Tech Brief

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Effort to Test, Evaluate and Deploy Technologies to Automate the Measurement of Real-Time Border Wait Times at United States – Canada Land Border Crossings

Project Background

The United States and Canada share the largest bi-national trading relationship in the world. An efficient and cost-effective border crossing system for both freight and passenger vehicle traffic is thus vital to the economic well-being and security of both countries.

A 2005 study conducted by the Ontario Chamber of Commerce estimated United States-Canada border delays cost approximately $10 billion per year—more than $4 billion annually to the US economy and about $6 billion a year to the Canadian economy. While it is impossible to eliminate all delay due to the necessary and effective completion of compliance activities and other operational requirements, the need exists to identify and implement solutions that reduce unnecessary delay.

Collecting timely and accurate data regarding the amount of time that border users wait to cross is crucial to creating a more reliable border crossing experience. Such data can be used to:

- Enable drivers to make more informed decisions about when and where to cross the border;
- Operate transportation and border facility systems effectively;
- Plan appropriately for future needs;
- Evaluate the effects of various improvement initiatives; and
- Educate and inform public agency and industry officials, and the motoring public.

In an effort to move toward timely and accurate information, this project, the "Effort to Test, Evaluate and Deploy Technologies to Automate the Measurement of Real-Time Border Wait Times at United States – Canada Land Border Crossings," is designed to develop an automated process for collecting border wait times that will be facilitated by the use of existing or emerging technology. This effort is sponsored by the bi-national, multi-agency Border Wait Time Working Group (BWT-WG) comprised of representatives from US and Canadian Transportation and Customs agencies and is supported by stakeholders that operate at or near the border.

The objectives of this project are to identify, implement, test, and evaluate several technologies for automated measurement of border wait times. The

U.S. Department of Transportation
Federal Highway Administration

Transport Canada / Transports Canada

U.S. Customs and Border Protection

Canada Border Services Agency / Agence des services frontaliers du Canada

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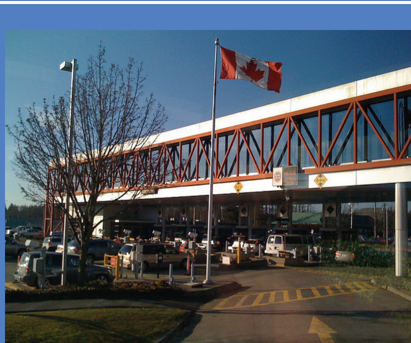
intent is to explore the viability of different options and establish their ability to meet the information needs of border stakeholders reliably.

Project Approach

The project is being conducted in two phases. Phase I involves the selection and testing of candidate border wait time technology solutions for a limited time period at two United States-Canada border crossings. Based on the results of the Phase I testing, the course of longer-term deployment at the two border crossing will be decided and carried out under Phase II of the project. Phase I is complete, and planning is underway for the execution of Phase II. A summary of Phase I activities follow.

Peace Bridge



Pacific Highway

Selecting Locations

Site Analysis

As part of the work conducted early in the BWT project, the project team reviewed characteristics for each of four crossing points in both the Niagara and Pacific regions.

The sites needed to be able to accommodate the installation and operation of technology devices and to have sufficient volumes of automobiles and trucks passing through in both directions to support a robust test. Finally, the test had to have the support of the agencies and other entities that operate and/or manage facilities on which any technology devices would be tested.

Selected Sites

After careful consideration of crossing characteristics and discussions with local stakeholders at the candidate crossings, the BWT-WG chose two sites:

- Peace Bridge between Buffalo, New York and Ft. Erie, Ontario
- Pacific Highway near Blaine, Washington and Douglas, British Columbia

Selecting Technologies

Identification of Options

The project team used two instruments for gathering information about potential technologies: a review of available documentation from previous studies and the results from a Request for Information (RFI) process issued on behalf of the BWT-WG. Based on both this information as well as a set of business requirements established by the BWT-WG, the project team identified a broad spectrum of technology options. Finally, potential technology providers participated in an "Industry Day" web seminar where they were given information about the project goals, objectives, and proposed approach and invited to provide input on the project. The project team used the output from each of these efforts to formulate the basic elements of a procurement document.

Procurement Process

Through a competitive procurement process managed by the lead project contractor, prospective vendors were given the opportunity to offer proposals for the trial implementation and operation of wait time measurement technology solutions at one or both of the test sites. In all, 23 vendors formed 9 teams and submitted a total of 10 proposals. The proposed solutions included the use of the following types of measurement technologies:

- Global Positioning System (GPS)
- Bluetooth
- Smartphone
- Video Image Recognition
- Radio Frequency Identification (RFID)
- Micro-loops
- RADAR
- Vehicle Waveform Identification (VWI)

Several responses proposed the coordinated use of more than one of the above technologies.

Selection Results

The project team evaluated the proposed solutions against selection criteria in four areas:

- Technology Capabilities
- Offeror's Management Approach
- Technical Approach to the Project
- Proposed Budget/Cost

Among the most heavily-weighted criteria regarding the technologies was the degree of knowledge already in-hand regarding capabilities in a border crossing setting. Those solutions that relied heavily on technologies already in use or being examined in other testing programs along international borders were set aside in favor of those for which additional information was needed.

Ultimately the BWT-WG decided upon four technologies, or combinations thereof, to test in Phase I:

- GPS/Smartphone
- Bluetooth
- RADAR
- Vehicle Waveform Identification (VWI)

The Bluetooth and RADAR solutions were deployed in both directions at both crossings. The GPS/Smartphone solution was deployed in both directions at Peace Bridge, and the VWI solution was implemented in the US-bound direction at Pacific Highway.

Gathering Data

From the Technologies

For Phase I testing, systems utilizing the four technologies were implemented at the crossings—with two technologies installed at both and two others deployed at one each. The intent was for each technology to be operational and delivering data for a 30-day period, with the last week of data gathered during the same period as manually observed data was captured. This approach allowed the technology providers the opportunity to get their systems up and running and calibrated prior to evaluation.

Business requirements formulated by the BWT-WG required each of the technologies to provide values for *current wait time*, which is defined as the amount of time the next vehicle arriving at the end of the queue at the crossing would be expected to wait before reaching the customs primary inspection point. Additionally, the business requirements specified a preference that the technologies also provide values for *actual wait time,* which is defined as the amount of time it actually took vehicles to actually reach the primary customs inspection point.

The business requirements dictated that the systems provide data in a format consistent with standards typically used for Intelligent Transportation Systems (ITS). Vendors were instructed to apply Traffic Management Data Dictionary (TMDD) standards, whether the data was provided in a streaming "real-time" feed or through the periodic transfer of datasets.

Each vendor team captured and provided data for at least a portion of the one-week period at each site, during which period manually observed "ground truth" data was collected.

From "Ground Truth"

In order to establish the accuracy and reliability of the technology options, the project team captured data for cars and trucks waiting at each crossing by visual observation over portions of each day during a 1-week period. This observation process consisted of the capture of license plate data for a representative number of vehicles as they arrived at the end of the queue leading to the primary customs inspection point and again as they arrived at the primary inspection booth.

The project team used these data, which were collected separately for cars and trucks undergoing standard and expedited processing (NEXUS and FAST), as a basis for comparison to tested technology-generated wait times.

These observed values were referred to during the Phase I test as "ground truth" values.

Findings

Analytical Approach

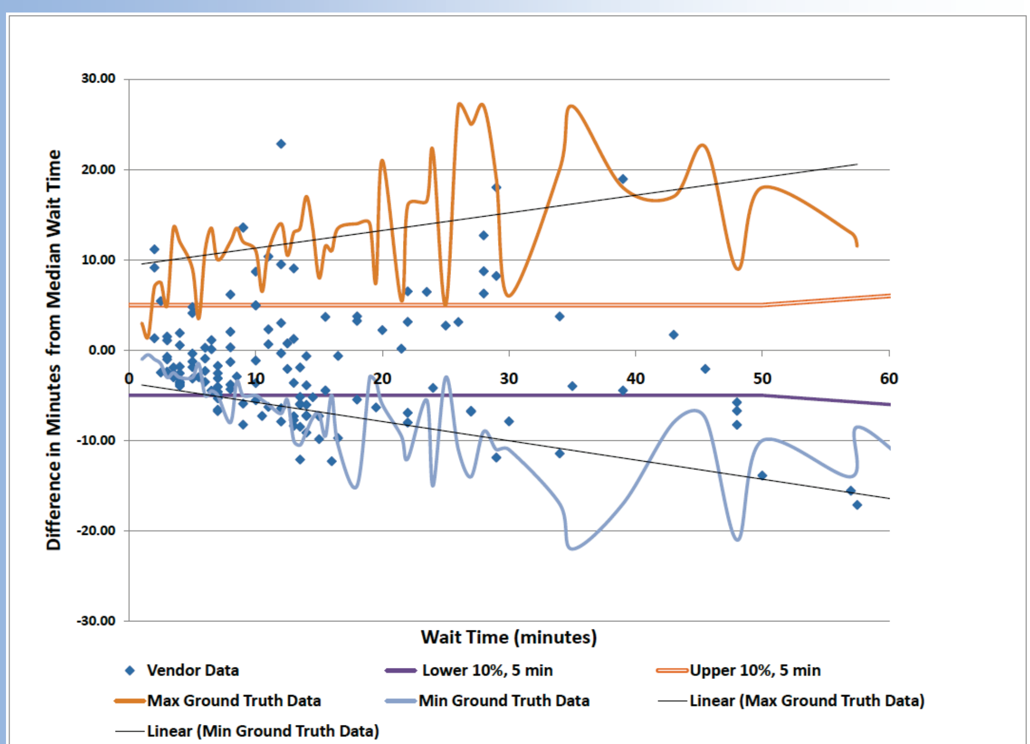
The fundamental analytical approach consisted of two elements: 1) the comparison of tested, technology-generated values for current wait time and actual wait time (defined as the actual wait time experienced by a vehicle arriving at primary inspection) against values captured as part of the ground truth data collection effort, and 2) the observation of tested technology implementation and operation for consistency with defined requirements.

The project team conducted the data comparison so that all periods during which ground truth wait time median values were similar were used as a basis for comparison to the system data. This significantly increased the total volume of data available for each discrete analysis and had the effect of minimizing the net influence of outlying data points on the results.

Throughout the process, data for cars and trucks were handled separately, as were data for vehicles passing through expedited lanes (FAST, NEXUS) and standard lanes.

Performance Results

The principal functional requirement the team used for assessing accuracy was derived from an accuracy goal developed for freeway travel time measurement. This goal, which is specified in the Notice of Proposed Rulemaking for Real-Time System Management Information Program (23 CFR Part 511), is set at 85 percent. The project team adopted this target for Phase I analysis in the absence of a more specifically defined value for border wait time measurement.



Examination of system-provided data against ground truth data revealed that none of the technologies consistently met the 85 percent accuracy threshold, although two of them—Bluetooth and GPS/Smartphone—came closest, with *current wait time* accuracy values as high as 70 percent for vehicles passing through standard processing lanes.

Generally, the values for accuracy were higher at the Peace Bridge crossing than at the Pacific Highway crossing. Though the cause for this phenomenon is not clear from the data, the opportunity for vehicles to exit and enter the traffic stream is greater at Pacific Highway, where traffic queues routinely extend beyond the entry points for areas such as duty-free shops, confounding attempts to exclude them from wait time calculations.

Accuracy for *actual wait times* was also highest for the Bluetooth and GPS/smartphone technologies, with the GPS/smartphone system providing accuracy that exceeded the target performance threshold of 85 percent at the Peace Bridge crossing. It should be noted that this is based on a limited number of samples; however, these results are considered important.

Other Observations

In addition to the numerical analysis, the project team assessed each technology through feedback from local, State, Provincial, and Federal stakeholders, as well as the observation of the degree to which they complied with provisions identified in the functional requirements.

Across the board, agency representatives offered a positive perspective of the elements associated with the technologies tested, and the vendors that were responsible for them. None of the stakeholders perceived that the technologies affected enforcement procedures, and considered disruptions to traffic minor and only necessary for very short periods, even for those technologies that required diversion of traffic during installation.

None of the stakeholders expressed serious concern over potential future disruptions should any of the technologies be deployed on a permanent basis. As for any particular attributes from any of the technologies that were considered positive or negative, few of the stakeholders offered opinions.

Lessons Learned

Technology Capabilities

The testing completed under Phase I of the project yielded a significant amount of information about the capabilities of each of the technologies for measuring border wait times. The primary lessons learned in this regard are termed Technology Capability Lessons (TCLs) and Technology Implementation Lessons (TILs):

TCL-1: The computation of a class-specific (i.e., car, car-NEXUS, truck, truck-FAST) wait time value is difficult, particularly if more than one lane is open for a particular vehicle type, since customs inspectors do not detain each vehicle for the same amount of time. This is substantiated by the variability seen in ground truth data.

TCL-2: The configuration of roadways on the approach to the crossing, in particular between end of queue and primary inspection, can have a profound effect on the complexity of the technology needed to deliver wait times. This is more significant for technologies that require the installation of sensors on-site.

TCL-3: The determination of wait time reporting accuracy is a difficult undertaking in the border environment. Ground truth data collection, as conducted during this test, represents only a sample of the overall flow of vehicles, and assumptions must be made regarding ground truth values.

TCL-4: Much remains to be learned about the use of VWI and RADAR sensors for determination of wait time. Specifically, it is not completely clear from the data captured during the test whether either can be relied upon for the delivery of accurate wait time values.

TCL-5: The use of a longer ground truth data collection period would have been useful, particularly since some of the technologies were not implemented in full before ground truth data collection began. This would have allowed for a longer period during which technology-provided values could be compared.

Implementation Challenges

Phase I of the project also provided important information about the implementation of each of the technologies for measuring border wait times. The primary lessons learned in this regard are:

TIL-1: A well-considered design document must take into full consideration the effects of traffic stream characteristics on the performance of individual sensors. In the case of the VWI sensors, their placement in reference to other sensors of the same type is critically important. In a similar fashion, the RADAR devices implemented demonstrated a very high sensitivity to the nature of the traffic flow through their signal footprint.

TIL-2: Cellular telephone modems operating in the border environment are sensitive to some phenomenon that may be related to the close proximity of separate wireless networks, or to the placement of antennas.

TIL-3: It is important not to make assumptions regarding the ability of existing infrastructure to accommodate the addition of devices it was not originally designed to support. For example, some of the proposed mounting poles were not designed to handle the wind loads that could result from changing the cross-section of the pole.

TIL-4: Advance coordination with State and local agencies regarding the installation of devices on their rights-of-way was invaluable during the project. The use of local installation contractors familiar with existing requirements also expedited the process and offered agencies peace of mind.

Conclusions & Recommendations

Conclusions

Based on the observed results from the full data collection period, the following conclusions are offered regarding the use of the various technologies tested for the measurement of wait time across international border crossings, both in general terms and in terms specific to the Peace Bridge and Pacific Highway crossings.

- While none of the technologies tested achieved target accuracy as defined in the functional requirements, at least two of the solutions—the Bluetooth solution and the GPS/smartphone technology—showed the most promise as viable near-term approaches to automated wait time measurement.
- Based upon the differences inherent in measuring freeway-based travel time versus border wait time measurement, and the degree of variability of the ground truth data, is the conclusion is that the functional requirement that wait time accuracy performance meet the same 85 percent standard as freeway travel time systems warrants re-examination.
- The project team concurs with the consensus among the technology providers that a solid historical dataset is essential to formulating predicted wait time values, and likely indispensible for calculating current wait times, as well. This is yet to be proven, however.
- The project team suspects that an extended period of ground truth data collection during which solution providers are given access to historical data might facilitate the process of calibrating technology solutions.
- Questions remain about how long it would take to achieve the level of market penetration needed for both the Bluetooth solution and the GPS/smartphone solution to function effectively in the border environment. Both technology approaches have proven effective as traffic speed and travel time measurement systems in other settings, but the border presents a unique operational environment that presents challenges.
- It is important to note that the abbreviated data collection period imposed significant constraints on the breadth and depth of the testing and analysis. In addition to introducing challenges associated with dropped data and late implementation, the test did not allow for adequate capture of data related to technology reliability.

In summary, much was learned during the test, but several items of interest appear to need further examination in Phase II. At least two of the technologies showed significant promise and warrant further deployment testing: Bluetooth and GPS/smartphone. Moving forward it will be important to revisit both the test approach and the functional requirements to ensure that the appropriate expectations are placed on the systems.

Recommendations

Based upon the results captured and the conclusions drawn from them, the following recommendations were developed for Phase II of the project.

- **Conduct Phase II Deployment for Two of the Technologies.** Though neither technology met performance targets during the Phase I testing, both the Bluetooth and GPS/smartphone solutions showed significant promise.
- **Consider Capturing and Sharing Ground Truth Data.** Giving technology providers access to this data has the potential to assist them in isolating and correcting implementation and computational errors. As part of this process, it may be useful to consider other methods to create ground truth data that assists in the calibration of the technologies.
- **Revisit and Refine Functional Requirements.** It may be useful to re-examine the functional requirements to determine whether adjustments are necessary to more adequately assess technology accuracy, precision, and information timeliness targets from the perspective of the various potential users of the information.
- **Gather a Robust set of Historical Wait Time Data.** Historical data is of significant importance in calculating both current and predicted wait time values, and reveals important details about how traffic reacts to changes in conditions at the border.
- **Explore Further Integration of Data.** As part of the Phase II activities, the project team recommends that each solution deployed be expected to accommodate integration with existing systems at the crossing(s) and in the jurisdictions adjacent to it (them).
- **Explore Options for Information Dissemination and Presentation.** Both CBP and CBSA currently publish wait time data, and there are numerous State and local agencies that serve as avenues of dissemination for such information.
- **Ensure Phase II Evaluation Addresses Requirements Not Yet Tested.** Much remains to be determined regarding issues such as system reliability, performance under adverse weather conditions, and system diagnostics and self reporting.

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