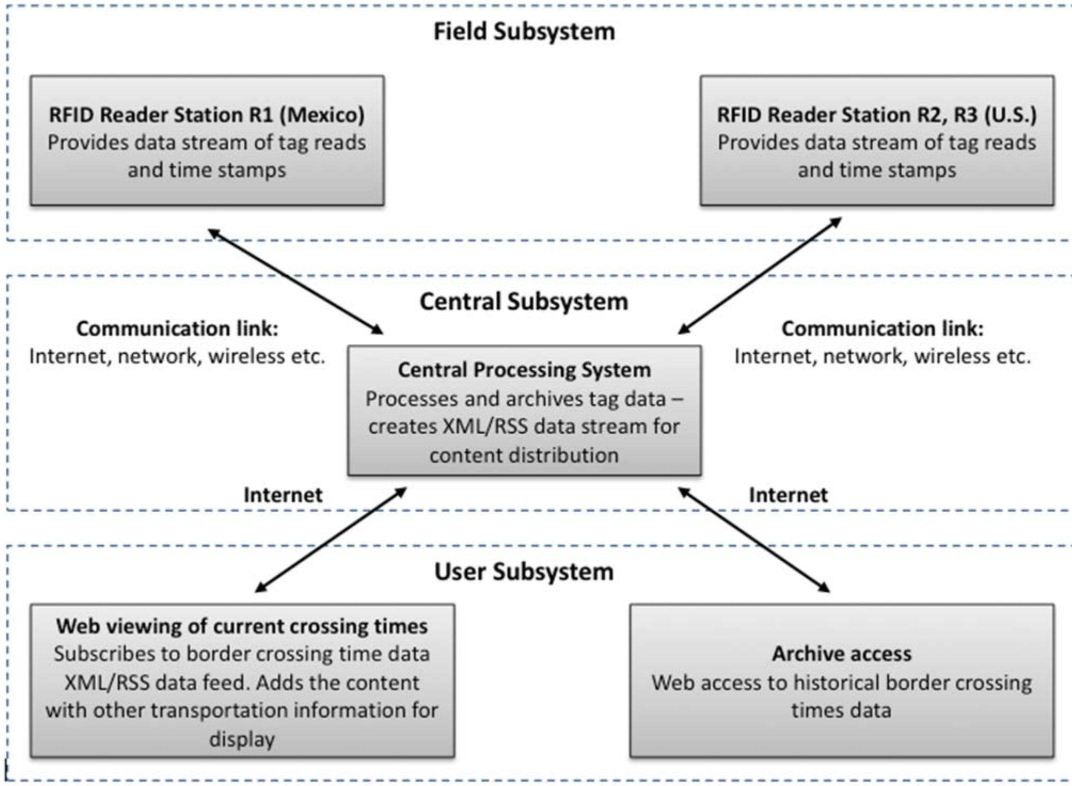


Figure 51. Subsystem Organization Diagram.

The central facility receives data from all tag-reading stations associated with the project. The central facility is a secured database server located at TTI's office in College Station, Texas. The database server 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 database server acts as a data center for the system. The database server has enough storage space to archive several years of data from the system, and the server is expandable if additional storage space is required in the future.

The raw data are processed to match tag reads of individual trucks at the entrance point on the Mexican side and the exit point on the U.S. side. The difference in time stamps yields a single truck's progression as a function of time through the POE. The tag matching and travel time computation of individual tags happens in real time; however, the aggregation of individual travel times to compute wait time and crossing time for reporting purposes happens every 15 minutes.

The user subsystem manages access of border-crossing time data for the users. The most recent, average crossing-time data are available to the public via an RSS subscription. TTI has developed a border-crossing information system through funding from FHWA. The system includes a map-based website to view the most recent, average crossing-time data and segment travel times, and will also include interfaces to query archived border-crossing data. BCIS (http://bcis.tamu.edu) provides real-time and archived data, as shown in Figure 52.

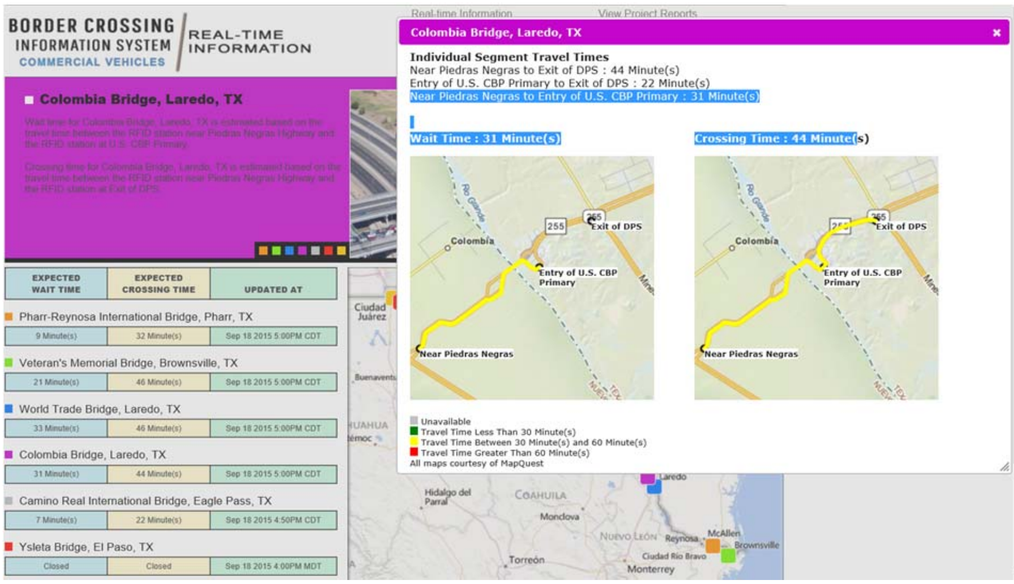


Figure 52. BCIS.

These systems are a result of coordination between border agencies on both sides of the border and being upfront about a need to deploy a system that measures wait times without scientific bias. These wait-time systems have been in operation for several years and are being funded by the U.S.-Mexico JWC through TxDOT. The JWC comprises transportation and border agencies from both the United States and Mexico.

At the U.S.-Canada border, FHWA has been coordinating with local agencies and binational groups to install border-crossing time measurement systems using similar technologies to the ones described above.

KEY FINDINGS

From the above discussion, it can be seen that no cross-border TMCs operations have been found at the U.S.-Mexico or U.S.-Canada borders. The proposed TMC in Tijuana that will have communication and data exchange with the existing TMC in Tijuana is the only planned binational TMC along the border.

International research identified that border crossings between Singapore and the State of Johor in Malaysia and between the Hong Kong SAR and the City of Shenzhen in China are examples or binational efforts. At these locations, TMCs operate on at least one side of the border monitoring crossing traffic conditions and relaying that information to the public over the Internet (via CCTV images and speed maps).

In Europe, there is DATEX that was developed under the sponsorship of the European Commission. The upgraded version of the system, DATEX2, has a vision "to enable exchange information in an unambiguous manner whereby it is represented in common structures and users are able to fully understand the semantics and context of the information being exchanged" (*53*).

At the Italy/Slovenia border, a project to provide tactical management of a cross-border corridor linking both regions and to make their TMCs interoperable and compatible from the users' point of view was launched. The project, PROMET, is one of the first true interoperable cross-border initiatives in Europe. One of the most relevant activities in this project is the implementation of an international data exchange link between the existing TMCs in Italy and Slovenia. Subsequently, Austria was added to PROMET.

Another European program, the EasyWay program, was created in 2007 to foster European harmonization of ITS including cross-border TMCs. EasyWay has several projects in several stages of planning and implementation that focus on multinational ITS.

Connected vehicle systems have the potential to reduce costs relative to deployment of older technologies. For example, at border crossings, DMS, HAR, or static signs may become unnecessary if vehicles receive traveler information directly from their onboard connected vehicle devices. Several border crossings have technology in place to measure wait times and provide traveler information that could benefit from connected vehicle systems.

Border wait times and crossing times are the main information elements that are estimated and disseminated to the border traveler communities. At the U.S.-Canada border, various binational systems share information on border crossing times in both directions of travel. At the Texas-Mexico border, a system has been implemented to inform truck border-crossing time entering from Mexico into Texas at seven POEs. One passenger vehicle border wait-time system has been implemented at the Ysleta-Zaragoza POE in El Paso.

Border crossing and wait-time information is estimated using various technologies, including RFID, Bluetooth, GPS, or even manual detection and is disseminated via DMS, mobile applications, and radio. There are no DMS in Texas informing border wait times, while at the U.S.-Canada border this technique is widely used.

3. STAKEHOLDERS NEEDS ASSESSMENT

This chapter:

- Identifies key stakeholders from federal and Texas state agencies, local entities (including counties and cities), and Mexican agencies that would be involved in cross-border ITS and TMCs along the Texas-Mexico border.
- Develops an information-gathering tool aimed at collecting information needs from key stakeholders identified throughout the border region.
- Analyzes the information obtained from the data-gathering tool, identifies stakeholder needs, and prepares recommendations for the next phase of the project.

IDENTIFY STAKEHOLDERS

To be able to properly determine needs for border region implementation and operation of cross-border ITS and TMCs, researchers identified several stakeholders to contact and get information from. The stakeholders were selected from public and private organizations from the United States and Mexico. Most of the stakeholders selected were either directly involved in the operation of international bridges or were from city agencies, county agencies, and MPOs since these agencies are recognized as the main source of traffic and road information along the Texas-Mexico border. The final stakeholder list, presented in Table 10, was developed in consultation with TxDOT.

Table 10. Stakeholders Contacted.

Border Bridge Operators	
Anzaludas International Bridge	Juárez-Lincoln Bridge
Bridge of the Americas	Laredo-Colombia Solidarity Bridge
Brownsville and Matamoros International Bridge	McAllen-Hidalgo-Reynosa Bridge
Camino Real International Bridge	Paso del Norte Bridge
Del Rio-Ciudad Acuna International Bridge	Pharr-Reynosa International Bridge on the Rise
Donna International Bridge	Progreso International Bridge
Eagle Pass Bridge I	Roma-Cd. Miguel Alemán International Bridge
Free Trade Bridge (Los Indios)	Tornillo Bridge
Gateway International Bridge	Veterans International Bridge
Gateway to the Americas Bridge	World Trade Bridge
Good Neighbor Bridge (southbound only, northbound dedicated commuter lane)	Ysleta-Zaragoza Bridge
MPOs	
El Paso	Hidalgo
Laredo	Harlingen-San Benito
Brownsville	Cameron County Regional Mobility Authority
Cities (Excluding U.S. Cities Already Included in MPOs)	
Eagle Pass	Nuevo Laredo
Matamoros	Ciudad Juárez Instituto Municipal de Investigación y Planeacíon (IMIP)
Reynosa	Rio Grande
Counties	
Cameron (Brownsville)	Maverick (Eagle Pass)
Hidalgo (McAllen/Pharr)	Val Verde (Del Rio)
Starr (Rio Grande)	El Paso (El Paso)
Webb (Laredo)	
DPS	
Department of Public Safety	
TxDOT	
Freight	Office of Operations
Border district with TMC: El Paso	Border district with TMCs: Laredo/Del Rio
Other Mexican Agencies	
Secretaria de Comunicaciones y Transportes	CAPUFE international toll bridge operators
Toll Road Operators	
Camino Colombia (TxDOT)	Camino Real Regional Mobility Authority
SH 550, Brownsville, Texas	Hidalgo County Regional Mobility Authority
Mexico toll roads operated by CAPUFE	

TRANSPORTATION INFORMATION-GATHERING TOOL

To identify the stakeholders' needs, researchers identified the data elements that currently generate transportation information for stakeholders throughout the border region. Researchers also identified data elements that could be involved in the future to generate more accurate transportation information. After the data elements were identified, researchers developed an information request form to be used during the interviews with the stakeholders identified in the previous chapter. This chapter presents the elements of the information-gathering tool used in the stakeholder needs-gathering process.

First Part of Information Request Form

The form is broken into two sections. The first section of the form requests information on current active information-sharing systems, elements that are currently being used to disseminate the information gathered, and the frequency of the reports.

Second Part of Information Request Form

The second section of the form presents a list of existing ITS technologies, the level of priority each of these technologies represents for the selected party, and any comments associated with it. Interview forms were prepared in English and Spanish to facilitate gathering data from stakeholders in Texas and Mexico. Copies of the interview forms are included in the appendix. The following is a list of the selected ITS technologies included in the form:

- Surveillance cameras: used to observe and/or supervise a location.
- Vehicle detectors: used to detect the presence of vehicles.
- Portable and permanent DMSs: used on roadways to provide information to motorists.
- Lane control signal stations: used to manage traffic on a multi-way road or highway.
- HAR: low-power AM radio stations that provide information to motorists.
- Coordinated signal control: a system that manages traffic flows in arterials based on the hour of the day.
- Adaptive signal control: a system that manages traffic flows in arterials based on traffic volumes.
- LPRs: used to automatically identify vehicles by their license plates.
- RFID readers: used to automatically identify and track tags attached to vehicles.
- Wait time measuring systems at POEs: systems used to estimate vehicle border crossing time at land POEs.
- Weather stations: used to measure atmospheric conditions to provide information for weather forecasts.
- Flood, ice, and fog detection devices: used to detect certain environmental conditions potentially dangerous for motorists.
- Computer-aided dispatch for transit and emergency vehicles: a system used to expedite deployment of certain vehicles upon request.
- GPS on buses and emergency vehicles: a system used to track vehicle position in real time.
- Traffic signal preemption: ITS that allows the emergency vehicle the right of way to help reduce response times and enhance traffic safety.
- Wired (including fiber) and wireless (Wi-Fi and radio-based) communications: a system that allows ITS interactions.
- WIM stations: used to measure and record axle weights and gross vehicle weights while vehicles are in movement.

- Technology for information dissemination to users: systems used to communicate certain information to motorists (e.g., websites, email, text, 511 number, and reverse 911).
- Ramp meters: used to manage the rate of automobiles entering the freeway.
- Speed monitoring: used to display speeds in the road network.
- Incident events: used for incident tracking.
- Construction events: used for tracking lane closures and construction activity.

These ITS technologies are currently in use in the United States, but not all of them are currently used in the border regions and Mexico. The objective of including them was to allow the interviewee to identify future needs.

RESULTS FROM THE INTERVIEWS

Researchers and TxDOT personnel selected 53 stakeholders to contact for information and conducted the interviews during December 2015 and January 2016. The method of communication for conducting the interviews was by phone, email, and in a few cases face-to-face meetings.

Types of Stakeholders and Agencies Surveyed

The stakeholder list includes a diverse range of agencies that operate near the border: 22 of the selected stakeholders are involved in international bridge operations, 7 are county offices, 6 are MPOs, 6 are cities, 4 are agencies within TxDOT, and 8 are another type of agency (Figure 53).

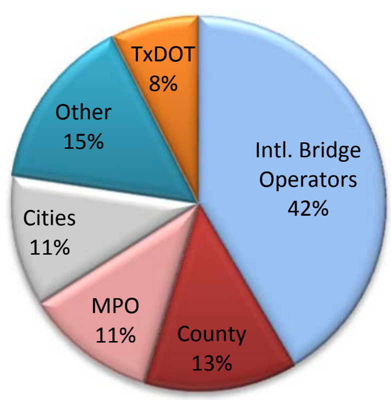


Figure 53. Breakdown of Potential Stakeholders to Interview by Type of Organization.

Figure 54 shows the breakdown of stakeholders by type of organization that responded to the survey. Thirty-five out of the 53 stakeholders contacted responded to the request for information. The breakdown stayed fairly similar when compared to Figure 53. Common causes for lack of information responses were that the contacted agency either is not involved in traffic information gathering or did not have information that would be useful for this project.

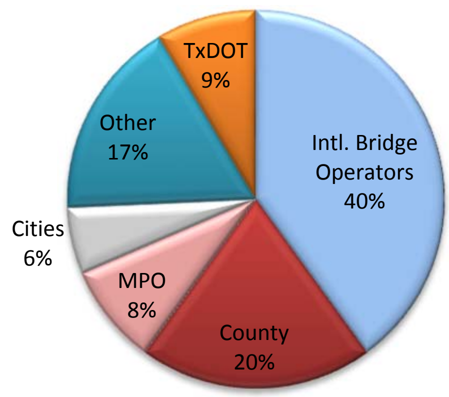


Figure 54. Breakdown of Stakeholders by Type of Organization That Responded.

Detailed Results

The detailed results for each of the 22 ITS technologies included in the survey are presented in this section. There were six types of possible responses:

- No response: No answer was provided.
- Existing: ITS technology is currently in operation. Researchers consider this similar to high priority given that the stakeholder at some point deemed it important enough to make the investment.
- Not applicable: The technology is not applicable to the stakeholder.
- High priority: ITS technology is not in operation but is seen as critical.
- Medium priority: ITS technology is not in operation but is seen as of medium importance.
- Low priority: ITS technology is not in operation and is seen as not needed or of low importance.

Surveillance Cameras

Forty-four percent of the respondents already have surveillance cameras, and 47 percent indicated they are a high priority. The combination of these two numbers indicates this ITS technology is extremely important to the respondents. A respondent commented, “Having cameras at the border would be helpful; would speed up responses in the event of accidents or other incidents” (Figure 55).

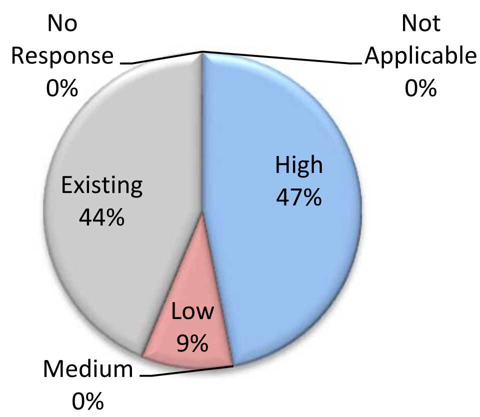


Figure 55. Surveillance Cameras.

Vehicle Detectors

Forty-one percent of the respondents already have vehicle detectors—mostly at tolling facilities—and 44 percent indicated they are a high priority (Figure 56). The combination of these two responses shows that this ITS technology is extremely important to the respondents. A respondent commented, “Loop detectors at toll booths. Detectors are able to count and classify vehicles.”

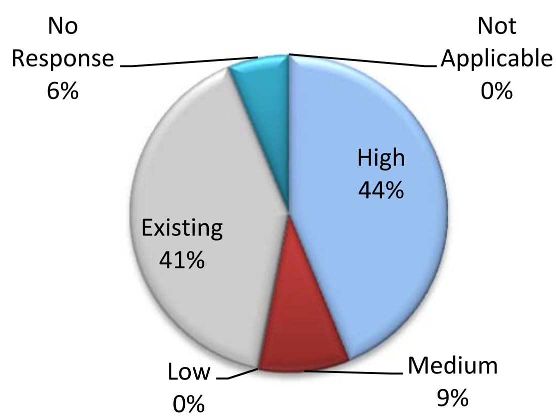


Figure 56. Vehicle Detectors.

Portable and Permanent DMSs

Forty-one percent of the respondents already have portable and permanent DMSs (Figure 57). The majority of the respondents indicated they are a medium priority. A respondent commented, “We don’t have DMS. But medium importance for hurricane season or reroute circumstances.”

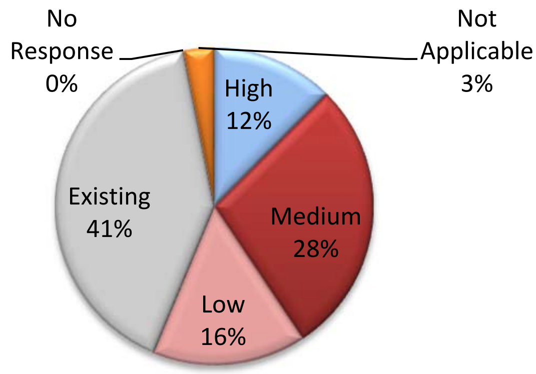


Figure 57. Portable and Permanent DMSs.

Lane Control Signal Stations

Twenty-eight percent of the respondents already have lane control signal stations (Figure 58). The majority of the respondents indicated they are a medium priority.

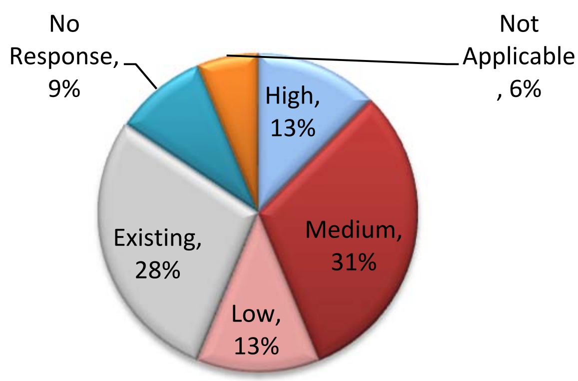


Figure 58. Lane Control Signal Stations.

Highway Advisory Radio

There is low interest in HAR technology (Figure 59). The respondents indicated that this ITS technology is a low priority (37 percent). However, regional agencies that cover large areas (e.g., TxDOT) indicated it is a high priority or the agency already has it.

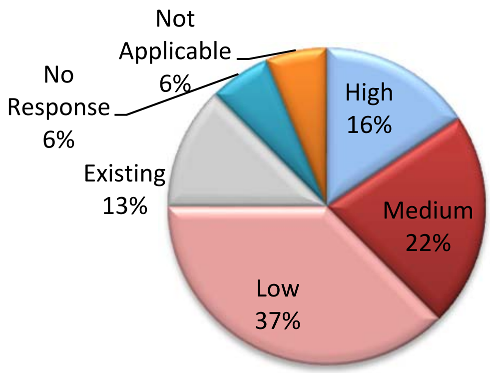


Figure 59. Highway Advisory Radio.

Coordinated Signal Control

Coordinated signal control is of low interest for the border stakeholders. Only two agencies have this ITS technology in place. Forty-eight of the respondents indicated it is a low priority or it is not applicable (Figure 60).

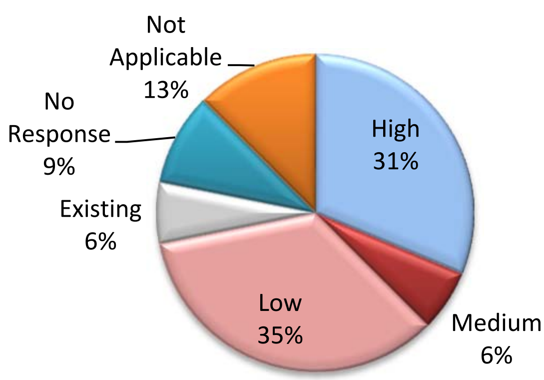


Figure 60. Coordinated Signal Control.

Adaptive Signal Control

There is low to medium interest in adaptive signal control systems. None of the respondents currently have this ITS technology in place. Twenty-eight percent indicated it is a medium priority, and 16 percent said it is not applicable (Figure 61). A respondent commented, “Would be useful in some situations such as I-69 E: East Loop or University Blvd. intersection.”

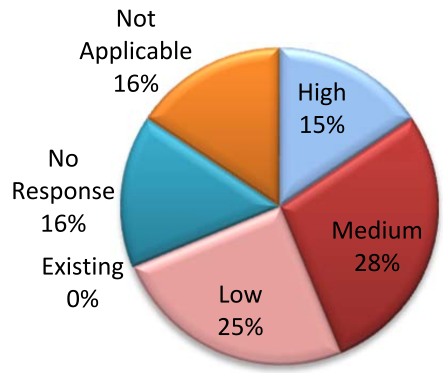


Figure 61. Adaptive Signal Control.

License Plate Readers

There is high interest in LPR ITS technology (Figure 62). This ITS technology is mostly used by CBP at international crossings and tolling agencies. Also, a high number of agencies already have this ITS technology in operation (28 percent). A respondent commented, "TxDOT is not allowed to install license plate readers in state property."

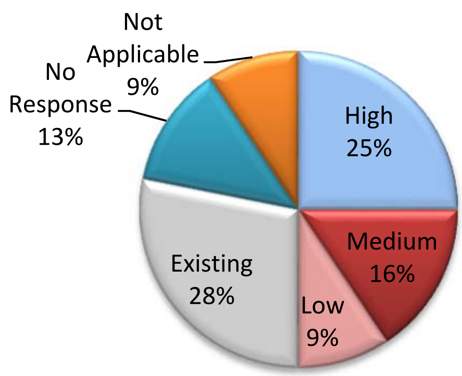


Figure 62. License Plate Readers.

RFID Readers

There is high interest in RFID technology. Thirty-one percent of the respondents already use RFID technology—mostly at tolling facilities—and 38 percent indicated it is a high priority (Figure 63). The combination of these two responses indicates this ITS technology is important to the respondents. Two of the respondents commented that RFID "is desirable in the near future to coordinate with law enforcement agencies" and "sharing of account information between CBP and the city and CRRMA [Camino Real Regional Mobility Authority] should be a high priority to provide priority lanes at the border crossings."

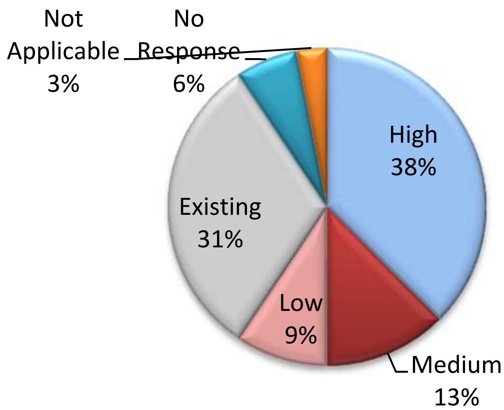


Figure 63. RFID Readers.

Wait Time Measuring Systems at POEs

Most of the respondents currently have no wait time measurement systems at land POEs. However, CBP has implemented a system and makes the information available to the public. Forty-seven percent indicated that this ITS technology is a high priority (Figure 64). A respondent commented, "Currently working on bringing the 'Metropia' app to El Paso, which will include the Juárez component that will explicitly identify bridge wait times."

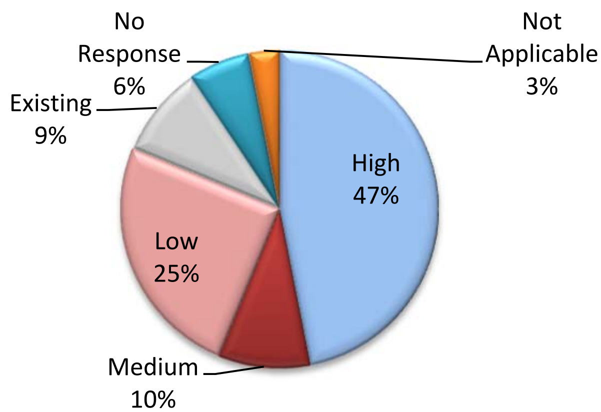


Figure 64. Wait Time Measuring Systems at POEs.

Weather Stations

There is low interest in weather station technology. Only one of the respondents currently has this ITS technology in operation, and 38 percent indicated a low priority to get them (Figure 65). A respondent commented, "The fire department has some only for emergency."

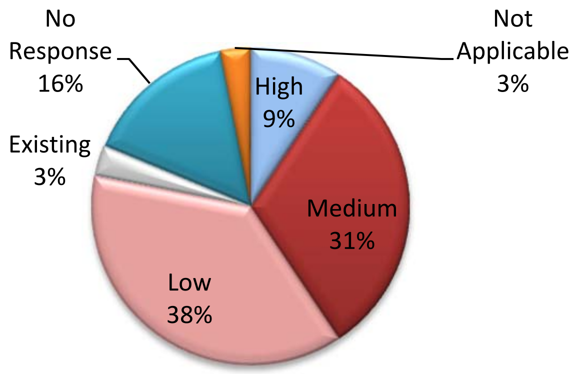


Figure 65. Weather Stations.

Flood, Ice, and Fog Detection Devices

There is low interest in flood, ice, and fog detection devices. None of the respondents currently have this ITS technology in operation, and 50 percent indicated it is a low priority (Figure 66). A respondent commented, "We have foggy conditions during parts of the year; such equipment is of low value, important after other investments are made."

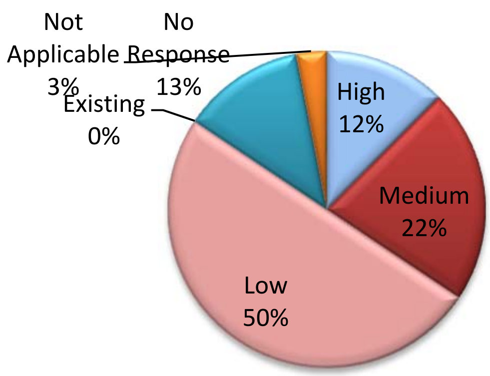


Figure 66. Flood, Ice, and Fog Detection Devices.

Computer-Aided Dispatch for Transit and Emergency Vehicles

There is low to medium interest in computer-aided dispatch for transit and emergency vehicles. Three of the respondents currently have this ITS technology in place, and 35 percent indicated it is a low priority (Figure 67). Although this ITS technology is critical for emergency services, most of the agencies do not foresee a need to deploy it since the emergency services agencies already have it. Agencies have low interest in deploying their own.

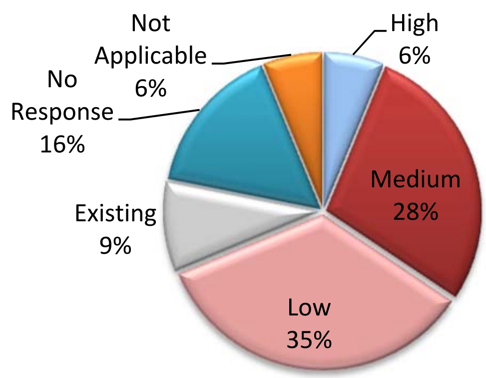


Figure 67. Computer-Aided Dispatch for Transit and Emergency Vehicles.

GPS on Buses and Emergency Vehicles

There is low interest in GPS on buses and emergency vehicles, with 41 percent of the respondents ranking it as a low priority. Two of the respondents currently have this ITS technology (Figure 68). The low interest in this ITS technology is due to its limited use in applications other than for emergency services and transit agencies. A respondent commented, “BMetro has real-time tracking of vehicles.”

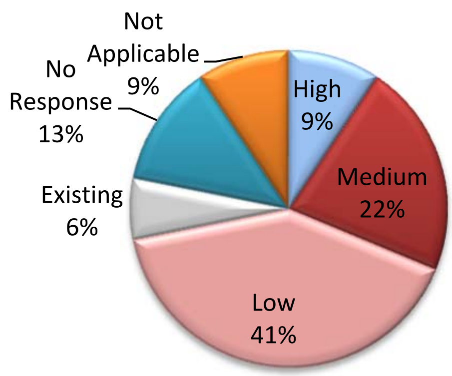


Figure 68. GPS on Buses and Emergency Vehicles.

Traffic Signal Preemption

There is medium interest in traffic signal preemption technology. None of the respondents currently have this ITS technology in place, 16 percent indicated it is not applicable to them, and 37 percent indicated it is a medium priority (Figure 69). This technology is usually deployed by agencies responsible for arterial operations.

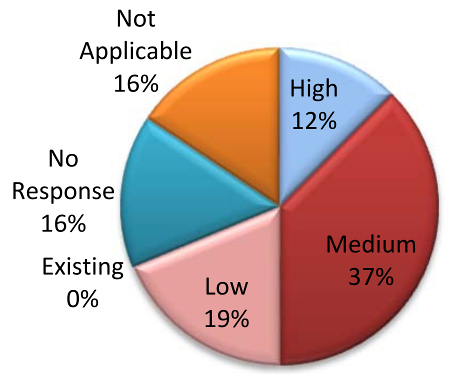


Figure 69. Traffic Signal Preemption.

Wired and Wireless Communications

There is high interest in wired and wireless communication technology. Forty-four percent of the respondents indicated that this ITS technology is a high priority, and 25 percent currently have it in operation (Figure 70).

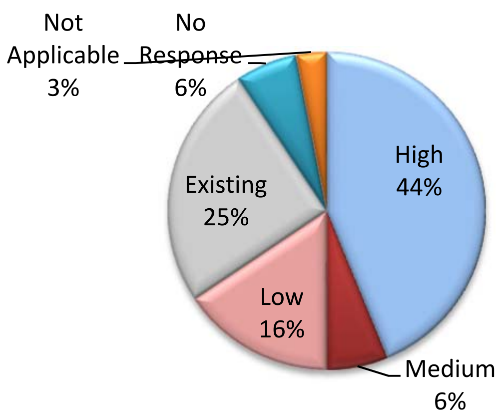


Figure 70. Wired and Wireless Communications.

WIM Stations

Responses are evenly distributed among high, medium, and low interest for WIM stations (Figure 71). This ITS technology is very specific and only used—or wanted—by agencies with special needs. A respondent commented, “Currently, WIM is local and data not shared with anybody. WIM works with snapshot camera, dimensioning system (height and length). There are plans for installing WIM at the Pharr-Reynosa Border Safety Inspection Facility and Los Indios (scaled downed version).”

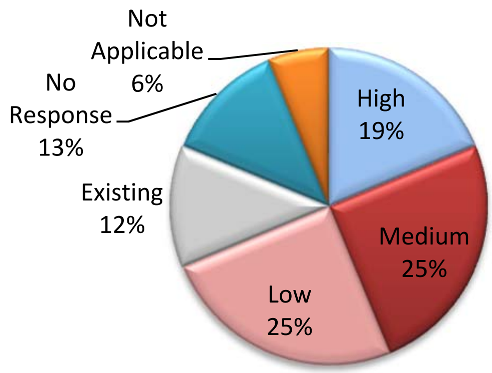


Figure 71. WIM Stations.

Technology for Information Dissemination to Users

Nineteen percent of the respondents already use technology for information dissemination to users in the region, and 34 percent indicated it is a high priority (Figure 72). The combination of these three figures indicates this ITS technology is important to the respondents. A respondent commented, "Currently working on bringing the Metropia app to El Paso, which will include the Juárez component that will share information with users."

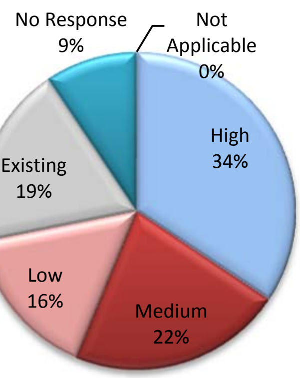


Figure 72. Technology for Information Dissemination to Users.

Ramp Meters

There is low interest in ramp meters. None of the respondents currently have this ITS technology in place, 16 percent indicated that it is not applicable to them, and 66 percent indicated it is a low priority (Figure 73). A respondent commented, "This is done manually by supervisors. In case of congestion, supervisor goes out and opens an additional lane."

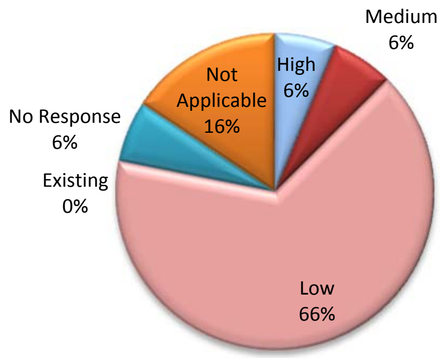


Figure 73. Ramp Meters.

Speed Monitoring

There is low interest in this speed-monitoring technology. Only one of the respondents has this ITS technology in place, and 44 percent indicated it is a low priority (Figure 74). A respondent commented, “Vehicles do speed when bridge is empty, but it is not a big concern for them.”

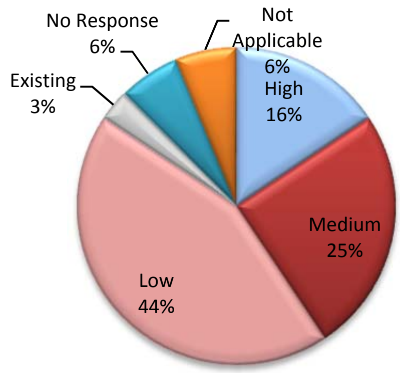


Figure 74. Speed Monitoring.

Incident Events

There is high interest in incident events ITS technology, even though only two respondents currently have it in operation. Forty-one percent of the respondents indicated it is a high priority (Figure 75). A respondent commented, “We do keep track. Highly important. We use a GIS [geographical information system] tool.”

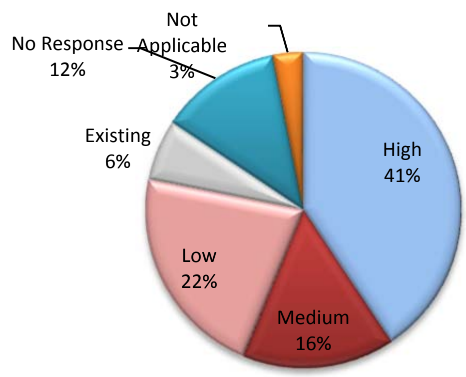


Figure 75. Incident Events.

Construction Events

There is medium interest in construction event ITS technology. Only two of the respondents have implemented this ITS technology, and 32 percent indicated it is a medium priority (Figure 76).

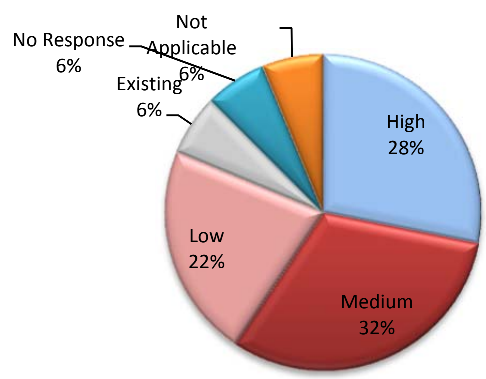


Figure 76. Construction Events.

Trends

Based on the responses from the interviewed stakeholders, researchers identified several trends that resulted in similar answers for most of the border region.

Information Sharing

Agencies in the border region share basic information mostly with other agencies. Forty-six percent of the respondents indicated some level of sharing. Most of the information being shared is with another agency of the same country, although two agencies indicated binational data sharing.

In general, the following data are shared in the region. The list is organized in order of most common data sharing:

- Traffic volumes: shared via email on a weekly and monthly basis.
- Special events: shared via email, phone, and text messages as needed.
- Accidents, traffic, and road conditions: shared by phone and text messages on a daily basis.
- Wait times: shared by phone on a weekly basis.
- Miscellaneous: There were also single responses indicating sharing information related to planning strategies, hours of operation, emergencies, lane closures, and revenue statistics.

ITS Technologies

For this study, researchers assumed that an ITS technology is *important* to the stakeholders if they assigned a high priority ranking or the technology is already in operation. Based in this definition of *important*, 60 percent of the ITS technologies were considered to be *important* to the stakeholders.

In general terms, the following ITS technologies were identified to be operational in the region:

- Surveillance cameras: used for monitoring and security purposes; indicated as operational in 44 percent of the responses.
- Portable and permanent DMSs: signs are placed to report information and to control operations; indicated as operational in 41 percent of the responses.
- Vehicle detectors: used at all roads, bridges, and toll roads to detect the presence of vehicles; indicated as operational in 41 percent of the responses.
- RFID readers: used at international crossings and toll roads, and for computing travel time; indicated as operational in 31 percent of the responses.
- Lane control signal stations: used on toll booth lanes; indicated as operational in 28 percent of the responses.
- LPRs: used at international crossings and toll roads; indicated as operational in 28 percent of the responses.
- Wired and wireless communications: allows ITS interactions; indicated as operational in 25 percent of the responses.
- Technology for information dissemination to users: video and traffic conditions provided to the public; indicated as operational in 19 percent of the responses.

SUMMARY OF FINDINGS

In order to identify ITS technology priorities at the border region, a numerical value was assigned to each response (high = 3, existing = 3, medium = 2, and low = 1). A high priority was given to technologies that are already in operation or those that were identified as high priority by stakeholders. This ranking will provide information for the next phase of the project, which includes the definition of an implementation plan for cross-border TMCs.

The systems that were described as high priority are:

- Surveillance cameras.
- Vehicle detectors.
- RFID readers.
- Wired and wireless communications.
- Portable and permanent DMSs.
- Technology for information dissemination to users.
- Wait time measuring systems at POEs.

The high-priority category had two types of technologies:

- Technology used to communicate information to users: wired and wireless communications, portable and permanent DMSs, and other dissemination technology.
- Technology used to collect information from the field: surveillance cameras, vehicle detectors, RFID readers, and wait time measuring systems at POEs.

The systems that were described as medium priority are:

- LPRs.
- Lane control signal stations.
- Incident events.
- Construction events.
- WIM stations.
- HAR.
- Coordinated signal control.

The systems that were described as low priority are:

- Speed monitoring.
- Weather stations.
- Computer-aided dispatch for transit and emergency vehicles.
- Flood, ice, and fog detection devices.
- GPS on buses and emergency vehicles.
- Traffic signal preemption.
- Adaptive signal control.
- Ramp meters.

Most of the systems and technologies in the medium- or low-priority categories are data/information-gathering technologies.

4. ACTION PLAN FOR CROSS-BORDER TMC IMPLEMENTATION

GENERAL APPROACH

The action plan describes a set of actions that are likely to be needed for TxDOT and its potential Mexican counterpart agencies to pursue the establishment of cross-border TMCs in major urban areas along the Texas-Mexico border. TxDOT has been operating TMCs on the U.S. side of the border in most of these urban areas. However, Mexico does not currently operate any TMCs in any of these locations and has no plans to do so any time in the near future. Consequently, any advances toward establishing the basic conditions needed for the cross-border TMC concept as defined in this research (e.g., real-time communications and coordination between traffic management agencies on both sides of the border) will likely have to take place in incremental steps.

The action plan acknowledges these limitations and builds on current conditions by proposing an action plan consisting of two stages:

- The first stage, basic TMC, involves setting up the cross-border TMC concept via relatively small and achievable changes over the current situation.
- The second stage, advanced TMC, builds on the basic TMC concept by setting up a more formalized and sustainable regulatory, institutional, and financial framework, and by adding additional technological capabilities.

A framework consisting of four categories of key conditions or characteristics was developed to describe the current situation on both sides of the border and the envisioned future basic and advanced TMC. This framework was also used to structure the action plan to move from the current situation to the future basic and advanced TMC stages by defining actions that help close the gap between the current situation and each of the future TMC stages. The four categories are defined as follows:

- **Legal and regulatory:** a set of federal, state, and local laws and regulations that govern the generation, transmission, and distribution of relevant traffic information, including its ownership and sharing mechanisms.
- **Institutional and policy:** a set of agreements between different stakeholder agencies at different levels of government (domestic and international) and the private sector that enable the flow of traffic data across these agencies.
- **Financial:** funding sources and financing mechanisms that support the cost of the development, implementation, operations, and maintenance of the technologies, and data generation, transmission, distribution, and sharing (if applicable).
- **Technology:** a set of ITS technologies (existing and future), communications infrastructure, and systems to collect, exchange, manage, and distribute traffic data in the border region.

Table 11 depicts the basic elements that the research team has defined for the current, basic, and advanced TMC concepts in each of the four categories.

This chapter presents a description of the actions that are needed to transition from the current situation to the basic TMC concept and from the basic to the advanced TMC.

Table 11. Cross-Border ITS Systems and TMC Implementation Stage Matrix.

		Current	Basic	Advanced
Legal and Regulatory	U.S.	1. TxDOT does not currently have statutory authority to sign an agreement (of any kind) with a government agency in a different country 2. FHWA does not explicitly allow states to share federally funded ITS data with another country	1. TxDOT shares data with a Mexican entity through a third party (e.g., TTI) that is able to sign a traffic data-sharing agreement with TxDOT's Mexican counterpart 2. Sharing of federally funded ITS data with Mexican entity through a third party is approved by FHWA	1. TxDOT has explicit statutory authority to sign agreements to share ITS data with Mexican counterparts 2. Sharing of federally funded ITS data with Canadian or Mexican entities in U.S. border regions is explicitly allowed or encouraged by FHWA policy
	Mexico	3. TxDOT's Mexican counterparts are not clearly defined, but the Mexican federal government through the SCT is the obvious one because it has been the only agency along the border engaged in ITS activities on the federal network 4. Laws, regulations, or administrative rules specifically dealing with ITS data sharing with foreign governing entities do not exist at any level of government 5. Mexican agencies at all levels of government do not have any significant restriction on signing technical interinstitutional collaboration agreements with foreign agencies	3. TxDOT's most likely Mexican counterpart will initially be SCT, but in large border cities with growing ITS networks, this could start shifting to local government agencies 4. In the absence of specific laws, Mexican counterparts are able to share data with TxDOT through ITS data-specific agreements with a third party	3. TxDOT's Mexican counterparts are clearly defined in every major binational border region 4. The Mexican legal and regulatory framework for ITS data sharing is mature and enables agencies at all levels of government to easily share ITS data with other U.S. and Mexican agencies and with the private sector

Table 11. Cross-Border ITS Systems and TMC Implementation Stage Matrix (Continued).

		Current	Basic	Advanced
Institutional and Policy		1. TxDOT has no agreements in place defining traffic data sharing with Mexico 2. Communication channels between TxDOT and SCT are not defined	1. Memoranda of understanding (MOUs) that allow data sharing between agencies need to be signed 2. Basic communication channels between agencies need to be defined	1. Development of the Texas part of the border regional ITS architecture 2. Advanced communication channels between agencies need to be defined
		3. SCT (or another agency) has no agreements in place defining traffic data sharing with Texas 4. Communication channels between SCT and TxDOT are not defined 5. The organizational structure in local Mexican agencies is not developed and implemented 6. There is a lack of trained staff in Mexico	3. MOUs that allow data sharing between agencies need to be signed 4. Basic communication channels between agencies need to be defined 5. The organizational structure in Mexican agencies needs to be in place to support public partnerships 6. Agencies identify and train staff and stakeholders	3. Development of the Texas part of the border regional ITS architecture 4. Advanced communication channels between agencies need to be defined 5. Policies to support public partnerships at the local and regional level in Mexico are needed

Table 11. Cross-Border ITS Systems and TMC Implementation Stage Matrix (Continued).

		Current	Basic	Advanced
Financial		1. Texas already has in place ITS-project funding sources at the three levels of government, and financial mechanisms at the state and local levels	1. The basic scenario is the same as the existing condition in Texas	1. TxDOT needs to encourage toll POE owners to establish funding sources from toll revenues to operate and maintain TMCs
		2. Mexico currently has neither funding sources nor financial mechanisms already established (at any level of government) that are explicitly dedicated to fund ITS projects	2. TxDOT needs to encourage SCT and border states to give priority to ITS projects 3. Mexican authorities need to establish funding sources and financial mechanisms dedicated to fund ITS projects	2. TxDOT needs to encourage Mexican border states to establish funding sources from toll revenues to operate and maintain TMCs

Table 11. Cross-Border ITS Systems and TMC Implementation Stage Matrix (Continued).

	Current	Basic	Advanced
Technology 	1. TxDOT does not currently have an established protocol to exchange traffic data with Mexico 2. TxDOT does not currently have a northbound (NB) wait time measuring system for NB passenger vehicles	1. TxDOT and Mexico agree on a protocol to exchange traffic data 2. TxDOT and FHWA deploy an NB wait time measuring system	1. Local agencies connect to the Lonestar traffic management system for entering incidents and construction events on their facilities 2. TxDOT and local agencies incorporate connected vehicle technology 3. TxDOT deploys a statewide 511 system 4. Agencies operating POEs deploy dynamic managed lanes
	3. Mexico does not currently have an established protocol to exchange traffic data with TxDOT 4. Mexico is missing basic ITS technologies 5. Mexico does not currently have operational or planned TMCs along the Texas-Mexico border	3. TxDOT and Mexico agree on a protocol to exchange traffic data 4. Mexico deploys missing ITS technologies 5. Mexico establishes one or multiple TMCs to cover selected POEs along the Texas-Mexico border	5. Mexico deploys an advanced traffic management system 6. Mexico incorporates connected vehicle technology 7. Mexico deploys a regional 511 system 8. Mexican agencies operating POEs deploy dynamic managed lanes

CURRENT SITUATION

In the previous tasks of this project, the research team conducted a literature review, a state-of-the-practice analysis, interviews, and a survey with stakeholders. This information allowed the research team to identify the current situation for each of the four categories of the proposed framework.

Legal and Regulatory

In this category, the most important conditions or characteristics that describe the current situation refer to the existence (or absence) of laws and regulations that allow the agencies that own or produce relevant ITS data on each side of the border to share it.

On the U.S. side, TxDOT owns and operates a statewide network of ITS infrastructure that consists of the following two main components (*83*):

- **ITS field network.** This network includes, but is not limited to, sensors, cameras, signs, and communications links constructed along segments of the Texas state highway system.
- **ITS business network.** This network produces transportation-related information that is used for the purpose of traffic management in which Texas owns certain rights, title, and related interests (including copyrights).

The largest and most comprehensive and connected TMCs located along the Texas-Mexico border are part of this network.

TxDOT currently has the legal ability to sign agreements with U.S. public- and private-sector third parties (also called partners) to share traffic data and infrastructure (such as its fiber-optic cable). More specifically, according to the Texas Transportation Code, Section 201.205, TxDOT may (*84*):

- Apply for, register, secure, hold, and protect its intellectual property, patents, copyrights, trademarks, or other evidence of protection of exclusivity.
- Enter into non-exclusive license agreements with any third party for the receipt of fees, royalties, or other things of monetary and non-monetary value.
- Waive or reduce the amount of fees if it determines that such a waiver will further the goal and missions of TxDOT and result in a net benefit to TxDOT.

Additionally, the Texas Transportation Code in Section 202.052 authorizes TxDOT to lease highway assets if the area to be leased is not needed for a highway purpose during the term of the lease, and if TxDOT charges fair market value for the leased asset. This section of the code also authorizes TxDOT to waive such fees for social, economic, and environmental mitigation purposes (*85*).

Typically, third parties with whom TxDOT has already signed data or infrastructure sharing agreements include entities such as other state agencies (e.g., TTI or the Texas DPS), local governments, universities, and television stations. However, TxDOT is currently prevented by state law from signing legally binding agreements of any kind with foreign governments. This restriction means that TxDOT would be unable to sign an ITS data (or ITS infrastructure) sharing agreement with a Mexican government entity. Conversations between researchers and TxDOT staff indicated that there may also be potential federal restriction on ITS data sharing with foreign governments. More specifically, this refers to possible restrictions from FHWA or state DOTs sharing federally funded ITS data (or infrastructure). Such restrictions have not been confirmed, and the existence of an ITS data-sharing MOU between the Whatcom Council of Governments in Washington State and the Province of British Columbia in Canada suggests that such restriction may not exist or that there may be a legal mechanism to overcome it.

The experience with ITS data and infrastructure sharing in Mexico is significantly more limited than in the United States, and researchers found no evidence of laws and regulations that specifically address it. Only major cities in the interior of Mexico have urban ITS networks. The Mexican federal government, through SCT and CAPUFE, owns and operates most of the existing ITS infrastructure network on the primary national and regional road networks. There are a very limited number of TMCs across the country, and the owners/operators of those that exist are diverse (e.g., federal, state, and local government agencies). There are currently no TMCs operating in border communities on the Mexican side of the border.

Mexico's SCT has been entering into public-private partnership agreements with the private sector for highway concessions for a long time. Some of these concessions include the operation by private concessionaires of highway-specific TMCs on the country's primary network. This suggests that SCT's current legal and regulatory framework may allow it to enter into agreements (at least with private entities) to share ITS data and infrastructure. Specific legal restrictions on SCT's ability to enter into similar agreements with foreign governments were not identified. According to guidance published by Mexico's federal Secretaría de Relaciones Exteriores (Foreign Relations Secretariat), federal, state, and local government agencies are not prevented from signing interinstitutional agreements with foreign governments, as long as the subject matter is limited to their institutional competencies (e.g., traffic management) (*86*). Based on the limited experience with ITS in the country and the findings from the stakeholder survey, the scope of existing applicable state and local legislation in Mexico is even more limited than at the federal level or is nonexistent.

The fact that SCT is one of the most active Mexican transportation agencies in the field of ITS—and has a long history of cooperation with USDOT and TxDOT in ITS and all other cross-border transportation issues—makes it the most likely potential counterpart for TxDOT on any cross-border ITS initiatives. However, SCT's jurisdiction is limited to the federal highway network and the international border crossings. Important road links leading to the border crossings are increasingly within the jurisdiction of local governments or concessionaires. With several Mexican communities along the border already exceeding 1 million inhabitants (e.g., Ciudad Juárez and Tijuana) and experiencing significant traffic congestion issues within their network, it is very likely that the larger ITS deployments will soon occur at the local level. This means that over time, TxDOT's Mexican counterpart will likely be a local government.

Institutional and Policy

Current cross-border agreements among stakeholders at the Texas-Mexico border do not exist. Interviews with stakeholders on both sides of the border and a review of available information showed that traffic data sharing between stakeholders from both sides of the border is mainly done informally with no written agreement.

The U.S. side of the border has several policies in place related to ITS. There is the National ITS Architecture developed by FHWA. Mexico also has a national ITS architecture. However, it is not generally used, and stakeholders have very little knowledge of it.

In Texas, TxDOT has developed the regional ITS architectures over the last 12 years. With the exception of Eagle Pass, which was completed in 2013, the rest of the ITS architectures have not been kept current. Within the border region, Laredo, El Paso, Del Rio, Eagle Pass, and the LRGV have regional ITS architectures (*87*). However, there is little or no mention of cross-border ITS initiatives in these cities' regional ITS architecture. Similar to the National ITS Architecture, service package CVO05 (International Border Electronic Clearance) is the only ITS package mentioned that is related to a cross-border environment. The deployment status of service package CVO05 varies by border city:

- Laredo: existing.
- Del Rio: planned.
- Eagle Pass: planned.
- El Paso: not planned.

The LRGV region ITS architecture includes service package CVO05 with a deployment status shown as future. However, unlike the other border cities, the architecture in the LRGV also includes interfaces to SCT and Mexico emergency management systems.

At the U.S.-Canada border, the BIFA was developed by U.S. and Canadian stakeholders. The BIFA is a framework intended to promote the implementation of interoperable technology with the objective of facilitating the use of technology to gather data that will be available to agencies on both sides of the border. At the U.S.-Mexico border, there is nothing similar to the BIFA, and there are no plans to developed one in the near future.

Financial

This financial category aims to identify current funding sources and financial mechanisms in both countries that support the cost of the development, implementation, operations, and maintenance of ITS technologies, and the generation and sharing (if applicable) of ITS data. Funding sources are the sources of money used to pay for investment and/or operational needs. Financial mechanisms are broadly defined as the tools used to leverage existing funding sources and secure the capital needed for infrastructure investment.

In the United States, there are specific funding sources at the federal level that can be used to carry out ITS projects. There are also a number of financial mechanisms at the state and local government level that can be used for the same purpose. Although Mexico has no ITS-specific funding sources or financial mechanisms at the federal, state, or local government level, transportation agencies increasingly have access to funding sources that could potentially be used for ITS projects. Multilateral banks, for example, are currently making loans to the Mexican federal government for transportation improvement projects, and many of these projects are beginning to include ITS elements.

The U.S. Federal Government provides funds for ITS and traffic management development and implementation initiatives through five core programs included in the Fixing America's Surface Transportation Act (FAST Act) (*88,89*):

- National Highway Performance Program.
- National Highway Freight Program.
- Congestion Mitigation and Air Quality Improvement Program.
- Highway Safety Improvement Program.
- Nationally Significant Freight and Highway Projects Program.

The Congestion Mitigation and Air Quality Improvement Program can also provide funds for operations and maintenance of the technologies, and ITS data generation and sharing. The rest of these federal programs only provide funds to cover capital costs. Additionally, the FAST Act allows states to spend federal transportation funding in Mexico through the Cross Border Infrastructure Program. The objective of the Cross Border Infrastructure Program is to facilitate cross-border motor vehicle and cargo movements at international POEs.

At the state level, Texas relies on fuel tax revenues to fund transportation projects through the State Highway Fund. These funds can be used to pay for the cost of projects that include the development, implementation, operations, maintenance of technologies, and ITS data generation and sharing. In addition to the State Highway Fund, Texas has other financial mechanisms available, such as Highway Improvement General Obligation Bonds, which are payable from the general revenue fund.

At the local level, municipalities can establish funding sources from their general tax revenue fund and also establish financial mechanisms such as:

- **Transportation reinvestment zones.** Funding is captured from increased property values within a designated area around a transportation facility such as a highway or a transit station. This funding can only be used for transportation improvements within the transportation reinvestment zone.
- **Tax increment reinvestment zones.** As property values increase in the designated area, the increased taxes are used exclusively in that area to fund infrastructure improvements.

In Mexico, SCT developed the country's National ITS Strategic Plan in 2010. This plan identified 74 strategic ITS implementation projects that would take place between 2011 and 2020, and identified some potential funding sources. However, SCT has not established specific funding sources and/or financial mechanisms yet. The projects in the plan are proposed to be carried out on federal highways located in urban and interurban areas. The total cost for implementing these projects is estimated at USD $296 million (*90*).

At the local level, the Mexican National Bank of Public Works and Services (BANOBRAS) has financial mechanisms and funding sources (i.e., loans and grants) available to states and municipalities that can potentially be used to fund these projects. BANOBRAS is often designated as the financing entity in charge of channeling funds secured from multilateral banks such as the World Bank or the Inter-American Development Bank to states and municipalities. These international loans and grants are currently being used to carry out transportation and mobility improvement projects. These funds, however, can only be used for development and implementation projects, not operations and maintenance.

At the state and local level, there are no dedicated financial mechanisms or funding sources already established. However, CAPUFE (the federal toll road and bridge operator) has recently transferred the authority for operating toll facilities at international POEs that connect El Paso and Ciudad Juárez to the State of Chihuahua. The State of Chihuahua is planning to use the revenues from these POEs to fund transportation projects in Ciudad Juárez. These funds could potentially be used for the development, implementation, operations, and maintenance of the technologies, and for data generation, transmission, distribution, and sharing. Mexican municipalities do not currently have any dedicated funding sources or mechanisms to fund these projects.

Technology

The types of existing ITS technologies along the Texas-Mexico vary significantly by geographic area, agency, and country. Based on the findings from the earlier research conducted under this project, the research team was able to identify the existing ITS technologies that are more prevalent along the Texas-Mexico border. The research team conducted interviews with 35 stakeholders about 22 ITS technologies. The stakeholders were selected from public and private organizations from the United States and Mexico that are involved in transportation or provide traffic and road information along the Texas-Mexico border.

In Texas, the TMCs managed by TxDOT operate the highest number of ITS technologies. Other stakeholders, with smaller operations such as international bridge crossings, usually only operate a couple of ITS technologies. The most common ITS technologies currently in operation in Texas near the border are, in order of most common ITS technology:

1. Surveillance cameras.
2. Vehicle detectors.
3. Portable and permanent DMS.
4. RFID readers.
5. Lane control signal stations.
6. LPRs.
7. Wired (including fiber) and wireless (Wi-Fi and radio-based) communications.
8. Technology for information dissemination to users.

This list only includes those ITS technologies that are currently in operation in at least 20 percent of the interviewed agencies.

On the Mexican side, the Mexican authorities have not yet developed citywide systems that accurately and centrally control traffic. The use of ITS technologies near the Texas-Mexico border is limited mostly to highways. SCT and CAPUFE are the only two agencies that use ITS technologies. The most common ITS technologies currently in operation in Mexico are:

1. Vehicle detectors.
2. Portable and permanent DMSs.
3. RFID readers.
4. Lane control signal stations.
5. Technology for information dissemination to users.

In terms of information sharing and data exchange, agencies in the border region share basic information mostly with other agencies. Forty-six percent of the interviewees indicated some level of sharing. Most of the information being shared is with another agency of the same country, although two agencies indicated binational data sharing. In general, the following data are shared in the region, in order of most common data sharing:

- **Traffic volumes:** shared via email on a weekly and monthly basis.
- **Special events:** shared via email, phone, and text messages as needed.
- **Accidents, traffic, and road conditions:** shared by phone and text messages on a daily basis.

- **Wait times:** shared by phone on a weekly basis.

BASIC SCENARIO FOR CROSS-BORDER ITS SYSTEMS AND TMCS

Table 11 presents key characteristics of the basic scenario. This section describes the characteristics of the basic TMC scenario divided into the four categories and then the actions that are required to transition from the current situation to the basic scenario.

Legal and Regulatory Basic Scenario

The basic scenario assumes that TxDOT and its potential Mexican counterpart(s) are able to implement simple measures to overcome the current legal and regulatory challenges. Although the measures may not represent the ideal solution to these challenges, they provide a way for TxDOT and its Mexican counterpart to temporarily or permanently work around the restrictions they currently face to share data.

In this scenario, to overcome the lack of statutory authority to sign an agreement with a foreign government, TxDOT signs an agreement with one or more U.S. third parties that in turn have the legal ability to sign a traffic data sharing agreement with a Mexican entity. Such a third party could include a local government or a higher-education entity (e.g., TTI or another university). This third party would in turn sign a data-sharing agreement with the designated Mexican entity representing TxDOT's Mexican counterpart(s). Alternatively, to overcome possible administrative restrictions from FHWA for the sharing of federally funded ITS data (i.e., produced or transmitted using federally funded infrastructure) with a foreign entity, TxDOT could seek blanket or site-specific federal approval to share data. The fact that ITS data sharing is already occurring between U.S. and Canadian agencies along the northern border suggests that overcoming this unconfirmed barrier would not be a problem.

On the Mexican side of the border, TxDOT's Mexican counterpart in the first few cross-border TMC initiatives would be SCT. However, over time, in the larger Mexican communities along the border where roads leading to international border crossings are within urban areas, local governments may emerge as a partner due to the scope of their urban ITS deployments. In the absence of specific legal restrictions on the sharing of ITS data with foreign entities for Mexican federal or local agencies, a likely legal framework to share these data with TxDOT (through the third party) would be through an agreement specifically designed for this purpose. This scenario assumes that such an agreement could be signed under the aforementioned existing guidance for interinstitutional agreements with foreign entities provided by Secretaría de Relaciones Exteriores.

Institutional and Policy Basic Scenario

To establish cross-border TMCs along the Texas-Mexico border, several items need to be met at the institutional and policy levels.

Memoranda of Understanding

TxDOT and the local jurisdictions in Texas need to develop and sign MOUs with Mexican counterparts that establish rules under which data sharing between agencies should be performed. TxDOT should be involved when the TMC on the U.S. side of the border is operated by TxDOT, and SCT in Mexico should be the counterpart when the TMC in Mexico is operated by the federal government. This is the most common case of stakeholder intervention. However, it might change on a project-by-project basis. Under some instances, private-sector stakeholders could be involved if the data are being provided by these stakeholders or when the TMC is operated under a concession by the private sector.

Communication Channels

The main objective of cross-border TMCs is the sharing of traffic information on both sides of the border. To have an organized and efficient data exchange, agencies must clearly define the communication channels. Specifically, media details such as email, phone calls, and/or text messages have to be defined and agreed upon. It is also important to define the schedule of the information exchange and specify the media to be used.

Organizational Structure

The organizational structure in Mexico is not fully developed to support public partnerships to share information at the regional and local levels. The proposed TMC basic scenario requires that an organization within the municipal and state government allow an exchange of traffic information with counterparts on the U.S. side of the border. The structure needs to be in place so that the cross-border TMC can be operational within the local legal structure in Mexico.

Staff Capacity

Because Mexico currently has no TMCs in operation in the border region, there is no staff with experience and training to develop and operate such infrastructure on the Mexican side of the border region. The basic scenario of the cross-border TMCs needs to have trained staff on both sides of the border, not only to implement the selected technologies but to operate and maintain the system so that data exchanges are done as agreed.

Financial Basic Scenario

The basic TMC scenario can be described through a set of financial mechanisms and funding sources that need to be established by each country for the basic TMC concept to be implemented. Since the financial mechanisms and funding sources available are not the same for Texas and Mexico, the scenario has been adapted to the specific circumstances of each. In the case of Texas, the basic TMC scenario has established funding sources at the federal, state, and local levels, and financial mechanisms at the state and local levels. In Mexico, this scenario has established funding sources and financial mechanisms at the federal and state levels.

As documented previously, Texas already has in place funding from ITS-project sources at the three levels of government and financial mechanisms at the state and local levels. In other words, Texas is financially ready to implement a basic binational TMC. However, Mexico currently has neither funding sources nor financial mechanisms already established (at any level of government) that are explicitly dedicated to funding ITS projects. Therefore, TxDOT needs to encourage SCT and Mexican border states to give priority to ITS projects.

Technology Basic Scenario

During the survey conducted previously, the stakeholders identified these ITS technologies as high priority:

1. Surveillance cameras.
2. Vehicle detectors.
3. RFID readers.
4. Wired and wireless communications.
5. Portable and permanent DMSs.
6. Technology for information dissemination to users.
7. Wait time measuring systems at POEs.

The high-priority categories had two types of technologies:

- **Technology used to communicate information to users:** wired and wireless communications, portable and permanent DMSs, and other dissemination technology.
- **Technology used to collect information from the field:** surveillance cameras, vehicle detectors, RFID readers, and wait time measuring systems at POEs.

These seven ITS technologies align well with the eight existing ITS technologies in Texas described in the previous section. Six ITS technologies are represented on both lists.

On the Mexican side, there are no TMCs near the Texas-Mexico border. A new TMC would need to be added. Given that this will take time and funding from the Mexican government, the research team explored an alternative where TxDOT or USDOT could assist the Mexican agencies in deploying a set of selected ITS technologies at key locations to transmit their data directly to a TxDOT TMC. The idea behind this is to accelerate the deployment of cross-border ITS technologies without having to wait for the Mexican government to establish its own TMCs. This approach was not considered feasible and was not furthered explored, given the legal and regulatory issues that this involves and the fact that it will require providing funding and resources outside the United States.

Combining the high-priority and existing ITS technologies in Mexico and Texas—described in the previous section—the research team proposes the ITS elements for the basic scenario shown in Table 12.

All of the proposed ITS technologies for the basic scenario currently exist in a typical TxDOT TMC with the exception of wait time measuring systems for passenger vehicles. By selecting existing technologies on the Texas side, TxDOT will be able to focus its efforts on working with the Mexican agencies to add the missing ITS technologies on the Mexican side and agreeing on a common standard for data exchange. These are the first steps for a cross-border ITS system with binational TMCs.

Table 12. ITS Technologies for the Basic Scenario.

ITS Technology	Existing (Yes/No)	
	Texas	Mexico
Surveillance cameras	Yes	No
Vehicle detectors	Yes	Yes
Portable and permanent DMSs	Yes	Yes
RFID readers	Yes	Yes
Lane control signal stations	Yes	Yes
Wired and wireless communications	Yes	No
Technology for information dissemination to users	Yes	Yes
Wait time measuring systems at POEs	No*	No*
TMCs	Yes	No

* Currently only for NB commercial vehicles. Systems for SB commercial and NB/SB passenger vehicles need to be added.

Actions for Implementing the Basic Scenario

Table 13 through Table 24 provide a description of actions for implementing the basic scenario for each of the four categories identified as critical (legal and regulatory, institutional and policy, financial, and technology).

Table 13. Legal and Regulatory Action 1—Sign a Data-Sharing Agreement with a U.S. Third Party Able to Share Each Agency's ITS Data.

Attribute of Action	Description of Attribute
Description	• TxDOT and its Mexican counterpart (most likely SCT but possibly local governments) sign a data-sharing agreement with a U.S. third party that has the legal ability to share ITS data from both agencies (in both directions)
Current situation	• TxDOT does not currently have statutory authority to sign an agreement (of any kind) with a government agency in a different country • TxDOT's Mexican counterparts are not clearly defined, but the Mexican federal government through SCT is the obvious one because it has been the only agency along the border engaged in ITS activities on the federal network • Mexican agencies at all levels of government do not have significant restrictions on signing interinstitutional collaboration agreements with foreign entities
Responsible and involved parties	• TxDOT • SCT/Mexican counterparts • U.S. third party
Time frame	During the first year of the program
Actions that precede	None

Table 14. Legal and Regulatory Action 2—Obtain Federal Approval to Share Federally Funded ITS Data with a Mexican Agency (through a U.S. Third Party).

Attribute of Action	Description of Attribute
Description	• TxDOT and FHWA work together to obtain general or site-specific federal approval for TxDOT to share federally funded ITS data with a Mexican entity
Current situation	• In the United States, FHWA does not explicitly allow states to share federally funded ITS data with another country • In Mexico, laws, regulations, or administrative rules specifically dealing with ITS data sharing with foreign governing entities do not exist at any level of government
Responsible and involved parties	• TxDOT • FHWA
Time frame	During the first year of the program
Actions that precede	None

Table 15. Institutional and Policy Action 1—Establish MOUs for Data Sharing between Mexico and Texas.

Attribute of Action	Description of Attribute
Description	• TxDOT and the lead Mexican agency (SCT or other agency) define and agree to the rules under which data exchange will be made, and define an MOU that will be signed by both parties identifying conditions and the time period for the data exchange
Current situation	• TxDOT has no agreements in place defining traffic data sharing with Mexico • SCT or local agencies have no agreements defining data exchange with TxDOT
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	During the first year of the program
Actions that precede	None

Table 16. Institutional and Policy Action 2—Define Basic Communication Channels between Texas and Mexican Agencies.

Attribute of Action	Description of Attribute
Description	• TxDOT and the lead Mexican agency (SCT or other agency) specify details of how communications and data exchange will be performed, establishing stakeholders' roles in terms of data exchange, and define technologies and media that will be used to exchange information including periodicity of data exchange and methods
Current situation	• There are no communication channels established and no definition of key stakeholders that will provide the information to be shared
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	During the first year of the program
Actions that precede	None

Table 17. Institutional and Policy Action 3—Define the Organizational Structure in Mexico.

Attribute of Action	Description of Attribute
Description	• The lead Mexican agency (SCT or other agency) defines the organizational structure in Mexican agencies to support public partnerships at the local and regional levels • The lead Mexican agency (SCT or other agency) defines the structure that the municipality or state needs to facilitate the development of partnerships with Texas' counterparts that will enable information exchange
Current situation	• Mexican state and municipal governments do not have a structure that supports partnerships to exchange information with other agencies
Responsible and involved parties	• Mexican state and municipal agencies
Time frame	During the first year of the program
Actions that precede	None

Table 18. Institutional and Policy Action 4—Identify and Train Staff and Stakeholders in Mexico.

Attribute of Action	Description of Attribute
Description	• The lead Mexican agency (SCT or other agency) identifies stakeholders in Mexico and trains them to operate and maintain a TMC • It develops a workforce in Mexico that could assume the role of TMC operator and data analyst • It trains staff to provide seamless data interchange and analysis
Current situation	• There is a lack of trained staff in Mexico to operate and maintain a TMC
Responsible and involved parties	• Mexican federal, state, and local agencies
Time frame	During the first three years of the program
Actions that precede	None

Table 19. Financial Action 1—Encourage SCT and Border States to Give Priority to ITS Projects.

Attribute of Action	Description of Attribute
Description	• TxDOT and the lead Mexican agency (SCT or other agency) encourage SCT and border states to give priority to ITS projects and share lessons learned
Current situation	• SCT and Mexican border states do not prioritize ITS projects over other transportation improvement projects
Responsible and involved parties	• TxDOT • SCT, State of Chihuahua, State of Coahuila, State of Nuevo Leon, and State of Tamaulipas
Time frame	During the first year of the program
Actions that precede	None

Table 20. Financial Action 2—Establish Funding Sources and Financial Mechanisms Dedicated to Fund ITS Projects.

Attribute of Action	Description of Attribute
Description	• The lead Mexican agency (SCT or other agency) establishes funding sources at the federal, state, and local levels, and financial mechanisms at the state and local levels in Mexico
Current situation	• SCT, Mexican border states, and municipalities have not identified funding sources or financial mechanisms to implement, operate, and maintain TMCs in Mexico
Responsible and involved parties	• SCT, State of Chihuahua, State of Coahuila, State of Nuevo Leon, State of Tamaulipas, and border municipalities
Time frame	During the third year of the program
Actions that precede	None

Table 21. Technology Action 1—Establish Protocol for Data Exchange between TxDOT and Mexican Counterpart.

Attribute of Action	Description of Attribute
Description	• TxDOT identifies its Mexican counterpart agency (lead agency) with authority to establish a data exchange protocol; the counterpart may vary by location and may be a federal, state, or local government agency • TxDOT and the lead Mexican agency (SCT or other agency) establish a protocol to enable data exchange of traffic and travel information in an unambiguous manner between TxDOT and the counterpart Mexican agency
Current situation	• TxDOT does not currently have an established protocol to exchange traffic data with Mexico • Mexico does not currently have an established protocol to exchange traffic data with TxDOT
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	Between the fourth and fifth year of the program
Actions that precede	None

Table 22. Technology Action 2—Deploy a Wait Time Measuring System for NB Passenger Vehicles.

Attribute of Action	Description of Attribute
Description	• The U.S. federal government allows TxDOT's TMCs to receive and disseminate to the public and Mexico NB passenger vehicle wait time measuring data. • TxDOT, the U.S. Department of Homeland Security (DHS), and FHWA work together to deploy the system • TxDOT deploys and operates the wait time measuring system • TxDOT defines which POEs get priority
Current situation	• TxDOT is missing one ITS technology identified in Table 12
Responsible and involved parties	• TxDOT • FHWA • DHS
Time frame	Between the third and fourth year of the program
Actions that precede	None

Table 23. Technology Action 3—Deploy Surveillance Cameras and a Southbound Wait Time Measuring System Including Required Wireless or Wired Communications to Transmit Data.

Attribute of Action	Description of Attribute
Description	• The Mexican federal government allows the Mexican counterpart to operate surveillance cameras and wait time measuring system data and disseminate this information to the public and Texas • TxDOT identifies its Mexican counterpart agency (lead agency) with authority to add these ITS technologies • The Mexican counterpart deploys missing ITS technologies and the necessary communication network • TxDOT assists the Mexican counterpart by providing know-how and technical support
Current situation	• Mexico is missing several ITS technologies identified in Table 12
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	Between the second and fourth year of the program
Actions that precede	None

Table 24. Technology Action 4—Establish a TMC, or Equivalent, in Mexico That Covers the Texas-Mexico Border.

Attribute of Action	Description of Attribute
Description	• The Mexican federal government allows Mexico to collect and disseminate traffic and road information • TxDOT identifies its Mexican counterpart agency (lead agency) with authority to establish a TMC, or equivalent, in Mexico; the counterpart may vary by location, and it may be a federal, state, or local government agency • TxDOT assists the Mexican counterpart to establish TMCs by providing know-how and technical support
Current situation	• Mexico does not currently have operational or planned TMCs along the Texas-Mexico border
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	During the fourth and fifth year of the program
Actions that precede	None

ADVANCED SCENARIO FOR CROSS-BORDER ITS SYSTEMS AND TMCS

Table 11 presents key characteristics of the advanced TMC scenario. This section describes the characteristics of the advanced TMC scenario divided into the four categories of characteristics (legal and regulatory, institutional and policy, financial, and technology) and then describes the actions that are required to transition from the basic scenario to the advanced scenario.

Legal and Regulatory

In the advanced scenario, TxDOT and/or its potential Mexican counterpart(s) would move from the simple measures implemented in the basic scenario to more permanent and sustainable solutions to solve the legal and regulatory challenges that may still remain to cross-border ITS data sharing. In other words, the patches used to enable the basic TMC scenario would give way to formal policy and regulations that facilitate cross-border ITS data sharing.

In this scenario, TxDOT has gained from the appropriate state legislative or regulatory body statutory authority to sign agreements to share ITS data with its Mexican counterparts for the purpose of improving mobility in the border region. This would enable TxDOT to have the option to directly enter into data-sharing agreements with any of its possible Mexican counterparts if it finds value in doing so. Under this scenario, FHWA would develop policies that explicitly enable U.S. border states to share federally funded ITS data across the northern and southern border when that sharing has significant mobility improvement potential.

On the Mexican side of the border, TxDOT's Mexican counterparts would be clearly defined in every major binational border region. Depending on the location, such a role may be played by Mexican federal, state, or local agencies. Nonetheless, the legal and regulatory framework for ITS data sharing would be mature and enable agencies at all levels of government to easily share ITS data among themselves and with U.S. agencies and the private sector.

Institutional and Policy

An advanced cross-border TMC system should include the following institutional and policy items.

ITS Architecture

To better serve the needs of the local cross-border community, the TMC should follow a pre-established border-region-specific ITS architecture that considers stakeholder needs on both sides of the border. This architecture should establish data exchange rules for the specific regions where the TMCs will be operating.

Communication Channels

In the advanced cross-border TMC scenario, a more robust communication protocol should be established to define the role for each stakeholder and agency on both sides of the border and to hold formal regular meetings among stakeholders.

Policies and Organizational Structure

Regional stakeholders should develop and implement policies to support the involvement of public- and private-sector stakeholders that could participate in the data exchange. Agencies should define the organizational structure required to support public and private partnerships to augment data availability and processing of the information to better serve the local community.

Financial

To be ready for implementing advanced binational TMCs, both countries need to have already established funding sources and financial mechanisms. In this scenario, Texas and Mexico could both consider using toll revenue generated at the POEs as a funding source to operate and maintain TMCs. Currently, neither Texas nor Mexico have established funding sources from toll collection revenues generated at the POEs to operate and maintain TMCs. Only the State of Chihuahua has established funding sources for transportation improvement projects in Ciudad Juárez through the collection of toll revenues at the POEs. Therefore, in this scenario, actions would focus on using toll POE revenue as a funding source on both sides of the border.

Technology

The advanced scenario has the following ITS elements.

Traffic Management Software for Entering Incidents and Construction Events by Local Agencies

TxDOT TMCs use Lonestar traffic management software to enter incidents and construction events on its highways. In Mexico, CAPUFE uses its Highway Alert traffic management software to provide traffic information on its roads. This system is very basic traffic management software that is due for an upgrade. Smaller agencies on both sides of the border that operate other facilities along the border, such as the international border crossing POEs and the local roads that connect to/from the POEs, do not have this capability. The advanced scenario includes providing smaller agencies the capability of entering and managing incident and construction event information on their facilities, and allows CAPUFE to upgrade to an advanced traffic management system.

Connected Vehicles

Future deployment of connected vehicle systems and applications has the potential to reduce costs compared to deployment of older technologies. For example, DMSs, HAR, speed-monitoring devices, or static signs may become unnecessary if vehicles receive traveler information directly from their connected onboard vehicle devices. It can be expected that agencies will migrate to connected vehicle technology only after there is a significant penetration of new devices and demonstrated capabilities for advanced data collection (e.g., position data to the lane level) resulting in more precise traffic information. The advanced scenario TMC can take advantage of this revolutionary technology in the long term.

511 Statewide System

Texas does not operate a 511 system statewide for providing traveler information. As part of the Integrated Corridor Management initiative, the Dallas-Fort Worth region added a regional 511 system in 2013. There are no plans to extend this system to other regions. TxDOT has been working on a statewide 511 system procurement for the last couple of years, and it is expected that such a system will be deployed in the near future.

Dynamic Managed Lanes

Many POEs are equipped with signs that indicate the type of lane at that particular time of day. With dynamic lane management, traffic lanes at the POE could be designated as manual, FAST, or SENTRI, based on demand at a particular time of day. Agencies have not fully implemented this idea of managed lanes at land POEs, but managed lanes are planned for the Otay Mesa East POE to make more efficient use of the infrastructure. A similar concept can be applied in Texas.

Actions for Implementing the Advanced Scenario

Table 25 through Table 35 provide a description of actions for implementing the advanced scenario for each of the four categories or characteristics (legal and regulatory, institutional and policy, financial, and technology).

Table 25. Legal and Regulatory Action 3—Seek Statutory Authority to Sign ITS Data-Sharing Agreements with Mexican Agencies.

Attribute of Action	Description of Attribute
Description	• TxDOT seeks statutory authority from the relevant state legislative or regulatory body to sign agreements to share ITS data with Mexican agencies for the purpose of improving mobility in the border region
Current situation	• TxDOT does not currently have statutory authority to sign an agreement (of any kind) with a government agency in a different country
Responsible and involved parties	• TxDOT • State legislature
Time frame	Between the 10th and 15th year of the program
Actions that precede	None

Table 26. Legal and Regulatory Action 4—Work with Other U.S. Border States and FHWA to Develop Policies That Support Sharing of Federally Funded ITS Data across Borders.

Attribute of Action	Description of Attribute
Description	• TxDOT works alongside peer U.S. border states on the northern and southern border and FHWA to develop policies that explicitly support sharing of federally funded ITS data with Mexican and Canadian counterparts
Current situation	• FHWA does not explicitly allow states to share federally funded ITS data with another country
Responsible and involved parties	• TxDOT • Other U.S. border states • FHWA
Time frame	Between the fifth and 10th year of the program
Actions that precede	None

Table 27. Legal and Regulatory Action 5—Seek Mexican Approval of Advanced Federal and State Laws and Regulations for ITS Applications and Data.

Attribute of Action	Description of Attribute
Description	• SCT and Mexican state and local agencies work alongside the private sector to develop advanced legal and regulatory frameworks that facilitate ITS applications and data sharing for the purposes of improving mobility, including sharing of data with foreign transportation agencies
Current situation	• Mexican laws, regulations, or administrative rules specifically dealing with ITS data sharing with foreign governing entities do not exist at any level of government
Responsible and involved parties	• SCT • Mexican state and local DOTs • Mexican private sector
Time frame	• Between the fifth and 10th year of the program
Actions that precede	• None

Table 28. Institutional and Policy Action 5—Develop Border Region ITS Architecture.

Attribute of Action	Description of Attribute
Description	• TxDOT and SCT identify stakeholders in Mexico and Texas involved in ITS and data sharing • They identify needs and requirements, and develop an ITS architecture similar to the one developed at the U.S.-Canada border • They develop a cross-border ITS architecture that considers needs from stakeholders on both sides of the border in the region
Current situation	• There is no binational ITS architecture in the border region that could serve as the basis to develop and implement ITS technologies to collect and exchange traffic data in the border region
Responsible and involved parties	• TxDOT • SCT
Time frame	Between the fifth and 10th year of the program
Actions that precede	None

Table 29. Institutional and Policy Action 6—Define Advanced Communication Channels between Texas and Mexican Agencies.

Attribute of Action	Description of Attribute
Description	• TxDOT and Mexican counterparts establish stakeholders' roles in terms of data exchange, specify and define advanced technologies and media that will be used to exchange information, and identify the periodicity of data exchange and methods
Current situation	• Basic communication channels have been established, but advanced features need to be defined
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	Between the fifth and 10th year of the program
Actions that precede	Basic communication channels

Table 30. Institutional and Policy Action 7—Develop and Implement Policies to Support Public and Private Partnerships.

Attribute of Action	Description of Attribute
Description	• TxDOT and Mexican counterparts identify public and private stakeholders that could participate in the collection, analysis, and dissemination of traffic data on the border • They develop policies in Mexico and Texas to support a public-private development and operation of cross-border TMCs that could augment data sharing and processing, and implement public-private partnerships to secure the long-term operation of the cross-border TMCs
Current situation	• There are no policies in Texas or in Mexico that support public-private partnerships to collect, analyze, and disseminate traffic information at the border region
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	Between the fifth and 10th year of the program
Actions that precede	MOUs to exchange information

Table 31. Financial Action 3—Encourage Establishment of Funding Sources from Toll Revenues to Operate and Maintain TMCs.

Attribute of Action	Description of Attribute
Description	• TxDOT encourages U.S. counties and municipalities that own toll POEs to establish funding sources from toll revenues to operate and maintain TMCs • TxDOT encourages SCT and Mexican border states to establish funding sources from toll revenues to operate and maintain TMCs
Current situation	• Funding sources to operate and maintain TMCs from toll collection revenues generated at the POEs have not been established so far in the United States • In Ciudad Juárez, the State of Chihuahua is planning to establish a funding source using these revenues to fund transportation projects in the city
Responsible and involved parties	• TxDOT • Owners of toll POEs in the United States (i.e., cities and counties) • CAPUFE, State of Chihuahua, State of Coahuila, State of Nuevo Leo, and State of Tamaulipas
Time frame	During the eighth year of the program
Actions that precede	None

Table 32. Technology Action 5—Deploy Traffic Management Software for Entering Incidents and Construction Events.

Attribute of Action	Description of Attribute
Description	• TxDOT allows Texas local agencies operating border facilities to use Lonestar to enter incident and construction information • Mexican local agencies deploy advanced traffic management software to manage traffic operations on Mexican facilities near the border
Current situation	• U.S. local agencies do not have the capability of entering incidents and construction events on their facilities in Lonestar • Mexico does not have an advanced traffic management system, and local agencies cannot enter incident and construction information
Responsible and involved parties	• TxDOT • Local U.S. agencies that operate facilities near the border • Mexican counterparts
Time frame	Between the sixth and eighth year of the program
Actions that precede	None

Table 33. Technology Action 6—Incorporate Connected Vehicle Technology.

Attribute of Action	Description of Attribute
Description	• TxDOT and local agencies incorporate connected vehicle technology gradually as it becomes available • Mexico incorporates connected vehicle technology
Current situation	• This is a future technology not currently in operation anywhere
Responsible and involved parties	• TxDOT • FHWA • Mexican counterparts
Time frame	Between the 10th and 15th year of the program
Actions that precede	None

Table 34. Technology Action 7—Deploy 511 System.

Attribute of Action	Description of Attribute
Description	• TxDOT establishes a statewide 511 system (this effort is currently ongoing) • Mexico establishes a regional 511 system • TxDOT explores integrating both 511 systems, such as the ongoing effort at Otay Mesa in California
Current situation	• TxDOT does not have a statewide 511 system • Mexico does not have a regional 511 system
Responsible and involved parties	• TxDOT • Mexican counterparts
Time frame	Between the fifth and sixth year of the program
Actions that precede	None

Table 35. Technology Action 8—Deploy Dynamic Managed Lanes.

Attribute of Action	Description of Attribute
Description	• U.S. agencies operating POEs deploy dynamic managed lanes • Mexican agencies operating POEs deploy dynamic managed lanes
Current situation	• Border crossings along the Texas border do not have dynamic managed lanes in either direction
Responsible and involved parties	• U.S. POE operators • DHS • Mexican counterparts
Time frame	Between the sixth and eighth year of the program
Actions that precede	None

SUMMARY OF FINDINGS

The research team identified 23 actions to develop a cross-border TMC at the Texas-Mexico border (see Table 36). These actions were classified in the same four categories defined previously:

- Five actions in the legal and regulatory area.
- Six actions in the institutional and policy area.
- Eight actions in the technology area.
- Three actions in the financial area.

Twelve actions need to be implemented to move from the current situation to the basic cross-border TMC, and 11 need to be implemented to reach the advanced TMC scenario.

The 23 actions were also classified in terms of the time frame in which they need to be implemented in order to move from the basic TMC to the advanced cross-border TMC:

- 12 actions need to be implemented in the short term, in the first four years of the program.
- 9 actions need to be implemented in the medium term, between the fifth and 10th year of the program.
- 2 actions are long term, between the 10th and 15th year of the program.

Most of the actions (78 percent) require TxDOT intervention. However, some have to be led by the Mexican counterpart, which most likely will be SCT.

The first step in order to move from the current scenario to the basic cross-border TMC is to define the region where the cross-border TMC is most likely to be implemented. Based on the analysis of the border region, the El Paso/Ciudad Juárez region is the largest binational metro area at the Texas-Mexico border. Ciudad Juárez has an operational planning agency (Instituto Municipal de Investigación y Planeacíon); other Mexican border regions do not have this type of agency with substantial activity.

Once the region is defined, the recommendation is to start with legal and regulatory actions and institutional and policy actions. Actions such as signing data-sharing agreements and defining MOUs for data sharing at the border are the key actions that are needed in order to move into implementation. Financing actions are important as well, especially encouraging Mexican agencies to prioritize ITS projects in the planning process and defining the funding mechanism and source. Figure 77 shows the time frame defined by the research team for the actions.

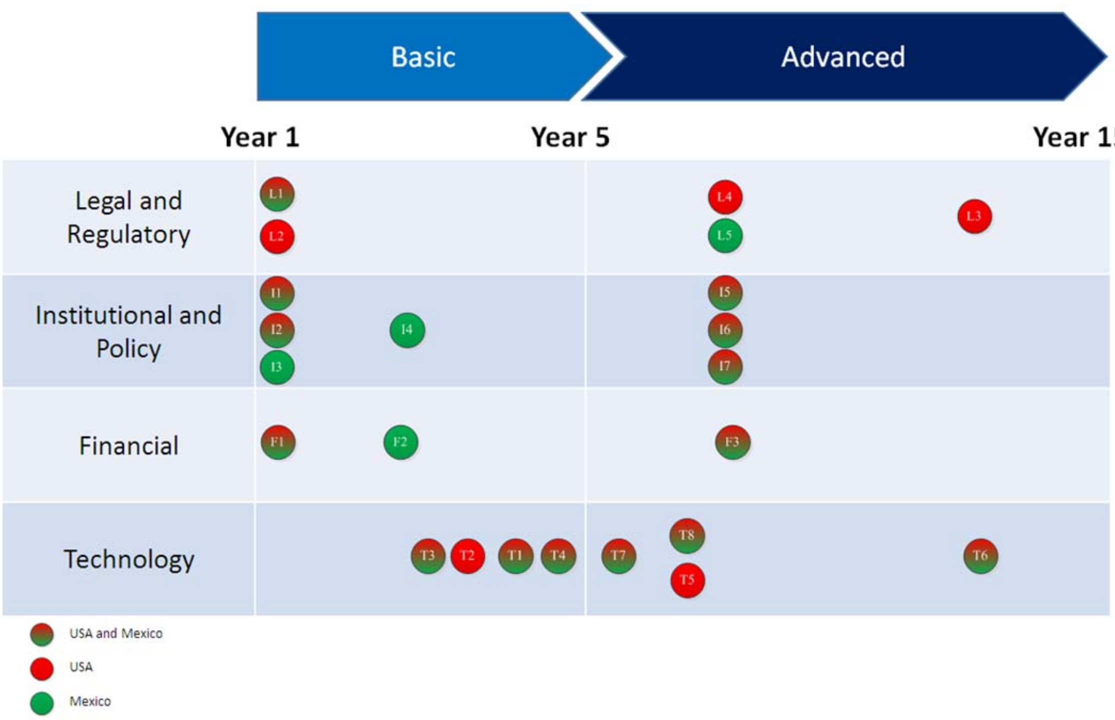


Figure 77. Actions Timeline for the Basic and Advanced Scenarios.

Table 36. Actions Summary.

Action			Categories	Stage	Stakeholder Participants	Time Frame
1	L1	Sign a data-sharing agreement with a U.S. third party able to share each agency's ITS data	Legal and regulatory	Basic	TxDOT/SCT or Mexican counterpart/U.S. third party	Short (year 1)
2	L2	Obtain federal approval to share federally funded ITS data with a Mexican agency (through a U.S. third party)	Legal and regulatory	Basic	TxDOT/FHWA	Short (year 1)
3	L3	Seek statutory authority to sign ITS data-sharing agreements with Mexican agencies	Legal and regulatory	Advanced	TxDOT/state legislature	Long (years 10–15)
4	L4	Work with other U.S. border states and FHWA to develop policies that support sharing of federally funded ITS data across borders	Legal and regulatory	Advanced	TxDOT/other border states/FHWA	Medium (years 5–10)
5	L5	Seek Mexican approval of advanced federal and state laws and regulations for ITS applications and data	Legal and regulatory	Advanced	SCT/Mexican state and local DOTs/Mexican private sector	Medium (years 5–10)
6	I1	Establish MOUs for data sharing between Mexico and Texas	Institutional and policy	Basic	TxDOT/SCT or Mexican counterpart	Short (year 1)
7	I2	Define basic communication channels between Texas and Mexican agencies	Institutional and policy	Basic	TxDOT/SCT or Mexican counterpart	Short (year 1)
8	I3	Define the organizational structure in Mexico	Institutional and policy	Basic	Mexican state and municipal agencies	Short (year 1)
9	I4	Identify and train staff and stakeholders in Mexico	Institutional and policy	Basic	Mexican federal, state, and local agencies	Short (year 3)
10	I5	Develop a border region ITS architecture	Institutional and policy	Advanced	TxDOT/SCT or Mexican counterpart	Medium (years 5–10)
11	I6	Define advanced communication channels between Texas and Mexican agencies	Institutional and policy	Advanced	TxDOT/SCT or Mexican counterpart	Medium (years 5–10)
12	I7	Develop and implement policies to support public and private partnerships	Institutional and policy	Advanced	TxDOT/SCT or Mexican counterpart	Medium (years 5–10)
13	F1	Encourage SCT and border states to give priority to ITS projects	Financial	Basic	TxDOT/States of Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas	Short (year 1)

Table 36. Actions Summary (Continued).

Action			Categories	Stage	Stakeholder Participants	Time Frame
14	F2	Establish funding sources and financial mechanisms dedicated to fund ITS projects	Financial	Basic	SCT/States of Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas/Mexican border municipalities	Short (year 3)
15	F3	Encourage establishment of funding sources from toll revenues to operate and maintain TMCs	Financial	Advanced	TxDOT/owners and operators of tolled POEs on the U.S. and Mexican side of the border	Medium (year 8)
16	T1	Establish a protocol for data exchange between TxDOT and Mexican counterpart	Technology	Basic	TxDOT/Mexican counterparts	Short (years 4–5)
17	T2	Deploy a wait time measuring system for NB passenger vehicles	Technology	Basic	TxDOT/FHWA/DHS	Short (years 3–4)
18	T3	Deploy surveillance cameras and a southbound wait time measuring system including required wireless or wired communications to transmit data	Technology	Basic	TxDOT/Mexican counterparts	Short (years 2–4)
19	T4	Establish a TMC, or equivalent, in Mexico that covers the Texas-Mexico border	Technology	Basic	TxDOT/Mexican counterparts	Short (years 4–5)
20	T5	Deploy traffic management software for entering incidents and construction events	Technology	Advanced	TxDOT/local U.S. agencies that operate facilities near the border/Mexican counterparts	Medium (years 6–8)
21	T6	Incorporate connected vehicle technology	Technology	Advanced	TxDOT/FHWA/Mexican counterparts	Long (years 10–15)
22	T7	Deploy a 511 system	Technology	Advanced	TxDOT/Mexican counterparts	Medium (years 5–6)
23	T8	Deploy dynamic managed lanes	Technology	Advanced	U.S. POE operators/DHS/Mexican counterparts	Medium (years 6–8)

APPENDIX: INTERVIEW FORMS IN ENGLISH AND SPANISH

CROSS-BORDER ITS SYSTEMS WITH TRAFFIC MANAGEMENT CENTERS

Project Objective

Texas A&M Transportation Institute (TTI) is carrying out a study to develop a framework and an action plan for the deployment of cross-border Traffic Management Centers (TMCs). As part of the study, TTI is gathering information to identify stakeholder needs related to binational TMCs along the Texas-Mexico border.

Information request

1. Please let us know what traffic-related information you currently share with partners across the border using email, phone, txt msg, etc.

Information Element	Technology (email, text, etc.)	Frequency (daily, weekly, monthly, etc.)	Agency contacted (Aduanas, operators, etc.)

2. The following list presents a series of intelligent transportation systems (ITS) devices or systems that are used at TMCs. Please indicate which ones you currently have and which ones would be desirable in your region.

ITS	Level of priority	Comments
Surveillance cameras. Used to observe and/or supervise a location	☐ High ☐ Medium ☐ Low	
Vehicle detectors. Used to detect the presence of vehicles	☐ High ☐ Medium ☐ Low	
Portable and permanent Dynamic Message Signs (DMS). Used on roadways to provide information to motorists	☐ High ☐ Medium ☐ Low	
Lane control signal stations. Used to manage traffic on a multi-way road or highway	☐ High ☐ Medium ☐ Low	
Highway advisory radio. Low-power AM radio stations that provide information to motorists	☐ High ☐ Medium ☐ Low	
Coordinated signal control. System that manages traffic flows in arterials based on the hour of the day	☐ High ☐ Medium ☐ Low	

CROSS-BORDER ITS SYSTEMS WITH TRAFFIC MANAGEMENT CENTERS

ITS	**Level of priority**	**Comments**
Adaptive signal control. System that manages traffic flows in arterials based on traffic volumes	☐ High ☐ Medium ☐ Low	
License Plate Readers. Used to automatically identify vehicles by their license plates	☐ High ☐ Medium ☐ Low	
Radio Frequency Identification Readers. Used to automatically identify and track tags attached to vehicles	☐ High ☐ Medium ☐ Low	
Wait Times Measuring Systems at Ports of Entry. System used to estimate vehicle border crossing time at land ports of entry	☐ High ☐ Medium ☐ Low	
Weather stations. System used to measure atmospheric conditions to provide information for weather forecasts	☐ High ☐ Medium ☐ Low	
Flood, ice, and fog detection devices. System used to detect certain environmental conditions potentially dangerous for motorists	☐ High ☐ Medium ☐ Low	
Computer-aided dispatch for transit and emergency vehicles. System used to expedite deployment of certain vehicles upon request	☐ High ☐ Medium ☐ Low	
Global positioning system on buses and emergency vehicles. System used to track vehicle position in real time	☐ High ☐ Medium ☐ Low	
Traffic signal preemption. ITS that allows the emergency vehicle right-of-way, to help reduce response times and enhance traffic safety	☐ High ☐ Medium ☐ Low	
Wired (including fiber) and wireless (Wi-Fi and radio-based) communications. System that allows ITS interactions	☐ High ☐ Medium ☐ Low	
Weigh-in-motion stations. System used to measure and record axle weights and gross vehicle weights while vehicles are in movement.	☐ High ☐ Medium ☐ Low	
Technology for information dissemination to users. Systems used to communicate certain information to	☐ High ☐ Medium ☐ Low	

CENTROS DE MANEJO DE TRAFICO Y SISTEMAS DE ITS TRANSFRONTERIZOS

Objetivo del Proyecto

El Instituto de Transporte de Texas A&M (Texas A&M Transportation Institute - TTI) está llevando a cabo un estudio para desarrollar un marco de referencia y plan de acción para la implementación de Centros de Manejo de Tráfico (TMCs por sus siglas en inglés) con información de tráfico binacional a lo largo de la frontera Texas-México. Como parte de este estudio, TTI se encuentra recopilando información para identificar las necesidades de información y tecnologías que pudieran ser parte de los TMCs a lo largo de la frontera.

Información requerida

1. Por favor indique que tipo de información relacionada al tráfico comparte con otras entidades por medio de correos electrónicos, teléfono, mensajes, etc.

Tipo de Información	Tecnología (Email, teléfono, etc.)	Frecuencia	Compartida con… (CBP, Operadores, etc.)

2. La siguiente lista representa un conjunto de tecnologías de sistemas inteligentes de transporte (ITS) que se usan en TMCs. Por favor indique cuales utiliza y cuales se desearía implementar en su región.

ITS	Prioridad	Comentarios
Cámaras de Seguridad (Surveillance cameras). Usadas para supervisar operaciones y para seguridad.	☐ Alto ☐ Mediano ☐ Bajo	
Detectores de vehículos (Vehicle detectors). Usados para detectar la presencia de vehículos.	☐ Alto ☐ Mediano ☐ Bajo	
Mensajes dinámicos fijos y portátiles (Portable and permanent Dynamic Message Signs). Usadas en caminos para brindar información.	☐ Alto ☐ Mediano ☐ Bajo	
Estaciones de control de carriles (Lane control signal stations). Usados para administrar el tráfico en caminos con múltiples carriles.	☐ Alto ☐ Mediano ☐ Bajo	
Mensajes por la radio (Highway advisory radio). Sistemas de bajo poder en estaciones de AM, para informar a usuarios.	☐ Alto ☐ Mediano ☐ Bajo	
Control coordinado de señales (Coordinated signal control). Sistema que maneja los flujos,	☐ Alto ☐ Mediano	

CENTROS DE MANEJO DE TRAFICO Y SISTEMAS DE ITS TRANSFRONTERIZOS

ITS	Prioridad	Comentarios
dependiendo de la hora del día.	☐ Bajo	
Sistemas de señalización adaptables (Adaptive signal control). Sistemas que manejan los flujos de tráfico basados en volúmenes.	☐ Alto ☐ Mediano ☐ Bajo	
Lectores de placas (License Plate Readers). Usados para identificar vehículos por sus placas.	☐ Alto ☐ Mediano ☐ Bajo	
Lectores de Sistemas de Identificación por Radio Frecuencia (Radio Frequency Identification Readers). Usados para automáticamente identificar y vehículos.	☐ Alto ☐ Mediano ☐ Bajo	
Sistemas de medición de tiempo de espera (Wait Times Measuring Systems at Ports of Entry). Sistema utilizado para estimar el tiempo de cruce de vehículos en cruces fronterizos	☐ Alto ☐ Mediano ☐ Bajo	
Estaciones meteorológicas (Weather stations). Sistema utilizado para medir las condiciones atmosféricas	☐ Alto ☐ Mediano ☐ Bajo	
Sistemas de detección de inundaciones, niebla, hielo y neblina. (Flood, ice, and fog detection devices). Sistemas usados para detectar la presencia de condiciones peligrosas.	☐ Alto ☐ Mediano ☐ Bajo	
Sistema de despacho de vehículos de transporte y de emergencia. (Computer-aided dispatch for transit and emergency vehicles). Sistema utilizado para acelerar el proceso de envío de vehículos de emergencia.	☐ Alto ☐ Mediano ☐ Bajo	
Sistemas de Posicionamiento Global para autobuses y vehículos de emergencia (GPS on buses and emergency vehicles). Sistema usado para rastrear este tipo de vehículos.	☐ Alto ☐ Mediano ☐ Bajo	
Priorización de vehículos mediante señales de tráfico (Traffic signal preemption). Sistema que permite a un vehículo de emergencia tener el derecho de paso en situaciones que permitan reducir el tiempo de respuesta. I	☐ Alto ☐ Mediano ☐ Bajo	
Sistemas de comunicación. (Fibra optica, Wi-Fi, y radio) (Wired (including fiber) and wireless (Wi-Fi and radio-based) communications). Sistemas que permiten la interacción de ITS.	☐ Alto ☐ Mediano ☐ Bajo	
Estaciones de pesaje en movimiento (Weigh-in-motion stations). Sistema usado para medir y registrar los pesos por eje mientras los vehículos están en movimiento.	☐ Alto ☐ Mediano ☐ Bajo	
Tecnologías de diseminación de información a	☐ Alto	

CENTROS DE MANEJO DE TRAFICO Y SISTEMAS DE ITS TRANSFRONTERIZOS

ITS	Prioridad	Comentarios
usuarios (Technology for information dissemination to users). Sistemas usados para presentar cierta información a usuarios. (Páginas de internet, email, mensajes, etc.)	☐ Mediano ☐ Bajo	
Sistemas de control de rampas de acceso (Ramp meters). Usados para administrar el número de vehículos que entran a las autopistas en rampas de acceso.	☐ Alto ☐ Mediano ☐ Bajo	
Vigilancia de velocidad (Speed monitoring). Sistemas que permiten administrar y vigilar la velocidad de los vehículos.	☐ Alto ☐ Mediano ☐ Bajo	
Sistemas de Incidentes (Incident events). Sistemas que permiten rastrear incidentes.	☐ Alto ☐ Mediano ☐ Bajo	
Eventos de construcción (Construction events). Usados para rastrear carriles cerrados por obras y actividades similares.	☐ Alto ☐ Mediano ☐ Bajo	

REFERENCES

1 Z. Martin. *RFID Enabled Border Crossings Open.* SecureIDNews, November 2008. URL: http://www.secureidnews.com/news-item/rfid-enabled-border-crossings-open/.

2 *2.0 Technical Approach.* U.S. Department of Transportation, Federal Highway Administration, Washington, D.C. URL: http://ops.fhwa.dot.gov/freight/freight_analysis/auto_tech/sect_2a.htm.

3 J. Villa. Status of the US-Mexico Commercial Border Crossing Process: Analysis of Recent Studies and Research. Texas A&M Transportation Institute, Texas, 2006.

4 *Measuring Border Delay and Crossing Times at the U.S.–Mexico Border—Part II*, Federal Highway Administration, Texas, 2014. URL: http://ops.fhwa.dot.gov/publications/fhwahop12016/sys_design.htm.

5 J. Villa. Using RFID Readers to Measure Wait Times at the U.S.-Mexico Border. Texas A&M Transportation Institute, Texas, 2013.

6 City of Laredo, 2015. URL: http://www.ci.laredo.tx.us/bridgesys/Cameras/bridge4cam.html.

7 TBWG. *About Us.* The Canada-United States Transportation Border Working Group. URL: http://www.thetbwg.org/contact_e.htm.

8 U.S. Department of Transportation. *Border Information Flow Final Report*, 2006. URL: http://www.iteris.com/itsarch/bifa/.

9 Whatcom Council of Governments. *British Columbia-Washington State Cross-Border ATIS Data Management System Project Report.* Whatcom Council of Governments, Bellingham, Washington, May 2007. URL: http://theimtc.com/wp-content/uploads/atisdms_finalreport.pdf.

10 *Entry/Exit Initiative: Enhancing Border Security and the Integrity of Immigration Programs.* Canada Border Services Agency, Ottawa, Canada, February 2015. URL: http://www.cbsa-asfc.gc.ca/btb-pdf/ebsiip-asfipi-eng.html.

11 *U.S.-Mexico Joint Working Committee Work Plan 2013–2015.* U.S.-Mexico Joint Working Committee, US Department of Transportation Federal Highway Administration, Washington, DC. URL: https://www.borderplanning.fhwa.dot.gov/documents/WorkPlans/WorkPlan2013_2015.asp.

12 *Joint Statement: United States-Mexico High Level Economic Dialogue*. The White House, Washington, D.C., January 2015. URL: https://www.whitehouse.gov/the-press-office/2015/01/06/joint-statement-united-states-mexico-high-level-economic-dialogue.

13 *Commercial and Private Vehicle Border Crossing and Wait Time Measurement Project at Zaragoza-Ysleta Bridge and Dissemination of Information from Texas Border Crossings.* Texas A&M Transportation Institute, Texas, 2015.

14 *White Paper: State of ITS Industry and Assessment of Project Types.* Texas Transportation Institute, Report FHWA/TX-11/0-6672-1, College Station, Texas, 2011.

15 2010 Deployment Tracking Survey Results. Intelligent Transportation Systems Website. Washington, DC: Research and Innovative Technology Administration, U.S. Department of Transportation. URL: http://its2010.ornl.gov/TMC.aspx. Accessed July 2015.

16 *CVO05-International Border Electronic Clearance USDOT Website*. URL: http://www.iteris.com/itsarch/html/mp/mpcvo05.htm#tab-1. Accessed July 2015.

17 *Research to Develop an ITS Strategic Plan for Texas.* Texas A&M Transportation Institute, Report FHWA/TX-13/0-6672-2-Vol-1, College Station, Texas, 2014.

18 E. Seymour, B. Kuhn, K. Balke, N. Chaudhary, D. Jasek, R. Rajbhandari, T. Voigt, K. Miller, T.Geiselbrecht, and S. Venglar. *TxDOT ITS Strategic Plan 2013.* Texas A&M Transportation Institute, Report FHWA/TX-13/0-6672-2-Vol-2, College Station, Texas, 2014.

19 *Agency Strategic Plan for the Years 2013–2017.* TxDOT Website. URL: http://ftp.dot.state.tx.us/pub/txdot-info/oeo/strategic_plan2013.pdf. Accessed July 2015.

20 *Texas Regional ITS Architecture Home Page*. Consystec Website. URL: http://www.consystec.com/texas/default.htm. Accessed July 2015.

21 *Vermont Statewide ITS Architecture*. Consystec Website. URL: http://www.consystec.com/vermont/web/_inventory.htm. Accessed July 2015.

22 *North Country Regional ITS Architecture*. Consystec Website. URL: http://www.consystec.com/newyork/north/web/inventory.htm. Accessed July 2015.

23 *Buffalo-Niagara Bi-National Regional ITS Architecture*. Consystec Website. URL: http://www.consystec.com/newyork/north/web/inventory.htm. Accessed July 2015.

24 *New Mexico Statewide ITS Architecture*. Consystec Website. URL: http://www.consystec.com/nm2012/web/inventory.htm. Accessed July 2015.

25 *Connected Vehicle Reference Implementation Architecture*. USDOT Website. URL: http://www.iteris.com/cvria/html/applications/app5.html#tab-5. Accessed July 2015.

26 Songchitruksa, P., A Guidebook for Effective Use of Archived Operations Data at Texas Transportation Management Centers. 2008: Texas Transportation Institute, Texas A&M University System.

27 RITA. ITS Asset Viewer. Website. URL: http://www.itsassets.its.dot.gov/.

28 City of El Paso. Live Traffic Cameras. Website. URL: https://www.elpasotexas.gov/international-bridges/live-traffic-cameras.

29 Texas Department of Transportation. TxDOT Intelligent Transportation Systems website. URL: http://its.txdot.gov/.

30 Transportation, N.M.D.o. Intelligent Transportation Programs ITS Bureau. [cited 2015 July 15]; Available from: http://dot.state.nm.us/en/ITS.html.

31 New Mexico Department of Transportation. NMRoads. Website. URL: http://nmroads.com/.

32 Brent Jennings, G.Y.B., Eddie Curtis, Steve Misgen, Vanloan Nguyen, Jacob B Renick, Kevin N. Balke, *Best Practices In Regional, Multiagency Traffic Signal Operations Management*. NCHRP Project 20-68A. March 2013. Available from: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/nchrp20-68a_07-04.pdf.

33 Tucson, C.o. Regional Traffic Operations Center (RTOC). [cited 2015 July 15]; Available from: http://www.tucsonaz.gov/tdot/regional-traffic-operations-center-rtoc.

34 Tucson, C.o. Intelligent Transportation Systems and Signal Design Section. [cited 2015 July 15]; Available from: http://www.tucsonaz.gov/tdot/intelligent-transportation-systems-and-signal-design-section.

35 FAQ. Secretaria de Seguridad Publica. URL: http://www.caepccm.df.gob.mx/preguntas_frecuentes.

36 Refuerzan Vigilancia del DF. Periodico Excelsior, Mexico City, January 2014. URL: http://www.excelsior.com.mx/comunidad/2014/01/14/938197.

37 C. Ocaranza. *Seguridad vs Privacidad?* Periodico Excelsior, Mexico City, August 2013.

38 Centro de Atención a Emergencias y Protección Ciudana de la Ciudad de México, CDMX, Mexico City, 2015. URL: http://www.caepccm.df.gob.mx/preguntas_frecuentes.

39 Gestión Urbana de la Ciudad de Mexico. Agencia de Gestion Urbana de la Ciudad de Mexico, Mexico City, 2014. URL: http://www.agu.df.gob.mx/sintesis/index.php/con-3-mil-semaforos-inteligentes-buscan-agilizar-movilidad-en-el-df/.

40 Centro de Orientación Vial. Secretaria de Seguridad Publica del Distrito Federal, Mexico City. URL: ttp://www.ssp.df.gob.mx/cov.html.

41 Orientación Vial Facebook. URL: https://www.facebook.com/orientadorvialsspCDMX.

42 Instalación de Cámaras en Semáforos, Toluca Digital, Toluca, Estado de Mexico, 2014. URL: http://tolucadigital.mx/2014/toluca.

43 *Instalan Semaforos Inteligentes.* Novedades Quintana Roo, Quintana Roo, Mexico, February 2013. URL: http://sipse.com/novedades/instalan-semaforos-inteligentes-en-cancun-77295.html.

44 *Refuerzan Infraestructura de Calidad.* Ayuntamiento de Benito Juarez, Quintana Roo, Mexico, June 2014. URL: http://cancun.gob.mx/sala-de-prensa/prensa/con-trabajo-coordinado-se-refuerza-infraestructura-de-calidad-en-*benito*-juarez-paul-carrillo/.

45 *Plan Sectorial de Movilidad Urbana Sustentable de la Ciudad de Chihuahua.* IMPLAN Chihuahua, Chihuahua, Mexico, February 2011. URL: http://www.implanchihuahua.gob.mx/PDU2040/psmus/DIAGNOSTICO_SISTEMA_VIAL.pdf.

46 *Alerta Carretera.* Caminos y Puentes Federales, Mexico City, Mexico, July 2015. URL: http://www.capufe.gob.mx/site/wwwCapufe/menuitem.fccf9f7b2e9987015a034bd7316d8a0c/.

47 Que es IAVE? Caminos y Puentes Federales, Mexico City, Mexico, 2015. URL: https://www.capufe-iave.com.mx/public.

48 *Calidad de los Equipos y Sistemas.* Instituto Mexicano del Transporte, Mexico City, Mexico, 2013. URL: http://normas.imt.mx/normativa/N-EIP-1-01-008-13.pdf.

49 *Caracteristicas de los Equipos de Instalacion Permanente.* Instituto Mexicano del Transporte, Mexico City, Mexico, 2013. URL: http://normas.imt.mx/normativa/N-EIP-1-01-007-13.pdf.

50 U.S. Department of Transportation. Knowledge Resources. http://www.itscosts.its.dot.gov/ITS/benecost.nsf/SubsystemCostsAdjusted?ReadForm&Subsystem=Transportation+Management+Center+(TM). Accessed May 2016.

51 Transportation Systems Planning and Development. Manitoba. www.gov.mb.ca/mit/tpd/tspd/planning.html. Accessed August 2015.

52 Flickr website. https://www.flickr.com/photos/planeta/13997567091/. Accessed August 2015.

53 Datex Brochure 2011. http://www.datex2.eu/. Accessed August 2015.

54 C. Costa and T. Fernandes. *DATEX2 Toolkit—A Working Example of DATEX2.* 16th ITS World Congress and Exhibition on Intelligent Transport Systems and Services, 2009.

55 Mobility and Transport. http://ec.europa.eu/transport/themes/its/road/action_plan/. Accessed August 2015.

56 PROMET Brochure. DARS. www.dars.si/Dokumenti/1_mednarodno_sodelovanje/PROMET%20bro%C5%A1ura.pdf . Accessed September 2015.

57 B. Gostisa and J. Pirc. Cross-Border Integration of Traffic Management: The Promet Project. Presented at the 15th World Congress on Intelligent Transport Systems and ITS America's 2008 Annual Meeting, New York, NY.

58 G. Koklas. EasyWay Program: Fostering Sustainable Mobility across Europe. Presented at the Transport Research Arena, Europe, 2012.

59 The EasyWay Programme (2007-2020) and Its Projects. EasyWay. https://www.easyway-its.eu/highlights/easyway-programme-2007-2020-and-its-projects. Accessed September 2015.

60 EasyWay Project—An Overview. European Commission. http://ec.europa.eu/transport/themes/infrastructure/events/doc/2009_06_26_easy_way_project_arnaoutis.pdf. Accessed September 2015.

61 Crocodile. EasyWay. https://crocodile.easyway-its.eu/. Accessed September 2015.

62 EDITS Final Conference. EDITS. http://edits-project.eu/?p=1328. Accessed September 2015.

63 P. A. Barter. Multiple Dimensions in Negotiating the Cross-Border Transport Links That Connect and Divide Singapore and Johor, Malaysia. Asia Pacific Viewpoint, 2006, pp. 287-303.

64 D. Lai. *Bridge the Border: A Border Crossing Complex across the Johor Strait*. Auckland, New Zealand: Unitec Institute of Technology, 2011.

65 Traffic Conditions. My Transport Singapore. http://www.mytransport.sg/content/mytransport/home/motoring/informations.html#Traffic_Conditions. Accessed September 2015.

66 Checkpoint. http://www.checkpoint.sg/. Accessed August 2015.

67 Beat the Jams by Monitoring the Roads Online. Malaysian Insider. http://www.themalaysianinsider.com/citynews/greater-kl/article/beat-the-jams-by-monitoring-the-roads-online/beat-the-jams-by-monitoring-the-roads-online. Accessed August 2015.

68 Jalanow. http://www.jalanow.com/johor-singapore-live-traffic-cam-J33WBBVJ5-9VN. Accessed September 2015.

69 Iskandar Malaysia. http://iskandarmsia.blogspot.com/p/edl-traffic-cameras.html. Accessed August 2015.

70 Monthly Traffic and Transport Digest 2015. Transport Department Hong Kong. http://www.td.gov.hk/en/transport_in_hong_kong/transport_figures/monthly_traffic_and_transport_digest/2015/201506/index.html. Accessed August 2015.

71 Shenzhen Passes Guangzhou in Economic Performance. http://www.wantchinatimes.com/news-subclass-cnt.aspx?id=20150513000025&cid=1102. Accessed August 2015.

72 Route Search. Transport Department Hong Kong. http://hketransport.gov.hk/?l=1. Accessed August 2015.

73 State Route 11 and Otay Mesa East Port of Entry. SANDAG. http://www.sandag.org/index.asp?projectid=56&fuseaction=projects.detail. Accessed September 2015.

74 J. Villa. State-of-the-Practice Scan Final Technical Memorandum I. SANDAG, February 2012.

75 Canadian Border Traffic. Washington State Department of Transportation. http://www.wsdot.com/traffic/border/default.aspx. Accessed September 2015.

76 Crossings. Cascade Gateway Border Data Warehouse. http://www.cascadegatewaydata.com/Crossing?data=sum-vol%2Cavg-delay%2Cavg-rate%2Cavg-qveh%2Cavg-qmtr. Accessed September 2015.

77 Detectors. Cascade Gateway Border Data Warehouse. http://www.cascadegatewaydata.com/Detector. Accessed September 2015.

78 Projects. IBI. http://www.ibigroup.com/projects/cross-border-atis-expansion. Accessed August 2015.

79 BWT CBP Border Wait Times. U.S. Customs and Border Protection. https://bwt.cbp.gov. Accessed August 2015.

80 Canada to U.S. Border Wait Times. Government of Canada. http://travel.gc.ca/travelling/border-times-us. Accessed August 2015.

81 The Peace Bridge. http://www.peacebridge.com/. Accessed August 2015.

82 Google Play App Store. https://play.google.com/store/apps?hl=en. Accessed September 2015.

83 According to TxDOT's draft template for Agreement for Sharing ITS Data.

84 See http://www.statutes.legis.state.tx.us/Docs/TN/htm/TN.201.htm for the text of Section 201.205 of the Texas Transportation Code.

85 See http://www.statutes.legis.state.tx.us/Docs/TN/htm/TN.202.htm for the text of Section 202.052 of the Texas Transportation Code.

86 Secretaria de Relaciones Exteriores. Guía para la Conclusión de Tratados y Acuerdos Interinstitucionales en el Ámbito Internacional Según la Ley sobre Celebración de Tratados. http://tratados.sre.gob.mx/guia.pdf. Accessed April 7, 2016.

87 Consystec. *Texas Regional ITS Architecture Home Page*. http://www.consystec.com/texas/default.htm. Accessed July 1, 2015.

88 U.S. Department of Transportation. Federal-Aid Highway Program Authorizations under the Fixing America's Surface Transportation (FAST) Act. March 2016. https://www.fhwa.dot.gov/fastact/estfy20162020auth.pdf. Accessed April 7, 2016.

89 According to TxDOT's draft template for Agreement for Sharing ITS Data.

90 ITS America. World Bank Presentation on Intelligent Transportation Systems (ITS). http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1153409213417/2772794-1284492028594/ICTandITS.pdf. Accessed April 25, 2016.