Develop a Plan to Deploy an ITS Solution to Measure Volume and Crossing Times of Passenger Vehicles at the Bridge of the Americas

by

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EXECUTIVE SUMMARY

Millions of commuters cross the U.S. and Mexico border every day for work, business, and social activities. The ports of entry in the El Paso region saw about 13 million passengers' vehicles crossing into the United States in 2008, according to the Bureau of Transportation Statistics. The morning crossing time of northbound passenger vehicles into the United States is measured in hours during peak periods. Until recently, crossing times for southbound vehicles were measured in minutes. The southbound passenger vehicles will, however, encounter longer crossing times after the Mexican government starts a program to read license plates of individual vehicles, and perform background checks on the vehicles and owners entering Mexico from the United States. The program will not only increase southbound crossing times but also increase queues on roadways in El Paso. Already, the Texas Department of Transportation, City of El Paso, and El Paso Metropolitan Planning Organization are developing plans to increase the capacity of roadway segments entering Mexico, mainly to store queued vehicles.

Understanding the flow of passenger vehicles (and trucks) between the two countries is crucial for many different reasons (economy, mobility, security, etc.). However, transportation agencies in the region have not installed data collection systems to measure the volume (both southbound and northbound) and crossing times of passenger vehicles. The only data source for monthly and annual flow of passenger vehicles is Customs and Border Protection (CBP), which reports only northbound flow. Similar information for southbound vehicles is not collected by Mexican authorities and hence is not available.

The Texas Transportation Institute proposed a system to measure crossing times and the volume of passenger vehicles at the Bridge of the Americas. The system includes a separate setup for measuring crossing times and volume of northbound and southbound passenger vehicles. Because traffic congestion and queues are frequent at the bridge, requiring systems that can successfully operate in a stop-wait-go environment is critical.

The proposed system utilizes a Bluetooth signal identification technique to determine crossing times of passenger vehicles and newer vehicle detection technologies to measure the volume of passenger vehicles. The proposed system includes several Bluetooth signal readers deployed around the Bridge of the Americas and a series of either laser or microwave detectors to measure the volume of passenger vehicles. Bluetooth readers and vehicle detectors operate independently, and a centralized data processing system is required to communicate with the field devices. Finally, cost estimates to install, operate, and maintain the system were determined to deploy the system at the Bridge of the Americas.

CHAPTER 1: BACKGROUND

INTRODUCTION

The region containing the metropolitan areas of El Paso, Texas, and Ciudad Juarez, Chihuahua, combined with the more rural Santa Teresa, New Mexico, contains five major ports of entry (POEs). Two of these ports combined—the Bridge of the Americas (BOTA) and the Ysleta-Zaragoza Bridge—form the third largest commercial POE along the U.S. southern border. In addition to the commercial ports, two POEs located in downtown El Paso are dedicated to noncommercial vehicles. They are the Paso Del Norte (PDN) Bridge and Good Neighbor Bridge (Stanton Street Bridge). Of these four POEs, BOTA is the only one that it is not tolled; the rest charge a toll for commercial, noncommercial, and pedestrian traffic. All together, the POEs in El Paso represent the second highest passenger vehicle international traffic flow along the southern border. The final POE in the region, Santa Teresa, is located in New Mexico 35 miles from downtown El Paso. Figure 1 shows the major road network in the region. Each POE in the region has a different physical configuration and traffic mix.

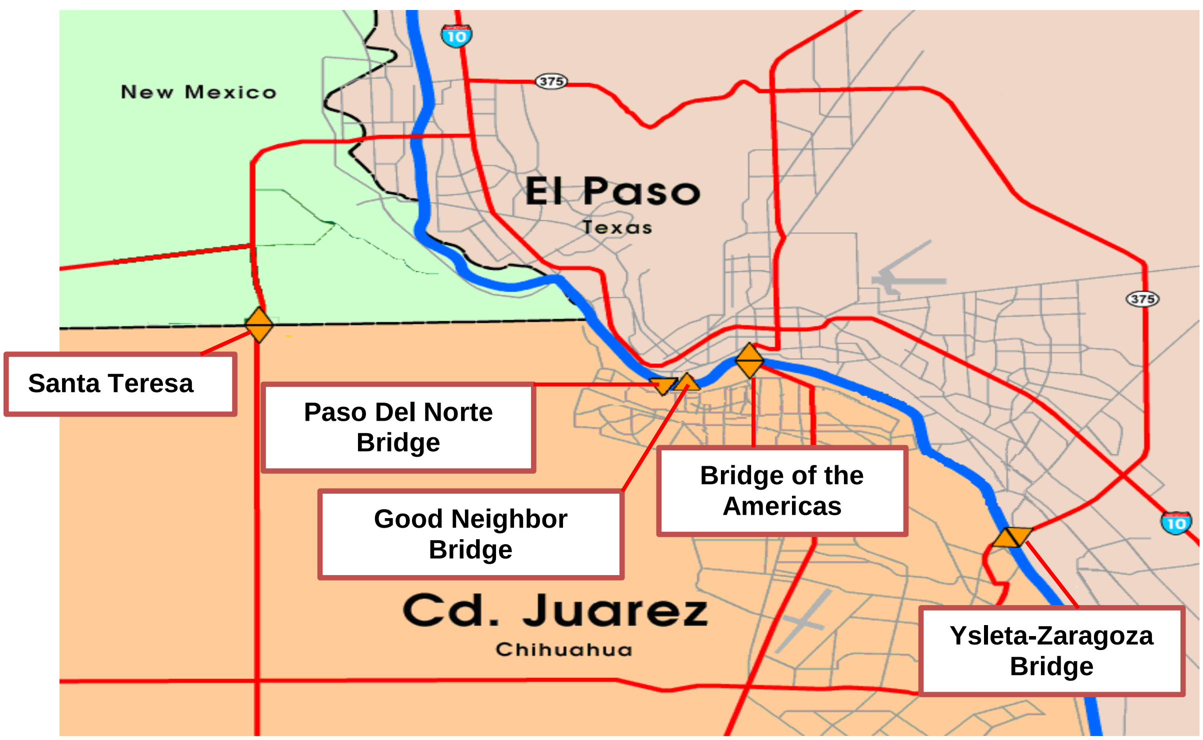

Figure 1. Land Ports of Entry in the Paso Del Norte Region.

Millions of commuters cross the U.S. and Mexico border every day for work, business, and social activities. The El Paso POEs saw about 13 million passengers' vehicles crossing into the United States in 2008, according to the Bureau of Transportation Statistics. The morning crossing time of northbound passenger vehicles into the United States is measured in hours during peak periods. Until recently, crossing times for southbound vehicles were measured in minutes. The southbound passenger vehicles will, however, encounter longer crossing times after the Mexican government starts a system based on license plate recognition to read license plates of individual vehicles entering Mexico, and perform background checks on the vehicles and owners entering Mexico from the United States. The program will not only increase southbound crossing times but also increase queues on roadways in El Paso. Already, the Texas Department of Transportation (TxDOT) and the City of El Paso (including the El Paso Metropolitan Planning Organization) are developing plans to increase the capacity of roadway segments entering Mexico, mainly to store queued vehicles. Counting vehicles in a standing queue is different from counting moving vehicles, so this project had to evaluate technologies, types of detectors available, and potential placement of these detectors for accurate counting of vehicles.

Traffic circulation at this POE appears to work reasonably well although CBP has intentionally created restrictions on the outflow side, apparently to reduce opportunities for evading search operations. CBP has placed sections of concrete barriers downstream of the booths to impede high-speed exits, but these barriers are not as restrictive as those at other POEs. Vehicles pulling trailers could easily negotiate these barriers. Vehicular throughput could probably be increased by adding two more lanes in the center, displacing the wide median and the current situation requiring a lane split just before vehicles approach the inspection booths. In addition, the use of single inspection booths to serve two lanes could be both inefficient and restrictive in the number of vehicles that are processed.

BRIDGE OF THE AMERICAS

The Bridge of the Americas facility is located in the center of the El Paso–Ciudad Juarez metropolitan area with easy access to IH 10 and is the only non-tolled port of entry in El Paso. The aerial image of the bridge is shown in Figure 2. The physical bridge is 506 ft long and consists of four separate bridge structures. There are two two-lane structures (northbound and southbound) for commercial traffic and two four-lane structures (northbound and southbound) for passenger vehicles. BOTA has up to six operational inspection booths for commercial vehicles entering the United States and 12 lanes serving up to 14 inspection booths for passenger vehicles entering the United States. Noncommercial-vehicle inspection and pedestrian access are available 24 hours a day and seven days a week. Commercial-vehicle inspections operate from 6 a.m. to 6 p.m. Monday through Friday and from 6 a.m. to 2 p.m. on Saturdays. Empty trucks use this toll-free bridge to avoid paying the toll at the Ysleta-Zaragoza Bridge.

PROBLEM STATEMENT

Understanding the flow of passenger vehicles (and trucks) between the two countries is crucial for many different reasons (economy, mobility, security, etc.). However, transportation agencies in the region have not installed data collection systems to measure the volume (both southbound and northbound) and crossing times of passenger vehicles. The only data source for monthly and annual flow of passenger vehicles is CBP, which reports only northbound flow. Similar information for southbound vehicles is not collected by Mexican authorities and hence is not available.

Figure 2. Aerial Image of the Bridge of the Americas.

INTELLIGENT TRANSPORTATION SOLUTIONS AT THE BORDER

In 2008, researchers from the Texas Transportation Institute (TTI) performed tests to identify the potential of Bluetooth technology to measure the border-crossing times of passenger vehicles at three ports of entry in the region. The results from the tests were very encouraging in terms of total number of matching device addresses that were discovered within a certain time period, which can be used to estimate average passenger vehicle crossing times. Hence, it was determined that Bluetooth technology would be suitable to measure crossing times of passenger vehicles at the border. However, tests have not been performed to identify suitable devices to measure the volume of vehicles (passenger vehicles and trucks) going northbound and southbound.

Agencies on both sides of the border are looking for innovative and sustainable intelligent transportation system (ITS) solutions that can accurately collect volumes of passenger vehicles and determine border-crossing times. Agencies are also looking for a system that can relay pre-trip traveler information to commuters and truckers through various means such as mobile devices, the Internet, local media, etc. The information will also be archived and used in planning future infrastructure development in and around the border area.

OBJECTIVES OF THE PROJECT

The overall objective of this project is to investigate suitable ITS solutions at the Bridge of the Americas to measure the traffic volume and crossing times of northbound and southbound passenger vehicles. Results from the project should include a plan that will help the agencies in the region seek funding for the full-scale deployment of the system at BOTA. Hence, this plan should also include a conceptual design of the system, including the location of field devices, cost of hardware installation, operation and maintenance cost, system reliability, etc. The results of this deployment will be helpful in implementing similar ITS projects at other ports of entry in the El Paso region. The following tasks were envisaged for this particular project:

- Identify suitable technology to measure the northbound and southbound volume of passenger vehicles and trucks, taking into account local conditions at the Bridge of the Americas. Bluetooth technology has already been identified as the preferred technology to measure passenger vehicle crossing times.
- Develop a plan to deploy a system to measure the volume and crossing times of passenger vehicles at the Bridge of the Americas.
- Identify the location and number of field devices to be deployed on both sides of the border. The location should take into account existing power sources, available gentries, communication needs, etc. to reduce overall cost.
- Develop cost estimates for purchasing hardware, installing the hardware, and developing software.

CHAPTER 2: MEASUREMENT OF PASSENGER VEHICLE CROSSING TIMES

BACKGROUND

Traffic frequently becomes congested at the Bridge of the Americas border crossing. A system is desired to measure current border-crossing times and to make the information available to different area agencies and the public. Because of heightened security concerns along the border, additional security measures have been implemented at the crossing. These measures contribute to the congestion. It is common for traffic to queue for up to a mile in advance of the border crossing.

Measuring a travel time is very difficult under queuing conditions. Traditional traffic sensors need to observe some movement of vehicles to render a measurement, and under queuing conditions vehicles within the detection zone may not move. Speed measurements from these sensors reach zero, and thus an average speed along a segment is essentially lost.

A system is needed to identify vehicles in the queue and to follow them as they progress from the tail to the head of the line. In this approach, a vehicle's speed is not measured, but rather the time it takes for that vehicle to travel between one point and another is measured. The system does not need to measure every vehicle, with the premise being that the entire queue moves at generally the same speed. Only a few vehicles in the stream would need to be analyzed. The wireless identification matching approach can provide this capability.

WIRELESS PROBES

The cellular telephone has become a staple of modern life. In 2007, a wireless industry study revealed that over 80% of the public subscribes to cellular phone service, a 10-fold increase since 1997. Most states have enacted or are considering laws to discourage the use of cellular phones in vehicles without some form of hands-free device. These hands-free devices use a low-power radio system to communicate with the cellular device, which then can stay out of the hands of the driver.

The wireless radio system used by the hands-free device is widely used by other devices as well, including global positioning system (GPS) receivers, speakers, and notebook computer accessories. The system is known as Bluetooth. The Bluetooth system creates a short-range personal wireless network with the purpose of connecting multiple external devices to a single host, as shown in Figure 3. The radios are low power and low cost with a range varying between 1 meter and 100 meters, depending on the class of radio used. Most modern cellular handsets contain a Bluetooth transceiver for use with, at minimum, an external hands-free device.

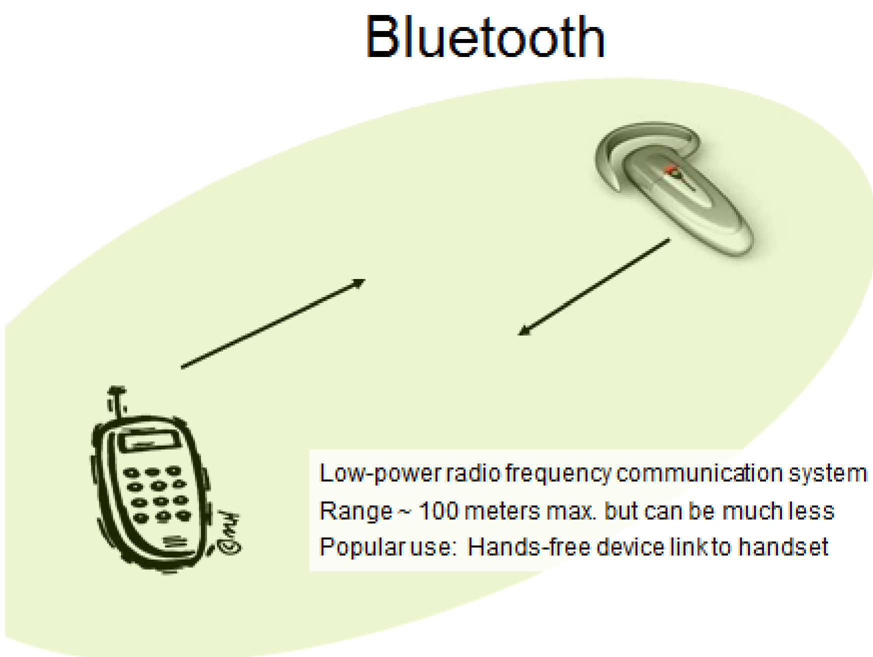

Figure 3. Wireless Bluetooth Use with a Mobile Device Handset.

Although it is clear that not every vehicle will have a detectable wireless device, only a sampling of vehicles are required to determine an average travel time in a roadway link. A study conducted in 2008 by the University of Maryland's Center for Advanced Transportation Technology found that approximately 1 in 20 vehicles had some type of Bluetooth-capable device operational (*1*). The auto industry forecasts the number of new vehicles with onboard Bluetooth to rise 30% by 2010 (*2*).

The most beneficial attribute of the Bluetooth system is that the devices are assigned with a unique identifier. This identifier is shared when a host device scans for other Bluetooth devices within radio range, as shown in Figure 4. The unique identification of Bluetooth devices can be acquired by placing a host Bluetooth device in scan mode and log all identifications (IDs) sensed during a scan.

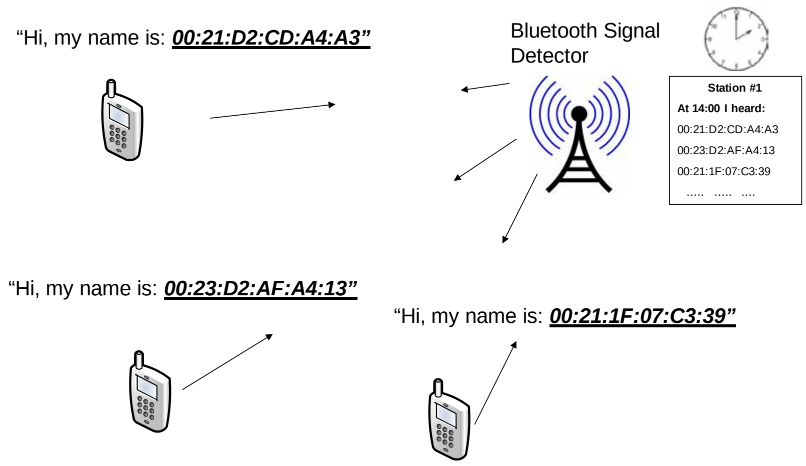

Figure 4. Bluetooth Identifier Scanning Process.

The Bluetooth approach has some advantages over the radio frequency identification (RFID)–based system to measure the travel time of vehicles. The equipment for a Bluetooth scanner is low cost with a simple radio priced in the $50 range. The scanner does not need to be installed directly over the travel lane, as a tag reader application would require. The reader detects Bluetooth devices in all lanes at an intersection with a single piece of equipment mounted off the right of way. The reader could be located in a nearby traffic signal cabinet, thus greatly reducing the time to deploy and deployment costs. Motorists participate by using their cellular phones, an item they purchase for reasons other than transportation data collection. The cellular phone operates in its normal mode, and detection takes place in the background without interfering with the communication.

CONCEPT OF OPERATION

To accomplish the goal of measuring crossing times of passenger vehicles, a system of Bluetooth reader stations is proposed for the main roadway(s) leading up to the Bridge of the Americas on both sides of the border. The reader stations scan for Bluetooth devices within the station's wireless range (typically a 100-meter radius maximum). It is assumed that the Bluetooth devices detected reside in vehicles within the detection radius, and thus the identification can be a surrogate for a vehicle. The exact vehicle is not known, nor is the owner of the wireless device. The Bluetooth identification information does not contain any ownership data. As wireless devices (vehicles) come within range of a reading station, they share their identification with a Bluetooth reader.

Because the queue velocity of the traffic is expected to be low during times of congestion, reader stations will need to be located in shorter intervals than in deployments where free-flow traffic is the norm. The closer spacing will allow vehicles in a slow-moving queue to be detected at more reasonable time intervals. For example, in a free-flow case, sensor stations may be deployed every mile, yielding a tracked vehicle being detected every couple of minutes (assuming a 30- to 40-mph vehicle speed for an urban arterial). For a slow-moving queue, the time between same vehicle detections could easily grow to be many minutes. The station spacing for this effort is chosen to be approximately 0.25 miles between detection stations, as shown in Figure 5. The exact distance between stations is not important, and actual field deployment locations will be chosen based upon reuse of existing infrastructure to help minimize deployment costs.

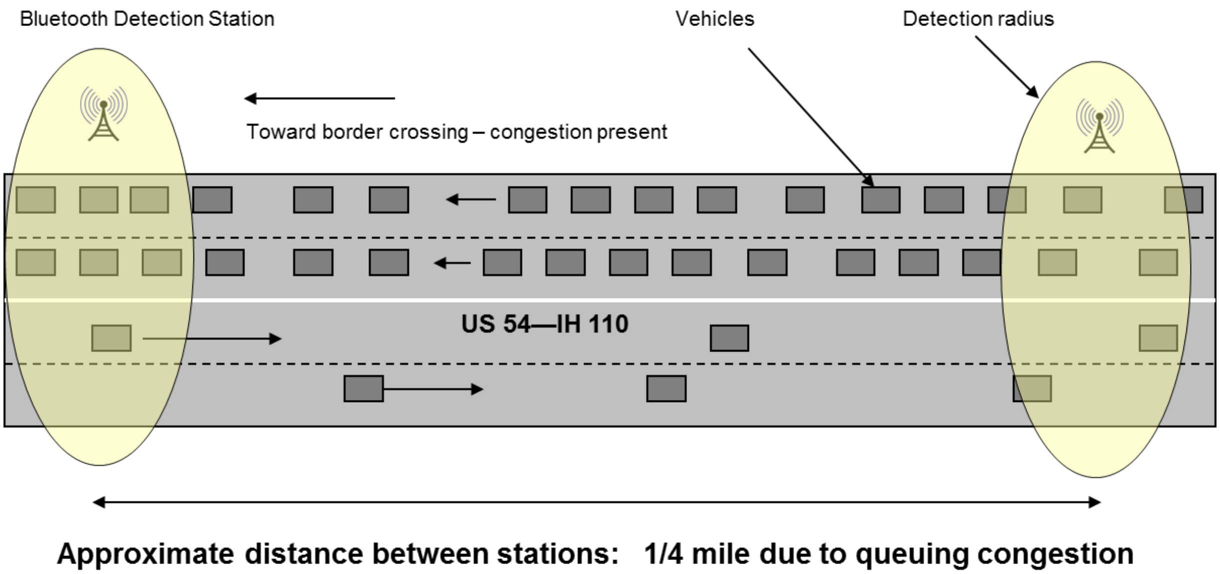

Figure 5. Concept of Deploying Bluetooth Reader Stations for Congested Roadways.

Travel time between reader stations has to be kept to a reasonable limit in order to filter out devices that do not travel directly between stations. If a vehicle deviates from the expected route (a direct path between detection stations) but still goes by the detection stations at either end of the link, a longer and inaccurate travel time will be recorded for that identification (vehicle). An upper-limit ceiling must be defined or dynamically calculated to remove trip times that are inordinately high because of these trips.

The reader stations continuously scan the roadway and send captured identifications to a central location for processing. The processing system matches identifications as the vehicles move along the roadway and calculates the time between reading stations for the probe vehicles. Link travel times are collected for a period and then introduced to an averaging algorithm. The averaging algorithm will likely need to be fine-tuned to meet unique needs and the system geometry. For example, the averaging function will need to be dynamic enough to manage free-flow traffic as well as heavy queuing and extended delays.

The central processing system uses the calculated link travel times to create a webpage showing times between stations and thus an indication of delay times at the border crossing for users. The information can be presented as a standalone webpage or as a data feed that can be incorporated into a larger, regional transportation web presentation. Internet web pages are an excellent method for delivering information to a wide audience including the public. Local agencies may also be interested in direct access to data rather than having to extract data presented on a webpage. A functional block and information flow diagram of the central processing system is shown in Figure 6.

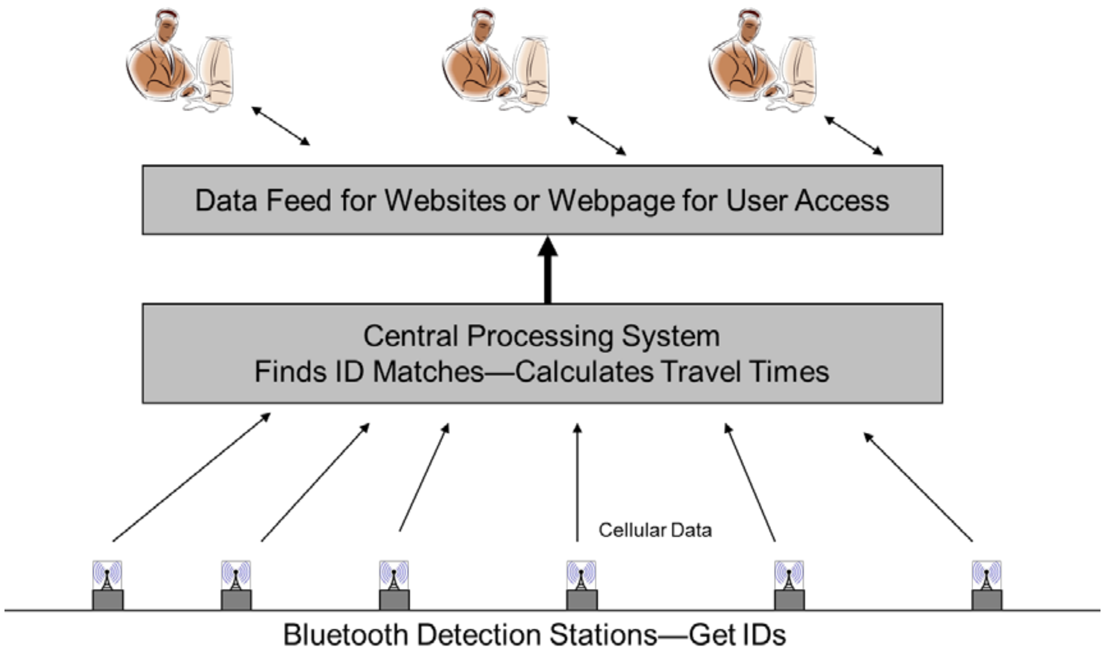

Figure 6. Information Flow of the Central Processing System.

TYPICAL FIELD SITE

A short list of equipment is needed to outfit a typical Bluetooth reader station and is shown pictorially in Figure 7.The heart of the reader station is a hardened computer platform that runs the Bluetooth identification acquisition program and network communication software. A Windows or Linux platform can be used, but it must have an Ethernet and at least one universal serial bus (USB) port. A regular consumer-grade Bluetooth adapter is connected to the computer via USB. The Bluetooth adapter includes an attached antenna or an external antenna adapter. Adapters with an attached antenna will need to be installed in an electrically neutral housing that has access to the outside. Typically, this can be done by mounting the adapter inside a piece of plastic pipe/conduit and mounting the assembly on the top of a cabinet. Adapters with an external antenna connection can marry up with a proper 2.4-gigahertz external mount antenna.

Communication for the reader station is provided by a cellular wireless modem or router. These modems use normal commercial cellular service providers and deliver high-quality communication to the site for a nominal monthly fee. All the major cellular networks offer a data package, with a typical governmental yearly contract being approximately $50 per month or $600 per year. This contract includes unlimited service and thus removes the concern for overuse charges. The cellular modem should be installed with an external cellular antenna to maximum signal quality. A single external antenna solution for both the Bluetooth and the cellular modem is available, minimizing installation time and exposed devices.

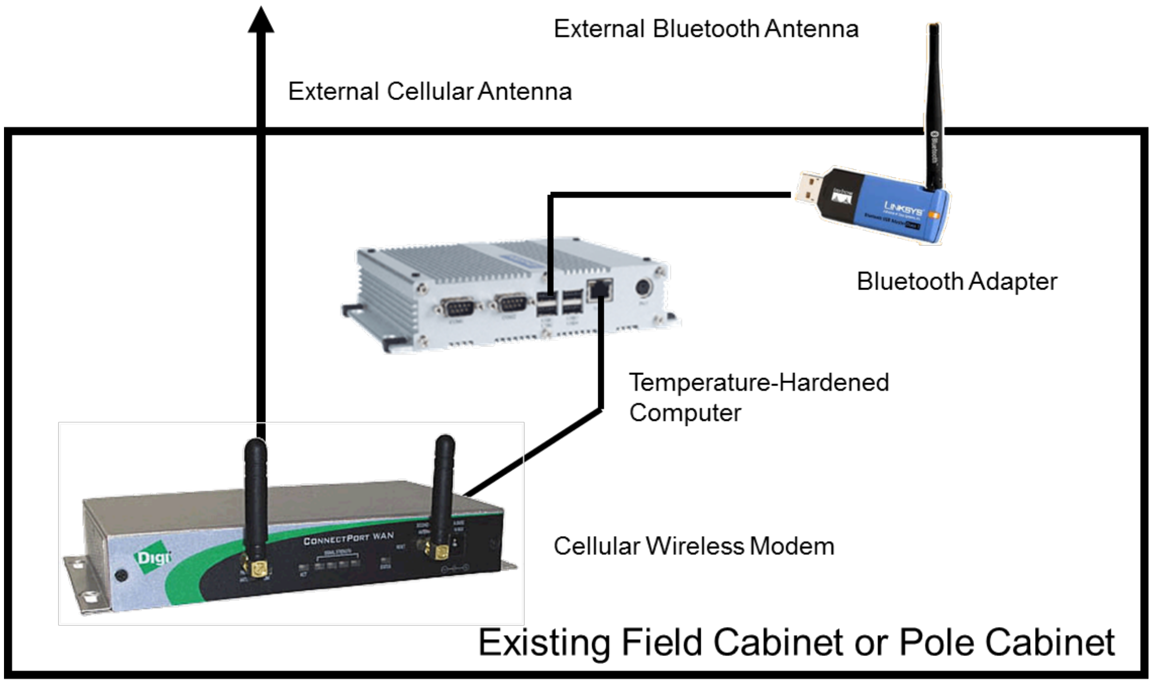

Figure 7. Example Setup of Devices of a Bluetooth Reader.

Figure 8 shows two suggested field installation options. The first installation option is that all the field devices can be contained inside an existing roadside cabinet such as a traffic signal cabinet or a small pole cabinet. The equipment takes up a small amount of room and does not require any special power. The second option for installation of a reader station is to attach a cabinet with field devices on an existing pole. A cabinet sized 18 inches by 18 inches by 6 inches would be ideal; however, the National Electrical Manufacturers Association's NEMA 4 rating is recommended for the cabinet. A site with access to 110-volt alternating current (AC) line power is optimum since the detection equipment will run continuously. A pole cabinet mounted on an existing luminaire standard makes for an easy installation using a luminaire light sensor (photocell) tap to provide the needed 110-volt AC.

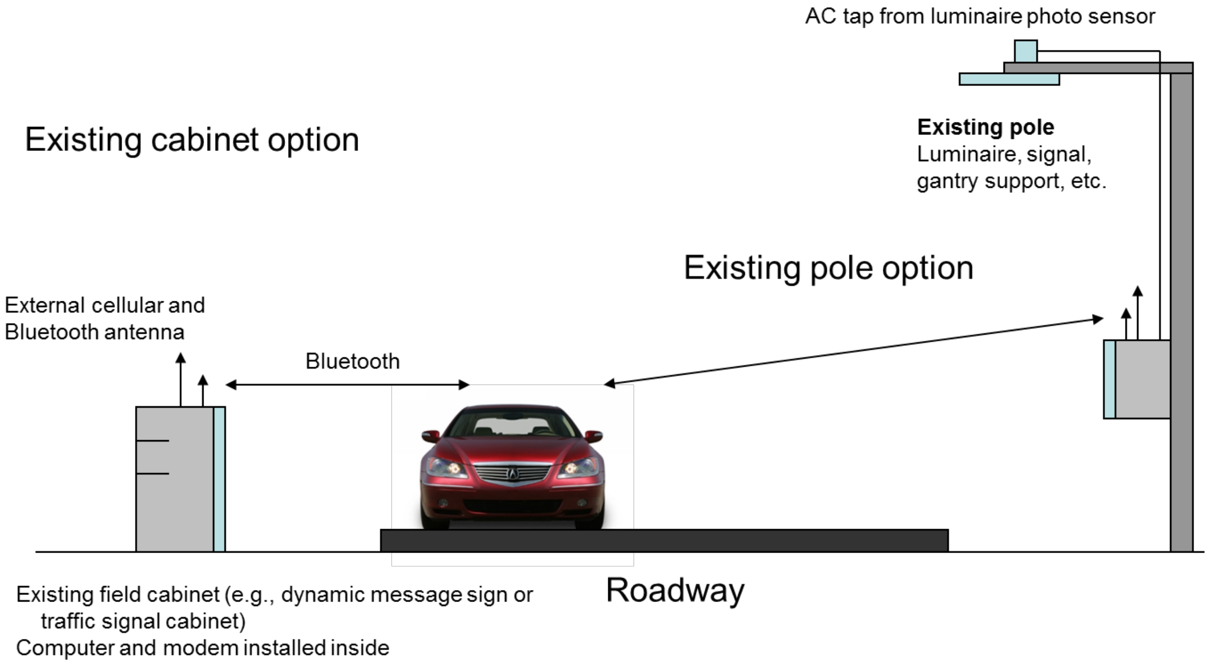

Figure 8. Field Installation Options.

CENTRAL PROCESSING SYSTEM

The field stations scan and capture Bluetooth identifications and forward them to a central location (a server) for processing the raw data and desired output. This central processing system, such as the Texas Transportation Institute El Paso office, houses the computation platform and the software to:

- receive raw data packets (with identification of Bluetooth devices) from the stations,
- find identification matches between reader stations,
- calculate the travel time for the match,
- filter out-of-range travel times,
- calculate an average travel time for the link,
- calculate average border-crossing times, and
- post the information on the Internet for access by users.

A server-grade computer (or a server itself) is required to host software that will need to be created to accomplish the processing tasks. The software in concept is similar to the toll tag matching software that is currently operational to recover commercial-vehicle border-crossing times. The toll tag solution uses RFID tags, whereas this solution would use Bluetooth identifications. A customized filtering and averaging algorithm would need to be developed to manage the “noise” that will be present in the Bluetooth data (noise being identification matches from vehicles that do not follow the expected route).

Another server will be used to host the end-product information on the Internet. This server will receive data from the processing server and create feeds such as a dedicated webpage for direct viewing of border-crossing times and/or a really simple syndication (RSS) feed for use by other websites and agencies that only need data and not a full webpage presentation.

SYSTEM COSTS

The Bluetooth travel time measurement system costs are organized into the following tables. Each table addresses a component of the overall system. The components are the field equipment, central office processing equipment, and operational costs. The equipment cost is a single initial expenditure, while the operating cost is a yearly recurring item.

The field equipment costs shown in Table 1 represent a site deployed using a small pole cabinet and include an estimate for installation by a contractor. The estimate assumes a pole currently exists to mount the pole cabinet onto, and thus there is no line item for a new pole installation. For sites that can be installed in traffic signal cabinets, the pole cabinet will not be required, and the installation cost should be much less.

Table 1. Cost of Installing Bluetooth Reader Equipment per Site.

Field Equipment	***Cost***
Hardened Computer (without Fan)	$1,000
Hardened Cellular Modem and Antennas	$1,000
Pole Cabinet—NEMA 4	$500
Installation Cost—Contractor	$2,500
Total Cost	**$5,000**

For sites where alternating current power is not available or is unreliable or the cost for delivering the service is overly expensive, solar power is an option. Table 2 lists the expected costs for a solar-powered field site. These costs assume an existing pole to mount the solar modules (panels). If no existing pole is available, a new construction pole will be required and will significantly increase the total cost. The quality of the pole required by the owning agency will drive the extra expense.

Table 2. Cost of Installing Optional Solar Power per Site.

Field Equipment	***Cost***
Two Photovoltaic Modules 200 Watt	$1,000
Charge Controller	$200
Four Batteries	$800
Pole Mount	$300
Cabinet	$1,200
Wires	$100
Shipping	$200
Total Cost	**$4,000**

The central processing functions are performed by a dedicated system server. A software package will need to be developed that can address the specific issues of the BOTA deployment. Techniques and approaches can be reused from other similar software systems such as RFID toll tag travel time calculation systems to decrease development time. Table 3 lists the central office expected costs.

Table 3. One-Time Cost of Software Development to Process Bluetooth Reader Data.

Office Equipment	***Cost***
Development Server	$8,000
Software Development	$50,000
Total Cost	**$58,000**

The Bluetooth system will require some recurring cost items. Each field site is outfitted with a cellular modem with an associated cellular service contract. A typical price for government data service is $50 per month with a yearly contract required. In addition, a budget should be created to fund equipment upgrades and/or replacements due to potential destructive events in the field (lightning strikes, vandalism, physical damage due to roadway accident, etc.). Table 4 lists the annual cost for each Bluetooth reader site.

Table 4. Annual Cost to Maintain and Operate a Bluetooth Reader per Site.

Item	***Cost***
Wireless Data Service	$600
General Equipment Replacement	$400
Total Cost	**$1,000**

Office processing equipment is expected to be much less susceptible to damage and have a longer useful life than field equipment. The costs listed in Table 5 reflect the annual cost for staff to administer the hardware and software and to maintain a web presence.

Table 5. Annual Cost of Administration and Labor.

Item	***Cost***
Computer and Network Usage	$1,000
Staff and Labor	$10,000
Total Cost	**$10,000**

SUGGESTED DEPLOYMENT SITES

Deployment sites will be along the major traffic arteries in the near-border area on both the U.S. and Mexico sides of the border. Sites will be chosen at approximate ¼-mile intervals and use existing infrastructure as much as possible. Existing infrastructure will include overhead gantries, overhead sign supports, roadside luminaires, and traffic signal cabinets.

US 54 and US 62 (Paisano Drive) will be targeted for instrumentation on the U.S. side. In the near-border area, US 54 is a relatively short (approximately 1-mile) section of divided freeway, and US 62 is a divided surface arterial. Both thoroughfares are principal routes for passenger vehicles headed for the BOTA crossing.

Four detection stations are proposed for US 54 beginning just south of the IH 10 interchange and continuing to the entry area into BOTA. Six Bluetooth reader stations are proposed for US 62, with three extending to the east of US 54 and three to the west of US 54. Figure 9 shows proposed locations overlaid on a street map of the area, and Table 6 provides additional detail on each site. This group includes US 54 and US 62 east of US 54.

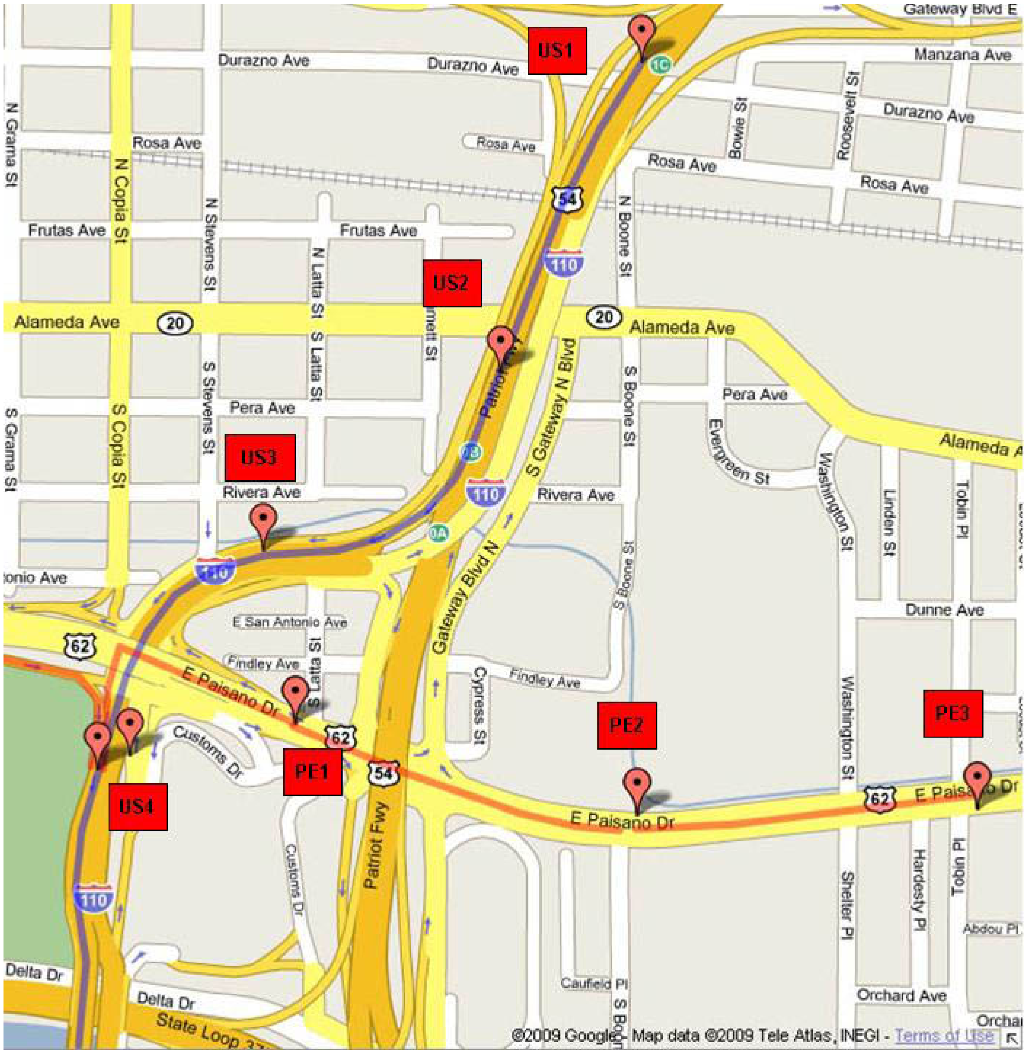

Figure 9. Suggested Sites for Deployment of Bluetooth Readers on US 54 and US 62 East of US 54.

Table 6. List of Suggested Sites for Deployment of Bluetooth Readers on US 54 and US 62 East of US 54.

Site	***Location***	***Installation***
US1	US 54 ramp from IH 10	Mount pole box on overhead sign gantry support—power from sign
US2	US 54 at TxDOT DMS sign	Mount pole box on TxDOT DMS support pole—power from DMS
US3	US 54 at TxDOT overhead sign	Mount pole box on TxDOT overhead sign support pole—power from sign
US4	US 54 at BOTA entrance	Mount pole box on TxDOT overhead sign support pole—power from sign
PE1	US 62 at ramp for US 54	Mount pole box on TxDOT overhead sign support pole—power from sign
PE2	US 62 at Boone Street	Mount inside traffic signal cabinet at Boone Street
PE3	US 62 at Tobin Place	Mount pole box on luminaire near overhead bridge step landing

Figure 10 shows proposed locations on US 62 west of US 54 overlaid on a street map of the area. Table 7 provides additional detail on each west-side site.

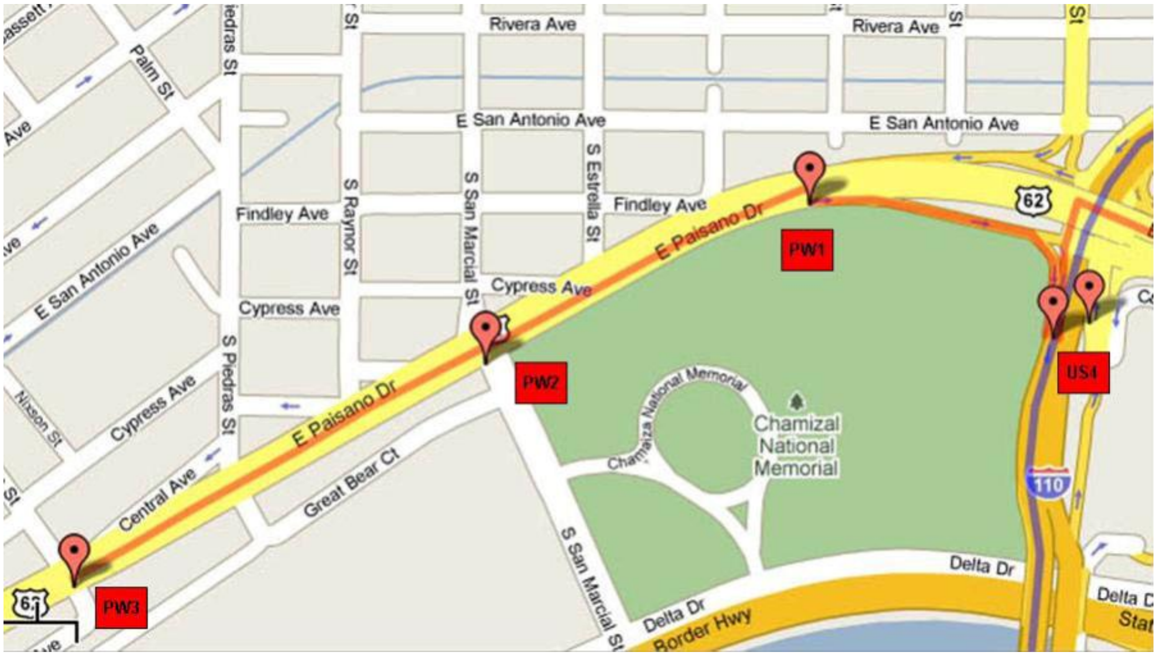

Figure 10. Suggested Sites for Deployment of Bluetooth Readers on US 62 and West of US 54.

Table 7. List of Suggested Sites for Deployment of Bluetooth Readers on US 62 and West of US 54.

Site	***Location***	***Installation***
PW1	US 62 at ramp to US 54	Mount pole box on overhead sign gantry support—power from sign
PW2	US 62 at San Marcial Street	Mount in traffic signal cabinet at San Marcial Street
PW3	US 62 at Eucalyptus Street	Mount in traffic signal cabinet at Eucalyptus Street

Eight sites are suggested for deployment in Mexico, with four residing on Abraham Lincoln Avenue and the remaining four on Rafael Perez Serna Avenue. These two roads are the main arteries for traffic moving toward BOTA from Ciudad Juarez. Figure 11 and Table 8 list the deployments recommended for the area leading up to BOTA on the Mexican side.

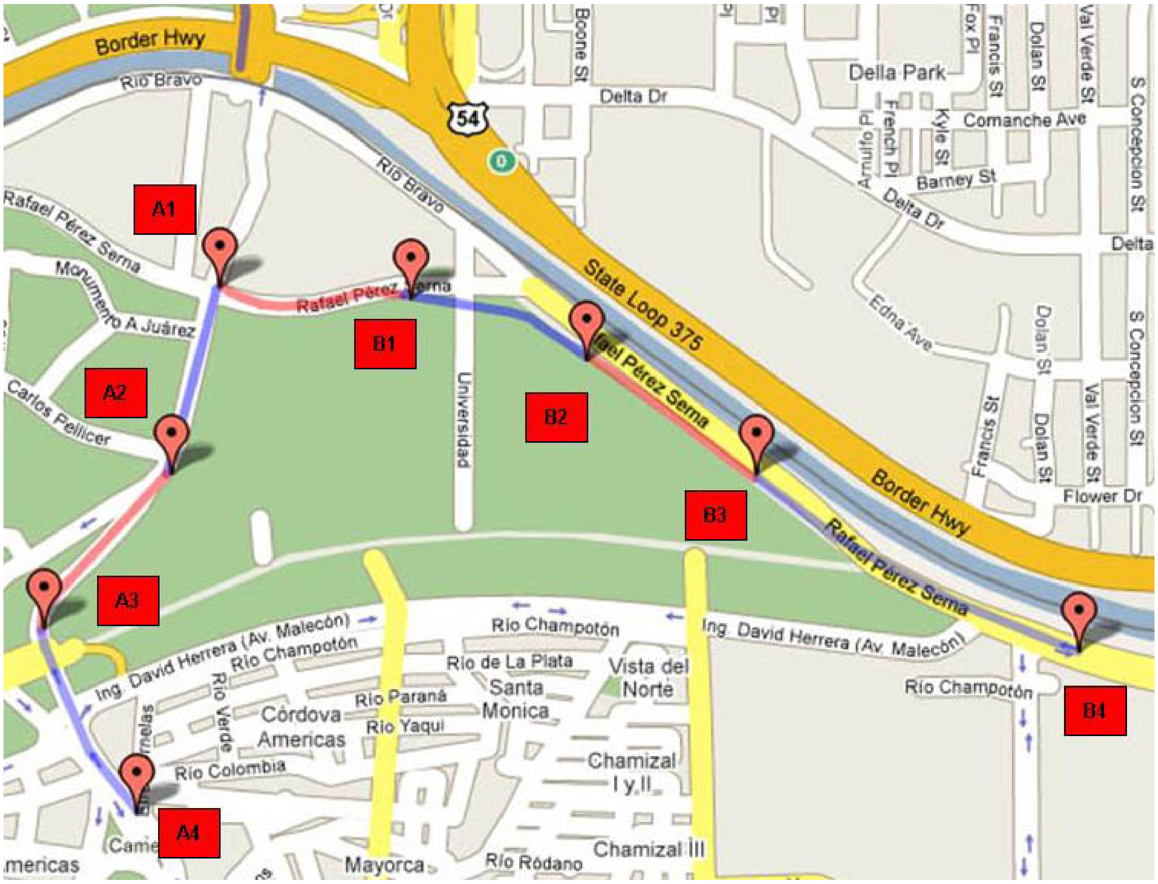

Figure 11. Suggested Sites for Deployment of Bluetooth Readers on the Mexican Side.

Table 8. List of Suggested Sites for Deployment of Bluetooth Readers on the Mexican Side.

Site	*Location*	*Installation*
A1	Abraham Lincoln at Rafael Perez Serna	Mount inside the traffic signal cabinet or in a pole box on a nearby luminaire pole
A2	Abraham Lincoln near Carlos Pellicer	Mount pole box on a luminaire pole
A3	Abraham Lincoln near Bernardo Norzagaray	Mount pole box on a luminaire pole
A4	Abraham Lincoln near Efren Ornelas	Mount pole box on a luminaire pole
B1	Rafael Perez Serna near basketball courts east of Universidad	Mount pole box on a luminaire pole
B2	Rafael Perez Serna west of the baseball field	Mount pole box on a luminaire pole
B3	Rafael Perez Serna between the baseball field and David Herrera	Mount pole box on a luminaire pole
B4	Rafael Perez Serna just east of Avenida del Charro	Mount pole box on a luminaire pole

CONCLUSION

A system is desired to measure border-crossing times for passenger vehicles moving through BOTA. Traffic congestion and queues are frequent at BOTA, requiring a method that can successfully operate in a stop-wait-go environment. The Bluetooth identification matching solution is an attractive option for this task. The solution recovers a unique identifier from passing Bluetooth devices and matches them at downstream detection station, thus revealing a travel time.

The complete solution as presented suggests 18 detection station deployments with 10 in the United States and 8 in Mexico. With this coverage, the principal routes to BOTA are instrumented on both sides of the border. The solution will also require a central office to be established that receives data from the field, calculates border-crossing times, and publishes the information to the Internet. This office can be the TTI El Paso office, which is currently providing a similar function for a commercial-vehicle border-crossing time project. Table 9 lists the expected initial deployment costs, including the deployment of 18 sites (none uses the solar-power option, but the cost figure is included for reference) and the outfitting of a central office.

Table 9. Total Cost of Installing Bluetooth Readers at BOTA.

Item	***Quantity***	***Unit Cost***	***Cost***
Bluetooth reader sites	18	$5,000	$90,000
Solar option additional cost	0	$4,000	$0
Database server	1	$8,000	$8,000
Software development	1	$50,000	$50,000
Total Cost			**$148,000**

Along with the equipment and installation costs goes an annual operating cost. This cost includes items such as cellular communication for the field detection stations, a repair/replace budget for damaged or failed equipment, and a budget for central office operation and administration. Table 10 lists the annual cost of operating and maintaining all the Bluetooth reader sites at BOTA.

Table 10. Total Annual Cost for Operation and Maintenance.

Item	***Quantity***	***Unit Cost***	***Cost***
Field sites—communication	18	$600	$10,800
Field sites—repair/replace	18	$400	$7,200
Central—computer/network use	1	$1,000	$1,000
Central office—system administration	1	$10,000	$10,000
Total Cost			**$29,000**

Based on an initial system estimate, the Bluetooth solution can be deployed to the field for approximately $150,000 in equipment and software costs. Project management costs for any deployment efforts have not been included in this estimate. An annual operating cost is estimated to be approximately $30,000.

CHAPTER 3: MEASUREMENT OF TRAFFIC VOLUME

BACKGROUND

The current sources of traffic volume for vehicles crossing the international border at the Bridge of the Americas are either inadequate or unavailable for the public. There are vehicle detectors (inductive loops) in the pavement on the IH 110 southbound approach to the border, but vehicle counts at that location do not necessarily reflect the southbound vehicular traffic right at the border. Customs and Border Protection maintains information on border-crossing activity but does not make all of it available to the public. Therefore, there is a need to measure flow of traffic independently, which gave rise to the need for this project.

POTENTIAL TECHNOLOGIES ANALYZED AND PROPOSED

For conducting vehicle counts at the international border, TTI researchers investigated a variety of technologies and detection techniques but settled on two technologies that seemed to be the most promising—radar and scanning laser. There are two major manufacturers of radar detectors for roadway applications in the United States. The one being considered for this application is a product by Electronic Integrated Systems, Inc. (EIS), a Canadian firm. Image Sensing Systems, Inc. (ISS) (*3*), recently bought EIS, so this product now appears with the ISS label. The ISS G4 is the latest version of equipment currently installed on El Paso freeways, the Remote Traffic Monitoring Sensor (RTMS) line of radar detectors. The laser sensor being investigated is the LMS 111 sensor by SICK, a company headquartered in Germany (*4*).

ISS G4 Radar Detector

The ISS G4 radar detector has demonstrated in limited testing that it could also be a viable contender under stop-and-go traffic, but TTI has not tested it under those conditions. TTI has requested data from ISS in response to ISS's claims that it has been installed in New York City and worked well. If it is accurate under these conditions, it will likely be a cost-effective solution since it will cover up to 10 lanes of traffic. The use of radar detectors will require at least two detection units—one for northbound traffic (entering the United States) and the other for southbound traffic. Laser detectors might be required for the southbound direction depending on the site (see information in section titled, "Proposed Location of Vehicle Sensors"). If so, TTI anticipates needing to purchase two to three of them for the southbound direction alone since each detector only covers one lane width (two lanes in some cases).

The cost of each radar detector is anticipated to be about $4,500 (only the detector), and the cost of each laser detector is expected to be about $5,500 to $6,000. Other costs related to the operation of these sensors will depend on the availability of power and communications. The radar can be installed in an autonomous mode with its own pole, power, and communications at a cost of about $8,900 (minus installation cost) per site. Wireless modems costing about $1,100 each will be accompanied by a monthly fee of about $50.

Figure 12 shows a picture of the ISS G4 detector. It offers an optional camera mounted in the detector housing for remote monitoring purposes to allow visual verification of traffic conditions. Its reported coverage area is 250 ft over as many as 12 detection zones (e.g., lanes). Zone widths are variable from 7 ft to 20 ft. It offers radio modems as a built-in option. It can output volume, occupancy, speed, headway, and six vehicle classifications based on vehicle length. It can operate on 12- to 24-volt AC or direct current (DC) at 3 watts (without additional options). Its low power consumption makes it ideal for operating with solar panels and batteries. The typical setback of the detector is 6 ft; it can be used with zero setback but only covers four lanes. Following are some other pertinent facts based on a recent conversation with a local ISS G4 representative:

- G4 has been installed in New York City to detect vehicles in stop-and-go locations;
- the local vendor plans to install one G4 detector in San Antonio August 25, 2009, on Houston Street where traffic is stop and go at times; and
- the vendor is willing to loan a detector for demonstration purposes.

Figure 12. ISS G4 Radar Detector (*3*).

LMS 111 Laser Detector

The scanning laser device made by SICK (a German company) and distributed in the United States by Comtrol® has been used at toll plazas under similar conditions and is being considered in case the location finally selected has vehicle speeds that are unpredictable with a high probability of vehicles stopping in the detection zone. Scanning lasers have been used for a number of years for vehicle detection but are not as popular as other detectors for freeway applications due to the need to install them overhead. Figure 13 and Figure 14 provide more information, with additional pertinent facts describing the LMS 111 as follows:

- LMS 111 as-is can perform presence detection and vehicle counts in slow and stopped traffic;
- LMS 111 does not store data, so some development work is required for data storage;
- LMS 111 has been used successfully at toll booths and work zones;
- a 50-Hz scan covers 270 degrees and can cover two lanes if the device is centered between the lanes;
- LMS 111 can use solar power, but the size of the solar panel must be determined;
- LMS 111 lists for $6,500, but the street price is $5,000 to $5,500;
- LMS 111 will require software development in order to perform classification counts;
- LMS 111 cannot communicate directly with a modem, so an interface is necessary; and
- the vendor will loan one unit for testing for a limited time.

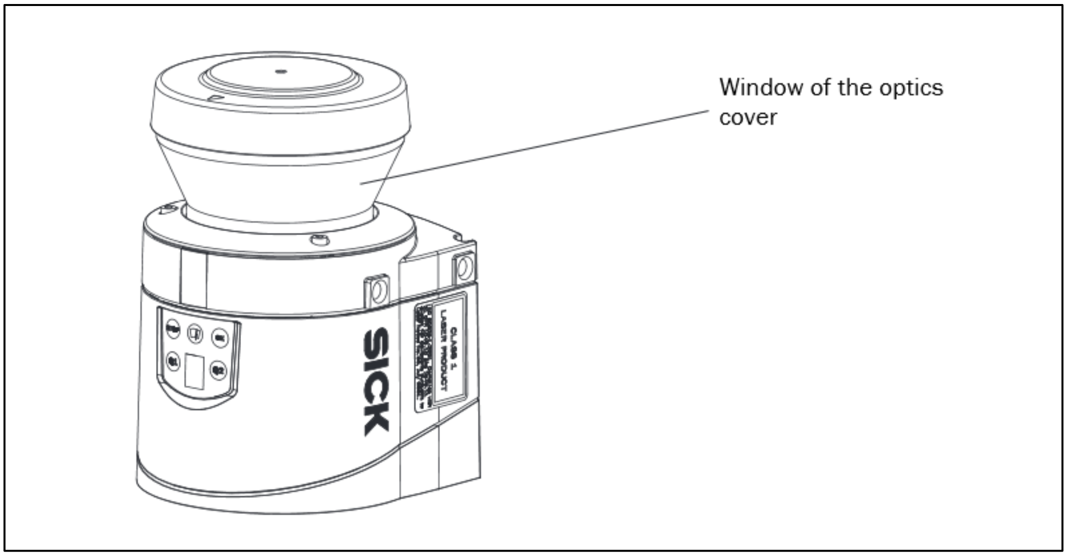

Figure 13. SICK LMS 111 Laser Detector (*4*).

Figure 14. Typical Application of Laser Detector at Toll Plaza (*4*).

PROPOSED LOCATION OF VEHICLE SENSORS

The location of the detectors for counting vehicles is anticipated to be near the CBP facility just north of the U.S./Mexico border. Placing detection on the Mexico side of the border is more challenging for several reasons, so TTI recommends placing detectors on the U.S. side. The optimum location for northbound detectors appears to be on a sign bridge, which is about 100 ft. north of the CBP facility. It has power for lighting, so detectors might simply draw power from there. If power and/or communications are not available here or elsewhere, the radar detector has modest power and communication needs, so solar panels and wireless modems are appropriate for use. The northbound traffic is usually free flow at this sign bridge. There are also luminaire poles in the immediate vicinity in case the sign bridge is not usable.

There are a few minor challenges to accurately counting the number of vehicles in the northbound direction from the proposed location. One of the early-perceived challenges was that vehicles exiting the CBP facility were not organized in well-defined lanes. According to the radar manufacturer's representative, however, the radar detector can count accurately even if vehicles are not displaced laterally in a predictable fashion. Another issue is that non-border-crossing vehicles pass this point from two sources—a local access road, which circulates traffic into a parking area just east of this sign bridge, and a U-turn lane, which occasionally serves vehicles that approach the border from the north but do not cross the border. Another less significant challenge is that vehicles exit the CBP facility in two streams—one left and one right of the building. One radar detector might be able to cover both streams of traffic as long as the radar beam does not encounter flat vertical surfaces (e.g., traffic barriers and sign bridge components) that might reflect its signal in a detrimental manner, and the distances are not greater than about 250 ft. Based on observation and map views, these challenges will not be insurmountable.

For the southbound movement, there are a few luminaire poles south of the CBP building (before vehicles reach the bridge) that appear to be located appropriately for the use of radar detectors. Depending on the site selected, either one or two radar detectors would be needed for the southbound traffic stream although one will probably suffice. There is also an overhead sign bridge over the southbound traffic on the north side of the building, but vehicles usually stop at that point, potentially causing a reduction in count accuracy. The use of one laser detector there would probably solve the problem. For radar detectors south of the CBP building, trucks are required to use the right lanes, but the detector could be programmed to exclude those lanes. As long as passenger vehicles do not infiltrate the truck lanes, counts south of the building should meet the desired accuracy requirements.

PLAN TO DEPLOY TRAFFIC VOLUME SYSTEMS

The researchers propose that the two technologies be installed for testing at the Bridge of the Americas. Figure 15 and Figure 16 show the site and most likely locations that could be used as mounting locations for laser detectors and radar detectors. Some of these sites have access to power, but solar panels are also an option. Labels placed near the detectors indicate the intended traffic flow (NB for northbound and SB for southbound) and detector type (L for laser and R for radar). As noted above, communications with the ISS G4 detector could be wireless, and solar panels could be used for power to minimize hard wire connections.

Figure 15. Candidate Locations on North Side of CBP Facility.

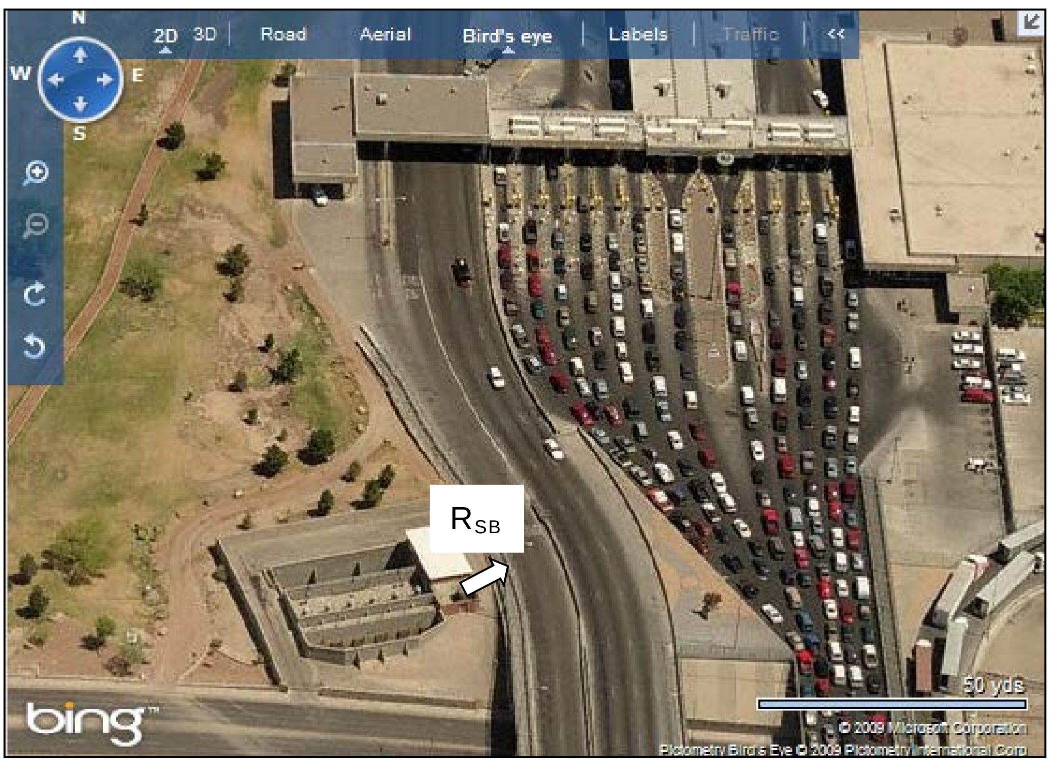

Figure 16. Candidate Location on South Side of CBP Facility.

COMPARISON OF THE TWO CANDIDATE DETECTORS

Table 11 summarizes the differences between the two selected detectors. At this time, there is a need to test both detectors since data proving that these detectors will work accurately under the specified conditions have not become available. Fortunately, both vendors have agreed to loan a test unit to TTI for a few weeks to conduct a field test.

As the summary shows, the ISS G4 is a significantly better choice than the laser detector if it can accurately count vehicles that are stopped and/or moving very slowly. The laser detector requires some development work to create a data storage unit and does not communicate via modem without an interface. The laser costs more than the radar detector, even when considering only the detector. Adding the other components will only increase this difference.

Table 11. Comparison of Laser and Radar Detectors.

Characteristic	***LMS 111***	***ISS G4***
Technology	Laser	Radar
Mounting location	Directly over lanes	Beside roadway at 17 ft high
Orientation	Vertical facing down	Sidefire
No. of lanes/range	2 lanes	8 lanes/250 ft
Conducive to solar power	Acceptable	Excellent
Communicates with modem	No	Yes
Stores data as-is	No	Yes
Accuracy in stopped traffic	Good	Must be verified
No. of units needed	1 SB, 2 NB (minimum)	1 NB, 1 SB
Cost per unit (detector only)	$5,500 to $6,000	$4,500
New components needed	Modem interface, software for communication	All components available

CONCLUSION

A system is desired to measure the volume of passenger vehicles entering and exiting the Bridge of the Americas. Traffic congestion and queues are frequent at BOTA, requiring a method that can successfully operate in a stop-wait-go environment.

Inductive loops and other intrusive vehicle detectors are undesirable due to lane closure requirements and lateral displacement of vehicles not coinciding with point detectors where monitoring occurs. The complete solution as presented suggests either a laser detector or a microwave detector that is able to count the number of passenger vehicles under stop-and-go conditions. Based on the existing conditions at BOTA, the researchers propose three laser detectors or two microwave vehicle detectors. The decision on which technology to use depends on the total cost and accuracy of vehicle counts, which has not been established. However, with the proposed setup, the bridge will be instrumented to count the volume of both southbound and northbound passenger vehicles. The solution will also require a central office to be established that receives data from the field devices to archive the volume. This office can be the TTI El Paso office, which is currently providing a similar function for a commercial-vehicle border-crossing time project.

Based on the cost of individual types of detectors, installation costs, and the number of detectors proposed at the Bridge of the Americas, Table 12 and Table 13 list the cost of installing both detector types and the annual cost of operation and maintenance (O&M) of each type of system.

Table 12. Cost of Installing and Maintaining LMS 111 Detectors at the Bridge of the Americas.

One-Time Field Device Installation and Central Data Processing System—LMS100	
Item	***Cost***
Installation of Laser Vehicle Detectors (3 x $12,000)	$36,000
Solar Power for Field Devices (3 x $4,000)	$12,000
Central Data Processor Software Development ($20,000)	$20,000
Total One-Time Installation Cost	**$68,000**
Annual Maintenance and Operation Cost	
Item	***Cost***
Maintenance Cost (3 x $1,200)	$3,600
Wireless Data Communication (3 x 12 x $50)	$1,800
Computer and Network Usage ($300)	$300
Staff Time ($5,000)	$5,000
Total Annual O&M Cost	**$9,700**

Table 13. Cost of Installing and Maintaining ISS G4 Detectors at the Bridge of the Americas.

One-Time Field Device Installation and Central Data Processing System—ISS G4	
Item	***Cost***
Installation of Laser Vehicle Detectors (2 x $10,000)	$20,000
Solar Power for Field Devices (2 x $4,000)	$8,000
Central Data Processor Software Development ($20,000)	$20,000
Total One-Time Installation Cost	**$48,000**
Annual Maintenances and Operation Cost	
Item	***Cost***
Maintenance Cost (2 x $1,000)	$2,000
Wireless Data Communication (2 x 12 x $50)	$1,200
Computer and Network Usage ($200)	$200
Staff Time ($4,000)	$4,000
Total Annual O&M Cost	**$7,400**

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