Implementation Report – DRAFT

CASCADE GATEWAY ADVANCED BORDER INFORMATION SYSTEM (ABIS) DESIGN PROJECT

whatcom council of governments

August 29, 2024

Project Title	Cascade Gateway Advanced Border Information System (ABIS) Design Project
Recipient Name	Whatcom Council of Governments (WCOG)
Fiscal Year of Award	FY22
Period of Performance	18 Months
Prepared By	WCOG Transpo Group USA, Inc. Sarakki Associates Inc. Texas A&M Transportation Institute
Date Submitted	August 29, 2024

Prepared By:

transpogroup
WHAT TRANSPORTATION CAN BE.

Transpo Group USA, Inc.
12131 113th Avenue NE, Suite 203
Kirkland, WA 98034-7120
Phone: 425-821-3665
www.transpogroup.com

Texas A&M Transportation Institute

Texas A&M Transportation Institute
3135 TAMU

SAI SARAKKI Associates Inc.

Sarakki Associates Inc.
4199 Campus Drive, Ste 550

1. INTRODUCTION AND PROJECT OVERVIEW

In 2023, the Whatcom Council of Governments (WCOG) was awarded project funding for the Cascade Gateway Advanced Border Information System (ABIS) Design Project through the U.S. Department of Transportation's (USDOT) Strengthening Mobility and Revolutionizing Transportation (SMART) Grants Program. This program funds purpose-driven innovation to build data and technology capacity and expertise for State, local, and Tribal governments, with the goal of using new technologies and approaches to target real-world challenges and create benefits.

The Stage 1 ABIS Design Project is evaluating technologies to replace and improve aging wait time systems at the Cascade Gateway system of border crossings between the Lower Mainland of British Columbia and Whatcom County, Washington State.

This Implementation Report provides a summary of the project, an overview of the Stage 1 activities and accomplishments; an assessment of the goals, objectives, and expectations met; performance data and results, a benefit-cost assessment; requirements for at-scale implementation (including operations and maintenance); lessons learned; and recommendations. Additionally, as this project was conducted in accordance with systems engineering standards and best practices, the *Concept of Operations* (attached as ***Appendix A: Concept of Operations)*** provides more information on the details of the at-scale concept and highlights the traceable flow of the development of the system concept from user needs to essential features, system diagrams, user interfaces, information flows, system assumptions and constraints, culminating with descriptive day-in-the life operational scenarios that describe how users will access and benefit from the system.

This report is written at the end of the Stage 1 effort and will frame the context and details for the Washington State Department of Transportation's (WSDOT) Stage 2 grant application, submitted on August 14, 2024.

1.1 Project Description

The Cascade Gateway system of border crossings consists of four land Ports-Of-Entry (POEs) connecting the Lower Mainland in British Columbia and Whatcom County in Washington State. To optimize traffic flow across the Cascade Gateway POEs and to provide travelers with real-time traveler information on nearby cross-border routes, WSDOT and the B.C. Ministry of Transportation and Infrastructure (BCMOTI) each installed a northbound and southbound ATIS, respectively, at all four POEs. Since 2007, both systems have exported their data in real-time to an online archive at www.borderdata.org.

Currently, the operating hours and lane types at each border crossing are as follows:

- **Peace Arch/Douglas**: Open 24 hours for passenger traffic and NEXUS, serving U.S. I-5 and B.C. Hwy 99.
- **Pacific Highway**: Open 24 hours for passenger traffic, NEXUS, buses, commercial traffic, and FAST, serving WA SR 543 and B.C. Hwy 15.
- **Lynden (Kenneth G. Ward)/Aldergrove**: Open from 8:00 am to 12:00 am for northbound passenger traffic, NEXUS, and commercial traffic, and from 8:00 am to 12:00 am for southbound passenger and permit-only trucks, serving WA SR 539 and B.C. Hwy 13.
- **Sumas/Abbotsford-Huntingdon**: Open 24 hours for passenger traffic, NEXUS, and commercial traffic, serving WA SR 9 and B.C. Hwy 11.

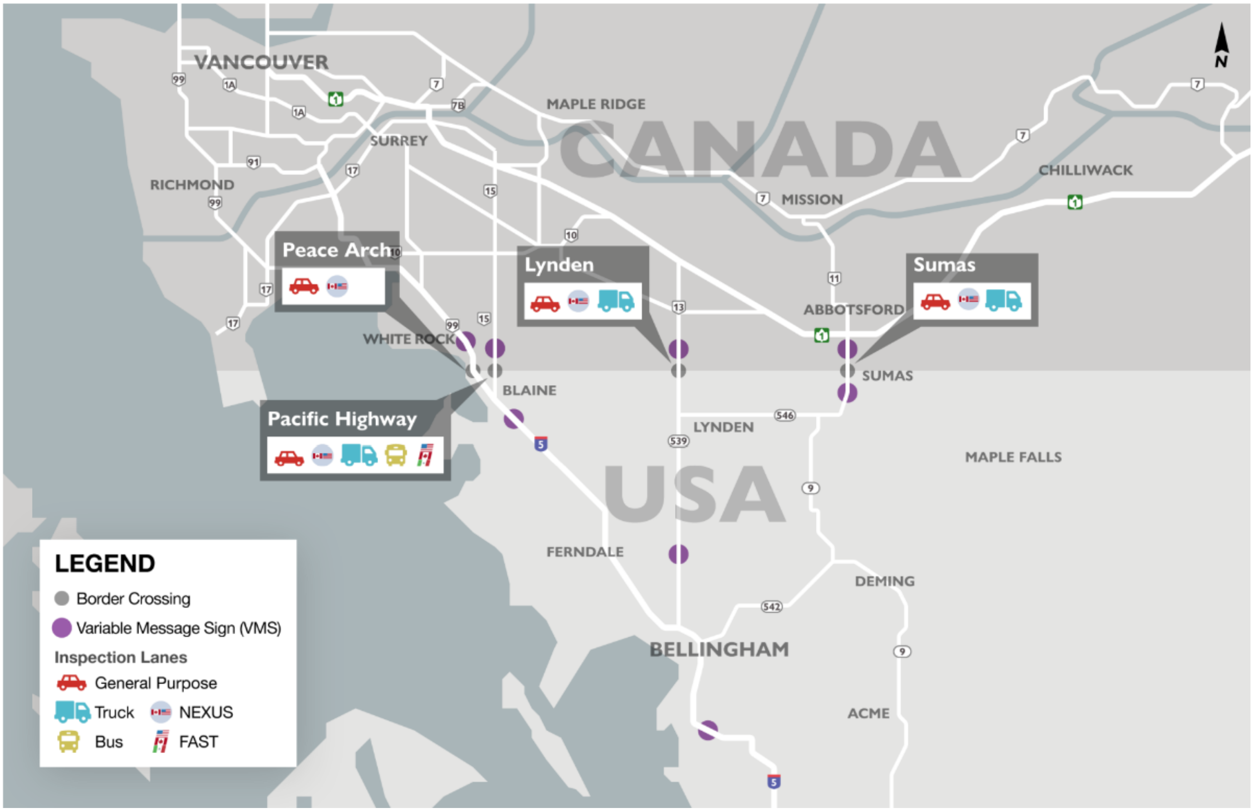


Figure 1. The Cascade Gateway ABIS Project Area Overview

The purpose of this Stage 1 project is to evaluate and identify technology options for a new Cascade Gateway ABIS. The existing system, known as the Advanced Traveler Information System (ATIS), is 20 years old with ageing hardware and software systems. This Stage 1 project, which is 90% complete with only the *System Requirements* and *High-Level Design* to be completed in the September/October 2024 timeframe, involves systems engineering, technology evaluation, and design activities; the ABIS will be implemented as part of a future Stage 2 project. Given the critical need to provide cross-border traffic information and system data for the13 FIFA World Cup matches taking place in Seattle, WA and Vancouver, project partners hope to have the initial system functions operational by June 2026. ***Figure 11*** presents an overview of the anticipated project schedule and the need for the accelerated timeline. Given the binational nature of the project, the geographic scope, and the unique challenges of a border environment, the project team's focus in Stage 1 was on establishing user needs and requirements prior to evaluating and piloting any hardware.

Overall, this project aims to develop a binational wait time system, known as the Cascade Gateway ABIS, that can be utilized by inspection agencies, departments of transportation, the traveling public, commercial importers and exporters, and others with the goal of improving transportation efficiency and safety across nine objectives (see ***Table 1*** below) that were developed by the project stakeholders prior to Stage 1.

The Stage 1 project used the U.S. Federal Highway Administration (FHWA)'s technology development systems engineering process, with a focus on responding to user needs defined through an extensive international stakeholder engagement process that included workshops, site surveys, and technology evaluations (including vendor showcases) focused both on near- and long-term technology solutions. The results of this approach, in terms of how it addresses the nine objectives defined by the stakeholders for Stage 1, are summarized in ***Table 1***.

Table 1. Stage 1 Design Project Outcomes

Stage 1 Objectives			Stage 1 Outcomes
1	Report traveler wait times for the region's four POEs, northbound and southbound.	✓	Developed a hybrid solution for a binational system that uses new sensors, a mobile application, and open interfaces to provide accurate and reliable border wait-time (BWT) measurement and disseminate data to both government agencies and the traveling public.
2	Report commercial vehicle wait times for the three commercial POEs, northbound and southbound.	✓	The hybrid solution includes additional sensors and means to measure BWT for commercial vehicles. Additionally, all travelers will be able to use new predictive analytics tools to better plan trips.
3	Provide a real-time data feed to applications, websites, and variable message signs.	✓	The system provides open source BWT data to all systems interested in sharing the information using an improved communications network for increased reliability.
4	Provide a real-time data feed to U.S. and Canadian inspection agencies.	✓	The project will develop dashboards that provide inspection agencies with data in the formats they need, based on stakeholder inputs from U.S. Customs & Border Protection (CBP) and Canada Border Services Agency (CBSA).
5	Provide a real-time data feed to the Cascade Gateway Border Data Warehouse (CGBDW).	✓	The system will feed compatibly-formatted real-time border data into the existing CGBDW for the purposes of archiving the data.
6	Incorporate anti-idling system components at one or more POEs.	✕	After evaluation, this component was ultimately rejected due to planned POE construction projects through 2030.
7	Integrate with existing traveler information systems.	✓	The system will be compatible with existing traveler information systems.
8	Improve cyber-security.	✓	The system will be designed to meet state and federal security standards like FedRAMP and NIST 800-53. Privacy will also be protected for U.S. and Canadian data.
9	Document the process.	✓	Project exceeded SMART requirements by completing all systems engineering documents, resulting in a scalable and replicable system that can serve as a blueprint for other POEs at northern and southern U.S. borders.

This project fits within two technology areas: intelligent, sensor-based infrastructure; and systems integration. As detailed in the ***Appendix A: Concept of Operations***, the proposed technology concept for the ABIS involves a hybrid suite of technologies, deployed and integrated to enhance accuracy and reliability of BWT measurements and estimates. The preferred technology concept utilizes a combination of technologies, including radar detection, Bluetooth/Wi-Fi readers, and a new smartphone application that will work with upcoming GPS Block III lane-by-lane accuracy, and also support migration/integration with CV2X emerging applications being defined by USDOT and the private sector. By strategically combining these technologies, the proposed hybrid solution provides increased accuracy and reliability:

1. **Bluetooth/Wi-Fi-Based Measurement:** Utilizing the unique Media Access Control (MAC) addresses of smart devices, the system anonymously identifies vehicles when they join the back of the

queue and reidentifies them as they travel up to and through the primary inspection area. This provides real-time, granular data on wait times for both privately-owned and commercial vehicles.

2. **Radar-Based Detection System:** The proposed radar detection system complements the Bluetooth/Wi-Fi data by accurately measuring the location of the back of the queue and counting the number of vehicles in each lane for improved wait time calculations.
3. **Map-Based Border Wait Time (BWT) Mobile Application:** This user-friendly app integrates the various data sources that collect traffic data with historical information. Patterns, Artificial Intelligence (AI), and Machine Learning (ML) algorithms are used to provide real-time updates, generate accurate predictions for current and future wait times, and plan for border operations. Integration with mapping platforms and interfaces provides users with navigational assistance via natural language routing information, and more.
4. **AI and Machine Learning Tools:** Leveraging historical and real-time data, the AI algorithms perform analyses that reveal hidden patterns in data and day-to-day operations. Agency-specific dashboards, self-learning algorithms, and intuitive natural language interfaces provide users with actionable insights.
5. **Leverage Future Developments in GPS and Connected Vehicle Technologies:** The mobile application will be designed to work with smartphones that will soon contain chipsets that will be able to take advantage of the new GPS Block III constellation of satellites, which will support positioning accuracy for lane-by-lane vehicle positioning. Additionally, the BWT mobile application will be designed to integrate with the C-V2X family of applications and standards being promoted by the USDOT and the private sector.

In addition to the nine project objectives listed previously in this section, the Stage 2 project is also anticipated to meet the SMART Grants Program Priorities of safety and reliability; resiliency; equity and access; climate; partnerships; and integration: these goals are discussed in detail in ***Section 3.1***.

1.2 Community Impacts

The four POEs that make up the Cascade Gateway system of border crossings include several census tracts. ***Table 2*** provides the project's census tract information, per the Climate and Economic Justice Screening Tool (CEJST) and the USDOT Equitable Transportation Community (ETC) Explorer. ***Figure 2*** shows the project area and ***Figure 3*** shows the combined disadvantaged scores for the four census tracts.

Table 2. Project Location Census Tracts

CEJST Census Tract	ETC Explorer Census Tract	Disadvantaged Status
53073010401	**53073010409** **53073010410**	Not disadvantaged per CEJST. **Fully disadvantaged per ETC Explorer.**
53073010301	**53073010301**	Not disadvantaged per CEJST. Not disadvantaged per ETC Explorer but is **highly disadvantaged (80%) in Transportation Insecurity.**
53073010200	**53073010202**	***Partially disadvantaged per CEJST.*** **Fully disadvantaged per ETC Explorer.**

This solution benefits a broad spectrum of the community, from regional businesses and tourism venues serving U.S. or Canadian visitors, to local farmers carrying goods across the border, as well as nearby Whatcom County and B.C. residents. Given the project's location in a predominantly rural region, any effort to reduce regional travel restrictions will improve accessibility to local businesses and services.

In addition to the local benefits, however, the project will also serve those travelling along the I-5 corridor between Vancouver, B.C. and Seattle, WA, and points south. This includes tourists and visitors to the area, such as the influx of travelers expected for the 2026 FIFA World Cup, as well as commercial freight movements from California to Canada.

The ABIS will provide data to all border crossers, even those who do not have smartphones, via traveler information systems that include variable/dynamic message signs, websites, and highway advisory radio.

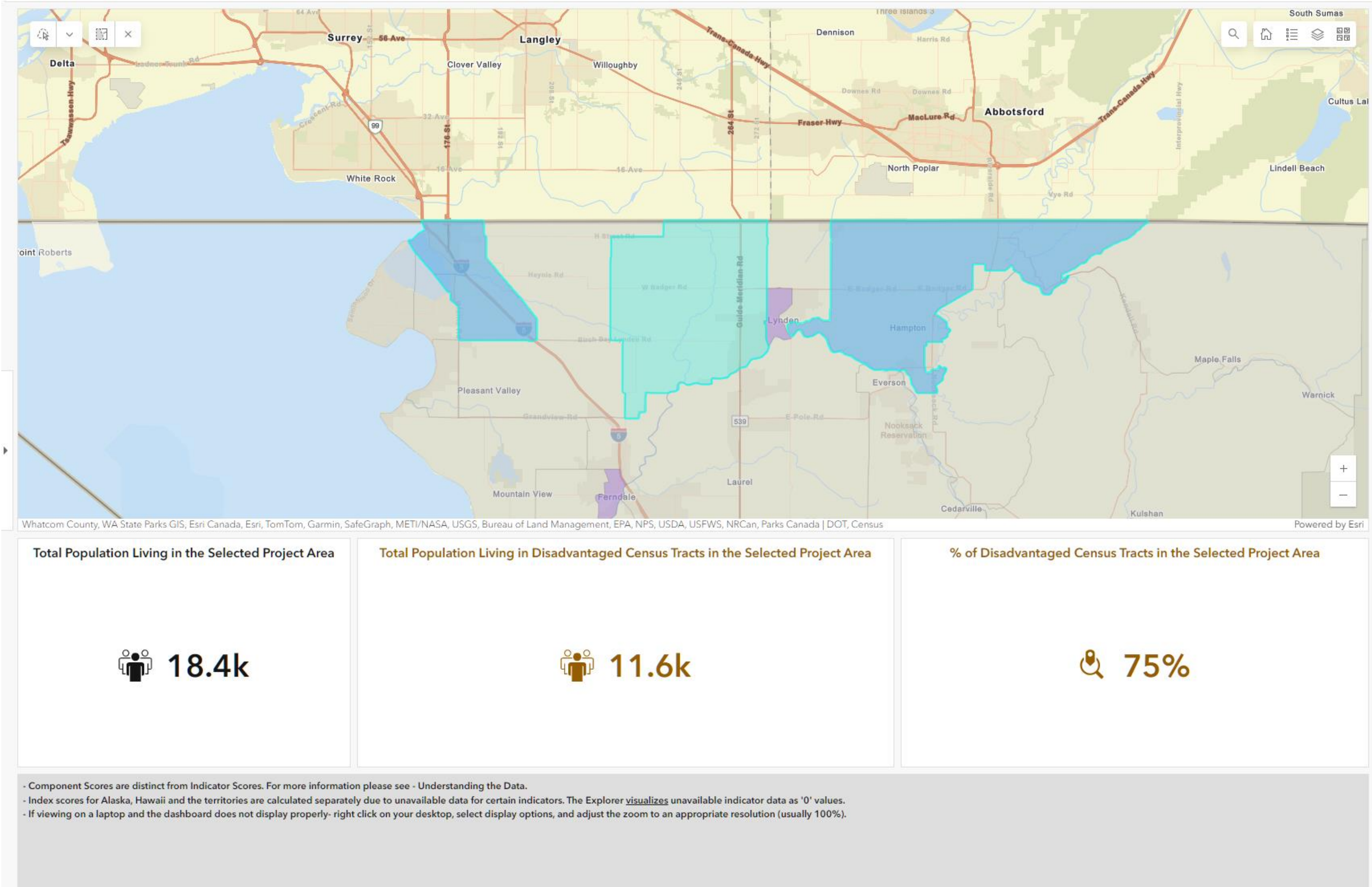


Figure 2. Project Area - USDOT ETC Explorer Census Tracts

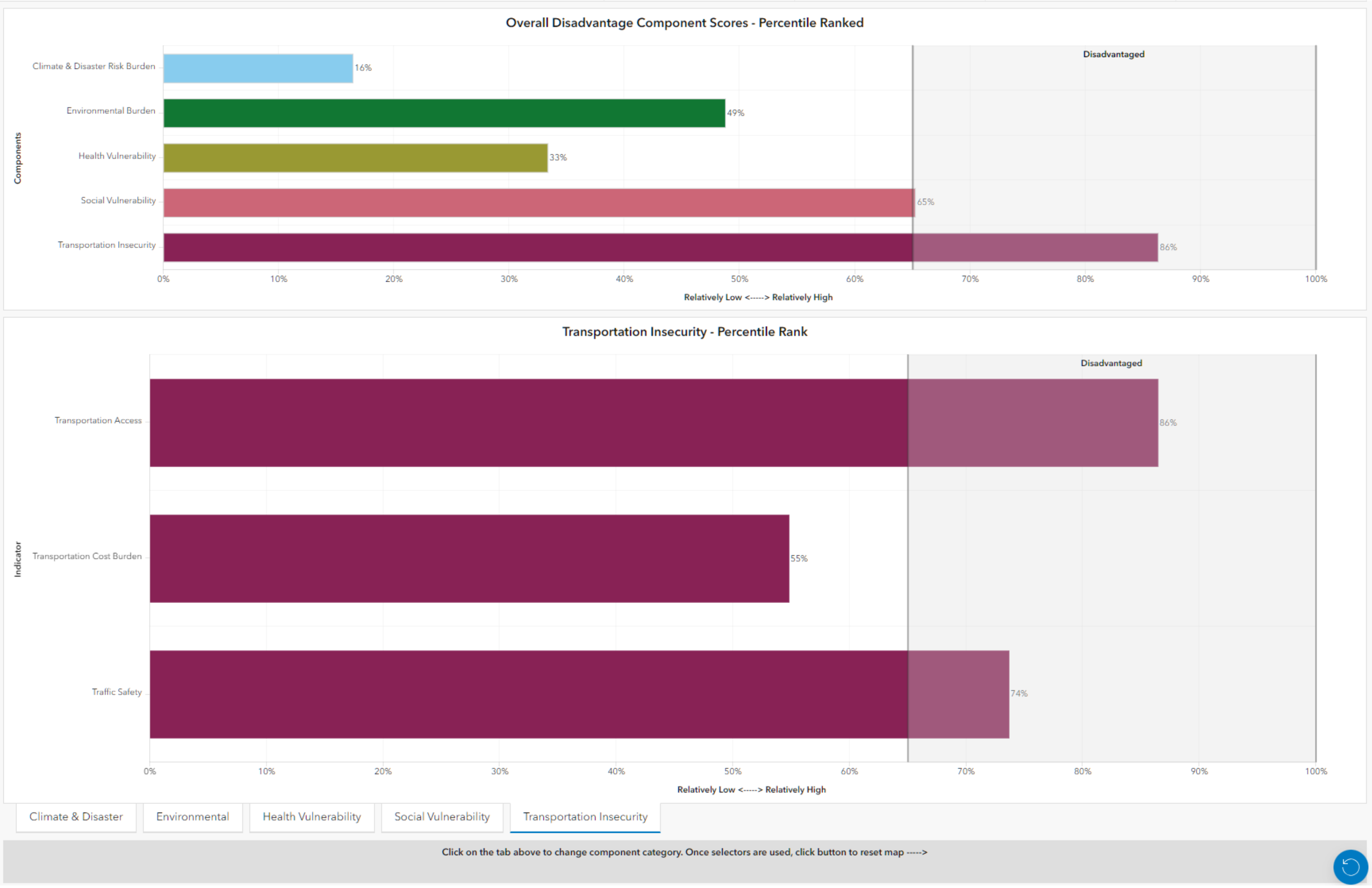


Figure 3. Project Area - USDOT ETC Explorer Disadvantaged Scores

1.3 Anticipated At-Scale Implementation

The Stage 1 project completed the systems engineering and design, and Stage 2 will physically deploy components as part of the at-scale implementation. Stage 1 included a state-of-the-practice review, documenting the existing ATIS, and extensive stakeholder engagement and research in identifying, conceptualizing, and evaluating several technology solutions. This subsection provides an overview of this proposed at-scale implementation; for more technical details, please see ***Appendix A: Concept of Operations***; for cost estimation and projected benefits, see ***Section 3***.

Radar detection would be used to determine the location of the end of the queue and to count the number of vehicles entering the system. This may be used in conjunction with existing loop detectors in locations where loop detectors are known to be reliable (although many, including those southbound in B.C., are already considered too unreliable to be incorporated into the system). Given loop detector inaccuracies in queued conditions close to the primary inspection booths at each crossing, the most likely scenario would be to recalibrate existing loop detectors upstream of the POEs where stop-and-go traffic is not typically present, and rely exclusively on radar detection in locations where vehicles are traveling more slowly and where a non-intrusive form of detection is preferred due to maintenance needs. The system will be designed to rely solely on radar detection in lieu of existing loop detectors, should they prove too unreliable to be useful. Note that, while radar detection is the primary choice for non-intrusive detection, there is also the possibility of using LiDAR or video analytics if a system can prove capable of fulfilling all the requirements of the system. Radar detection and the algorithms developed by the system will provide an *estimated* wait time – specifically, a measurement of what the vehicle entering the end of the queue is likely to experience. This is the most useful calculation for variable message signs and applications.

Bluetooth/Wi-Fi readers will be deployed to re-identify vehicles using the Media Access Control (MAC) addresses of devices like smartphones and vehicle infotainment systems. The Bluetooth/Wi-Fi readers will also provide an *actual* wait time – specifically, the actual time it took for a vehicle to travel from the end of the queue to the primary inspection booth. In addition to being the most useful calculation for performance measurement and agency reporting purposes, it will also serve as a comparable number to the estimated wait time, providing real-time ground truthing of estimates and allowing the system to learn as it matures.

In order to capture the lane type used by travelers (e.g. whether they use the standard lanes or the pre-approved traveler lanes, NEXUS for passenger vehicles and FAST for commercial vehicles), a new smartphone application will be developed that will track vehicles by lane type based on the app user’s lane type selection (since current GPS II technology does not provide per-lane accuracy to achieve individual lane identification) while also providing travelers with navigation/BWT/travel time information. With user consent, the BWT app, once installed, tracks vehicles continuously (within the geofenced area) from the time a vehicle joins the back of the queue to the time it exits primary inspection. Because this approach can be used to determine BWT for both passenger and commercial vehicles, and since it minimizes the need for roadway infrastructure, it is a very cost-effective means for providing *actual* wait time. Additionally, this provides the system with a pathway to mature alongside upcoming advancements in GPS technology like GPS Block III.

Care will be taken to ensure that the location tracking process is anonymous and secure and complies with Federal Risk and Authorization Management Program (FedRAMP) standards, a government program that provides a standardized approach to security assessment, privacy, authorization, and continuous monitoring of IT products and services used by federal agencies to store, process, and transmit information. The program is based on the Risk Management Framework (RMF) that implements the Federal Information Security Modernization Act (FISMA) requirements and NIST SP 800-53. By integrating GPS readings into the system, the system enhances the precision of vehicle identification and wait time calculations. This approach retains the reliability of radar (and loop detectors, if desired) while harnessing the benefits of GPS technology for improved real-time tracking and data accuracy.

The approach for the implementation of this system is designed to be forward compatible and futureproofed**,** relying initially on physical infrastructure and gradually moving towards the infrastructureless approach that will leverage improved GPS and C-V2X developments. ***Figure 4*** illustrates the anticipated transition from an infrastructure-based system to an infrastructureless system over time. More specifically:

- Given that the accuracy of BWT data collected from the mobile app will depend heavily on the number of users of the app, it is expected that toward the beginning of the system's lifecycle, the reliance on the system's BWT data sources will lean more heavily on the deployed physical infrastructure (i.e., radar detection and Bluetooth/Wi-Fi readers).
- As more travelers use the app, increasing the penetration rate, the ABIS will be able to rely on the app's data more. Once it has been deemed that the data provided through the app is accurate and reliable enough such that the physical infrastructure would no longer be needed for BWT measurement, the system will transition fully to infrastructureless operation.

Note that for BWT measurement purposes, a 100% penetration rate is not needed; only a statistically significant enough portion of the population needs to be using the app to generate accurate BWT. This number is estimated to be approximately 25%, though more will be better.

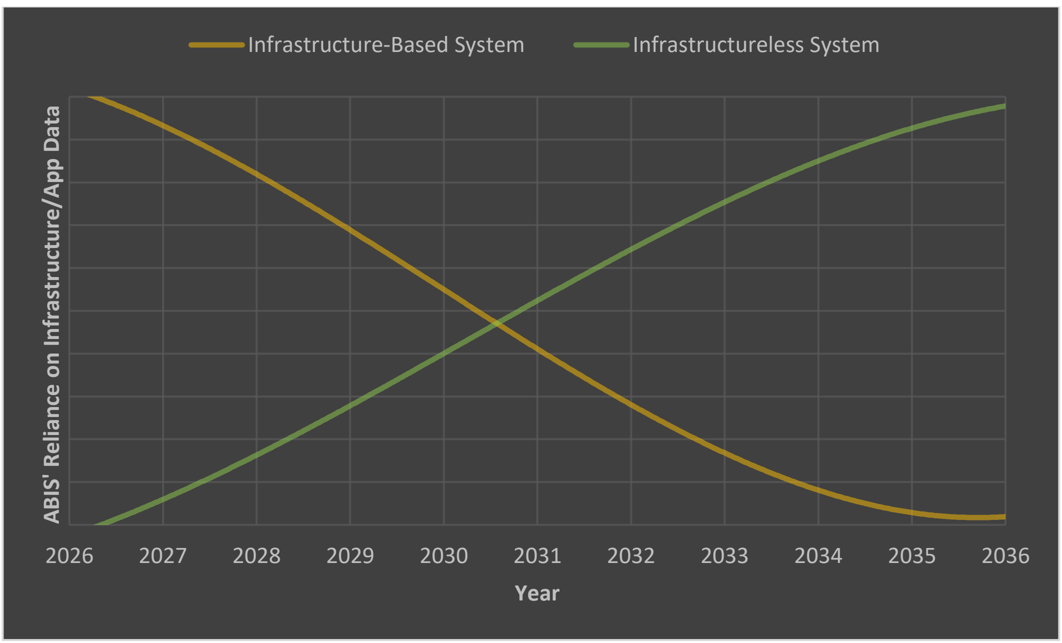


Figure 4. Transition from Infrastructure-Based to Infrastructureless System

Wait times will be calculated using Artificial Intelligence (AI) and Machine Learning (ML) that will develop and continuously improve its delay algorithms based on data from all the above-listed sources along with the archive of historic wait times in the CGBDW, which includes seventeen years of five-minute increment wait time data. The archived data will be leveraged to enable predictive analytics based on historical trends for different dates, times, and situations.

The proposed technologies are shown in ***Figure 5***, with proposed deployment locations shown in ***Figure 6***.

Figure 7 shows the concept's proposed system architecture and data flow diagram.

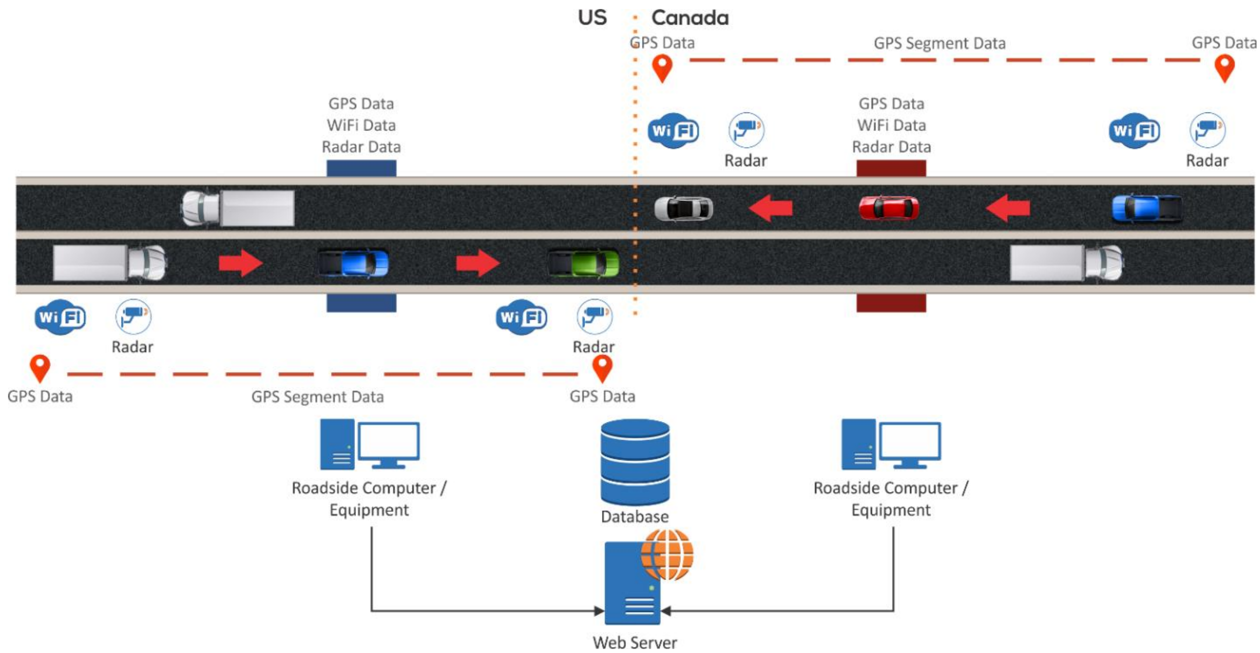


Figure 5. Proposed Technologies Overview

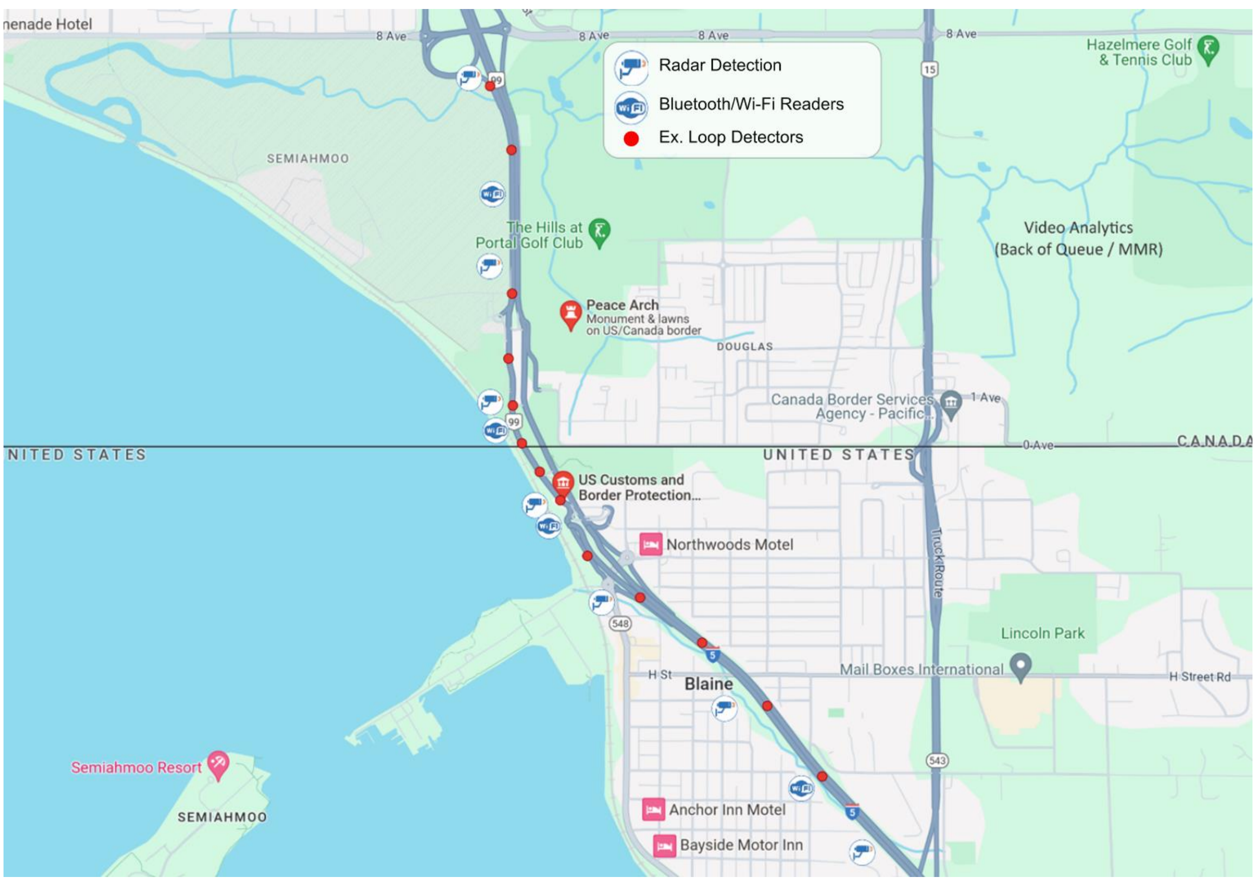


Figure 6. Proposed Roadside BWT Measurement Technologies

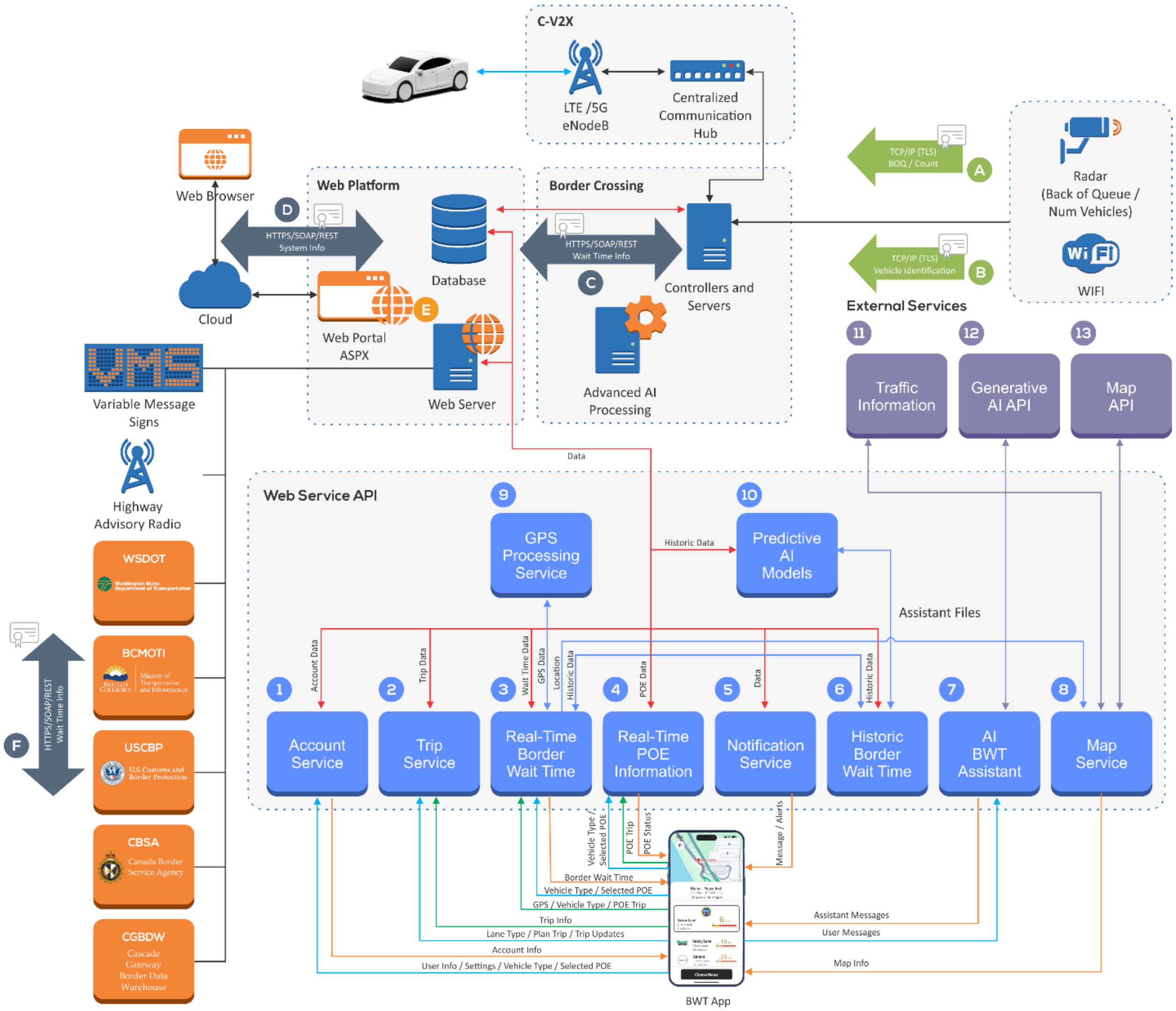


Figure 7. Proposed System Architecture and Data Flows

The proposed system architecture includes a central server and communications hub that processes data from the radar detection system, Bluetooth/Wi-Fi readers, and the mobile app. C-V2X communications technology would connect to this hub as another data input/output channel. The hub would collect data from C-V2X-equipped vehicles, process it alongside data from existing sources, and then send relevant information back to the vehicles. Middleware software and Application Programming Interfaces (API) would facilitate communication between the C-V2X platform and the existing systems. These would standardize data formats, manage communication protocols, and ensure compatibility. APIs would allow C-V2X data to be accessed and used by existing systems without needing to overhaul the entire infrastructure. The C-V2X technology relies on Vehicle-To-Infrastructure (V2I) communication, where vehicles interact with RoadSide Units (RSU) or other infrastructure components. These RSUs would need to be installed at strategic locations near the border, such as entry points, lanes, and checkpoints. RSUs would be connected to the central system to send and receive data. These units would communicate with C-V2X-enabled vehicles in real-time, providing updates on wait times, lane assignments, and any changes in conditions.

Highlighted in ***Figure 8*** below, as part of the High-Level Design task that the project team is currently completing and based on the ConOps architecture, information flows, operational scenarios, and stakeholder feedback, a video demonstrating a mock-up of the conceptual design of the mobile app that summarizes its capabilities and the user experience was developed. This video can be viewed at: https://vimeo.com/999161315/fc244206c1?share=copy.

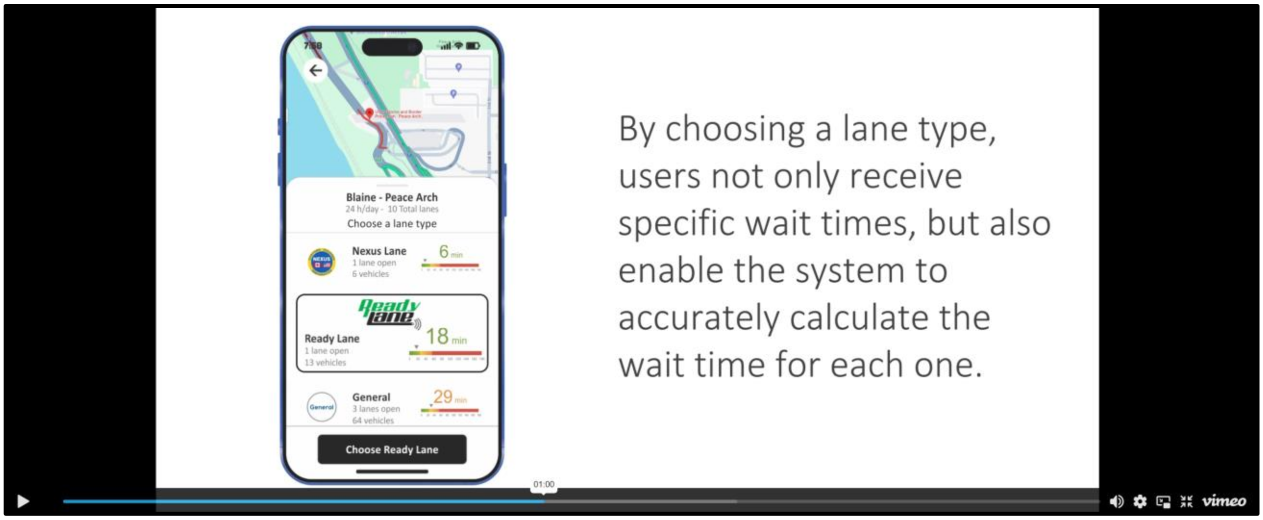


Figure 8. Screenshot from ABIS BWT Mobile Application Demonstration Video

In summary, the system combines the existing VDS/data station infrastructure and enhances accuracy by replacing (or supplementing) existing loop detectors with radar detection, deploys new radar detection to capture back-of-queues during peak periods, develops a new dedicated Cascade Gateway BWT app based on GPS II technology, deploys Bluetooth/Wi-Fi readers to re-identify vehicles and supplement the data gathered from the BWT app, and utilizes AI and advanced data analytics to optimize BWT measurement and management. ***Table 3*** below provides a summary of the technologies proposed, while ***Table 4*** provides a summary of the concept's advantages and disadvantages.

Table 3. Summary of Proposed Technologies

Technology	Purpose
Radar Detection	Determine the number of vehicles (counts) and back of the queue. Radar can be more accurate than loop detectors in stop-and-go traffic, and can provide additional traffic data (e.g., vehicle classifications). As a non-intrusive form of detection, maintenance of radar detection is expected to be easier when compared to loop detectors.
Loop Detectors	Determine the number of vehicles (counts) and back of the queue. Note that loop detectors would only be needed if the agencies desire for the existing loop detectors to remain and their data outputs are shown to be reliable. They would serve as a backup/supplemental data source, but would not be needed, as the maintenance of loop detectors near the border has been a pain point for the agencies.
Bluetooth/Wi-Fi Readers	Vehicle identification and re-identification and *actual* wait times for all vehicles. However, Bluetooth/Wi-Fi readers cannot reliably differentiate between NEXUS, Ready, and standard lane groups.

Technology	Purpose
Cascade Gateway BWT C-V2X Mobile App	New smartphone application that provides traveler information, trip planning tools, and map-based navigation assistance to measure BWT by lane type. This also serves as a C-V2X application that enables future infrastructureless operation once GPS Block III is operational; GPS Block III involves significant improvements to GPS reliability and accuracy through the deployment of ten new satellites, expected by the end of 2026. Provides *actual* wait times for all vehicles.
AI & ML	Analysis of existing data, dashboards, reports, predictive BWT capability, and data archival. Provides What-If scenario analyses and capabilities for predicting traffic surges based on analytics.
Mapping Interface	Map-based interface; real-time data depicted on map.
Stakeholder-Specific Dashboards and Outputs	Dashboards tailored to the needs of each agency, providing operational insights into BWT and traffic operations leading up to and at the POEs.
Cascade Gateway Border Data Warehouse (CGBDW)	The existing system that has archived BWT data since 2007 will continue to operate. The ABIS will be compatible with the CGBDW, and future upgrades may be implemented to expand its capabilities.

Table 4. Advantages and Disadvantages of Technology Concept

Advantages	Disadvantages
Enhanced accuracy of wait time measurements using radar detection, additional detection, and AI algorithms.	Reliance on physical detection like radar or loop detectors.
Leverages the use of existing VDS/data station infrastructure, if desired.	Need for additional VDS/data stations to cover extended back-of-queues during high demand.
Predictive analytics for better resource allocation and improved efficiency.	Users need to download the app, which may be a barrier to entry. Approximately 25% penetration rate is needed for accurate measurements.
Improved traveler experience through real-time data and predictive analytics.	Users need to provide consent for tracking within geofenced port of entry approaches.
Scalable and flexible system that is adaptable to various traffic patterns and border POEs.	Manual user input is needed to select which lane they are traveling in.
The use of the Cascade Gateway BWT app serves as the backup and a validation method to ensure increased accuracy and lower overall costs.	App will require maintenance and marketing.

Advantages	Disadvantages
The Cascade Gateway BWT app can provide additional traveler information, such as dynamic routing to alternative POEs based on real-time demand, communicating lane status and changes, etc.	It has been postulated that perhaps by the 2030's, the private sector will begin to provide options that may supersede the Cascade Gateway BWT app. While public agencies will benefit from this, they will also need an independent data set in order to provide real-time data and archived data that is free to the public, similar to how the CGBDW currently operates.
Hybrid solution that utilizes more than one data source for measuring wait times, making it easier for cross verification and validation.	A hybrid solution typically costs more than a singular solution, both in terms or additional sensors and software development.

1.4 Summary of Stage 1 Activities

To date, the project team has completed over 80% of the Stage 1 activities, which are summarized in ***Figure 9*** below.

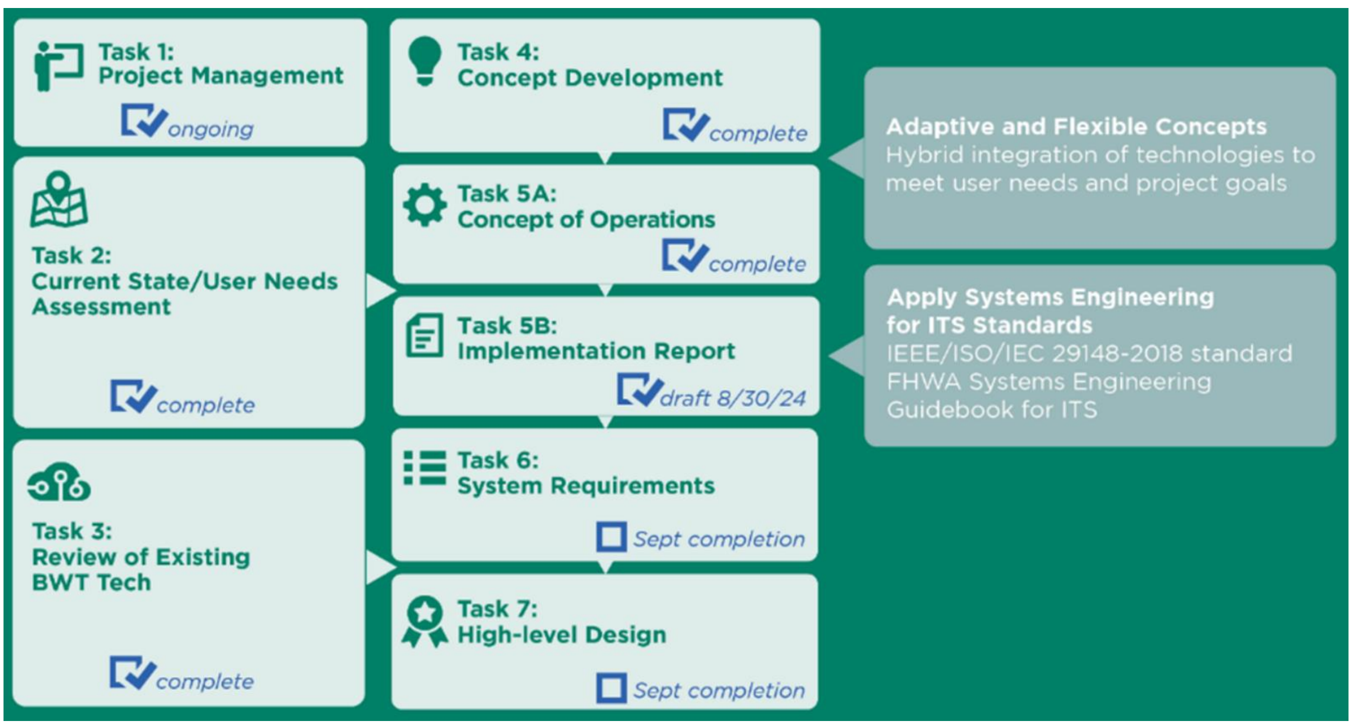


Figure 9. Stage 1 Activities

- *Task 1: Project Management* includes overall management of the project, including bi-weekly check-in meetings, managing the scope, schedule, and budget of the project, preparing for and presenting on the project at conferences, and completing documentation needed for the Stage 1 SMART grants reporting requirements (e.g., Evaluation Plan, Data Management Plan, progress reports, etc.).
- *Task 2: Current State Assessment Report* documents the existing northbound (WSDOT-owned) and southbound (BCMOTI-owned) ATIS, including the existing designs, equipment, functionality, and accuracy. Additionally, it includes a comprehensive list of existing challenges and identifies areas that

need to be addressed in the new ABIS. This document is publicly accessible at https://theimtc.com/wp-content/uploads/1-Current-State-Existing-Technology-Report.pdf.

- *Task 3: Existing Measurement Technology Review Report* provides a review of the state-of-the-practice regarding Border Wait Time (BWT) measurement technologies, including case studies from other U.S.-Canada and U.S.-Mexico border crossings. This document is publicly accessible at https://theimtc.com/wp-content/uploads/1-Current-State-Existing-Technology-Report.pdf.
- *Task 4: Concept Exploration and Recommendations Report* provides additional detail on BWT measurement technologies and how they can be applied to this project. Additionally, specific vendor technologies were investigated through a series of Vendor Showcases in which technology providers were invited to present on their product offerings and answer questions specifically as they related to BWT applications like the Cascade Gateway ABIS. Building on this additional knowledge, three potential technology concepts are presented, along with each concept's advantages and disadvantages. The three concepts and the technologies involved were reviewed with WSDOT, BCMOTI, and WCOG during an interactive workshop, during which a preferred technology concept was selected – Concept I – involving new radar detection (or other non-intrusive form of detection capable of measure the volume, speed, and occupancy of vehicles in a stop-and-go border crossing environment), new Bluetooth/Wi-Fi readers, and a new smartphone mobile application based on GPS II technology. This document is publicly accessible at https://theimtc.com/wp-content/uploads/2-Concept-Exploration-Recommendations-Report.pdf.
- *Task 5a: Concept of Operations* (ConOps), included as ***Appendix A***, serves as the foundational guide for communicating user needs and system requirements to support the detailed design and implementation for Stage 2. It presents a high-level description of the proposed system and describes, from the perspective of the system's users, how the system is intended to operate and be maintained using day-in-the-life operational scenarios.
- *Task 5b: Draft Implementation Report*, submitted, as required, one year following the execution of the Stage 1 grant, that describes the implementation plans as well as supporting the Stage 2 SMART grants funding application (submitted August 14, 2024) for implementing the ABIS project as soon as possible in order to meet cross-border traffic management needs associated with the 2026 FIFA World Cup in Seattle and Vancouver in June 2026.

The remaining tasks for this Stage 1 project are currently underway, and include:

- *Task 6: System Requirements* (September 2024), which builds upon the ConOps to develop a formal System Requirements document. As stated in the FHWA Systems Engineering Guidebook for ITS, system requirements define what the system is to do, through statements defining system capabilities, conditions, and constraints.
- *Task 7: High-Level Design* (October 2024), which builds upon the ConOps and the System Requirements by defining exactly how the system is to be built. This design takes the previously defined requirements (i.e., "what the system will do") and translates them into hardware and software components.
- Additionally, the project team will be finalizing the *Draft Implementation Report* based on review comments provided by USDOT and SMART Grants Program staff, as well as based on additional details developed in the *System Requirements* and *High-Level Design*. The *Final Implementation Report* will be submitted by the end of the period of performance of the Stage 1 project.

1.5 Project Outreach to Date

This project emerged as a critical need identified by IMTC stakeholders, all of whom have been part of the initial discussions and dissemination of information regarding the effort and are updated on progress at monthly IMTC Steering Committee meetings. Key project stakeholders – USCBP, CBSA, WSDOT, BCMOTI, and WCOG have also done their own outreach with staff, partner organizations, and members of the public regarding the project.

Specific outreach efforts are listed below:

- **Stakeholder Workshops:** As part of the systems engineering process, project stakeholders including WCOG, WSDOT, BCMOTI, USCBP, CBSA, Transport Canada, U.S. General Services Administration (GSA), and members of the IMTC (see https://theimtc.com/about/) participated in a series of workshops.. This project is also highlighted on the IMTC's website at https://theimtc.com/project/2023-cascade-gateway-advanced-border-information-system-planning-phase/
- **Conference Presentations:** The project team recently presented on the project at the ITS Canada conference in Vancouver, B.C. on June 19-21, 2024, and the ITS California conference in San Francisco on August 26-28, 2024. A presentation on the project will also be made as part of the FHWA/Transport Canada U.S. - Canada Transportation Border Working Group (TBWG) meeting September 10-12 in Whitehorse, Yukon, and at the ITS Washington conference in Tacoma, WA on November 6-7, 2024.
- **Coordination with USCBP Headquarters.** While the Stage 1 and Stage 2 projects focus on the Cascade Gateway POEs between B.C. and WA, the project team (as part of separate projects) has begun engaging with USCBP Headquarters at the national level. This includes discussions with the Executive Director for Planning, Program Analysis, and Evaluation and the Chief Technology Officer, who have shown tremendous interest in the potential for this project to be expanded at-scale in the future to all major ports of entry along U.S. - Canada and U.S. - Mexico borders.

1.6 Deviations from Original Proposal

There are no major deviations or changes from the original proposal, with the exception that the anti-idling dynamic traffic metering system will not be carried forward to Stage 2.

2. PROOF-OF-CONCEPT OR PROTOTYPE EVALUATION FINDINGS

The Stage 1 project involved the systems engineering and design for the ABIS, which will be implemented in Stage 2. As such, this project did not deploy physical proof-of-concepts or prototype deployments. However, similar field components and systems have been implemented and evaluated on the US-Mexico border with comparable traffic and lane configuration characteristics at several land POEs. Texas A&M university's Transportation Institute (TTI) has designed, implemented and performed evaluations of both legacy and newer border technology systems. This is by design, as a legacy border wait time system is still in operation at a portion of these crossings (i.e., the overall concept is proven), and so the focus of Stage 1 was on studying which technologies would support a more capable, future-proofed system. For this, the project team undertook a rigorous systems engineering process, during which stakeholders were engaged extensively. Based on stakeholder user needs that emerged from the process, a comprehensive assessment of how existing, available technologies could be combined with a new infrastructureless solution was conducted.

2.1 Evaluation Findings

To guide the Stage 1 project, several evaluation questions were developed at the onset of the project. ***Table 5*** below presents a summary of these evaluation questions, the tasks that were completed to answer these questions, and the project team's findings.

Table 5. Summary of Findings from Stage 1

Evaluation Question	Stage 1 Planning-Level Assessment Process	Assessment Work Elements	Findings from Stage 1
What technology(ies) can accurately estimate wait times for the different modes and lane types in an area with mixed wireless data coverage?	Evaluate existing technologies for cross-border wait time measurements (including but not limited to Bluetooth, Wi-Fi, or microwave detection, as well as the possibility of purchasing subscriptions to existing datasets) by efficacy in meeting project goals, functionality in a binational border environment, and cost	Current State & User Needs Assessment Review of Existing BWT Measurement Technologies Concept Development	The Stage 1 assessment of BWT measurement technologies showed that radar detection, Bluetooth/Wi-Fi readers, mobile apps, LiDAR, and license plate recognition cameras have all been successfully deployed in instances at other land POEs. No one technology can estimate wait time by mode and lane type single-handedly in this context, so the system that was developed incorporates multiple technologies to meet stakeholder needs. In addition to the hybrid solution, the project identified a need to improve communications at rural POEs to maintain a consistent system connection.
What are the costs of these technologies? What are the maintenance costs?	Review of existing BWT deployments and their costs and maintenance needs; develop and refine implementation and O&M cost estimates through the systems engineering process steps	Concept Development Concept of Operations High-Level Design Implementation Report	With the preferred technology concept select, costs associated with implementation, operations, and maintenance have been evaluated and are included as part of this Implementation Report – see ***Section 3*** and ***Appendix B: Benefit-Cost Assessment*** for details.
Has a system like this been deployed in a heavily queued traffic area like a border crossing?	Evaluate existing technologies for functionality in border environments with specific challenges that include: heavily-queued conditions, sporadic Wi-Fi coverage and competing U.S. / Canadian cell phone coverage, potential power and fiber access issues,	Review of Existing BWT Measurement Technologies Concept Development Concept of Operations	Yes, the *Task 3: Existing Measurement Technology Review Report* includes several case studies of BWT solutions that have been deployed along the US–Canada and US–Mexico borders. These case studies document the successes and shortcomings of these systems, providing the team with insights on what technologies work best in different scenarios. This analysis also led to the inclusion of improved communications technologies like fiber optic communications.

Evaluation Question	Stage 1 Planning-Level Assessment Process	Assessment Work Elements	Findings from Stage 1
	security concerns from federal inspection agencies, ports-of-entry under construction, and infrastructure with dynamically-changing modes.		
How will the system integrate with existing traveler information systems and data archives?	Determine whether the proposed technology will integrate with existing state and provincial ATIS systems, and the Cascade Gateway Border Data Warehouse with minimal impact or changes needed by partner agencies	Concept of Operations System Requirements High-Level Design Implementation Report	***Appendix A: Concept of Operations*** discusses how the proposed technologies will introduce new sources of more reliable and accurate wait time information that can be integrated with the existing BCMOTI, WSDOT, and WCOG data systems. It will also enable border agencies to optimize POE operations and enhance the border crossing experience for travelers. It is envisioned that one overall system will be implemented that encompasses the northbound and southbound approaches (though each country will install its own physical equipment). The ABIS will need to integrate with and be fully compatible with the existing Cascade Gateway Border Data Warehouse. Additionally, it will need to interface with existing traveler information systems like existing DMS/VMS, HAR, and websites.

2.2 Goals Assessment

Stage 1 Goals Assessment

Given that this Stage 1 project did not involve proof-of-concept or prototype deployments, the goals of this Stage 1 project were to answer the evaluation questions discussed previously in ***Table 5***, and to complete the following scope of work elements:

- ***Table 1. Stage 1 Design Project Outcomes*** outlines the outcomes and results from the Stage 1 systems engineering activities for each of the nine major project objectives that were developed by the stakeholders and documented in the Stage 1 grant application.
- ***Table 5. Summary of Findings from Stage 1*** provides the results of the Stage 1 evaluation, consistent with the *Evaluation Plan* previously submitted to USDOT for this project.
- ***Table 6. Summary of Goals and Objectives from Stage 1*** below summarizes the results of the scope of work elements that have been completed to date as part of Stage 1, consistent with what WCOG proposed in the Stage 1 grant application.

Table 6. Summary of Goals and Objectives from Stage 1

Stage 1 Scope of Work Elements	Results from Stage 1
Evaluate advanced technologies for cross-border wait time measurements (including but not limited to Bluetooth, Wi-Fi, or microwave detection, as well as the possibility of purchasing subscriptions to existing datasets).	See ***Table 7*** and ***Table 8***, which summarize the evaluations conducted for each technology and identify which systems will be moving forward in the *Concept of Operations*, and further refined as part of the *High-Level Design*, *System Requirements*, and the *Final Implementation Report*.
Evaluate partnership agreements needed to complete the project (e.g., installing equipment in U.S. and Canada, on property owned by federal agencies, etc.).	Partnerships and agreements between the relevant parties have been in place for decades through the IMTC and the existing ATIS. Initial discussions have taken place to identify roles and responsibilities for each agency (described in the ConOps) and a list of needed agreements will be finalized in the High-Level Design. Since the Stage 2 SMART Grants Program will only pay for hardware installed in the United States, discussions are being held with BCMOTI and Transport Canada to coordinate funding efforts and identify means for procuring the Canadian components separately. WSDOT will lead the design and implementation of the system, but BCMOTI will be responsible for the installation of any field equipment that is needed outside of the US.
Work with archive maintenance team to develop options for archiving the data.	A core requirement of the ABIS is that it will be fully integrated and compatible with the existing Cascade Gateway Border Data Warehouse.
Confirm the proposed solution will integrate with existing traveler information and inspection agency systems.	As part of the systems engineering process, extensive coordination with the transportation agencies (WSDOT and BCMOTI) and inspection agencies (USCBP and CBSA). Through this, it was determined that the ABIS will need to be integrated with existing traveler information systems that include existing DMS/VMS, HAR, and traveler information websites. For the inspection

Stage 1 Scope of Work Elements	Results from Stage 1
	agencies, no integration will be needed with existing systems; a custom ABIS dashboard will be developed for use by inspection agencies, and the system will need to infer changes in lane type/status.
Complete an installation plan that includes an assessment of cost savings and performance improvements.	This *Implementation Report* includes details on the implementation approach, cost estimates for implementation, operations, and maintenance, and a benefit-cost assessment

Based upon the results of the five stakeholder workshops that were conducted during Stage 1, the following two program objectives have been developed for Stage 2 implementation, both of which are time-critical in terms of the need to deploy the ABIS by mid-2026:

- Provide real-time traffic management information and predictive analytics to WSDOT, BCMOTI, USCBP, and CBSA to support surges in cross-border traffic during the 13 FIFA World Cup soccer games scheduled for Seattle and Vancouver in June 2026 by providing traveler information to all vehicles/drivers using these crossings to access the events.
- Provide real-time information to WSDOT, BCMOTI, USCBP, and CBSA to support traffic mitigation, diversion, and maximizing border throughput capacity between 2026 and 2030 when three of the four primary border crossings in Western Washington will be under construction.

The original set of objectives, plus these two newly defined objectives, will continue to serve as guidance for project implementation. Given that Stage 2 will involve deployment of the actual system, three specific performance goals have been developed, which are presented in ***Section 3.4*** and provide the metrics of project performance for Stage 2.

Technology Assessment

As part of the systems engineering process, multiple technologies were assessed through a five-step process, which resulted in the development of the ABIS design concept for Stage 2 (details of each review have been described in Section 1):

1) An Existing Border Wait Time Measurement Technology Review was completed (*Task 3*) and documented.
2) A comprehensive Concept Exploration and Recommendations review was conducted (*Task 4*) and documented.
3) Based on the results of the above two steps, the project team organized vendor showcases and invited selected vendors representing technologies identified by the project team as potentially providing a potential solution option or element to present their technologies and avail themselves to questions from key stakeholders.
4) From the presentations, technologies deemed sufficiently mature and applicable to a border crossing environment were carried forward for further evaluation and consideration. ***Table 7*** provides the evaluation matrix from this activity.
5) Building on the completion of the above steps, three potential technology concepts were developed, along with each concept's advantages and disadvantages. See ***Section 1.3***, ***Figure 7***, and ***Appendix A: Concept of Operations*** for the complete description of this finalized system concept for Stage 2.

Table 7. Vendor Showcase Summary

Vendor/Technology Information			Metrics/Evaluation Criteria					
Vendor	**Technology**	**Technology Maturity/ Applicability**	**Back of Queue**	**Number of Vehicles in Queue**	**Vehicle Re-Identification**	**Speed**	**Accuracy**	**Cost (Including O&M)**
Wavetronix	Radar	Pass. Runner up to Houston Radar	✓	✓		✓	High	Low-Med
Houston Radar	Radar	Pass. Preferred technology.	✓	✓		✓	High	Low-Med
Miovision	Video Analytics, Bluetooth/Wi-Fi	Fail. Technology is not mature enough for BWT applications.						
Currux Vision	Video Analytics, Vehicle Reidentification	Fail. Technology is not mature enough for BWT applications.						
Adaptive Recognition	Video Analytics, Bluetooth/Wi-Fi	Fail. Technology is not mature enough for BWT applications, and vendor is a hardware-only provider.						
CLR Analytics	Loop Signatures, Pavement Sensors	Fail. Technology is not mature enough for BWT applications.						
TTI	LiDAR	Pass	✓	✓		✓	High	Low-Med
Transcore	RFID (Commercial Vehicles)	Pass. However, this technology is duplicative of other technologies and does not count all trucks			✓			High
Tattlile	Machine Vision, ALPR	Fail. Technology is not mature enough for BWT applications.						

Table 8. Technology Concept Evaluation Summary

Concept/ Criteria	Accuracy	Initial Cost	User Exp-erience	O&M Costs	Flex-ibility	Future Proofing	Security	Ease of Implem-entation	Inno-vation	Scal-ability	Total Score
Weight	*30*	*10*	*10*	*10*	*10*	*5*	*5*	*10*	*5*	*5*	***100***
Concept I – Loop Detectors, Vehicle Re-Identification, and AI	24	5	5	3	1	1	3	5	1	2	**50**
Concept II – Mobile Application (GPS II), Bluetooth/Wi-Fi, Radar, and AI	28	7	8	6	10	5	5	7	5	5	**86**
Concept III – Mobile Application (GPS III) and AI	22	5	8	7	8	5	5	7	4	5	**76**

3. ANTICIPATED COSTS AND BENEFITS OF AT-SCALE IMPLEMENTATION

This section focuses on the expected costs and benefits of project implementation at the four Cascade Gateway POEs. However, the ABIS is intended to be highly scalable; its infrastructureless concept could be adapted to any POE along the northern and southern U.S. borders.

3.1 Impacts

The anticipated impacts of the at-scale implementation for each of the SMART Grants Program's key goal areas are described in the sections below.

Safety and Reliability

The hybrid technology approach to BWT data collection and analysis using AI algorithms that leverage real-time and historical data ensures that BWT predictions are consistently accurate. A noticeable benefit will be the reliability of the wait times produced. Trucks and passenger vehicles crossing will be more confident that the delays times reported are accurate. Accurate information will also help spread demand across available crossings, maximizing the available infrastructure.

Minimizing system downtime is a priority, and several aspects of this solution are specifically designed to improve upon prior reliability issues: the system uses multiple sources of data to determine delay, so the built-in redundancies allow for one technical component to be impacted/under repair while minimizing impacts on accuracy; dashboards designed for inspection agencies at the border will provide a real-time interface between inspection and transportation agencies that allow for immediate reporting of system issues; and the inclusion of improved communications systems at the Lynden/Aldergrove POE should minimize communication outages that have historically impacted this rural area.

Additionally, the ABIS is expected to provide secondary benefits of safety. The system will provide travelers with more informed route planning and decision-making capabilities, helping to avoid impulsive route changes that may result in side-swipe collisions. Additionally, where congestion is detected near a POE, the BWT app's navigation interface can provide notifications to the driver of slow traffic ahead, reducing the risk of rear-end collisions.

Resiliency

The decentralized nature of the proposed hybrid BWT system eliminates single points of failure. Even if one component experiences an outage, the other components can continue to function and provide reliable data. For example, if a radar detector fails, the Bluetooth/Wi-Fi detectors and the mobile app will remain operational to provide relatively accurate data.

Additionally, the Stage 2 system will incorporate more robust cybersecurity measures that are compliant with NIST-500, FedRAMP, and other state and local standards. By prioritizing data security and implementing best practices, the project will contribute to a more secure and resilient transportation infrastructure.

Lastly, the project generates valuable data on traffic patterns, wait times, and other relevant metrics that lead to data-driven decision making. This data can be used to inform infrastructure improvements, policy decisions, and emergency response plans, enhancing the overall resilience of the transportation system to various disruptions and challenges.

Equity and Access

Both users of the mobile app, as well as those without smartphones, will benefit from the more accurate and reliable BWT information through roadside message signs (e.g., Variable Message Signs [VMS] and Dynamic Message Signs [DMS]), Highway Advisory Radio (HAR) broadcasts, traveler information website postings, etc. Additionally, three of the four POEs are located within disadvantaged census tracts per the USDOT Equitable Transportation Community (ETC) Explorer – see ***Section 1.2*** for details.

By providing accurate and timely wait time information, the project will improve access to essential services and employment opportunities for underserved and disadvantaged populations who rely on cross-border travel. There are many underserved communities along the border and the project hopes to promote a more equitable distribution of economic and social benefits.

Climate

The system is designed to better distribute demand and reduce delays, resulting in less congestion, less greenhouse gas emissions, and fewer environmental impacts on the already disadvantaged border communities. This aligns with broader climate goals by minimizing unnecessary vehicle emissions.

Partnerships

This is a binational project with five key agency partners – WSDOT, BCMOTI, USCBP, CBSA, and the region's metropolitan planning organization, the WCOG. All agencies are coordinating efforts through a binational project advisory team. These agencies, along with over a dozen others, participate in the International Mobility & Trade Corridor Program (IMTC), a binational planning coalition of government, business interests, and non-governmental entities that supports improvements to safety, mobility, and security for the Cascade Gateway border crossings. IMTC participants have coordinated planning, identified shared system needs, and optimized investments to fund and implement improvements to operations and infrastructure through collaboration, innovation, and partnership for 27 years. This partnership was in place before the implementation of the original ATIS and will continue into and beyond Stage 2. Additional information on the IMTC can be found at https://theimtc.com/.

IMTC participants typically match U.S. and Canadian funding sources to better leverage federal investments to accomplish projects of mutual benefit in the Cascade Gateway. As a bi-directional need being funded on both sides of the border, this project highlights what dedicated stakeholder engagement, a shared vision, and an innovative ITS solution can accomplish.

It will also benefit from longstanding partnerships between B.C. and WA State in coordinating the system that intends to result in a seamless experience for the end users, and a replicable pilot project demonstrating how projects can be designed to span across jurisdictional boundaries.

Integration

The integration of different types of sensors, historic data archives, and new software is the most unique and critical component of the ABIS. None of the specific technologies used in the project are new in themselves, but this approach of combining data from varied, proven data sources is the primary component being piloted in Stage 2.

Workforce Development

This project will significantly involve WSDOT maintenance staff, who will install, operate, and maintain the ABIS and are represented by the Washington Federation of State Employees (WFSE) union that is part of the American Federation of Labor and Congress of Industrial Organizations. This deployment will support the creation of several well-paying union jobs, which will be of a technical nature involving the operations and maintenance of ITS. WSDOT is also committed to deploying and operating the ABIS such that there are no negative effects on union jobs through the deployment of AI. Stage 2 implementation also supports private sector engineering staff, as well as staff from WSDOT's planning and engineering offices.

3.2 Implementation Cost Estimate

The total estimated cost of the project, including design, implementation, and operations and maintenance (for two years) of the radar detection system, Bluetooth/Wi-Fi reader system, the BWT app, and the back-end systems is $8,371,000. Note that this includes costs associated with the procurement and installation of equipment on the Canadian side as well. Only funds for the U.S. deployment ($6,599,400) are being pursued through the Stage 2 SMART grants application; funding is concurrently being sought on the Canadian side with Canadian partners including BCMOTI and Transport Canada. ***Figure 10*** provides a summary of the implementation cost estimate, divided into six overall tasks.

SF-424A & SF-424C Budget Categories										
Task	Personnel	Travel	Contract.	Construction						Total
				A&E	Other A&E	Inspect.	Construct.	Equipment	Misc.	
Project Management	$ 550,000	$ 18,300								***$ 568,300***
Software Development		$ 4,700	$ 2,015,000							***$ 2,019,700***
ITS PS&E	$ 38,000	$ 1,700		$ 647,000	$ 50,000					***$ 736,700***
Construction/Installation	$ 72,000	$ 1,700				$ 54,000	$ 863,000	$ 551,000	$ 20,000	***$ 1,561,700***
System Integration		$ 4,700	$ 668,000							***$ 672,700***
System Op., Eval. & Refinements		$ 6,300	$ 1,034,000							***$ 1,040,300***
Total	***$ 660,000***	***$ 37,400***	***$ 3,717,000***	*$ 647,000*	*$ 50,000*	*$ 54,000*	*$ 863,000*	*$ 551,000*	*$ 20,000*	**$ 6,599,400**
				$ 2,185,000						

Figure 10. Implementation Cost Estimate

<u>Task 1: Project Management</u>

- **Advertise for Consultants**. One of the first tasks will be developing a Request for Qualifications for consultant services to assist with the management, design, development, and facilitation of the Stage 2 project.
- **Grant Requirements**. This includes completing the Assessment Plan, Data Management Plan, Annual Implementation Report, and Quarterly Progress Reports. This also includes travel for three trips to Washington, DC/Cambridge, MA for four staff members, as defined in the NOFO.

- **Project Management**. This includes overall project management and administration tasks, including the development of a Project Management Plan, which will be developed at the onset of the project, consistent with the Project Management Institute's Project Management Body of Knowledge guidance.

<u>Task 2: Software Development</u>

- **Mobile App Development**. This includes developing the software architecture, specifications, user interface, and iOS/Android apps, including associated testing and documentation.
- **Cloud Infrastructure**. This includes developing and setting up the cloud infrastructure that is needed to support the ABIS.
- **AI/ML Development**. This includes developing the AI and ML software models that will enable the predictive analytics capabilities of the ABIS.
- **Business Intelligence/Dashboards**. This includes developing custom dashboards for the agencies, as well as providing a user-friendly interface for accessing the predictive analytics.
- **Integrations & Interfaces**. This includes developing integrations and interfaces with existing and future systems like the CGBDW, DMS/VMS, HAR, and travel information websites.

<u>Task 3: ITS Plans, Specifications, and Estimates (PS&E)</u>

- **Data Collection**. This is anticipated to include collection of geotechnical data for designing pole foundations (should new poles be needed) and aerial imagery (given the condensed project schedule due to the need to meet the 2026 FIFA World Cup, the use of aerial imagery is proposed for the development of the ITS PS&E over full topographic survey information), if needed.
- **PS&E Development**. This includes the design of the physical infrastructure (e.g., radar detection and Bluetooth/Wi-Fi readers), along with any supporting infrastructure (e.g., poles, foundations, cabinets, power, and communications systems) that may be needed. Federal funding documentation, including NEPA environmental documentation/checklists, proprietary items certification, and public interest findings will also be prepared during this time. As a state agency regularly involved with construction projects, WSDOT is very familiar with these requirements.
- **Procurement/Construction Support**. This includes consultant support during the procurement, as well as support during construction of the physical infrastructure.

<u>Task 4: Construction/Installation</u>

- **Advertise for Construction**. This involves advertising the construction documents developed as part of the ITS PS&E for contractors to furnish and install the equipment.
- **Equipment Procurement**. During this time, equipment will be procured by the contractor. Given that the physical equipment will be commercial off-the-shelf products, procurement lead times are not expected to be too lengthy.
- **Equipment Installation**. During this time, the contractor will be constructing the physical improvements and installing the equipment. Equipment is generally expected to use existing

infrastructure (e.g., cabinets, power, communications, poles, etc.) and will have minimal impacts on moving traffic.

Task 5: System Integration

- **System Setup and Configuration**. Once the equipment and the ABIS software systems have been installed and tested, the system can be configured to ensure that the roadside equipment, the mobile app, and the back-end systems are functioning cohesively.
- **System Tuning and Testing**. This task will involve an operational test (e.g., 30-days), during which the system will be tested for bugs and defects. The system's parameters will be tuned and tweaked to ensure the data is timely, accurate, and meets expectations.

Task 6: System Operation, Evaluation, and Refinement

- **System Operation**. The project aims to be operational in advance of the first match of the FIFA World Cup in June 2026, meaning it will have been tested, configured, and tuned to ensure proper operation. This task includes staff time, warranty, support, and hosting fees needed to operate the system for the duration of the project. During the FIFA World Cup, the system's performance will be monitored and evaluated – see below.
- **System Evaluation**. Given the tight timeframe associated with this project, it is anticipated that the system will undergo a series of evaluations to determine if the system fully meets the needs of its stakeholders. After the FIFA World Cup concludes, two separate stages of system evaluation will be conducted to identify any deficiencies, necessary improvements, and/or additional features desired.
- **System Refinement**. Based on the System Evaluation, the system may undergo additional refinement. After the first stage of evaluations, refinements will be implemented. The system will then undergo a second stage of evaluations, providing a final opportunity for additional refinements to the system to be made. After this final stage of refinements, a final project evaluation will be conducted to validate that the project meets the needs, requirements, and objectives of the project.

3.3 Benefit-Cost Assessment

The Texas A&M University's Transportation Institute (TTI) has independently conducted a comprehensive Benefit-Cost Analysis (BCA) for this project. The full BCA report is provided in ***Appendix B: Benefit-Cost Assessment***. The following discussion summarizes the BCA.

This BCA compares the estimated capital costs of the ABIS to the anticipated benefits over an 11-year period, with implementation in the first year, benefits beginning in the second year, and an assumed 10-year life cycle. The BCA assumes that the ABIS is also deployed on the Canadian side of the POEs by BCMOTI in the same timeframe as the Stage 2 SMART project. Net Present Value (NPV) was calculated by subtracting the total cost from the total benefit at the federal guidance recommended discount rate of 3.1%.

The primary benefit stemming from the Stage 2 project will be improved accuracy and reliability of border wait time information, with secondary benefits related to decreased congestion and wait times by distributing traffic to less-utilized POEs, increased safety by providing drivers with advance notification of upcoming congestion, and workforce development through additional on-the-job technical training.

Quantified benefits include:

- Crossing Delay Benefit: Value of time savings and fuel cost savings from reduced crossing delays.
- Environmental Benefit: Reduced emissions costs due to decreased crossing delays.
- Trip Planning Reliability Benefit: Value of time savings from increased trip planning reliability.
- Residual Value: Remaining useful life of project components.

Quantified costs include:

- Operations and Maintenance (O&M) Costs

The BCA results are summarized in *Table 9*.

Table 9. Benefit-Cost Assessment Summary

Category	**Undiscounted**	**Present Value at 3.1%**
Construction Costs	$8,371,000	$7,638,382
Evaluated Benefits/Costs		
Crossing Delay Benefit	*$12,421,251*	*$9,592,670*
Environmental Benefit	*$615,213*	*$473,371*
Planning Reliability Benefit	*$26,545,672*	*$20,500,664*
Residual Value	*$1,316,528*	*$885,253*
O&M Costs	*-$837,100*	*-$648,257*
Total Evaluated Benefits	$40,061,564	$30,803,701
Net Present Value	$31,690,564	$23,165,320
B-C Ratio	**4.79**	**4.03**

Based on TTI's independent analysis, the Benefit-Cost Ratio (BCR) of 4.03:1 over a 10-year period for the ABIS project indicates a highly favorable and viable project outcome. This ratio suggests that for every dollar invested, the project is expected to return $4.03 in benefits; this BCR underscores the project's potential to deliver significant returns on investment, thus providing the evaluation team with a clear and compelling rationale for funding this highly viable deployment phase.

Furthermore, these calculations do not encompass the potential large-scale savings achievable through future at-scale deployments leveraging the infrastructureless concept. More than 1.2 million people cross the U.S. - Canada and U.S. - Mexico border each day. This ultimate at-scale expansion and deployment of the proposed technologies at nearly 70 of the busiest land POEs yields tremendous savings, given that the infrastructureless system can be deployed at any POE with minimal re-design needed and with minimal/no field infrastructure, making it highly transferable and scalable. This at-scale deployment is anticipated to yield even greater benefits without a significant increase in investment.

3.4 Performance Evaluation (Baseline and At-Scale Implementation)

Based on the findings from the Stage 1 project and the BCA, three primary performance goals have been developed for the deployment of the ABIS for Stage 2:

- Achieve a 5% overall traffic delay reduction across the four POEs.
- Improve traffic management during the Vancouver-Seattle 2026 FIFA World Cup.
- Improve traffic management during the 2026-2030 POE construction.
- Achieve a 98% uptime for northbound and southbound systems.
- Measure actual border wait times with 95% accuracy.
- Archive data for all ports, all modes, at a minimum increment of five minutes.

Table 10 presents the evaluation approach that will be implemented during Stage 2 to assess the performance of the ABIS in meeting these goals. More details on this evaluation approach will be developed and documented as part of the future Stage 2 Evaluation Plan.

Table 10. Stage 2 Performance Evaluation Overview

Stage 2 Project Goal	Data Collection / Operations	Evaluation Approach
Achieve a 5% overall traffic delay reduction across the four POEs	Collect six months of Before baseline data from the CGBDW from July 2025 to December 2025. Collect Initial After data (with system operational) from July 2026 to December 2026. Collect Final After data (operational with system refinements) from July 2027 to December 2027.	Conduct analysis of both before and after data sets to remove effects of demand and anomalies (e.g. traffic growth, incidents, customs operations events, weather, etc.). Conduct comparative analysis of before versus after data to determine delay reduction due to the ABIS for both system operational performance periods in 2026 and 2027.
Improve traffic management during the Vancouver-Seattle 2026 FIFA World Cup	Conduct historical data assessment using over two decades of CGBDW delay data for periods of special events (e.g. concerts, 2010 Vancouver Olympics, etc.). Collect BWT data during the FIFA events. Conduct interviews with USCBP, CBSA, WSDOT, and BCMOTI staff to determine use and success of the system for managing event traffic.	Develop a case study of the experience of better management of cross-border travel during the FIFA games, with both quantitative and qualitative results.
Improve traffic management during the 2026-2030 POE construction.	Work with USCBP, CBSA, WSDOT, and BCMOTI staff to determine how to best use the system to assist in construction traffic diversion to both reduce delay and	Develop a case study of the experience of utilizing the system to improve work zone operations and traffic diversion, noting safety impacts and including lessons-

Stage 2 Project Goal	Data Collection / Operations	Evaluation Approach
	improve safety. Operate the system in an agile fashion where the agencies leverage the ABIS' capabilities to use dashboards customized to construction operations to optimize traffic flow around work zones.	learned from the collaboration.
Achieve a 98% uptime for northbound and southbound systems.	Collect Initial After data (with system operational) from July 2026 to December 2026. Collect Final After data (operational with system refinements) from July 2027 to December 2027.	Analyze data using network management tools (if available) or by identifying gaps in the data for both system operational performance periods in 2026 and 2027, which should correspond with system downtime.
Measure actual border wait times with 95% accuracy.	Collect on-going system operational data from July 2026 to December 2027. Collect manual wait time measurements through a ground truthing exercise.	Compare reported wait times with those captured manually in the field in the summer of 2026 and summer of 2027.
Archive data for all ports, all modes, at a minimum increment of five minutes.	Collect system operational data between July 2026 and December 2027.	Conduct analysis of the data collected to verify that data is archived in the appropriate manner.

In support of the evaluation and ABIS performance measurement, access to comprehensive baseline data in five-minute increments since 2007 is available from the CGBDW. Data is publicly available, with some metrics specifically made accessible through the administrative portals. This data will be used as a benchmark for evaluating the impact of the at-scale implementation. This data includes:

- **Wait Times**: Detailed records of average, maximum, and minimum wait times for passenger vehicles, segmented by time of day (five-minute increment) and day for both northbound and southbound directions.
- **Traffic Volumes**: Vehicle counts are available at the individual loop detector level as well as for each POE and categorized by mode. This data provides insights into traffic patterns and peak congestion periods.

Comparison metrics may include:

- **Accuracy**: The accuracy of the data being collected may be determined using manual verifications. ABIS system data can then be verified against ground truth manual counts or vehicle counts provided by USCBP or CBSA, when available.

- **Reliability**: The reliability of the system could involve an assessment of how timely and complete the data is, as well as an examination of how much downtime is experienced (and where the failures are).
- **Distribution of Traffic**: Using data archived from the beginning and end of the project, an analysis of wait times/volumes at the two closest POEs can determine if the ABIS is resulting in a better spread of demand between ports.
- **Wait Time Reduction**: Archived data from special events can be compared to new special event wait time averages to determine if the system is affecting average delay.

Additionally, although not part of the CGBDW, safety data (e.g., crash statistics) is also available that can be used to evaluate safety impacts associated with the at-scale implementation.

4. CHALLENGES AND LESSONS LEARNED

Several important lessons were learned through the Stage 1 project:

- Some technology solutions that were considered (e.g., loop detector signatures and video feeds for vehicle re-identification without license plate readers) proved not mature enough in a border crossing environment to be reliable in this scenario.
- Transportation agencies expressed hesitation at installing hardware embedded in the road due to challenges with long-term maintenance, thereby removing several technology options under consideration.
- Three of the four POEs are scheduled for major construction over the next five years, meaning that the project must be designed in a way that is flexible and relies on easily movable hardware that is not negatively impacted by infrastructure changes at the border.
- The pressing need for traffic management tools and accurate public wait time data in advance of the 2026 FIFA World Cup requires a more ambitious timeline.

The hybrid solution agreed upon by stakeholders in Stage 1 was determined to be the best option given these lessons and the systems engineering process. The preferred technology concept is technically feasible, appropriate for border crossing environments, and widely accepted by the stakeholder group. Every individual element of the hybrid solution has been tested and proven as effective and reliable in other deployments; the new approach here is integrating these technologies with AI and ML software models to offer a suite of border traffic management tools.

Additional considerations that need to be addressed in Stage 2 are listed below:

- **Legal, policy, and regulatory requirements**: Stage 1 fell under the Categorical Exclusion class of actions for NEPA, and Build America, Buy America did not apply. Stage 2 will include installations in both Canada and the United States, so any decisions made regarding procurement must abide by both U.S. and Canadian requirements.
- **Technology suitability and procurement**: The vendor showcases demonstrated that several of the technologies under consideration at the beginning of the project are not mature enough for deployment in this instance. Those that have proven track records of successful deployment moved forward for the recommendations for Stage 2. Procurement needs to be conducted based on both U.S. and Canadian requirements.
- **Additions to the Stage 2 budget**: Stage 2 needs to incorporate improved communication systems at the two remote POEs to reduce system downtime.
- **Data governance**: The project learned more about the National Institute of Standards and Technology (NIST-500 series) standards that govern data and cloud privacy. It sets standards for data collection, storage, and transfer between government agencies to make data secure and minimize cyberattacks. It also lays out procedures for data protection and recovery in case of an attack. Project partners will need to adhere to these standards, as well as data privacy concerns regarding the transfer of data across the U.S. – Canada border. The project must also abide by stringent Canadian privacy laws.
- **Workforce capacity:** It is expected that the at-scale deployment of the project has the potential to create high-skilled jobs for nearly 15 people over approximately three years,

including positions in private industry as well as at WSDOT to oversee and manage the Stage 2 project.

- **Partnerships and project coordination**: The project will need to be tightly coordinated between U.S. and Canadian transportation and inspection agencies. The pre-existing working group IMTC that regularly meets and a specialized binational advisory team consisting of key project partners make coordination much easier. The strong partnerships that have been built over the last 27 years through monthly participation at IMTC meetings will assist in the coordination.
- **Community impacts:** Regional businesses and tourism venues serving U.S. or Canadian visitors, local producers and shippers, and the population of Whatcom County and B.C. residents that regularly cross the border will all benefit from a more predictable and better managed border system.
- **Public acceptance**: In 2019, WCOG and the Western Washington University's Border Policy Research Institute (BPRI) completed a passenger vehicle intercept survey in the winter and the summer and asked drivers whether they used the border wait time signage to make travel decisions. They were also asked if they thought the messages reported on the signs to be accurate. 60% of drivers through the major crossings in Blaine/Surrey reported using the border wait time system often, with 7% saying they used it occasionally. Even though more than half of surveyed drivers used the signs, 46% also said they did not believe the signs to always be accurate. This implies that *any* information is better than *no* information. It is also valuable to note that nearly 50% of cross-border travelers surveyed cross the border at least twice per month. Border crossings are a regular part of life in Whatcom County and B.C. communities, so it is presumed that this will be a widely popular service. The unknown factor is how motivated the public will be in using the mobile app component. The project will require outreach to border communities to explain the features availed and the purposes of the app.

4.1 Lessons Learned from US Southern Border BWT Studies and Deployments

The project team conducted an extensive assessment of BWT studies and deployments along the U.S. – Mexico and U.S. – Canada border, which provided several key insights that have gone into the design of the Stage 2 project. Some assessment insights are summarized as follows:

- **Technology penetration rates:** The importance of evaluating the penetration rates of various technologies at each POE is crucial, as well as recognizing that these rates may change over time. For instance, a study by TTI in 2015, which examined Bluetooth device penetration rates in passenger vehicles at five border crossings, revealed that Bluetooth's effectiveness is influenced by user behavior, device usage, and the physical layout of the crossing facilities. The study concluded that only the Gateway to the Americas Bridge in Laredo demonstrated penetration rates consistently over 10 percent, making it suitable for a Bluetooth-based wait time measurement. However, by 2022, Bluetooth penetration rates had notably increased across most Texas border crossings, leading to the successful implementation of a Bluetooth-based BWT system at the Los Indios, Texas crossing. The study also observed that at certain locations, Wi-Fi penetration exceeded that of Bluetooth, and with the growing ubiquity of

RFID tags on passenger vehicles, RFID technology has emerged as a feasible option at other crossings, as demonstrated by a TTI pilot project at the Paso Del Norte Bridge in El Paso.

- **Locations for sensors**: The operational setup of many re-identification BWT systems suggests that selecting a technology for a location with an existing anti-idling system, such as the Canadian side of the Peace Arch crossing, would be practical. The well-defined staging area at the border process allows for the straightforward deployment of readers at the staging area's entry and exit points. Adjustments to the travel time measurement algorithms would then be required to account for this as an additional leg of the journey.
- **Vandalism**: This is a major concern on the southern border but may not be as much of an issue along the northern border. Equipment needs to be mounted high up in public places or be hidden in plain sight. As such, in-pavement sensors have been preferrable along the southern border, since these are not as visible.
- **Operations and Maintenance**: Maintaining system functionality begins the moment technology is deployed, yet it is often overlooked. Because this will be a pilot project of a new hybrid system, funding has been budgeted for at least two years of operations to make changes and respond to needs discovered after deployment.
- **Border community acceptance**: Like the northern border, southern border crossers have a strong appetite for border travel information. U.S. – Mexico wait time projects have been readily accepted, especially when it makes their border-crossing experience more predictable.

5. DEPLOYMENT READINESS

One of the key driving needs for the Stage 2 project, which was uncovered as part of the Stage 1 stakeholder engagement process, revolves around key events that will take place beginning in 2026. The FIFA World Cup in June/July 2026 include thirteen matches split between Seattle, WA and Vancouver, B.C. Rough initial estimates predict between 5,000 and 10,000 additional cross-border cars per day during this time, although that number could be higher or lower. The ABIS would greatly benefit those unfamiliar with the area (and local knowledge of the best times and locations to cross) and allow them to better plan to arrive on time at scheduled events.

Additionally, GSA is planning major reconstruction at three of the region's four POEs that will impact throughput and may even lead to border closures. CBSA is also planning a complete replacement of the largest commercial crossing at Pacific Highway that will have major impacts on cross-border trade.

These upcoming events have led to the need for an accelerated project schedule. Although aggressive, the project team believes that this timeline is achievable. A detailed list of tasks/scope of work to be completed has also been developed (see ***Section 3.2*** for details).

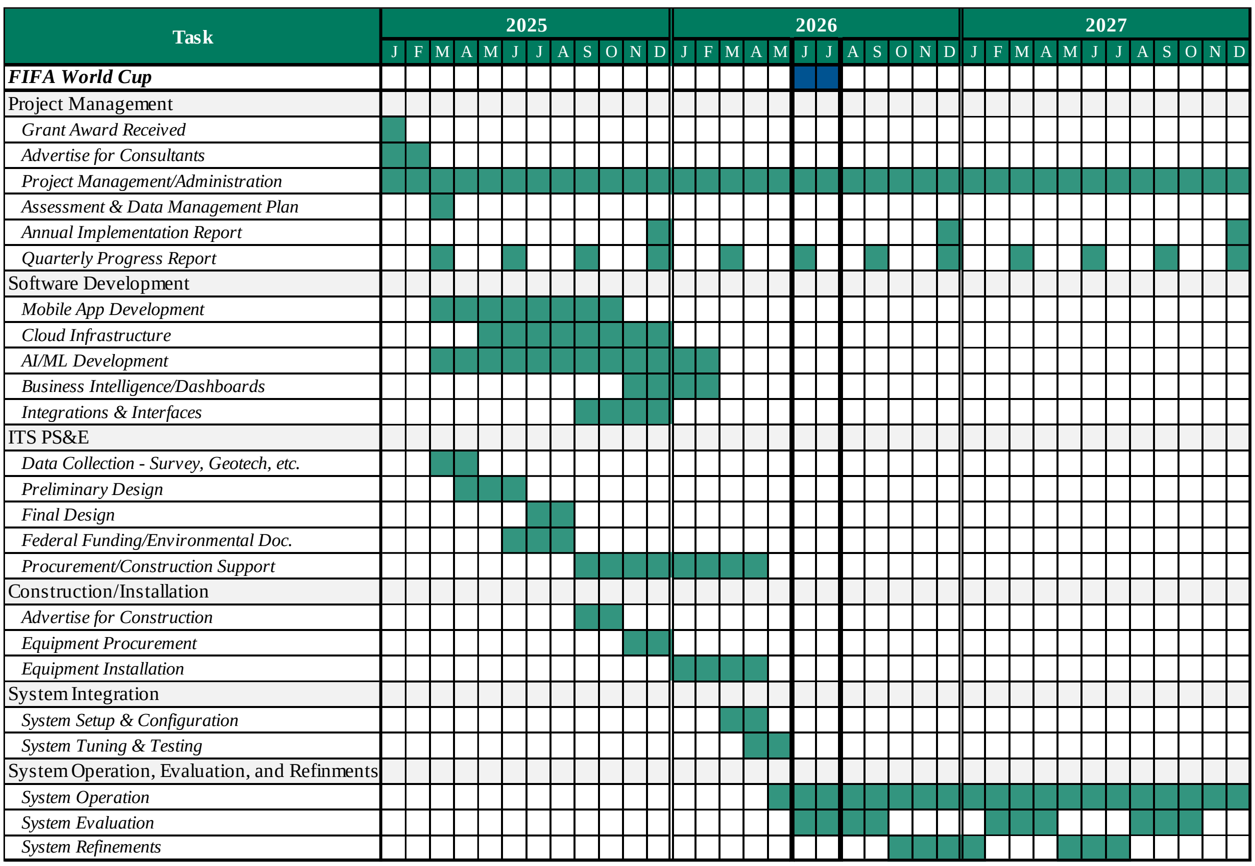


Figure 11. Project Schedule

6.1 Requirements for Successful Implementation

The project team and its stakeholder agencies have made significant progress in preparing for at-scale implementation. Key achievements to date include:

- Successful completion of the Stage 1 technology selection, with broad acceptance by the project's stakeholders.
- Establishment of strong partnerships with bi-national stakeholder agencies.
- Understanding of comprehensive data governance and privacy protection protocols.
- In-house agency knowledge and experience for managing, operating, and maintaining the system.
- Knowledge of associated risks in implementation and ways to mitigate based on past experiences of similar projects.
- Updates project schedule to address upcoming border traffic constraints expected starting in 2026.

Additionally, the project team understands that there are several important elements to consider, including:

Legal, Policy, and Regulatory Requirements

Legal, policy, and regulatory requirements are generally expected to include Right-Of-Way (ROW) certification, environmental documentation, and procurement practices. The lead agency for the Stage 2 project, WSDOT, has extensive experience administering federally-funded construction projects and is well versed in the requirements that come along with it. Infrastructure installations will take place within ROW that is owned by WSDOT, USCBP, or U.S. General Services Administration (GSA). U.S. POE facilities are owned and managed by GSA who are part of the Project Advisory Team but follow the lead of USCBP. The installation of hardware along an international border also requires permission from border security agencies. USCBP and CBSA are partners in this project and will facilitate this process. Similarly, any installations in Canada will be conducted by partner agencies in Canada, specifically BCMOTI.

Regulatory compliance issues include environmental documentation, ROW certification, and the Build America Buy America (BABA) Act. This project is expected to fall under NEPA Categorical Exclusion. Care will be taken to ensure procurement and installation activities comply with BABA and eligible costs adhere to 2 CFR Part 200.

Given the binational nature of this project, there are also some unique requirements that will need to be followed. For example, due to stringent privacy laws in Canada and concerns regarding sharing of private information in another country, this project will need to abide by both U.S. and Canadian regulations and will not store any Personally Identifiable Information (PII).

Procurement and Budget

As part of the Stage 1 systems engineering process, specifically with the development of the *Concept of Operations* and this *Implementation Report*, the project team identified the steps needed to deploy the ABIS in Stage 2, including both U.S. and Canadian procurement processes; staffing and expertise required; the distinct design tasks for the physical infrastructure and back-end software systems; and the evaluation and refinement approach to meet the aggressive schedule resulting from the 2026 FIFA World Cup are described in ***Section 3.2***. This approach will continue to be refined with the development of the *System Requirements* and the *High-Level Design* and updates will be reflected in the *Final Implementation Report*.

Partnerships

Partnerships have already been formed as part of Stage 1, which will need to continue into Stage 2.

Technology Suitability

The systems engineering process in Stage 1 evaluated the technical feasibility and suitability of several technologies as they apply to border crossing environments, resulting in a shortlist of viable options (see ***Table 7***, with ***Table 8***) that will be deployed Stage 2.

Data Governance

As mentioned previously, data privacy and PII are extremely important considerations. The project team has experience handling these issues:

- WCOG has managed the Cascade Gateway Border Data Warehouse for nearly 20 years, which includes vehicle counts and BWT at the four Cascade Gateway POEs. WCOG also regularly coordinates with international partners like BCMOTI, CBSA, and Transport Canada and has a strong understanding of international data and privacy requirements.
- WSDOT owns, operates, and maintains an extensive ITS network, which includes various sensors that collect data similar to what the ABIS will provide. This existing expertise within the organization will be leveraged for the Stage 2 project.

Additionally, the project team will consider robust cybersecurity measures that are compliant with NIST-500, FedRAMP, and other state and local standards, as mentioned previously.

At the onset of Stage 2, the project team will review the Data Management Plan that was developed in Stage 1 and substantially update it to meet the needs of the Stage 2 project. The types of data that will be needed for system operation and evaluation will be identified, and methods to ensure data privacy and security will be discussed.

Workforce Capacity

As discussed in detail in both *Section 3.1* and *Section 4*, as well as in *Section 5.3* below, the proposed at-scale implementation will significantly involve WSDOT maintenance staff, who are represented by the WFSE union who are strong supporters of this project. Additionally, the project will result in the creation of several jobs related to the design, development, implementation, operations, and maintenance of the system.

Internal Project Coordination

As part of Stage 1, effective project management, clear communication channels, and well-defined roles and responsibilities are essential for ensuring smooth coordination among team members and stakeholders. The same successful approach will be carried forward to Stage 2 implementation. The organizational chart presented in ***Figure 12*** details staff qualifications and highlights of the outstanding management team and expert technical staff involved in Stage 2. All these individuals have been involved in Stage 1, ensuring continuity and established relationships. While the lead agency will transition from WCOG to WSDOT, WCOG will remain a project partner and be heavily involved.

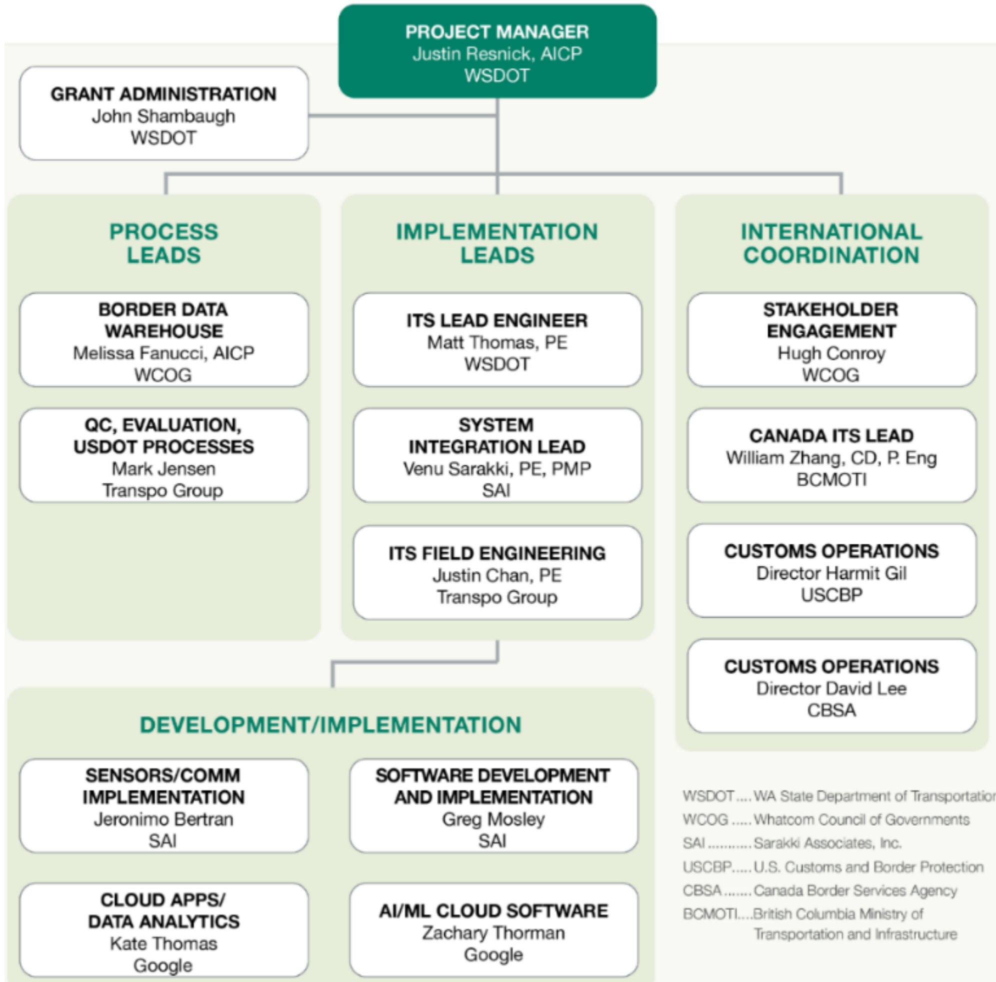


Figure 12. Project Team Organizational Chart

Community Impact and Public Acceptance

As mentioned previously in ***Section 4***, most cross-border travelers use the existing traveler information system, even when they are not confident of the information provided. For this project to be a success, the travelling public will need to use and trust the system. Additionally, since a major component of the ABIS will be the mobile app, public use and adoption of the app will be critical to the project's success.

Overall, transparent communication, community outreach programs, and incorporating feedback mechanisms will be key to fostering trust and support. Public outreach and gaining public acceptance will be crucial to ensuring long-term sustainability.

6.2 Operations, Maintenance, and Process for Future Upgrades

As shown in the project schedule in ***Figure 11*** and discussed in ***Section 3.2***, the Stage 2 project will feature several periods of System Operation, Evaluation, and Refinement, allowing stakeholder agencies opportunities to test the core functionality of the ABIS in a real-world setting and evaluate the system's features and performance, and make any refinements that may be needed.

WSDOT's in-house experts who currently maintain similar hardware and software components will oversee the operations and maintenance of field devices and software updates. They will work with device manufacturers to understand their recommended maintenance schedules and procedures. Additionally, remote monitoring and diagnostics capabilities to proactively identify and address potential issues before they impact system performance will be included.

To ensure the continued functionality and user-friendliness of the border wait time app, a regular update and maintenance schedule will be implemented. This includes addressing user feedback, fixing bugs, and optimizing performance. This may also include the integration of new features and functionalities as and when they become available which will enhance border crossing experience for both agencies and the public. The operation and maintenance costs will be borne by the stakeholder agencies.

6.3 Work Force Enhancement Approach

The installation, operation, and maintenance of the U.S. portion of the project will be conducted by staff represented by the Washington Federation of State Employees (WFSE) union that is part of the American Federation of Labor and Congress of Industrial Organizations. John Matthews, a union leader and WSDOT's Electrical, ITS, and Assets Program Deputy Administrator will serve as a union stakeholder on the Stage 2 project.

This deployment will support the creation of highly-skilled, well-paying union jobs. The deployment of the ABIS will also support approximately five private sector engineering staff, as well as staffing from WSDOT's planning and engineering groups for operations and management of the Stage 2 effort. As previously stated, WSDOT is committed to deploying and operating the ABIS such that there are no negative effects on union jobs through the deployment of AI.

Additionally, BCMOTI operates similarly to WSDOT in terms of relying on unionized staff to maintain and operate ITS, and it is expected that their parallel system deployment will involve significant use of Canadian union workers, public sector transportation agency management staff, and staff from private sector technology vendors.

6. WRAP UP

The stakeholder engagement, systems engineering, technology evaluation, and development of the Stage 2 concept were successfully completed according to the plan and schedule provided by WCOG to USDOT in the original Stage 1 grant application. The hybrid solution developed for implementation in Stage 2 will meet not only the identified objectives for the ABIS project, but also the additional requirements identified in Stage 1, including more detailed technology requirements and an expedited at-scale timeline.

The implemented project will provide trip planning information and border management tools to the traveling public, commercial carriers, inspection agencies, and transportation agencies to result in a more reliable, expedited border crossing system. The replacement of dated and/or failed BWT technology will benefit all users of the Cascade Gateway system of border crossings while also continuing to archive valuable data in an open-source platform for public use.

The proposed Stage 2 concept will represent a solution that can be applied to other crossings on both the northern and southern U.S. borders, improving both traffic throughput and the management of traffic across U.S. borders as a whole USCBP headquarters staff and several stakeholders involved in the California-Mexico crossings have already expressed interest in the pilot project results for possible duplication in other regions and will be monitoring developments in this project.

In conclusion, the successful implementation of the ABIS project will demonstrate a new hybrid approach to border wait time measurement and prediction, improve accuracy, reliability, and accessibility of delay data, and ultimately lead to the project goals of reducing overall border delay, improving system performance, and increasing the functionality of the system for both travelers and the agencies responsible for their safe passage into and out of the United States.

APPENDICES

Appendix A: Concept of Operations

Concept of Operations

CASCADE GATEWAY ADVANCED BORDER INFORMATION SYSTEM (ABIS) DESIGN PROJECT

whatcom council of governments

August 30, 2024

Prepared By:

Transpo Group USA, Inc.
12131 113th Avenue NE, Suite 203
Kirkland, WA 98034-7120
Phone: 425-821-3665
www.transpogroup.com

Texas A&M Transportation Institute
3135 TAMU
College Station, Texas 77843-3135
Phone: (979) 317-2000
tti.tamu.edu

Sarakki Associates Inc.
4199 Campus Drive, Ste 550
Irvine, CA 92612
Phone: 949-825-7046
www.sarakki.com

TABLE OF CONTENTS

1. SCOPES

1.1 Introduction

In 2023, the Whatcom Council of Governments (WCOG) was awarded funding to complete the Cascade Gateway Advanced Border Information System (ABIS) Stage 1 Design Project. Funding was provided through the U.S. Department of Transportation's (USDOT) Strengthening Mobility and Revolutionizing Transportation (SMART) Grants Program to meet its goal of using new technologies and approaches to target real-world challenges and create benefits.

This project has evaluated technologies to replace and improve aging wait time systems at the Cascade Gateway system of border crossings between the Lower Mainland of British Columbia and Whatcom County, Washington State.

1.2 Purpose

This report serves as the Concept of Operations (ConOps) document that conceptualizes the Cascade Gateway ABIS, a cross-border traveler information system that can be utilized by inspection agencies, departments of transportation, the traveling public, and more to improve transportation efficiency and safety with the following objectives:

1. **Report traveler wait times for the region's four Ports Of Entry (POE), northbound and southbound:** improve transportation efficiency by distributing traffic volumes across available capacity
2. **Report commercial vehicle wait times for the three commercial POEs, northbound and southbound:** reduce truck travel times and assist with more reliable scheduling
3. **Provide a real-time data feed to applications, websites, and variable message signs:** improve travel time expectations to allow for more reliable cross-border experiences
4. **Provide a real-time data feed to U.S. and Canadian inspection agencies:** improve safety by providing tools for law enforcement to better manage travel demand
5. **Provide a real-time data feed to the Cascade Gateway Border Data Warehouse:** improve system performance metrics and allow for more datasets for research and analysis
6. **Incorporate anti-idling system components at one or more POEs:** include traffic condition monitoring that may encourage travelers to switch off engines and reduce greenhouse gas emissions
7. **Integrate with existing traveler information systems:** build upon the existing partnership between the British Columbia Ministry of Transportation and Infrastructure (BCMOTI), Washington State Department of Transportation (WSDOT), United States Customs and Border Protection (USCBP), and Canada Border Services Agency (CBSA) by collaborating on a system that benefits all stakeholders and enhances their information networks.
8. **Improve cyber-security:** any solution identified will improve the security of the data feed by not relying on outdated servers located on the side of the roadway and may suggest updates for the data transmission network/method.
9. **Document the process:** serve as a test case for other border crossings looking to provide wait times and improved reporting functionality.

This ConOps serves as the foundation for the development of the vision and concept for the ABIS. Proper translation of the user needs into a valid ConOps also demonstrates the utility of the proposed solution to users and stakeholders. The ConOps approach codifies the vision, details the conceptual framework, outlines the system capabilities, and discusses scenarios that describe to the users how they will use and benefit from the system. The purpose of the ConOps is to clearly convey a high-level view of the system to be developed from the viewpoint of each stakeholder. This ConOps document is organized based on the format and guidelines for ConOps documentation provided in FHWA's online Systems Engineering Guidebook for ITS Version 3.0 (U.S. Department of Transportation, 2009). The ConOps also builds on the previous three tasks that have been completed to date on this project:

- *Task 2: Current State Assessment Report* documents the existing northbound and southbound ATIS, which are separately owned and operated by WSDOT and BCMOTI, including the existing designs, equipment, functionality, and accuracy. Additionally, it includes a comprehensive list of existing challenges and areas that need to be addressed in the new ABIS. To this end, this report includes a review of the systems' details and available documentation, insights gathered from site visits of the existing systems, and findings from the kick-off meeting and discussions with key stakeholders, during which initial user needs were identified.
- *Task 3: Existing Measurement Technology Review Report* provides a review of the state-of-the-practice regarding Border Wait Time (BWT) measurement technologies, including case studies from other U.S.-Canada and U.S.-Mexico border crossings.
- *Task 4: Concept Exploration and Recommendations Report* provides additional detail on BWT measurement technologies, focusing on how they can be applied to this project. Additionally, specific vendor technologies were investigated through a series of Vendor Showcases in which technology providers presented their products and answered questions as they related to BWT applications. Based on this information, potential technology concepts are presented here, along with each concept's advantages and disadvantages. The three concepts and the technologies involved were reviewed with WSDOT, BCMOTI, and WCOG during an interactive workshop, during which a preferred technology concept was selected – Concept II involving new radar detection (or other non-intrusive form of detection capable of measuring the volume, speed, and occupancy of vehicles in a stop-and-go border crossing environment), new Bluetooth/Wi-Fi readers, and a new smartphone mobile application based on GPS II technology.

1.3 Document Overview

This ConOps for the Cascade Gateway ABIS serves as the foundational guide for communicating user needs and system requirements to support the detailed design and implementation of the system in Stage 2. The ConOps has been developed in parallel with the Draft Implementation Report, with the details from each document iteratively informing the development of the other document. As the project's Stage 1 design phase continues and the High-Level Design is completed, the Final Implementation Report will continue to be updated based on the project's findings. The overall concept is not expected to change, but additional design details may emerge with the completion of the upcoming *Task 6: High-Level Design* and *Task 7: System Requirements*. The structure of this document, which is consistent with the FHWA guidance, is as follows:

- **Chapter 2 – The Current Situation** describes the situation that has motivated a new ABIS to replace the existing ATIS. This section provides a description of the problem(s) to be addressed and is tailored to describe the motivation for the development of the new system.
- **Chapter 3 – Justification for and Nature of Changes** outlines the deficiencies of the existing situation and the benefits of the proposed system.

- **Chapter 4 – Concepts for the Proposed System** is a high-level description of the proposed system, indicating the operational features that are to be provided without specifying design details. It includes diagrams, graphics, and a high-level information connectivity diagram that together present the overall system concept.
- **Chapter 5 – Operational Scenarios** contains narrative descriptions of the step-by-step process by which the system could operate and interact with users and external interfaces under given sets of circumstances. These are developed as "day-in-the-life" descriptions of how participants/stakeholders would interface, use, and benefit from the system. These are developed through significant interaction with the project's stakeholders.
- **Chapter 6 – Summary of Impacts** analyzes the impacts of the proposed system on users, developers, and support and maintenance organizations during operations, development, and installation of the new system.
- **Chapter 7 – Analysis of Proposed System** summarizes the benefits, limitations, advantages, disadvantages, and alternatives/tradeoffs considered.

2. THE CURRENT SITUTATION

The Cascade Gateway system of border crossings consists of four land POEs connecting the Lower Mainland in British Columbia and Whatcom County in Washington State. To optimize traffic flow across the Cascade Gateway POEs and to provide travelers with real-time traveler information on nearby cross-border routes, WSDOT and BCMOTI each installed a northbound and southbound ATIS, respectively, at all four POEs. Since 2007, both systems have exported their data in real-time to an online archive at www.borderdata.org.

Currently, the operating hours and lane types at each border crossing are as follows:

- **Peace Arch/Douglas**: Open 24 hours for passenger traffic and NEXUS, serving U.S. I-5 and B.C. Hwy 99.
- **Pacific Highway**: Open 24 hours for passenger traffic, NEXUS, buses, commercial traffic, and FAST, serving WA SR 543 and B.C. Hwy 15.
- **Lynden (Kenneth G. Ward)/Aldergrove**: Open from 8:00 am to 12:00 am for northbound passenger traffic, NEXUS, and commercial traffic, and from 8:00 am to 12:00 am for southbound passenger and permit-only trucks, serving WA SR 539 and B.C. Hwy 13.
- **Sumas/Abbotsford-Huntingdon**: Open 24 hours for passenger traffic, NEXUS, and commercial traffic, serving WA SR 9 and B.C. Hwy 11.

Both systems use loop detectors to collect data in real time to estimate current delays. This data includes vehicle counts and speeds, estimated queue end locations, the number of inspection booths open, and the current average inspection booth processing rate. Separate algorithms for WSDOT and BCMOTI calculate the estimated wait time, which is transmitted through a combination of fiber optic and wireless communication systems between the roadside, WSDOT and BCMOTI Traffic Management Centers (TMC), and the Cascade Gateway Border Data Warehouse.

The southbound system has been modified to include real-time booth-type data from USCBP. Booth type, and consequently lane type (standard or trusted-traveler), must be known for accurate wait time estimation, since processing times for NEXUS (trusted-traveler) booths and standard booths differ significantly. Although there is only one NEXUS approach lane, the number of inspection booths serving the NEXUS travelers can vary.

As the POEs and operational procedures have evolved, certain complications in the original system setup have impacted its performance. These challenges primarily relate to the accuracy and reliability of the loop detectors. When lane configurations change, the roads are paved, or when other maintenance occurs, the loop detectors may become damaged and rendered inoperable. Additionally, these detectors are not well suited to low-speed situations, typical of the stop-and-go traffic experienced at border crossings, degrading the accuracy of the data being collected. Figure 1 below provides an overview of the Cascade Gateway POEs and the types of traffic that each serves.

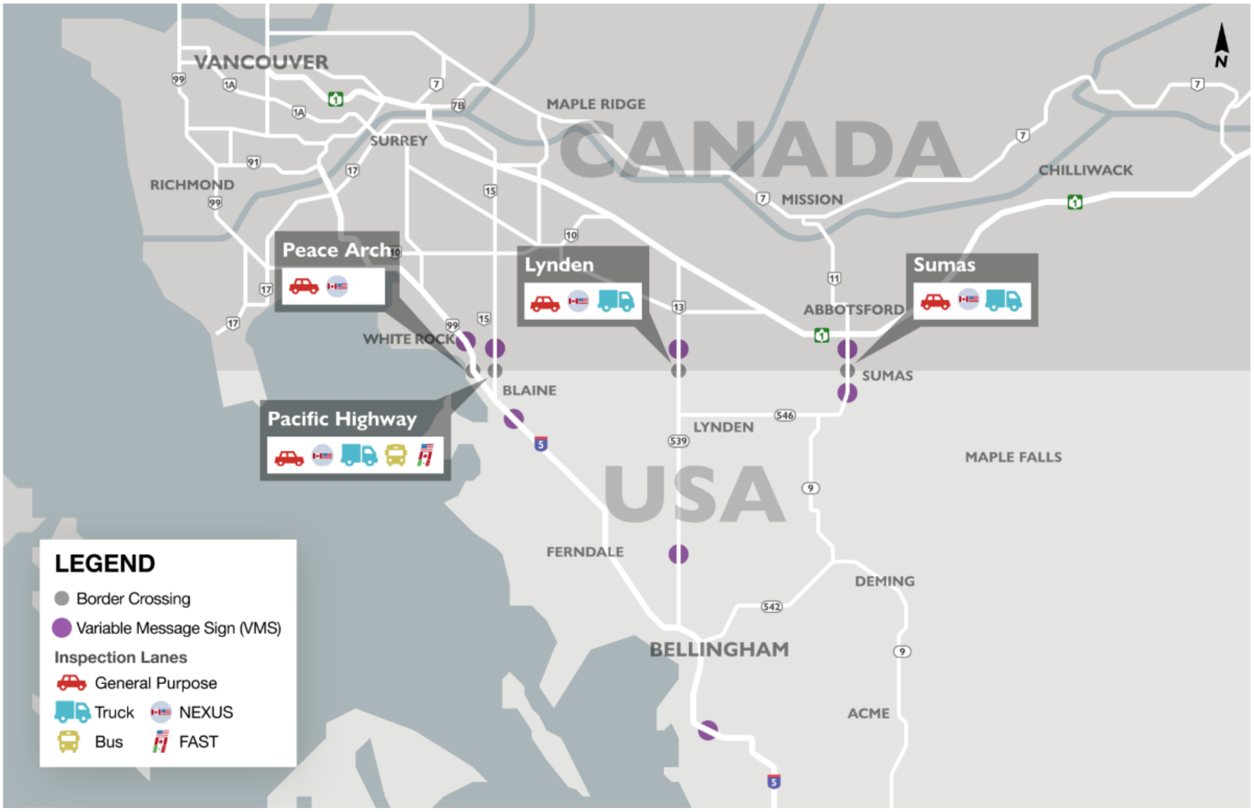


Figure 1. The Cascade Gateway ABIS Project Area Overview

2.1 Existing System Overview

Initially introduced in 2004, the existing ATIS is designed to monitor traffic flow and estimate wait times at the various border crossings. Originally, it primarily targeted southbound traffic near the Peace Arch/Douglas (Hwy 99) and Pacific Highway (Hwy 15) border crossings, but over time, it has undergone expansions and upgrades to accommodate additional crossings and features, such as an anti-idling system at Peace Arch/Douglas for the southbound approach. Currently, the ATIS consists of the northbound and southbound system; the northbound system is operated by WSDOT, while the southbound system is operated by BCMOTI. Each system collects traffic data using inductive loop detectors located at the POE and the approaching roadways to calculate estimated wait time information, which is then disseminated to the public through Dynamic Message Signs (DMS) or Variable Message Signs (VMS), Interactive Voice Response (VIR) system (BCMOTI only – travelers can call 604-542-4360 for an audio/voicemail system), websites, and mobile apps. In 2007, the Cascade Gateway Border Data Warehouse (BDW) was also developed, which ingests data from the northbound and southbound systems and serves as a publicly accessible repository of historical wait times and traffic volumes.

2.1.1 System Stakeholders

As the existing system is utilized by both sides of the border, multiple stakeholders and entities are involved in its operation, data management, maintenance, and support. These entities, hailing from both the Canadian and U.S. sides, include transportation agencies, governmental bodies, border inspection agencies, and are represented by a public-private coalition called the **International Mobility & Trade Corridor (IMTC)**

Program. This coalition, which also includes U.S. and Canadian businesses involved in cross-border trade, is aimed at enhancing mobility and security for the Cascade Gateway. The IMTC Program focuses on five POEs connecting western Washington state and the Lower Mainland of British Columbia, though only four are included in this project. Members and supporting entities of the IMTC include, but are not limited to the following:

- **Whatcom Council of Governments (WCOG)**, the region's Metropolitan Planning Organization (MPO) and Regional Transportation Planning Organization (RTPO) for Whatcom County, facilitates cooperation on regional transportation issues. Its membership encompasses Whatcom County, its seven cities, the Port of Bellingham, the Lummi Nation, and other regional entities. Additionally, WCOG manages the IMTC Program, oversees the Cascade Gateway Border Data Warehouse, and is managing this ABIS SMART Stage 1 project
- **Washington State Department of Transportation (WSDOT)** is a governmental agency that constructs, maintains, and regulates the use of transportation infrastructure in the state of Washington. It has a widely deployed network of Intelligent Transportation Systems (ITS), including VMS, CCTV cameras, data stations, weather monitoring stations, and more. WSDOT owns, operates, and maintains the existing ATIS in the northbound direction, and were the original developers of the northbound ATIS.
- **British Columbia Ministry of Transportation and Infrastructure (BCMOTI)** is the government ministry responsible for transport infrastructure and law in the province of British Columbia. BCMOTI owns, operates, and maintains the existing ATIS in the southbound direction. BCMOTI operates and maintains the back-end and physical systems through private contractors.
- **U.S. Customs and Border Protection (USCBP)** oversees border security and operations for the United States, though do not directly interact with the ATIS, aside from providing booth status data to the southbound ATIS.
- **Canadian Border Services Agency (CBSA)** oversees border security and operations for Canada, though do not directly interact with the ATIS.
- **General Services Administration (GSA)** owns and manages the U.S. border stations.
- **Western Washington University's Border Policy Research Institute (BPRI)** conducts project analysis and evaluates how the system's outputs can contribute to academic research on border-related issues. BPRI is another crucial stakeholder utilizing the project outcomes for further policy development.
- **System Users**, which includes the traveling public who will be the end-users directly interacting with the system on a day-to-day basis, using it for traveler information and trip planning purposes. With the upcoming 2026 FIFA World Cup and the planned construction/expansion of several POEs (see 3.2 Assumptions and Constraints), the Stage 2 implementation of the system is of the utmost importance to help minimize delay and deliver a seamless traveler experience. These system users include:
    - **The general public.** Canadians and U.S. residents cross the border for shopping, tourism, to visit family, for medical visits, and for work commutes. Travelers from the West Coast of the U.S. and all of Western Canada use this region as their primary border crossing between countries.
    - **Private industry**. This region has the fourth busiest commercial crossing on the U.S. – Canada border and is a critical component of U.S. and Canadian trade networks. Private users of the border include freight providers (e.g., BC Trucking Association, Burlington Northern

Santa Fe Railway, etc.), transportation providers (e.g., Amtrak Cascades, Airporter Shuttle/ Bellair Charters, Vancouver International Airport Authority, etc.) and local businesses/organizations (e.g., BC Chamber of Commerce, Bellingham/Whatcom Chamber of Commerce, Lynden Chamber of Commerce, Vancouver Board of Trade, White Rock/South Surrey Chamber of Commerce, West Coast Duty Free, etc.).

2.1.2 Southbound ATIS

The southbound ATIS is comprised of several components, including inductive loop detectors and associated controller cabinets (known as Vehicle Detection Stations [VDS]), DMS, hybrid DMS, CCTV cameras, Uninterruptible Power Supplies (UPS) for some roadside equipment, and the ATIS server, which is a roadside cabinet located on the northeast corner of the Pacific Weigh Scale near Hwy 15 & 4th Ave in BC. The controller cabinets collect data from the inductive loop detectors and reports it back to the ATIS server via the communications network, which utilizes a combination of fiber optic, wireless, and leased line communications.

The ATIS server processes this data, which includes the roadside traffic data and geographical distances between the loop detectors to estimate queue lengths and discharge rates, as well as booth status data from USCBP, to calculate the estimated border wait times. The booth status data is provided by USCBP via a raw data feed for Privately Owned Vehicle (POV) lanes only and does not include lanes dedicated to Commercial Motor Vehicles (CMV). However, since this currently involves a manual process for USCBP to provide this data, the algorithm only utilizes this data feed when it is available. The system and associated algorithm, which was originally developed by Arcadis/IBI Group for BCMOTI, is proprietary in nature, so specific details on the software and programming are not known. The border wait times are then transmitted from the ATIS server to the relevant DMS, as well as the ATIS website (https://www.th.gov.bc.ca/ATIS/index.htm) for public consumption, though the latter has since been taken offline due to data inaccuracies and unreliability. Figure 2 below shows the network diagram of the existing southbound ATIS.

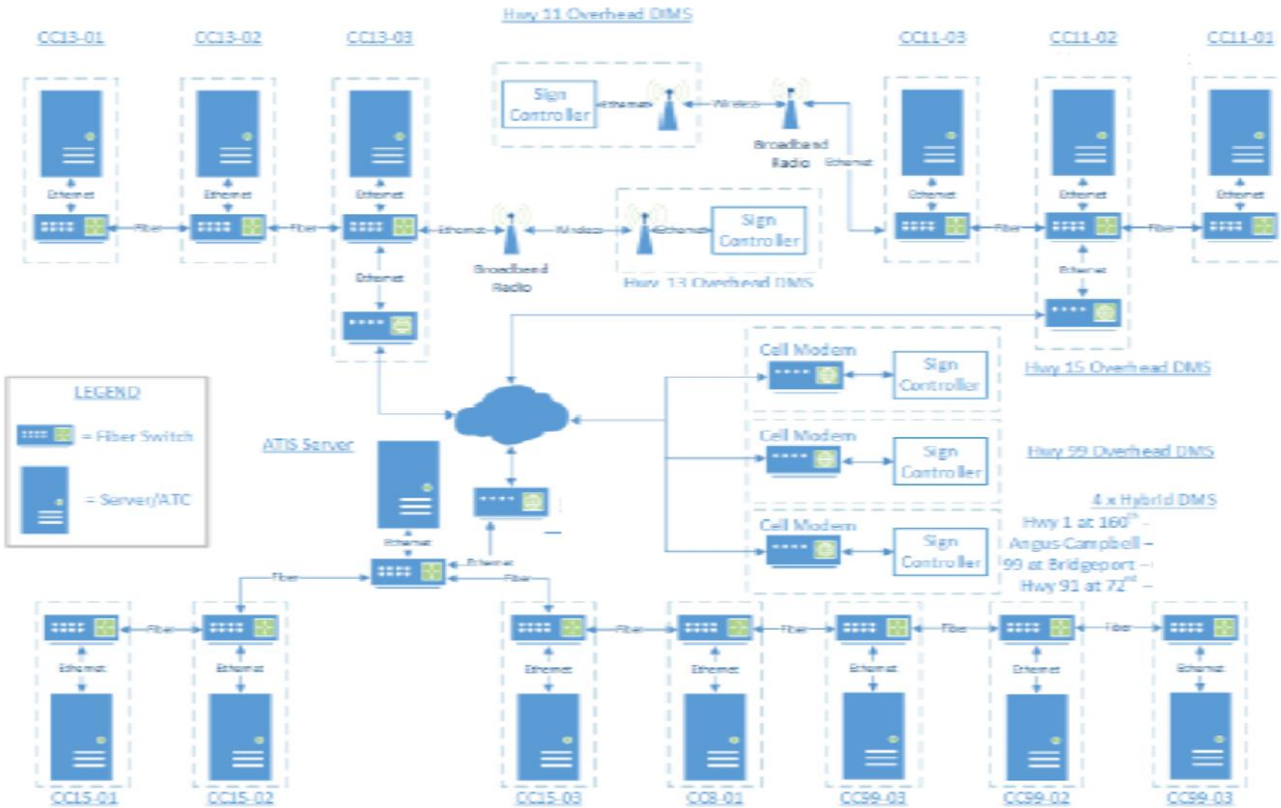


Figure 2. Southbound ATIS Network Diagram

The Peace Arch crossing also features an anti-idling system, which instructs vehicles to turn off their engines when queues extend beyond a certain point along the southbound approach. When a pre-determined queue length is exceeded, a traffic signal changes to red to halt traffic. When the queue is reduced, the traffic signal changes to green and allows groups of vehicles to proceed toward a staging area near the primary inspection booths.

Figure 3 below is extracted from the southbound ATIS' private webpage and shows an overview of the system components, identifying any system faults that have been detected. This includes information on current traffic flows, messages and wait times that are being shown on DMS, and links to images from CCTV camera video feeds (which are pulled from BCMOTI's File Transfer Protocol (FTP) webpage and also displayed on the DriveBC webpage).

In 2022, an additional enhancement was made to the queueing algorithm. Previously, the algorithm had a maximum queue value for all crossings, but users found that there were becoming more frequent events in which the queue became substantially higher than the pre-configured maximum value. As such, a dynamic maximum queue algorithm was implemented.

The southbound ATIS is operated by Arcadis/IBI Group on behalf of BCMOTI and maintained by Cobra Electric on behalf of BCMOTI.

Additional details on system components can be found in Section 2.1.5 Existing System Components.

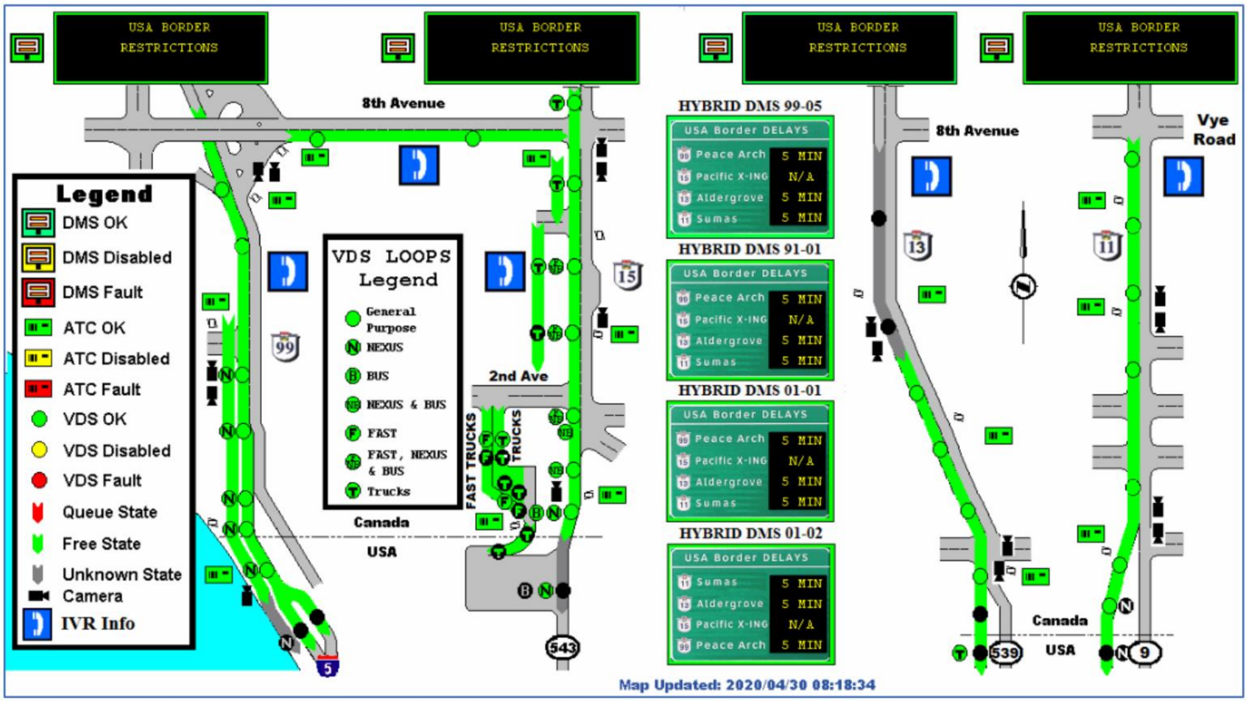


Figure 3. Existing Southbound ATIS Layout

2.1.3 Northbound ATIS

The northbound ATIS is similar to the southbound ATIS, but was developed by and is operated and maintained by WSDOT. The northbound ATIS consists of inductive loop detectors and associated controller cabinets (known as Data Stations), VMS, and CCTV cameras. The controller cabinets collect data from the inductive loop detectors and reports it back to the WSDOT TMC via the communications network, which utilizes a combination of fiber optic and wireless communications. The northbound system lacks the anti-idling system that is currently present at the southbound Peace Arch/Douglas crossing.

WSDOT is currently in the process of migrating the BWT algorithm from C++ to C# so that the underlying code can become more manageable and accessible. The algorithm, housed on a server at WSDOT’s Bellingham facility, is primarily divided into three services, which include: 1) NG_ES for traffic data collection; 2) NG_TravelTimeEx for queue length calculations; and 3) NG_VMS for VMS messaging. An overview of the data flow is shown in Figure 4 below.

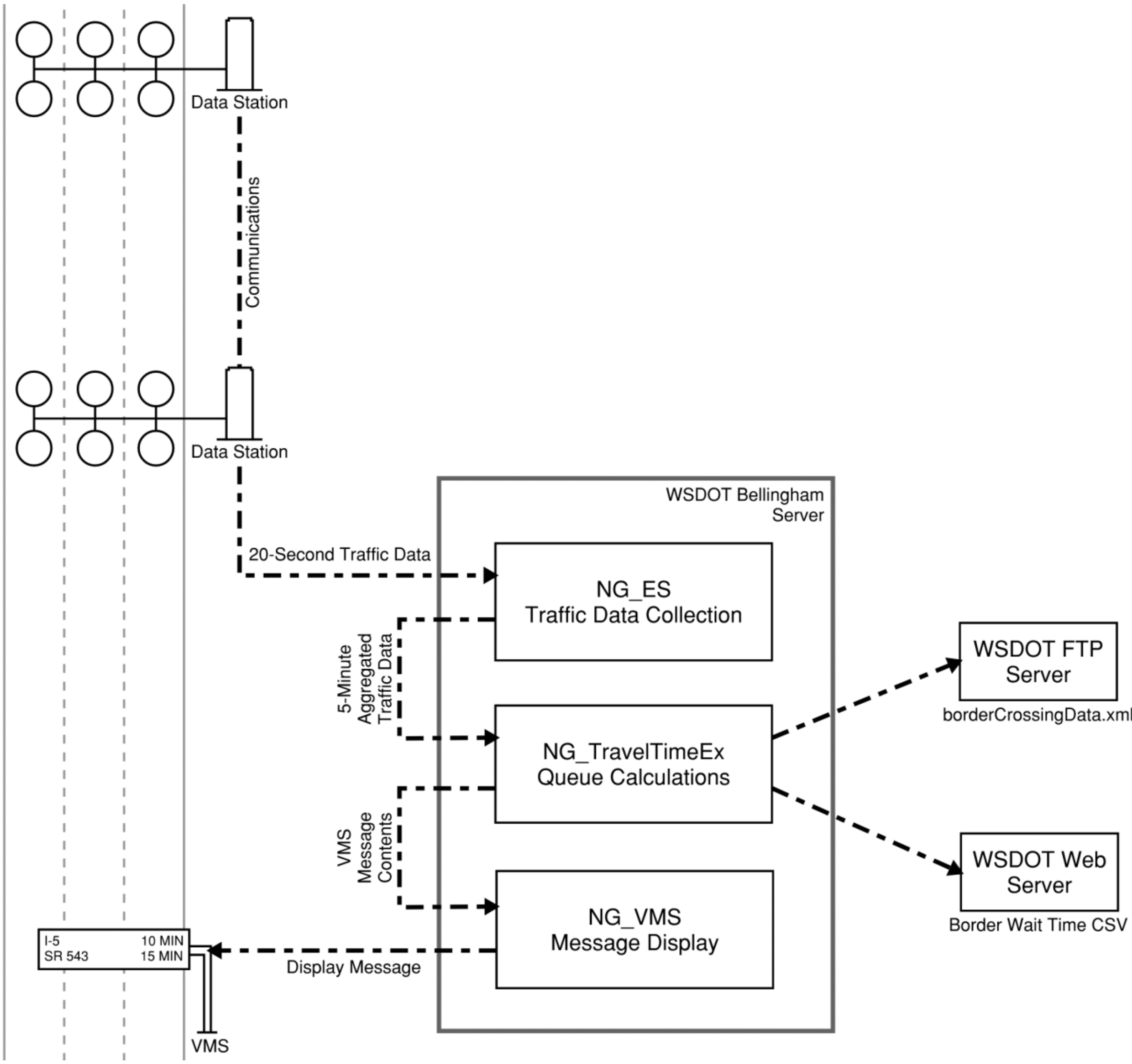


Figure 4. Northbound ATIS Data Flow Diagram

Traffic data is collected using inductive loop detectors in the field, which measure vehicular volumes and occupancy (i.e., the percentage of time that the loop detector is actuated). Note that although the data stations include two loop detectors in each lane to measure vehicle speeds, speed data is not used for the BWT algorithm. The loop detectors are connected to the adjacent roadside data station cabinets, which transmit traffic data back to the NG_ES service every 20 seconds. The NG_ES service then aggregates the traffic data for the data that were received for the previous five minutes into single values each for volume and occupancy and provides the NG_TravelTimeEx service with those two values every five minutes.

The NG_TravelTimeEx service uses the volume and occupancy data to determine the queue lengths and wait times for each POE. After going through a series of checks to validate the traffic data, the service performs the calculation, which includes several checks and parameters. Ultimately, the service rate loop detectors at the primary inspection area and upstream loop detectors, and the associated volume and occupancy data, are used to calculate the queue lengths and the service rates.

The queue length is determined based on the relative locations of the data stations, in conjunction with the volume and occupancy data. For example, if a downstream loop detector has an occupancy that is greater than a pre-configured threshold (15%), then it is considered occupied. The queue length is then calculated based on the known location of the furthest upstream loop detector that is occupied, plus the number (volume) of vehicles counted beyond that point (by another data station that is located further upstream) multiplied by an assumed average vehicle length (25 feet). However, one of the limitations of this approach is that if the queue extends beyond the last loop detector, the system would not be able to determine the back-of-queue and would just report that it is beyond the maximum back-of-queue. Another limitation is related to the assumed average vehicle length, particularly for locations where there is a significant amount of commercial/bus traffic.

To determine the wait time, the service rate loop detectors at the primary inspection area are used to determine a raw service rate. Exception/adjustment factors, which were developed based on WSDOT's observations of field conditions, are then applied to determine a calculated service rate. The queue length is then divided by the calculated service rate to determine the wait time. The service rate loop detectors are critical to the algorithm; if a service rate loop detector fails, the system stops reporting data.

The algorithm also takes into consideration how many lanes are open at each POE. Included in the calculation is each POE's hours of operation (open or closed). The algorithm also infers how many lanes are open at any given time; if the service rate loop detectors count a vehicle in the lane, then the lane is considered open, which factors into the service rate calculation.

Every time the NG_TravelTimeEx service runs, two parallel services also operate to generate the borderCrossingData.xml, which includes data (e.g., inferred lane open/close status, queue length, vehicle volume, occupancy, calculated service rate, etc.) for all four POEs and is posted to the WSDOT File Transfer Protocol (FTP) server for use by the Cascade Gateway Border Data Warehouse, as well as individual CSV files for each POE for each mode (e.g., general purpose, NEXUS, trucks, FAST) with data (e.g., delay/wait time, queue length, raw and calculated service rates, queue lengths, exception/adjustment factors, and number of open lanes) that is posted to the WSDOT Web Service so that wait times can be viewed by the public on the WSDOT travel time website (https://wsdot.com/travel/real-time/border-crossings and https://wsdot.com/Travel/Real-time/Map/). Note though that while the data includes different lane assignments, these are static in nature; the current algorithm is not capable of automatically adjusting for dynamic lane/booth status changes.

Lastly, the NG_VMS service runs every five minutes to update the wait times that are displayed on VMS located in advance of the POEs.

Additional details on system components can be found in Section 2.1.5 Existing System Components.

2.1.4 Cascade Gateway Border Data Warehouse

The original iteration of the Cascade Gateway Border Data Warehouse, which was launched in 2007 and operated until January 2010, was designed as a border data warehouse accessible through www.CascadeGatewayData.com. This was in response to the recognition of the value of preserving historic wait time data from the WSDOT and BCMOTI systems, which were not previously archived. This online platform served as a repository for all data collected from the BCMOTI and WSDOT ATIS in five-minute increments. The database stored various traffic-related metrics, including traffic volume, delays, arrival rates, and other relevant information categorized by crossing and direction.

Key features of the original system included custom query functions, allowing users to access data by individual loop detector, as well as an email notification system for border wait times exceeding specified thresholds. The backend functionalities utilized FTP protocols based on an interagency XML schema, and the system ran on a UNIX server employing Ruby on Rails technology backed by a PostgreSQL database, with Apache serving the website.

A data collection service polls the data sources for the NB and SB ATIS, aggregates the data, cleans the data, and archives it. Raw data from the SB system is privately accessible to BCMOTI, while raw data from the NB system is publicly available. An API enables the calculated BWT to be posted to DMS/VMS.

The database infrastructure transitioned to a SQL Server 2008 relational database to accommodate the full history of collected data, which continued to be queried by web applications, API users, and the data collection service. Amazon Web Services (AWS) Glacier was utilized to maintain full backups to alleviate the strain on the database. The Cascade Gateway BDW website offered users access to query, reporting, and subscription functions, as well as numerous APIs utilized by various applications, including the DriveBC Historical Border Delays website and the WSDOT mobile app.

Following the initial phase, a significant upgrade was deemed necessary to maintain the functionality of the data warehouse. The subsequent iteration of the system (BDW 2.0) introduced enhancements to improve data collection and accessibility. The data collection service was responsible for polling configured data feeds to capture detector data, with the database maintaining the relationship between crossings, lanes, and detectors.

To address challenges faced by the previous version (BDW 2.0), an upgrade to BDW 3.0 occurred in 2020, which is the current version in use today. This upgrade included restructuring the warehouse, incorporating USCBP booth status data, enhancing visualization interfaces, and improving backend reporting and maintenance procedures. USCBP booth status data was captured for each vehicle, including information such as the number of passengers, state/province indicated by the license plate, lane number, and traffic mode (e.g., NEXUS, Car, Ready). A five-minute binned version of the booth data feed was employed to enhance query and report performance. CBSA booth status data is not currently available.

In the past, additional data sources were available to the BDW; freight data from private trucking companies were available via an API, and WSDOT weigh-in-motion data was available as well. However, data access issues led to discontinuing these data feeds on the site.

The current system (BDW 3.0) features an updated Extract-Transform-Load engine (ETL) to improve notifications to system administrators about data source availability and system health. Separate repositories for reporting data and storing data help to optimize performance and support improved querying capabilities.

Hardware and equipment for data collection are owned by partner agencies, with BDW 3.0 hosted on an AWS instance. WCOG oversees system administration and maintenance, coordinating with the development team. Ongoing support is provided through existing infrastructure funded by partner agencies, with WCOG responsible for administering the database and seeking funding for ongoing maintenance post-upgrade. The system architecture of the Cascade Gateway BDW 3.0 is shown below in Figure 5.

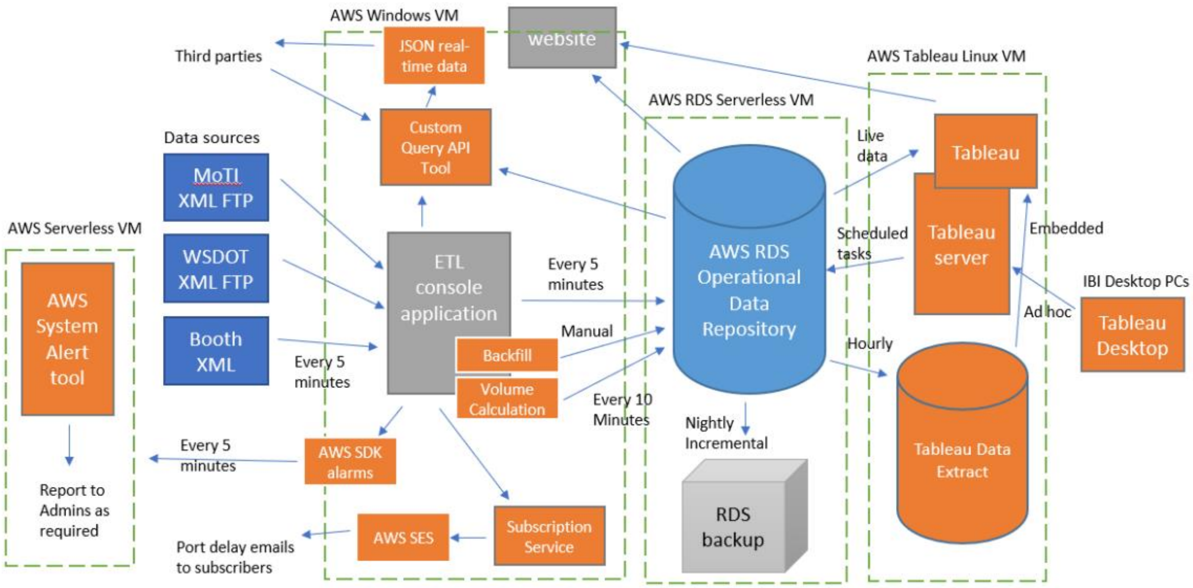


Figure 5. System Architecture of BDW 3.0

The current system is sustained through the collaborative efforts and financial support of partner agencies including WSDOT and BCMOTI. These agencies contribute to the maintenance and upkeep of the infrastructure that underpins the BDW. WCOG is also responsible for administering the database and establishing a maintenance agreement with a suitable entity to ensure its continuous operation. Hosting the archive at AWS falls under the purview of WCOG. This responsibility involves managing the infrastructure required to store and maintain the vast amount of border data collected.

2.1.5 Existing System Components

As discussed in Section 2.1.2 Southbound ATIS and Section 2.1.3 Northbound ATIS, the existing system components consist of:

- Inductive loop detectors
- Roadside controller cabinets (vehicle detector stations/data stations) for data collection
- Anti-idling system (at Peace Arch/Douglas for the southbound direction only)
- Dynamic/variable message signs
- Traffic monitoring cameras/Closed-Circuit Television (CCTV) cameras
- Communications systems
- Electrical service
- Back-office systems/servers
    - Southbound ATIS server near Pacific Highway
    - Northbound ATIS server at WSDOT TMC

Figure 6 to Figure 8 below present an overview of the technologies that are currently deployed at each of the POEs, along with how they are connected. An online version of this map can be found at https://www.google.com/maps/d/u/0/edit?mid=1Ok2w2dyaRlLhB7f64rVqehhgGn4gRrQ&usp=sharing, which is the recommended method for viewing.

Note that this map does not show the locations of individual loop detectors or traffic monitoring cameras; only controller cabinets are shown. For locations of individual loop detectors, please visit the Cascade Gateway Border Data Warehouse website (https://cascadegatewaydata.com/Detector). For locations of individual traffic monitoring cameras, please visit the BCMOTI ATIS website (https://www.th.gov.bc.ca/atis/) and the WSDOT Travel Center Map website (https://wsdot.com/Travel/Real-time/Map/).

The following pages also include photos that were taken during the December 2023 site visits, along with brief descriptions of individual components.

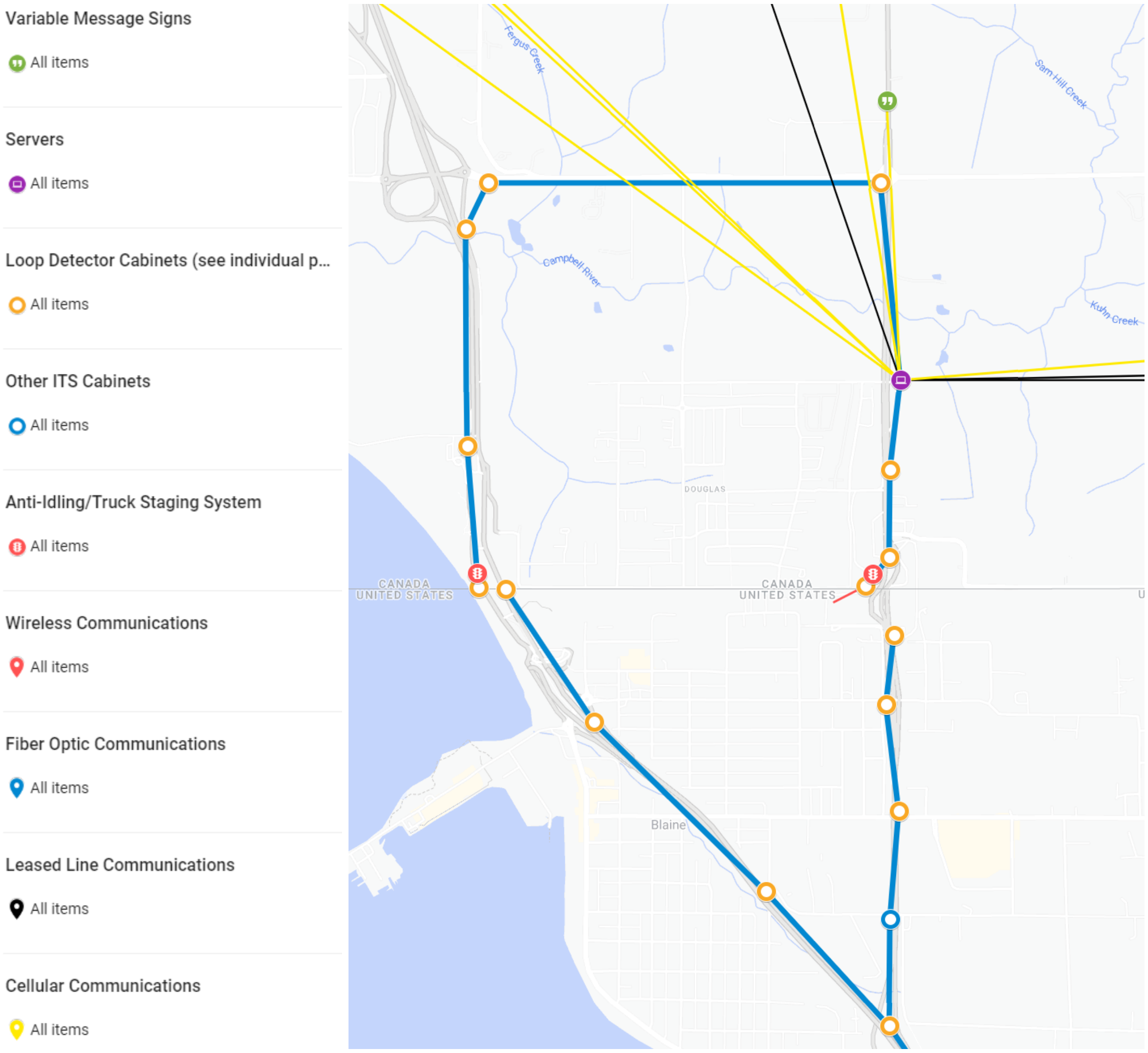


Figure 6. Excerpt from Online Map of Existing System Components at Peace Arch/Douglas and Pacific Highway

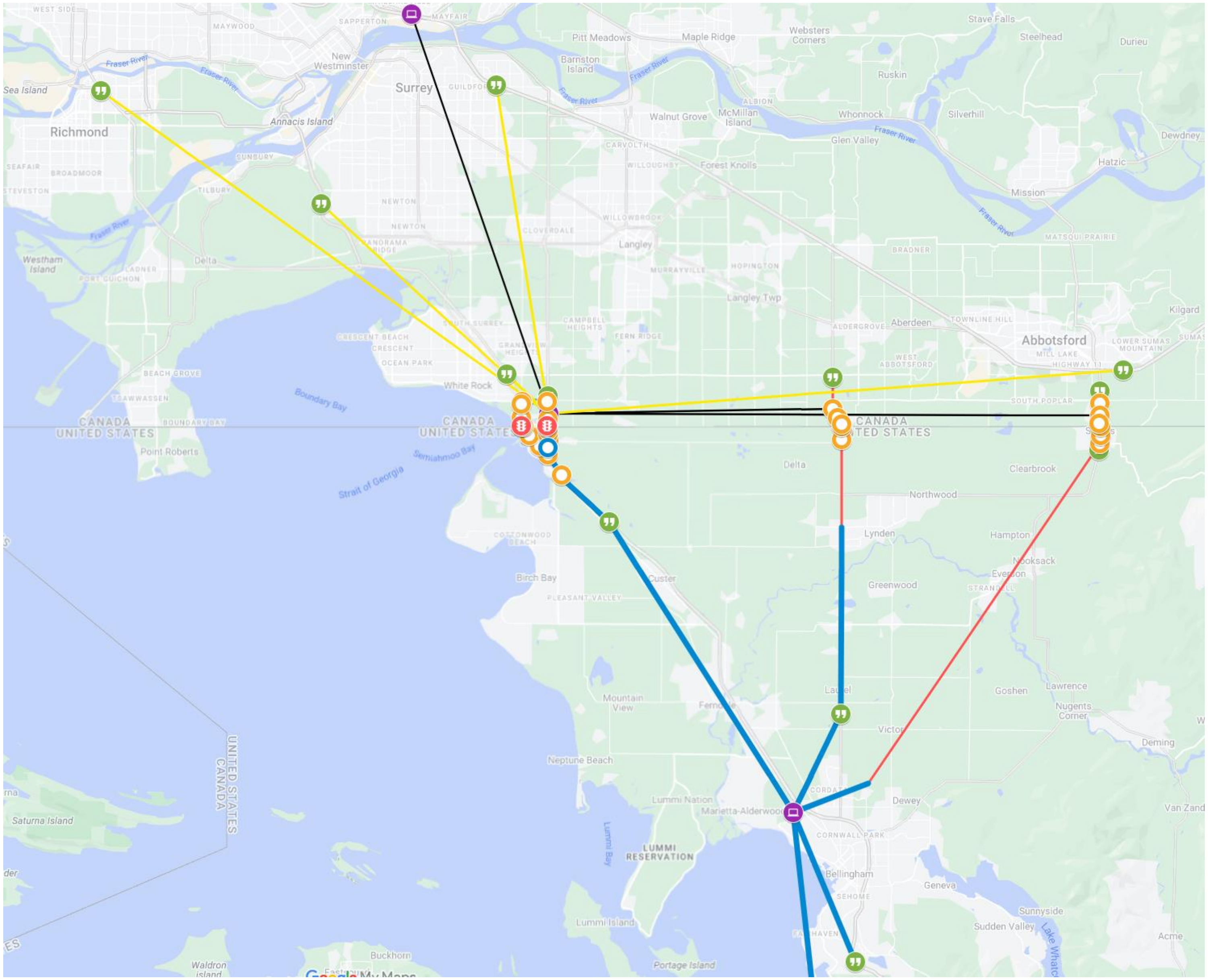


Figure 7. Excerpt from Online Map of Existing System Components - Cascade Gateway Overview

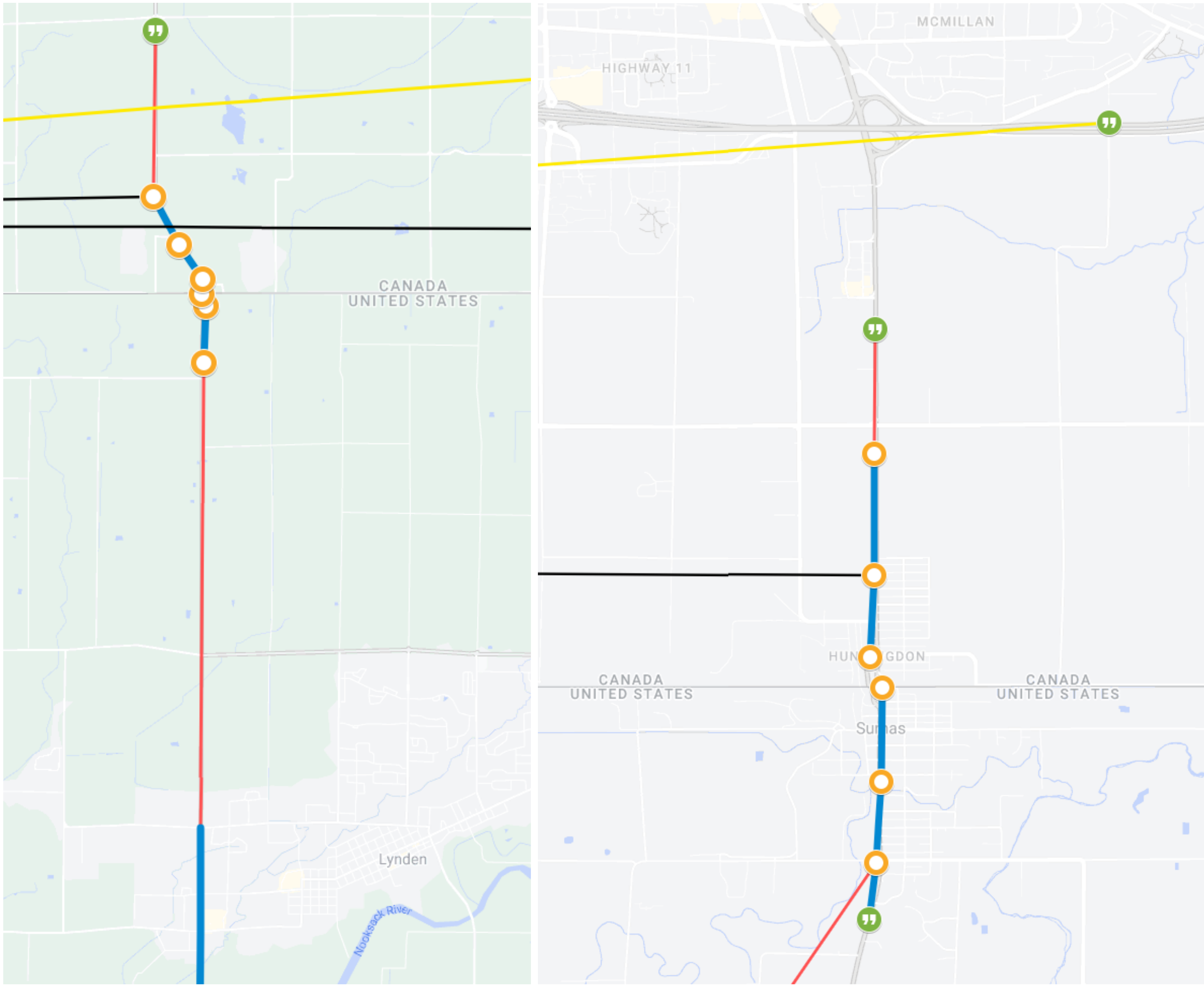


Figure 8. Excerpt from Online Map of Existing System Components at Lynden/Aldergrove and Sumas/Abbotsford-Huntingdon

Inductive Loop Detectors

Inductive loop detectors are installed within the pavement to collect traffic data (i.e., occupancy, volume, and, when combined with a second loop detector, speed) on vehicles traveling over them. The image on the left shows a pair of loop detectors in each lane at Peace Arch/Douglas, which provides vehicle count and speed data as traffic approaches the POE; this is typical for Vehicle Detection Stations and Data Stations on roadways that approach the POE. The image on the right shows a single loop detector (also known as a passage loop detector) just past each Primary Inspection booth, which counts the number of vehicles passing through the POE. See Section 3 for additional details on inductive loop detectors.


Roadside Controller Cabinets

Roadside cabinets house equipment that is needed to collect, process, store, and transmit data for use as part of the BWT calculation and data archival processes. The image on the left shows a BCMOTI Vehicle Detection Station, while the image on the right shows a WSDOT Data Station, both of which are used for inductive loop detector data. These cabinets typically contain loop detector cards, traffic controllers, and communications equipment. For WSDOT, packets of data are sent every 20 seconds from the controller cabinets to the TMC. Data is aggregated every five minutes for archival in the Cascade Gateway Border Data Warehouse, and the VMS are updated every five minutes. See the online version of the Existing ATIS map for locations of existing cabinets.

Anti-Idling System

The southbound Peace Arch/Douglas approach is equipped with an anti-idling system located approximately 1,000 feet away from the Primary Inspection area, as shown in the upper image. The system consists of a traffic signal that halts traffic for specified time increments at the stop bar when the inductive loop detectors identify that the queue has extended beyond a certain point. Once that occurs, the traffic signal changes to red and vehicles wait typically for 5-20 minutes, or until the queue has dispersed, at which point the traffic signal changes to green. Signage on the traffic signal instructs drivers to turn off their engines when the traffic signal is red. Also shown in this image is a CCTV camera, wireless antenna, and solar panel, though those elements are not directly tied to the anti-idling system. A similar system (truck staging system) also exists at the southbound Pacific Highway approach, consisting of traffic signals, signage, inductive loop detectors, and associated controller cabinet as shown in the bottom images, though it only serves commercial vehicles and sees low compliance from drivers.

Dynamic/Variable Message Signs

Dynamic (BCMOTI's nomenclature) and variable (WSDOT's nomenclature) message signs are electronic signs that can display messages for traveler information. In the context of the ATIS, these signs are used to display the current estimated wait times at nearby border crossings, or to indicate the operating hours for the crossing or for specific lane types. The image on the left shows a shoulder/post-mounted VMS from the Sumas/Abbotsford-Huntingdon POE on the U.S. side, while the image on the right shows the VMS equipment that is housed in an adjacent controller cabinet. DMS/VMS are currently installed well in advance of all four POEs, typically prior to decision points. See the online version of the [Existing ATIS map](#) for locations of existing DMS/VMS.

Traffic Monitoring Cameras

Traffic monitoring cameras, typically ones with pan-tilt-zoom capabilities, are used for traffic monitoring purposes. Both BCMOTI and WSDOT post still images from these cameras on their traveler information websites so that travelers can get a visual sense of how far back the queue currently extends at the border. The images below are from the Sumas/Abbotsford-Huntingdon POE on the U.S. side; the image on the left shows a camera mounted on a luminaire arm, while the image in the middle shows a camera mounted on a standard WSDOT camera pole (behind a weather station tower, which is unrelated to the ATIS), while the image on the right shows a controller cabinet containing both data station (inductive loop detector) and camera equipment. Traffic monitoring cameras are installed extensively throughout BC and WA.

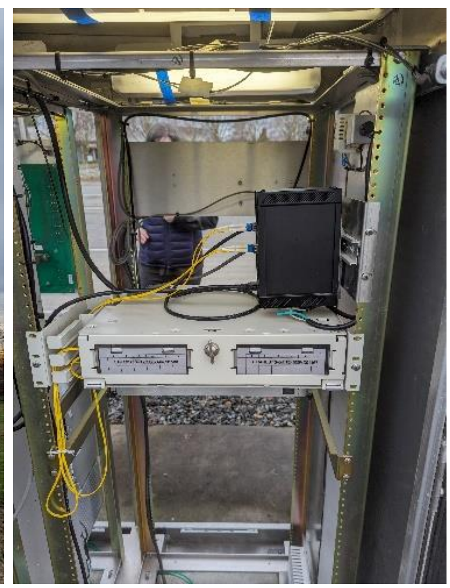
RFID Readers

RFID readers are typically installed overhead at two or more locations to collect data from truck transponders and/or toll tags, to determine the time it took for a vehicle to travel the distance between two readers. The image below shows RFID readers installed on a sign bridge near the Pacific Highway crossing on the U.S. side; RFID readers were not found to be present at any of the other POEs. However, it is unclear as to whether these readers are still in operation; WSDOT ITS has noted that these are not owned or operated by them. See Section 3 for additional details on RFID readers.

Communications Systems

Network communications is a critical component of the ATIS. It allows footage from traffic monitoring cameras to be viewed, and more importantly, serves as the means to transmit the traffic data that is collected at the roadside to server(s) where the data is processed and calculated into estimated border wait times. Various methods of communications are used for both the northbound and southbound ATIS, but generally includes fiber optic, wireless, and leased line communications systems. Based on discussions with WSDOT and BCMOTI, fiber optic communications has been working well, but wireless communications has been unreliable and have resulted in frequent data drops, which may be due to the age of the equipment. Additionally, the wireless communications technologies used by WSDOT at the Lynden and Sumas POEs are vastly different from one another. At Lynden, the existing NB ATIS is connected locally via fiber optic communications. However, there is a small fiber optic communications gap to the south, so WSDOT's uses a Ubiquiti point-to-point wireless system that connects the NB ATIS equipment to the nearby traffic signal at SR 539 & Badger Road (approximately two miles away to the south), which is then connected back to the WSDOT TMC via fiber optic communications. At Sumas, the existing NB ATIS is also connected locally via fiber optic communications. However, there is no other nearby fiber optic communications, so WSDOT uses a Solectek point-to-point wireless system that connects the NB ATIS equipment to WSDOT's existing network at King Mountain (approximately 16 miles away). The image on the left shows wireless communications in use by BCMOTI at Pacific Highway, while the image in the middle shows wireless communications in use by WSDOT at Sumas/Abbotsford-Huntingdon, while the image on the right shows fiber optic communications utilized by WSDOT.





Electrical Service

Traffic signal and ITS cabinets typically operate on 120V power. A metered electrical service cabinet (pictured in the middle, which is from Pacific Highway on the U.S. side) is typically required to convert the utility power source to 120V, which is the voltage typically needed to power the controller cabinet and the components that it is connected to, which typically draws utility power from a nearby power source (pictured on the left, which is from Lynden/Aldergrove on the Canadian side). Battery backup/Uninterruptible Power Supply (UPS) systems are also beneficial in keeping systems running in the event of a power outage (typically 24 hours or less for WSDOT UPS); the image on the right is from Pacific Highway on the Canadian side, though UPS are not in use consistently.

Back-Office Systems

The back-office systems refer to servers and other IT-related infrastructure that are critical to the operation of the ATIS. In particular, the southbound system relies on the ATIS server, which is located at the roadside at the northeast corner of the Pacific Weigh Scale near Hwy 15 & 4th Avenue in BC. The images below show the front and rear views of this cabinet, which houses a computer that handles the border wait time calculations, and communications equipment for transmitting data. See Section 2.1.2 Southbound ATIS and Section 2.1.3 Northbound ATIS for additional details.

Systems Unrelated to ATIS

Near the POEs, there are also other systems in use, but they are unrelated to the ATIS. This includes DMS/VMS to convey booth assignments, and sensors like monitoring cameras, license plate recognition cameras, and radiation sensors for USCBP/CBSA operations.

3. JUSTIFICATION FOR AND NATURE OF CHANGES

The existing northbound and southbound ATIS have been in place for 20 years and the hardware and back-end systems are ageing. The main challenges associated with the existing system are generally related to accuracy and reliability.

With accuracy, the existing system relies on loop detectors to measure vehicular traffic volumes, speeds, and occupancy, which in turn estimates the BWT. However, loop detectors generally do not perform well under stop-and-go conditions that are typically present in border crossing environments. As such, the underlying traffic data being collected and used to estimate BWT is often itself inaccurate, exacerbating the inaccuracy of BWT estimates. Additionally, the fixed locations of loop detectors result in a lack of flexibility for maintenance purposes (e.g., lane closures would be needed to replace existing detectors), as well as costly replacements in the event roadway construction results in lanes being paved or shifted. Their inability to re-identify vehicles along a corridor also means that wait times that are personalized to each lane type (e.g., general, NEXUS, etc.), which may change over time, cannot be provided unless lanes are physically separated, reducing flexibility in border operations. Lastly, estimated wait times (the wait time likely to be experienced by the next arriving vehicle) is not as appropriate a metric compared to measured wait times (the actual wait time experienced by travelers).

With reliability, the existing field systems are ageing, the algorithms used for data processing were developed 20 years ago, and network communications between field devices vary between fiber optic communications at the Peace Arch and Pacific Highway POEs, and less-reliable wireless communications systems at the Lynden and Sumas POEs, which have been observed to drop packets intermittently and disrupt system operations.

3.1 Existing System Issues and Challenges

A kick-off meeting was conducted on December 12, 2023 at the CBSA's Douglas POE offices to begin the stakeholder engagement as part of the systems engineering process. This included key stakeholders with representatives from WCOG, USCBP, CBSA, WSDOT, BCMOTI, and the project consultant team. Within this meeting, breakout sessions were conducted with various stakeholder groups to obtain input tailored to their unique perspectives and experiences with the system. The objectives of these breakout sessions were:

1) To inquire about the current methods of collecting, processing, and disseminating border wait times for both private vehicles and commercial motor vehicles; and
2) To identify deficiencies and challenges encountered by stakeholder agencies within the existing system.

The insights gathered from the kick-off meeting, breakout sessions, and site visits have elicited the issues and challenges, as summarized in the section below. Table 1 below presents a summary of the issues and challenges that stakeholders face with the existing ATIS, which have been grouped into logical classifications.

Table 1. Existing Issues and Challenges with Current ATIS

Classification	Issue/Challenge
System	Reliability issues with the existing wireless communications system caused data updates to be delayed by 15 minutes at Ports of Entry (POEs) such as Sumas and Lynden.
	Loop detector maintenance is an ongoing issue requiring significant effort and labor.
	Lack of information on upstream traffic data hampers wait time estimation.

Classification	Issue/Challenge
	The system's data updating frequency needs to be lowered as this affects the accuracy and utility of the system
	Slow speed and lane changes within the loop detectors result in inaccurate data records.
Algorithm	Inaccurate wait time estimates, particularly at Lynden POE where issues with data transmission reliability are present. The inaccuracy in wait time estimates is especially significant on the BC side which has stopped the wait time being shown online.
	Lack of transparency and documentation on the border wait time algorithm for the SB ATIS, which was developed years ago and is proprietary, hindering understanding and optimization of the algorithm.
	The VMS displays the wait time solely, rather than reflecting the travel time and wait time for traffic management issues.
	The algorithm lacks scenario analysis to accommodate factors like heightened traffic, increased demand, and special events.
Operations	Lack of information regarding what mode is being processed through each lane.
	At booths where officers process both pedestrian and motorized traffic simultaneously, there are additional motorized vehicle delays.
	Inspection agencies lack real-time information on upcoming traffic demand, hindering the effective allocation of inspector officers at booths.
	Agencies need to adjust operations and staffing to ensure lower waiting times for NEXUS users.
	Not all lanes are interchangeable for the NB POEs, like at Douglas where the NEXUS lane is physically separated, leading to extra delays when one lane has shorter queues.
	Traffic management center staff need the ability to disable wait time information from displaying (e.g., on websites, apps, VMS, etc.) when information is inaccurate, or the border is closed.
	Several of the POEs will undergo redevelopment and/or expansion, which will alter traffic patterns and operations. Flexible technologies that can easily be re-located, re-installed, or simply re-configured would be preferred. Information will be needed to ensure that the system's physical design and algorithm accommodate these changes.
Roadway Design	Uneven lane branching at the SB Pacific Highway POE leads to delays, particularly affecting NEXUS and Ready lanes due to unaccounted traffic from lane merging upstream.
	Inadequate turning radius for commercial vehicles at the southbound Pacific Highway lanes hinders lane utilization, leading to higher-than-reported border wait times.
	Truck staging area design issue in SB POE; insufficient space dedicated to stage trucks causing delays in both approaches at Pacific Highway.
Equipment	Ageing equipment and inaccurate data contribute to delays at the border.

Classification	Issue/Challenge
Other	Routing applications and tools not accounting for border wait times, defaulting to Peace Arch border crossing irrespective of wait times.

3.2 Assumptions and Constraints

The design and deployment of the ABIS will need to consider several known constraints. This includes planned construction at several POEs, upcoming bi-national events like the FIFA World Cup in 2026, and constraints associated with the SMART grants funding source.

Within the next few years, several of the POEs and the adjacent roadways will be undergoing significant development. With the deployment of the ABIS (pending available project funding anticipated through Stage 2 of the SMART Grants Program) anticipated around the same time, it will be important to consider the physical changes that will be coming to the project area to ensure that the technologies being deployed do not significantly conflict with other proposed improvements, and vice versa. Below is a summary of the planned U.S. and Canadian projects that the project team is aware of:

- U.S. POE Projects
  - o **Pacific Highway POE**: "The expansion project will add four new POV inspection lanes, expanding capacity to ten lanes total. The project also expands the secondary inspection area to provide six enlarged bays for vehicle enforcement inspections, 24 secondary main building referral parking spots, and six enlarged bays for secondary inspection enforcement. All inspection areas will include extended overhead canopies, replaced pavement, and upgraded lighting."
  - o **Lynden/Aldergrove POE**: "The expansion project will expand and separate personal vehicle traffic and commercial screening operations, possibly allowing for a 24-hour, full-service port operations. When completed, the port at Lynden will feature five personal vehicle lanes and four commercial processing lanes."
  - o **Sumas/Abbotsford-Huntingdon POE**: This project will "expand and modernize personal vehicle and commercial screening operations. Commercial inspection lanes will increase from two to four, and personal vehicle lanes will increase from five to six. Main building operations will be fully modernized and a dedicated pedestrian corridor will be constructed."
- Canadian POE Projects
  - **Pacific Highway POE:** As part of the CBSA's Land Border Crossing Project, the northbound POE will be completely reconstructed. Construction is expected to begin in 2025 and be completed in 2026.
  - **Highway 13 (Lynden/Aldergrove POE) Expansion:** The ongoing expansion of Highway 13, which will include NEXUS lanes, is almost complete. This project modifies roadway geometry, so roadside cabinets/equipment and system algorithms will be updated.
- Approach Road Projects
  - **George Massey Tunnel Redevelopment**: The Highway 99 Tunnel Program aims to replace the aging George Massey Tunnel with a toll-free, eight-lane immersed tube tunnel. This program encompasses improvements for motorists, transit, and active transportation users along the Richmond to Delta corridor.

- **Vye Road Overpass and Highway 11 Widening Project**: This project, which was recently completed, involved widening Highway 11 to extend the NEXUS lane, along with constructing a two-lane overpass on Vye Road. This project modified roadway geometry, so roadside cabinets/equipment and system algorithms were updated.
- **CBSA Assessment and Revenue Management (CARM) Digital Initiative**: This initiative will introduce a new system for assessing and collecting duties and taxes on commercial goods imported into Canada, akin to the USCBP's Automated Commercial Environment (ACE).
- **CBSA Travel Monitoring System**: CBSA is implementing a travel monitoring system focused on NEXUS lanes, utilizing eGates to select commercial motor vehicles for inspection, employing electronic (chip) cards to streamline processes, and integrating CARM in May 2024 (note – this system tracks cargo but does not include wait times).

The 2026 FIFA World Cup will take place in the summer (June and July) of 2026 and will include several matches in the Group Stage, Round of 32, and Round of 16 in Vancouver, BC and Seattle, WA, as summarized below in Table 2. Given the proximity between the two cities, it is expected that the U.S.-Canada border, particularly at the Peace Arch/Douglas and Pacific Highway POEs, will see increased traffic during the summer months, typically the period of highest cross-border volume.

Table 2. 2026 FIFA World Cup Match Schedule

Match Date	Vancouver, BC	Seattle, WA
Saturday, June 13	X	
Monday, June 15		X
Thursday, June 18	X	
Friday, June 19		X
Sunday, June 21	X	
Wednesday, June 24	X	X
Friday, June 26	X	X
Wednesday, July 1		X
Thursday, July 2	X	
Monday, July 6		X
Tuesday, July 7	X	

The combination of the 2026 FIFA World Cup and the planned construction at three of the four POEs presents an urgent need for an improved traveler information system. The unreliability and inaccuracy of the existing ATIS risks additional delay, uneven distribution of traffic across the POEs, and driver frustration with posted wait times not aligning with reality. The implementation of the ABIS provides several advantages as well, including more reliable and accurate wait time estimates, improved traveler information that includes dynamic re-routing to alternate POEs, and predictive analytics to better plan future trips.

Another consideration involves constraints associated with what the SMART grants program can fund. For example, funds cannot be used to purchase License Plate Recognition (LPR) cameras. While LPR cameras would be the most accurate method to re-identify vehicles and validate border wait times, and while privacy concerns could potentially be mitigated by processing data anonymously in the field through advances in edge computing, the technology cannot be used for this project. Funding also cannot be used for construction of the improvements in Canada; strategies for overcoming this constraint will be explored in the Implementation Report.

4. CONCEPTS FOR THE PROPOSED SYSTEM

The concept for the proposed ABIS presented in this ConOps resulted from a state of the practice and literature review, research, stakeholder engagement activities involving workshops to elicit user needs, and meetings with technology vendors to gain a deeper understanding of available technologies and their applicability to BWT applications. This section of the document includes: a description of the ConOps essential features, capabilities, and functions; profiles of the user classes and other involved personnel, conceptual high-level system architecture, and support environment.

4.1 Description of Essential Features, Capabilities, and Functions

One of the key inputs to this ConOps document is the user needs, which are derived from the issues and challenges that staff face with the existing system. Ultimately, the user needs describe what users of the system need the system to do, which in turn translate into the essential features, capabilities, and functions of the ABIS, and are used to develop the operational scenarios, which ultimately feed into the required functionality of the system, the high-level design, and finally the system requirements with which the system will be procured. Table 3 below presents a summary of the user needs, which have been grouped into logical classifications and includes traceability to the Issues and Challenges described previously in Table 1.

The user needs are categorized into the following functional classes:

- System Features
- System Algorithm and Data Collection
- Traveler Information
- Data Transmission, Storage, and Archival
- System Operation and Maintenance

The user needs are also categorized into three priority levels:

- High: Critical functionality that is essential for the success of the system.
- Medium: Desirable capabilities with considerable interest, but not critical.
- Low: Additional functionalities that provide extra value.

Table 3. User Needs for Future ABIS

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
System Features	UN-1	The ABIS needs to consider and be compatible with the existing anti-idling system at Peace Arch/Douglas (SB).	Medium	System
	UN-2	The ABIS needs provide a new anti-idling system at Peace Arch/Douglas (NB).	Medium	System
	UN-3	The ABIS needs to consider and be compatible with upcoming initiatives, including but not limited to: • CBSA Assessment and Revenue Management (CARM) • USCBP Automated Commercial Environment (ACE) • NEXUS eGate • Planned/on-going construction projects (e.g., reconstruction and expansions at Pacific Highway, Lynden/Aldergrove, and Sumas/Abbotsford-Huntingdon, George Massey Tunnel replacement project, Highway 13 expansion, Abbotsford overpass construction, etc.).	Low (for CARM, ACE, and eGate), High (for planned/on-going construction)	Operations
	UN-4	The ABIS needs to consider privacy as it relates to laws and regulations for both the U.S. and Canada.	High	Data Sharing

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-5	The ABIS needs to consider data security and cybersecurity best practices. For example, servers that calculate the BWTs should not be located at the roadside.	High	Equipment
	UN-6	The ABIS needs to utilize open standards and algorithms.	Medium	Algorithm
	UN-7	The ABIS needs to be updated on a regular basis. This may include system/server updates, security updates, algorithm updates, and data transmission networks/methods.	High	System
	UN-8	The ABIS needs to be scalable to accommodate future data needs (e.g., additional lanes, lane types, POEs, data sources, etc.)	High	System
	UN-9	The ABIS needs to serve as a test case for other agencies, such that a similar system can potentially be deployed at other U.S. – Canada and U.S. – Mexico border crossings.	Medium	Other
	UN-10	The ABIS needs to be resilient and reliable (e.g., minimal down-time).	High	System
System Algorithm and Data Collection	UN-11	The ABIS needs to automatically adjust to changing inspection lane types (e.g., open vs closed, NEXUS vs general purpose vs FAST vs bus vs commercial vs pedestrian, etc.)	High	Algorithm

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-12	The ABIS needs to accurately measure BWTs for each lane and lane type at each POE in real-time. • At Pacific Highway NB and SB going to/from BC 15 and SR 543, the physical geometry results in uneven lane bifurcation (e.g., two lanes becoming four or six) where a bottleneck forms, since drivers might not be aware of additional lanes becoming available near the primary inspection area. • At Pacific Highway SB for commercial vehicles, the physical geometry is insufficient for trucks to make wide turns as they approach the inspection area., resulting in some lanes being underutilized and delays being more than what is reported.	High	Infrastructure
	UN-13	The ABIS needs to consider both real-time and historical traffic data in its calculation of travel time and BWT.	High	Algorithm
	UN-14	The ABIS needs to measure emissions in real-time at each POE.	Medium	System
	UN-15	The ABIS needs to estimate emissions in real-time at each POE.	Medium	System
	UN-16	The ABIS needs to consider and not preclude the use of crowdsourced data (e.g., location-based services data), either in lieu of or to supplement the use of field equipment.	Medium	Algorithm

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-17	The ABIS needs to consider the use of freight data (e.g., data feeds from trucking companies, data collected from RFID readers/truck transponders, etc.).	Medium	System
	UN-18	The ABIS needs to measure how traffic diverts to other POEs as they approach the border. This may involve a report that documents the quantity and type (e.g., general purpose, freight, etc.) of vehicles traveling in certain directions along certain corridors, and the percentage of vehicles that head towards the various POEs.	Medium	System
	UN-19	The ABIS needs to be suitable for use in border crossing environments, such as being capable of measuring slow-moving vehicles that are changing lanes.	High	System
Traveler Information	UN-20	The ABIS needs the ability to disseminate BWTs for each lane type at each POE for a vehicle at the current back-of-queue.	High	System
	UN-21	The ABIS needs the ability to disseminate BWTs for each lane type at each POE for a vehicle at the VMS displaying the BWT message. The BWT displayed needs to include the time needed for the vehicle to travel to the back-of-queue, as well as any additional wait time associated with the formation of longer queues.	High	System

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-22	The ABIS needs the ability to identify alternative POEs that drivers should divert to, based on factors such as distance, BWT (inclusive of travel time to forecasted back-of-queue), greenhouse gas emissions, etc.	High	Other
	UN-23	The traveler information system needs the ability to automatically divert traffic to other POEs.	High	System
	UN-24	The traveler information system needs to provide more clear and detailed VMS messaging.	Medium	System
Data Transmission, Storage, and Archival	UN-25	The ABIS needs to reliably disseminate BWTs to various sources in a timely manner, including existing traveler information systems (e.g., Variable Message Signs [VMS], traveler information websites, mobile apps, etc.) and the BDW. BWTs need to be disseminated to traveler information systems at a minimum frequency of every minute.	High	System
	UN-26	The ABIS needs to include an Application Programming Interface (API) for others to access the data. Real-time data feeds will need to be provided to, at a minimum: WSDOT, BCMOTI, USCBP, CBSA, WCOG (Cascade Gateway Border Data Warehouse [BDW]).	Medium	Data Sharing
	UN-27	The ABIS needs to archive BWT data indefinitely in the BDW.	High	Data Sharing

Functional Class	**User Need ID**	**User Need**	**Priority**	**Traceability to Issues/Challenges Categories**
	UN-28	The ABIS needs to collect and archive the following data, at a minimum: • Measured BWT for each lane and lane type at each POE. • Vehicle volumes for each lane and lane type at each POE. • Vehicle speeds for each lane and lane type at each POE. • Queue length/location of back-of-queue at each POE.	High	Data Sharing
	UN-29	The ABIS needs to collect and archive the following data, at a minimum: • Vehicle classifications for each lane and lane type at each POE.	Low	Data Sharing
	UN-30	The ABIS needs to be compatible with the existing BDW.	High	Data Sharing
	UN-31	The ABIS needs to, at a minimum, utilize the existing data fields and formats that are currently in use by the existing BDW.	High	Data Sharing
	UN-32	Wireless communication at Lynden (NB) is expected to remain for the foreseeable future. A more reliable wireless communications system is needed.	Medium	Data Sharing
System Operation and Maintenance	UN-33	Customs officers need to know the real-time traffic demand at and approaching each Port Of Entry (POE), in order to be able to adequately staff the inspection booths at any given time.	High	Algorithm

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-34	Customs officers need the ability to change inspection lane assignments (e.g., NEXUS vs general purpose) via the ABIS.	Low	Operations
	UN-35	Customs officers need to have easy and reliable access to accurate wait times, issues, and alerts. Currently, there are various sources of information (e.g., WSDOT's Border Wait Time [BWT] website, WSDOT's Travel Center Map website, BCMOTI's DriveBC.ca website, etc.).	High	Operations, Data Sharing
	UN-36	The data that customs officers primarily need access to on a day-to-day basis includes BWTs for each lane type at each POE.	High	Operations, Data Sharing
	UN-37	Customs officers need the ability to perform "what-if" scenario analysis to predict how BWTs may change within the near future (e.g., within the next few minutes or hours). • This needs to consider both real-time upstream traffic data, as well as manually-entered traffic volumes (to simulate surges in traffic, special events, etc.). A range of BWTs (e.g., 15–20 minutes) may be provided.	High	Algorithm

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-38	Customs officers need the ability to perform "what-if" scenario analysis to predict how BWTs may change for any given time, date, or month (e.g., 4pm on July 1st). • This needs to consider historical traffic data, as well as manually-entered traffic volumes (to simulate surges in traffic, special events, etc.). A range of BWTs (e.g., 60–90 minutes) may be provided.	High	Algorithm
	UN-39	The ABIS needs the ability to automatically alert/notify users of various conditions, including but not limited to: • Suspected inaccuracies in the data. • BWTs, volumes, and/or speeds exceeding configurable thresholds.	High	Equipment
	UN-40	The ABIS needs to be easily maintainable by agency staff. • Equipment located within the U.S. will be maintained by WSDOT. • Equipment located within Canada will be maintained by a contractor on behalf of BCMOTI.	High	Equipment
	UN-41	The ABIS should include configurable dashboards to aid in operations, monitoring, and decision-making.	High	System

Functional Class	User Need ID	User Need	Priority	Traceability to Issues/Challenges Categories
	UN-42	The ABIS's field equipment needs to be adaptable to changing conditions at the POEs, such as changing lane types and geometry, maintenance activities (e.g., paving), and physical construction (e.g., planned reconstruction and expansions at Pacific Highway, Lynden/Aldergrove, and Sumas/Abbotsford-Huntingdon).	High	Equipment
	UN-43	Staff need to be trained adequately in the operations and maintenance of the ABIS.	High	Equipment
	UN-44	By 2026, the ABIS needs to be operational to help manage the increase in cross-border traffic anticipated with the 2026 FIFA World Cup.	High	Operations
	UN-45	By 2026, the ABIS needs to be operational to help support cross-border traffic management, given the planned reconstruction and expansions at several of the POEs.	High	Operations

Based on the user needs that were identified with a priority level of High, the critical user needs translate into the following essential features of the system:

Table 4. Traceability of Essential Features to Critical User Needs

Essential Feature	Traceability to Critical User Needs
The system needs to accurately and reliably measure BWT at each of the region's four POEs for each lane type in real time.	UN-7 UN-10 UN-12 UN-19 UN-33 UN-35 UN-36

Essential Feature	Traceability to Critical User Needs
The system needs to automatically adjust to changing conditions, such as lane status changes, lane closures, etc.	UN-11 UN-22 UN-23 UN-42
The system needs to incorporate predictive analytics to allow users to leverage historical and real-time traffic data to predict conditions at the POEs.	UN-13 UN-37 UN-38
The system needs to integrate with existing and future systems and provide real-time data feeds, as needed. This may include existing traveler information systems such as DMS/VMS, websites, etc.	UN-20 UN-21 UN-25
The system needs to archive data indefinitely and integrate and be fully compatible with the Cascade Gateway Border Data Warehouse.	UN-27 UN-28 UN-30 UN-31
The system needs to include reporting capabilities and dashboards.	UN-41
The system needs to be secure (data security, cybersecurity, etc.) and comply with US and Canadian privacy laws.	UN-4 UN-5
The system needs to be scalable and forward compatible, allowing for additional features and technologies to be incorporated and	UN-8
The system needs to be maintainable.	UN-39 UN-40 UN-43
The system needs to be operational in time for the 2026 FIFA World Cup and the planned reconstruction/expansions.	UN-44 UN-45

4.2 Conceptual High-Level System Overview

The preferred technology concept utilizes a combination of technologies, including radar detection, Bluetooth/Wi-Fi readers, and a new smartphone application.

Radar detection would be used in addition to/conjunction with existing loop detectors, where feasible. For example, at locations upstream of the POEs where stop-and-go traffic is not typically present, existing loop detectors could potentially remain and be recalibrated, while radar detection is installed near the POEs where vehicles are traveling more slowly and maintenance activities could benefit from non-intrusive forms of detection. Alternatively, radar detection can be used completely in lieu of existing loop detectors. Note that radar detection is only one potential option; other non-intrusive forms of detection that are capable of collecting the traffic data needed for the system could also be used, such as those involve video analytics.

Bluetooth/Wi-Fi readers will be deployed to re-identify vehicles using the Media Access Control (MAC) addresses of devices like smartphones and vehicle infotainment systems.

A new smartphone application will be developed to provide travelers with navigation/BWT/travel time information, while also re-identifying vehicles by lane type based on the app user's lane type selection. The app can help provide increased accuracy with lower implementation costs due to the minimal infrastructure required. With user consent, the BWT app, once installed, tracks vehicles continuously (within the geofenced area) from the time a vehicle joins the back of the queue to the time it exits primary inspection. However, GPS II technology does not allow for tracking of vehicles within individual lanes, so the BWT app will need to ask users to identify which lane they are traveling in, in order to measure BWT by lane type. This approach minimizes the need for roadway infrastructure and makes it very cost effective. It can be used for determining BWT for both passenger and commercial vehicles. By serving as a Cellular-Vehicle-to-Everything (C-V2X) application, the app provides a pathway to a future "infrastructureless" system that leverages upcoming GPS Block III technology to provide per-lane BWT information without the need for physical roadside infrastructure.

Care will be taken to ensure that the location tracking process is anonymous and secure and complies with Federal Risk and Authorization Management Program (FedRAMP) standards, a government program that provides a standardized approach to security assessment, privacy, authorization, and continuous monitoring of IT products and services used by federal agencies to store, process, and transmit information. The program is based on the Risk Management Framework (RMF) that implements the Federal Information Security Modernization Act (FISMA) requirements and NIST SP 800-53. The app, using GPS II technology, offers an additional layer of accuracy by tracking vehicle movements with satellite-based positioning. By integrating GPS readings into the system, the system enhances the precision of vehicle identification and wait time calculations. This approach retains the reliability of radar (and loop detectors, if desired) while harnessing the benefits of GPS technology for improved real-time tracking and data accuracy.

Lastly, the data will be integrated into new and existing systems. This includes existing traveler information systems like websites, VMS/DMS, and the Cascade Gateway Border Data Warehouse. Additionally, Artificial Intelligence (AI) and Machine Learning (ML) will be leveraged to enable predictive analytics based on historical data to better predict what the BWT might be for different dates, times, and situations.

The proposed technologies are shown in Figure 9, with proposed deployment locations shown in Figure 10. Figure 11 shows the concept's proposed system architecture and data flow diagram.

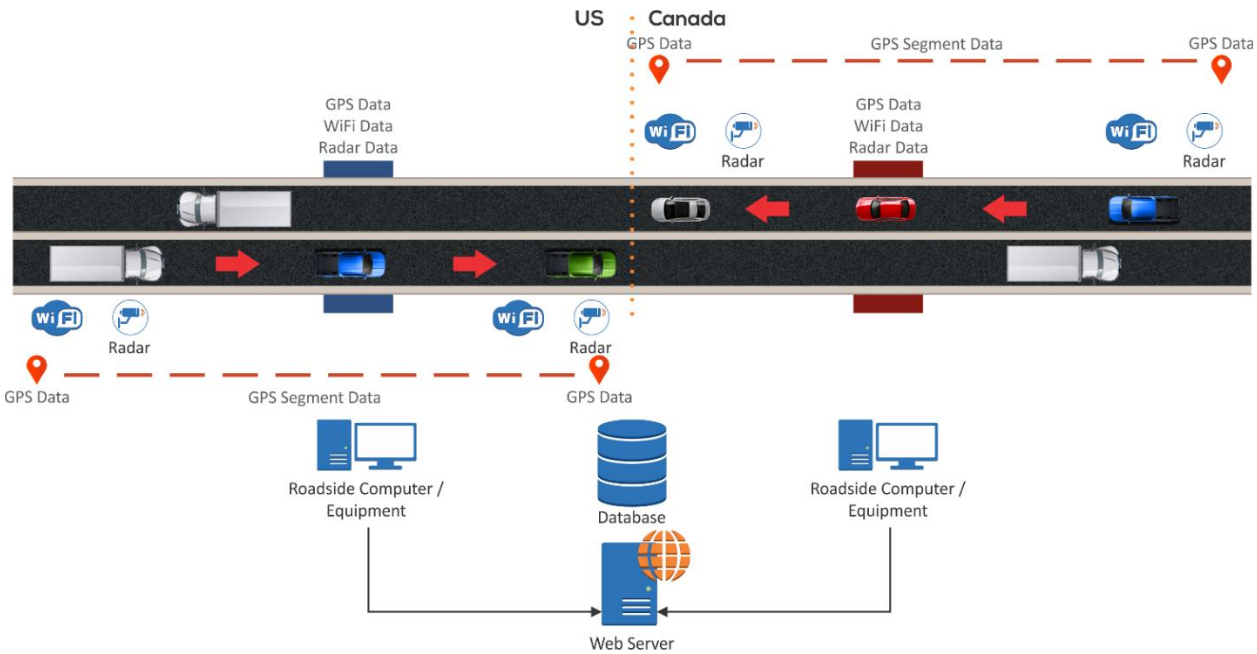


Figure 9. Proposed Technologies Overview

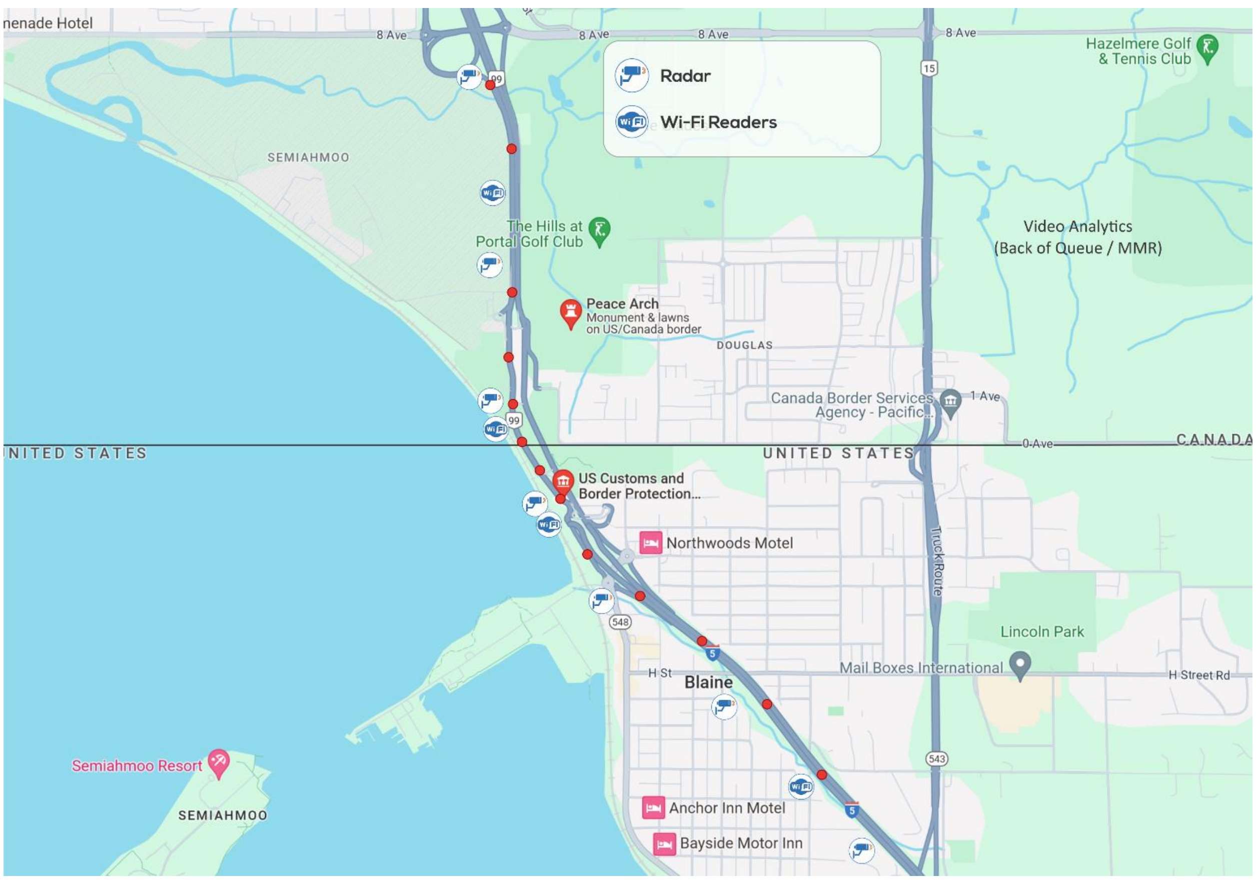


Figure 10. Proposed Roadside BWT Measurement Technologies

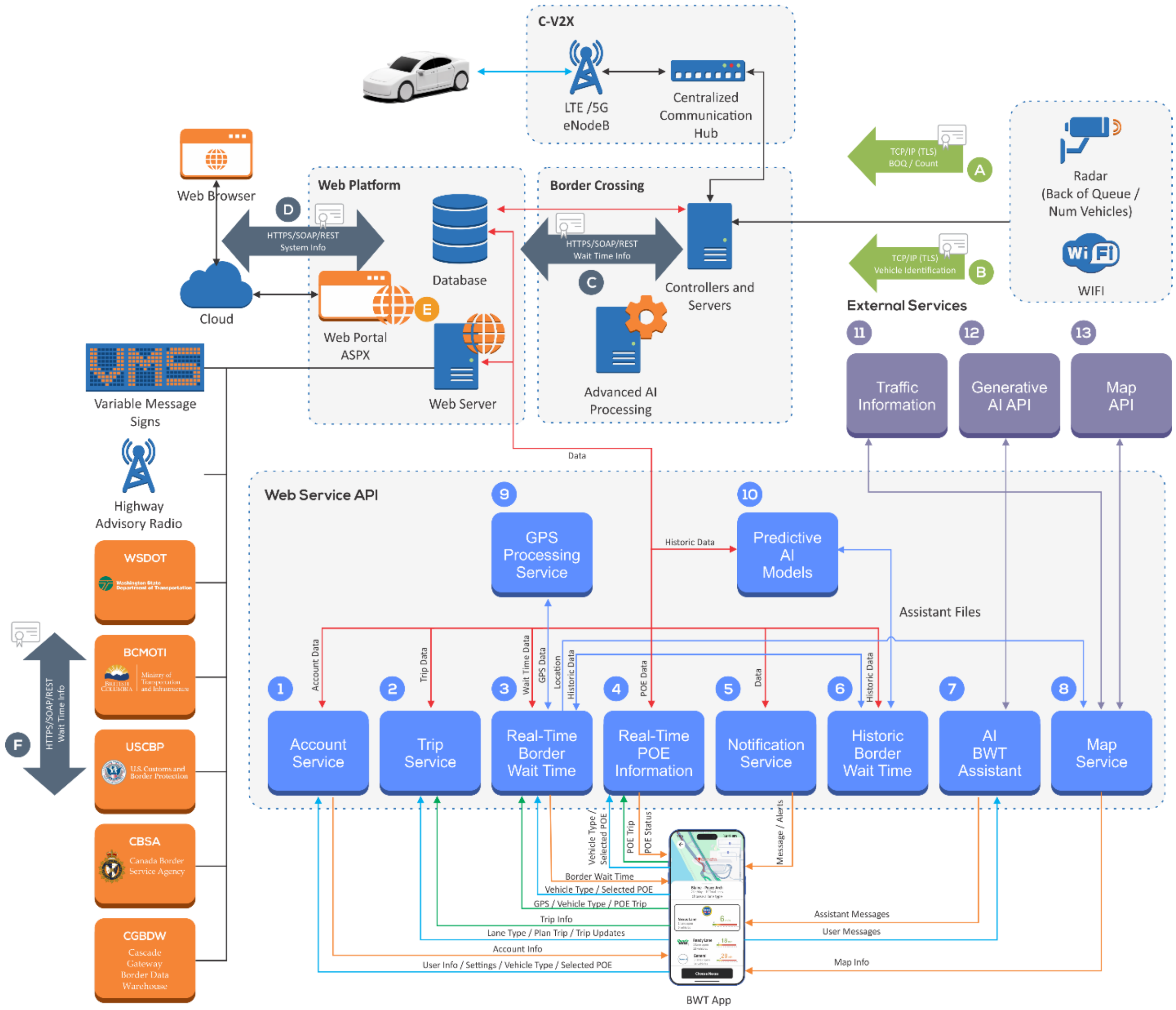


Figure 11. Proposed System Architecture and Data Flow

The proposed system architecture includes a central server and communications hub that processes data from radar detection system, Bluetooth/Wi-Fi readers, and mobile app. C-V2X communications technology would connect to this hub as another data input/output channel. The hub would collect data from C-V2X-equipped vehicles, process it alongside data from existing sources, and then send relevant information back to the vehicles. Middleware software and Application Programming Interfaces (API) would facilitate communication between the C-V2X platform and the existing systems. These would standardize data formats, manage communication protocols, and ensure compatibility. APIs would allow C-V2X data to be accessed and used by existing systems without needing to overhaul the entire infrastructure. The C-V2X technology rely on Vehicle-To-Infrastructure (V2I) communication, where vehicles interact with RoadSide Units (RSU) or other infrastructure components. These RSUs would need to be installed at strategic locations near the border, such as entry points, lanes, and checkpoints. RSUs would be connected to the central system to send and receive data. These units would communicate with C-V2X-enabled vehicles in real-time, providing updates on wait times, lane assignments, and any changes in conditions.

A short video demonstrating the conceptual design of the mobile app can be found at: https://vimeo.com/999161315/fc244206c1?share=copy.

In summary, the system combines the existing VDS/data station infrastructure and enhances accuracy by replacing (or supplementing) existing loop detectors with radar detection, deploys new radar detection to capture back-of-queues during peak periods, develops a new dedicated Cascade Gateway BWT app based on GPS II technology, deploys Bluetooth/Wi-Fi readers to re-identify vehicles and supplement the data gathered from the BWT app, and utilizes AI and advanced data analytics to optimize BWT measurement and management. Table 5 below provides a summary of the technologies proposed, while Table 6 provides a summary of the concept's advantages and disadvantages.

Table 5. Summary of Proposed Technologies

Technology	Purpose
Radar Detection	Determine the number of vehicles (counts) and back of the queue. Radar can be more accurate than loop detectors in stop-and-go traffic, and can provide additional traffic data (e.g., vehicle classifications). As a non-intrusive form of detection, maintenance of radar detection is expected to be easier when compared to loop detectors.
Loop Detectors	Determine the number of vehicles (counts) and back of the queue. Note that loop detectors would only be needed if the agencies desire for the existing loop detectors to remain. Note that loop detectors would only be needed if the agencies desire for the existing loop detectors to remain. They can serve as a backup/supplemental data source, but would not be needed. Maintenance of loop detectors near the border has been a pain point for the agencies.
Bluetooth/Wi-Fi Readers	Vehicle identification and re-identification and wait times for all vehicles. However, Bluetooth/Wi-Fi readers cannot reliably differentiate between NEXUS, Ready, and standard lane groups.
Cascade Gateway BWT C-V2X Mobile App	New smartphone application that provides traveler information, trip planning tools, and map-based navigation assistance to measure BWT by lane type. This also serves as a C-V2X application that enables future infrastructureless operation once GPS Block III is operational; GPS Block III involves significant improvements to GPS reliability and accuracy through the deployment of ten new satellites, expected by the end of 2026.
AI & ML	Analysis of existing data, dashboards, reports, predictive BWT capability, and data archival. Provides What-If scenario analysis and capabilities for predicting traffic surges based on analytics
Mapping Interface	Map based interface; real-time data depicted on map.
Stakeholder-Specific Dashboards and Outputs	Dashboards tailored to the needs of each agency, providing operational insights into BWT and traffic operations leading up to and at the POEs.
Cascade Gateway Border Data Warehouse (CGBDW)	The existing system that has archived BWT data since 2005 will continue to operate. The ABIS will be compatible with the CGBDW, and future upgrades may be implemented to expand its capabilities.

Table 6. Advantages and Disadvantages of Technology Concept

Advantages	Disadvantages
Enhanced accuracy of wait time measurements using radar detection, additional detection, and AI algorithms.	Reliance on physical detection like radar or loop detectors.
Leverages the use of existing VDS/data station infrastructure, if desired.	Need for additional VDS/data stations to cover extended back-of-queues during high demand.
Predictive analytics for better resource allocation and improved efficiency.	Users need to download the app, which may be a barrier to entry. Approximately 10-15% penetration rate is needed for accurate measurements.
Improved traveler experience through real-time data and predictive analytics.	Users need to provide consent for tracking within geofenced port of entry approaches.
Scalable and flexible system that is adaptable to various traffic patterns and border POEs.	Manual user input is needed to select which lane they are traveling in.
The use of the Cascade Gateway BWT app serves as the backup and a validation method to ensure increased accuracy and lower overall costs.	App will require maintenance and marketing.
The Cascade Gateway BWT app can provide additional traveler information, such as dynamic routing to alternative POEs based on real-time demand, communicating lane status and changes, etc.	
Hybrid solution that utilizes more than one data source for measuring wait times, making it easier for cross verification and validation	

4.3 User Class Profiles and Other Involved Personnel

The users and stakeholders of the ABIS are expected to be the same as those described previously in Section 2.1.1 System Stakeholders. However, roles and responsibilities are expected to change, as described below.

- **WCOG** will continue to oversee the Cascade Gateway Border Data Warehouse. WCOG may also take on operations and maintenance, including on-going updates, of the mobile app; discussions around this topic are on-going.
- **WSDOT** will continue to own, operate, and maintain the field equipment installed on the US side. This includes any roadside sensors, communications systems, and central system equipment needed to collect, transmit, and store the data. As Lead Application for the Stage 2 project, WSDOT will also be responsible for contracting with a consultant, developer, and/or design-builder for the detailed design and implementation of the system. Once implemented, WSDOT will be responsible for operations and maintenance of the system.

- **BCMOTI** will continue to maintain the field equipment on the Canadian side. However, there will no longer be separate northbound and southbound systems, so BCMOTI will no longer need to maintain its own algorithm.
- **USCBP** will continue to oversee border security and operations for the United States. With the ABIS, they will have greater access to more accurate and reliable data, including dashboards.
- **CBSA** will continue to oversee border security and operations for Canada. With the ABIS, they will have greater access to more accurate and reliable data, including dashboards.
- **System Users**, which includes the traveling public (e.g., general public, private industry, etc.), will have access to significantly improved traveler information in the form of more reliable and accurate wait time estimates, navigational assistance, and predictive analytics for trip planning.

5. OPERATIONAL SCENARIOS

This section presents the "day-in-the-life" descriptions of different operational scenarios that are intended to illustrate how stakeholders will use and interact with the system, as summarized below in Table 7.

Table 7. Summary of Operational Scenarios

Operational Scenario	ABIS Functional Class	Issues and Challenges Categories Addressed	Benefits
Traveler Trip Planning (2026 FIFA World Cup)	Traveler Information	Algorithm Operations Other	Travelers can be provided with additional information to help plan for their trips (e.g., when do they need to leave to arrive at a cross-border destination at a certain time). This can be particularly beneficial during situations with cross-border traffic that is atypical from day-to-day conditions, such as with the 2026 FIFA World Cup.
Traveler Notifications and Diversions (2026 FIFA World Cup)	Traveler Information	Algorithm Operations Other	Travelers can be provided with real-time information to avoid lengthy wait times. Doing so can also reduce the strain on congested POEs by re-routing drivers to better distribute traffic between the crossings.
Traffic Management During Port-of-Entry Construction	Traveler Information	Algorithm Operations Other	With the planned reconstruction/expansions of several POEs, the system can serve as a means to help manage traffic during construction.
Automated Alerts for Increasing BWT	System Features Traveler Information System Operation and Maintenance	Algorithm Operations Other	Inspection agencies can be alerted of increasing wait times and be proactive in opening additional lanes. Transportation agencies can investigate if roadway incidents are the cause of the increased delay, and can post information on traveler information systems.

Operational Scenario	ABIS Functional Class	Issues and Challenges Categories Addressed	Benefits
Automated Maintenance Alerts for Faulty Equipment	System Features System Algorithm and Data Collection Data Transmission, Storage, and Archival System Operation and Maintenance	Algorithm Operations Equipment	Transportation agencies can be alerted of maintenance issues and dispatch technicians to resolve the issue in a timely manner.
Validating Data and Improving Accuracy	System Features System Algorithm and Data Collection Data Transmission, Storage, and Archival	System Algorithm Operations	Since the system employs multiple technologies, the data being collected can be validated against each other to increase accuracy. For example, counts from inspection agencies could be obtained to validate data from the new radar detection, which can then be used to improve the accuracy of existing loop detectors.
Automated and Canned Reports	System Features System Algorithm and Data Collection Data Transmission, Storage, and Archival System Operation and Maintenance	Operations	Automated reports can be generated, reducing the staff time needed to complete reports that might be needed on an hourly/daily/monthly basis. Canned reports can provide staff with additional operational insights.
Planning for Special Events	System Features System Algorithm and Data Collection System Operation and Maintenance	Operations	Predictive analytics, leveraging historical data that the Cascade Gateway Border Data Warehouse has collected over the years and new advances in AI and ML, can be used to help plan for special events like the upcoming FIFA 2026 games. This can help inspection agencies plan staffing levels accordingly based on the predicted demand.

Operational Scenario	ABIS Functional Class	Issues and Challenges Categories Addressed	Benefits
Commercial Goods Import/Export Planning	System Features Traveler Information System Algorithm and Data Collection	Operations Other	To minimize delay in goods movement across the border, commercial carriers can use the system to determine queue lengths in advance of their trucks' departures to the border and plan accordingly. They may also use the predictive analytics tools to plan future movements at less busy times.
Inspection Agency Predictive BWT	System Features Traveler Information System Algorithm and Data Collection System Operation and Maintenance	Algorithm Operations Equipment	CBP and CBSA can use the system's tools that draw on historical data and predictive analytics to respond to upcoming surges in demand by opening more booths in advance, thereby reducing the formation of queues and reducing overall wait times. This will also assist in allocating staffing.

5.1 Traveler Trip Planning (2026 FIFA World Cup)

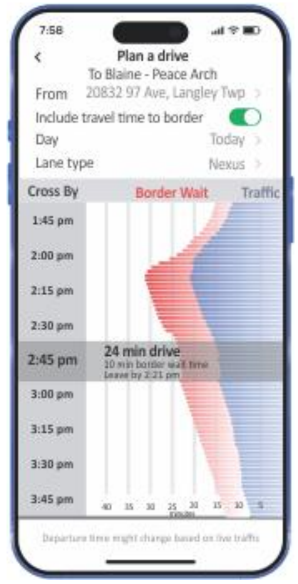


Figure 12. BWT App - Travel Time Predictions

It's June 2026 and Russell has been looking forward to the FIFA World Cup matches for the past year. As a soccer fanatic, he has tickets to the June 24th match in Seattle, the June 26th match in Vancouver, the July 1st match in Seattle, and the July 2nd match back in Vancouver. Russel lives in Richmond, BC and will be traveling as a general purpose traveler (i.e., without NEXUS). Given the matches on both sides of the border and the upcoming July 1st Canada Day and July 4th Independence Day holidays, Russell is expecting lengthy wait times at the border. He recalls hearing that a new BWT app was recently released, so he decides to download it and check it out. After it is installed, the app presents a brief tutorial on its features; interestingly, it includes trip planning capabilities, allowing him to set depart at/arrive by times to see which dates/times and which POEs are expected to have shorter wait times. The app notes that this data is based on historical data that has been collected since 2005, and that predictions will continue to be updated based on real-time traffic conditions. Russell reviews this information, which can be presented as graphs or in map-based formats, and decides that the best time to leave would be early Tuesday morning via the Peace Arch/Douglas POE. Doing so would place his arrival at the border at around 9:30am, with an estimated border wait time of 15-30 minutes and an overall trip time – which includes the travel time between his home and the border, the expected wait time at the border, and the travel time between the border and his destination – of 2.25-2.75 hours.

5.2 Traveler Notifications and Diversions (2026 FIFA World Cup)

Figure 13. BWT App - Navigation Interface

Russell departs from Richmond, BC to Seattle, WA on Tuesday morning, though a little later than expected. While the app recommended that he depart at 7am, his dog Doug had an accident which delayed his trip by an hour. Russell recalls from the app tutorial that it also includes navigational features, so he decides to try it out. He types in his destination, and the app asks whether he is a general purpose traveler, a NEXUS traveler, or a commercial freight traveler. He selects general purpose, and is presented with a familiar map-based navigation interface. It appears that the best route still involves taking the Peace Arch/Douglas crossing. However, his delay means that rush hour traffic is building up, so we again uses the app's prediction feature which recommends that he depart at 9:30am instead. Doing so would result in lighter traffic along the way and minimal wait times at the border. At 9:30am, Russel gets into his car, opens up the app, and starts the navigation; as predicted, traffic is lighter now, and the border wait time and overall trip time is still on the lower end of the initial estimate.

As Russell is passing through Surrey, BC, the app's navigation interface presents a non-intrusive notification, informing him that a significant increase in wait times is being detected at the Peace Arch/Douglas POE. The app recommends re-routing to Pacific Highway. To minimize driver distraction, the non-intrusive notification that the app presents includes a countdown; if Russell takes no action, the route is automatically updated based on the app's recommendation. Alternatively, Russell could cancel the recommendation and proceed to the Peace Arch/Douglas POE as originally planned.

Russell decides to accept the recommendation and proceeds toward the Pacific Highway POE as directed by the app. Upon arriving at this destination, the app presents a summary, noting that his trip ended up taking 15 minutes longer than originally estimated. However, doing so avoided a 2 hour delay at the Peace Arch/Douglas POE. Curious about what happened, Russell checks the BCMOTI website and sees that there was an accident leading up to the POE, which closed several lanes. While this was occurring, the system had automated posted messages to WSDOT's traveler information systems (e.g., VMS, websites, HAR, etc.) alerting travelers of increasing wait times at the Peace Arch/Douglas POE and recommending them to use the Pacific Highway POE instead. The system also automatically alerted BCMOTI TMC staff of increasing wait times, prompting staff to investigate the issue and respond as needed.

5.3 Traffic Management During Port-of-Entry Construction

USCBP and GSA are hard at work with the reconstruction and expansions at the Pacific Highway, Lynden/Aldergrove, and Sumas/Abbotsford-Huntingdon POEs so that the improvements can be completed ahead of the 2026 FIFA World Cup that begins in June 2026. During this time, there are several lane shifts, lane closures, and detours that will be taking place in order for construction to occur, potentially causing lengthy delays for travelers. In a few weeks, several of the northbound lanes at the Pacific Highway POE will be closed to traffic between Monday and Wednesday. To prepare for this, WSDOT and BCMOTI have been investigating this upcoming impact. Using the new ABIS, which includes predictive capabilities integrated into the Cascade Gateway Border Data Warehouse, the team leverages the historical data going back to 2005 to predict what the wait times will look like given the planned lane closures. They also look at how wait times might improve if traffic were diverted to other POEs to help distribute demand. Using these findings, WSDOT and BCMOTI begin posting messages in the new mobile app, as well as on their websites, social media, and VMS/DMS.

5.4 Automated Alerts for Increasing BWT

USCBP prefers to keep NEXUS lane wait times to be less than 15 minutes. The current NEXUS lane wait time at the Pacific Highway POE is 12 minutes and climbing. With the implementation of the recent ABIS project, the port director now has access to a new dashboard that has been customized to USCBP's needs, which includes current wait times, projected wait times, number of vehicles in queue, number of lanes open, etc. When the dashboard was originally set up, several automated alerts were set up, one of which was to inform the port director of increasing wait times. If the system detects that if the NEXUS lane wait time is predicted to exceed a configurable threshold that was set to 15 minutes – based on factors like the current wait time, the current number of vehicles in the queue, and the

Figure 14. Inspection Agency Dashboard

number of vehicles approaching the POE – the system will alert the port director that action may need to be taken.

The port director leverages the predictive capabilities built into the new dashboard. This includes “what-if” scenarios, which can be used for predicting how wait times might change based on additional lanes being open. The port director runs through these scenarios and determines that one additional NEXUS lane needs to be open to keep wait times under 15 minutes.

As additional lanes/inspection booths are opened, the system automatically identifies this change and continually updates the BWT measurements and the travel time estimates that are disseminated to traveler information systems, as needed.

5.5 Automated Maintenance Alerts for Faulty Equipment

The ABIS, which uses several technologies to measure BWT, identifies a discrepancy between the BWT measurements collected from the mobile application and the Bluetooth/Wi-Fi sensors, compared to the measurements from the radar detectors. The discrepancy is only present for the Lynden POE; all other POEs and approaches appear to be reporting data normally. An automated email alert is generated and sent to BCMOTI and its electrical contractor, noting that there may be a fault associated with the radar detector. A technician is dispatched, who investigates and discovers that the sensor was knocked off calibration due to the recent windstorm. Since the detector is mounted on the side of the roadway, no traffic control is needed, and the technician can easily adjust/re-calibrate it. During the time that the radar detector was reporting faulty data, the BWT measurements were largely unaffected, since two other sources of data remained available (or three, if the existing loop detectors remained as well).

5.6 Validating Data and Improving Accuracy

The ABIS primarily uses the mobile app, Bluetooth/Wi-Fi readers, and radar detection as its data sources for measuring BWT. However, WSDOT would like to maintain the investments that it has made to date into the existing loop detectors, rather than fully replacing them with radar detection. As such, the existing loop detectors will remain in place and operate in parallel with the radar detection, serving as a supplemental/backup data source. However, given that there are concerns with data accuracy associated with these loop detectors, and that the radar detectors are expected to improve upon that, WSDOT would like to use the data from the radar detectors to validate/benchmark the loop detector data. The system, leveraging AI and ML, calibrates the loop detector data based on the traffic conditions (free flow vs congested) observed at each location, improving data accuracy. Over time, this method of calibration is expanded to other loop detectors throughout the state.

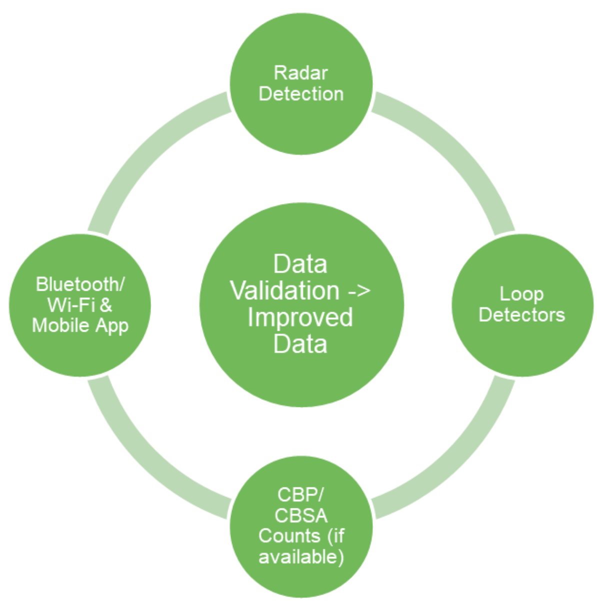
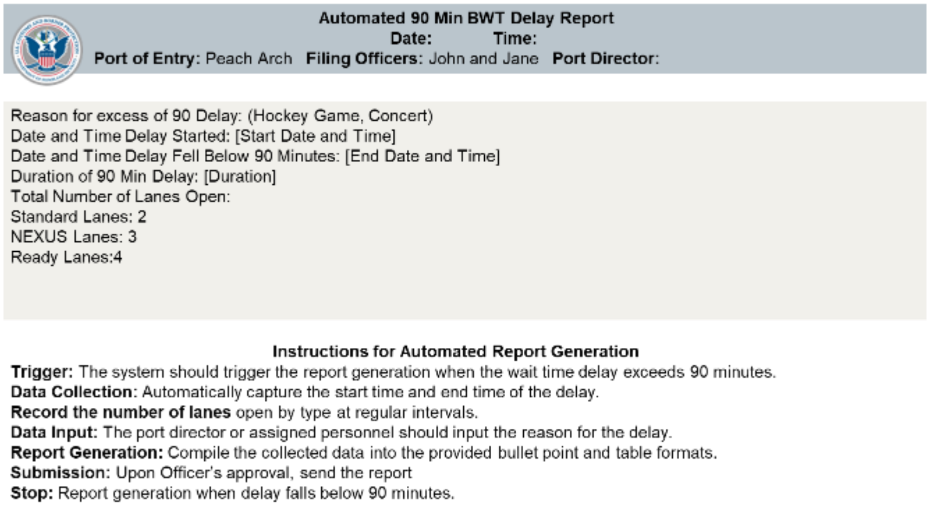


Figure 15. Data Validation Methodology

5.7 Automated and Canned Reports

USCBP and CBSA inspection officers have several hourly and daily reports that they need to complete. For example, when wait times exceed certain thresholds (e.g., 60 minutes for CBSA and 90 minutes for USCBP), inspection officers need to complete a report that identifies the date and time the delay started and ended, the number of lanes open, the reason for the delay, etc. Since the ABIS collects much of this information already, large portions of these reports are now automatically pre-populated. The inspection officer on duty now only needs to review and verify the information and include a brief description regarding the cause and nature of the delay. What was once a time-consuming process can now be streamlined, resulting in significant time savings.



Automated 90 Min BWT Delay Report
Date: **Time:**
Port of Entry: Peach Arch **Filing Officers:** John and Jane **Port Director:**

Reason for excess of 90 Delay: (Hockey Game, Concert)
Date and Time Delay Started: [Start Date and Time]
Date and Time Delay Fell Below 90 Minutes: [End Date and Time]
Duration of 90 Min Delay: [Duration]
Total Number of Lanes Open:
Standard Lanes: 2
NEXUS Lanes: 3
Ready Lanes:4

Instructions for Automated Report Generation
Trigger: The system should trigger the report generation when the wait time delay exceeds 90 minutes.
Data Collection: Automatically capture the start time and end time of the delay.
Record the number of lanes open by type at regular intervals.
Data Input: The port director or assigned personnel should input the reason for the delay.
Report Generation: Compile the collected data into the provided bullet point and table formats.
Submission: Upon Officer's approval, send the report
Stop: Report generation when delay falls below 90 minutes.

Figure 16. Automated Inspection Agency Reports

5.8 Planning for Special Events

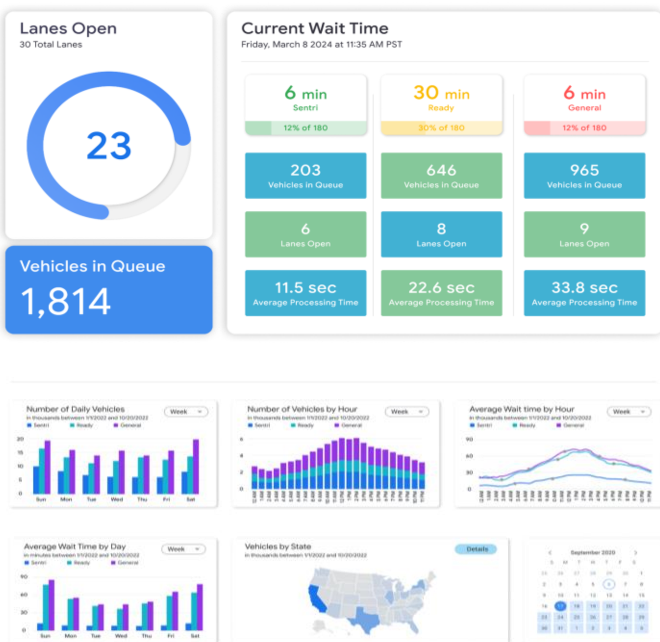


Figure 17. Inspection Agency Dashboard

A large concert is being held in Vancouver, BC in a few months, and it is expected that there will be a large influx of U.S. travelers coming through the Peace Arch and Pacific Highway POEs. There was a similar event that took place last summer, during which border wait times exceeded two hours for several hours on the days leading up to the event. Although the data from that event was collected through the previous system (ATIS), the current system (ABIS) was designed with a requirement for data reporting to remain consistent, so the data fields did not change, and historical data can still be used for the prediction. CBSA would like to proactively plan for this event and ensure that staffing levels are sufficiently and adequately deployed at the necessary POEs to keep wait times to a minimum. Similar to the scenario described in Section 5.4 Automated Alerts for Increasing BWT, CBSA can utilize the ABIS dashboard and "what-if" scenarios to determine how many lanes they might have to open to minimize wait times. The difference here is that the prediction would not be based on current and imminent traffic conditions, but would instead be projected further out into the future and leverage historical data.

5.9 Commercial Goods Import/Export Planning

Similar to Section 5.1 where individual travelers can use the ABIS' predictive analytics capabilities to plan their trips during dates and times of lower congestion, freight operators can also use this feature.

5.10 Inspection Agency Predictive Border Wait Times

Similar to Section 5.1 and Section 5.9 where individual travelers and freight operators can use the ABIS' predictive analytics capabilities to plan their trips during dates and times of lower congestion, inspection agencies can also use this feature. However, this feature will be built into the customized dashboards that inspection agencies have access to, providing easy access and glanceable information.

6. SUMMARY OF IMPACTS

This section describes the impacts of the proposed system on stakeholders as it relates to the use, operations, and maintenance of the system.

6.1 Inspection Agency Impacts

Inspection agencies like USCBP and CBSA do not currently directly interact with the existing ATIS. With the ABIS, their interaction will continue to be limited. However, the system will provide inspection agencies with more reliable and accurate BWT information that can be accessed through dashboards customized to each agency's needs. This includes conducting "what-if" scenarios to improve staffing levels and overall operations, automated alerts, and automated reports. Training will need to be provided to inspection agency staff who will be using these tools.

6.2 Transportation Agency Impacts

Transportation agencies like WSDOT and BCMOTI will be responsible for operations and maintenance of the system. Primarily this will involve the field devices that will be installed. New equipment in the form of radar detectors and Bluetooth/Wi-Fi sensors will be deployed, so WSDOT and BCMOTI staff will require training to install, operate, and maintain these new devices. With the transition from loop detectors to non-intrusive forms of detection, maintenance efforts are expected to be easier, primarily resulting from the reduced need for traffic control.

A new mobile application will also be developed. This will be part of the Stage 2 project that WSDOT will be leading. The development of the mobile app will be contracted to a vendor that WSDOT will oversee. However, once the app has been developed, it will need enough members of the traveling public to be using it in order for the system to accurately measure BWT. As such, the application will need to be marketed to help increase penetration, and the application will also need to be continually maintained/updated so that it does not become deprecated. It will need to be determined whether WSDOT or WCOG should have primary responsibility for the on-going operation and maintenance of the mobile app. Additional staff time may also be needed to support the mobile app.

6.3 Traveler Impacts

Travelers will have access to more reliable and accurate BWT information, which will be a significant improvement to the status quo given that the existing BCMOTI ATIS website is currently offline due to unreliable data. Travelers will also have access to a new mobile app, through which they will be able to select their vehicle/lane type to receive information that is applicable to their mode of travel; for example, if wait times are high at one POE, the app may divert drivers to another POE to distribute traffic and reduce wait times. This will also provide the system with improved BWT measurements that is specific to each lane type. Travelers will also have easier access to historical data to help determine which hours are best for travel to avoid lengthy wait times.

With the upcoming 2026 FIFA World Cup, cross-border traveler information will be of the utmost importance, particularly given the expected increase in traffic and tourists who are unfamiliar with the area. The system will provide more reliable and accurate wait time estimates and an improved traveler information experience through new features that are incorporated into the mobile app, such as navigation assistance, dynamic re-routing, predictive analytics, trip planning capabilities, and more.

There are also several planned reconstruction and expansion projects across the Pacific Highway, Lynden/Aldergrove, and Sumas/Abbotsford-Huntingdon POEs. With the atypical traffic patterns that come with construction projects, the new system will provide the inspection and transportation agencies with an additional means to convey traffic impacts to the traveling public, as well as provide the public with additional tools to avoid delays.

6.4 Supporting Environment Impacts

This section is intended to cover the supporting systems that may be needed for the ABIS to operate as intended. This includes elements such as communications systems, central/back-end system improvements, interfaces, and policies, to name a few:

- At the Lynden POE (northbound), wireless communications is currently used for a short distance to bridge two segments of fiber optic communications. WSDOT desires to replace this wireless link, between approximately H Street and Main Street, with new fiber optic communications.
- At the Sumas POE (northbound), the existing wireless communications system is unreliable. WSDOT desires to replace/upgrade this wireless communications system.
- Additional radar detector installations may be needed to capture the back-of-queue. If no other ITS is currently in place in the area, additional infrastructure (e.g., power, communications, poles, cabinets, etc.) will need to be installed.
- Development of interfaces between the ABIS and existing systems (e.g., DMS/VMS, traveler information websites, etc.) will be needed.
- The use of radar detectors, Bluetooth/Wi-Fi sensors, and the mobile application will provide the Cascade Gateway Border Data Warehouse with the data that it currently receives today (e.g., volumes, wait times). However, these devices may also collect additional data that could be beneficial. If additional data fields are desired, the BDW and the associated interfaces with WSDOT's and BCMOTI's field systems may need to be modified.
- The BDW serves as a repository for BWT data and will need to continue to serve this purpose. The map interface may need to be updated to reflect new radar detector locations. Back-end architecture changes may also be needed to support lane status changes (e.g., making NEXUS be a field rather than a separate category). System development may also be needed to integrate the predictive capabilities from the ABIS into the BDW.
- With additional types of data being collected (e.g., MAC addresses from Bluetooth/Wi-Fi sensors and location-based data from the mobile app), new data management policies may be needed to ensure data privacy. This may include separate polices for data collected within the U.S. and Canada.

7. ANALYSIS OF THE PROPOSED SYSTEM

This section summarizes the benefits, limitations, advantages, disadvantages, and alternatives/trade-offs considered. Note that a full Benefit-Cost Assessment is included as part of the Implementation Report.

7.1 Summary of Improvements

The existing northbound and southbound ATIS are aging and the BWT information that it provides has become inaccurate and unreliable. The new system aims to meet the project objectives identified in Section 1.2 Purpose. Overall, the project should result in a system that provides accurate and reliable BWT information that travelers, transportation agencies, inspection agencies, and planners can use and rely on.

7.2 Advantages/Benefits and Disadvantages/Limitations

Advantages and benefits of the system include:

- The system uses a hybrid solution of technologies, so if one component fails, the others can continue to provide relatively accurate and reliable data.
- The system uses traditional technologies that are proven and have been well-tested in a border crossing environment.
- The system uses non-intrusive detection technologies, providing improved flexibility for relocating sensors/adjusting detection zones and easier maintenance.
- The system uses a combination of hardware-based system components and infrastructure-less components (e.g., mobile app), which provides a future pathway to complete infrastructure-less operation once the technology matures sufficiently and market coverage requirements are met.

Disadvantages and limitations of the system include:

- The use of license plate recognition cameras would provide the most accurate method for re-identifying vehicles and measuring BWT. However, the SMART Grants program precludes the use of this technology.
- The ability to validate the system's volume measurements against USCBP's and CBSA's counts would provide a trusted baseline. However, it does not appear that this data can currently be obtained in real-time, if at all.
- GPS III will provide significant improvements to GPS location data. However, this technology is not yet ready.

7.3 Alternatives and Trade-Offs Considered

Building on the User Needs presented in Table 3, several technology options and concepts were developed and evaluated. In parallel with this, the project team conducted vendor showcases. These place during the week of April 15, 2024, during which various technology providers were invited to present on their product offerings and answer questions specifically as they related to BWT applications like the Cascade Gateway ABIS. On May 9, 2024, these vendors were evaluated with WCOG, WSDOT, BCMOTI, and the project team; the results of this evaluation are summarized below in Table 8. Only vendors who provide technologies that were deemed mature enough and applicable to the BWT environment were carried forward in the evaluation.

Using the technologies evaluated as part of the vendor showcases, three technology concepts were initially developed, each of which use a combination of technologies that together form a hybrid solution. These concepts are aimed at improving traveler information and BWT measurements by accurately determining queue lengths and the number of vehicles, leveraging both existing infrastructures, as well as implementing new and innovative technologies. Utilizing hybrid solutions involving a combination of technologies is also expected to provide more accurate and real-time data that reflects the real-world ground-truth conditions, which is essential for accurate BWT measurements, the optimal allocation of resources, and the seamless facilitation of border traffic. Combining multiple methods for border wait time calculation, such as leveraging existing in-pavement sensors with advanced algorithms, vehicle identification cameras, USCBP/CBSA vehicle throughput benchmarking, and GPS information services can enhance accuracy, reliability, and overall effectiveness. Though each port of entry can vary significantly, data-driven border wait time measurement methodologies can be standardized at the enterprise level to enable scalability at the nearly 70 ports of entry along the northern and southern borders.

Concept I combines the existing VDS/data station infrastructure and enhances the accuracy of the existing loop detectors by recalibrating and implementing new algorithms, deploys new in-lane vehicle detection to capture back-of-queues during peak periods (if necessary), implements vehicle re-identification technologies (e.g., Bluetooth/Wi-Fi readers, RFID readers, and video analytics) for re-identifying privately-owned and commercial vehicles, and utilizes AI and advanced data analytics to optimize BWT measurement and management. Concept II combines the existing VDS/data station infrastructure and enhances accuracy by replacing (or supplementing) existing loop detectors with radar detection, deploys new radar detection to capture back-of-queues during peak periods, develops a new dedicated Cascade Gateway BWT app based on GPS II technology, deploys Bluetooth/Wi-Fi readers to re-identify vehicles and supplement the data gathered from the BWT app, and utilizes AI and advanced data analytics to optimize BWT measurement and management. Concept III develops a new dedicated Cascade Gateway BWT app based on GPS III technology and utilizes AI and advanced data analytics to optimize BWT measurement and management. Existing physical infrastructure such as existing VDS/data stations, loop detectors, radar detection, and Bluetooth/Wi-Fi readers can continue to be used, though they would primarily be used for data validation purposes.

These three concepts were evaluated by WSDOT, and BCMOTI, and WCOG, with Concept II emerging as the preferred solution. The results of this evaluation are shown in Table 9.

Table 8. Vendor Showcase Summary

Vendor/Technology Information			Metrics/Evaluation Criteria					
Vendor	**Technology**	**Technology Maturity/ Applicability**	**Back of Queue**	**Number of Vehicles in Queue**	**Vehicle Re-Identification**	**Speed**	**Accuracy**	**Cost (Including O&M)**
Wavetronix	Radar	Pass. Runner up to Houston Radar	✓	✓		✓	High	Low-Med
Houston Radar	Radar	Pass. Preferred technology.	✓	✓		✓	High	Low-Med
Miovision	Video Analytics, Bluetooth/Wi-Fi	Fail. Technology is not mature enough for BWT applications.						
Currux Vision	Video Analytics, Vehicle Reidentification	Fail. Technology is not mature enough for BWT applications.						
Adaptive Recognition	Video Analytics, Bluetooth/Wi-Fi	Fail. Technology is not mature enough for BWT applications, and vendor is a hardware-only provider.						
CLR Analytics	Loop Signatures, Pavement Sensors	Fail. Technology is not mature enough for BWT applications.						
TTI	LiDAR	Pass	✓	✓		✓	High	Low-Med
Transcore	RFID (Commercial Vehicles)	Pass. However, this technology is duplicative of other technologies and does not count all trucks			✓			High
Tattlile	Machine Vision, ALPR	Fail. Technology is not mature enough for BWT applications.						

Table 9. Technology Concept Evaluation Summary

Concept/ Criteria	Accuracy	Initial Cost	User Exp-erience	O&M Costs	Flex-ibility	Future Proofing	Security	Ease of Implem-entation	Inno-vation	Scal-ability	Total Score
Weight	*30*	*10*	*10*	*10*	*10*	*5*	*5*	*10*	*5*	*5*	***100***
Concept I – Loop Detectors, Vehicle Re-Identification, and AI	24	5	5	3	1	1	3	5	1	2	**50**
Concept II – Mobile Application (GPS II), Bluetooth/Wi-Fi, Radar, and AI	28	7	8	6	10	5	5	7	5	5	**86**
Concept III – Mobile Application (GPS III) and AI	22	5	8	7	8	5	5	7	4	5	**76**

This page intentionally left blank.

Appendix B: Benefit-Cost Assessment

Whatcom Council of Governments

Cascade Gateway Advanced Border Information System Design Project

Benefit Cost Analysis Technical Memo

FY 2024

Texas A&M Transportation Institute

The Texas A&M University System

College Station, Texas

August 2024

Contents

Whatcom Council of Governments

Cascade Gateway Advanced Border Information System Design Project

Benefit Cost Analysis Technical Memo

August 2024

The benefit-cost analysis (BCA) was conducted for the Cascade Gateway Advanced Border Information System Design Project using best practices for transportation planning and reflecting the US DOT 2024 benefit-cost analysis guidance. This analysis focuses on the anticipated benefits and costs associated with at-scale implementation. Narrative documentation of each benefit is brief by design as the Cascade ABIS BCA excel spreadsheet is formatted to provide clear, detailed documentation. Sheet 1 in the file "Notes" describes the content of each sheet in the Excel file. All analyses contain live formulas, clear documentation of assumptions, and assume 2022 constant dollars at a 3.1% discount rate.

Table 1. BCA Summary

Current Status and Problem to be Addressed	Change in Baseline	Type of Impacts	Affected Populations	Economic Benefits
The Cascade Gateway Advanced Border Information System (ABIS) Design Project is designed to provide a modern alternative to the Advanced Traveler Information System. ATIS records traffic flows and estimates wait times for several locations US and Canada border locations. There is a need to calculate more reliable wait times that the current equipment cannot provide	The project will provide Customs and Border Patrol Agents with better delay information, allowing them to open lanes more efficiently and reduce overall delay.	Value of Time Savings	Drivers and commercial truck operators using the POEs.	Benefit 1. Crossing Delay Benefit
		Fuel Cost Savings	Drivers and commercial truck operators using the POEs.	Benefit 1. Crossing Delay Benefit
		Emissions Reductions	Residents living and working the area.	Benefit 2. Environmental Benefit
	The project will provide drivers with better information on current delays, allowing them to plan trips more reliably.	Value of Time Savings	Drivers and commercial truck operators using the POEs.	Benefit 3. Trip Planning Reliability Benefit
	Project components will have useful life remaining after the 11-year analysis period.	Residual Value	Washington State Department of Transportation	Benefit 4. Residual Value
	Project improvements will result in additional maintenance costs.	Maintenance and Operations Costs	Washington State Department of Transportation	(Dis)Benefit 5. Maintenance Costs

Benefit Cost Analysis

The computed benefit-cost ratio for the Cascade Gateway Advanced Border Information System Project was conducted using a 3.1 percent real discount rate recommended by the Benefit-Cost Analysis Guidance for Discretionary Grant Programs[1]. The BCA compares the estimated capital costs to the quantifiable anticipated benefits of the project for an analysis period of 11 years with implementation occurring in the first year. Benefits begin in year 2 and assume a 10-year life cycle.

The quantified benefits are:

1. Crossing Delay Benefit – Value of time savings and fuel cost savings from reduced crossing delay
2. Environmental Benefit – Reduced emissions costs from reduced crossing delay
3. Trip Planning Reliability Benefit – Value of time savings from increased trip planning reliability
4. Residual Value – Remaining useful life of project components
5. Maintenance and Operation Costs

Discount Rates

Federal guidance recommends that applicants discount future benefits and costs to the year 2022 and present discounted rates of both the stream of benefits and the stream of costs. For this analysis, final streams of benefits and costs are presented at a 3.1 percent discounted rate.

Project Description and Cost Estimates

The Cascade Gateway Advanced Border Information System (ABIS) Design Project is intended to provide a modern alternative to the Advanced Traveler Information System (ATIS). Established in 2004, ATIS records traffic flows and estimates wait times for several US and Canada border crossings. Although this system has been in use for several years, there is a need to calculate more reliable wait times than the current equipment can provide. A key to providing the best alternative is to integrate new and old technologies, which minimizes costs while producing more accurate results. Therefore, as part of the project, several design concepts were recommended that utilize a mix of technologies to more thoroughly record the number of vehicle and wait times.

The project area consists of four ports of entry: Peace Arch/Douglas, Pacific Highway, Lynden/Aldergrove, and Sumas/Huntingdon. Combined these crossing experience about 7.98 million passenger vehicle crossings per year and about 1.07 million commercial truck crossings per year. This analysis assumes that the project would reduce delay at the border crossing by giving Customs and Border Patrol better wait time information, and increase the planning time reliability of drivers, decreasing the amount of time they budget for delay at the crossing. Value of time and emissions costs were calculated in a build and no-build scenario, with the difference in costs resulting in a cost-savings or positive project benefit. Because future impacts on delay

[1] https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance

are unknown but anticipated to be positive, a conservative estimate of a five percent reduction in delay times was used for this analysis. Total project costs were estimated at $8.37 million in 2025 or $7.64 million in 2022 dollars at a 3.1 percent discount rate.

Benefit-Cost Ratios

Table 2 summarizes the estimated project costs and the quantifiable anticipated benefits of the project. With a conservative estimate of a five percent reduction in delay, the project scenario has a net present value of $31.69 million undiscounted and $23.17 million at a 3.1 percent real discount rate. The benefit cost ratio of the project is 4.03:1 discounted at 3.1 percent.

Table 2: Benefit Cost Analysis ($2022)

Category	Undiscounted	Present Value at 3.1%
Construction Costs	**$8,371,000**	**$7,638,382**
Evaluated Benefits		
1. Crossing Delay Benefit	$12,421,251	$9,592,670
2. Environmental Benefit	$615,213	$473,371
3. Planning Reliability Benefit	$26,545,672	$20,500,664
4. Residual Value	$1,316,528	$885,253
5. Maintenance and Operation Costs	-$837,100	-$648,257
Total Evaluated Benefits	**$40,061,564**	**$30,803,701**
NPV[2]	**$31,690,564**	**$23,165,320**
B-C Ratio	**4.79**	**4.50**

Benefit Calculations

The benefits of the project are derived by comparing conditions under a “Build” and “No-Build” scenario. Benefits will accrue over the 10-year operational period of the analysis. Travel impact costs are generated for the “No-Build” baseline scenario and the “Build” project scenario. The difference in costs between the baseline and project scenarios is the cost savings or benefits of the project. The project is anticipated to allow for more efficient crossing operations and reduce crossing delay time by five percent for each trip. This results in a reduction of about 53,000 hours of delay time and about 125,000 hours of planning time, for a total of about 178,000 hours of time in the first year of operation. This reduction in time results in value of time savings for passenger vehicles and trucks, as well as a reduction in fuel consumption and emissions due to idling. Default parameters used in the calculations are included in the spreadsheet accompanying this document.

[2] Net present value (NPV) was calculated by subtracting the total benefit from total cost at 3.1% discount and undiscounted figures.

Benefit 1: Delay Time Reduction Benefit

Benefit one is the value of time benefit generated by reducing crossing delay time in the project scenario. The four border crossings experience about 13.6 million passenger vehicle crossings and about 1.6 million commercial truck crossing per year. In the no-build scenario the average passenger vehicle crossing delay is about 7.24 minutes and the average truck delay about 3.59 minutes. This results in about 994 thousand hours of delay for passenger vehicles and about 66 thousand hours of delay for trucks in the first year of the analysis. With the improvements from the project a 5 percent reduction in these delay times was anticipated. This results in both a value of time savings for each vehicle, as well as a fuel cost reduction since the vehicles are idling for a shorter period of time. The value of delay time is an estimate of the average differential cost of the extra travel time resulting from delay or congestion. These benefits were summed to generate the total Delay Time Reduction Benefit.

Delay Time Reduction Benefit

- Value of Time Cost (Trucks) = Reduced Delay Hours * Truck Driver Hourly Wage
- Value of Time (Passenger Vehicles) = Reduced Delay Hours * Passenger All Purpose Cost Factor
- Fuel Cost Savings = Reduced Hours of Delay * Idle Fuel Consumption * Fuel Price

The total Delay Time Reduction Benefit for the 11-year analysis period was $12.42 million undiscounted, and $9.59 million discounted at 3.1 percent.

Benefit 2: Environmental Benefit

Benefit two is the emissions benefit generated by reducing crossing time delay in the project scenario. Currently, vehicles are idling when they are delayed at the crossing. The build scenario reduces the delay time, thus reducing idling time. The difference in idling time in the build and no-build scenario generates an emissions cost savings. Emissions costs were calculated by multiplying the hours of delay by the idle emission rates for cars and trucks, then by the USDOT Benefit Cost Analysis Guidance emission monetized value.

- Emissions Cost = Vehicle Hours of Delay * Idle Emission Rate per Hour * Emission Monetized Value

The total Environmental Benefit for the 11-year analysis period was $0.62 million undiscounted and $0.47 million discounted at 3.1 percent.

Benefit 3: Trip Planning Reliability Benefit

The third benefit calculated was the value of time savings associated with increased trip planning reliability. The project benefits will give drivers a better understanding of the expected delay times and allow them to better plan their trips, generating a value of time savings. This benefit is based on the Planning Time Reliability Index.[3] This methodology assumes that in order to get to their destination on time, drivers will plan for delays based on the 95th percentile delay. With 20 weekdays in a month this means that drivers plan for the worst day of the month, and 19 out of 20 times will arrive at the destination earlier than necessary. Arriving earlier than necessary means that time has been wasted and generates a value of time cost.

In order to calculate this, delay on the worst day of the month was calculated for each crossing and varied from 12 to 40 minutes depending on the crossing. This means that in order to ensure they arrive on time, in the worst case, drivers must leave 40 minutes earlier than would be necessary if there was no delay. Most of the time drivers will not actually encounter this much delay, meaning they arrive earlier than necessary. The project scenario assumes a five percent reduction in delay times, reducing the delay on the worst day of the month, and allowing drivers to leave slightly later than before. Total planning hours are the difference in hours between the 95th percentile wait time and the average wait time. Reducing these hours saves drivers time, generating a benefit.

Trip Planning Reliability Benefit

- Planning Hours = (95th Percentile Delay Time * Number of Trips) – (Average Delay Time * Number of Trips)
- Reduced Planning Hours = Planning Hours * Percent Reduction in Delay Time
- Value of Time Cost (Trucks) = Reduced Planning Hours * Truck Driver Hourly Wage
- Value of Time (Passenger Vehicles) = Reduced Planning Hours * Passenger All Purpose Cost Factor

The total Trip Planning Reliability Benefit for the 11-year analysis period was $26.55 million undiscounted and $20.50 million discounted at 3.1 percent.

The actual project benefits are likely to be higher than what was estimated here, because in addition to being able to plan for reduced delay, drivers should have a much better understanding of the actual delay they will encounter. Instead of assuming the worst delay, they will be able to see a prediction of crossing delay at their travel time and plan accordingly. This could substantially increase the amount of time saved above the five percent reduction assumed, but currently cannot be calculated.

Benefit 4: Residual Value

The fourth benefit calculated was the residual value of the project. Several of the project components have useful lives beyond the 11-year analysis period. The residual value is the benefit associated with the remaining useful lives of these components. Table 3 shows the useful life and remaining life, after the analysis period, associated with these project components.

[3] https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2023-appx-a.pdf

Table 3. Project Component Remaining Life

Item Description	Useful Life	Remaining Life
Radar Design, Implementation, Testing	12	2
Wi-fi System Design and Implementation	10	0
Fiber Network	25	15
Cascade Gateway Custom BWT App/Interface	15	5

Residual value was calculated by dividing the estimated cost by the useful life of the component, then multiplying that by the remaining life of the of the component. These values were then summed and discounted to 2022 dollars.

- Residual Value = (Component Cost/Useful life) * Remaining Life

The total residual value was $1.32 million undiscounted and $0.89 million discounted at 3.1 percent.

Benefit 5. Maintenance and Operation Cost

The project includes annual maintenance and operation costs of $84 thousand undiscounted. Over the 11-year analysis period this is $0.84 million undiscounted and $0.65 million discounted at 3.1 percent. This annual cost is presented as a disbenefit.

Qualitative Benefits

Safety and Reliability

The improved detection of traffic at the border crossing will enable a more accurate estimation of wait and delay times. A noticeable benefit of this upgrade will be the reliability of the times produced. Trucks and passenger vehicles crossing will be more confident that the wait and delays times they are receiving will be accurate. Additionally, this new equipment will enable border crossing operators to monitor the movement of people and vehicles in a way that promotes safety. Since this project will give drivers better information about crossing times, it will also help to spread demand across available crossings, maximizing the available infrastructure.

Resiliency

Improving the border information system will draw benefits from a more resilient transportation system. Reliable wait time estimates will inform drivers and operators as to the conditions at the border crossing. Drivers will see benefits in the form of reduced fuel consumption and travel time, extending to health benefits from lower emissions. Furthermore, the installation of modern technology will enable the border crossing to be better prepared against cyber-attacks.

Equity and Access

Improvement to border crossing movements will lead to improved access. Jobs, schools, tourist sites, and other locations will be more accessible for people that travel through border entries. The ease of access will place less of a burden on disadvantaged communities traveling through borders as less time and resources will be needed to cross.

Climate

The improvement in traffic and wait time estimations, and subsequent improvements to operations, will generate climate benefits. The reduction in the amount of time spent at the border crossing will result in reduced congestion, decreased vehicle idling, and improved flow times. Ultimately, the change in traffic conditions will reduce emissions and fuel consumption.

Partnerships

A border crossing is vital for the US and Canadian economies, therefore ensuring smooth ingress and egress from one country to another will promote partnerships between the country's industries. Goods and people will cross the border more efficiently as wait times predictions improve and crossing times become more reliable. This change in operations will stimulate the economies of both countries in several ways. As more people cross the border, the country's respective economy will experience a surge in consumer spending, whether from daily commutes or tourism. For the private sector, reliable crossing times will help the industry make better both informed decisions and enable collaboration between industries. Furthermore, border wait time systems will integrate with connected systems south of the border to better estimate overall travel times across the region.

Integration

Improvements to detection equipment will help integrate different components of border to obtain more robust data. Information gathered by the upgrade includes technologies form Bluetooth and Wi-Fi receptors and radars, which all work together to generate Border Wait Times. This infrastructure picks up information such as traffic, type of vehicle, number of gates open, and others which then generates actual and estimated wait times. With all the gathered information, border crossing operators will help the economy by optimizing the border crossing procedures.

Workforce Development

The installation of new equipment will require the involvement of different areas of the workforce. Not only will new equipment be installed, but the training of personnel will require a different set of skills. Additionally, based on the new information derived from infrastructure updated, border port of entry operators will be able to determine the appropriate level of labor needed to efficiently attend vehicles passing through.

Tab:	Description:			
Inputs and Results	**Includes inputs as well as project parameters and costs**			
BCA Summary	**Summary of all costs and benefits both undiscounted and discounted**			
Costs	**Calculates annual costs for the entire analysis period**			
Delay	**Calculates Delay Reduction Benefit**			
Planning	**Calculates Trip Planning Reliability Benefit**			
Residual Value	**Calculates residual value of project components**			
Traffic	**Traffic Assumptions**			
Defaults	**All other assumptions are documented and sourced here**			

Current Status and Problem to be Addressed	Change in Baseline	Type of Impacts	Affected Populations	Economic Benefits
The Cascade Gateway Advanced Border Information System (ABIS) Design Project is designed to provide a modern alternative to the Advanced Traveler Information System. ATIS records traffic flows and estimates wait times for several locations US and Canada border locations. There is a need to calculate more reliable wait times that the current equipment cannot provide	The project will provide Customs and Border Patrol Agents with better delay information, allowing them to open lanes more efficiently and reduce overall delay.	Value of Time Savings	Drivers and commercial truck operators using the POEs.	Benefit 1. Crossing Delay Benefit
		Fuel Cost Savings	Drivers and commercial truck operators using the POEs.	Benefit 1. Crossing Delay Benefit
		Emissions Reductions	Residents living and working the area.	Benefit 2. Environmental Benefit
	The project will provide drivers with better information on current delays, allowing them to plan trips more reliably.	Value of Time Savings	Drivers and commercial truck operators using the POEs.	Benefit 3. Trip Planning Reliability Benefit
	Project components will have useful life remaining after the 11-year analysis period.	Residual Value	Washington State Department of Transportation	Benefit 4. Residual Value
	Project improvements will result in additional maintenance costs.	Maintenance and Operations Costs	Washington State Department of Transportation	(Dis)Benefit 5. Maintenance Costs

Benefits and Costs	Present Value (2022 $mil)
Maintenance and Operations Costs	($0.6)
Benefit 1	$9.6
Benefit 2	$20.5
Total Benefits	***$29***
Capital Costs	$7.6
Total Costs	***$8***
Benefit/Cost Ratio	***3.9***
3.1% Discount Rate	

Inputs	
Cost	
Construction Cost (M$)	8.37
Annual O&M Cost (M$)	0.08
Construction Start Year	2025
Operation Start Year	2026
Constant Dollar Year	2022
Discount Rate	3.1%

	Project Costs		Project Benefits									
	Construction Costs		Maintenance and Operation Costs		Crossing Delay Reduction		Crossing Delay Environmental Cost Savings		Trip Planning Reliability		Residual Value	
Year	Undiscounted	3.1% Discount	Undiscounted	3.1% Discount	Undiscounted	3.1% Discount	Undiscounted	3.1% Discount	Undiscounted	3.1% Discount	Undiscounted	3.1% Discount
2025	$8,371,000	$7,638,382	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2026	$0	$0	-$83,710	-$74,087	$1,181,873	$1,046,011	$54,397	$48,144	$2,525,801	$2,235,448	$0	$0
2027	$0	$0	-$83,710	-$71,859	$1,194,873	$1,025,719	$56,021	$48,090	$2,553,585	$2,192,083	$0	$0
2028	$0	$0	-$83,710	-$69,699	$1,208,017	$1,005,822	$57,660	$48,009	$2,581,674	$2,149,559	$0	$0
2029	$0	$0	-$83,710	-$67,603	$1,221,305	$986,310	$59,123	$47,747	$2,610,073	$2,107,861	$0	$0
2030	$0	$0	-$83,710	-$65,570	$1,234,740	$967,177	$60,824	$47,644	$2,638,784	$2,066,971	$0	$0
2031	$0	$0	-$83,710	-$63,599	$1,248,322	$948,415	$62,403	$47,411	$2,667,810	$2,026,875	$0	$0
2032	$0	$0	-$83,710	-$61,687	$1,262,053	$930,017	$63,780	$47,000	$2,697,156	$1,987,556	$0	$0
2033	$0	$0	-$83,710	-$59,832	$1,275,936	$911,976	$65,412	$46,753	$2,726,825	$1,949,000	$0	$0
2034	$0	$0	-$83,710	-$58,033	$1,289,971	$894,285	$67,072	$46,498	$2,756,820	$1,911,192	$0	$0
2035	$0	$0	-$83,710	-$56,288	$1,304,161	$876,937	$68,523	$46,076	$2,787,145	$1,874,118	$1,316,528	$885,253
TOTAL:	**$8,371,000**	**$7,638,382**	**-$837,100**	**-$648,257**	**$12,421,251**	**$9,592,670**	**$615,213**	**$473,371**	**$26,545,672**	**$20,500,664**	**$1,316,528**	**$885,253**

Benefit-Cost Summary				
	Undiscounted BCA		BCA: 3.1% Discount Rate	
Year	Total Undiscounted Costs	Total Undiscounted Benefits	Total Costs (3.1% Discount)	Total Benefits (3.1% Discount)
2025	$8,371,000	$0	$7,638,382	$0
2026	$0	$3,678,361	$0	$3,255,515
2027	$0	$3,720,769	$0	$3,194,033
2028	$0	$3,763,642	$0	$3,133,692
2029	$0	$3,806,791	$0	$3,074,315
2030	$0	$3,850,637	$0	$3,016,222
2031	$0	$3,894,825	$0	$2,959,102
2032	$0	$3,939,279	$0	$2,902,887
2033	$0	$3,984,462	$0	$2,847,898
2034	$0	$4,030,153	$0	$2,793,943
2035	$0	$5,392,646	$0	$3,626,096
	$8,371,000	**$40,061,564**	**$7,638,382**	**$30,803,701**
TOTAL:	**B-C Ratio**	**4.79**	**B-C Ratio**	**4.03**
	NPV	**$31,690,564**	**NPV**	**$23,165,320**

Project Scenario (2022 $M)

Construction	8.37	2025	Construction Start Year
		2026	Operation Start Year
		2022	Constant $ Year

		3.1%	**Startup Costs**	
			Undiscounted	**Discounted**
2025	3	0.91	$8.4	$7.6
2026	4	0.89	$0.0	$0.0
2027	5	0.86	$0.0	$0.0
2028	6	0.83	$0.0	$0.0
2029	7	0.81	$0.0	$0.0
2030	8	0.78	$0.0	$0.0
2031	9	0.76	$0.0	$0.0
2032	10	0.74	$0.0	$0.0
2033	11	0.71	$0.0	$0.0
2034	12	0.69	$0.0	$0.0
2035	13	0.67	$0.0	$0.0
			8.37	**7.64**

Crossing Delay Reduction Benefit

Delay per Passenger Vehicle (Minutes	7.24
Delay per Truck (Minutes)	3.59
Project Delay Reduction	5.00%

No Build Scenario

	Annual Passenger Trips	Annual Truck Trips	Annual Passenger Delay Hours	Annual Truck Delay Hours	Value of Time Costs: Passenger	Value of Time Costs: Truck	Fuel Costs: Passenger	Fuel Costs: Truck	Total Delay Cost	Emissions Costs: Passenger Delay Emissions	Emissions Costs: Truck Delay Emissions	Total Emissions Cost
2026	8,241,447	1,104,255	994,027	66,047	$ 19,482,925	$ 2,212,583	$ 1,760,411	$ 181,537	$23,637,457	$949,229	$138,706	$1,087,935
2027	8,332,103	1,116,402	1,004,961	66,774	$ 19,697,237	$ 2,236,921	$ 1,779,776	$ 183,534	$23,897,469	$977,555	$142,856	$1,120,410
2028	8,423,756	1,128,682	1,016,016	67,508	$ 19,913,907	$ 2,261,527	$ 1,799,354	$ 185,553	$24,160,341	$1,006,222	$146,986	$1,153,208
2029	8,516,418	1,141,098	1,027,192	68,251	$ 20,132,960	$ 2,286,404	$ 1,819,146	$ 187,594	$24,426,104	$1,031,637	$150,832	$1,182,468
2030	8,610,098	1,153,650	1,038,491	69,002	$ 20,354,422	$ 2,311,554	$ 1,839,157	$ 189,658	$24,694,792	$1,061,356	$155,121	$1,216,478
2031	8,704,809	1,166,340	1,049,914	69,761	$ 20,578,321	$ 2,336,981	$ 1,859,388	$ 191,744	$24,966,434	$1,089,326	$158,736	$1,248,062
2032	8,800,562	1,179,170	1,061,463	70,528	$ 20,804,682	$ 2,362,688	$ 1,879,841	$ 193,853	$25,241,065	$1,113,665	$161,929	$1,275,593
2033	8,897,369	1,192,141	1,073,139	71,304	$ 21,033,534	$ 2,388,678	$ 1,900,519	$ 195,986	$25,518,717	$1,142,570	$165,660	$1,308,230
2034	8,995,240	1,205,254	1,084,944	72,088	$ 21,264,903	$ 2,414,953	$ 1,921,425	$ 198,142	$25,799,423	$1,171,977	$169,454	$1,341,431
2035	9,094,187	1,218,512	1,096,878	72,881	$ 21,498,817	$ 2,441,518	$ 1,942,561	$ 200,321	$26,083,216	$1,197,637	$172,813	$1,370,450

Build Scenario

	Annual Passenger Delay Hours	Annual Truck Delay Hours	Value of Time Costs: Passenger	Value of Time Costs: Truck	Fuel Costs: Passenger	Fuel Costs: Truck	Total Delay Cost	Emissions Costs: Passenger Delay Emissions	Emissions Costs: Truck Delay Emissions	Total Emissions Cost	Delay Cost Reduction	Emissions Cost
2026	944,325	62,745	$18,508,779	$ 2,101,953	$ 1,672,391	$ 172,461	$22,455,584	$901,768	$131,770	$1,033,538	$1,181,873	$54,397
2027	954,713	63,435	$18,712,375	$ 2,125,075	$ 1,690,787	$ 174,358	$22,702,595	$928,677	$135,713	$1,064,390	$1,194,873	$56,021
2028	965,215	64,133	$18,918,211	$ 2,148,451	$ 1,709,386	$ 176,276	$22,952,324	$955,911	$139,636	$1,095,547	$1,208,017	$57,660
2029	975,832	64,838	$19,126,312	$ 2,172,084	$ 1,728,189	$ 178,215	$23,204,799	$980,055	$143,290	$1,123,345	$1,221,305	$59,123
2030	986,566	65,552	$19,336,701	$ 2,195,977	$ 1,747,199	$ 180,175	$23,460,052	$1,008,289	$147,365	$1,155,654	$1,234,740	$60,824
2031	997,419	66,273	$19,549,405	$ 2,220,132	$ 1,766,418	$ 182,157	$23,718,113	$1,034,860	$150,799	$1,185,659	$1,248,322	$62,403
2032	1,008,390	67,002	$19,764,448	$ 2,244,554	$ 1,785,849	$ 184,161	$23,979,012	$1,057,981	$153,832	$1,211,814	$1,262,053	$63,780
2033	1,019,483	67,739	$19,981,857	$ 2,269,244	$ 1,805,493	$ 186,186	$24,242,781	$1,085,442	$157,377	$1,242,819	$1,275,936	$65,412
2034	1,030,697	68,484	$20,201,658	$ 2,294,206	$ 1,825,354	$ 188,234	$24,509,452	$1,113,378	$160,981	$1,274,360	$1,289,971	$67,072
2035	1,042,034	69,237	$20,423,876	$ 2,319,442	$ 1,845,433	$ 190,305	$24,779,056	$1,137,755	$164,173	$1,301,928	$1,304,161	$68,523

Planning Time Reliabilty Benefit

95th Percentile Delay Reduction 5.00%

No Build Scenario — Planning Hours

	Peace Arch Car Hours	Pacific Highway Car Hours	Lynden/Aldergrove Car Hours	Sumas/Huntingdon Car Hours	Total Car Hours	Pacific Highway Truck Hours	Lynden/Aldergrove Truck Hours	Sumas/Huntingdon Truck Hours	Total Truck Hours	Total Car Planning Cost	Total Truck Planning Cost	Total Planning Cost
2026	1,072,804	1,013,742	133,998	189,301	2,409,844	97,557	445	0	98,002	$ 47,232,949	$ 3,283,072	$ 50,516,021
2027	1,084,605	1,024,893	135,472	191,383	2,436,353	98,630	450	0	99,080	$ 47,752,512	$ 3,319,186	$ 51,071,697
2028	1,096,535	1,036,167	136,962	193,488	2,463,153	99,715	455	0	100,170	$ 48,277,789	$ 3,355,697	$ 51,633,486
2029	1,108,597	1,047,565	138,469	195,617	2,490,247	100,812	460	0	101,272	$ 48,808,845	$ 3,392,609	$ 52,201,454
2030	1,120,792	1,059,088	139,992	197,769	2,517,640	101,921	465	0	102,386	$ 49,345,742	$ 3,429,928	$ 52,775,670
2031	1,133,120	1,070,738	141,532	199,944	2,545,334	103,042	470	0	103,512	$ 49,888,546	$ 3,467,657	$ 53,356,203
2032	1,145,585	1,082,516	143,089	202,143	2,573,333	104,176	475	0	104,651	$ 50,437,320	$ 3,505,801	$ 53,943,121
2033	1,158,186	1,094,423	144,663	204,367	2,601,639	105,322	480	0	105,802	$ 50,992,130	$ 3,544,365	$ 54,536,495
2034	1,170,926	1,106,462	146,254	206,615	2,630,257	106,480	486	0	106,966	$ 51,553,044	$ 3,583,353	$ 55,136,397
2035	1,183,806	1,118,633	147,863	208,888	2,659,190	107,651	491	0	108,142	$ 52,120,127	$ 3,622,770	$ 55,742,897

Build Scenario — Planning Hours

	Peace Arch Cars	Pacific Highway Cars	Lynden/Aldergrove Cars	Sumas/Huntingdon Cars	Total Car Hours	Pacific Highway Trucks	Lynden/Aldergrove Trucks	Sumas/Huntingdon Trucks	Total Truck Hours	Total Car Planning Cost	Total Truck Planning Cost	Total Planning Cost	Planning Time Cost Reduction
2026	1,019,163	963,055	127,298	179,836	2,289,352	92,679	423	-	93,102	$ 44,871,302	$ 3,118,918	$ 47,990,220	$ 2,525,801
2027	1,030,374	973,648	128,698	181,814	2,314,535	93,699	427	-	94,126	$ 45,364,886	$ 3,153,226	$ 48,518,113	$ 2,553,585
2028	1,041,708	984,358	130,114	183,814	2,339,995	94,729	432	-	95,162	$ 45,863,900	$ 3,187,912	$ 49,051,812	$ 2,581,674
2029	1,053,167	995,186	131,545	185,836	2,365,735	95,771	437	-	96,208	$ 46,368,403	$ 3,222,979	$ 49,591,382	$ 2,610,073
2030	1,064,752	1,006,133	132,992	187,880	2,391,758	96,825	442	-	97,267	$ 46,878,455	$ 3,258,432	$ 50,136,887	$ 2,638,784
2031	1,076,464	1,017,201	134,455	189,947	2,418,067	97,890	447	-	98,337	$ 47,394,118	$ 3,294,274	$ 50,688,393	$ 2,667,810
2032	1,088,305	1,028,390	135,934	192,036	2,444,666	98,967	451	-	99,418	$ 47,915,454	$ 3,330,511	$ 51,245,965	$ 2,697,156
2033	1,100,277	1,039,702	137,430	194,149	2,471,557	100,055	456	-	100,512	$ 48,442,524	$ 3,367,147	$ 51,809,671	$ 2,726,825
2034	1,112,380	1,051,139	138,941	196,284	2,498,744	101,156	461	-	101,617	$ 48,975,391	$ 3,404,186	$ 52,379,577	$ 2,756,820
2035	1,124,616	1,062,702	140,470	198,443	2,526,231	102,269	466	-	102,735	$ 49,514,121	$ 3,441,632	$ 52,955,752	$ 2,787,145

Cost Category	Cost	Estimated Life	Residual Value 2035	Discounted
Radar Design, Implementation, Testing	$ 825,552	12	$ 137,592	$ 92,519
Wifi System Design Implementation	$ 1,041,410	10	$ -	$ -
Fiber Network Installation	$ 550,000	25	$ 330,000	$ 221,897
Cascade Gateway Custom BWF APP/Interface	$ 2,546,808	15	$ 848,936	$ 570,837
			$ 1,316,528	$ 885,253

	Northbound	Southbound	North Delay	South Dela	North Truck	South Truck	North Dela	South Dela	Total Car Delay	Delay Per (	Total Truck D	Delay per Truck
Peace Arch	1,857,818	1,727,048	3.98	13.01					29,853,037	8.33	-	-
Pacific Highway	1,214,640	1,254,546	5.92	10.78	374,855	356,048	4.76	5.74	20,703,817	8.38	3,827,942	5.24
Lynden/Aldergrove	393,090	432,115	3.83	3.29	48,537	45,931	0.14	-	2,923,875	3.54	6,944	0.07
Sumas/Huntingdon	542,058	554,040	2.95	4.76	100,629	142,602	-	-	4,235,224	3.86	-	-
Total	4,007,606	3,967,749			524,021	544,581			57,715,953	7.24	3,834,886	3.59

June 95th Percentile Delay	Cars	Trucks
Peace Arch Southbound	39.56	
Peace Arch Northbound	12.82	
Pacific Highway Southbound	29.12	12.80556
Pacific Highway Northbound	13.17	13.15972
Lynden/Aldergrove Southbound	13.98	
Lynden/Aldergrove Northbound	11.86	0.675393
Sumas/Huntingdon Southbound	16.49	
Sumas/Huntingdon Northbound	11.23	

	Peace Arch / Douglas					Pacific Highway						Lynden / Aldergrove					Sumas / Abb-Huntingdon								
	STANDARD		NEXUS		READY	STANDARD		NEXUS		TRUCK		STANDARD		NEXUS	TRUCK		STANDARD		NEXUS		READY	TRUCK		Total Car	Total Truck
	NB	SB	NB	SB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	NB	SB	NB	SB	NB	SB	SB	NB	SB		
Jan	72,432	71,469	48,943	40,864		49,570	58,112	31,489	29,877	30,068	28,945	21,091	26,545	4,037	3,732	3,241	27,471	34,775	6,692	261		7,636	11,442	523,628	85,064
Feb	71,201	69,705	46,085	38,940		48,045	54,154	28,926	27,729	28,466	26,953	20,703	25,629	3,834	3,529	2,940	27,499	34,087	6,140	349		7,295	10,675	503,026	79,858
Mar	88,762	83,708	54,920	47,755		60,881	64,904	35,005	34,339	34,053	31,984	25,409	31,617	4,608	4,451	3,832	33,258	40,992	7,432	562		8,289	12,377	614,152	94,986
Apr	89,726	87,072	56,810	48,679		59,757	65,369	35,480	34,105	30,197	27,949	26,191	31,943	4,852	3,898	3,624	33,629	40,060	7,443	687		7,977	11,265	621,803	84,910
May	95,346	91,185	61,642	54,675		64,240	67,593	38,382	37,035	32,924	31,864	28,002	34,288	5,286	4,436	4,155	38,392	44,408	8,228	1,262		9,074	13,127	669,964	95,580
Jun	100,356	98,567	64,085	56,790		67,719	69,755	39,158	38,189	33,593	32,097	29,562	37,444	5,340	4,330	4,426	41,265	48,609	8,360	1,081		9,178	12,717	706,280	96,341
Jul	130,550	121,338	69,174	63,657		83,739	85,332	42,386	39,781	31,934	30,687	35,224	50,104	5,489	4,222	4,366	50,031	57,891	9,560	1,244		9,057	13,074	845,500	93,340
Aug	125,978	120,851	70,401	62,828		82,586	86,658	42,702	41,881	33,349	30,581	36,351	49,137	5,696	4,415	3,819	49,255	60,772	9,947	862		9,636	12,873	845,905	94,673
Sep	104,509	102,749	63,767	57,770		69,782	73,310	38,933	36,926	31,182	29,870	31,101	40,614	5,342	3,928	4,059	41,442	52,327	8,828	771		8,562	11,907	728,171	89,508
Oct	90,377	86,125	58,708	53,700		62,218	67,461	37,600	34,508	31,795	31,006	26,979	34,444	5,233	4,433	5,065	37,212	46,021	8,621	902		8,475	11,896	650,109	92,670
Nov	83,739	78,566	56,294	50,193		57,688	63,590	35,300	34,262	29,430	28,203	25,661	33,654	4,733	3,878	3,613	32,116	40,726	7,401	756		8,453	11,533	604,679	85,110
Dec	93,468	85,947	60,545	53,915		64,607	72,429	38,447	37,247	27,864	25,909	27,397	36,696	4,969	3,285	2,791	33,962	43,621	7,874	1,014		6,997	9,716	662,138	76,562
2023 Total	1,146,444	1,097,282	711,374	629,766	0	770,832	828,667	443,808	425,879	374,855	356,048	333,671	432,115	59,419	48,537	45,931	445,532	544,289	96,526	9,751	0	100,629	142,602	7,975,355	1,068,602

Time/Value Factors	2022$	USDOT BCA Guidance December 2023	https://www.transportation.gov/sites/dot.gov/files/2023-12/Benefit%20Cost%20Analysis%20Guidance%202024%20Update.pd
Passenger All Purpose Cost Factor (88.2% personal, 11.8% Business)	$19.60		
Truck Drivers	$33.50		

Per Vehicle Cost Factors			
Passenger Vehicle Idle Fuel Consumption (Gallons per Hour)	0.39	Dept of Energy. Based on large sedan	https://www.energy.gov/eere/vehicles/fact-861-february-23-2015-idle-fuel-consumption-selected-gasoline-and-diesel-vehicles
Truck Idle Fuel Consumption (Gallons per Hour)	0.6		
Washington Gasoline Price 2023	$ 4.541	EIA	https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_swa_a.htm
West Coast less California Diesel Price 2023	$ 4.581	EIA	https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r5xca_w.htm

Emissions Rates (Mileage Based) metric tons per mile			
NOX (Passenger Veh)	0.0000002175	TREDIS/ MOVES3	
SO2 (Passenger Veh)	0.0000000022	TREDIS/ MOVES3	
PM (Passenger Veh)	0.0000000094	TREDIS/ MOVES3	
CO2 (Passenger Veh)(per gallon consumed)	0.0088870000	EPA	Greenhouse Gases Equivalencies Calculator - Calculations and References | Energy and the Environment | US EPA
NOX (Truck)	0.0000039024	TREDIS/ MOVES3	
SO2 (Truck)	0.0000000055	TREDIS/ MOVES3	
PM (Truck)	0.0000000839	TREDIS/ MOVES3	
CO2 (Truck) (Per Gallon)	0.0101800000		

Emissions Rates (Metric ton per Gallon)			
NOX (Passenger)	0.000004829	Converted From above assuming 22.2 mp	https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
SO2 (Passenger)	0.000000049		
PM (Passenger)	0.000000209		
CO2 (Passenger)	0.008887000		
NOX (Truck)	0.000024975	Converted from above assuming 6.4 mpg	
SO2 (Truck)	0.000000035		
PM (Truck)	0.000000537		
CO2 (Truck)	0.010180000		

Idle Emissions Rates per Hour (Metric ton per Hour)	
NOX (Passenger)	0.000001883
SO2 (Passenger)	0.000000019
PM (Passenger)	0.000000081
CO2 (Passenger)	0.003465930
NOX (Truck)	0.000014985
SO2 (Truck)	0.000000021
PM (Truck)	0.000000322
CO2 (Truck)	0.006108000

Emission Costs per metric ton USDOT BC https://www.transportation.gov/sites/dot.gov/files/2023-12/Benefit%20Cost%20Analysis%20Gu

Emission Type	**NOX**	**SO2**	**PM**	**CO2**
2023	$19,800	$52,900	$951,000	$228
2024	$20,100	$53,800	$963,200	$233
2025	$20,300	$54,800	$975,500	$237
2026	$20,600	$56,100	$993,500	$241
2027	$21,000	$57,400	$1,011,900	$245
2028	$21,300	$58,700	$1,030,600	$250
2029	$21,700	$60,100	$1,049,600	$253
2030	$22,000	$61,500	$1,069,000	$257
2031	$22,000	$61,500	$1,069,000	$262
2032	$22,000	$61,500	$1,069,000	$265
2033	$22,000	$61,500	$1,069,000	$270
2034	$22,000	$61,500	$1,069,000	$274
2035	$22,000	$61,500	$1,069,000	$278
2036	$22,000	$61,500	$1,069,000	$282
2037	$22,000	$61,500	$1,069,000	$287
2038	$22,000	$61,500	$1,069,000	$290
2039	$22,000	$61,500	$1,069,000	$294
2040	$22,000	$61,500	$1,069,000	$299
2041	$22,000	$61,500	$1,069,000	303.3818525
2042	$22,000	$61,500	$1,069,000	307.8598134
2043	$22,000	$61,500	$1,069,000	312.3377744
2044	$22,000	$61,500	$1,069,000	316.8157353
2045	$22,000	$61,500	$1,069,000	321.2936962
2046	$22,000	$61,500	$1,069,000	325.7716571
2047	$22,000	$61,500	$1,069,000	331.3691083
2048	$22,000	$61,500	$1,069,000	335.8470692
2049	$22,000	$61,500	$1,069,000	340.3250301
2050	$22,000	$61,500	$1,069,000	344.8029911
2051	$22,000	$61,500	$1,069,000	349.280952
2052	$22,000	$61,500	$1,069,000	352.6394227
2053	$22,000	$61,500	$1,069,000	357.1173836

https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey&1903=13

Discount Rate 3.1%

Inflation Adjustment USDOT BCA Guidance December 2023 https://www.transportation.gov/sites/dot.gov/files/2023-12/Benefit%20Cost%20Analysis%20Guidance%202024%20Update.pd

Base Year of Nominal Dollar	Multiplier to Adjust to Real 2022 $
2003	1.53
2004	1.49
2005	1.45
2006	1.40
2007	1.37
2008	1.34
2009	1.33
2010	1.32
2011	1.29
2012	1.27
2013	1.24
2014	1.22
2015	1.21
2016	1.20
2017	1.18
2018	1.15
2019	1.13
2020	1.12
2021	1.07
2022	1.00

Traffic Growth Factor 1.10%