Blue Water Bridge International Smart Freight Corridor Project

Implementation Report

Submitted to: Office of the Assistant Secretary for Research and Technology (OST-R), U.S. Department of Transportation (USDOT) Strengthening Mobility and Revolutionizing Transportation (SMART) Grant Program

Submitted by: Michigan Department of Transportation (MDOT)

September 15, 2025

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Prepared By:
Michigan Department of Transportation

Prepared For:
U.S. Department of Transportation

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Acronyms and Abbreviations

ACE	Automated Commercial Environment
BWB	Blue Water Bridge
BCR	Benefit/Cost Ratio
Caltrans	California Department of Transportation
CBA	Cost-Benefit Analysis
CBP	U.S. Customs and Border Protection
CBSA	Canada Border Services Agency
ConOps	Concept of Operations
DMP	Data Management Plan
DTMB	Department of Technology, Management and Budget
EIA	U.S. Energy Information Administration
EDI	Electronic Data Interchange
FBCL	Federal Bridge Corporation Limited
FHWA	Federal Highway Administration
GHG	Greenhouse Gas
GPS	Global Positioning System
IRR	Internal Rate of Return
ISFC	International Smart Freight Corridor
ITS	Intelligent Transportation Systems
MDOT	Michigan Department of Transportation
MTO	Ontario Ministry of Transportation
NPV	Net Present Value
OBU	Onboard Computer and Communications Units

POC	Proof-of-Concept
POE	Port of Entry
PIL	Primary Inspection Lane
SMART	Strengthening Mobility and Revolutionizing Transportation
UI	User interfaces
USDOT	U.S. Department of Transportation

Terminology

ISFC System: The preferred term used for describing the underlying system architecture, system requirements, and system functionality of the fully developed software solution that meets all requirements outlined in the ISFC System Concept of Operations (ConOps) for the Blue Water Bridge (BWB) and envisioned to be deployed in a potential Stage 2 at-scale implementation.

ISFC Prototype: The preferred term used for the preliminary version of the ISFC system as developed and implemented in Stage 1, serving as a Proof of Concept (POC) solution to demonstrate feasibility and core functionality as defined within the ISFC System ConOps document.

Note: ISFC prototype was not available to the public and/or the main user groups at time of writing. All benefits of the ISFC prototype interaction with users are based on perceived future use.

Part 1: Executive Summary

The Blue Water Bridge (BWB) is an important artery for commercial and freight traffic which links Port Huron, Michigan with the broader national and international transportation network. The movement of goods across the U.S.-Canada border via the BWB alone was valued at $71.5 billion in 2020. With its three (3) travel lanes in each direction, the bridge handles volumes of up to 3,500 commercial vehicles daily. This high commercial traffic underscores the bridge's importance in supporting the seamless flow of goods within North America's integrated supply chain.

The BWB International Smart Freight Corridor Project aims to alleviate congestion caused by freight traffic at the Blue Water Bridge Port of Entry (POE) through an International Smart Freight Corridor (ISFC) Platform. The platform provides users with real-time and predictive travel time data that allows them to plan trips more efficiently and avoid congestion when possible. **Key stakeholders** include shippers, carriers, U.S. Customs and Border Protection (CBP), the Ontario Ministry of Transportation (MTO), and local communities. The **project goals** are to:

- Provide more accurate and accessible information and enable better decision-making for its key users, including Commercial Carriers and their drivers;
- Support timely response to disruptions/incidents along U.S.-Canada border crossings in Michigan; and
- By meeting the above, provide an improvement to commercial traffic flow across the BWB to reduce border wait times, queuing, and congestion.

Stage 1 of the project covers westbound traffic, travelling from Ontario to Michigan at the BWB POE. Stage 2 at-scale deployment would include all traffic at the BWB POE, and would evaluate the ISFC's replicability at similar crossings in Michigan.

The **Stage 1 project scope** was organized in four tasks as follows:

- Task 1: Needs Assessment & Data and Processes;
- Task 2: Concept of Operations;
- Task 3: Development and Implementation of a Proof-of-Concept; and
- Task 4: Proof-of-Concept Evaluation and Future Implementation Program.

An ISFC Prototype has been developed as part of the Stage 1 Proof of Concept. The analysis found the ISFC Prototype, projected out to at-scale implementation, may reduce total vehicle-hours of delay by approximately **7 percent**, and greenhouse gas emissions caused by idling by **7 percent** within the first year.

Stakeholder engagement and user buy-in proved crucial for the success of this Stage 1 project. As such, considerable effort was made to involve stakeholders, and through the use of a hybrid development approach, MDOT can adapt the solution based on user needs.

Part 2: Introduction and Project Overview

Part 2 of this document introduces the motivation for the development and implementation of the BWB ISFC System including the issues currently experienced and how the project aims to alleviate them. It gives a high-level description of the ISFC System, noting the different platform components and how they function under different conditions. Part 2 also describes the stakeholders involved in this project, the project milestones and adjustments made throughout Stage 1 (ISFC Prototype), and how the project specifically benefits disadvantaged communities.

A. Introduction

The purpose of the Implementation Report is to document the development of the ISFC System. More specifically, this report aims to:

- Verify how the project has met its original expectations.
- Further analyze the success of the platform and discuss any adjustments that had to be made.
- Validate the above by establishing and analyzing performance measures.
- Assess the anticipated costs and benefits of at-scale implementation.
- Identify the requirements and confirm the feasibility of at-scale implementation.
- Identify challenges and lessons learned to support future deployment readiness.

The report is structured in seven parts, as follows:

- Part 1: Executive Summary
- Part 2: Introduction and Project Overview
- Part 3: Prototype Evaluation Findings
- Part 4: Anticipated Costs and Benefits of At-Scale Implementation
- Part 5: Challenges & Lessons Learned
- Part 6: Deployment Readiness
- Part 7: Wrap-Up

i. Referenced Documents

The following documents were referenced in the development of this implementation report:

- Grant Recipient Guidance for the Implementation Report, 2024, Prepared for U.S. Department of Transportation (USDOT)
- Blue Water Bridge International Smart Freight Corridor Concept of Operations, 2025, Prepared by Arcadis for Michigan Department of Transportation (MDOT)
- Blue Water Bridge International Smart Freight Corridor Solution Design Report, 2025, Prepared by Arcadis for MDOT

B. Project Overview

Project Title	Blue Water Bridge International Smart Freight Corridor Project
Award Number	69A355234101021
Recipient	Michigan Department of Transportation
Fiscal Year of Award	2022
Period of Performance	September 2023 – September 2025
Organization preparing the Implementation Report	Michigan Department of Transportation

i. Background

The BWB is an important artery for commercial and freight traffic which links Port Huron, Michigan with the broader national and international transportation network. The movement of goods across the U.S.-Canada border was valued at $398.2 billion in 2020, with $71.5 billion passing through the BWB alone. With its three (3) travel lanes in each direction, the bridge handles an impressive volume of up to 3,500 commercial vehicles daily. This high commercial traffic underscores the bridge's importance in supporting the seamless flow of goods within North America's integrated supply chain.

Despite its important role, the BWB faces significant challenges in maintaining efficient and reliable freight movement. The high volume of commercial vehicles often results in lengthy and unpredictable delays, particularly during peak hours. These delays increase shipping costs, cause excessive idling, and negatively impact local communities through congestion and environmental pollution. Furthermore, the limited physical infrastructure of the bridge restricts expansion options, making it challenging to meet growing demand. These issues highlight the need for innovative solutions to optimize traffic flow and enhance the efficiency of cross-border freight operations.

Recognizing these challenges, the Michigan Department of Transportation (MDOT), in collaboration with U.S. and Canadian partners, developed the International Smart Freight Corridor (ISFC) System. This project builds on MDOT's long-standing leadership in applying innovative technology to optimize border crossing performance without relying on costly physical infrastructure expansions. The ISFC System aims to maximize the utilization of existing infrastructure and information while laying the groundwork for scalable, replicable applications at other border crossings. The project has been shaped by strong stakeholder engagement, with continuous collaboration from public and private sector partners to ensure its development aligns with cross-border trade and transportation needs.

ii. Purpose

The ISFC System is a software application designed to improve the efficiency of truck-borne freight transportation. By leveraging advanced technologies and data-sharing mechanisms, the ISFC System offers key functionalities that enhance border operations, helping to reduce delays, lower shipping costs, and minimize environmental impacts. This innovative solution addresses current challenges at the border while paving the way for future advancements in cross-border logistics.

iii. Objectives

The Proof of Concept (POC) developed under this Stage 1 grant successfully met the expectations outlined in the original project proposal, by designing and delivering an ISFC Prototype solution that meets the following main objectives:

- Providing more accurate and accessible information and enabling better decision-making for its key users, including Commercial Carriers and their drivers;
- Supporting timely response to disruptions/incidents along U.S.-Canada border crossings in Michigan; and
- By meeting the above, provide an improvement of commercial traffic flow across the BWB to reduce border wait times, queuing, and congestion.

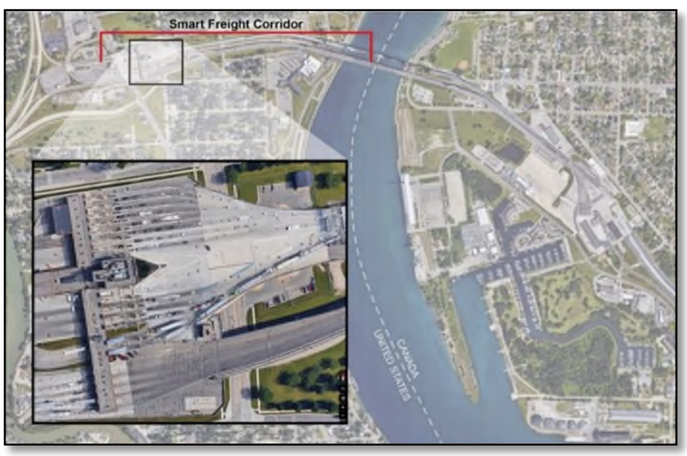
In addition to achieving these objectives, the ISFC Prototype was developed with the following guiding principles stated in the initial project proposal:

- Minimizing the need for changes to physical infrastructure (tolling, primary-inspection-lanes (PIL), bridges, and approaches);
- Enabling scalability and replicability through standard architecture and design;
- Minimizing duplication of effort by adding new workflows only when necessary to the end users and stakeholders;
- Continuously improving accuracy of predictions; and
- By meeting the above, ultimately improving both the supply and demand aspects of the commercial vehicles' border crossing, thereby distributing utilization and demand across Michigan border crossings.

iv. Location

The ISFC System will be implemented in the City of Port Huron, within St. Clair County, Michigan. This digital platform will optimize freight operations along the corridor that begins at the international border on the Blue Water Bridge (BWB) and extends westward on I-94/I-69 through the Port Huron Port of Entry (POE) at Pine Grove Avenue. Located within the Detroit–Warren–Dearborn Metropolitan Statistical Area and the Detroit–Warren–Ann Arbor Combined Statistical Area, this strategic region will benefit from the enhanced data-driven coordination enabled by the ISFC System.

Figure 1: Project Location



C. ISFC Prototype

The ISFC Prototype is a web-based platform that integrates multiple sources of data to enable better decision-making by stakeholders and creates a more efficient border crossing system overall. More detailed descriptions of the ISFC Prototype can be found in the Concept of Operations (ConOps) and Solution Design documents.

i. Prototype Elements

The ISFC Prototype was designed with four main user groups considered:

- Fleet Managers, who are defined as users who are concerned with logistics and tracking of shipments and drivers,
- Drivers, who are defined as commercial truck drivers,
- Toll Management, who is defined as the toll staff, as well as the general bridge management and operations staff, and
- Border Services, who are defined as U.S. Customs and Border Protection (CBP) agents, whether they are physically at the border or not.

All four user groups have a common interest: bridge information. However, they are not aggregating their data in one centralized, easily accessible location. The ISFC Prototype aims to ingest as much relevant data as possible, apply intelligent algorithms to come up with valuable metrics, connect diverse users to enable more complex functions, and disseminate results to the users in a tailored, digestible way.

Ingesting Data

The ISFC Prototype uses various real-time and historic sources for relevant data. These data sources include:

- Bridge traffic volumes,
- Number of open primary inspection lanes,
- Border wait times,
- Border travel times,
- Weather data,
- Camera feeds of the bridge (Note: feeds provided through app only, not used for travel estimates) and
- Traffic incidents.

It also enables user entry of:

- Active and planned trips,
- Bridge Incidents (including entry of more details).

A public repository has been selected for the posting of public data, metadata, and information from the Prototype that can be posted as open access for use by partners, research institutions, and the public at large.

Analytics

By using regression and pulling a wealth of data sources, the ISFC Prototype develops a more accurate bridge travel time that is specific to freight vehicles. For more information, please see **Part 4 Section D.ii**.

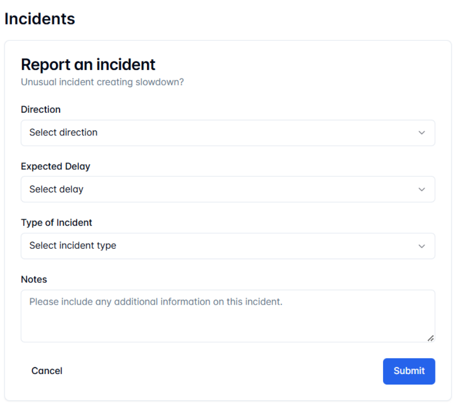
Functions

By connecting the different users, overarching functions can be developed that enable greater information sharing and efficiency.

Incidents

If toll management or border services notice some kind of unusual traffic on the bridge, they can enter an incident using the form shown below in **Figure 2.** This information is then disseminated to all other users.

Figure 2: Report an Incident User View



Trip Planner

The trip planner allows drivers to see how the predicted bridge travel time will affect their drive, whether now or in the future. **Figure** 3 and **Figure 4** demonstrate how drivers input their trip information to add it to their trips tab.

Figure 3: Add a New Trip User View

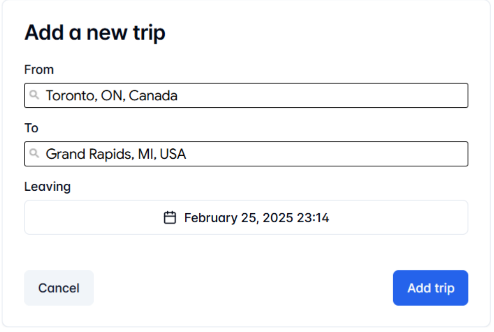
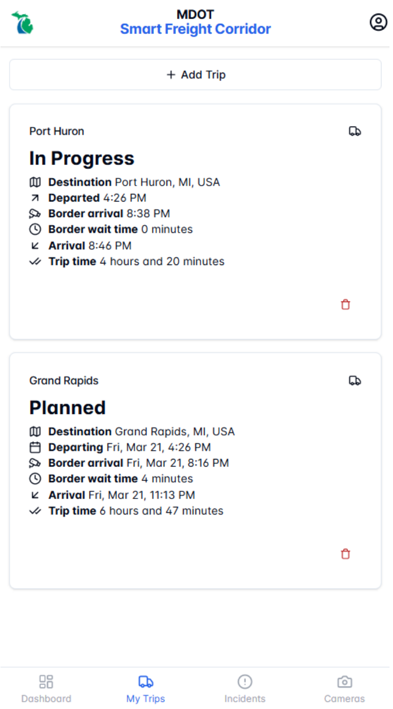


Figure 4: User Trips Tab



Google Maps integrations streamline the process for drivers by providing auto-complete forms. Google Maps is also used to generate part of the travel time prediction, which is subsequently fused with the bridge travel time model to provide a more accurate travel time for drivers overall.

While the ISFC Prototype does not have location services implemented, solution design for the ISFC System can include collecting and storing current GPS coordinates of drivers with location services enabled for the purpose of updating trip estimations.

Rerouting

If an incident is entered that causes a delay, the ISFC Prototype enables a rerouting process. Fleet managers will be shown their affected trips, and by reviewing the trip details and the incident details, then decide to request reroutes for as many of their drivers as they want. This will send a request to border services, who can review the same information and either approve or deny the request. The decision will send a notification back to the fleet manager, who is then responsible for any other documentation or communications. The ISFC Prototype retains a preliminary implementation of the rerouting process that includes the fleet manager functions. The ISFC System solution design would include further implementation including testing with fleet managers and commercial carriers and their interaction with border services.

Information Dissemination

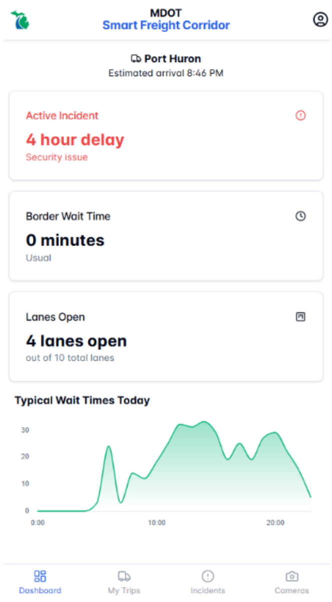
The ISFC Platform's user interfaces (UI) are intuitive, efficient, and flexible for its users. The UI also needs to incorporate agnostic design principles to provide similar user experiences to other future corridors.

Dashboards

All users are provided with a dashboard that consolidates key operational insights and historical and real-time conditions of the Port of Entry. The border information includes the predicted wait time, typical wait times, and actual wait times for the day. This allows users to review historical and predicted trends, plan the use of their resources accordingly, and monitor the execution of the plan.

The driver dashboard shown in **Figure 5** is formatted to give key information at a glance, and formats dynamically to adjust to a phone or tablet screen.

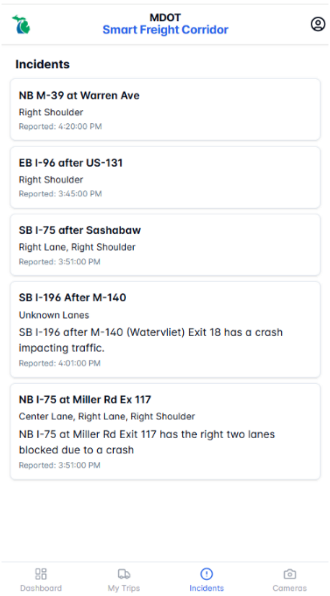
Figure 5: Dashboard User View



Rerouting

Fleet managers and border services have bespoke views that allow them to review and manage all reroute notifications, as well as see additional details, as shown in **Figure 6**.

Figure 6: Incident Tab User View



Camera Feeds

Camera feeds are collected and shown to the driver for them to reference at a glance (**Figure 7)**.

The Platform integrates various technologies and systems to create a cohesive framework, enabling an unrestricted flow of information exchange among all stakeholders. This system integration allows for real-time updates on shipment status, and traffic conditions at the bridge.

Figure 7: Camera Feed User View

Figure 8 and **Figure 9** showcases the current UI. The UI groups functionalities based on stakeholder roles.

Figure 8: ISFC Platform Fleet Management Dashboard View

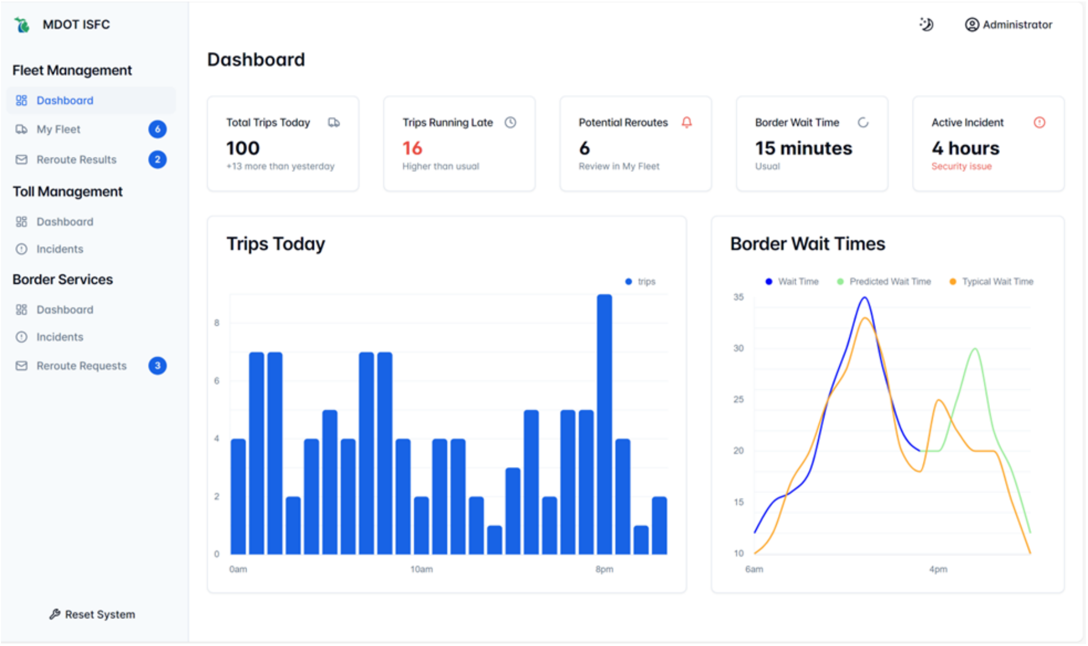
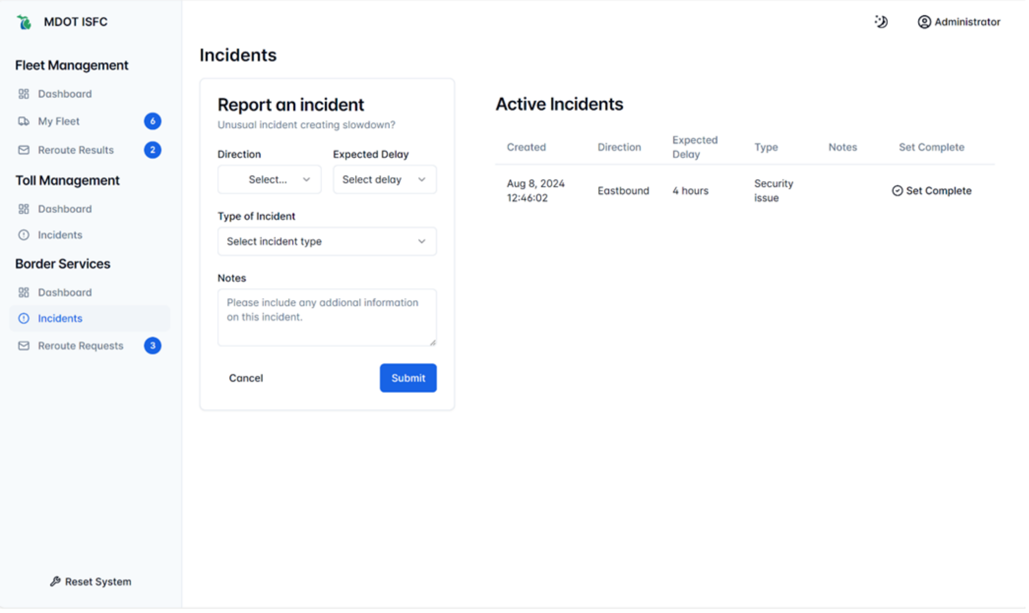


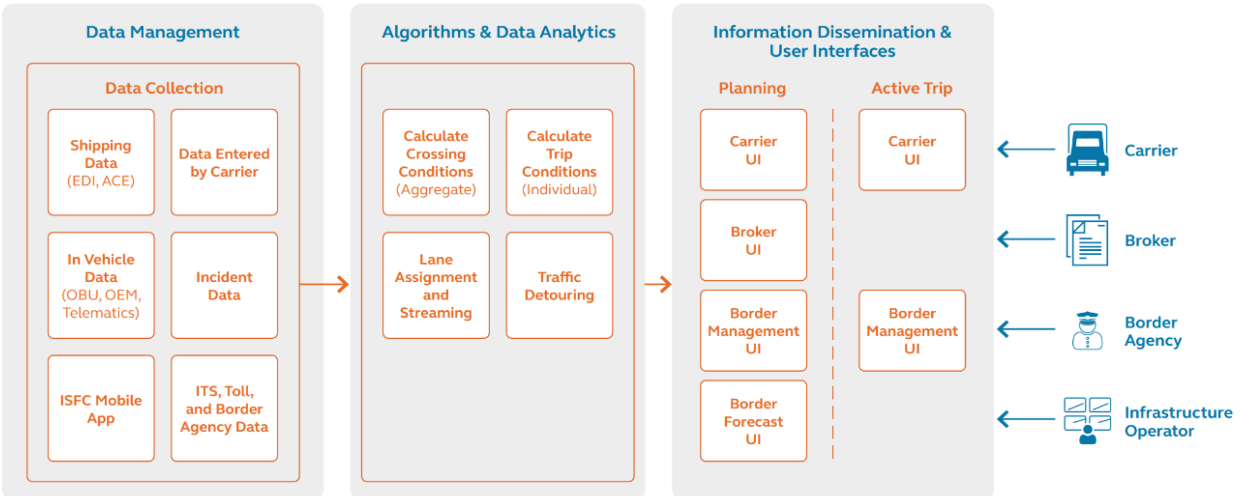
Figure 9: ISFC Platform Border Agency's Incident Management View



ii. Architecture

The ISFC Prototype architecture is made up primarily of data interfaces, and the headend systems. A high-level platform architecture diagram is provided in **Figure 10**.

Figure 10: High-Level Platform Architecture Diagram



Data Collection

There are two types of data collection that the ISFC System collects and consolidates:

- Indirect sources (such Google Maps, MDOT incident data, etc.) to be used for the System functions; and
- Data from System users collected during trips (such as information entered by the user, GPS data from the application, etc.).

Data Management

Data management is the process of collecting, storing, organizing, and ensuring the quality of data to facilitate its accurate and efficient use. For this project, effective data management is critical as it enables the ISFC System's functions by providing data-driven insights, subsequently improving the operational efficiency of the border crossing and better informing the end user's decision-making capabilities. In addition, because of the sensitive nature of the international border crossing, strong data security and access protocols as part of the data management practice are of utmost importance to ensure safety and security.

Table 1 shows the data that was used throughout the development of the ISFC Prototype to deploy preliminary solution functions. The table outlines the data, a brief description, its use cases, time frame, source, and if it will be archived after final submission of the project.

Table 1: Data Overview for ISFC Prototype Integration

Data	Input or Output	Description	Use Case	Time Frame	Source	Archived
Incident data	Input	This data describes incidents that are active on the MiDrive website within a 5-mile radius from the Blue Water Bridge (BWB).	Displayed in the prototype as real-time information for drivers.	Real-time – this data is pulled in real-time from the website and is discarded when the incident is cleared.	This data is sourced from MiDrive, Michigan Department of Transportation's (MDOT) public facing traveller information system. https://mdotjboss.state.mi.us/MiDrive/incident	No
Vehicle type and classification	Input	This data describes the number of commercial vehicles with a specific number of axles crossing the toll booth inbound into the United States per hour, per day.	Used in the cost-benefit analysis.	Historical – January to December 2023	This data is sourced from toll data collected from the Federal Bridge Corporation Limited (FBCL) and MDOT.	Yes
Border wait time	Input	This data describes the estimated wait time (delay) at the BWB Customs and Border Protection (CBP) checkpoint per hour, per day.	Used to develop a previous version of the travel time prediction model.	Historical – November 2024	This data is sourced from the public-facing Customs and Border Protection border wait time website. https://bwt.cbp.gov/details/03380201/POV	Yes
Vehicle type and count	Input	This data describes the number of commercial vehicles crossing the toll booth inbound into the	Used to develop the existing travel time	Historical – November 2024 to April 2025	This data is sourced from toll data collected from the Federal Bridge Corporation Limited (FBCL) and	Yes

Data	Input or Output	Description	Use Case	Time Frame	Source	Archived
		United States per hour, per day.	prediction model.		Michigan Department of Transportation (MDOT).	
Primary inspection lane availability	Input	This data describes the number of commercial vehicle general and FAST primary inspection lanes open at the BWB CBP checkpoint per hour, per day.	Used to develop the existing travel time prediction model.	Historical – November 2024 to April 2025	This data is sourced from the public-facing Customs and Border Protection border wait time website. https://bwt.cbp.gov/details/03380201/POV	Yes
Border travel time	Input	This data describes the average vehicle travel time between a Bluetooth reader positioned approximately 1km east of the interchange of Highway 402 and Modeland Road to a Bluetooth reader positioned at the U.S.-bound CBP primary inspection lane checkpoint, per hour, per day.	Used to develop the existing travel time prediction model.	Historical – November 2024 to April 2025	This data is sourced from Traffic and Parking Automation (TPA) North America Inc., MDOT's vendor for Bluetooth travel time data.	Yes
Weather data	Input	This data describes the monthly average temperature at the Sarnia weather station.	Used to develop the existing travel time prediction model.	Historical – January 2022 to December 2024	This data is sourced from the public-facing website, World Weather Online.	Yes
Predicted origin-	Output	This data describes the travel time between a user-inputted origin and	Used as a simulated predicted	Fictional*	This data is generated by the International Smart	Yes

Data	Input or Output	Description	Use Case	Time Frame	Source	Archived
destination travel time		destination predicted by the model within the prototype.	travel time output of the prototype.		Freight Corridor (ISFC) prototype.	
Fleet information	Input and output	This data describes fleet information of scheduled trips, including departure time, original arrival time, estimated arrival time, the border crossing, and trip status. This data is displayed on the "My Fleet" tab of the prototype.	Used as a simulation of the fleet information output of the prototype.	Fictional*	This data is displayed by the ISFC Prototype to demonstrate fleet management functionality. Due to the potential for PII to be contained in the production dataset, only synthetic data was used for the Stage 1 project. Anonymization of location and user data is required for the production dataset to feasibly be made available to the public if required as part of future work.	Yes
User inputted incident reports	Input and output	This data describes incidents that are reported and inputted by ISFC Prototype users in the "Incidents" tab of the Prototype.	Used as a simulation of user-inputted border incidents.	Fictional*	This data is displayed by the ISFC Prototype to demonstrate incident management functionality.	Yes

* No production data was collected and data security requirements for production data need to be reviewed as part of future work.

Algorithms and Data Analytics

The algorithms and data analytics requirements for the ISFC Prototype are categorized by crossing conditions, individual trip conditions, and traffic detouring. Within the data framework, response-predictor type regression models have been developed and integrated to leverage current and historical data on border wait times, volumes, and lane availability, enabling accurate predictions of future wait times for both short- and long-term scenarios. Paired with origin-to-destination travel time forecasts, the ISFC Prototype enhances end-to-end visibility into the status of commercial vehicle trips. These regression models provide users with precise and up-to-date insights into border crossing conditions, empowering drivers and trip planners to make more informed decisions to expedite deliveries and improve operational efficiency. However, while this functionality is enabled within the ISFC Prototype, the algorithm is not able to determine the most efficient traffic detouring route without further discussion with customs document processing who would need to verify the paperwork prior to fleet managers confirming rerouting to their drivers. This is expected to be further explored in the ISFC System.

D. Project Stakeholders

Table 2 below includes the key stakeholders of the project and their main roles and responsibilities. Each step of the design process of the solution is being reviewed with stakeholders – which includes agencies, end users, and local communities – in dedicated workshops, where objectives and relevant performance indicators have been set. Collaboration with key stakeholders, including CBP and Commercial Carriers, is important for the successful implementation of the ISFC Prototype, and to maximize the value of the benefits of an at-scale project implementation.

Table 2: Key Stakeholders

Stakeholders	Description	Roles and Responsibilities
Beneficiaries/ Local communities	The project area is the City of Port Huron, Michigan, with Point Edward, Ontario, on the Canadian side of the BWB. Port Huron is part of the larger Detroit-Warren–Ann Arbor Combined Statistical Area, and Point Edward is adjacent to the larger city, Sarnia.	• Provide stakeholder input for ISFC System design decisions • Provide local emergency services to respond to traffic incidents as applicable
Brokers	The brokers, made up of many different corporate entities, secure freight shipping services from freight carriers on behalf of businesses and individuals.	• Prepare necessary paperwork for shippers. • Update paperwork in response to route changes as needed
BWB-MDOT	The Michigan Department of Transportation Blue Water Bridge Operations is responsible for the U.S. side of the Blue Water Bridge	• Operate and maintain the bridge infrastructure and toll plaza on the U.S. side of the bridge • User of the ISFC System

Stakeholders	Description	Roles and Responsibilities
		• Approve suggested routes before they are recommended to carriers within a designated timeframe. • Limit queuing on the bridge by restricting vehicles at the toll plaza
BWB/FBCL	The Federal Bridge Corporation Limited is responsible for the Canadian side of the Blue Water Bridge	• Operate and maintain the bridge infrastructure and toll plaza on the Canadian side of the bridge • Limit queuing on the bridge by restricting vehicles at the toll plaza. • Provide feedback as a future user of the System to improve the platform's functions and compatibility with existing practices
Carriers	The carriers, made up of many corporate entities, deliver goods on both sides of the U.S.-Canadian border.	• Schedule inspection at border crossing based on estimated arrival time and available slot • Provide data on deliveries, including schedule and delivery progress • Update delivery data in real time, using Onboard Computer and Communications Units (OBUs) or phone apps • Provide data on delivery times and border wait times for MDOT for project evaluation
CBP	The U.S. Customs and Border Protection manages the flow of goods and people across United States borders, enforcing regulations regarding people and goods crossing the border.	• Provide information on border wait times for project evaluation • Own and manage agency systems that facilitate goods movement across the U.S. border • Approve suggested routes before they are recommended to carriers within a designated timeframe. • Provide feedback as a future user of the ISFC System to improve the platform's functions and compatibility with existing practices
CBSA	The CBSA manages the flow of goods and people across Canadian borders, enforcing regulations regarding people and goods crossing the border.	• Provide information on border wait times for project evaluation • Monitor traffic flows, provide inputs such as increased capacity (booths open), report on performance of system.

Stakeholders	Description	Roles and Responsibilities
DEA	The United States Drug Enforcement Administration (DEA) mission is to ensure that safety and health of American communities by combating criminal drug networks.	• Combating illicit drug trafficking at the border.
DHS	The United States Department of Homeland Security (DHS) is responsible for public security. Its mission involves anti-terrorism, border security, and disaster prevention.	• Border and public security.
FDA	The United States Food and Drug Administration (FDA) is responsible for protecting the public health by ensuring the safety, efficacy, and security of human and veterinary drugs, biological products, and medical devices; and by ensuring the safety of nation's food supply, cosmetics, and products that emit radiation.	• Promote public health through the control and enforcement of the exchange of food and drugs at the border.
FHWA	The Federal Highway Administration (FHWA) provides stewardship over the construction, maintenance and preservation of the Nation's highways, bridges and tunnels. FHWA also conducts research and provides technical assistance to state and local agencies to improve safety, mobility, and to encourage innovation.	• Provide project funding through SMART Grant • Provide feedback on various aspects of the ISFC System development • Key stakeholder for the at-scale implementation
MDOT	The Michigan Department of Transportation (MDOT) is responsible for Michigan's nearly 10,000-mile state highway system, comprised of all M-, I-, and U.S.-routes.	• Owner, operation, and maintenance of the ISFC Prototype and ISFC System and overall project manager of the project • Use the ISFC System • Monitor Smart Corridor roadways, noting traffic volumes and traffic incidents, alerting carriers, U.S. Customs and Border Protection (CBP), and Canada Border Services Agency (CBSA) as necessary • Record data on travel times for project evaluation • Record data on congestion levels, including time spent idling, for project evaluation

Stakeholders	Description	Roles and Responsibilities
MTO	The Ontario Ministry of Transportation (MTO) is responsible for provincial-level transportation infrastructure and projects.	• Monitor roadways surrounding the smart corridor on the Canadian side of the border • Share data regarding congestion and traffic incidents with MDOT, carriers, CBP, and CBSA
Local Traffic Agencies	The local traffic agencies, including St. Clair County, City of Port Huron, Detroit Office of Mobility and Innovation, manages the local traffic that are connected to the corridor.	• Manage local roadways surrounding the smart corridor • Assist MTO / MDOT in incident scenarios, through use of local roadways.
Shippers	The shippers, made up of many different corporate entities, have goods sent across the U.S.-Canadian border.	• Provide data regarding shipments, including the type, and quantity of goods crossing the border • Monitor trip progress of carriers • Provide data on delivery times and border wait times for MDOT for evaluation
USDA	The United States Department of Agriculture (USDA) mission is to promote agriculture production which includes helping keep America's farmers and ranchers in business.	• Promote agricultural trade and production at the border.

The engagement of stakeholders has been prioritized throughout the project. Dedicated workshops have been organized throughout 2024 and into 2025 to solicit input and feedback on different aspects of the solution design, including data needs, ConOps, and evaluation. A more detailed description of MDOT's stakeholder engagement is included below in **Section G**.

E. Deployment Stages

i. Stage 1 POC Deployment

This project is funded by Stage 1 of the U.S. Department of Transportation Strengthening Mobility and Revolutionizing Transportation (SMART) grant. The scope of Stage 1 of the project covers westbound traffic, travelling from Ontario to Michigan at the BWB POE. The results of the project are being evaluated based on the criteria described in this document. Quantitative data are being evaluated, such as congestion levels, truck idling times, and wait times at the border.

Work under this Stage 1 grant includes a needs assessment, stakeholder outreach, ConOps development, development of data and data exchange standards, implementation plan development, and ISFC Prototype demonstrations. The work has been organized in four (4) tasks:

- Task 1: Needs Assessment & Data and Processes;
- Task 2: Concept of Operations;
- Task 3: Development and Implementation of a Proof-of-Concept; and
- Task 4: Proof-of-Concept Evaluation and Future Implementation Program.

The product of the Stage 1 Proof of Concept is the ISFC Prototype.

ii. Stage 2 At-Scale Deployment

The Stage 2 scope of work that includes at-scale deployment would include the following by building on the work conducted in Stage 1:

- Full configuration, deployment and integration of the ISFC System at BWB for use by MDOT operation staff analyzing all inbound traffic, which includes eastbound and westbound traffic, representing an upgrade from a ISFC Prototype to a complete fully developed and operational system.
- Evaluation of solution replicability and deployment at similar border crossings, such as:
    - **Sault Ste. Marie International Bridge (Sault Ste. Marie, MI):** This bridge connects Sault Ste. Marie, Michigan, with Sault Ste. Marie, Ontario, and is a critical trade corridor between the U.S. and Canada. It handles significant cross-border commercial traffic and is an essential link for freight movement, making it a strong candidate for ISFC System implementation. Integrating the ISFC System at this location could enhance traffic management, reduce delays, and improve coordination between agencies. Note that the ISFC System would only include the inbound portion of the bridge.
    - **Gordie Howe International Bridge (Detroit, MI):** Currently under construction, this bridge will provide a new, high-capacity crossing between Detroit, Michigan, and Windsor, Ontario, aiming to alleviate congestion at the existing Ambassador Bridge. Given its strategic importance and expected high volume of commercial traffic, incorporating the ISFC System could optimize operations from the outset by enhancing data-sharing capabilities, improving predictive analytics for traffic flow, and streamlining border clearance processes. An ISFC System implementation would only include the inbound portion of the bridge.
- An expansion of the scope of the ISFC System to integrate more data and information sources (e.g., connected vehicle data) and to share data and insights with the existing systems used by commercial carriers and border agencies.
- Software development for the full extent of the functionality of the ISFC System (defined in the ConOps and developed as a ISFC Prototype in Stage 1), hosting of the solution, BWB configuration, integration, testing and operations, and maintenance for a period of three (3) years. Furthermore, it would also include the provision for upgrades and evolution of the solution throughout the project's duration.

The desired outcome is a secure, reliable, fully production-ready system that has the infrastructure to support widescale usage by the various users. As uptake increases, so will the value that the ISFC System can provide, by arming users with key data and analytics that they can leverage for informed decision making and optimization.

F. Project Coverage

The engagement and active participation of stakeholders has been an important element of the workplan for the project. End users (mainly commercial carriers) and agencies have shown great interest in the project during this period.

The project was initially identified by a large group of stakeholders as a quick win as part of a technology strategy project (supported by both the State of Michigan and the Province of Ontario) that aimed to create a 10-year roadmap for the implementation of border technologies. Stakeholder engagement and support for this project has been present from its onset and this engagement has been continuous throughout the Stage 1 implementation. This level of involvement and interest is expected to continue through Stage 2.

In addition to workshops with the broader stakeholder groups, one-on-one meetings and workshops have been organized with CBP and a limited number of Commercial Carriers.

In terms of broader coverage, a dedicated presentation has been given to the Council of the Great Lakes Region, a bi-national multi-sector forum for exchange and collaboration. Furthermore, a Special Interest Session on border technologies was organized by MDOT for the Intelligent Transportation Systems (ITS) World Congress 2024 in Dubai (September 16-20, 2024), with a panel that included representatives from:

- **North America:** MDOT and the Ontario Center of Innovation discussing the technology strategy for border crossings and this project.
- **Europe:** ERTICO presented their work on similar initiatives in Europe, including the 5G MOBIX project, with the purpose of developing and evaluating automated vehicle functionalities and the GUIDE Project, which is a support action that aims in seamless cross-border interoperability, along with initiatives from VTT for improvements in cross-border logistics in the Baltic Region.
- **Australia:** Similar initiatives are underway for cross border harmonization of C-ITS to support widescale cross border deployment of digital technology for road safety.

G. Project Activity Summary

Stage 1 of the project includes three phases, preparation, development and integration, and evaluation. A workplan showing the timeline for these phases, as well as the associated tasks and main deliverables, is shown below in **Figure 11**. Key milestones and their associated target and completion dates are included in **Table 3**, while a description of the stakeholder workshops performed during the project follows.

Figure 11: Project Workplan

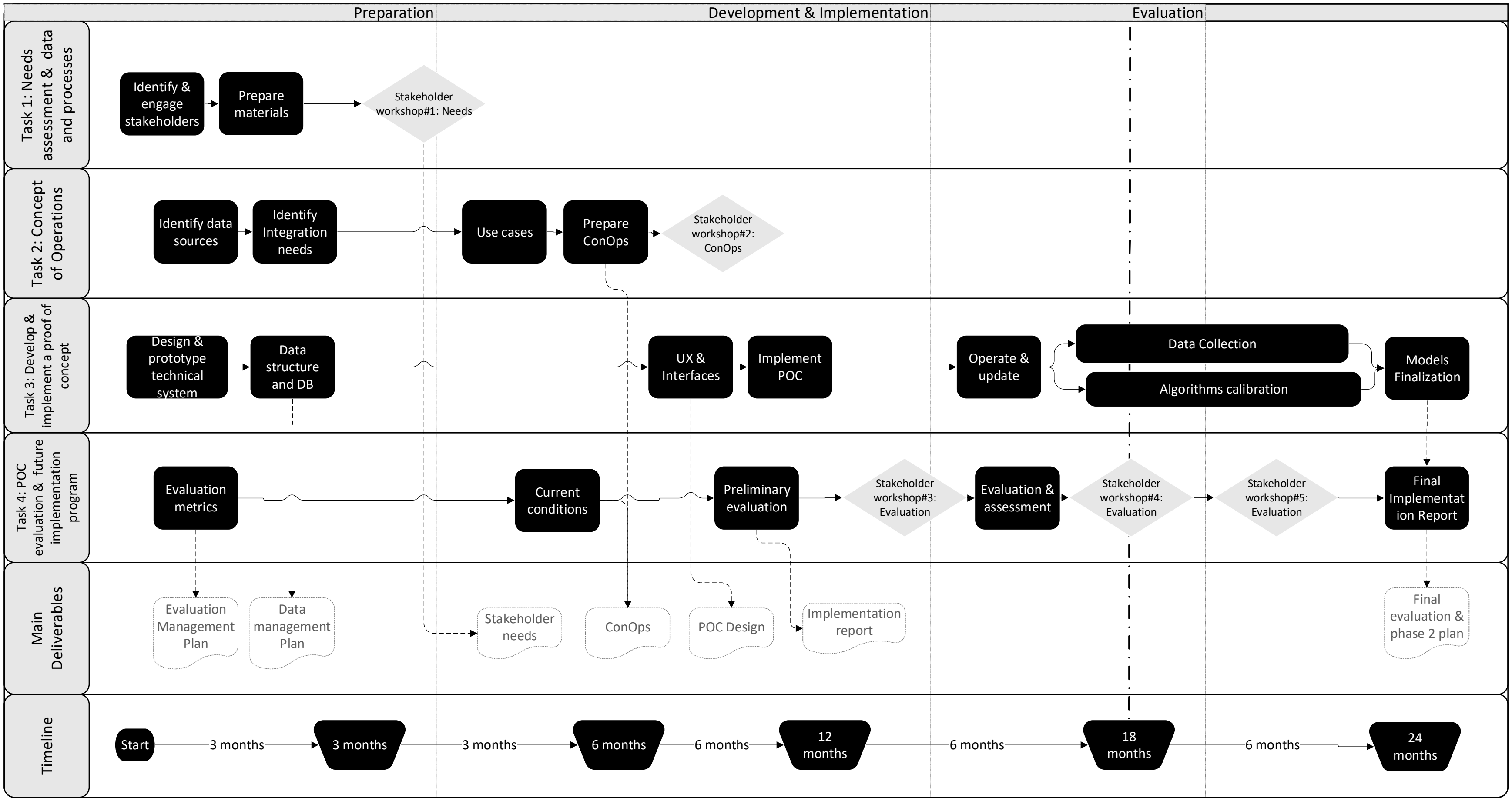


Table 3: ISFC Key Milestones & Deliverables

#	Milestone/ Deliverable	Planned & actual completion dates (if different)	Comment
1	Data Management Plan	February 20, 2024 (Draft) August 15, 2025 (Final)	• Provided a description of the data that will be gathered during the project or data from a third party that will be reused. • Addressed the expected nature, scope, and scale of the data that will be collected, as best as you can at this stage. • Described the characteristics of the data, their relationship to other data, and provided sufficient detail so that reviewers will understand any disclosure risks that may apply.
2	Evaluation Management Plan	February 14, 2024	• Submission and receipt of USDOT comments. Feedback incorporated into Draft Implementation Report
3	Stakeholder Needs Assessment	Planned Completion: May 30, 2024 Actual Completion: June 25, 2024	• Conducted an assessment to identify and document the needs of stakeholders involved in the ISFC project. • Engaged with various stakeholders to gather detailed requirements and expectations. • This milestone helped in understanding the foundational needs and priorities, setting the stage for further development.
4	Concept of Operations	Planned Completion: June 30, 2024 Actual Completion: August 02, 2024	• Developed a detailed ConOps to provide a high-level overview of the system and its intended operations. • The ConOps was prepared to inform and guide discussions during the second workshop. • It included input from stakeholders and outlined the functional and operational requirements of the proposed system.
5	POC Design	August 30, 2024	• An ISFC Prototype, including the full User Experience (UI and workflow)
6	Draft Implementation Report	Planned Completion: September 15, 2024 – Actual Completion: September 15, 2024	• Draft Report • Intended to verify feasibility, validate performance measures, assess costs and benefits, and identify challenges and lessons learned. • The report also determines potential issues and risks early in the project to enable timely adjustments before significant resource investment
7	Solution design refinement	Planned Completion: October 30, 2024 – Actual Completion: December 20, 2024	• Taking into account input from stakeholders
8	Data strategy and user interface refinements	planned completion: November 30, 2024 –	• Taking into account input from stakeholders

#	Milestone/ Deliverable	Planned & actual completion dates (if different)	Comment
		actual completion: December 20, 2024	
9	Final Implementation Report	September 15, 2025	• The present report

Stakeholder Workshops

Collaboration with key stakeholders, including the CBP and Commercial Carriers, is important for the successful implementation of the proof-of-concept and to maximize the value of the benefits of at-scale project deployment. A core stakeholder group was meeting on a bi-weekly basis for the duration of the project. Dedicated workshops with a broader stakeholder group have been organized throughout the project's duration to receive their input and feedback on different aspects of the solution design, including data needs, concept of operations and evaluation. These included the following:

Table 4: Stage 1 Stakeholder Workshops

Workshop	Comment
Workshop #1 April 18, 2024	• The first workshop was held to review and discuss various scenarios relevant to the BWB smart corridor project. • Participants reviewed different operational scenarios to identify potential challenges and opportunities. • Detailed discussions were held to gather insights and feedback from stakeholders regarding the proposed solutions. • Based on the discussions and feedback received, the ConOps was updated to better align with stakeholder needs and expectations
Workshop #2 July 18, 2024	• The second workshop focused on delving deeper into the ISFC System functionality and user experience aspects. • Detailed reviews of the platform's functional system were conducted to ensure it meets the technical and operational requirements. • Enhanced understanding of the functional system, leading to refinements and improvements in the design. • An ISFC Prototype was shared with stakeholders and feedback on the user experience, including UI and workflows was provided. This feedback will guide the development of interfaces and interactions to ensure ease of use and efficiency for all users involved.
Workshop #3 September 11, 2024	• The third workshop focused on reviewing the anticipated benefits of the ISFC System based on initial implementation data. • Detailed analysis of the early results based on the ISFC Prototype. • Discussions on how the project's benefits align with the original project goals.

Workshop	Comment
	• Collection of feedback from stakeholders on the effectiveness of the ISFC System benefits and identification of areas for further enhancement.
Workshop #4 February 26, 2025	• The fourth workshop focused on reviewing the actual ISFC Prototype and results of the project.

Furthermore, dedicated, one-on-one, meetings and workshops were performed with the following stakeholders:

- **Commercial Carriers:** six workshops focusing on user needs and review of the ISFC Prototype, in iterations.
- **CBP:** one workshop.

H. Project Adjustments

The ConOps and corresponding System and Prototype Design have been shaped through stakeholder workshops and one-on-one meetings. MDOT and their consultants engaged with CBP, as well as with a major Commercial Carrier. The four (4) one-on-one meetings with a major Commercial Carrier were to learn more about the processes in place and receive feedback on its applicability. The solution was adjusted to maximize its value.

In our last stakeholder meeting, the Commercial Carrier noted satisfaction with the project adjustments for usability since the start of the project, noted that they would use it, and shared their support for the project moving forward.

Table 5: Project Adjustments to the ISFC

Original Design	Modification for the ISFC Prototype	Reason
Three main user groups – Fleet Management, Toll Management, Border Services	Added Drivers as users	Through conversations with commercial carriers, we learned that drivers are given significant autonomy to make their own decisions. Drivers are interested in certain data sets. We developed a driver-specific view that is fit for a phone or tablet screen.
Passive data sources – EDI, OBU, ACE data integration	Pared down the list of data sources that would require integration	These passive data sources require complex buy-in from various third parties. By focusing on publicly available data and user-entered data,

Original Design	Modification for the ISFC Prototype	Reason
		the ISFC Prototype can prove the concept efficiently.
Active Data sources – extensive fleet management input required (documentation, drivers, cargo, etc.)	Reduced the scope of what the fleet management will be required to enter.	Conversations with commercial carriers revealed that most commercial carriers already have their own driver/cargo management systems, and they are not interested in having another system or having to duplicate effort. Also, as the rerouting scenario was modified (shown below), some of this information became irrelevant.
Analytics – the travel time algorithms originally included incidents	Travel time algorithms are now independent of incidents, and incidents are displayed with a flag.	There is no reliable way to model the extent to which an incident would impact travel times. For example, if one lane is closed, how much does it increase travel time? If there is a full closure for 3 hours, for how long will traffic increase? As such, the information was disaggregated out.
Analytics – the original design calculated fuel usage, suggested break times, and included lane assignment and streaming.	These functions were removed.	Commercial carriers showed a general lack of interest in these functions. They also indicated that drivers would rather see general information and then make decisions for themselves, hence why the driver view was added.
Functions – the original rerouting function provided alternate routes, more configurations, travel time differences, and paperwork packaging.	These functions were removed. Now the expectation is that fleet management will have to manage any paperwork independently, with their broker.	Commercial carriers indicated that drivers already have systems for wayfinding / travel time and would not want a duplicate system. Paperwork packaging was removed at the ISFC Prototype stage because the feasibility was considered low.

Original Design	Modification for the ISFC Prototype	Reason
Functions – trip planning was originally organized from the fleet management side.	Trip planning is now more ad hoc and managed by drivers.	Carriers felt that they already have systems that meet these objectives.

Overall, the modifications to the ISFC Prototype had the following themes:

- Accessing data through interfaces to existing platforms rather than direct entry from users.
- Streamlining processes and removing excess functions at the ISFC Prototype stage to produce a minimum viable product.
- Providing predictions with a high degree of confidence became a central element of the solution, as it is a major gap in the information that is already available.
- Complementing solutions already offered by CBP. This was reviewed in dedicated one-on-one meetings with them to ensure that what was developed under the project did not duplicate or conflict with solutions that are already available to the end users.

I. Benefits for Disadvantaged Populations

The ISFC System aims to enhance the efficiency of freight transportation, while addressing several real-world challenges that disproportionately impact underserved and disadvantaged populations living near the Blue Water Bridge (BWB) and along freight corridors that will experience the benefits of at-scale implementation.

Disadvantaged populations near freight corridors and border crossings often face persistent challenges that impact their health, economic stability, and overall quality of life. The ISFC System directly addresses these challenges through system-wide improvements in freight operations. Key challenges and the corresponding solutions provided by the platform include:

➢ **Poor Air Quality Due to Freight-Related Emissions**

- **Challenge:** Populations near border crossings and freight corridors are disproportionately exposed to high levels of harmful pollutants, including particulate matter (PM2.5), nitrogen oxides (NO_x), and carbon dioxide (CO_2), which contribute to respiratory illnesses and cardiovascular diseases.
- **ISFC System:** The platform reduces truck idling and optimizes traffic flow, significantly lowering emissions associated with border delays. At-scale implementation will extend these air quality improvements along major freight routes, reducing environmental health risks for communities across the region.

- **Economic Barriers for Small-Scale Trucking Entrepreneurs**
  - **Challenge:** Small-scale and independent owner-operator truckers face higher financial risks due to unpredictable border delays and inefficient inspection processes. These challenges lead to increased operational costs, missed delivery deadlines, and lost business opportunities.
  - **ISFC System:** By streamlining customs processes and providing real-time traffic and inspection updates, the ISFC System helps truckers reduce delays, better manage schedules, and lower costs. Expanding this system across other corridors would provide more equitable access to operational efficiencies for smaller carriers, supporting the growth of small businesses in the freight industry.
- **Congestion and Travel Time Unpredictability**
  - **Challenge:** Chronic congestion near the BWB and along freight corridors leads to extended travel times, increased fuel consumption, and elevated transportation costs. This unpredictability disrupts local traffic patterns and diminishes the quality of life for nearby residents.
  - **ISFC Solution:** The platform utilizes traffic forecasts, real-time updates, and adaptive traffic management strategies to minimize congestion and improve travel time reliability. At-scale implementation will extend these benefits to communities along other high-traffic corridors, reducing congestion-related stressors for both residents and truck operators.
- **Lack of Community Involvement in Freight Operations Planning**
  - **Challenge:** Historically, populations impacted by freight operations have had limited opportunities to participate in the planning and development of transportation initiatives.
  - **ISFC Solution:** The ISFC project team organized a structured series of workshops, each with specific objectives related to understanding stakeholder concerns, gathering feedback, and incorporating community-driven insights into the project design. The workshops were open to a diverse set of participants, including commercial carriers, small-scale owner-operators, local agencies, and other stakeholders

Part 3: Proof-of-Concept or ISFC Prototype Evaluation Findings

Part 3 of this document provides a brief analysis of the expected benefits created by the ISFC Prototype. It identifies the expected impact of the solution and the quantitative data being measured. Part 3 also qualitatively examines the benefits created by the solution that cannot be directly measured.

A. Findings

The solution's main benefits include a reduction in vehicle delay and emissions. The performance measures used to assess the potential benefits of the ISFC Prototype are reductions in travel time, reduced GHG emissions, and air quality. Efforts were made to collect the originally desired data, including information from CBP and Commercial Carriers, to support comprehensive evaluation and analysis. However, data limitations were encountered, particularly in terms of accuracy and availability, due to the complexities of stakeholder data sharing and access restrictions. While closer collaboration with Commercial Carriers improved data availability, access to certain critical datasets from CBP remained a challenge. As a result, the list of performance measures was refined to reflect the available data, which in turn influenced the scope and depth of the analysis. Further details on these limitations and their impact on the evaluation framework can be found in **Part 3**. **Table 6** lists the performance measures, and the analysis metrics used for this analysis.

Table 6: Performance Measures and Analysis Metrics

Evaluation Management Plan Performance Measures	Updated Analysis Metric	Description
Travel Time (Delay at the Border)	Vehicle-hours of delay	The solution helps reduce delays at the border, contributing to improved travel time, though overall travel duration is influenced by multiple factors beyond its control.
GHG Emissions and Air Quality	Idling emissions	Vehicles will emit GHG and air quality emissions on their trip, the solution aims to reduce excess emissions due to delay.

BWB westbound historical traffic and volume data have been used to establish the current status of the initial findings from the proof-of-concept evaluation. The following analysis metrics can be used to inform on the performance measures:

- Vehicle-Hours of Delay – BWB annual westbound historical traffic data was used to assess travel delays of trucks. The analysis found the ISFC Prototype, projected out to the at-scale implementation, may reduce total vehicle-hours of delay by approximately 7 percent within the first year. This is calculated based on **Table 7** (Actual* Trend from Baseline to Post ISFC At-Scale Implementation / Baseline Data *100).
- Idling Emissions – BWB annual westbound historical travel delay data was used to assess idling emissions, accounting for pollutant and vehicle type. The analysis found the ISFC Prototype, projected out to the at-scale ISFC solution implementation, may provide a net reduction in total emissions due to delays of up to approximately 7 percent within the first year, proportional to the reduction in vehicle-hours of delay. This is calculated based on **Table 7** (Actual* Trend from Baseline to Post ISFC At-Scale Implementation / Baseline Data *100). A more detailed calculation of the relationship between vehicle-hours of delay and idling emissions can be found in Part 4: Anticipated Benefits and Costs of At-Scale Implementation.

Table 7: Benefits Report Table

Performance Measure	Unit Reported	Expected Trend from Baseline to Post Construction	Baseline Data	At-Scale Implementation Data (Year 1)	Actual* Trend from Baseline to Post ISFC At-Scale Implementation
Travel Delay (Delay at the Border)	Vehicle-hours of Delay	Decreasing	395,000 vehicle-hours/year	365,000 vehicle-hours/year	Decreasing by 30,000 vehicle-hours/year
GHG Emissions and Air Quality	Idling Emissions	Decreasing	25,615,000 Mass(g)/year	23,693,000 Mass(g)/year	Decreasing by 1,922,000 Mass(g)/year**

*Actual trend is expected based on the evaluation data.

**Equivalent to planting approximately 77 trees.

B. Performance Measurement

The ISFC Prototype has been evaluated against the project objectives stated in Part 1 (noted in bold text below), as well as the following statutory categories: safety improvements, congestion reduction, providing public access to real-time information, and reducing barriers.

i. Project Objectives

Providing more accurate and accessible information and enabling better decision-making for its key users, including Commercial Carriers and their drivers

The ISFC Prototype provides data that empowers users to plan more efficient trips. Users are provided with more accurate travel time predictions based on current and predictive data regarding border crossing times, open toll lanes, and currently planned trips.

Supporting timely response to disruptions/incidents along U.S.-Canada border crossings in Michigan

The ISFC Prototype includes the ability for users to report incidents during their trips. Users are also able to update the incident's status based on real-time conditions. Carriers see these updates through the ISFC Prototype's dashboard and are able to plan trips strategically to avoid incidents when possible. Reducing queues at the POE will also reduce collision risks, which can improve emergency response times if responders are less likely to be overwhelmed.

Provide an improvement to commercial traffic flow across the BWB to reduce border wait times, queuing, and congestion

Through increased access to real-time and predictive data, implementation of the ISFC Prototype results in an overall reduction in delay for freight traffic crossing the BWB. Users can leverage the data provided by the ISFC Prototype to plan trips that avoid incidents and congestion and respond to real time conditions at the POE.

ii. Safety Improvements

By reducing queues at all border crossings, the risk of commercial vehicle rear end crashes and conflicts with small-vehicle traffic could be greatly reduced. The system enhances planning for all users by providing relevant data and assists in distributing demand more effectively. Lane openings and closure information from border agencies will be shared with drivers and carriers in advance of trip planning. These features contribute to the reduction in incidents at the POE which translates to greater safety for both individuals and infrastructure.

iii. Congestion Reduction

The ISFC Prototype can reduce congestion by allowing for more efficient planning of freight trips across the BWB. The ISFC Prototype empowers westbound freight carriers to plan trips at times that avoid peak traffic and allow them to take strategic breaks when unexpected delays, such as traffic incidents, arise. The reduction in delay created by the Prototype is mostly experienced at the POE plaza, but reduced congestion at the POE has positive impacts across the I-94/I-69 corridor. As adoption of the ISFC increases, the congestion reductions and travel time savings will continue to grow.

iv. Providing Public Access to Real-Time Information

The ISFC Prototype provides users with both historical and real-time data to help them plan more efficient trips across the BWB. The ISFC Prototype features a dashboard that includes multiple types of data, including total trips for the day, trips running late, border wait times, active incidents, and number of open toll lanes. This data empowers shippers to plan trips when border crossing times are shorter and potentially avoid incidents, allows carriers to take strategic breaks to avoid excess congestion, and allows CBP agents and toll operators to time breaks based on the current trips planned. Users with the correct permissions may input planned trips, update open toll lanes, and report incidents; which are reflected in the ISFC Prototype in real time.

v. Reducing Barriers

The ISFC Prototype solution may improve the user experience for stakeholders and infrastructure operators. Data collected from drivers, supplemented by traffic data from other sources, will provide border agency operators with reliable forecasts of expected traffic volumes, and can improve resource management. The system may also improve ease of use for fleet drivers and shippers by providing relevant data in a centralized system, including real-time information. Incident management could also be improved through streamlined communication and enable rerouting with minimal user effort. By increasing the throughput of goods, the rate at which products are produced and delivered is increased; theoretically leading to more jobs to keep up with production.

C. Qualitative Evaluation

A qualitative evaluation was performed on the ISFC, based on incorporating both internal system data and external evaluation data, as highlighted by stakeholders. This assessment considered the structured data categories utilized within the system, including trip details, vehicle location, traffic volumes, and incident reports, as well as the external performance evaluation metrics such as vehicle delay, emissions, and economic impact. Impacts were examined for both the ISFC Prototype and the System, as shown in **Table 9**: Impacts were classified as major, moderate, minor, or nonexistent, as shown in **Table 8**.

Table 8: Impact Scale Diagram

No Impact → **Significant Impact**

None	Minor	Moderate	Major

Table 9: Qualitative Evaluation

Impact Category	Impact Description	ISFC Prototype (Stage 1)	ISFC Solution (Stage 2)
Congestion Reduction	Because Stage 1 only impacts westbound traffic coming into the US, congestion mitigation will be limited, however reduced freight congestion coming through the POE plaza will have a positive impact on congestion in the Port Huron area. The at-scale system will further reduce freight congestion across the I-94/I-69 corridor, especially at the POE plaza.	Moderate	Major
Safety	Safety is improved by reducing queues at border crossings, reducing the risk of collisions, especially between trucks and small-vehicle traffic.	Minor	Moderate
Increased Access	The ISFC Prototype will make shipping more efficient, which has the potential to grow the industry, and provide new local jobs. The at-scale Implementation will reduce congestion on the I-94/I-69 corridor, making it easier to access jobs and essential services for road users.	Minor	Major

Impact Category	Impact Description	ISFC Prototype (Stage 1)	ISFC Solution (Stage 2)
Connecting Underserved Communities	The ISFC Prototype will reduce freight emissions at the POE plaza, improving air quality for underserved communities. The at-scale Implementation will further improve air quality by reducing congestion across the I-94/I-69 corridor.	Moderate	Major
Economic Competitiveness	The ISFC will make shipping more efficient which has the potential to grow local industries in the Port Huron area.	Moderate	Major
Reliability Improvements	The ISFC promotes the reliability of the I-94/I-69 corridor and at the POE plaza by providing users with real-time and predictive data at and approaching the POE. This empowers users to plan more efficient trips and reduce overall congestion, further improving reliability.	Moderate	Major
Connected Transportation	The ISFC provides real-time and predictive traffic conditions. Users of the ISFC solution will be able to make more informed and efficient trip plans by leveraging the data provided by the solution.	Minor	Moderate
Private Sector Partnerships	The ISFC relies on adoption by private sector users for it to function. Private sector stakeholders were included in the development of the ISFC Prototype to ensure it addresses their needs.	Major	Major
Increased Efficiency	Reduced wait times at border crossings reduce emissions from idling, improving air quality.	Moderate	Major
Resilience	Transportation resilience is improved by providing users with real-time data to aid in decision making.	Moderate	Major
Emergency Response	The ISFC Prototype will alert users of incidents along their route and allow them to avoid excess congestion. Shorter queues at incidents will improve incident response time. The at-scale implementation of the ISFC will further reduce congestion along the I-94/I-69 corridor, which can improve emergency response times.	Minor	Moderate

Additional qualitative benefits, that are difficult to quantify and monetize, are further discussed in Part 4, Section C, of this report.

Part 4: Anticipated Benefits and Costs of At-Scale Implementation

Part 4 of this document examines the expected cost and benefits of implementing the solution over time. The benefits of the project throughout its lifespan are identified, quantified, and monetized as appropriate. Then the costs of the project are estimated for both the ISFC Prototype and ISFC System and compared to the expected monetizable benefits.

A. Anticipated Impact of At-Scale Implementation

The anticipated impacts of the project as aligned with the Goal Areas from the original grant application are presented in **Table 10**. Benefits across all the impacts can be realized, however, not all benefits can be credibly quantified and included in the CBA detailed in this section. Impacts that are included in the CBA are appropriately identified. Benefits that may be realized but cannot be quantified due to unavailable data or lack of credible method to monetize are discussed as qualitative benefits later in this chapter. As the ISFC Prototype transitions into a full at-scale implementation, more data may become available to further refine the CBA with the goal areas, listed below, that are not quantifiable.

Table 10: Anticipated Impacts of ISFC System

Goal Areas	Anticipated Impact	Quantified in CBA
Congestion Reduction	The ISFC system will reduce congestion along the I-94/I-69 corridor, and especially at the POE plaza, by empowering carriers to plan more efficient trips. This includes travelling during off-peak hours and taking strategic breaks during periods of congestion.	Yes – Reduction in delay can be estimated and monetized.
Safety	By reducing queues at all border crossings, the risk of commercial vehicle rear-end crashes and conflicts with passenger vehicle traffic will both be greatly reduced. The ISFC System will also improve the reliability of traveler experience at the border by providing users with information related to their trip, mitigating the impacts of unexpected delays due to congestion and incidents.	The general value of safety as defined by the USDOT CBA guidelines was used in this analysis. Reliability benefits were considered through reduction in delay.
Increased Access	By improving reliability and reducing congestion along the I-94/I-69 corridor, road users will have improved access to jobs, education, and essential services, such as healthcare. Additionally, improved freight shipment efficiency has the potential to grow local industry, producing local jobs. Also, developing, implementing, and operating the ISFC System will provide valuable experience for the diverse stakeholder groups in working toward shared objectives.	No – not easily quantified.
Connecting Underserved Communities	The ISFC will support mitigation of GHG and pollutant emissions along the I-94/I-69 corridor, and especially at the POE plaza in an otherwise residential district of Port Huron. This area is considered disadvantaged and would benefit from reduced exposure to environmental and health risks. The project will improve the quality of life of the community by reducing idling vehicles and relieving traffic congestion. The proposed ISFC System also opens quick border crossings to smaller motor carriers and owners, thus improving economic mobility.	Yes – Reduction in emissions and delay can be estimated and monetized.

Goal Areas	Anticipated Impact	Quantified in CBA
Economic Competitiveness	The proposed ISFC System will provide stakeholders and border operators with the necessary tools to support border crossing operations and improve the flow of commercial goods across the border. Developing, implementing, and operating the ISFC System will also provide valuable experience for the diverse stakeholder groups in working toward shared objectives.	No – not easily quantified.
Transportation Reliability	The ISFC promotes reliability along the I-94/I-69 corridor, and at the POE plaza, by providing users with real-time and predictive data at and approaching the POE. This empowers users to plan more efficient trips and reduce overall congestion, further improving reliability.	Yes – Reduction in delay can be estimated and monetized.
Connected Transportation	The ISFC promotes connectivity among all road users by providing real-time and predictive traffic conditions. Users of the ISFC solution will be able to make more informed and efficient trip plans by leveraging the data provided by the solution.	No – not easily quantified.
Private Sector Partnerships	MDOT has worked with private shippers, carriers, and in the development of the ISFC. They were included to ensure that the ISFC's functionality meets the needs of private users, increasing adoption of the solution. These private stakeholders are the target users for this solution.	No – not easily quantified.
Energy Efficiency	Idling/in-queue trucks are a well-known source of GHG and pollutant emissions, and one of the major sources in the project area. The ISFC will support mitigation of emissions due to mitigation of delay.	Yes – Reduction in emissions can be estimated and monetized.
Resilience	The ISFC system promotes transportation resilience by providing a data exchange platform for border crossing stakeholders to share real-time data with one another to improve the operational efficiency of the trade corridor under various conditions, including during extreme weather conditions, which are becoming more frequent due to climate change. An example includes making it easier to divert truck-borne goods to the "best" crossing for shippers' needs based on real-time conditions during a snowstorm.	Yes – Reduction in delay can be estimated and monetized.
Emergency Response Improvements	The ISFC will alleviate freight congestion along the I-94/I-69 corridor, which can improve emergency response times. Faster responses from emergency vehicles have the potential to save lives.	Yes – Reduction in delay can be estimated and monetized.

B. ISFC Prototype and ISFC System Costs

The ISFC Prototype cost is **$1,806,218,** as approved in the Stage 1 SMART grant. There are no expectations to deviate from this cost. MDOT has made the decision to pursue cloud infrastructure rather than physical hardware to host the platform. This decision reflects the advantages of cloud-based solutions, including enhanced system flexibility as the platform can be scaled as needed to accommodate increasing demand. This also enables cost optimization by avoiding the limitations of fixed-capacity physical hardware, which can lead to underutilization. Cloud infrastructure also ensures resilience and adaptability against changes to technology, whereas physical hardware typically has a useful lifetime of 5-7 years before replacement is needed and requires dedicated data centers and IT personnel for maintenance. By leveraging cloud infrastructure, MDOT can significantly reduce O&M costs for the platform, benefiting from scalability and eliminating the need for physical hardware upkeep.

ISFC system, described in Part 2, is estimated to cost **$8,211,885** (excluding the Stage 1 prototype cost) over a three-year period. The cost breakdown is further detailed in the CBA. This cost includes development fees for the technology solution, licensing fees for supporting cloud infrastructure and software, as well as consulting fees for studying the feasibility for expansion to other POEs. Beyond the three-year initial period, ongoing licensing costs are estimated to be $261,000 per year, including costs required for database hosting and third-party licenses, such as APIs.

C. Cost-Benefit Analysis

MDOT has conducted a CBA to compare the deployment and operational costs of an at-scale implementation to the benefits and cost savings that the ISFC System would provide across a ten-year timeframe. The focus of the at-scale implementation CBA is for the deployment of the ISFC System for westbound freight and commercial vehicles traveling into the U.S. via the BWB. The expected service life of transportation software and technology is generally less than 20 years; as a conservative estimate, a shorter analysis period of ten years was chosen for this analysis. For this CBA, MDOT has followed the 2024 update of the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs methodology, published in December 2023. This methodology provides both consistency and credibility with established USDOT-approved monetization factors and is a useful technique to evaluate and compare various transportation investments against their contribution to the economic strength of the country. MDOT acknowledges that there may be potential limitations to the analysis when applying national-level data and parameters to unique local conditions; however, the USDOT factors have been adjusted for applications to nationwide project comparisons and is sufficient for national grant projects such as this one. Additional sources were used for parameters not covered by USDOT guidance, further described in the following sections.

i. Barriers to Implementation

Regulatory Environment – There are a few regulatory challenges. The ISFC System has the capacity to identify feasible alternate routes and, upon approval, exchange paperwork to a new crossing. This functionality can be advantageous in mitigating the impacts of extended delays caused by incidents. However, there may be concerns regarding the passage of goods paperwork and shipment information due to border security. This functionality would be subject to collaborative protocols and business rules established by CBP, as well as the willingness of CBP and brokers to accept documents through new channels.

Technology Maturity – The integration and procurement of a new technology can be challenging. By adopting a phased approach, the technology can be refined in controlled environments, allowing for early resolution of technical issues. Technology selection is not limited to a specific vendor or framework for all use cases. The ISFC System will use the most appropriate technology component for each use case. By aligning the well-used and understood technology choices with the data and workflows in the system the overall platform will be adaptable to new requirements and benefit from reduced development roadblocks.

Supporting Infrastructure – By conducting a comprehensive assessment of supporting infrastructure needs for the platform and by leveraging existing infrastructure where feasible, costs can be reduced, and implementation can be accelerated. Additional funding and partnerships with public and private stakeholders can provide the resources needed for infrastructure enhancements. Investment in staff training will ensure that the infrastructure is well-managed, while proactive risk management and monitoring allows for real-time adjustments.

Societal Readiness – Proactive engagement is necessary to communicate the benefits and achieve a high utility rate. The full benefit of the ISFC System will be evident with a large user base. Hesitancy from the public is alleviated by leveraging existing systems used by stakeholders and minimizing duplication efforts.

State-Level IT Compliance – The ISFC System will likely need to go through rigorous approval and certification procedures to adhere to Michigan's IT compliance and cybersecurity standards for systems that interact with state infrastructure. This may result in the need to extend the timeline and cost to meet these regulatory requirements. Early collaboration with state agencies to understand specific IT governance requirements and the execution of a compliance gap analysis will help to identify compliance challenges before they become roadblocks and create a smoother approval process for the ISFC System.

Interagency collaboration can be a challenge due to differing priorities and limited cross-agency expertise. This can be mitigated by ensuring continuous and clear engagement with the Department of Technology, Management and Budget (DTMB) and the solution team with well-defined roles and responsibilities and regular communication channels.

ii. Analysis Parameters

Four (4) economic indicators were used to assess the economic case for the benefits: Benefit-Cost Ratio (BCR), Net Present Value (NPV), Internal Rate of Return (IRR), and time to break even (years). BCR is the total benefits divided by the total incremental costs. The NPV shows the difference between the total benefits and incremental costs. The IRR provides the annual return that would make the NPV equal to zero. Based on the CBA, the following BCR, NPV, IRR, and time to break even values were calculated, shown in **Table 11**. The calculation of the BCR, NPV, and IRR are described in the following sections.

Table 11: Economic Indicators of the ISFC System Implementation (Ten-Year Timeframe)

Value	Pessimistic Scenario (5% Delay Reduction)	Base Scenario (7.5% Delay Reduction)	Optimistic Scenario (10% Delay Reduction)
BCR	1.27	1.90	2.54
NPV	$2,981,791	$9,982,225	$16,981,334
IRR	6%	18%	27%
Time to Break Even	7 to 8 years	5 to 6 years	4 to 5 years

It is important to note that the fundamental quantifiable impact that the ISFC System has on commercial vehicles is mitigating delay at the POE. This is because the purpose of the ISFC System is to maximize efficiency and improve reliability at border crossing by reducing queuing and congestion; as a result, all the functions of the platform (including optimal lane assignments, recommended departure times based on forecasted conditions, etc.) fundamentally only change what happens at the POE, rather than metrics that cannot be impacted by the ISFC System , such as vehicle-miles travelled. As a result, all the benefits that the ISFC System will provide are calculated based on the delay saved, in vehicle-hours, by the ISFC functions.

The primary monetized benefits for the ISFC at-scale implementation are categorized as:

1. **Delay savings** – The reduction in labor costs due to reducing time spent at the POE during the trip.
2. **Fuel consumption savings** – The reduction of fuel usage from reducing idling time at the POE.
3. **Idling emissions reduction** – The reduction of carbon dioxide, toxic gasses, and other emissions released during idling when waiting at the POE.
4. **Vehicle operating cost savings** – The reduction in indirect costs of vehicle ownership and maintenance, such as truck/trailer lease or purchase payments, depreciation, insurance, etc. from reducing overall vehicle operating time.
5. **External highway use cost savings** – The general safety, noise, and congestion savings resulting from reduced external highway use (i.e., reducing traffic, congestion, and noise on the road network). Please note that incident reductions were not included in this analysis but were considered as a qualitative benefit, rationale for this is outlined below (see incident reduction).

In addition, MDOT expects various other benefits, not quantified within the scope of this CBA, as a result of the at-scale ISFC System implementation, including the following:

- **Economic uplift** – The state will receive economic benefits of increased throughput of cross-border freight. A study between the U.S.-Mexico border shows that a 10-minute reduction in wait times could lead to an additional $26-million worth of cargo entering the United States monthly via commercial vehicles[1]. Improved throughput of cross-border freight will promote supply chain resilience, improve competitiveness, and ensure economic growth for both Canada and the United States. The proposed ISFC System will also open faster border crossing options to smaller carriers and owner/drivers, improving economic mobility. This benefit was left as a qualitative benefit as MDOT lacks information on the value of cargo and percentage of loaded freight vehicles on BWB.

- **Incident reduction** – It is anticipated that the border crossing will experience a reduction in vehicle incidents due to the reduction of queues, resulting in lower risk of commercial vehicle rear-end crashes and conflicts with passenger vehicles. In addition, the ISFC lane optimization function will also improve separation of traffic between commercial vehicles and passenger cars, further enhancing safety and reducing vehicular incidents. A review of the available incident data that is currently collected by MDOT was conducted. The review found that the level of detail provided from the incident data and incident clearance procedures was limited or non-representative (for example, lacking details on the severity and response time of the incidents logged), resulting in difficulty quantifying the benefits of incident reduction as a result of the ISFC System. Additionally, a reduction in incidents was difficult to establish as a result of the platform given that the primary objectives of the ISFC System are more focused on improving efficiency and mobility by building awareness of incidents to reduce their impact on the transportation network, rather than improvements in safety via incident reductions. Tangential safety benefits as a result of reducing congestion and delay were included in this analysis instead (see road safety savings above).
- **Travel time reliability** – ISFC System will enhance the reliability of the cross-border freight experience by providing more accurate information related to entry requirements, procedures, and wait times to drivers, mitigating the impacts of unexpected delays due to congestion and incidents. MDOT has no data regarding on-time performance of commercial vehicles, and from past discussions with carriers, expected arrival times input into their system can vary and are o0ften not representative of their actual travel times. As such, this benefit was left as a qualitative benefit.
- **Informed decision-making** – ISFC System provides greater visibility and understanding of travel conditions and unplanned demand to drivers, facilitating improved guidance when making decisions such as when to take breaks / stop at rest stops, where to wait, etc. ISFC System is expected to improve driver satisfaction and result in safer and more efficient freight trips across the border. This benefit is difficult to quantify due to the complexities of driver compliance and driver satisfaction metrics.
- **Scheduling optimization** – One of the identified functions of the ISFC System is to provide CBP and BWB toll booth supervisors with expected volume information so border operators can

1 Brugués Rodríguez et al., "The economic impact of a more efficient US-Mexico border," Atlantic Council, Washington, DC, United States, Tech. Report. Sep. 2022.

optimize scheduling of shift breaks to maximize staff available during high demand periods. In the long term, the business rules used for scheduling can be incorporated into the platform, helping to reduce overtime hours experienced by the agencies. This benefit is difficult to quantify due to lack of information on current agency scheduling practices and overtime hours and staffing statistics.

Although these benefits will be delivered as part of the ISFC at-scale implementation, they are difficult to numerically quantify and monetize. As such, the CBA conservatively focuses solely on benefits that are quantifiable via a measurable unit and cost value, whereas in reality, further benefits can be realized by the ISFC Platform due to the qualitative benefits described above along with eventual improvements in data quality and quantity at minimal cost over time, providing an even greater CBA than what is described below. The existing data and parameters used in the at-scale CBA come from a variety of sources, summarized below in **Table 12** with the assumptions used in the analysis:

Table 12: Existing Data and Assumptions

Data	Description	Source	Assumptions
Border wait times	Historical wait times for commercial vehicles in the general lane at BWB.	U.S. Customs and Border Protection[2], October 2023	Average weekday wait times were calculated based on Tuesday, Wednesday, and Thursday data. Average weekend wait times were calculated based on Saturday and Sunday data.
Vehicle volumes	Hourly and yearly vehicle volumes for westbound trucks at BWB.	MDOT Toll Plaza, 2023 (Hourly), 2019-2023 (Yearly)	Average weekday volumes were calculated based on Tuesday, Wednesday, and Thursday data. Average weekend volumes were calculated based on Saturday and Sunday data. Heavy vehicles were assumed to be any trucks with more than 2 axles.
Parameters	Parameters used to translate delay into costs (including costs of delay, fuel consumption, vehicle operating costs, etc.), and to discount dollar values.	The parameters used come from a variety of sources, including the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, U.S. Bureau of Labor Statistics, U.S. Environmental Protection Agency, Argonne National Laboratory, California Department of Transportation (Caltrans), and the U.S. Energy Information Administration (EIA).	To use these parameters, it was assumed that all commercial vehicles were diesel vehicles. Dollar values were adjusted for inflation to 2024.

2 Oct. 2023, "Historical wait times." U.S. Customs and Border Protection. [Online]. Available: https://bwt.cbp.gov/historical

iii. Individual Estimations and Monetization

Estimation and Monetization of Annual Delay

Using the data above, an annual baseline delay was calculated. Average weekday hourly westbound border wait times were multiplied by the average weekday hourly westbound vehicle volumes to get an hourly vehicle-hour of delay value. The vehicle-hour of delay values across the entire day were summed to obtain a daily vehicle-hour of delay estimate and then multiplied by the number of weekdays in a year (approximately 260) to obtain the annual weekday vehicle-hour of delay estimate. The same process was repeated for weekend data and summed with the weekday value to obtain the total annual delay experienced by westbound traffic at BWB.

To quantify the annual cost of delay, the total annual vehicle-hour of delay value was multiplied by a parameter that estimates the value of travel time savings of commercial vehicle drivers, taken from the USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs[3] and inflated to 2024-dollar values using the U.S. Bureau of Labor Statistics methodology[4]. **Table 13** summarizes the annual estimate of delay and monetized value of delay.

Table 13: Estimation of Annual Vehicle-Hours of Delay for Base Year

	Weekday	Weekend	Total
Annual Vehicle-Hours of Delay	354,000	41,000	395,000
Annual Cost of Delay	$13,254,000	$1,525,000	$14,779,000

Estimation and Monetization of Annual Fuel Consumption

Annual fuel consumption was calculated based on the delay time, assuming that commercial vehicles will consume excess fuel when idling during delays at the POE. Idling fuel use parameters (in gallons per hour) for heavy and light trucks were taken from the Argonne National Laboratory and the U.S. Department of Energy's Idling Reductions Savings Calculator,[5] and multiplied by the annual delay to obtain the annual fuel consumption due to idling. To quantify the cost of fuel, the amount of fuel consumption was multiplied by the average annual price of diesel for the Midwest region as defined by the EIA[6]. **Table 14** summarizes the annual estimate for fuel consumed during idling and associated cost, rounded to the nearest hundred.

3 Office of the Secretary, "Benefit-cost analysis guidance for discretionary grant programs," U.S. Department of Transportation, Washington, DC, United States, Dec. 2023.
4 Aug. 2024, "CPI inflation calculator,". U.S. Bureau of Labor Statistics. [Online]. Available: https://www.bls.gov/data/inflation_calculator.htm
5 "Idling reductions savings calculator," Argonne National Laboratory, Lemont, IL, United States, 2018.
6 2023, "Weekly retail gasoline and diesel prices," U.S. Energy Information Administration, Washington, DC, United States. [Online]. Available: https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r20_a.htm

Table 14: Estimation of Annual Fuel Consumption from Idling for Base Year

	Weekday	Weekend	Total
Annual Fuel Consumption (gallons) during Idling	407,000	47,000	454,000
Annual Cost of Fuel Consumed during Idling	$1,761,000	$203,000	$1,964,000

Estimation and Monetization of Annual Idling Emissions

Annual idling emissions were calculated based on the delay time, assuming the commercial vehicles will release emissions when idling during delays at the POE. Idling emission parameters (in grams per hour) were taken from U.S. Environmental Protection Agency guidance on idling vehicle emissions for heavy-duty trucks[7], separated by emission type, and multiplied by the annual vehicle-hours of delay to obtain the mass of each type of emission released by commercial vehicles when idling at the POE. The health and damage costs of these emissions were quantified by multiplying the mass of emissions released by the health and damage cost parameters, obtained from both USDOT[3] and Caltrans[8] guidance on the costs of transportation emissions. **Table 15** summarizes the annual estimated idling emissions released and the associated cost for the base year, rounded to the nearest hundred.

Table 15: Estimation of Annual Idling Emissions Released for Base Year

Emission		Weekday	Weekend	Total
VOC	Mass (g)	1,224,000	141,000	1,364,000
	Cost ($)	$3,000	$1,000	$3,000
CO	Mass (g)	9,073,000	1,044,000	10,116,000
	Cost ($)	$2,000	$1,000	$2,000
NOx	Mass (g)	11,851,000	1,364,000	13,214,000
	Cost ($)	$294,000	$34,000	$328,000
PM2.5	Mass (g)	390,000	45,000	435,000
	Cost ($)	$457,000	$53,000	$509,000
PM10	Mass (g)	424,000	49,000	473,000
	Cost ($)	$92,000	$11,000	$103,000
SOx	Mass (g)	14,000	2,000	15,000
	Cost ($)	$1,000	$1,000	$1,000
Total	Mass (g)	22,972,000	2,643,000	25,615,000
	Cost ($)	$846,000	$98,000	$943,000

7 "Idling vehicle emissions for passenger cars, light-duty trucks, and heavy-duty trucks," U.S. Environmental Protection Agency, Washington, DC, United States, Tech. Report. Oct. 2008.

8 "Cal-B/C parameter guide, version 8.1," California Department of Transportation, San Francisco, California, United States, Mar. 2022.

Estimation of Vehicle Operating Costs

USDOT benefit-cost analysis guidance[9] provides recommended cost parameters per mile travelled for vehicle operating costs of commercial vehicles, taking into consideration insurance, purchase payments, permits and licenses, etc. Because this platform impacts the delay at the POE, rather than the total vehicle-miles travelled by the vehicle, the parameter was translated from a per-mile value to a per-minutes of idling value using a study conducted by the University of Malaya that found the fuel consumed during 5 miles of driving to be equivalent to 10 minutes of idling[10]. The cost was then estimated by multiplying vehicle-hours of delay by the value per hour, as summarized in **Table 16**, rounded to the nearest hundred.

Table 16: Estimation of Annual Vehicle Operation Costs due to Delay for Base Year

	Weekday	Weekend	Total
Annual Vehicle Operating Costs due to Delay	$15,718,000	$1,808,000	$17,526,000

Estimation of External Highway Use Costs

Similar to vehicle operating costs, USDOT benefit-cost analysis guidance[9] provides recommended value of safety, noise, and congestion per vehicle mile travelled of commercial vehicles due to external highway use. The same parameter was used to translate the per-mile traveled value into per-minutes of idling value in order to calculate the external highway use costs of delay. **Table 17** summarizes the annual estimated external highway use costs for the base year, rounded to the nearest hundred.

Table 17: Estimation of Annual Highway Use Costs due to Delay for Base Year

	Weekday	Weekend	Total
Annual Highway Use Safety Costs due to Delay	$213,000	$25,000	$237,000
Annual Highway Use Congestion Costs due to Delay	$4,036,000	$465,000	$4,500,000
Annual Highway Use Noise Costs due to Delay	$531,000	$62,000	$593,000

iv. Overall Benefits

Forecasting and Monetizing Benefits of the ISFC At-Scale Implementation

To determine the impact of the ISFC System on each of the costs, a blanket delay reduction was applied to the existing baseline delay. The blanket delay reduction was determined based on a previous study conducted at the Peace Arch between Washington State and British Columbia, which quantified the

9 Office of the Secretary, "Benefit-cost analysis guidance for discretionary grant programs," U.S. Department of Transportation, Washington, DC, United States, Dec. 2023.
10 S.M. Ashrafur Rahman, H.H. Masjuki, M.A. Kalam, M.J. Abedin, A. Sanjid, H. Sajjad, "Impact of idling on fuel consumption and exhaust emissions and available idle-reduction technologies for diesel vehicles – a review"," Energy Conversion and Management, vol 74., pp 171-182, 2013.

impact of optimizing workforce schedule as a means of reducing delay without increasing labor costs or compromising security or customs screening[11]. The study found that by deriving a near-optimal workforce schedule based on arrival rates of vehicles and service rates of border booths, average delay of vehicles can be reduced by up to 18%. Based on this, MDOT has assumed a range of delay reductions resulting from the ISFC System benefits. Three scenarios were analyzed: optimistic (10%) pessimistic (5%), and base (7.5%) delay reductions were applied to the existing baseline delay to forecast the improvements made to the POE from the ISFC System. It must be noted that all three (3) scenarios are conservative, in comparison to the above-mentioned study findings. Monetization of the five (5) benefits were then recalculated based on the difference in delay to quantify the benefits of the ISFC System.

In addition to the delay reduction, MDOT has applied a discount factor to convert future year cost and benefits into present value cost and benefits. The discount factor was chosen to be 3.1% as per USDOT guidance[9]. It was also assumed that not all benefits can be realized by the ISFC System until year four (2028) of the project given that the platform is still under development and consulting services are still being provided in the first three (3) years. As a result, a "ramp-up" period for the benefits was also applied by providing only a fraction of the benefits in years 2025 to 2027.

A summary of the total discounted costs, benefits, the BCR, and the NPV of the ISFC at-scale implementation for the three (3) scenarios is shown below in **Table 18**, **Table 19**, and **Table 20**, rounded to the nearest hundred, and is also summarized in **Table 11** above.

Overall, the benefits of the ISFC at-scale implementation are expected to exceed the deployment and operational costs in all three (3) scenarios. It is important to note that the at-scale implementation scope is limited to only westbound traffic along the BWB crossing. If the scope were to be expanded to other POEs between Michigan and Ontario, such as the Sault Ste. Marie International Bridge and the Gordie Howe Bridge, and/or in the eastbound direction, the benefits would be magnified given that the costs of consulting and implementation are already covered when implementing the ISFC System at one POE. These benefits concur with SMART Program Priorities such as safety and reliability, equity and access, climate, and integration.

11 M. Yu, Y. Ding, R. Lindsey, C. Shi, "A data-driven approach to manpower planning at U.S.–Canada border crossings," Transportation Research Part A: Policy and Practice, vol 91., pp. 31-47, 2016.

Table 18: Monetized Economic Benefits of the ISFC At-Scale Implementation (Base Scenario, 7.5% Delay Reductions)

	Base Year										
Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Project Year	1	2	3	4	5	6	7	8	9	10	11
Discount Factor	1.00	0.97	0.94	0.91	0.89	0.86	0.83	0.81	0.78	0.76	0.74
Costs											
Costs	$1,806,218	$2,695,322	$3,595,665	$1,920,899	$261,000	$261,000	$261,000	$261,000	$261,000	$261,000	$261,000
TOTAL DISCOUNTED COSTS	**$11,034,182**										
Monetized Benefits ($)											
Delay Reduction (Veh-Hours)		30,000	30,251	30,503	30,758	31,015	31,274	31,535	31,798	32,064	32,332
Delay Savings ($)		$1,109,000	$1,133,000	$1,143,000	$1,152,000	$1,162,000	$1,171,000	$1,181,000	$1,191,000	$1,201,000	$1,211,000
Fuel Consumption Savings ($)		$148,000	$149,000	$150,000	$151,000	$153,000	$154,000	$155,000	$157,000	$158,000	$159,000
Idling Emissions Savings ($)		$71,000	$72,000	$72,000	$73,000	$74,000	$74,000	$75,000	$75,000	$76,000	$77,000
Vehicle Operating Cost Savings ($)		$1,315,000	$1,326,000	$1,337,000	$1,348,000	$1,359,000	$1,371,000	$1,382,000	$1,394,000	$1,405,000	$1,417,000
External Highway Use Savings ($)		$400,000	$403,000	$407,000	$410,000	$414,000	$417,000	$421,000	$424,000	$428,000	$431,000
Fraction of Benefit		-	0.33	0.66	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TOTAL BENEFITS		**$ -**	**$1,017,390**	**$2,051,940**	**$3,134,000**	**$3,162,000**	**$3,187,000**	**$3,214,000**	**$3,241,000**	**$3,268,000**	**$3,295,000**
TOTAL DISCOUNTED BENEFITS	**$21,016,408**										

Benefit-Cost Ratio (BCR)	**1.90**
Net Present Value (NPV)	**$9,982,225**
Internal Rate of Return (IRR)	**18%**
Time to Break Even	**5 to 6 years**

Table 19: Monetized Economic Benefits of the ISFC At-Scale Implementation (Optimistic Scenario, 10% Delay Reductions)

	Base Year										
Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Project Year	1	2	3	4	5	6	7	8	9	10	11
Discount Factor	1.00	0.97	0.94	0.91	0.89	0.86	0.83	0.81	0.78	0.76	0.74
Costs											
Costs	$1,806,218	$2,695,322	$3,595,665	$1,920,899	$261,000	$261,000	$261,000	$261,000	$261,000	$261,000	$261,000
TOTAL DISCOUNTED COSTS	**$11,034,182**										
Monetized Benefits ($)											
Delay Reduction (Veh-Hours)		40,000	40,334	40,671	41,010	41,353	41,698	42,047	42,398	42,752	43,109
Delay Savings ($)		$1,478,000	$1,511,000	$1,523,000	$1,536,000	$1,549,000	$1,562,000	$1,575,000	$1,588,000	$1,601,000	$1,614,000
Fuel Consumption Savings ($)		$197,000	$198,000	$200,000	$202,000	$203,000	$205,000	$207,000	$209,000	$210,000	$212,000
Idling Emissions Savings ($)		$95,000	$96,000	$96,000	$97,000	$98,000	$99,000	$100,000	$100,000	$101,000	$102,000
Vehicle Operating Cost Savings ($)		$1,753,000	$1,768,000	$1,782,000	$1,797,000	$1,812,000	$1,827,000	$1,843,000	$1,858,000	$1,874,000	$1,889,000
External Highway Use Savings ($)		$533,000	$538,000	$542,000	$547,000	$551,000	$556,000	$561,000	$565,000	$570,000	$575,000
Ramp-Up Factor		-	0.33	0.66	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TOTAL BENEFITS		**$ -**	**$1,356,630**	**$2,734,380**	**$4,179,000**	**$4,213,000**	**$4,249,000**	**$4,286,000**	**$4,320,000**	**$4,356,000**	**$4,392,000**
TOTAL DISCOUNTED BENEFITS	**$28,015,516**										

Benefit-Cost Ratio (BCR)	**2.54**
Net Present Value (NPV)	**$16,981,334**
Internal Rate of Return (IRR)	**27%**
Time to Break Even	**4 to 5 years**

Table 20: Monetized Economic Benefits of the ISFC At-Scale Implementation (Pessimistic Scenario, 5% Delay Reductions)

	Base Year										
Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Project Year	1	2	3	4	5	6	7	8	9	10	11
Discount Factor	1.00	0.97	0.94	0.91	0.89	0.86	0.83	0.81	0.78	0.76	0.74
Costs											
Costs	$1,806,218	$2,695,322	$3,595,665	$1,920,899	$261,000	$261,000	$261,000	$261,000	$261,000	$261,000	$261,000
TOTAL DISCOUNTED COSTS	**$11,034,182**										
Monetized Benefits ($)											
Delay Reduction (Veh-Hours)		20,000	20,167	20,335	20,505	20,676	20,849	21,023	21,199	21,376	21,554
Delay Savings ($)		$739,000	$756,000	$762,000	$768,000	$775,000	$781,000	$788,000	$794,000	$801,000	$807,000
Fuel Consumption Savings ($)		$99,000	$99,000	$100,000	$101,000	$102,000	$103,000	$104,000	$105,000	$105,000	$106,000
Idling Emissions Savings ($)		$48,000	$48,000	$48,000	$49,000	$49,000	$50,000	$50,000	$50,000	$51,000	$51,000
Vehicle Operating Cost Savings ($)		$877,000	$884,000	$891,000	$899,000	$906,000	$914,000	$922,000	$929,000	$937,000	$945,000
External Highway Use Savings ($)		$267,000	$269,000	$271,000	$274,000	$276,000	$278,000	$281,000	$283,000	$285,000	$288,000
Ramp-Up Factor		-	0.33	0.66	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TOTAL BENEFITS		**$ -**	**$678,480**	**$1,367,520**	**$2,091,000**	**$2,108,000**	**$2,126,000**	**$2,145,000**	**$2,161,000**	**$2,179,000**	**$2,197,000**
TOTAL DISCOUNTED BENEFITS	**$14,015,974**										

Benefit-Cost Ratio (BCR)	**1.27**
Net Present Value (NPV)	**$2,981,791**
Internal Rate of Return (IRR)	**6%**
Time to Break Even	**7 to 8 years**

D. Stage 1 Data Collection and Analysis

i. Data Available

While historical data can provide valuable insights and serve as a foundation for analysis, MDOT acknowledges that there are potential limitations to using historical data to predict real-world future outcomes, such as past trends and patterns not fully accounting for diverse circumstances, and shifts in social, economic, or environmental factors. The historical data described in this section was used as a starting point for predictions and analysis. Continuous evaluation and incorporation of real-time information will be conducted as more data becomes available.

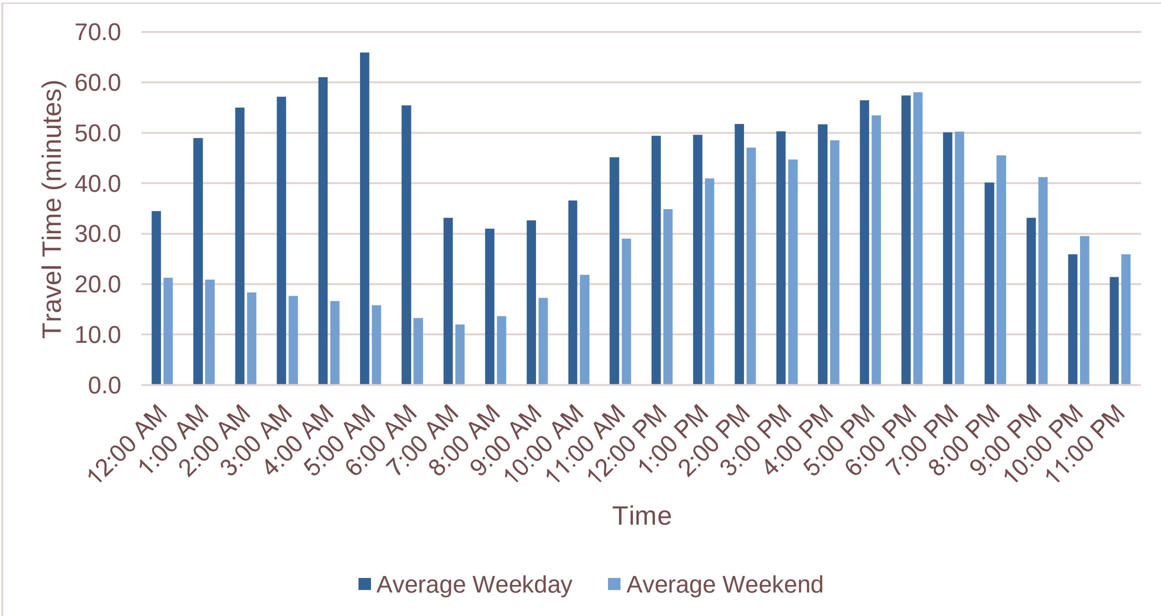
Historical data available for the ISFC Prototype consists of hourly and yearly volume data separated by passenger vehicles and commercial vehicles, provided by MDOT. Hourly travel time data, which includes time for tolling and border crossing, is available through a Bluetooth system installed and maintained at the border by Traffic and Parking Automation (TPA) North America Inc. TPA's Bluetooth data is used by MDOT and MTO. The hourly number of lanes available for passenger vehicles and commercial vehicles is provided by CBP via their public border wait time webpage. Historical weather data for Sarnia, ON is sourced from World Weather Online. The data used to develop the ISFC Prototype is summarized below in **Table 21**.

Table 21. ISFC System Data Type and Sources

Data	Unit	Source
Travel time through border	Minutes	TPA
Vehicle volumes	Number of vehicles	MDOT
Border Lane availability	Number of lanes open	US Customs and Border Protection
Weather data	Kelvin (temperature) Kilometers (visibility)	World Weather Online

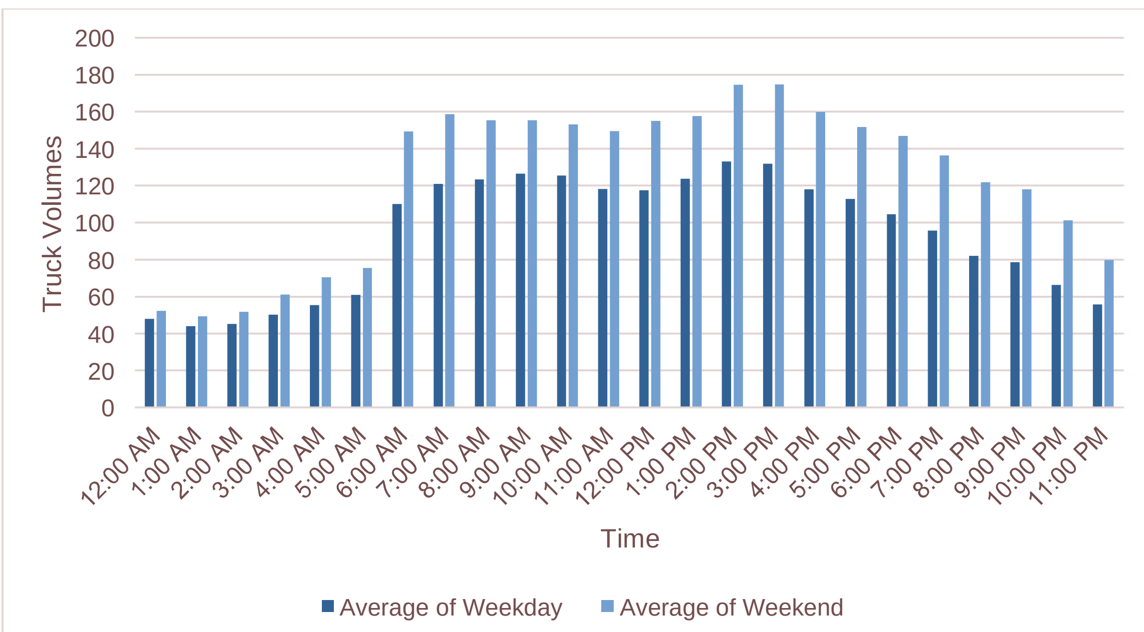
Historical data shows that the longest crossing times during weekday mornings, from 2 AM to 6 AM, and weekend afternoons, from 2PM to 7PM. as seen below in **Figure 12**. Crossing time is generally more spread out over the weekday hours in comparison to the weekend, which shows a sharp increase in time surrounding the peak hours.

Figure 12: Average Westbound Crossing Time (Nov 2024-March 2025)



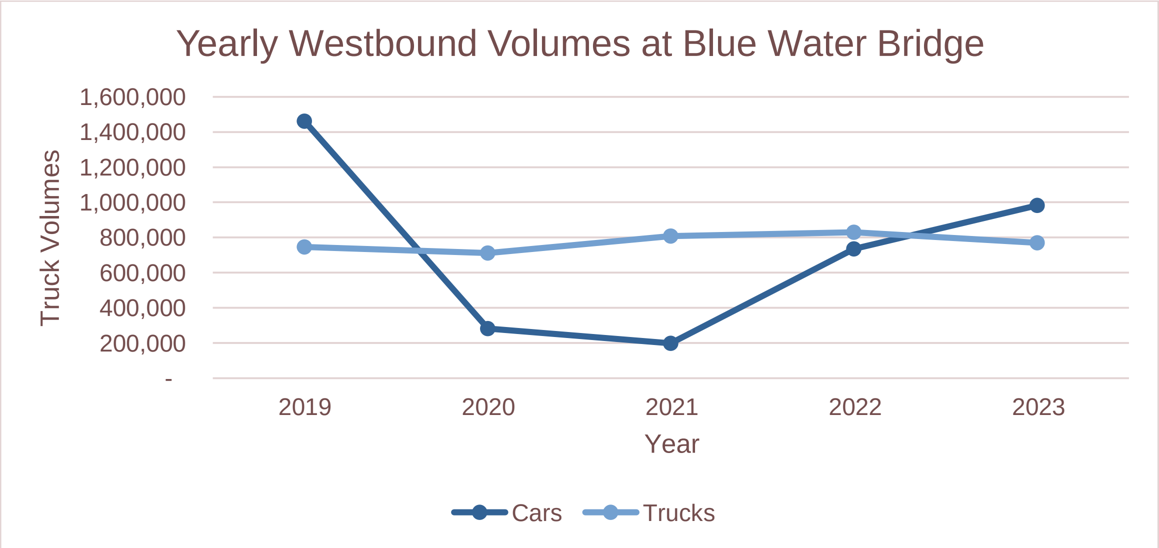
In comparison, weekday truck volumes are generally steady throughout the day, with the highest volumes being during the morning and the afternoon peak. The highest weekend volumes generally coincide with the hours of highest delay, notably in the afternoon, as shown in **Figure 13**.

Figure 13: Average Westbound Traffic Volumes at BWB (2024)



A comparison of yearly westbound truck volumes in **Figure 14** also shows a steady trend across the last five (5) years, even with the impacts of COVID-19 visible in 2020 and 2021.

Figure 14: Yearly Westbound Volumes at Blue Water Bridge



ii. Crossing Time Prediction Model Development

To support the ISFC Prototype feature of travel time prediction for truck trips, regression models were developed to predict crossing time at the border. Crossing time is defined as the time it takes for a vehicle to pass through the toll system and cross the border. This section outlines the procedure that was used to develop the border crossing time prediction models within the ISFC Prototype, along with limitations on the models and how these may impact predictions.

Two models were developed based on different use cases and user groups using multi-linear regression. The two models are as follows:

1. **General Time Model** – The general time model is used for trip planning features used by carrier and fleet managers in the ISFC Prototype. This model uses historical border crossing time to predict a crossing time for a generic hour.
2. **Time Series Model –** The time series model is used for real-time operational features used by drivers, border operators, and toll operators. Like the general time model, the time series model uses historical border crossing time to make predictions. The key difference between the two models is that the time series model uses real-time crossing times and volumes (from the hour leading up to the predicted hour) to predict a scenario-specific crossing time in the near future.

A comparison of the two prediction models is outlined in **Table 22**.

Table 22. ISFC System Prediction Models

Description	General Time Model	Time Series Model
Use Cases	Predicting border crossing time for future trip planning.	Predicting border crossing time for real-time operations.
User Groups	• Carrier partners	• Drivers

Description	General Time Model	Time Series Model
	• Fleet managers	• Border operators • Toll operators
Data Used	• Time of day • Day of week • Lane availability • Temperature	• Time of day • Day of week • Wait time of previous hours • Volume of previous hours • Visibility
Output	Provides a crossing time prediction for any generic input hour regardless of existing conditions.	Provides a crossing time prediction for the next hour using the existing conditions at the border.
Example	It is currently Monday, November 18, 2024. The user is planning a trip and would like to know what the border crossing time will be on Wednesday, November 20, 2024 at 2pm. This model will provide a predicted crossing time for 2pm on a Wednesday.	It is currently Monday, November 18, 2024, at 11AM. The user is currently driving towards the border and would like to know what the border crossing time is at 2PM, which is three hours from now. This model will provide a predicted crossing time for 2PM on November 18, 2024, based on the crossing time conditions at 1PM on November 18, 2024, when the data is captured.

Model Development

Response-predictor type models were developed, where the response variable is crossing time, and the predictor variables are described in **Table 22**. The generalized form of a response-predictor model is shown in Equation 1 below:

$$Response = \alpha + \beta_1 Predictor_1 + \beta_2 Predictor_2 + \beta_3 Predictor_3 + \cdots \qquad \text{Eq (1)}$$

In Equation 1, α represents the intercept, and β_n are the coefficients of the predictor variables. A power transformation was applied to some predictors to ensure a normal distribution and avoid violating underlying assumptions of linear regression. In addition, exponential adjustments were made to improve the model's fit, informed by ordinary least squares regression.

The models were developed in two-part iterations. Predictors were chosen and removed based on their significance and ability to explain variance in the data. The final model chosen was the one with the highest R^2 value (representing data explainability), and lowest multicollinearity and overfitting risk. **Table 23** below outlines the predictor variables that were used in both the final general time and final time series models.

Table 23. Predictor Variable Descriptions

Predictor Variable	Description
DOW	A categorical variable representing the day of the week, ranging from Monday to Sunday.
$PeakHours$	A categorical variable representing whether an hour falls within the peak period (7AM to 9PM) or non-peak period (9PM to 7AM).
$LanesT$	A numeric variable that represents the number of lanes open, which has been power transformed to ensure a normal distribution.
$HourGroups$	A categorical variable that splits the 24 hours of a day into contiguous groups of 3,4 or 5 hours based on similarity in historical volume per lane and crossing time statistics.
$Delay_{Lag1TE}$	A variable denoting the observed crossing time in the previous hour that has been power transformed to ensure a normal distribution, with exponential adjustments for an improved fit.
VL_{Lag1TE}	A variable denoting the observed volume per lane in the previous hour that has been power transformed to ensure a normal distribution, with exponential adjustments for an improved fit.
$TempKT$	A numeric variable that reports the monthly average temperature based on the last three years (in Kelvin), which has been power transformed to ensure a normal distribution.
$VisibilityFlag$	A categorical variable that represents whether conditions are ideal. The variable evaluates to 1 if visibility is under 10 miles and 0 otherwise (clear conditions).

General Time Model

The general time model was built using multi-linear regression and is seen in Equation 2. The benefits and drawbacks of the general time model are outlined in **Table 24**.

$$Delay = \alpha + \beta_1 DOW + \beta_2 HourGroups + \beta_3 LanesT^{0.8} + \beta_4 TempKT^{-3.27} \quad \text{Eq (2)}$$

Table 24. Benefits and Drawbacks of the General Time Model

Benefits	Drawbacks
• Generalized to fit an average scenario across all observations historically, making it ideal for planning into the future. • Provides updated predictions every hour within peak and non-peak periods.	• Fails to consider existing conditions for predictions in near future • May under/over predict because of generalization.

Time Series Model

The time series model was built using ordinary least squares-enhanced multi-linear regression and is seen in Equation 3. The benefits and drawbacks of the time series model are outlined in **Table 25**.

$$Delay = \alpha + \beta_1 DOW + \beta_2 PeakHours + \beta_3 HourGroups + \beta_4 {Delay_{Lag1TE}}^{-0.17} + \beta_5 {VL_{Lag1TE}}^{0.5} + \beta_6 VisibilityFlag \qquad \text{Eq (3)}$$

Table 25. Benefits and Drawbacks of the Time Series Model

Benefits	Drawbacks
• Designed to fit to current conditions across all scenarios without losing track of historical states, making it ideal for analyzing operational state. • Makes predictions based on the previous hour's crossing time and volume per lane, adjusted using exponents determined through ordinary least squares regression.	• At the limit of regression-based model development, can only be improved with machine-learning based implementation, which requires significantly more data that is not currently available.

Predictions and Explainability of Variance

Iterative model improvement techniques were continually tested until the improvements to the model plateaued and the limit of prediction accuracy using regression-based prediction models was reached, leading to the final two models described above. **Table 26** below presents the predictor coefficients, and R^2 (goodness of fit) values for the two models. The general time and exponential time series models have a R^2 of 25% and 61% respectively, meaning they explained the variance in the data relatively consistently.

Table 26. Model Coefficients and Goodness Measures

Model / Predictor Coefficient	General Time Model	Time Series Model
$Intercept$	43.19	167.92
DOW	19.42	7.67
$LanesT$	3.46	-
$HourGroups$	-2.07	4.61
$PeakHours$	-	-6.17
$Delay_{Lag1TE}$	-	-277.03
VL_{Lag1TE}	-	8.44
$TempKT$	-2.90e+09	-
$VisibilityFlag$	-	5.34
Goodness Measure	**General Time Model**	**Time Series Model**
R^2	0.25	0.61

Model Limitations

Limitations of the models developed in this project are related to data availability, data validity, subtle model violations, or problematic observations. While these did not significantly affect the predictions the models made, they are important to note when understanding the context in which the models were built.

- **Data Availability –** the dataset used to estimate the model only includes data between November 2024 and April 2025, suggesting that any predictions are only highly representative for those months.
- **Data Validity –** the crossing time is determined using a Bluetooth sensor to capture both the wait time at the toll booth and delays during crossing. However, there are limitations given that crossing times are averaged over an hour and thus the duration of individual trips across the border is not necessarily captured. In addition, this data collection method relies on a Bluetooth connection which means not all vehicles are represented.
- **Model Assumptions –** the volume per lane predictor uses volumes from the toll system data and number of lanes open at the border crossing. While the vehicles using both systems are the same, given that the data is collected from different sources, it might not be completely reasonable to combine them mathematically to create a predictor.
- **Problematic Observations** – the dataset contains certain observations that were found to be outliers, and these affected the model fit. However, due to a lack of real-life context, these observations were not removed as suggested when looking at them purely statistically.

Acknowledging the existing model limitations, these models effectively demonstrate predictive capabilities at the proof-of-concept stage that can be leveraged by a larger scale ISFC System. In the future at-scale implementation stage, incorporating higher-quality and more extensive data sets can enhance the models' predictive performance and yield more representative outputs.

iii. At-Scale Evaluation

For the at-scale evaluation of the system, MDOT will track the same metrics of system performance based on the available data, including hourly delay and vehicle volumes. Additional metrics related to the actual use of the ISFC System will also be recorded, including user engagement with the platform, measured by the number of companies or partners actively participating in the solution, number of trips made, number of devices the application is downloaded on, etc. This data will help inform the effectiveness of the ISFC through the comparison of the usage data with the historical data to understand to actual scale of the benefits in comparison to its uptake.

Part 5: Challenges and Lessons Learned

Part 5 of this document examines the evolution of the ISFC System, identifying several key challenges and valuable lessons. These insights are important to refining the platform and ensuring its successful implementation at-scale. This section highlights the primary challenges encountered during the project's initial phase, including limited feedback from key stakeholders like CBP, carrier use and acceptance concerns, and the complexities associated with system integration.

A. Coordination with CBP

Engagement and feedback from CBP are essential, as they will be one of the key users and enablers of the ISFC System. In this first stage of the project, coordination with CBP has taken place mainly through one-on-one meetings, as the relevant feedback during stakeholder workshops was limited. As the project progresses, increased CBP involvement is crucial to ensure that the system's detailed design aligns with CBP's specific requirements. Specific types of feedback required include identifying critical information and preferred presentation format, business rules associated with allowing feedback, lane assignment and streaming operations.

For the next phase of the project, CBP-specific stakeholder meetings will be conducted to gather feedback on the ISFC System. These meetings will demonstrate the platform, its benefits and usability, and how the solution can be used as a platform to gain buy-in, address any stakeholder concerns, and make the process more efficient for CBP and commercial carriers. The team will continue to engage in sustained communication and collaboration to align expectations and foster a sense of ownership among participants, with the ultimate goal of providing a design that is best aligned to the needs of the stakeholders and CBP.

During the at-scale implementation it will be important for the team to address any potential cyber security concerns for CBP and other federal agencies handling highly sensitive data. It is recommended that there is close coordination with DTMB and the relevant agencies to fully understand the security requirements.

Furthermore, in the future phase of the ISFC System, it will be important to discuss, explore, and confirm with CBP the process for verifying documents in order to enable rerouting for commercial carriers. The current ISFC Prototype includes the functionality for rerouting by which fleet managers can reroute their drivers in the event of incidents causing significant congestion, however, the final step to make the functionality complete would be to receive confirmation from CBP of re-verified documents that allows a carrier to go to another crossing for processing. Confirming this process would make the ISFC Solution practical for commercial carriers by fully enabling rerouting.

B. Carrier Use and Acceptance

The primary users of the envisioned ISFC System are the commercial carriers. The ISFC System processes trip data from carriers to generate accurate long-range and real-time traffic forecasts, with the prediction accuracy improving as more data is available to the system. Additionally, the ISFC System disseminates critical information from border operators and agencies, enabling carriers to make more informed decisions at various stages of the trip. These decisions span from the planning phase where carriers may optimize time spent driving during off-peak periods, to the in-transit phase where carriers may optimize break timings or detour routings in response to incident notification, and at the plaza, where the carrier receives lane assignment instructions. The positive impacts of these decisions (reducing delay, minimizing incidents) are amplified as user adoption increases. Therefore, broader adoption of the ISFC System within the carrier industry is essential for maximizing its effectiveness. Highlighting the benefits will help improve adoption of the ISFC System.

Feedback received during the initial stage's stakeholder workshops indicates that carriers are concerned about incorporating another system and adding processes into their existing workflows; they hope to minimize additional administrative tasks and avoiding duplication of efforts. The carriers noted they already input trip information into systems that interface with CBP systems. In response to this feedback, the proposed ISFC System is designed to gather as much information as possible passively through interfaces, reducing the need for active input from carriers. It is essential to thoroughly understand and design these interfaces to achieve the goal of minimizing duplicated efforts. Carriers and CBP also shared that brokers were a key user. For that reason, they were identified as a distinct user of the platform but challenges with their engagement meant that platform features could not be further developed to their specific needs.

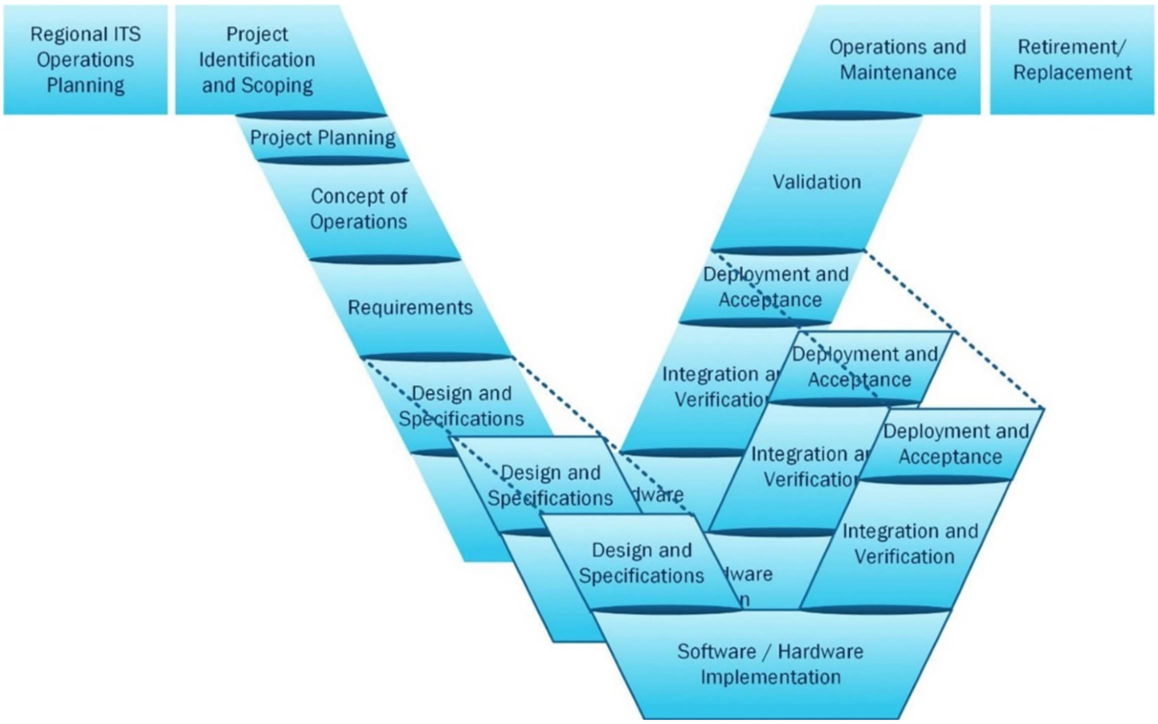
Lastly, it should be noted that the carriers are particularly interested in the solutions capability to reroute carrier trips based on traffic and incidents. Furthermore, it was explained by the carriers that it is a hassle to switch between POEs mid trip. For instance, there are challenges with sending processed broker paperwork between POEs and the time it takes to process that paperwork. By the time it is corrected and filed, it may be too late. The carriers would like to see broker paperwork moved automatically between POEs when there are carrier reroutes.

C. System Integration Complexity

The ISFC System relies on integrating multiple data sources to collect both historical and real-time information from a variety of systems. There are two dimensions which increase the number of systems to be integrated. First, there are many types of systems that need to be integrated as they provide different data sets and functionalities. Second, for each type of system, there may be different systems ranging from carrier to carrier and from port to port. This introduces significant complexity in ensuring seamless communication between these systems and the ISFC System. Variability in data formats and constraints posed by legacy systems demand additional efforts to standardize and streamline data flows. Additionally, ensuring secure data management will be a priority. This will be managed through the data management plan.

Systems Engineering is an interdisciplinary process focused on clearly defining customer needs, identifying required functionalities, documenting requirements, proceeding with design synthesis, and then providing system testing, requirements verification, and system validation while considering the complete problem. For ITS projects, the Systems Engineering process typically follows the “Vee” model. This project uses the Incremental Method of Systems Engineering Life Cycle Models described by FHWA, shown in **Figure 15**. This method combines the traditional waterfall method (“Vee” model) with the iterative approach of agile software development and is referred to as a **hybrid development approach**. This method is traditionally used when the project is implemented through multiple incremental projects.

Figure 15: Systems Engineering Vee with Multiple Incremental Projects (Source: FHWA)



Part 6: Deployment Readiness

Part 6 of this document describes the requirements that need to be addressed for the solution to be successful. This includes requirements for success during both the implementation and operations and maintenance phases. Part 6 also includes the risks identified in implementing the solution, and how MDOT has worked to mitigate them.

A. Requirements for Successful Implementation

Deploying the ISFC at-scale implementation requires meticulous planning to ensure successful implementation across multiple border crossings. The readiness for deployment involves meeting various key requirements outlined in the project details. Firstly, stakeholder involvement is pivotal, especially when scaling from initial implementation at the BWB to other crossings like the Sault Ste. Marie International Bridge and the Gordie Howe International Bridge. It’s important to involve stakeholders to capture their needs and how to address their needs in the solution. For the ISFC System, it is highly advisable to perform a demo with the stakeholder groups to capture their comments since they will be using the system. Each scaling step amplifies the number of stakeholders, each with unique business rules and levels of engagement. Effective stakeholder management and a flexible system approach are essential to securing buy-in across multiple ports.

Moreover, the ISFC System's technological suitability and flexibility is crucial for seamless interoperability among diverse systems, including carrier systems, vehicle technologies, and border agency systems. Leveraging standardized protocols, APIs, and cloud-based solutions is necessary to support efficient data exchange and scalability. Robust hardware infrastructure and user-friendly software platforms are vital for effective data collection, real-time updates, and advanced analytics implementation. Data governance plays a critical role in ensuring data integrity, consistency, and security in forecasting and decision-making processes. All of these pieces of the solution will be regulation compliant.

In terms of a detailed workplan for the full deployment of the ISFC System at the Blue Water Bridge, the project can be broken down into the following key tasks:

Task 1: Evaluation Assessment - The team will assess the ISFC Prototype, integrate POC lessons, and collaborate with Canadian agencies to refine outbound Port Huron processes and explore Stage 2 support. Emerging highway-freight technologies, including new apps and onboard advancements, will be evaluated. Coordination with Michigan bridge crossing experts will help assess ISFC scalability for bridges like Sault Ste. Marie and Gordie Howe, requiring tailored Needs Assessments. These assessments will address site-specific data, physical differences, and unique carrier, shipper, and ownership requirements.

Task 2: Develop Data Security Plan – MDOT along with their ISFC System provider will collaborate with Michigan DTMB to perform a security threat and risk assessment of the ISFC System, focusing on safeguarding data critical to the safety of infrastructure, staff, and commercial vehicle operations to mitigate potential cybersecurity and privacy risks. A standards-compliant security plan will be created to address identified risks. This plan will be prepared for implementation during Task 4.

Task 3: Conduct Technical Implementation - The team will update ISFC System data and process models, performing development, integration, and thorough testing, including unit, integration, and pre-go-live tests, based on insights from Tasks 1, 2 and 3.

Task 4: Stakeholder Engagement and Agency and Industry Coordination - The team will expand industry outreach from Stage 1, strengthening relationships with shippers, carriers, brokers, and operators while promoting ISFC System's benefits to boost adoption. Regular technical stakeholder meetings and user engagement activities will ensure ongoing coordination. Additionally, the team will prioritize early engagement with CBP and brokers to ensure their input informs system development and security planning. The team will collaborate with MDOT POE representatives and Canadian partners to address crossing needs and explore scalability. MDOT will also engage up to five other state agencies managing US-Canada POEs, such as Minnesota, New York, Montana, Vermont, and Michigan. A detailed community participation plan will be drawn up as part of this task to organize stakeholder efforts and ensure their feedback is accounted for in the project.

Task 5: ISFC Stage 2 Implementation - Combining the output of Tasks 2 through 4, the team will stage a roll-out of Stage 2 including full deployment of the improved functionality at Blue Water Bridge.

Task 6: Monitoring and Evaluation - After the initial implementation, the project team will oversee the ISFC System and refine it to enhance cost-effectiveness and operational efficiency. During this phase, a structured transition and operational handoff will be conducted to ensure the seamless transfer of the ISFC system to MDOT. This process will include thorough training for operational staff, the handoff of detailed system documentation, and dedicated knowledge transfer sessions.

Task 7: Project Management - This encompasses all project management/administration activities, including oversight of turnover activities, verifying all necessary training, documentation, and operational support are delivered before final handoff.

Table 27: Project Tasks with Schedule

Task	Quarters											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1: Evaluation Assessment	■	■					■	■	■	■		
Task 2: Develop Data Security Plan		■	■	■	■							
Task 3: Conduct Technical Implementation			■	■	■	■						
Task 4: Stakeholder Engagement and Agency and Industry Coordination		■	■	■	■	■	■	■	■	■	■	■
Task 5: ISFC Stage 2 Implementation						■	■	■				
Task 6: Monitoring and Evaluation							■	■	■	■	■	■
Task 7: Project Management	■	■	■	■	■	■	■	■	■	■	■	■

The meticulous deployment readiness and detailed workplan emphasize the importance of stakeholder management, technological adaptability, data governance, and continuous monitoring to ensure the successful and efficient implementation of the ISFC System to other border crossings.

Key Requirements and Obstacles for Scaling Project Implementation

Successful scaling of the project requires meeting various key requirements and overcoming obstacles for scaling the project. This includes:

- Establishing a structured early planning framework is critical for successful project scaling. This includes comprehensive scope and contract development, requirements definition, and risk management planning. Insights gained from Stage 1 to be utilized to align key stakeholders, set realistic expectations, and mitigate potential scope and schedule risks. A well-defined early planning process ensures that all parties have a shared understanding of project objectives, reducing the likelihood of delays and cost overruns.

- Ensuring regulatory compliance with all relevant laws and regulations is crucial for at-scale implementation. This includes addressing any legal implications related to data security and cross-border operations.
- Adequate funding and efficient procurement processes are essential for scaling the project. Budget constraints and procurement challenges may hinder the project's scalability if not managed effectively.
- Building strong partnerships with stakeholders such as CBP, freight carriers, brokers, and local agencies is vital. MDOT already has existing relationships with these stakeholders and continuing

to maintain collaborative relationships and ensuring stakeholder buy-in will enhance the project's readiness for expansion.

- Assessing the suitability of technology for scaling the project is critical. Regular updates and improvements to technology infrastructure may be necessary to prevent technical debt and ensure long-term sustainability.
- Implementing robust data governance practices is key to managing data effectively and securely. Developing data security plans and protocols is essential to mitigate cybersecurity and privacy risks related to data misuse or breaches.
- Assessing the impact on jobs and workforce capacity is important for successful implementation. Providing necessary training and support for staff, including freight partners and border agencies, is crucial for smooth operations and workforce development.
- Efficient coordination within the project team and among different agencies is essential for seamless implementation. Effective project management and coordination will help address challenges and ensure project milestones are met.
- Engaging with communities and ensuring public acceptance is crucial for the project's success. Addressing community concerns, promoting transparency, and fostering positive relationships contributes to the project's sustainability.

This project is part of MDOT's broader initiative to support border operations and enhance job quality, thereby improving the transportation network's efficiency. While the software solution may not directly create jobs, it will have a positive impact on other project workstreams, including large developments. MDOT will leverage its inclusive hiring practices and mentoring programs to develop a skilled workforce capable of meeting the needs of a modern transportation system while supporting workforce development, including supporting contracting and hiring of local and underrepresented communities.

B. At-Scale Maintenance and Operations Requirements

To better understand the maintenance and operating requirements post at-scale implementation, there's a need to focus on ongoing system updates, user support, and continuous monitoring for operational efficiency. Capacity to make future technological improvements and prevent technical debt requires a dedicated team with expertise in software development and system maintenance.

The at-scale implementation of the ISFC System will encompass full-scale software development, hosting, configuration, integration, and testing. Additionally, it will include system upgrades and evolution throughout the project's lifecycle. For the at-scale implementation, it is recommended that the same AWS cloud infrastructure will continue to be used. Cloud-based infrastructure advantages include enhanced infrastructure scalability as system resources can be adjusted to accommodate demand, something not possible with typical on-premises hardware. Cloud infrastructure also ensures best-in-class security and resilience features. Furthermore, it guarantees keeping the platform up to date with the latest technologies. Physical hardware requires dedicated data centers and IT personnel for maintenance and typically has a useful lifetime of 5-7 years before replacement is needed.

The ISFC Prototype and System will be owned by MDOT. To support long-term operations of the software platform, post-implementation of the ISFC Prototype, a Service Level Agreement (SLA) will be considered to define the maintenance and support framework, covering basic services, problem resolution, software patches and upgrades, monthly reporting, and emergency support. As part of Stage 1, MDOT will review the operations of the ISFC Prototype after the completion of Stage 1, and the roles and responsibilities of MDOT and Arcadis within this period.

While operations and maintenance may not be covered as part of Stage 2 grant funding, the following considerations should be noted for an operations and maintenance phase as part of a complete evaluation: enhancements in operations, stakeholders, interfaced systems, and emerging technologies are expected. The ISFC System's flexible architecture allows it to adapt to these evolving demands. Core software modules are deployed using a service-oriented architecture, enabling isolated updates or modifications, such as enhancements to supported services or integration of new data sources, without affecting other system components. The core software integrates with external services through APIs, which are managed and configured within the ISFC System, allowing seamless modifications without disrupting system operations. These principles ensure system resilience and adaptability throughout the O&M period.

C. Uncertainties and Risk Mitigation

To ensure a successful at-scale deployment of the ISFC System, potential risks need to be identified and mitigated. **Table 28** below describes the possible risks that may be experienced while deploying the ISFC solution, and how to mitigate them.

Table 28: Risk Assessment and Mitigation Strategies

Possible Risk	Risk Mitigation	Likelihood	Impact
Limited stakeholders buy-in	Comprehensive stakeholder engagement plan. Stakeholders were engaged throughout Stage 1, mainly through interactive workshops and the same approach will be followed during Stage 2	Low	Moderate
Existing dependence on disparate systems and not being able to integrate them	Follow the Hybrid Development Approach outlined in Part 5 for Systems Integration	Medium	High
Interoperability between diverse systems	Standardized protocols and APIs for data exchange and conduct thorough integration testing. Integration at headend system levels rather than at lower levels	Moderate	High
Cybersecurity risks, including unauthorized access and data breaches	Implement advanced cybersecurity measures, such as encryption, multi-factor authentication, and security audits	Moderate	High

Possible Risk	Risk Mitigation	Likelihood	Impact
Inconsistent data quality and integration issues	Continuously refine data governance strategies	Moderate	Moderate
Difficulty in adapting the system to diverse workflows, technologies, and stakeholders at new border crossings	Design system with inherent flexibility, employing service-oriented architecture to enable modular updates	Low	High
System disruptions or downtime during updates or integration of new technologies	Utilize secure APIs and isolate software components to allow updates and modifications	Low	Moderate
System adoption and staff retention across freight partners, border agencies, and MDOT	Implement comprehensive training programs, user support, and resources during the 3-year deployment plan to optimize adoption	Moderate	High

Part 7: Wrap Up

Part 7 of this document outlines the successes of the project throughout Stage 1 and looks forward to at-scale implementation during Stage 2. It identifies the expected challenges in rolling out the solution at scale, and how MDOT will address those challenges. Part 7 also provides advice for other groups who may roll out similar solutions in their communities.

A. Stage 1 Retrospective

Reflecting on the course of the ISFC project so far, the proposed ISFC System for BWB is on a path to meet expectations. While the complete solution will be implemented at-scale under Stage 2, the initial forecasts and early-stage evaluations of the ISFC Prototype as part of Stage 1 indicate that the ISFC System is well positioned to achieve its objectives.

The interconnected challenges experienced by different stakeholders at the BWB necessitate a comprehensive, multifaceted solution; in this case, an ISFC. The system's capability to provide both real-time and predictive information, enable efficient dissemination of information and enhance decision-making across the corridor, tailor UI to individual user needs, and handle complex workflows that today need access to several disparate systems, has shown significant potential to address the complex challenges faced by border operations and freight movement carriers.

Before implementation of the ISFC System, users faced many issues sending freight shipments across the BWB. Shippers contended with unpredictable delivery times, which impeded their ability to meet strict delivery windows. Carriers lacked accurate information on expected wait times at the BWB border crossing, resulting in longer delivery times, and suboptimal departure and break times. Border crossing agencies face variable demand at the BWB crossing, causing unnecessary staffing complexities and backups at the POE.

The ISFC System is designed to address these challenges by processing trip data from carriers, generating accurate long-range and real-time traffic forecasts that will become increasingly accurate as more data is integrated. Due to the exchange of data between infrastructure operators, border agencies, and carrier companies, the solution empowers carriers to make informed decisions throughout their trips. This includes optimizing driving schedules during off-peak periods, adjusting break timings and proposing detour routes in response to incidents, and receiving precise lane assignment instructions at the border plaza. These capabilities are expected to work together to reduce carrier delays and minimize incidents. The main features of the solution have been tailored to users' needs through demos and workshops that took place throughout the course of the project.

The at-scale implementation of the ISFC System presents substantial anticipated benefits across multiple goal areas, as highlighted in the CBA. Although certain qualitative benefits remain difficult to quantify, such as economic uplift and incident reduction, the quantifiable metrics present a strong economic case. The reduction in delays, fuel consumption, emissions, and vehicle operating costs underscore the solution's efficiency and its positive impact on cross-border operations. With a BCR of up to 2.53 and an IRR of up to 27%, the ISFC System not only addresses the immediate challenges at the BWB crossing but is also scalable across additional POEs, showing its value as a strategic investment in enhancing border efficiency, safety, and environmental sustainability.

Beyond the monetizable benefits found in the CBA, the ISFC System brings many improvements to users at the BWB. This solution enhances economic mobility through reduced delays, improves safety by minimizing traffic conflicts, and boosts environmental outcomes by lowering emissions and improving air quality. Economically, the reduction in travel times boosts local and regional economic activity, while cost savings are achieved through decreased vehicle-hours of delay and fuel consumption. Societally, the project improves mobility, reliability, and safety, enhancing the quality of life for users by reducing incidents and wait times. All of these benefits meet SMART grant program priorities. The ISFC System also fosters collaboration among stakeholders, streamlining communication and coordination to optimize border crossing operations.

In summary, the ISFC System***:***

- Stimulates economic growth by reducing travel delays, increasing delivery efficiency and opening up quicker border crossings to smaller carriers;
- Cuts carrier costs through delay savings, fuel consumption savings, and idling emission savings;
- Improves ease of use for fleet drivers and shippers by providing real-time relevant data;
- Increases reliability by improving border operation efficiency and reducing delays;
- Expands opportunities and promote local development for community members by promoting economic growth and increasing border-crossing efficiency;
- Improves safety by reducing queues at border crossings, reducing risk of collisions, especially between trucks and small-vehicle traffic;
- Improves quality-of-life for users by giving them access to more accurate and up-to-date trip information; and
- Cuts emissions and improves air quality by reducing idle time.

B. Potential Changes for At-Scale Implementation

The at-scale deployment of the ISFC solution represents a significant expansion from the initial prototype to a fully integrated system. This phase will involve the full configuration, deployment, and integration of the ISFC at the BWB, allowing MDOT operations staff to analyze all inbound traffic, including eastbound and westbound traffic. The solution's deployment at-scale also includes evaluating its replicability at other similar border crossings, such as the Sault Ste. Marie International Bridge and the Gordie Howe International Bridge. As the project progresses toward at-scale implementation, there are several areas where adjustments could further enhance the solution:

- **Optimized Data Integration**: Feedback from carriers raised concerns about integrating new systems into their existing workflows, emphasizing the need to minimize additional administrative tasks and avoid duplication. To address these concerns, the ISFC System is designed to gather information passively through interfaces, reducing the need for active input from carriers. As the implementation scales, it will be important to further standardize data formats and integration protocols. This standardization helps manage the increased variety of systems and data sources associated with a larger-scale deployment. Refining these interfaces will be essential to minimize duplicated efforts and ensure seamless integration with existing systems.
- **Ensuring Scalability and Flexibility**: As the ISFC System continues to grow, maintaining its scalability and flexibility will be vital. This includes preparing the system to handle larger data volumes, support new technologies, and accommodate varying operational practices across different regions.

C. Advice for Other Adopters

This project may be used as a model for other border-crossing solutions. The challenges encountered and solutions developed throughout Stage 1 can provide insight to other groups that want to achieve similar goals. For other adopters considering this solution, the following lessons learned can be considered:

- Maintain continuous stakeholder engagement. Early and ongoing communication with stakeholders, especially key users like CBP, brokers, shipping companies and carriers, ensures the project aligns with their needs.
- Prioritize strong data governance from the beginning to uphold the quality, security, and usability of the data collected. Early identification of available data resources, the depth of detail within datasets, and the processes for accessing or connecting to APIs governed by different stakeholder groups is essential for smooth integration and scalability.
- Incorporate all user needs to ensure widespread adoption. Because the solution relies on data to produce reliable predictions, collective adoption of the solution is critical.
- Tailor communication strategies to different groups and consider focused, one-on-one discussions, to gather specific feedback and encourage active participation from key stakeholders (in this case, CBP and carriers).
- Adopt a modular, adaptive, and agile design approach. Agile design allows for flexibility in both design and deployment to help the solution adapt to various regions and stakeholder needs, promoting long-term success.
- Prioritize strong data governance from the beginning to uphold the quality, security, and usability of the data collected. As the project scales, regularly update the Data Management Plan (DMP) to address new data sources and evolving requirements. Ensure the solution is designed with scalability in mind, including investments in infrastructure and protocols that can handle increased data volumes, diverse system integrations, and the addition of new functionalities over time.