Concept of Operations

CASCADE GATEWAY ADVANCED BORDER INFORMATION SYSTEM (ABIS) DESIGN PROJECT

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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

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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.

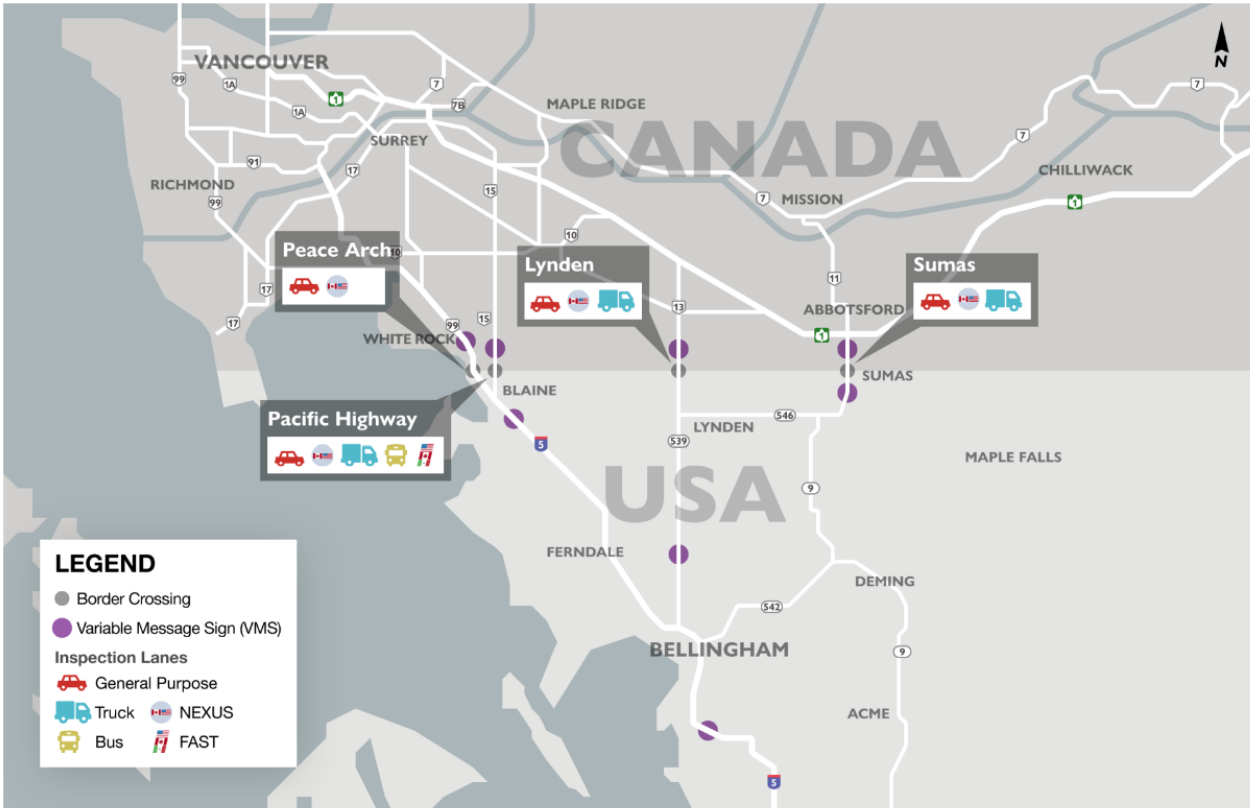


Figure 1. The Cascade Gateway ABIS Project Area Overview

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.

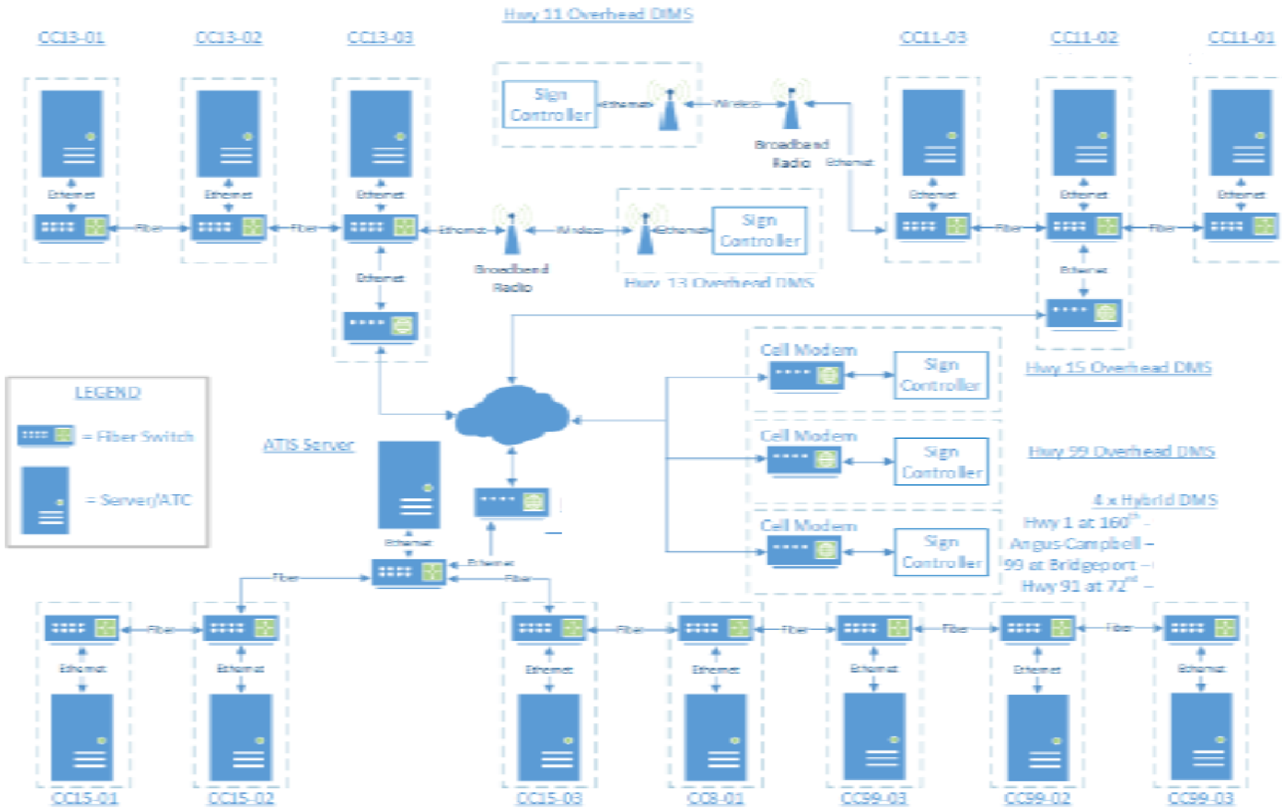


Figure 2. Southbound ATIS Network Diagram

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.

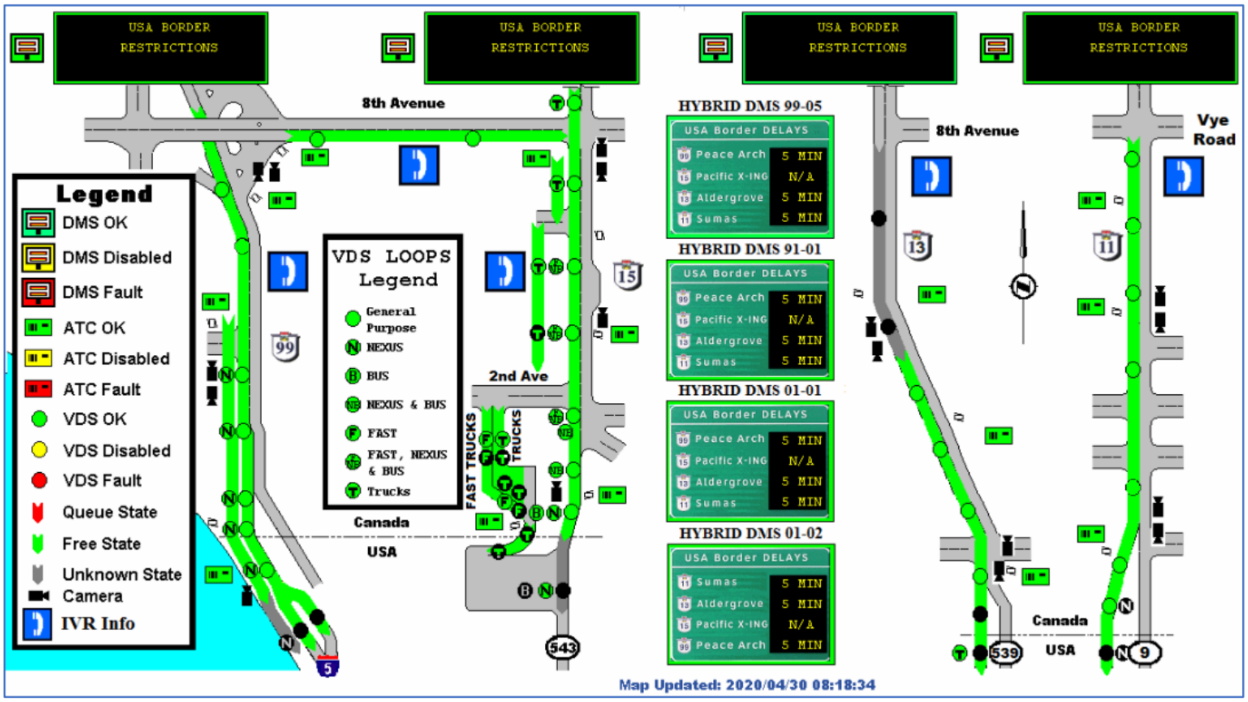


Figure 3. Existing Southbound ATIS Layout

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.

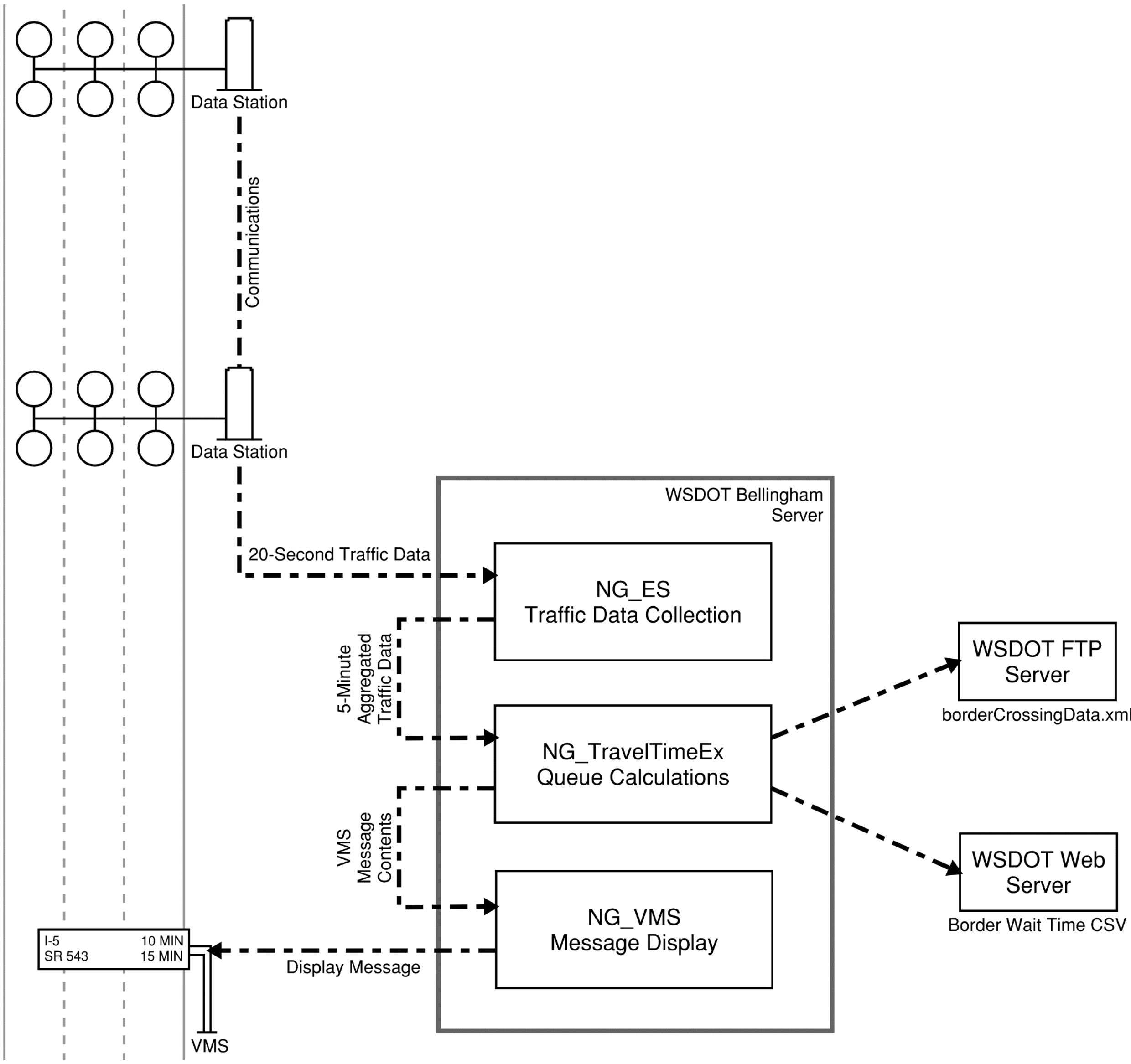


Figure 4. Northbound ATIS Data Flow Diagram

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.

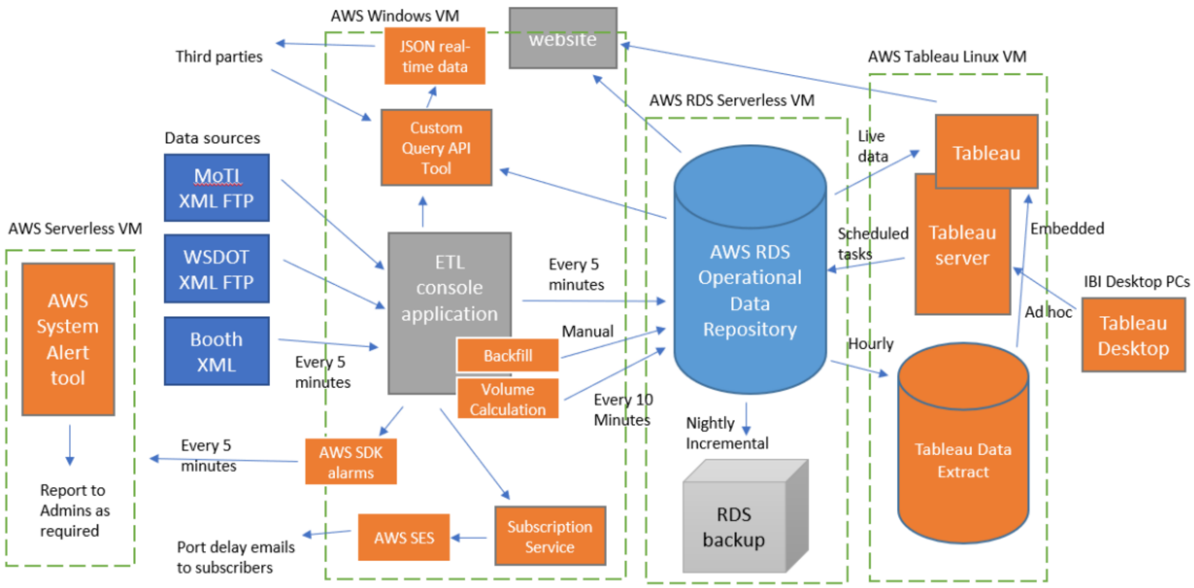


Figure 5. System Architecture of BDW 3.0

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.

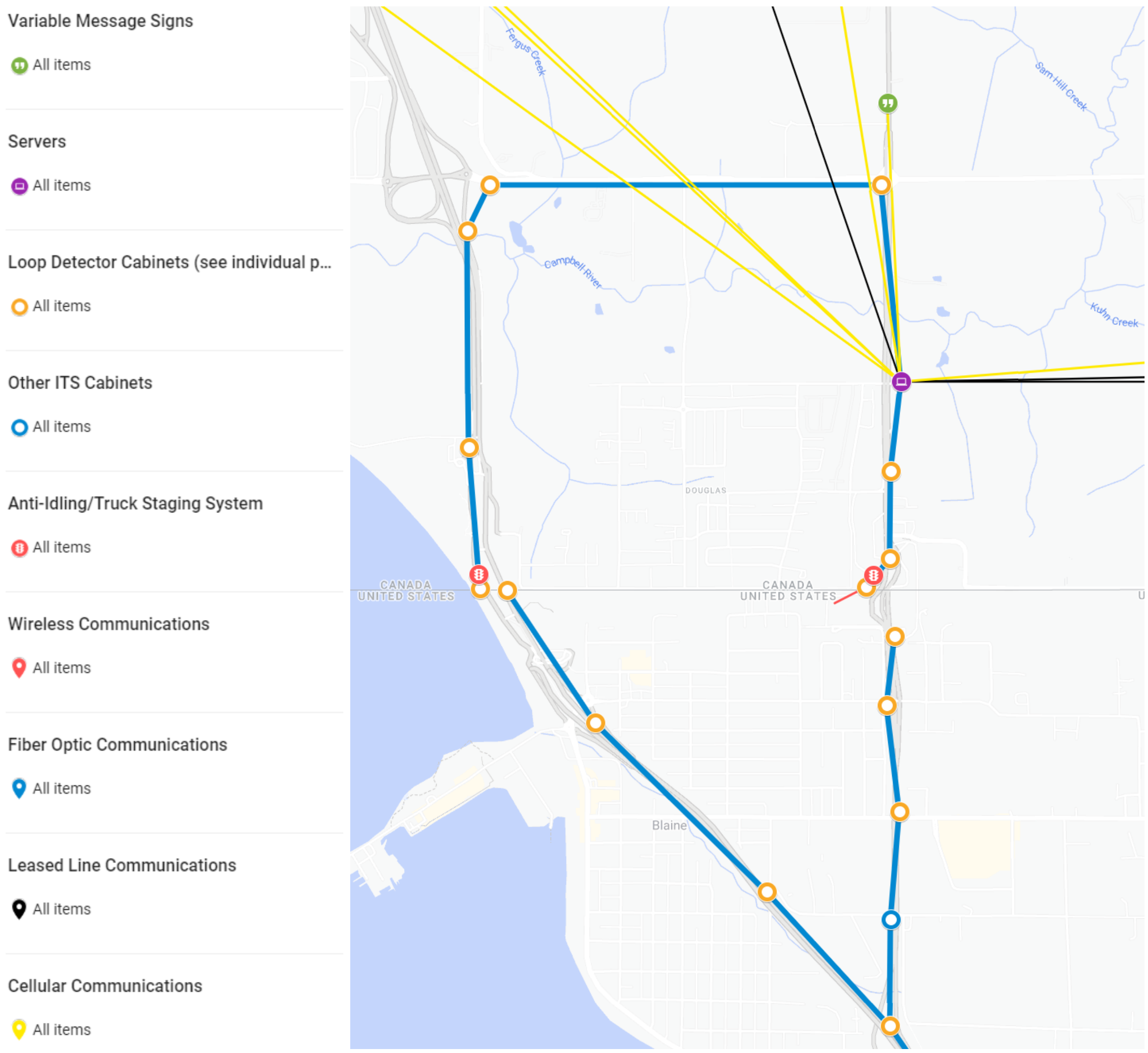


Figure 6. Excerpt from Online Map of Existing System Components at Peace Arch/Douglas and Pacific Highway

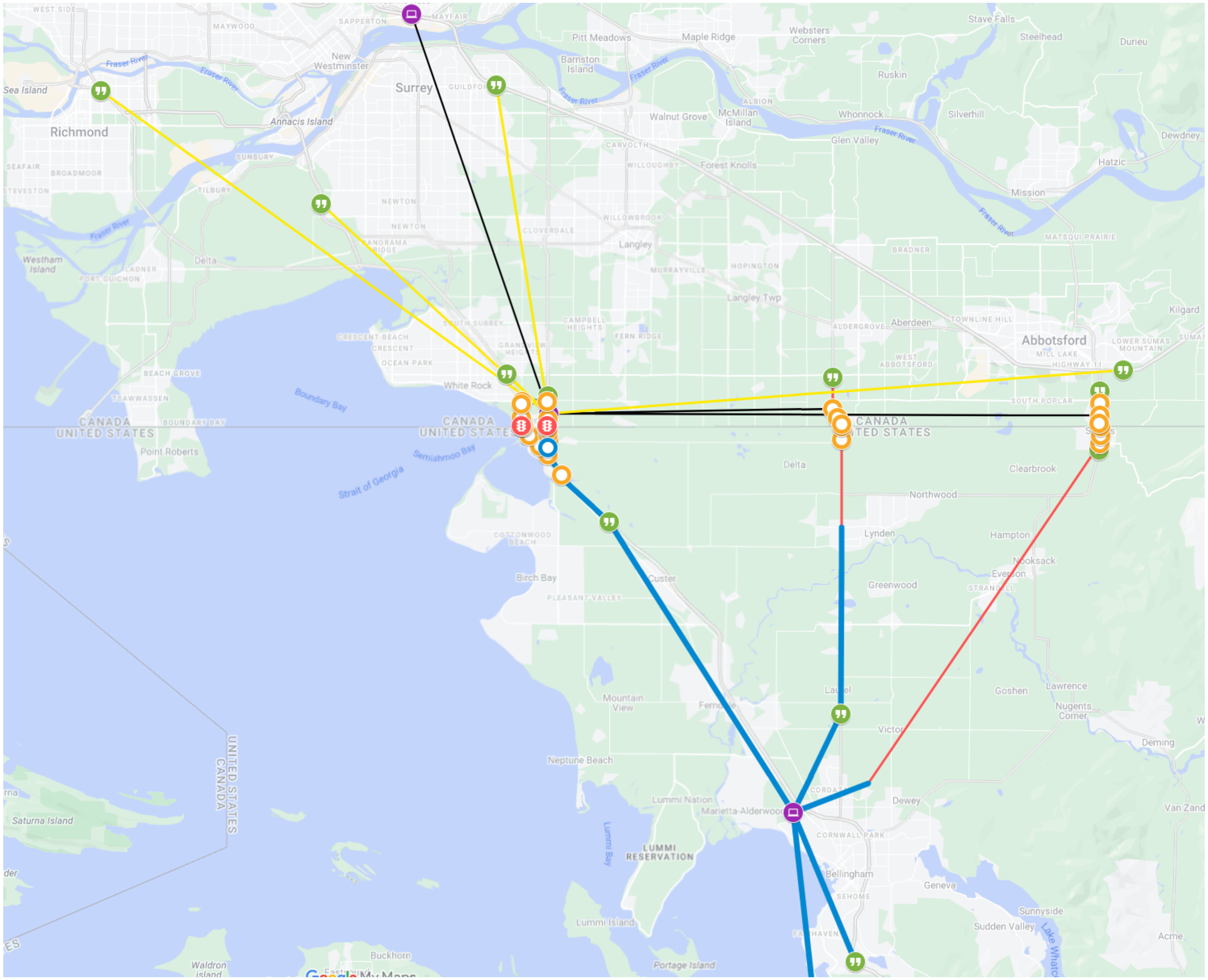


Figure 7. Excerpt from Online Map of Existing System Components - Cascade Gateway Overview

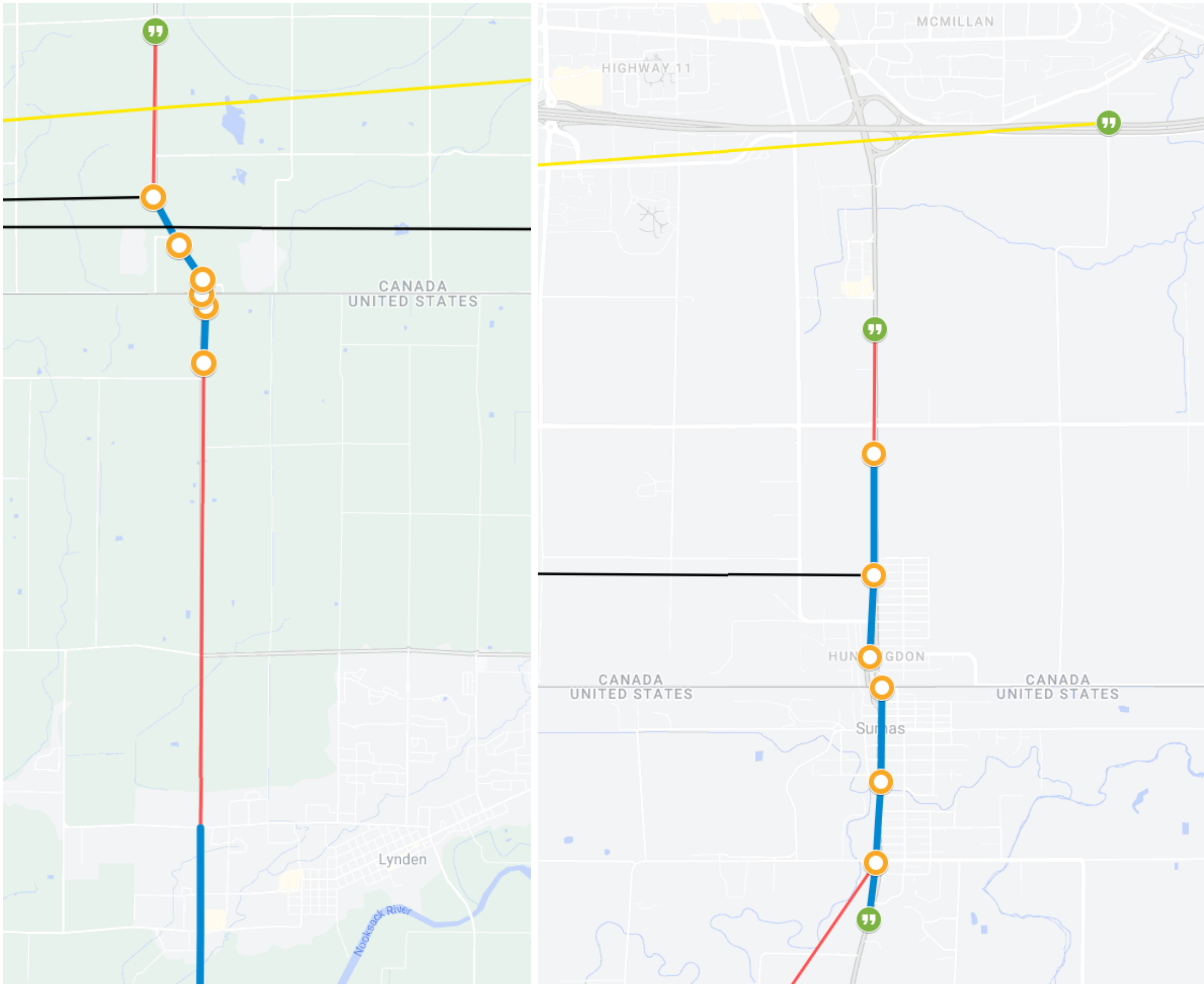


Figure 8. Excerpt from Online Map of Existing System Components at Lynden/Aldergrove and Sumas/Abbotsford-Huntingdon

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
    - **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."
    - **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."
    - **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.

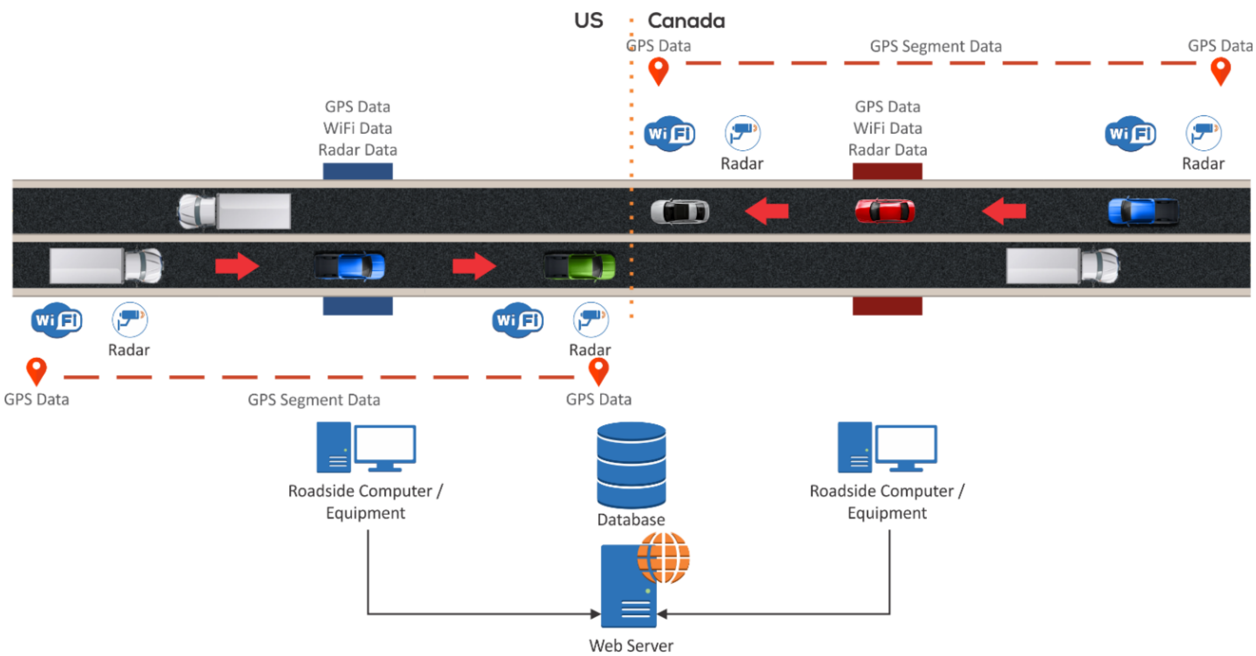


Figure 9. Proposed Technologies Overview

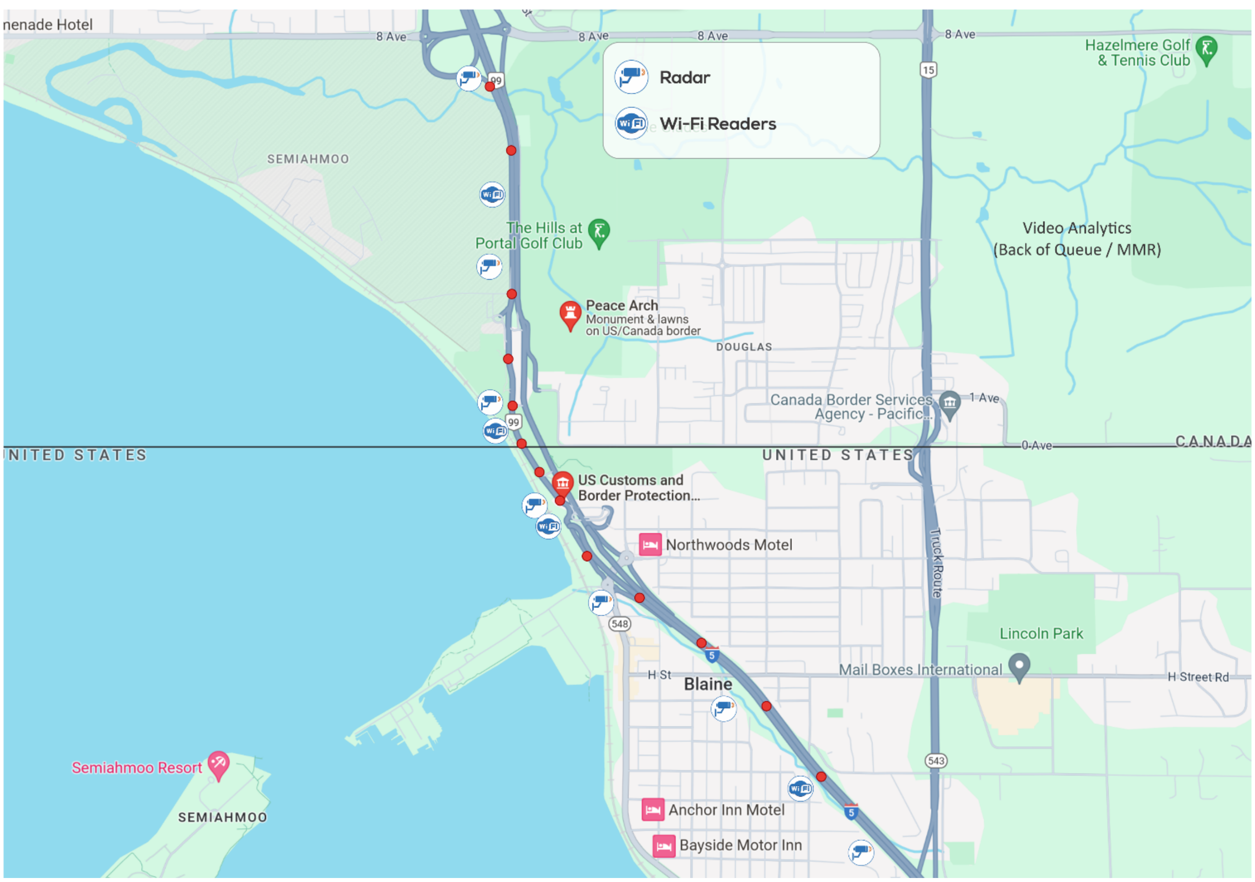


Figure 10. Proposed Roadside BWT Measurement Technologies

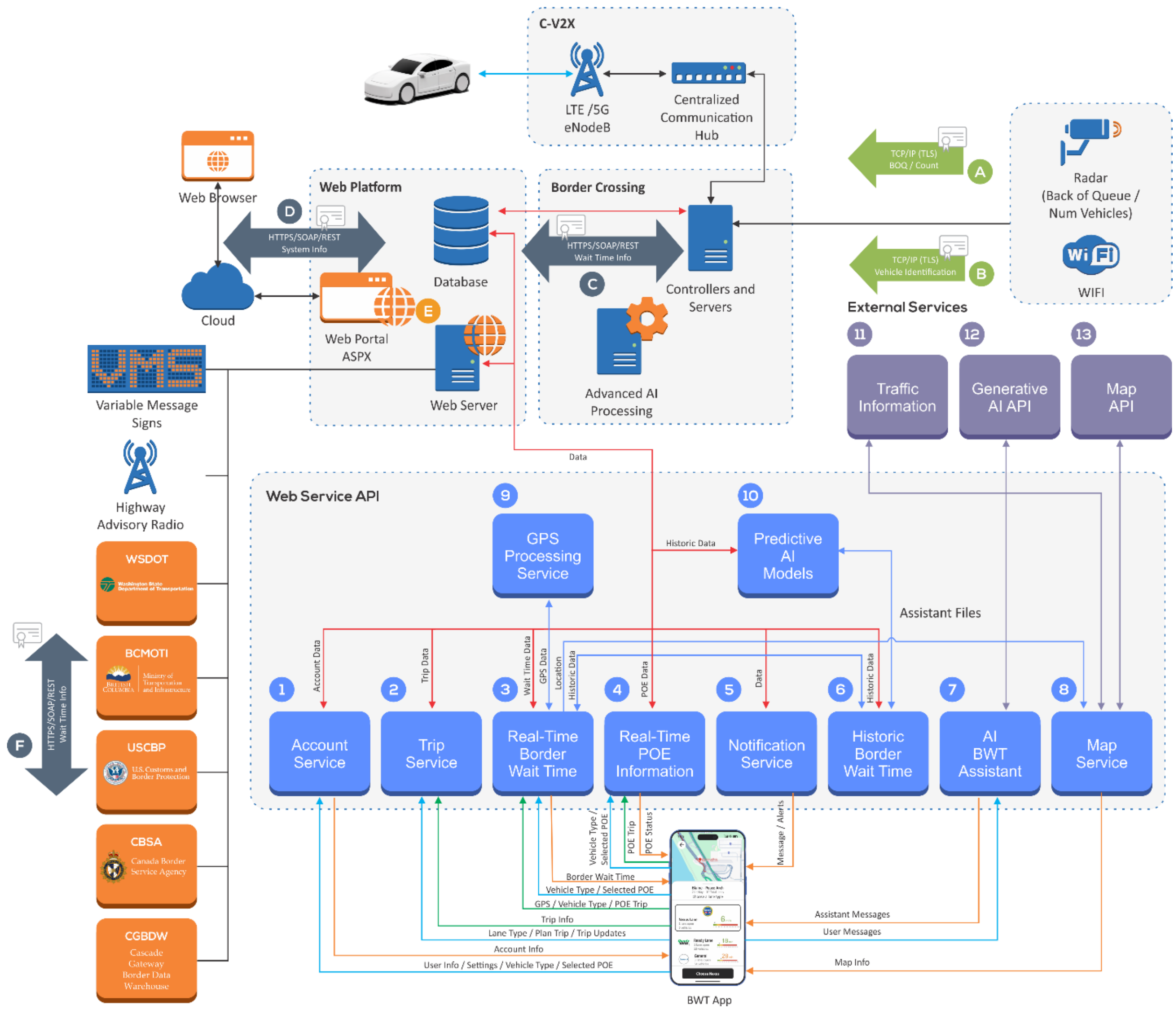


Figure 11. Proposed System Architecture and Data Flow

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)

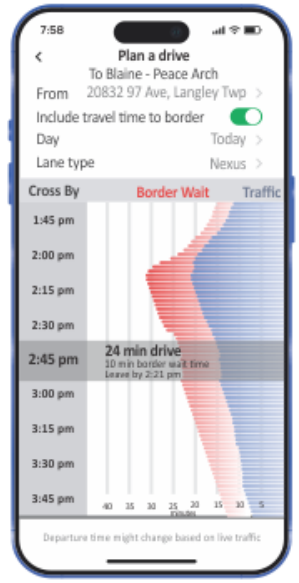


Figure 12. BWT App - Travel Time Predictions

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

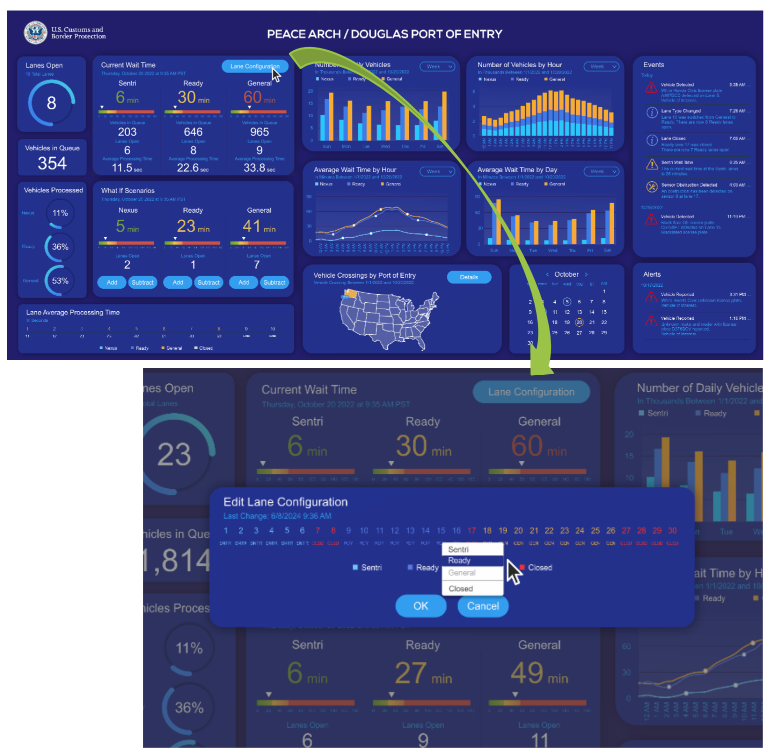


Figure 14. Inspection Agency Dashboard

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.

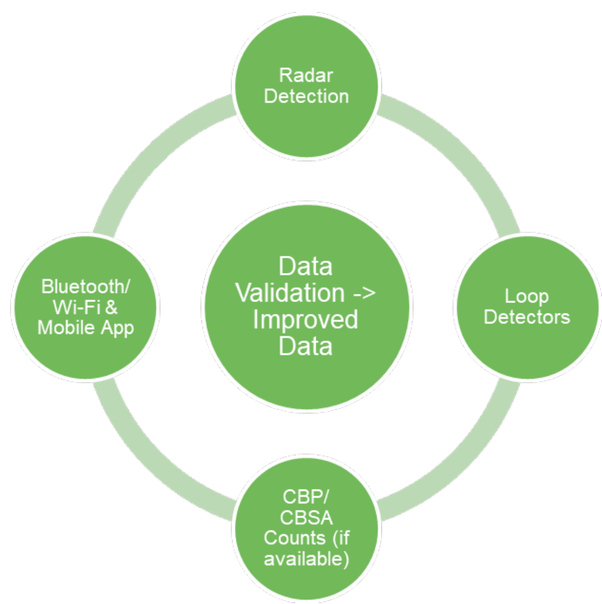
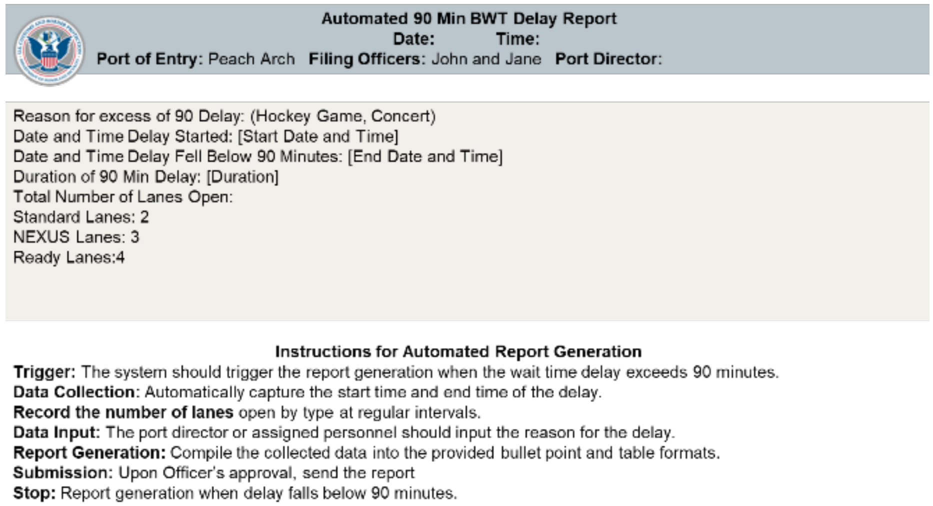


Figure 15. Data Validation Methodology

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

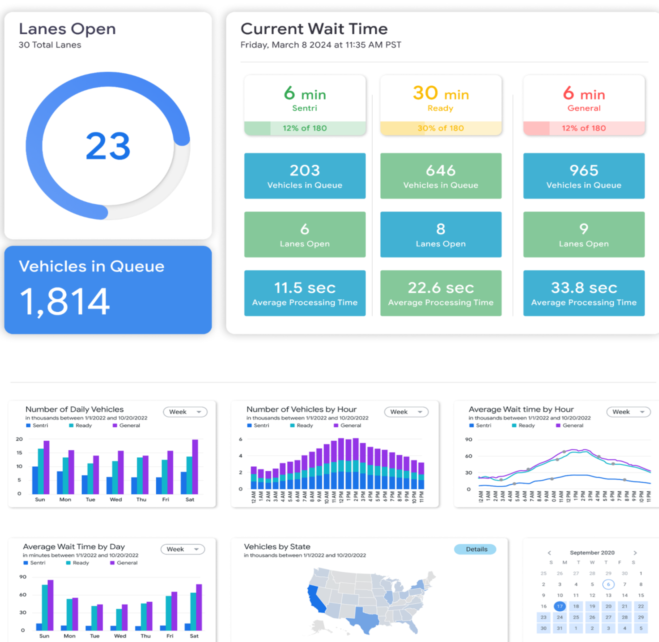


Figure 17. Inspection Agency Dashboard

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**

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