Implementation Report

CASCADE GATEWAY ADVANCED BORDER INFORMATION SYSTEM (ABIS) DESIGN PROJECT

whatcom council of governments

December 24, 2024

Project Title	Cascade Gateway Advanced Border Information System (ABIS) Design Project
Recipient Name	Whatcom Council of Governments (WCOG)
Fiscal Year of Award	FY22
Period of Performance	18 Months
Prepared By	WCOG Transpo Group USA, Inc. Sarakki Associates Inc. Texas A&M Transportation Institute
Date Submitted	December 24, 2024

Prepared By:

transpogroup
WHAT TRANSPORTATION CAN BE.

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

Texas A&M Transportation Institute

Texas A&M Transportation Institute
3135 TAMU

SAI SARAKKI Associates Inc.

Sarakki Associates Inc.
4199 Campus Drive, Ste 550

1. INTRODUCTION AND PROJECT OVERVIEW

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

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

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

On December 16, 2024, the Washington State Department of Transportation (WSDOT), as designee of WCOG, was awarded funding for Stage 2. In 2025, WSDOT will finalize the grant agreement with the SMART Grants Program team, then meet with project partners to start the development of the detailed design and implementation plan.

1.1 Project Description

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

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

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

- **Sumas/Abbotsford-Huntingdon**: Open 24 hours for passenger traffic, NEXUS, and commercial traffic, serving WA SR 9 and B.C. Hwy 11.

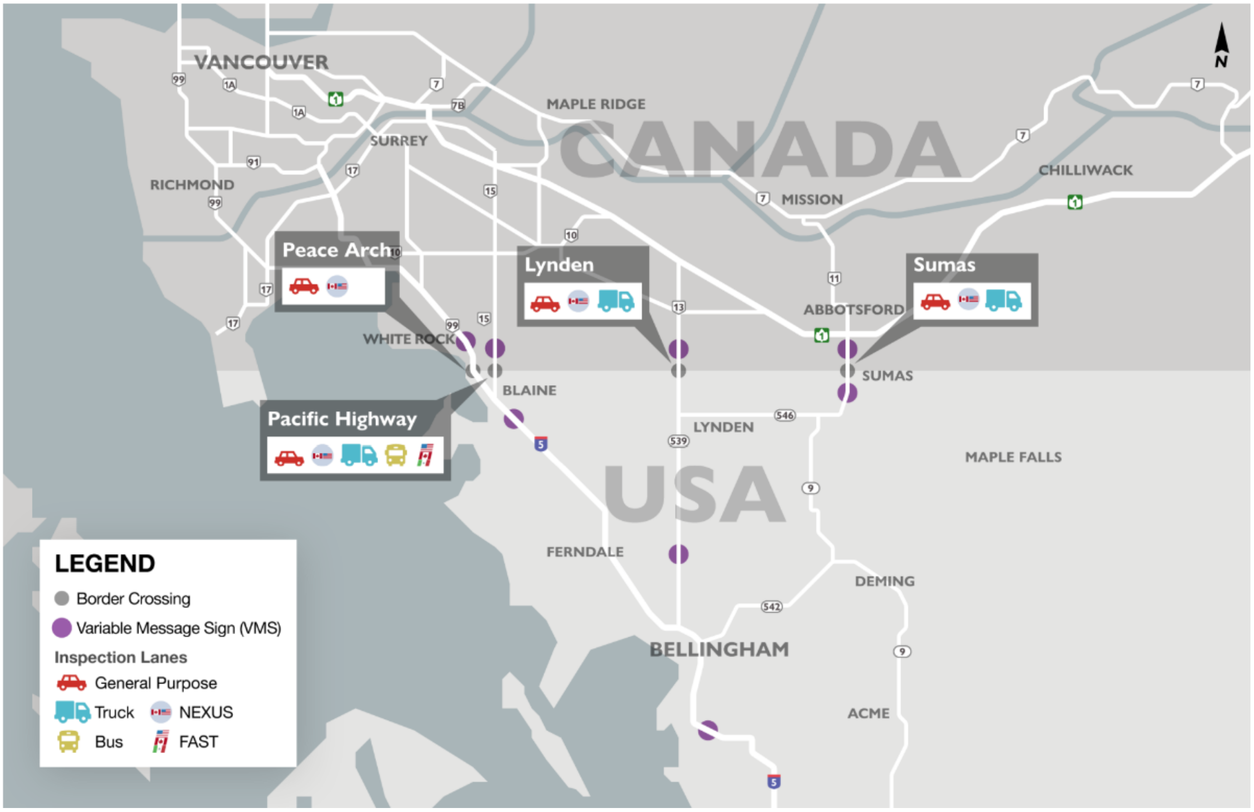

Figure 1. The Cascade Gateway ABIS Project Area Overview

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

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

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

Table 1. Stage 1 Design Project Outcomes

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

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

1. **Bluetooth/Wi-Fi-Based Measurement:** Utilizing the unique Media Access Control (MAC) addresses of smart devices, the system anonymously identifies vehicles when they join the back of the queue and reidentifies them as they travel up to and through the primary inspection area. This provides real-time, granular data on wait times for both privately-owned and commercial vehicles.
2. **Radar-Based Detection System:** The proposed radar detection system complements the Bluetooth/Wi-Fi data by accurately measuring the location of the back of the queue and counting the number of vehicles in each lane for improved wait time calculations. Note that radar detection is just one type of vehicle detection technology that could be deployed with the ABIS; as part of the detailed design, vehicle detection technologies will be further evaluated for technological maturity and technical relevance/applicability.
3. **Map-Based Border Wait Time (BWT) Mobile Application:** This user-friendly app integrates the various data sources that collect traffic data with historical information. Patterns, Artificial Intelligence (AI), and Machine Learning (ML) algorithms are used to provide real-time updates, generate accurate predictions for current and future wait times, and plan for border operations. Integration with mapping platforms and interfaces provides users with navigational assistance via natural language routing information, and more.
4. **AI and Machine Learning Tools:** Leveraging historical and real-time data, the AI algorithms perform analyses that reveal hidden patterns in data and day-to-day operations. Agency-specific dashboards, self-learning algorithms, and intuitive natural language interfaces provide users with actionable insights.
5. **Leverage Future Developments in GPS and Connected Vehicle Technologies:** The mobile application will be designed to work with smartphones that will soon contain chipsets that will be able to take advantage of the new GPS Block III constellation of satellites, which will support positioning accuracy for lane-by-lane vehicle positioning. Additionally, the BWT mobile application will be designed to integrate with the C-V2X family of applications and standards being promoted by the USDOT and the private sector.

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

1.2 Community Impacts

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

Table 2. Project Location Census Tracts

CEJST Census Tract	ETC Explorer Census Tract	Disadvantaged Status
53073010401	**53073010409**	Not disadvantaged per CEJST.
	53073010410	**Fully disadvantaged per ETC Explorer.**
53073010301	**53073010301**	Not disadvantaged per CEJST.

		Not disadvantaged per ETC Explorer but is **highly disadvantaged (80%) in Transportation Insecurity.**
53073010200	**53073010202**	***Partially disadvantaged per CEJST.*** **Fully disadvantaged per ETC Explorer.**

This solution benefits a broad spectrum of the community, from regional businesses and tourism venues serving U.S. or Canadian visitors, to local farmers carrying goods across the border, as well as nearby Whatcom County and B.C. residents. Given the project's location in a predominantly rural region, any effort to reduce regional travel restrictions will improve accessibility to local businesses and services. These stakeholders are represented by the International Mobility and Trade Corridor (IMTC) Program, as described in the ***Partnerships*** section below.

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

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

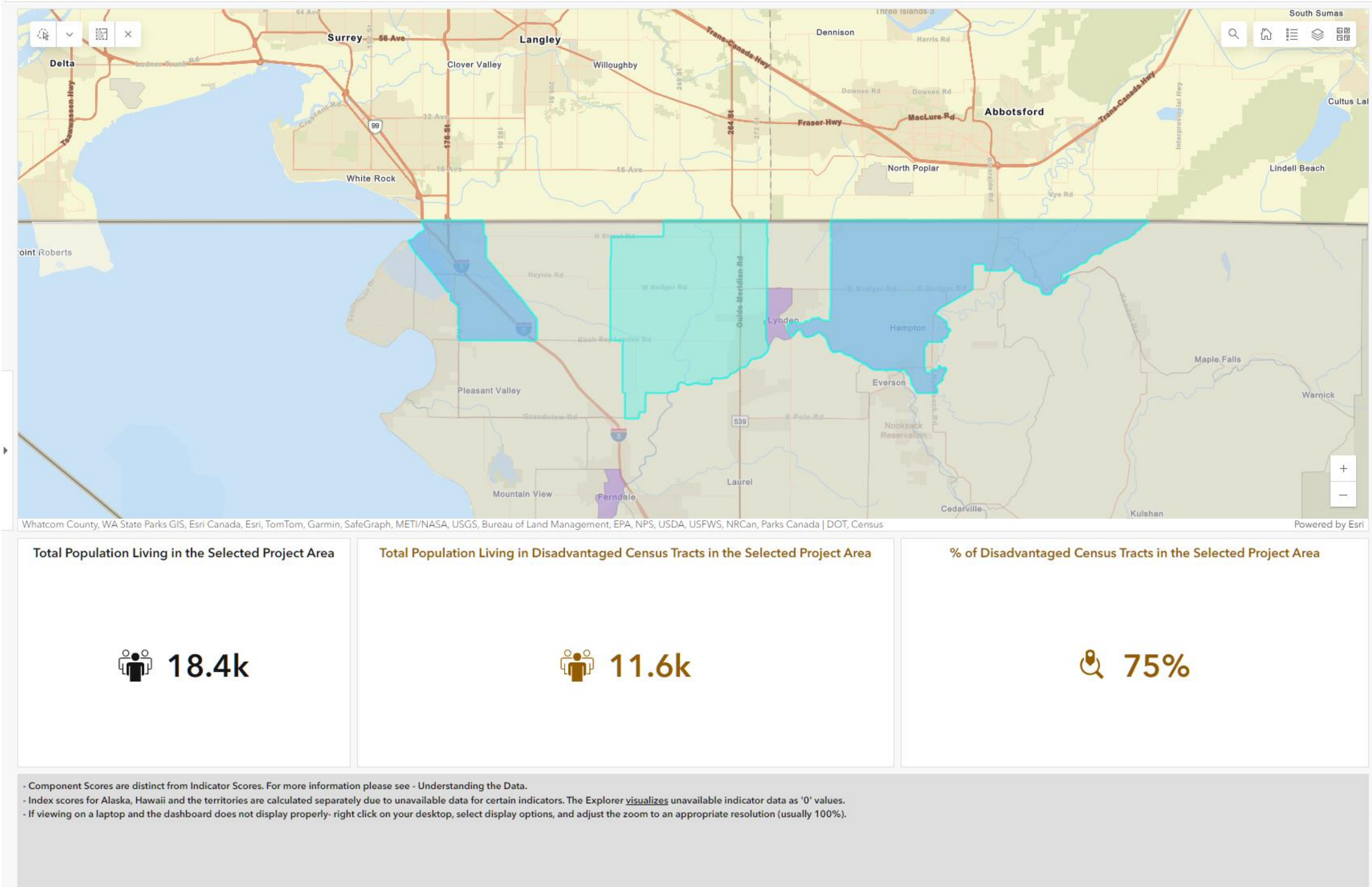

Figure 2. Project Area - USDOT ETC Explorer Census Tracts

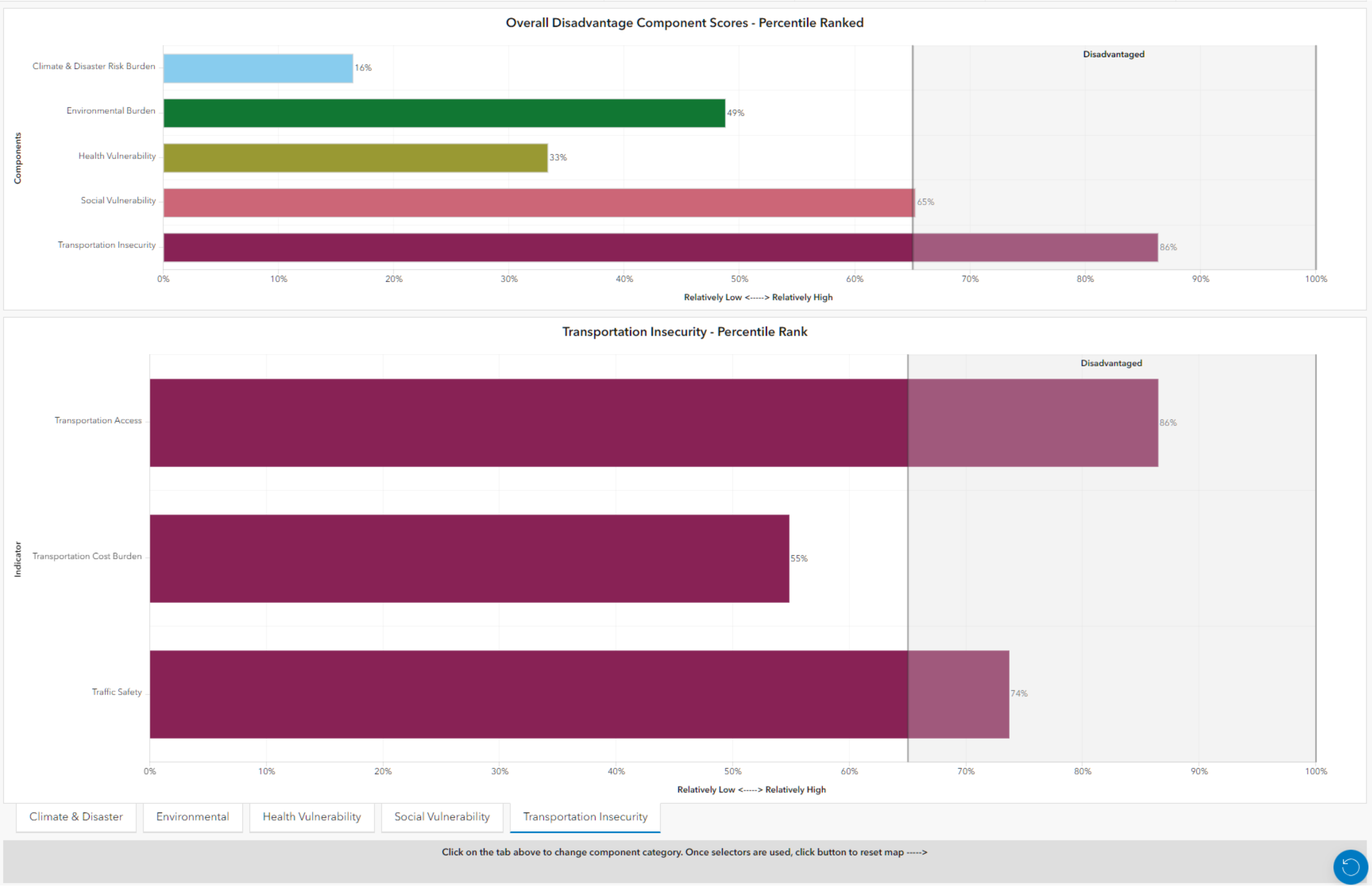

Figure 3. Project Area - USDOT ETC Explorer Disadvantaged Scores

1.3 Anticipated At-Scale Implementation

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

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

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

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

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

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

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

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

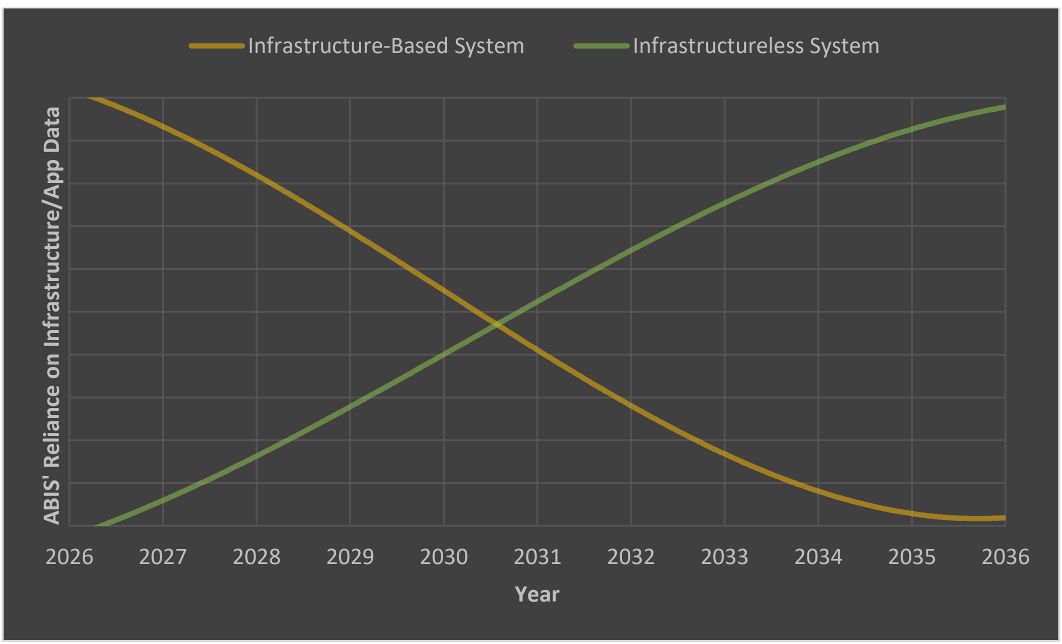

Figure 4. Transition from Infrastructure-Based to Infrastructureless System

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

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

(Douglas/Peace Arch shown only – see the *High Level Design* for the other POEs). ***Figure 7*** shows the concept's proposed system architecture and data flow diagram.

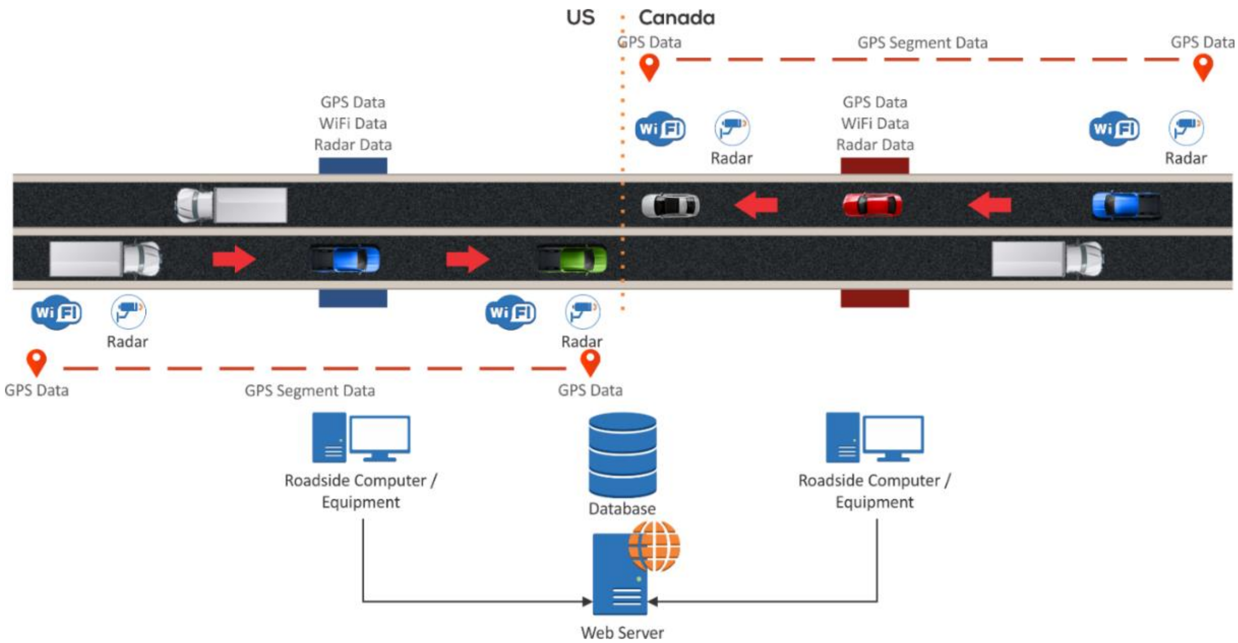

Figure 5. Proposed Technologies Overview

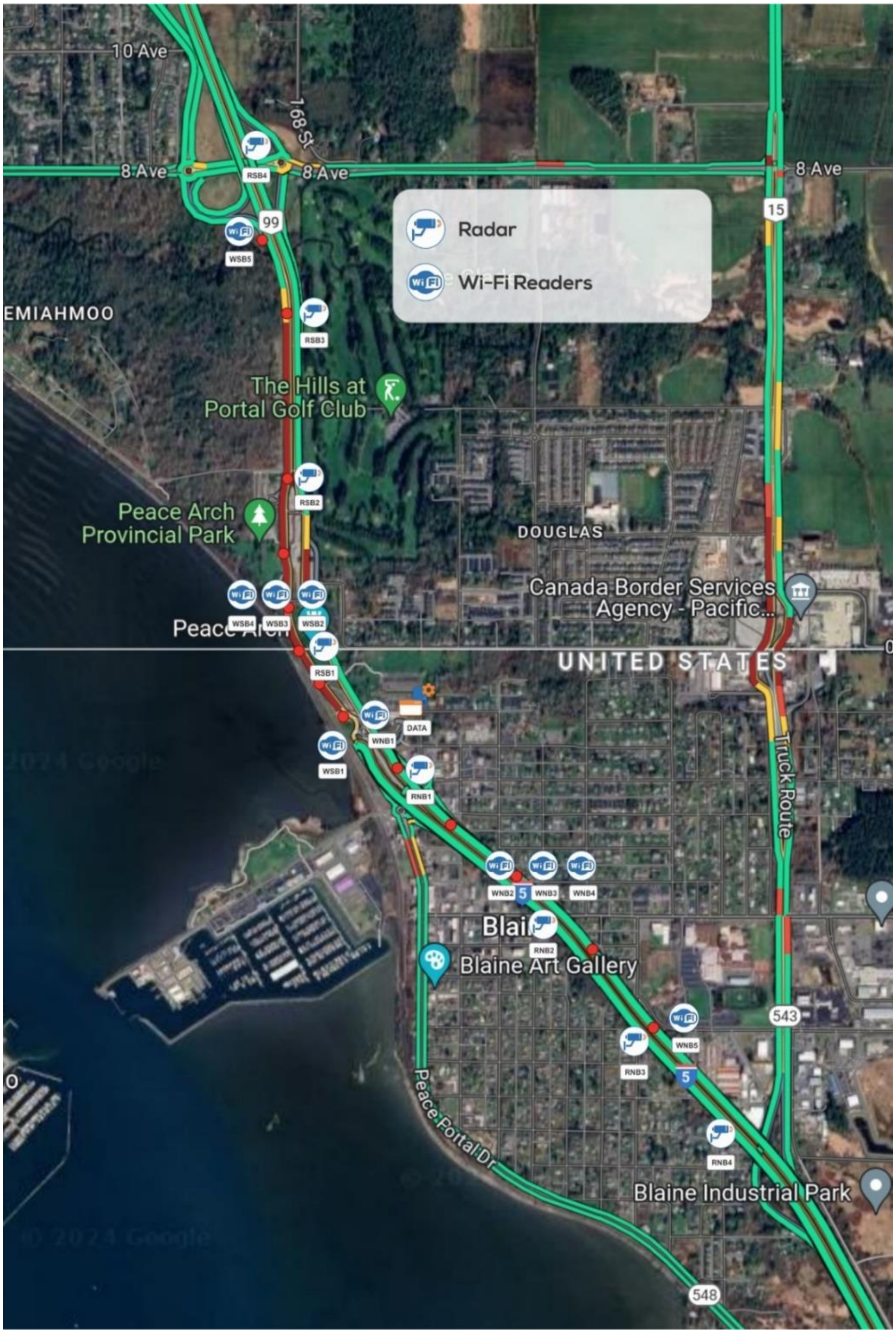

Figure 6. Proposed Roadside BWT Measurement Technologies

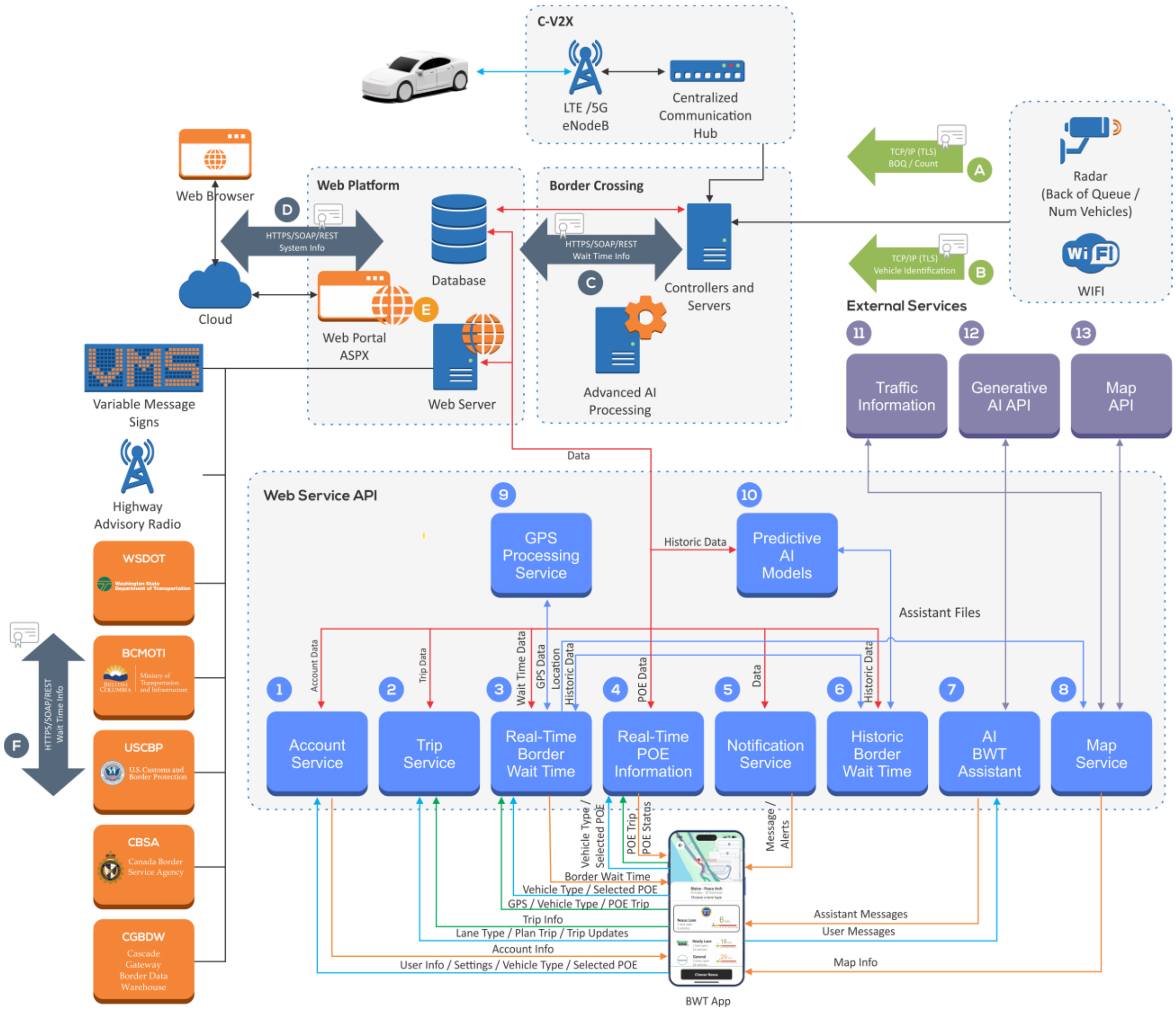

Figure 7. Proposed System Architecture and Data Flows

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

Highlighted in ***Figure 8*** below is a video demonstrating a mock-up of the conceptual design of the mobile app that summarizes its capabilities and the user experience was developed. This video can be viewed at: https://vimeo.com/999161315/fc244206c1?share=copy.

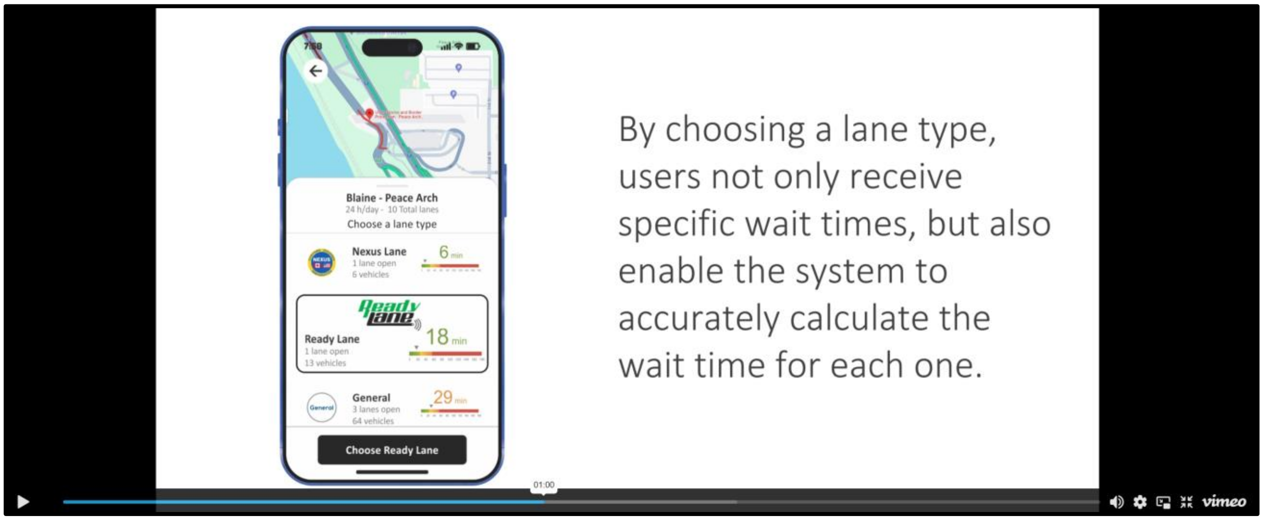

Figure 8. Screenshot from ABIS BWT Mobile Application Demonstration Video

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

Table 3. Summary of Proposed Technologies

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

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

Table 4. Advantages and Disadvantages of Technology Concept

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

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

1.4 Summary of Stage 1 Activities

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

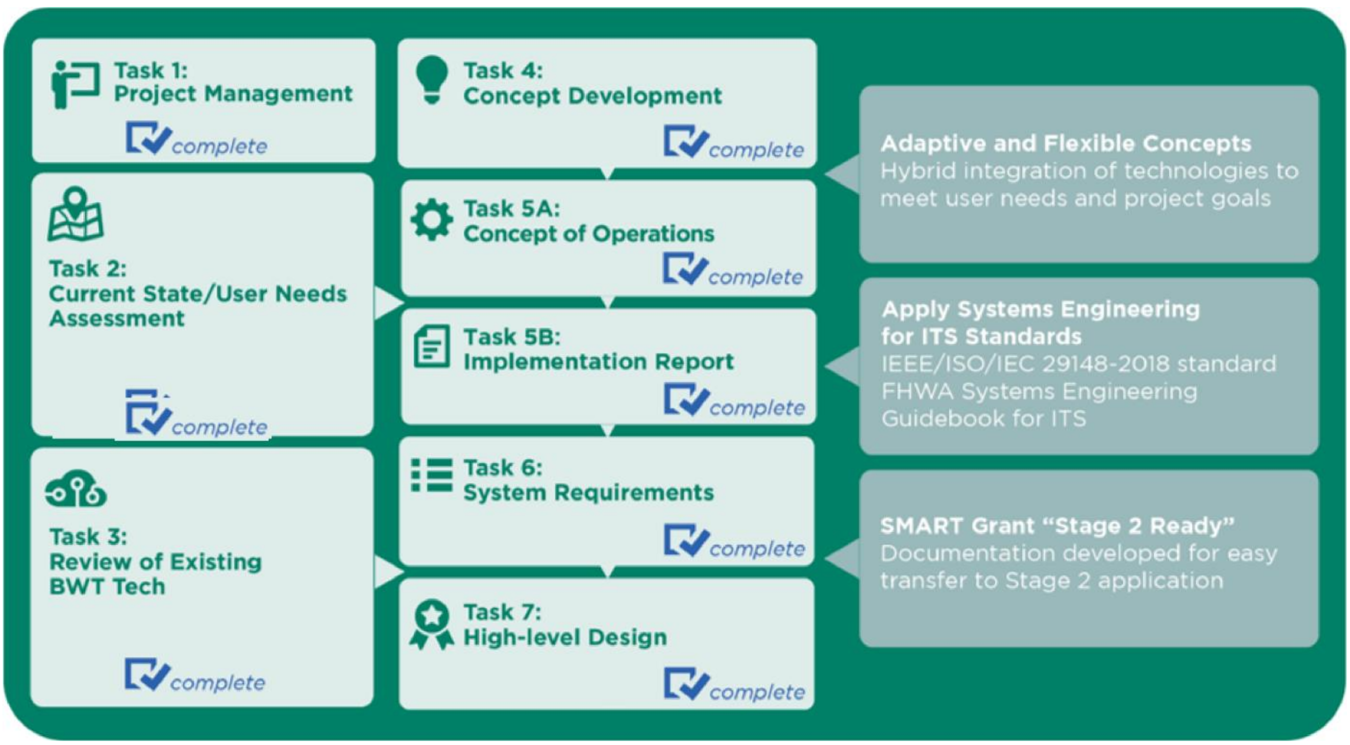

Figure 9. Stage 1 Activities

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

accuracy. Additionally, it includes a comprehensive list of existing challenges and identifies areas that need to be addressed in the new ABIS. This document is publicly accessible at https://theimtc.com/wp-content/uploads/1-Current-State-Existing-Technology-Report.pdf.

- *Task 3: Existing Measurement Technology Review Report* provides a review of the state-of-the-practice regarding Border Wait Time (BWT) measurement technologies, including case studies from other U.S.-Canada and U.S.-Mexico border crossings. This document is publicly accessible at https://theimtc.com/wp-content/uploads/1-Current-State-Existing-Technology-Report.pdf.
- *Task 4: Concept Exploration and Recommendations Report* provides additional detail on BWT measurement technologies and how they can be applied to this project. Additionally, specific vendor technologies were investigated through a series of Vendor Showcases in which technology providers were invited to present on their product offerings and answer questions specifically as they related to BWT applications like the Cascade Gateway ABIS. Building on this additional knowledge, three potential technology concepts are presented, along with each concept's advantages and disadvantages. The three concepts and the technologies involved were reviewed with WSDOT, BCMOTI, and WCOG during an interactive workshop, during which a preferred technology concept was selected – Concept I – involving new radar detection (or other non-intrusive form of detection capable of measure the volume, speed, and occupancy of vehicles in a stop-and-go border crossing environment), new Bluetooth/Wi-Fi readers, and a new smartphone mobile application based on GPS II technology. This document is publicly accessible at https://theimtc.com/wp-content/uploads/2-Concept-Exploration-Recommendations-Report.pdf.
- *Task 5a: Concept of Operations* (ConOps) serves as the foundational guide for communicating user needs and system requirements to support the detailed design and implementation for Stage 2. It presents a high-level description of the proposed system and describes, from the perspective of the system's users, how the system is intended to operate and be maintained using day-in-the-life operational scenarios. This document is publicly accessible at https://theimtc.com/wp-content/uploads/3-Concept-of-Operations.pdf.
- *Task 5b: Draft Implementation Report*, submitted, as required, one year following the execution of the Stage 1 grant, that describes the implementation plans as well as supporting the Stage 2 SMART grants funding application (submitted August 14, 2024) provides details for implementing the ABIS project as soon as possible in order to meet cross-border traffic management needs associated with the 2026 FIFA World Cup in Seattle and Vancouver in June 2026. At the conclusion of the Stage 1 project, this *Final Implementation Report* addresses comments on the draft report by USDOT and SMART Grants Program staff and includes additional details based on the *System Requirements* and *High-Level Design*.
- *Task 6: System Requirements* builds upon the ConOps to develop a formal System Requirements document. As stated in the FHWA Systems Engineering Guidebook for ITS, system requirements define what the system is to do, through statements defining system capabilities, conditions, and constraints. The system requirements are included as an appendix to the *High-Level Design* document.
- *Task 7: High-Level Design* builds upon the ConOps and the System Requirements by defining exactly how the system is to be built. This design takes the previously defined requirements (i.e., "what the system will do") and translates them into hardware and software components.

1.5 Project Outreach to Date

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

Specific outreach efforts are listed below:

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

1.6 Deviations from Original Proposal

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

2. PROOF-OF-CONCEPT OR PROTOTYPE EVALUATION FINDINGS

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

2.1 Evaluation Findings

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

Table 5. Summary of Findings from Stage 1

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

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

2.2 Goals Assessment

Stage 1 Goals Assessment

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

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

Table 6. Summary of Goals and Objectives from Stage 1

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

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

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

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

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

Technology Assessment

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

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

Table 7. Vendor Showcase Summary

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

Table 8. Technology Concept Evaluation Summary

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

3. ANTICIPATED COSTS AND BENEFITS OF AT-SCALE IMPLEMENTATION

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

3.1 Impacts

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

Safety and Reliability

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

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

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

Resiliency

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

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

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

Equity and Access

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

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

Climate

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

Partnerships

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

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

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

Integration

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

Workforce Development

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

3.2 Implementation Cost Estimate

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

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

Figure 10. Implementation Cost Estimate

<u>Task 0: Project Management</u>

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

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

Task 1: Detailed Design

The first task of the project in Stage 2 is the comprehensive build-quality detailed design of the various system components which include system hardware, software including the BWT app, and the communications system per applicable, local, state, and federal standards.

Task 1.1: ITS Plans, Specifications, and Estimates (PS&E)

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

Task 1.2: Software Development

- **Mobile App Development**. This includes developing the software architecture, specifications, user interface, and iOS/Android apps, including associated testing and documentation.
- **Cloud Infrastructure**. This includes developing and setting up the cloud infrastructure that is needed to support the ABIS.
- **AI/ML Development**. This includes developing the AI and ML software models that will enable the predictive analytics capabilities of the ABIS.
- **Business Intelligence/Dashboards**. This includes developing custom dashboards for the agencies, as well as providing a user-friendly interface for accessing the predictive analytics.
- **Integrations & Interfaces**. This includes developing integrations and interfaces with existing and future systems like the CGBDW, DMS/VMS, HAR, and travel information websites.
- **Acceptance Testing.** This ensures that the solution meets all specified requirements and functions correctly in real-world scenarios, validating its readiness for deployment.
- **Documentation.** This provides comprehensive records of the system's architecture, functionality, and usage guidelines, ensuring clarity for stakeholders, developers, and end-users throughout the software lifecycle.

Task 2: Construction/Installation

- **Advertise for Construction**. This involves advertising the construction documents developed as part of the ITS PS&E for contractors to furnish and install the equipment.
- **Equipment Procurement**. During this time, equipment will be procured by the contractor. Given that the physical equipment will be commercial off-the-shelf products, procurement lead times are not expected to be too lengthy.
- **Equipment Installation**. During this time, the contractor will be constructing the physical improvements and installing the equipment. Equipment is generally expected to use existing infrastructure (e.g., cabinets, power, communications, poles, etc.) and will have minimal impacts on moving traffic.

Task 3: System Integration

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

Task 4: System Operation, Evaluation, and Refinement

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

3.3 Benefit-Cost Assessment

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

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

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

Quantified benefits include:

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

Quantified costs include:

- Operations and Maintenance (O&M) Costs

The BCA results are summarized in *Table 9*.

Table 9. Benefit-Cost Assessment Summary

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

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

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

3.4 Performance Evaluation (Baseline and At-Scale Implementation)

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

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

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

Table 10. Stage 2 Performance Evaluation Overview

Stage 2 Project Goal	Data Collection / Operations	Evaluation Approach
Achieve a 5% overall traffic delay reduction across the four POEs	Collect six months of Before baseline data from the CGBDW from July 2025 to December 2025. Collect Initial After data (with system operational) from July 2026 to December 2026. Collect Final After data (operational with system refinements) from July 2027 to December 2027.	Conduct analysis of both before and after data sets to remove effects of demand and anomalies (e.g. traffic growth, incidents, customs operations events, weather, etc.). Conduct comparative analysis of before versus after data to determine delay reduction due to the ABIS for both system operational performance periods in 2026 and 2027.
Improve traffic management during the Vancouver-Seattle 2026 FIFA World Cup	Conduct historical data assessment using over two decades of CGBDW delay data for periods of special events (e.g. concerts, 2010 Vancouver Olympics, etc.). Collect BWT data during the FIFA events.	Develop a case study of the experience of better management of cross-border travel during the FIFA games, with both quantitative and qualitative results.

Stage 2 Project Goal	Data Collection / Operations	Evaluation Approach
	Conduct interviews with USCBP, CBSA, WSDOT, and BCMOTI staff to determine use and success of the system for managing event traffic.	
Improve traffic management during the 2026-2030 POE construction.	Work with USCBP, CBSA, WSDOT, and BCMOTI staff to determine how to best use the system to assist in construction traffic diversion to both reduce delay and improve safety. Operate the system in an agile fashion where the agencies leverage the ABIS' capabilities to use dashboards customized to construction operations to optimize traffic flow around work zones.	Develop a case study of the experience of utilizing the system to improve work zone operations and traffic diversion, noting safety impacts and including lessons-learned from the collaboration.
Achieve a 98% uptime for northbound and southbound systems.	Collect Initial After data (with system operational) from July 2026 to December 2026. Collect Final After data (operational with system refinements) from July 2027 to December 2027.	Analyze data using network management tools (if available) or by identifying gaps in the data for both system operational performance periods in 2026 and 2027, which should correspond with system downtime.
Measure actual border wait times with 95% accuracy.	Collect on-going system operational data from July 2026 to December 2027. Collect manual wait time measurements through a ground truthing exercise.	Compare reported wait times with those captured manually in the field in the summer of 2026 and summer of 2027.
Archive data for all ports, all modes, at a minimum increment of five minutes.	Collect system operational data between July 2026 and December 2027.	Conduct analysis of the data collected to verify that data is archived in the appropriate manner.

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

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

Comparison metrics may include:

- **Accuracy**: The accuracy of the data being collected may be determined using manual verifications. ABIS system data can then be verified against ground truth manual counts or vehicle counts provided by USCBP or CBSA, when available.
- **Reliability**: The reliability of the system could involve an assessment of how timely and complete the data is, as well as an examination of how much downtime is experienced (and where the failures are).
- **Distribution of Traffic**: Using data archived from the beginning and end of the project, an analysis of wait times/volumes at the two closest POEs can determine if the ABIS is resulting in a better spread of demand between ports.
- **Wait Time Reduction**: Archived data from special events can be compared to new special event wait time averages to determine if the system is affecting average delay.

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

4. CHALLENGES AND LESSONS LEARNED

Several important lessons were learned through the Stage 1 project:

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

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

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

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

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

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

4.1 Lessons Learned from US Southern Border BWT Studies and Deployments

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

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

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

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

5. DEPLOYMENT READINESS

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

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

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

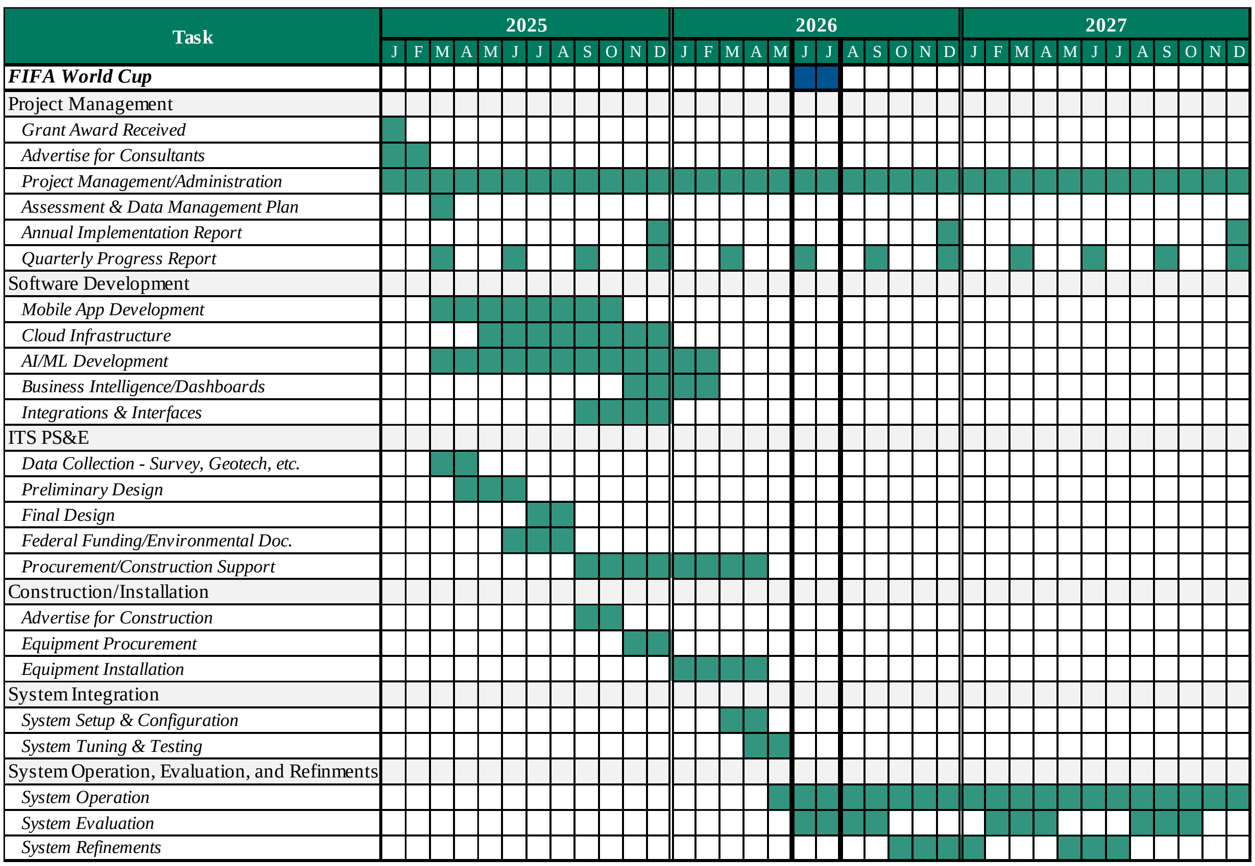

Figure 11. Project Schedule

6.1 Requirements for Successful Implementation

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

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

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

Legal, Policy, and Regulatory Requirements

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

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

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

Procurement and Budget

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

Partnerships

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

Technology Suitability

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

Data Governance

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

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

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

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

Workforce Capacity

As discussed in detail in both ***Section 3.1*** and ***Section 4***, as well as in ***Section 6.3*** below, the proposed at-scale implementation will significantly involve WSDOT maintenance staff, who are represented by the WFSE union who are strong supporters of this project. Additionally, the project will result in the creation of several jobs related to the design, development, implementation, operations, and maintenance of the system.

Internal Project Coordination

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

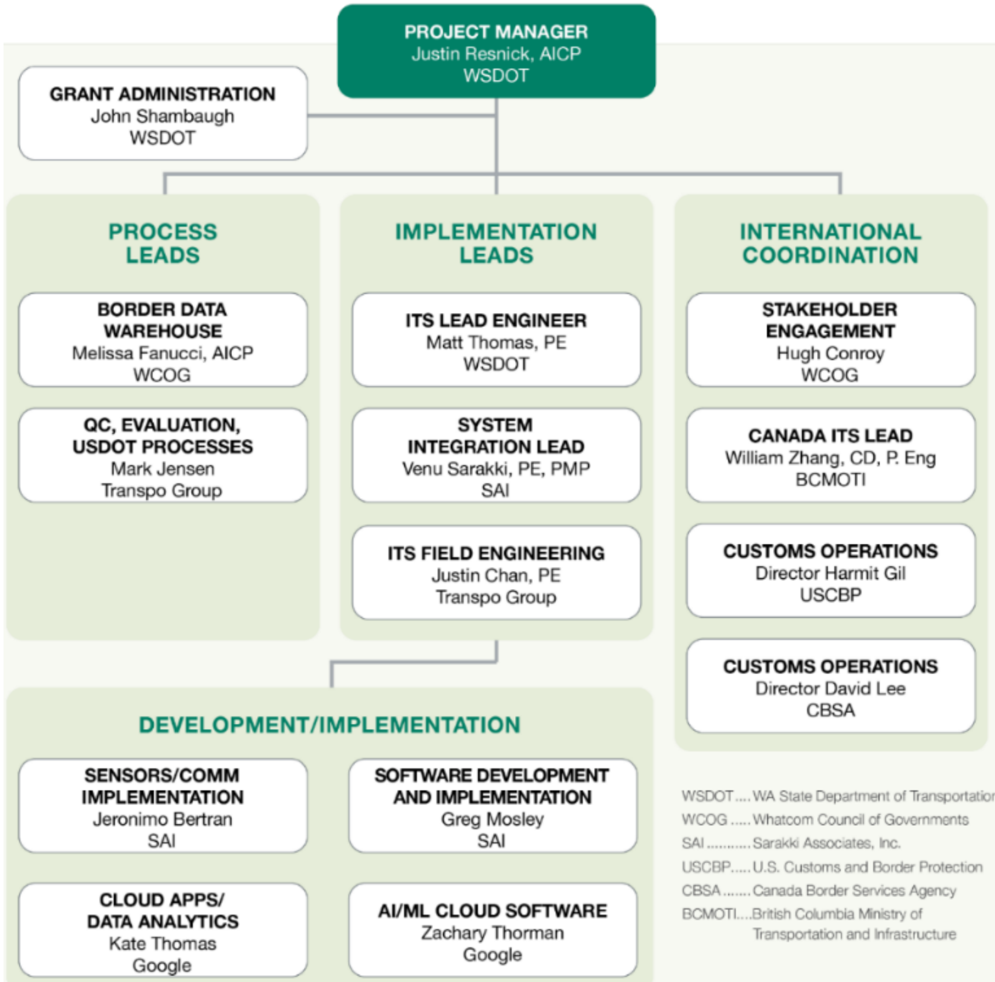

Figure 12. Project Team Organizational Chart

Community Impact and Public Acceptance

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

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

6.2 Operations, Maintenance, and Process for Future Upgrades

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

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

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

6.3 Work Force Enhancement Approach

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

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

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

6. WRAP UP

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

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

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

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

APPENDICES

Appendix A: Benefit-Cost Assessment

Whatcom Council of Governments

Cascade Gateway Advanced Border Information System Design Project

Benefit Cost Analysis Technical Memo

FY 2024

Texas A&M Transportation Institute

The Texas A&M University System

College Station, Texas

August 2024

Contents

Whatcom Council of Governments

Cascade Gateway Advanced Border Information System Design Project

Benefit Cost Analysis Technical Memo

August 2024

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

Table 1. BCA Summary

<table>
<tr><th>Current Status and Problem to be Addressed</th><th>Change in Baseline</th><th>Type of Impacts</th><th>Affected Populations</th><th>Economic Benefits</th></tr>
<tr><td rowspan="6">The Cascade Gateway Advanced Border Information System (ABIS) Design Project is designed to provide a modern alternative to the Advanced Traveler Information System. ATIS records traffic flows and estimates wait times for several locations US and Canada border locations. There is a need to calculate more reliable wait times that the current equipment cannot provide</td><td rowspan="3">The project will provide Customs and Border Patrol Agents with better delay information, allowing them to open lanes more efficiently and reduce overall delay.</td><td>Value of Time Savings</td><td>Drivers and commercial truck operators using the POEs.</td><td>Benefit 1. Crossing Delay Benefit</td></tr>
<tr><td>Fuel Cost Savings</td><td>Drivers and commercial truck operators using the POEs.</td><td>Benefit 1. Crossing Delay Benefit</td></tr>
<tr><td>Emissions Reductions</td><td>Residents living and working the area.</td><td>Benefit 2. Environmental Benefit</td></tr>
<tr><td>The project will provide drivers with better information on current delays, allowing them to plan trips more reliably.</td><td>Value of Time Savings</td><td>Drivers and commercial truck operators using the POEs.</td><td>Benefit 3. Trip Planning Reliability Benefit</td></tr>
<tr><td>Project components will have useful life remaining after the 11-year analysis period.</td><td>Residual Value</td><td>Washington State Department of Transportation</td><td>Benefit 4. Residual Value</td></tr>
<tr><td>Project improvements will result in additional maintenance costs.</td><td>Maintenance and Operations Costs</td><td>Washington State Department of Transportation</td><td>(Dis)Benefit 5. Maintenance Costs</td></tr>
</table>

Benefit Cost Analysis

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

The quantified benefits are:

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

Discount Rates

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

Project Description and Cost Estimates

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

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

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

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

Benefit-Cost Ratios

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

Table 2: Benefit Cost Analysis ($2022)

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

Benefit Calculations

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

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

Benefit 1: Delay Time Reduction Benefit

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

Delay Time Reduction Benefit

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

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

Benefit 2: Environmental Benefit

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

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

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

Benefit 3: Trip Planning Reliability Benefit

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

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

Trip Planning Reliability Benefit

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

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

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

Benefit 4: Residual Value

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

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

Table 3. Project Component Remaining Life

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

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

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

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

Benefit 5. Maintenance and Operation Cost

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

Qualitative Benefits

Safety and Reliability

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

Resiliency

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

Equity and Access

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

Climate

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

Partnerships

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

Integration

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

Workforce Development

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

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

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

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

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

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

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

Project Scenario (2022 $M)				2025 Construction Start Year
Construction	8.37			2026 Operation Start Year
				2022 Constant $ Year

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

Crossing Delay Reduction Benefit

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

No Build Scenario

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

Build Scenario

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

Planning Time Reliabilty Benefit

95th Percentile Delay Reduction 5.00%

No Build Scenario — Planning Hours

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

Build Scenario — Planning Hours

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

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

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

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

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

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

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

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

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

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

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

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

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

Discount Rate 3.1%

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

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

Traffic Growth Factor 1.10%