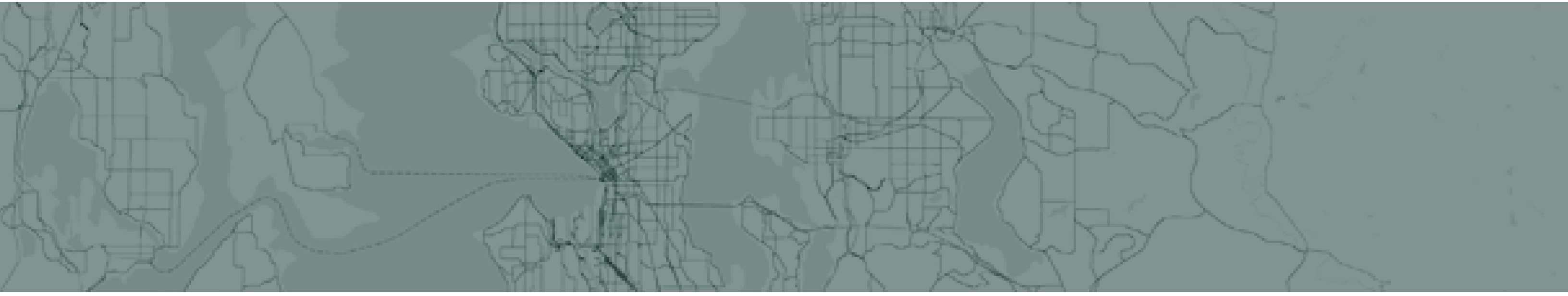

Model Deployment of the Virtual Coordination Center for Multimodal Integrated Corridor Management

Final Report

for the Advanced Transportation and Congestion Management Technologies Deployment Program

Washington State Department of Transportation

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SI* (Modern Metric) Conversion Factors

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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Executive Summary

The Virtual Coordination Center (VCC) is a digital collaborative environment for integrated multimodal corridor management. Under the Federal Highway Administration project "Model Deployment of the Virtual Coordination Center for Multimodal Integrated Corridor Management," an operational community of state, city, and county agencies including law enforcement, transit, and transportation departments developed, deployed, and evaluated a VCC for interagency management of the Seattle urban corridor.

Led by the Washington State Department of Transportation (WSDOT) and the University of Washington, this project produced an innovative collaborative environment that now supports Seattle Fire (SFD), Police (SPD), and Transportation (SDOT), King County Metro Transit, Sound Transit, Washington State Patrol (WSP), and WSDOT in their interagency management of incidents that impact the regional transportation system. The work accomplished under this project will be sustained and enhanced with funding by the state legislature and under WSDOT guidance.

The VCC provides daily operational value and is designed to support the management of high-impact situations that put unusual stress on the Seattle-area transportation corridors. The VCC supports increased shared situational awareness, enhanced incident and congestion management, and coordinated population movement. Key VCC features and capabilities include:

- An Integrated Dispatch Feed which provides a running account of dispatch events from three computer-aided dispatch systems (SFD, SPD, and WSP), operational dispatches from the King County Metro Transit Control Center, and information from the WSDOT Traffic Management Center Log.
- A Situational Map linked to the dispatch feed and with numerous informational layers such as cameras, traffic, and construction sites.
- Incident Models launched by users or the system indicating that a high impact event is likely in progress and providing information for coordinated action.
- A Population Movement Hub to help coordinate public messaging.
- A Records Management Capability that enables agencies to address issues of data retention and management.

From February 27 to September 30, 2023, the VCC model deployment underwent operational evaluation. During this time, 354 Incident Models were launched either manually or by the system. Some of the key conclusions from this initial evaluation were that the VCC:

- Improved operators' ability to get accurate information from other agencies.
- Delivered information that was highly trusted by operators.
- Encouraged operators to leverage information and resources from other agencies.
- Contributed to increased shared situational awareness.
- Has not significantly changed operator use of existing legacy systems.
- Reduced reliance on one-to-one phone calls.
- Encouraged operators to find VCC uses that were not the focus of initial design.
- Benefits of rapid incident clearance and congestion management will likely outweigh the costs of implementation.

Beyond the operational evaluation, several critical lessons and recommendations emerged from the overall project effort. These lessons and recommendations are especially relevant to future expansion and enhancement of the VCC or other VCC-like endeavors:

- Community-centered design is essential; this means that partnering and community building must precede technical development.
- Sharing a new operational environment will impact how people work together, but operators will not jump into a new concept of operations; operational changes must be built on the ways that agencies and operational roles currently interact.
- Managing multi-jurisdictional areas such as a state highway that also functions as a city street or ramps that connect city streets to interstate highways is a driving force behind VCC adoption and use.
- Community buy-in and time commitment is more significant than dollars. Any direction that lost engagement and buy-in of the operational community was too costly, no matter how seemingly beneficial or economical the effort.
- Expansion of VCC scope will require some modifications of interface and display features. A mobile VCC application and improvements to the system generated alerts are also desirable.
- The model deployment produced many community-generated ideas for future enhancements of VCC. These have been captured in an ideation log for future use.

Now that a city-based, urban corridor VCC has been produced and evaluated, possible next steps would be a rural corridor VCC and an interstate corridor VCC.

Chapter 1. Introduction

Eight and a half years before he was sworn in as the 19th U.S. Secretary of Transportation, the Mayor of South Bend, Indiana said,

> *In local government, it's very clear to your customers – your citizens – whether or not you're delivering. Either that pothole gets filled in or it doesn't. The results are very much on display, and that creates a very healthy pressure to innovate.*
>
> *– Pete Buttigieg, August 5, 2013*

The project "Model Deployment of a Virtual Coordination Center for Multimodal Integrated Corridor Management" (VCC)[1] stemmed from this healthy pressure to innovate, and it is perhaps not a coincidence that one of the more intensive VCC events during the project's operational evaluation involved the urgent filling of a massive hole on a ramp from the West Seattle Bridge.

The healthy pressure to innovate that led to VCC stemmed from a series of incidents that made for brutal transportation experiences for Seattle area travelers. These incidents had unique complications that required coordination among agencies that went beyond their usual interactions – a 2015 fish truck rollover that shut down a highly traveled state route and ground citywide traffic to a halt; a 2015 collision on a bridge between a charter bus and an amphibious tourist vehicle that killed 5 and injured more than 60 travelers (Figure 1.1); a 2016 incident where a truck dumped dozens of boxes of crab, again bringing to a halt a major state route running through Seattle (Figure 1.2). These incidents fueled a desire for innovation, focused on enhanced collaboration. "I definitely believe there is room for systemic improvement," said then Seattle Police Chief Kathleen O'Toole. "We look forward to planning and training with our partner agencies to make sure we have the right tools and protocols in place in the future."

[1] The VCC acronym refers to both the project and the virtual collaborative environment itself.

Figure 1.1 Ride-the-Duck Incident September 24, 2015 (Ken Lambert, The Seattle Times)

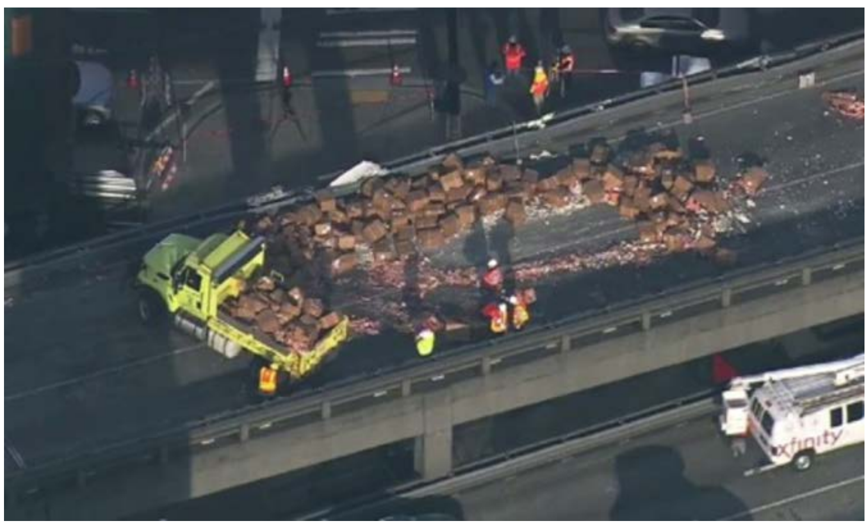

Figure 1.2 Crab Truck Incident April 4, 2016 (KOMO News/Air 4)

Perhaps the most significant incident in terms of impact on the overall Seattle area transportation system was a 2017 multi-vehicle rollover collision involving a propane tanker truck. This incident certainly could have been far worse; gasoline was leaking, and the propane truck could have exploded but that fortunately did not occur (Figure 1.3). Still, the tanker rollover on the southbound Interstate 5 collector-distributor lanes resulted in the complete closure of I-5 and as well as many on- and off ramps (Figure 1.4). Clearing this incident required extreme caution due to the propane the truck was hauling. The incident occurred late in the morning after the peak commute but since it took crews eight hours to clear the truck and reopen the roadway the regional transportation system was gridlocked for most of the day, including the evening commute (Figure 1.5).

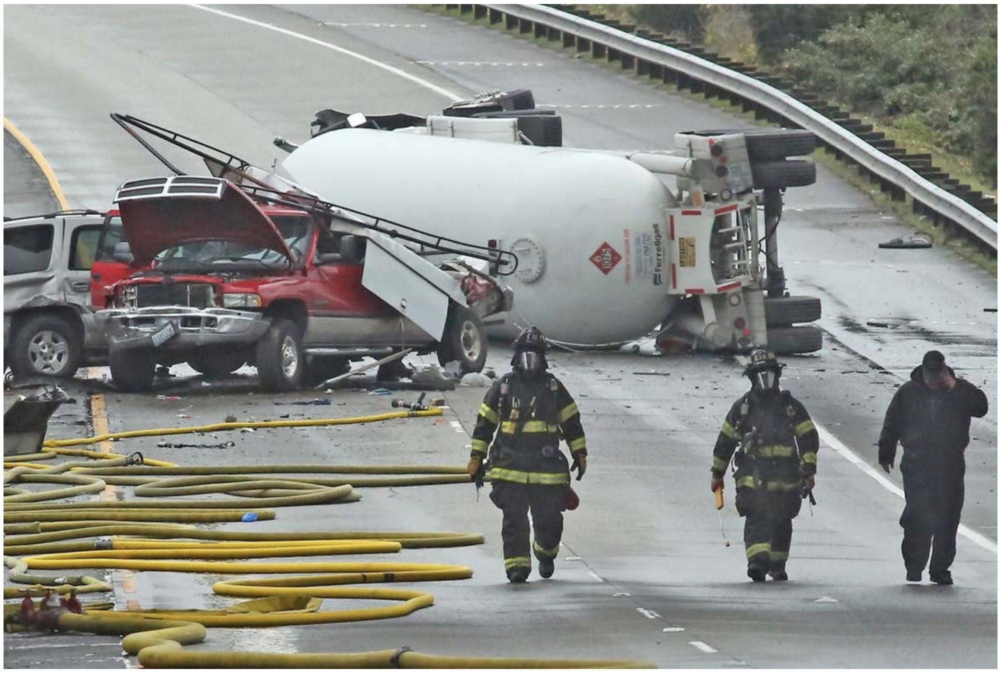

Figure 1.3 Propane Tanker Rollover February 27, 2017 (WSDOT)

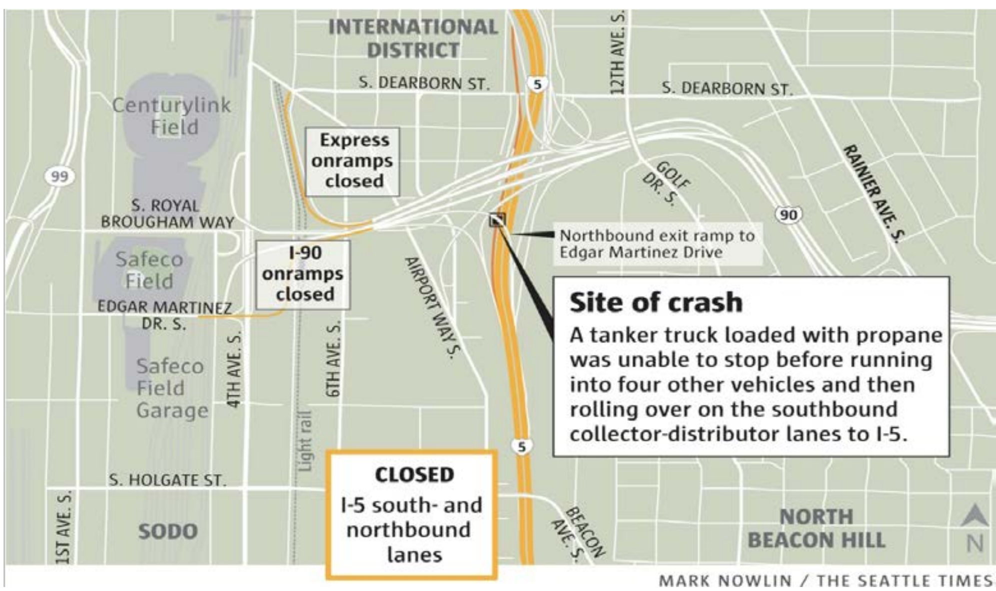

Figure 1.4 Map of Propane Tanker Rollover and closed roads (Mark Nowlin, The Seattle Times)

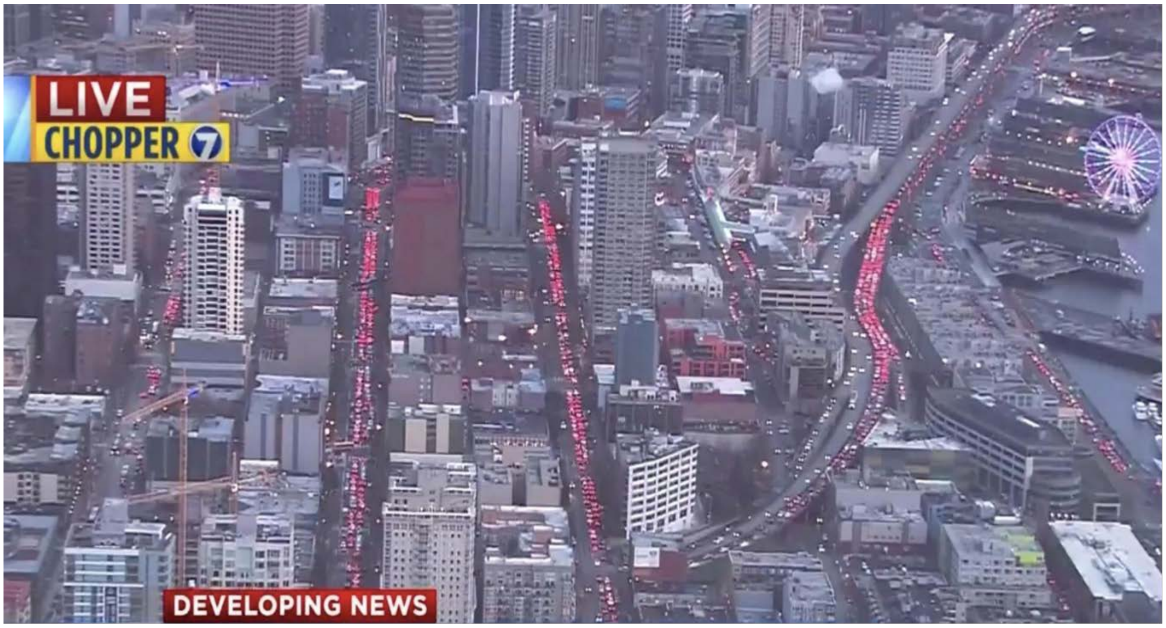

Figure 1.5 Downtown Seattle Gridlock from the Propane Tanker Rollover (KIRO News)

There was general agreement on the need to examine existing practices and explore innovative improvements to multi-agency management of major incidents. Beginning March 2017, Challenge Seattle[2] brokered a series of initial meetings with relevant agencies, held at the University of Washington's (UW) Center for Collaborative Systems for Security, Safety and Resilience (CoSSaR) and including the Washington State Department of Transportation (WSDOT), Washington State Patrol (WSP), King County Metro Transit (KCM), Seattle Department of Transportation (SDOT), Seattle Fire Department (SFD), and the Seattle Police Department (SPD). Participants determined that most detrimental impacts of recent events had resulted not from insufficient or ineffective efforts occurring at the incident sites – onsite responses were heroic and timely – but rather from interdependent stresses such as the shared impact on ramps that connect city streets to the Interstate. Interdependencies like these played out across the entire transportation system. The most promising areas identified for innovation involved improved collaborative management of these stresses. An initial project was launched, focused on enhancement of the interdependent activities of the complex community of agencies who managed the various components of Seattle's regional I-5 corridor.

Between 2017 and 2020, representatives from these regional transportation agencies met to better understand and consider how to improve their collaborative efforts. An evolving vision emerged – a vision of a shared coordination center that would enable and enhance multi-agency management of the Seattle area transportation system. The VCC was seen as a desirable enhancement to regional mobility and safety and was supported by leadership from

[2] A consortium of local private sector partners led by former Governor Christine Gregoire.

WSDOT, WSP, SDOT, SPD, SFD, KCM, and Sound Transit. In 2018, these agency leaders executed a charter establishing the Seattle Area Joint Operations Group (SAJOG), committing to work together to advance interagency collaboration and the VCC vision.

In addition to the major incidents mentioned earlier, there were other significant elements that contributed to this vision which became the VCC. Perhaps foremost of these elements was the rapid growth of cloud computing, which more than doubled during this period. A cloud-based environment and accompanying Infrastructure as a Service model could provide partner agencies with on-demand access to computing resources such as servers, storage, networking, and virtualization. Agencies did not need to acquire servers, run software, or manage data storage devices; their personnel would simply log in and access common capabilities and shared data.

Partners also recognized that integrated transportation management involves far more than technology – it is a complex socio-technical system of people, policies, practices, organizational structures and cultures, jurisdictions, missions, strategies, and, yes, technology. Cloud computing could make it easy to share data, but data governance and agreements were still necessary, and they could be far more complex to achieve than the technology. This was especially true since the partners were extremely diverse, including both law enforcement and non-law enforcement agencies, each with differing city, county, and state governments.

Figure 1.6 Interagency Design Session (UW)

In 2020, WSDOT was awarded a Federal Highway Administration's Advanced Transportation and Congestion Management Technologies Deployment award which has enabled the successful model deployment and evaluation of the VCC. COVID impacted this effort in both negative and positive ways. The face-to- face meetings that had been so essential to agency community building and collaborative visioning of VCC moved online. This made it more challenging to sustain the exciting synergy of face-to-face interagency design scrum sessions that were held prior to the pandemic (Figure 1.6). However, the shift to online interaction made it easier to include more people with less disruption to their busy schedules. More importantly, the shift to online interaction enforced the central vision of an online community collaborating within a virtual environment. The VCC was timely.

This report contains considerable information, analysis, and evaluation of the VCC itself; the agile, community-centered methods employed to design and develop it; and the use and impact of VCC during the model deployment period. This information is extremely valuable and especially applicable to potential future expansion or the initiation of similar projects in other cities and regions. The goal of VCC was to co-create a virtual collaborative environment that would become an ongoing, sustainable component of the region's multimodal integrated corridor management. This has already happened. In April 2023, the state legislature provided funding for continuing operations of the VCC and to expand operations to up to five additional jurisdictions in King County. With this funding, the VCC is now a state program, managed by WSDOT.

Today, the Virtual Coordination Center is an evolving yet robust cloud-based system that enables multi-agency, multimodal, integrated corridor management. The VCC:

- Securely ingests data from multiple public and private sources into a common data lake[3] for shared use with appropriate permissions, retention, and access;
- Enables real-time information flow to allow shared map-based situational awareness;
- Facilitates joint action in a virtual workspace to speed incident response, mitigate traffic impacts, and manage congestion both on a daily basis and, especially, during major incidents when interagency collaboration is especially critical;
- Provides actionable information and alerts to a trusted community of agency operators responsible for various aspects of regional mobility; and
- Enhances coordinated regional planning and operations through data analytics and predictive modeling.
- The Project Team believes that the VCC demonstrates a new and innovative approach to collaborative, multimodal management of a regional transportation corridor.

[3] What is a Data Lake? https://aws.amazon.com/big-data/datalakes-and-analytics/what-is-a-data-lake/
A data lake is a centralized repository that allows you to store all your structured and unstructured data at any scale. You can store your data as-is, without having to first structure the data, and run different types of analytics—from dashboards and visualizations to big data processing, real-time analytics, and machine learning to guide better decisions.

Chapter 2 The Virtual Coordination Center

Chapter 2 describes the state of the VCC as of December 2023. In addition to the scope and capabilities of the virtual environment, this chapter includes lessons learned during the design and development of this groundbreaking regional initiative. Evaluation of the current implementation is in Chapter 3, and lessons learned and recommendations for the future appear in Chapter 4.

2.1 Scope and Capabilities of the VCC

The VCC is not a fixed tool; it is a flexible, evolving operational environment that houses capabilities and information that supports multimodal integrated corridor management. The VCC described below is the state of this evolving environment after operational evaluation of the model deployment and transition from a model deployment to a permanent program.

The VCC enhances integrated mobility management along the I-5 corridor of the greater Seattle area as shown in Figure 2.1. The VCC provides value on a daily basis but is especially geared towards providing infrastructure for more intense collaboration and coordination during major incidents. The primary goal is to support the management of complex situations that put stress on the Seattle-area transportation system and that call for interagency collaboration beyond that usually required. Agencies engaged in addressing these diverse and dynamic circumstances use the VCC to enhance their existing processes for collaborative operations and communication.

The VCC operational environment is scoped around three interdependent functional components of transportation management, each of which has related features and capabilities described in this chapter:

1. Shared Situational Awareness: Shared situational awareness is key to coordinated operations. VCC partner agencies have well-defined internal processes and organizational structures for tracking evolving situations. The processes for achieving shared situational awareness among multiple agencies, however, have been less clearly defined. During a major incident that requires coordination among two or more agencies, regional transportation managers now use VCC to access and track relevant computer-aided dispatch (CAD) events from all participating agencies, inform partner agencies of their evolving perspectives and actions on the situation, and share status updates. This shared awareness enhances the collective ability of agency operators to define and coordinate strategies to address the situation.

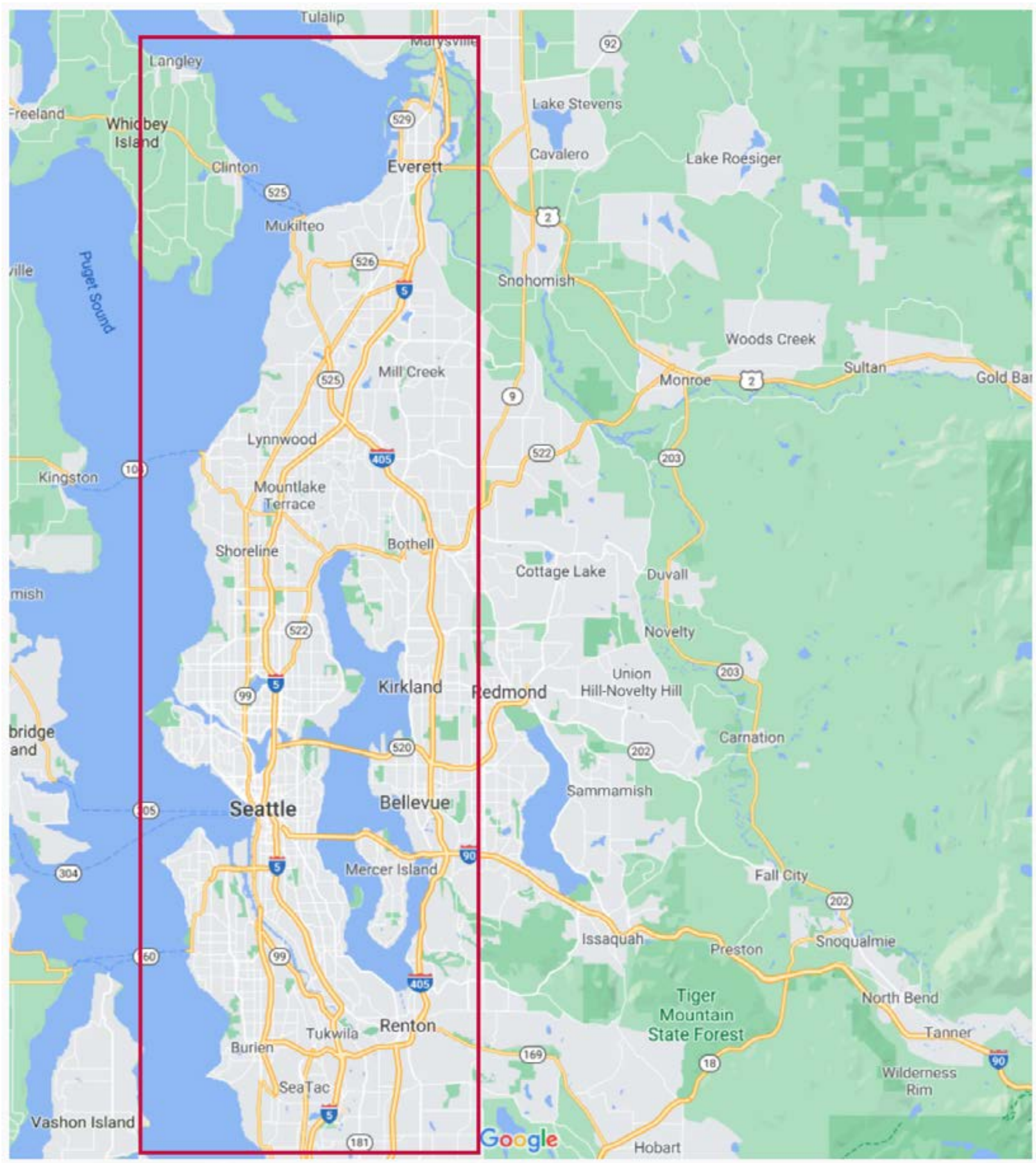

Figure 2.1 Greater Seattle Area I-5 Corridor

2. Traffic Incident Management and Congestion Management: The traffic incident and congestion management components of VCC support regional deployment of coordinated response and traffic/transit management plans, in order to improve safety, clear roadways more quickly, guide first responders to incident sites more efficiently, and ensure regional mobility. VCC traffic incident and congestion management features enable agency operators to share their plans and coordinate their actions as they are taken to alleviate congestion.
3. Population Movement: The population movement component supports secure, trusted interagency communication on public messaging. By assisting public information officers in the development and coordination of timely and unified messaging about mobility disruptions and the status of recommended solutions, the VCC supports agency personnel responsible for helping to make travelers part of the solution, rather than the problem.

2.1.1 User Roles and Permissions

A key component of VCC interagency operational practices are the user roles and permissions built into the VCC environment. These roles and permissions were worked out in design sessions with agency operational leaders. The current defined roles and permissions are outlined below in Table 2.1.

Table 2.1 User Roles and Permissions

Roles	Permissions
Basic User	Provides view only access to the VCC. All users receive the basic user permission, but this is primarily geared towards higher-level management and executives informed.
Incident Contributor	Allows users to add notes to Incident Models and pin dispatch events to their private view of the Dispatch Feed. Primarily for operational personnel with selected views of an incident, but not the big picture.
Incident Manager	Allows users to create, edit, close incidents, annotate Incident Model Situation Maps, and create and edit Mobility Strategies. Allows users to view and re-open closed incidents, but not deleted incidents. If a user is set as an Incident Manager, 0074hey should also be set as an Incident Contributor. Primarily for operational managers with a big picture of an incident.
Incident Records Manager	Allows users to view the Incident Model Records Management page. Primarily for Incident Managers who view and finalize records reports.
Public Information Officer	Allows users to create, edit, and close Scheduled Outreaches and Talking Points in the Public Information Hub. Primarily for PIOs and other personnel with public information responsibilities.
Site Administrator	Allows users to view the Admin page, add, remove, or edit any VCC users, and update user roles.

2.1.2 Shared Situational Awareness

The VCC Dashboard (Figure 2.2) has several features that contribute to shared situational awareness of the VCC user community. The screen is split into three panels. The center panel is a view of the Integrated Dispatch Feed, and the right panel has Active VCC Incidents. The green box represents redacted information and does not appear on the user's screen.

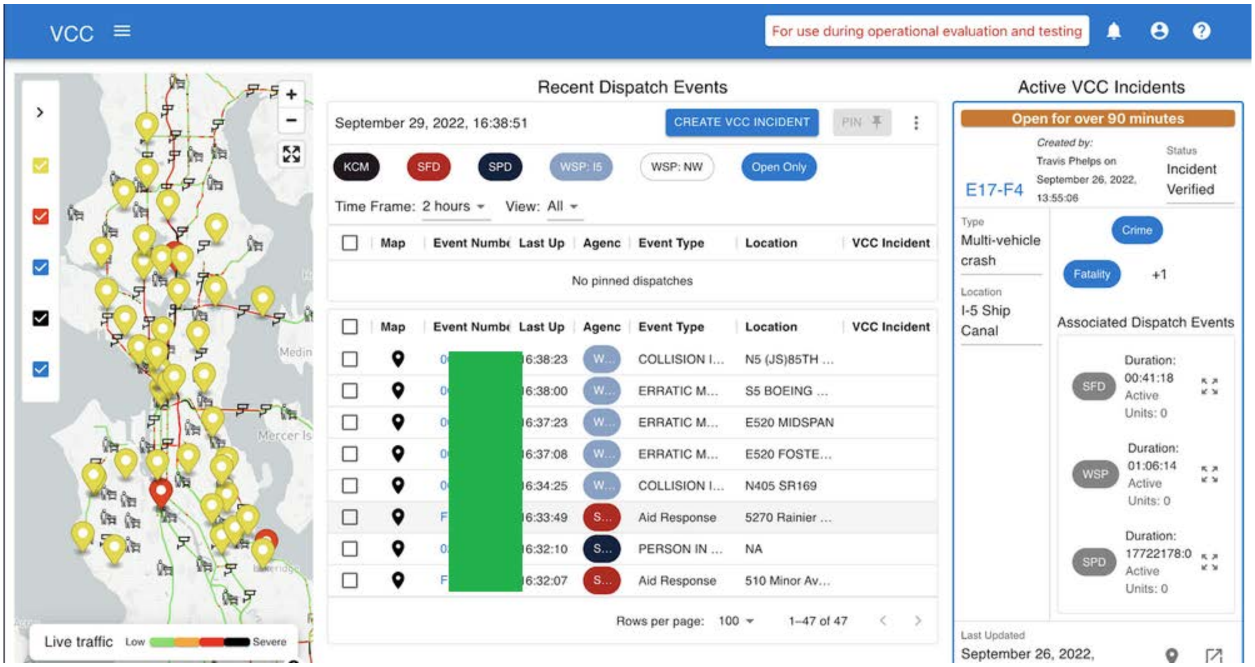

Figure 2.2 VCC Dashboard

The Integrated Dispatch Feed

The Integrated Dispatch Feed provides a running account of dispatch events from five sources: three computer-aided dispatch (CAD) systems (SFD, SDP, and WSP), operational dispatches from the King County Transit Control Center (TCC), and information from the WSDOT Transportation Management Center (TMC) Log delivered as an augmentation of the associated WSP CAD dispatch. A "Recent Dispatch Events" view of the Integrated Dispatch Feed is visible within the VCC Dashboard represented in the middle column of Figure 2.2, and a full-screen version is available via a link. The Integrated Dispatch Feed provides a link to the dispatch event on the accompanying Situation Map (2.1.3), the event number (an ID generated by the originating agency), time of last update, originating agency, event type, event location, and associated Incident Model (2.1.4), if applicable.

By selecting the event number, users can view more detailed information associated with each dispatch event (e.g., active response vehicles on scene) via a popup modal window (Figure 2.3). The green boxes represent redacted information and do not appear on the user's screen.

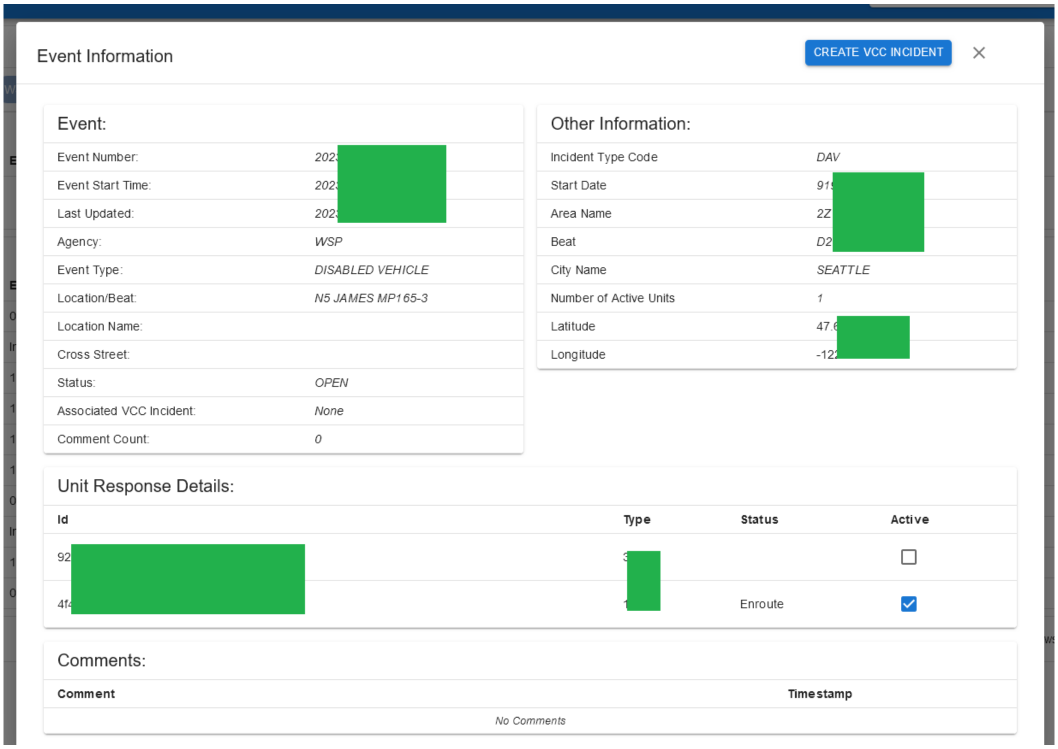

Figure 2.3 Dispatch Event Information Modal

By default, events are pulled directly from the originating agency's feed every 30 seconds. The feed can also be manually updated by users, which may be useful during rapidly evolving situations.

The Integrated Dispatch Feed is designed to be comprehensive and near real time, allowing users to stay aware of a wide variety of current response activities happening within the Seattle I-5 corridor. If a user wants to keep an eye on a specific dispatch that they are not yet ready to bring to the attention of others by creating an Incident Model (2.1.4), they can pin that dispatch to the top of their Integrated Dispatch Feed (Figure 2.4).

A dispatch event can be selected and pinned, putting that dispatch of interest in the upper portion of the Integrated Dispatch Feed, separated from the other dispatches. These pinned dispatches remain in the upper portion, highlighted yellow for visibility, until they are unpinned by the user who pinned them, or the event is closed. A user's pinned dispatches section displays only those dispatch records that the user has pinned in both the Integrated Dispatch Feed and the Dashboard. The yellow box in Figure 2.4 represents the pinned dispatches section. As before, the green box represents redacted information and does not appear on the user's screen.

Recent Dispatch Events

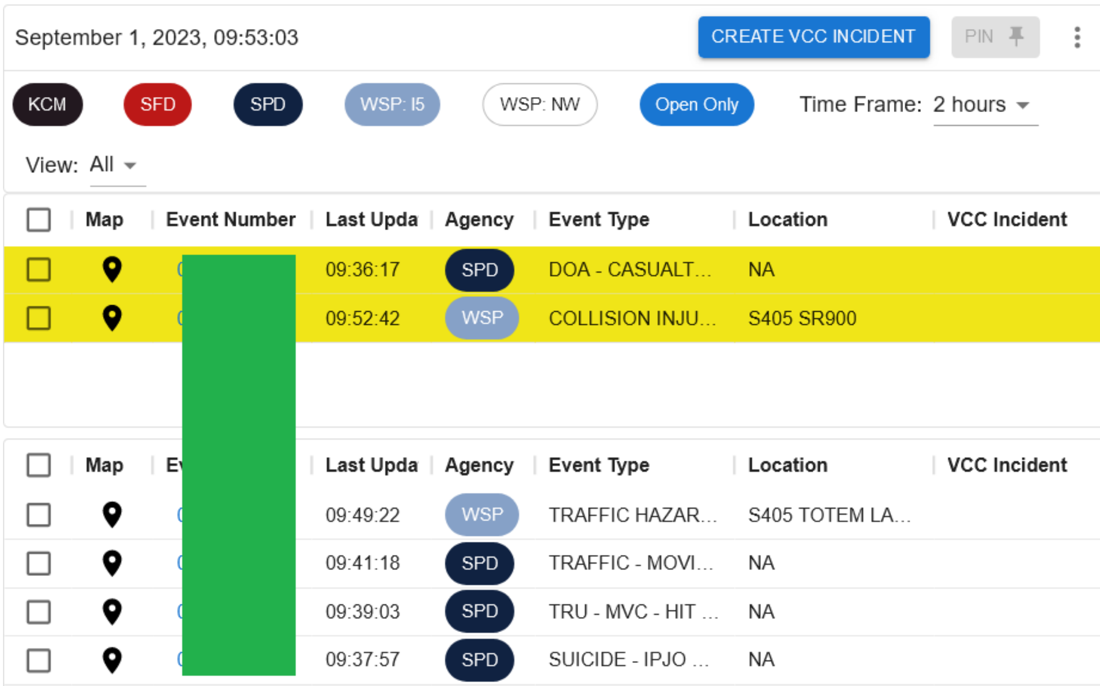

Figure 2.4 Pinned Dispatches

However, in addition to providing a quick way of bookmarking interesting dispatch events for an individual user to track, the pin feature also contributes to shared situational awareness. Any user can switch from View All to View Noteworthy in the upper left of the screen. Noteworthy shows only those dispatches that have been pinned by other users or used to launch an Incident Model (2.1.4).

Another feature of the Integrated Dispatch Feed is that it integrates valuable WSDOT information from the Transportation Management Center (TMC), even though WSDOT does not have a unique dispatch system. This information, known as the TMC Log, provides unique, valuable comments that are matched with a WSP dispatch record. WSP dispatches that have a corresponding TMC Log record display that record, with potentially personally identifiable information redacted, under More Information in the Event Information modal.

The Situation Map

The Situation Map (Figure 2.5) provides different layers of data overlaid on a map. Many of the map layers are linked to information in the dispatch feed and the Incident Model. For example, selecting the map icon on the event in the Integrated Dispatch Feed will zoom the map to the location of the incident. The VCC pulls in data from partner agencies and displays them on the map. The current set of data layered onto the map includes agency traffic cameras, INRIX Construction Data, and Mapbox Traffic Data.

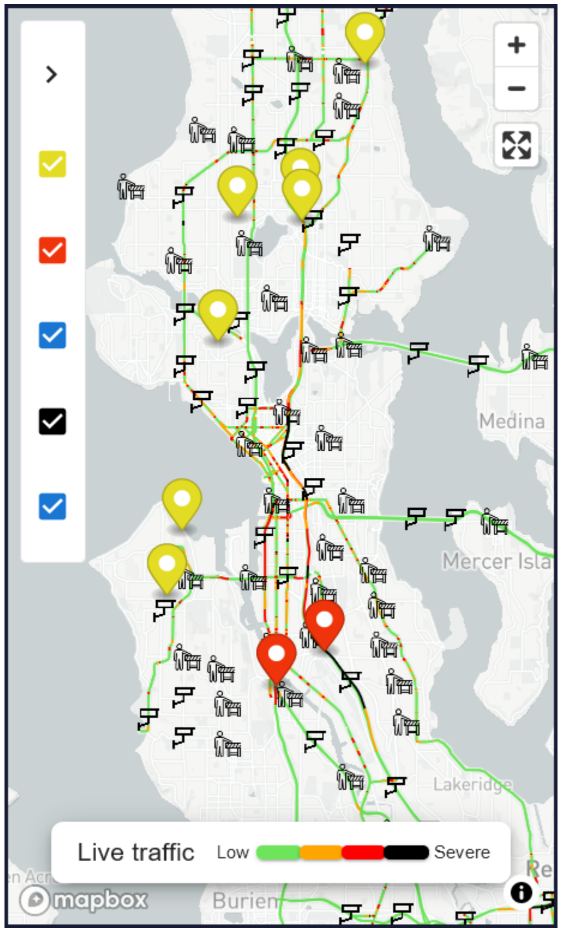

Figure 2.5 Situation Map

The yellow markers represent dispatch events and red markers represent VCC Incident Models. The map shows all active dispatch events as well as active VCC-level incidents (see 2.1.4). Dispatch Events and VCC-level incidents appear on the map at coordinates provided in the Integrated Dispatch Feed or derived from descriptive information in dispatches or Incident Models. In combination with an Incident Model, the Situation Map can be used to identify relevant conditions and dispatch events in the area surrounding a VCC-level incident. Additional future layers might show agency construction closures, WSDOT Incident Response Team (IRT) and SDOT Response Team (SRT) locations, tow trucks, non-roadway transportation systems such as ferry and rail traffic, and, when needed, a power outage map layer from local utility companies.

Incident Model Summaries

A final element of the VCC Dashboard is a column that displays summaries of any currently active Incident Models (see right-hand column of Figure 2.2). An active Incident Model indicates an ongoing situation that either a user or the system has determined is worth bringing to the attention of all other VCC users. Active Incident Models also appear on the Dashboard Situation Map as red pins (Figure 2.5).

Together, the Integrated Dispatch Feed, Situation Map, and Incident Models (described in 2.1.4) enhance shared situational awareness across agencies and roles. This shared awareness is the foundation for collaborative, coordinated action.

2.1.3 Collaborative Incident and Congestion Management

The VCC offers several key features that help break down operational silos and support collaborative action to better manage serious incidents and severe congestion. During incidents and situations that require close coordination among two or more agencies, regional transportation managers use the VCC to share information management, strategies, and actions that enhance their collective ability to understand and address the evolving situation. These features are not designed to replace existing agency operational processes, but rather to enhance, leverage, and integrate them. Most importantly, the information within the VCC is instantly shared with a broader range of operators and managers than current agency systems reach. Following is a brief overview of the Incident Model and Mobility Strategies features.

The Incident Model

A VCC-level incident is a transportation situation that may require enhanced collaboration across agencies and roles to address. The existence of a VCC-level incident is indicated by the initiation of an Incident Model, which sends an email alert to all users with a link to the Incident Model in the VCC. An Incident Model can originate in one of three ways:

- A user with permission to launch an Incident Model uses one or more dispatches in the Integrated Dispatch Feed to launch an Incident Model with pre-populated data from those dispatches. Because evaluating a situation as a VCC-level incident sends a strong signal to all VCC users, the ability to initiate Incident Models has only been assigned to an informed subset of VCC users, such as operators in the operations centers.
- An authorized user is aware of a situation that triggers them to launch an Incident Model without pre-populated data from the dispatch feed.
- An Incident Model is automatically generated by the VCC Rules Engine, which was developed with the stakeholder community. (For more information with an eye towards future enhancements, see Appendix G. Enhancing System-generated Incident Models and Alerts.) System-generated Incident Models start with a Status of “Open” and are verified by someone with authority to do so. An Incident Model is created according to the following rules:
    - Events from Seattle Fire Department that Include *“Tunnel MVI”*, *“Car Fire Freeway”,* or *“Fire Response Freeway”* in event type
    - Events from Washington State Patrol in Area “I5” that Include “Road Closure”, “Fatal Traffic Collision”, “Disabled Vehicle Fire”, or “Possible suicidal pedestrian on bridge or overpass” in event type
    - Events that include *“bridge”* in location and *“blocking”* in event type

The Incident Model captures information from associated dispatches (if applicable) and allows VCC users to manually input additional information, such as estimated clearance times and incident notes, as the situation evolves. In this way, the Incident Model becomes a shared digital space for the pooling of evolving interagency knowledge.

Some of the key components of an Incident Model are:

- Pre-populated information: When a user creates a VCC incident from one or more dispatch events, or when the rules engine creates a system-generated incident, some information from the pertinent dispatch events is automatically inserted into the newly created VCC incident, such as location and incident type. These values in the Incident Model can be modified by authorized users, without any impact on the originating dispatch record.
- Contributing Factors: Based on extensive user feedback and guidance, the Project Team identified several factors that, if they apply to an incident, tend to exacerbate incident severity, duration, and/or the need for interagency collaboration. These factors are Crime, Hazardous Materials, Fire, Fatality, Rollover (that is, one or more vehicles have rolled over), and Commercial Vehicle. Users who can edit Incident Models can select any or all of these factors where they appear prominently near the top of the Incident Model details page. When selected, these factors appear in blue for visibility.
- Details: There are four tabs across the top of the Incident Model: (1) Details, (2) Notes, (3) Mobility Strategies (2.1.4), and (4) Public Information Hub (2.1.5). The Details page is the default view of an Incident Model. It provides fields for an overview of key information including location, lane impacts, incident type and details, incident commander, lead agency, lead PIO, estimated clearance time, other response details, and an overview and quick access to associated dispatch events. Some of these fields are pre-populated from dispatch events; all can be entered or revised by users with appropriate permissions.
- Notes: The Notes page allows users to add pertinent, free-form incident information that does not easily fit into the detail fields. In practice, this enables a more fluid conversational communication across agencies during incidents. Users with the appropriate permissions can add text-based notes and/or upload image files.
- Map Annotations: Like the Dashboard, each Incident Model has a Situation Map on the left of the screen. The Incident Model Situation Map has the same information as the Dashboard Situation Map, plus specific map pins for the location of the VCC incident plus any dispatch event associated with the incident. Most importantly, the Incident Model Situation Map provides an “Annotate Map” tool. Using this tool, visual information specific to the incident, such as detour routes and an operational perimeter, can be drawn on the map. These map annotations are visible to anyone viewing the Incident Model but can only be added or removed by users with the Incident Manager role.
- Incident Status and Closing: At the top of an Incident Model is a status field which indicates the progress of resolving the VCC-level incident through multiple states until it is closed. When an authorized user deems the incident's work to be completed, road conditions to have sufficiently stabilized, and all responders have either left the scene or moved vehicles and debris off to the shoulder such that traffic is no longer blocked, they can close the Incident Model by setting the status field to “Closed.” Closing the Incident Model disables editing and removes it from the Active VCC Incidents card on the VCC Dashboard. After an Incident Model is closed, it can be temporarily viewed in the Records Management page by users with the Records Manager role.

Mobility Strategies

The Mobility Strategies tab of an Incident Model supports interagency, collaborative work of users engaged in congestion management. Users with the Incident Manager role can indicate their use of various strategies, such as managing traffic flow via ramp metering or signal timing, bringing special equipment to the scene, or posting messages on electronic roadway signs. Users can add a strategy in the Create Mobility Strategy modal (Figure 2.6) and share a mobility strategy being employed during an incident. Users can also indicate others as collaborators on their actions, automatically sending a notification to any collaborator who has been added.

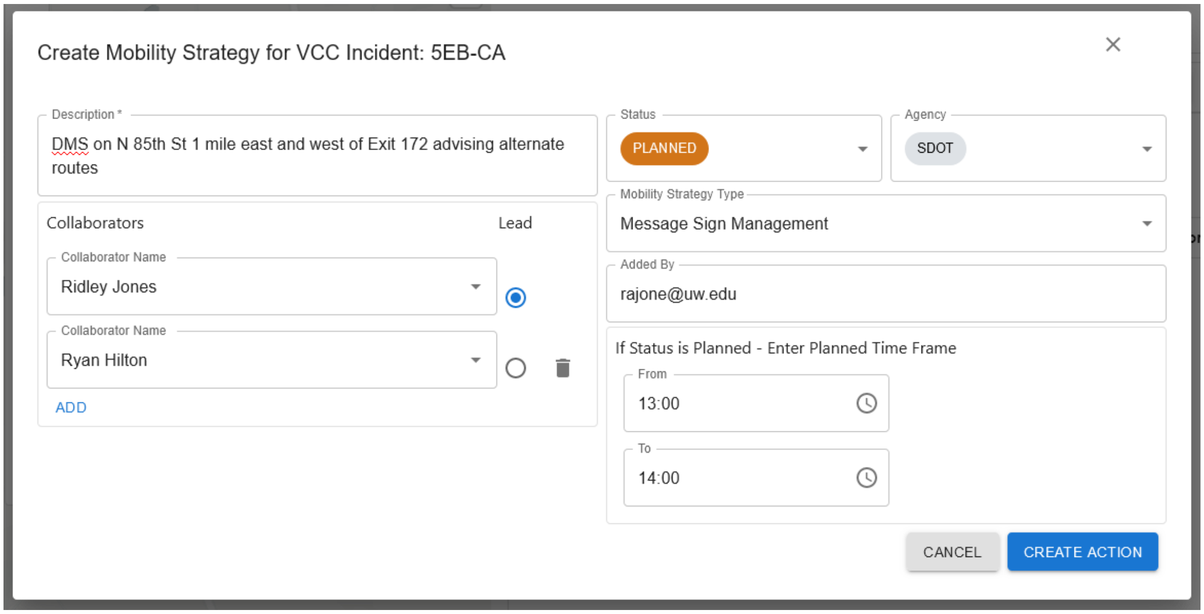

Figure 2.6 Create Mobility Strategy Modal

2.1.4 Population Movement

The Incident Model includes a Public Information Hub tab that supports coordinated messaging and public information engagements across the partner agencies.

The Public Information Hub

The Public Information Hub is a dedicated space within each Incident Model for use by Public Information Officers (PIOs) and other individuals responsible for communicating with the public. Two types of information are shared within the Public Information Hub: (1) coordinated outreach events and (2) shared approved talking points. The goal of the Public Information Hub is coordinated messaging across participating agencies. All users can view the Hub, but only those with the Public Information Officer role can add and edit information.

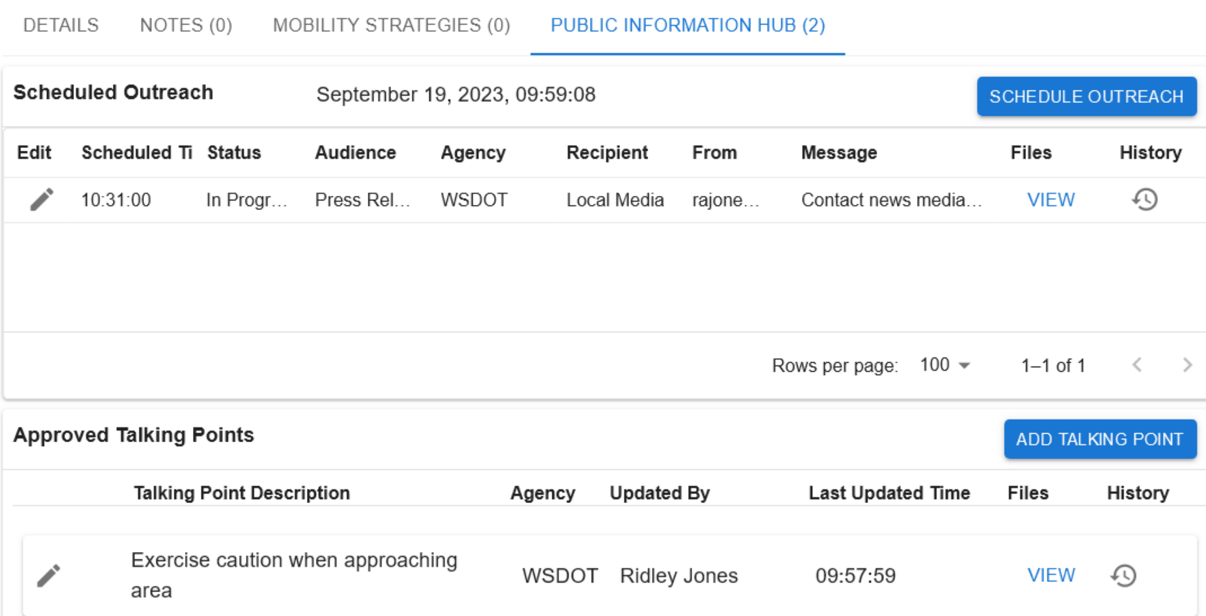

Figure 2.7 Public Information Hub

Figure 2.7 shows:

- The Scheduled Outreach information box which can be used to help coordinate meetings, debriefs, press releases, executive briefings, or other types of public information events associated with a VCC incident. In this space, users share details about their planned outreach opportunities.
- The Approved Talking Points information box which helps agencies share and coordinate messages and talking points regarding the associated VCC Incident. The goal is to align partner agencies and create a unified public message.

2.1.5 Security and the VCC Trusted Community

The VCC supports a trusted community of agency personnel. Users must be granted access by their agency. The VCC user community needs both to trust each other and to trust the technology they are using to share information and conduct community operations. For this reason, the VCC has a number of layers of security.

The VCC is built on Amazon Web Services (AWS) using AWS managed services. AWS is architected to be a secure global cloud infrastructure on which to build, migrate, and manage applications and workloads. Using a cloud-based infrastructure allows the project team to focus on creating operational value for the transportation community, leaving AWS responsible for maintaining the functioning of the VCC. The cloud-based infrastructure also assures that public agency partners have a mechanism for equal access to VCC data and capabilities. Infrastructure as a Service is a cloud computing model that provides on-demand access to computing resources such as servers, storage, networking, and virtualization. Individual agencies do not have to acquire equipment or worry about compatibility. Access and security are managed centrally and equally and easily distributed.

The VCC is a secure web application. Access to the VCC occurs through SecureAccess Washington (SAW), a central login that provides multi-factor, password protected access to the online services of multiple Washington state agencies (Figure 2.8). VCC users must create a SAW account using the email address associated with their VCC account, and sign into the VCC by first signing in to SAW. This helps administrators avoid the challenges of VCC passwords being lost or stolen. SAW's multi-factor authentication ensures an extra level of security for VCC accounts.

Figure 2.8 SecureAccess Washington Login Screen

The VCC environment securely integrates independent data from partner agencies in support of collaborative awareness and operations. The VCC is not meant to replace existing agency partners' systems; partners decide how the VCC fits into their existing systems and processes.

While the VCC's interface and data are built with secure technology, the VCC trusted community is not built upon a purely technical system. Equally if not more important as the technical security services are the guidelines and operational principles by which these services are used. The project team continually works with and guides the user community in discussion and implementation of how the various agencies want to work together, both within the virtual environment and in operational practice.

2.1.6 Records Management

During the process of creating and working VCC incidents, users generate valuable data and correlate existing data. However, the VCC as a shared, collaborative operational system is not intended to permanently retain this data. Therefore, issues of data retention and management had to be considered in the light of shared creation, use, and ownership of VCC data across several agencies. In particular, Washington state's public disclosure laws require that all public records maintained by state and local agencies be made available to all members of the public, with very narrow statutory exemptions. Each agency has different policies and processes for data retention and management that they must follow.

To address these challenges and comply with state public records laws and agency policies, the Project Team created an interface for finalizing VCC incident records after work on them had concluded. After a VCC Incident Model is closed, an Excel spreadsheet containing a report of incident activities (e.g., field value updates and text notes) is generated automatically. This report is available for inspection in a page within the VCC only accessible to those users with the Incident Records Manager role. Once a Records Manager has verified the report is complete and correct, they click a button to finalize the incident record. If the report is not finalized within 96 hours, it is automatically finalized.

Upon finalization, the generated report and any images uploaded to the Incident Model is emailed out to each agency. This allows each agency to retain and classify VCC incident data according to their own policies and procedures. Thirty days after finalization, the VCC Incident Model and its report are deleted from the VCC's backend systems.

2.1.7 User Administration

The User Administrator page on the VCC is where individuals with the Site Administrator role can manage the users from their agency. Each agency is responsible for deciding which roles to give to each of their users and each agency is responsible for designating at least one person to be their agency's Site Administrator. Site Administrators can add a new user, edit an existing user, and change a user's access within and to the VCC.

Site Administrators are not System Administrators who can make changes to the overall VCC system. Site administrators are only responsible for editing user information, not making structural or technical changes to the VCC. System Administrators are those who can view and edit the code and other structural elements of the VCC directly. When the VCC was in development, Pariveda provided system administration services. Now that VCC has transitioned to a State program, WSDOT Technology Services Division manages the system administration of the VCC.

2.2 Lessons Learned from Design and Development

Prior to the evaluation, the project team learned much about designing and developing a collaborative environment that enables multimodal integrated corridor management. There were especially vital lessons on how to successfully accommodate the diverse operational and organizational needs of the many agencies who manage and maintain a regional transportation system. This chapter describes key lessons learned during VCC design and development; lessons that should be useful to others planning a similar initiative. Chapters 3 and 4 describe results, conclusions, and lessons from the evaluation, as well as recommendations for moving the current implementation of VCC forward into the future.

2.2.1 Employ Community-Centered Design Methodologies

It was clear from the outset that VCC could not take a one size fits all approach. VCC agencies share overlapping goals, but they are motivated by unique missions, cover different jurisdictions, follow agency-specific policies, work within specialized organizational structures, and develop individual agency cultures. The VCC brings together agencies that are law enforcement and non-law enforcement, some with transportation focuses and others with missions whose scope goes well beyond transportation, and all housed within diverse city, county, state, and multi-county governmental structures. Each agency brings something to the table, and each must have ownership and agency in how they participate.

Some agencies have strong natural connections, but even where this is the case there are still key differences. WSP and SPD are both law enforcement agencies, yet different in mission and jurisdiction. WSDOT and SDOT are both transportation departments but with significant differences in jurisdiction and organizational home. KCM and Sound Transit are transit agencies with different operational focuses and jurisdictions. SFD is a city agency with a primary mission (save lives, protect property, provide emergency medical services) that is much larger than transportation, yet is a critical component of many transportation incidents. No outside organization or single agency could articulate and enforce a common solution for all these partners, let alone future additional partner agencies.

Over the years of working with partner agencies, the project team established processes and structures that give active ownership of design and development processes to the entire VCC community. See Appendix A for details on Project Management and Governance. Empowering and facilitating a diverse group of operational agencies in a community-centered design and development effort is no trivial task, but there are many reasons for doing this. First is the strong connection between collaborative design and development and collaborative use and operations. It is fine to bring together diverse stakeholders to discuss integrated corridor management but is far better to bring them together to collaboratively design shared tools, processes, and information resources that fit into their existing workflow; then implement, deliver initial versions of the new tools, and collaboratively use, evaluate, and refine these capabilities and resources. During this process of collaborative, iterative design and development, discussion is sharpened by the community's knowledge that their vision is being realized and returned to them in a tangible form. Trust is built by their shared experience of co-evolving usable, impactful operational enhancements. Adoption is promoted through the sense of ownership and responsiveness to individual agency needs. For more on the handling of VCC adoption, training, and user support issues, see Appendix C. VCC User Adoption, Training, and Support.

For example, one of the first things the community asked for was a single place where they could see all the dispatches from the various agency dispatch systems. This shared community desire led to the Integrated Dispatch Feed which became the centerpiece of the VCC Dashboard (see 2.1.3), but not before a series of collaborative interactions with the community finalized the design and promoted shared adoption of this feature. Some of these interactions were technical and definitional. The data streams had to be obtained and maintained, and data given sufficient uniformity for a useful, common display. Others were policy driven; agency policy differences had to be identified and accommodated, such as SPD's requirement that the location of their responding vehicles not be shared. Through iterative use, feedback, and refinement, features like the Integrated Dispatch Feed were evolved by the community to meet both shared needs and individual agency constraints.

2.2.2 *Employ Agile Development Methodologies*

Closely connected to community-centered design is the use of agile design processes, segmenting the project into stages and incorporating user feedback and other new learnings at each stage. (See Appendix B. VCC Systems Engineering Approach and Agile Methodologies.)

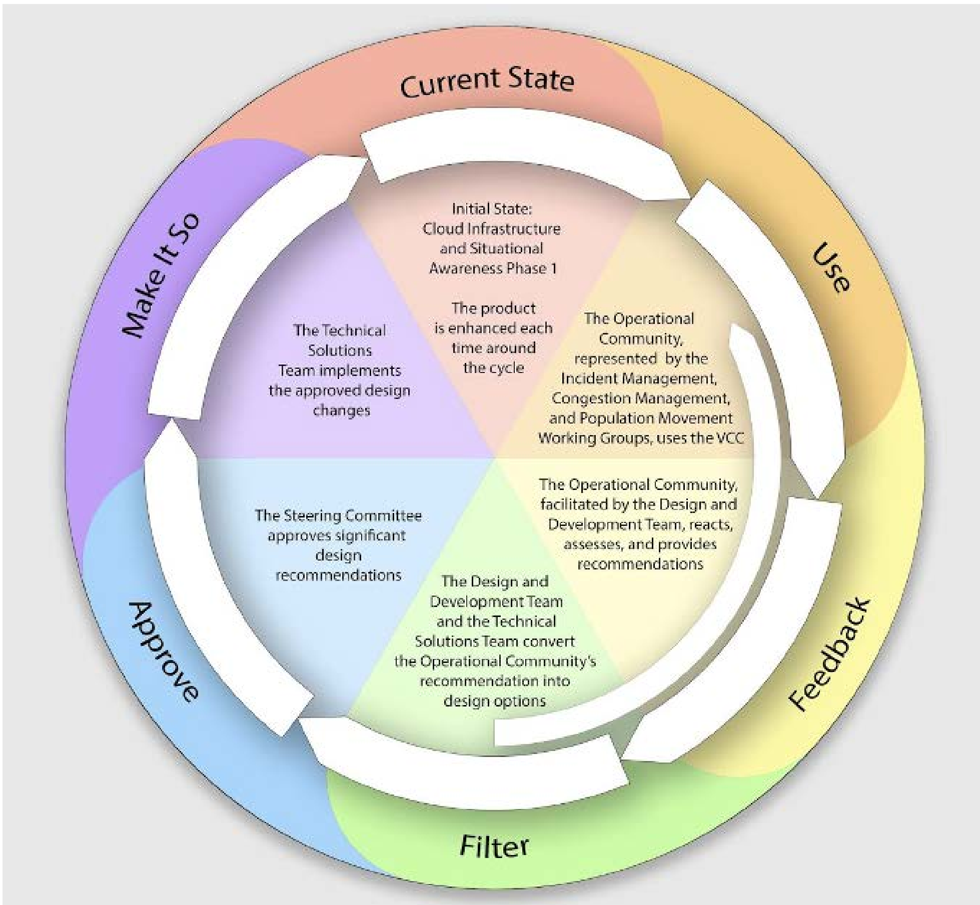

Figure 2.9 Iterative Development and Refinement Model (Pariveda Solutions)

Agile development provided the community with ongoing opportunities to influence and adjust the design and development of the VCC (Figure 2.9). Rather than articulate a finished product and build the pieces of that product, agile development's initial goal was the development of a minimum viable product (MVP). The goal of an MVP is to be in the position to learn as much from the user community as possible, not to design the final product that the community will use. MVP was achieved when a version of the VCC had enough features to be usable by early customers, who then provided feedback for ongoing product development. As the product evolved, so did the partner agencies' shared sense of ownership and trust that their perspectives would be represented and respected.

Using agile methodologies also had a significant impact on the nature and use of the Concept of Operations document, as described in Appendix E. Use of an Agile Concept of Operations. While agile methodologies created an environment where design and development danced together towards a shared viable product, there were still practicalities associated with establishing a sustainable state-funded program that needed to be addressed. As agile development cycles approached initial product status (i.e., the operational model deployment that would be evaluated), two key milestones were: (1) transition of technical management from the project team's sub-contractor, Pariveda, to WSDOT; and (2) transition of the day-to-day operations of the VCC from the project team to the WSDOT program team. For information on the handling of these transitions, see Appendix D.

2.2.3 Build on Existing Operational Relationships and Partnerships

While VCC is a groundbreaking approach to integrated corridor management, it still must be built upon existing relationships and partnerships that extend beyond agency boundaries. In some cases, these partnerships stem from having similar geographic jurisdiction, such as between state agencies like WSP and WSDOT, and among city agencies like SDOT, SFD, and SPD. While these organizational partnerships are significant, the team found that operational roles and relationships provided the strongest basis for cutting across agency boundaries and developing strong collaborative connections. Three operational roles became the backbone of VCC community-centered design: (1) responders, (2) congestion managers, and (3) public information officers, or population movers. Collaboration within these three communities relies not so much on organizational structures, but rather on active relationships and processes built and maintained during daily operations. These operations are supported by the VCC.

Responders meet at the incident site and together take heroic action to save lives, clear obstructions, and return the system to normal functioning. From a VCC perspective, incident responders are as much potential information sources as information users. Responders can use the VCC to become aware of an incident and to help identify the best routes to the scene, but once they arrive on-scene, they become aware of information that could be of significant use to others who are not on the scene. Generally, responders are too busy with urgent response activities to also be sources of information for the community, but the VCC can alter that equation, or at least make it easier to share information once pressing needs are met.

The activities of congestion managers revolve largely around traffic and transit management centers. In the Seattle area, the city's Transportation Operations Center (TOC) and WSDOT's Transportation Management Center (TMC) became natural hubs of VCC use and application. While these two centers had previous collaborative activity, they lacked a common platform for leveraging this activity and extending it to other users outside the centers. VCC provided this and shared useful operational information that was either new to the VCC (e.g., running notes under the Incident Model Notes tab) or had previously been unavailable (e.g., the TMC log). Through the VCC, a partnership previously based largely on phone calls made during major incidents was extended to a shared virtual environment that could be accessed and added to in real time.

The population movement community, largely Public Information Officers, came to the VCC as the most connected interagency group. This group had already developed a shared concept of operations which the VCC attempted to build upon. Given this existing relationship, the Public Information Hub was envisioned as a place where up-to-date information on what was being said and who it was being said to was available. This not only helps align messaging and activities across agencies, but also allows administrators and the other operational communities to see what information is being shared with the public and provide input as necessary.

By building on existing operational relationships, the VCC both increases collaboration within those communities and across all operational communities.

2.2.4 Build Trust

The VCC is designed to support a secure, trusted community of transportation-related agencies and personnel. There is no access outside the agencies and operational groups that make up this community. The goal is an openness of information and operations across all VCC users. In practice, trust building is an ongoing activity that cannot be achieved all at once.

In general, the VCC has been highly successful at achieving a level of trust that supports a common presentation of relevant shared operational information. Where there are constraints on information sharing, they come from differences in agency mission and scope. City law enforcement in particular was reluctant to share response information such as the type and location of responding vehicles. This reluctance stemmed from both security and privacy concerns in the context of a mission that extends beyond transportation.

Ongoing use of the VCC should include a focus on building trust through a “one team” approach to complex transportation issues. This does not require one cookie cutter solution; through the VCC design process, agency partners have developed sensitivity to the issues and situations where constraints like those desired by a law enforcement agency make sense and should be accommodated. Perhaps most important is building the trust that when a major regional disaster occurs such as the June 2023 I-95 collapse in Pennsylvania or the November 2023 massive freeway fire on I-10 in Los Angeles, these constraints will no longer apply and the VCC will provide a critical component of regional resiliency.

2.2.5 Managing Major Incidents and Providing Daily Value

The major disasters such as those in Philadelphia and Los Angeles are a central motivation for developing VCC-like infrastructures throughout the nation, but this does not mean that the VCC can simply be kept in reserve and employed by the operational community when these rare major and extremely complex situations arise. A virtual collaborative environment must be integrated into the daily work of the community. Employing an interagency operational environment is a complex undertaking. A community of agency transportation managers and operators cannot simply pick up a collaborative environment at will, and they will certainly not turn to a new system at a time when there is the greatest stress on the transportation facilities that they are responsible for.

It is necessary, therefore, that the VCC provides daily value; value that increases as the complexity of incidents being addressed increases. This is one reason for centering the VCC around a useful feature like the Integrated Dispatch Feed. Even when there are no active Incident Models, the VCC provides an overview of regional dispatch events and access to details about those events. One outcome of the community-centered design and development activities was the lesson that the VCC had to combine its support for managing rare major incidents with capabilities that were useful on a daily basis.

This chapter has emphasized the importance of taking a community-centered approach to the design and development of VCC-like systems for achieving multimodal integrated corridor management. Section 6004 of the Fixing America's Surface Transportation (FAST) Act "establish[es] an advanced transportation and congestion management technologies deployment initiative to... develop model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment." The introduction of advanced transportation technologies like VCC is an intervention into a complex regional socio-technical system owned by a diverse community with overlapping missions. Only this community can successfully implement such technology.

Effective regional transportation system management is achieved through the interactions of people, organizations, missions, policies, procedures, and technologies. With so many interdependent components, a shared, foundational intervention like the VCC can be extremely challenging to effectively manage and successfully complete. VCC is a virtual collaborative environment, owned and operated by the operational community, which empowers this community to articulate how it wants to work and coordinate those operations, especially during times of stress when collaboration is key. Community-centered design and development is the key to achieving this goal.

Chapter 3 Evaluation

3.1 Evaluation Plan

An evaluation of the VCC was conducted to assess the impacts of the VCC by measuring progress towards the goals and expectations detailed in the grant application, and to assess the users' acceptance of and experience with the VCC. A benefit-cost analysis was also performed to provide decision-makers with return-on-investment information to inform future investments and guide future deployments.

In September 2020, the VCC Evaluation Team conducted a literature review of other demonstration and Intelligent Transportation System projects. The team reviewed the "Evaluation Methods and Techniques: Advanced Transportation and Congestion Management 2019" report provided by FHWA and consulted with VCC's expert stakeholders to prepare a first draft of the VCC Evaluation Plan. This first draft was delivered to the team at the John A. Volpe National Transportation Systems Center (Volpe) in support of FHWA on December 18, 2020. Following a review by Volpe, a meeting was held to get additional guidance on the Plan and a second draft was delivered on January 26, 2021, incorporating this guidance. Driven by the VCC's agile development process, several modifications to the Plan were made under the guidance of Volpe and the fourth and final version was delivered and approved by FHWA on February 2, 2023, prior to the official post-deployment date of February 27, 2023.

3.2 Evaluation Team

In December 2020, an evaluation team was assembled to execute the evaluation plan. The evaluation team included:

- Sonia Savelli, Senior Research Scientist at the University of Washington, was appointed as the Evaluation workstream lead in September 2020. As lead, she oversaw all aspects of the survey and interview designs, data collection, and analyses.
- Hannah Webster Heublein, from the University of Washington, joined the team in January 2021 to lead the qualitative evaluation activities, such as designing the surveys and the semi-structured interviews.
- Jeffrey Connor, Data Analytics Supervisor (SDOT); David Baker, Northwest Region ITS Operations Engineer (WSDOT); John Lee, Transit Control Center Chief (KCM) were the data experts identified by the Steering Committee in April 2021, and provided quantitative baseline data from their respective agencies.
- Ridley Jones LeDoux, a PhD student from the University of Washington, joined the team in January 2022 to assist with the development of surveys and interview questions and data collection.
- Bianca Johnson, a University of Washington Masters student, also joined the team in April 2021 to assist with quantitative and qualitative activities design activities.
- Donghoon Lee, a Fulbright Scholar and PhD student from the University of Washington began the benefit-cost analysis in April 2022 under the supervision of Layla Booshehri, Clinical Assistant Professor, Health Systems and Population Health, and Jerome A Dugan, Affiliate Assistant Professor, Daniel J. Evans School of Public Policy and Governance.

- Andrea Figueroa, a PhD student from the University of Washington, joined in June 2023 to conduct the analyses on the VCC user analytics and to assist with the quantitative analyses.
- Mishti Dhawan, an undergraduate student from the University of Washington, joined the team in June 2023 to assist with the analysis of the survey data and data collection during Phase 2 interviews.

3.3 Evaluation Timeline

The VCC Evaluation was a post-implementation evaluation to assess the outcomes and impacts of the VCC, with baseline measures collected prior to the February 27, 2023, model deployment date. Post-implementation measures were collected during three separate intervals between February 27, 2023 and ending September 30, 2023. This timing allowed the team to make comparisons to baseline performance in three separate periods, allowing measurement of any incremental improvements as users became more familiar with the VCC. The timeline for this work is listed below:

- Baseline: November 2, 2020 – February 26, 2023
- Phase 1: February 27 - May 5, 2023
- Phase 2: May 6 - July 14, 2023
- Phase 3: July 15 - September 30, 2023

3.4 Evaluation Participants

Table 3.1 below summarizes the number of participants in the surveys and interviews during the various stages of the evaluation phase. Participants were from the following agencies: Seattle Department of Transportation, Washington State Department of Transportation, King County Metro, Sound Transit, Washington State Patrol, and Seattle Police Department. The participants represented a variety of roles within Congestion Management, Incident Response, Population Movement, and Executive roles. The Steering Committee identified personnel from their agencies who would be users of the VCC once it was ready to be deployed, and these users were asked to complete the baseline survey. Users received the post-deployment surveys if they had activated their VCC login. As not all users activated their VCC accounts at the same time, this led to the varying number of survey participants asked to complete the post-deployment evaluation survey as seen in Table 3.1.

Observations were also conducted with personnel who were available during observation periods from WSDOT TMC, SDOT TOC, KCM TCC, WSDOT Incident Response Team, and SDOT Seattle Response Team. Details regarding these participants are provided in 3.6.1 and 3.7.

Table 3.1 - Evaluation Collection Methods and Participants

Evaluation Phase and Timeline	Collection Method	Participants Requested	Final Number of Participants
Baseline	Survey	152	120
	Interviews	21	17
Phase 1	Survey	51	28
Phase 2	Survey	136	41
	Interviews	43	34
Phase 3	Survey	137	41

3.5 Model Deployment Incident Models

During the model deployment period from February 27, 2023 to September 30, 2023, there were 354 Incident Models launched either automatically by the VCC or manually by a VCC user, an average of about five Incident Models every three days. Fifty-two (15%) of these Incident Models were "deleted" by a VCC user, indicating that they did not consider it to be sufficiently severe to be a VCC-level incident and therefore should not have been launched. Of these 52 deleted incident models, 23 (44%) were generated by the system, while 29 (46%) were launched by a VCC user in error. See 3.7.2 and Appendix G for a discussion of the user generated incident models, rules engine generated incident models, and recommendations for rules engine improvements. The remaining 302 were "closed" by a VCC user, indicating that these were considered valid VCC-level incidents that had been resolved.

Of the 302 Incident Models that were considered valid, 85 (28.15%) were launched automatically by the VCC, 197 (65.23%) were launched by a WSDOT VCC user, and the remaining 20 (6.62%) were launched by an SDOT VCC user. These 302 Incident Models were concentrated along the I-5 corridor as shown in the heatmap below (Figure 3.1) and only these closed Incident Models are included in the analyses that follows.

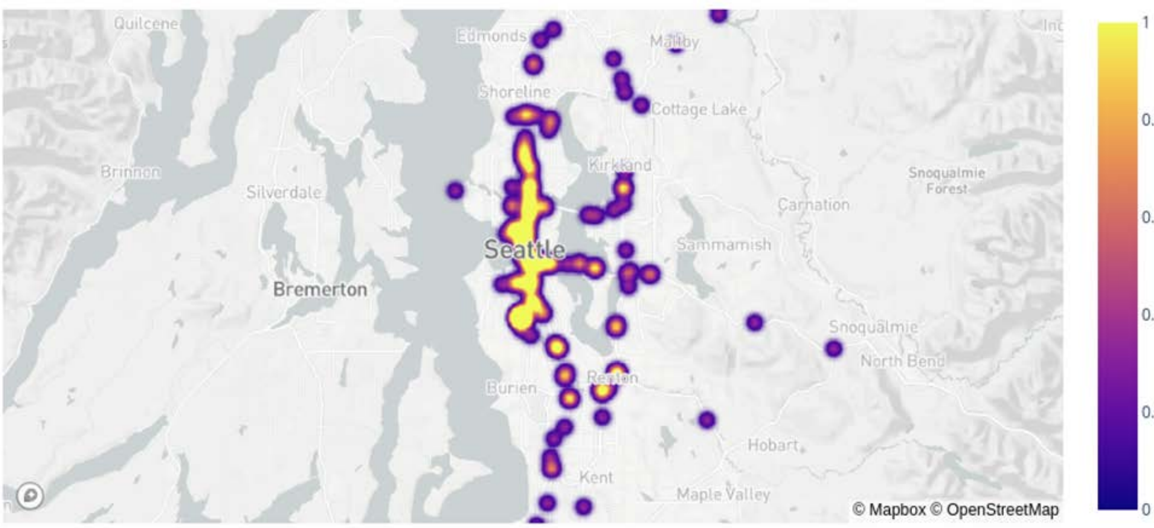

Figure 3.1 Heatmap of Incident Models

In the density scale on the right indicates, values closer to 1 represent more dense areas, such that yellow indicates incidents that are close together and purple more spread out. While the average duration of these 302 incidents was five hours and 22 minutes, with a median duration of one hour and 36 minutes, these incidents were not as severe or complex as the rollover tanker truck described in the Introduction. Contributing to these longer durations was that Incident Models may not have been closed immediately upon the clearance of an incident as VCC users may have been occupied with other tasks. As such, *Incident Model Duration* is not a true measure of an incident's severity. Furthermore, VCC users created Incident Models for types of incidents that had much longer *Incident Model Durations* (see Table 3.2). While the team did not anticipate that the VCC would be used for these types of incidents while developing the Evaluation plan, VCC users found it helpful to add these planned types of incidents to the VCC to alert other agencies that the roadways would be impacted for a prolonged period so that they could make necessary accommodations. This lack of complex incidents made it challenging to measure some of the evaluation goals and objectives included in the evaluation plan, which are further discussed in this chapter.

Table 3.2 Durations of Closed Incident Models

Incident Type	Number of Incident Models	Average Duration	Median Duration
Flammable Cargo Restriction	11	10 hours 23 minutes	5 hours 32 minutes
Maintenance Closure	19	15 hours 12 minutes	3 hours 57 minutes
Traffic Hazard Blocking Roadway	37	5 hours 24 minutes	2 hours 0 minutes
Fire Response	78	6 hours 9 minutes	1 hours 56 minutes
Collision	142	3 hours 39 minutes	1 hours 22 minutes
Other	15	1 hours 53 minutes	1 hours 22 minutes
TOTAL	302	5 hours 22 minutes	1 hours 36 minutes

3.6 Baseline Evaluation Activities

To quantify improvements resulting from the deployment of the VCC, specific baseline measurements were collected. Baseline performance measures were both qualitative and quantitative and included observations collected during the design process and a survey and interviews conducted prior to the deployment of the VCC.

3.6.1 Baseline Observations

Observations of the traffic incident management team, congestion management team, and PIOs performing tasks pre-deployment were conducted during the fourth Use Feedback Refine cycle from March 9, 2022 to March 24, 2022. Observations were conducted at the WSDOT TMC, SDOT TOC, and KCM TCC. One ride-along each was performed with Seattle's SDOT Response Team and with WSDOT's Incident Response Team. In addition to collecting feedback on the current release of the VCC, observers asked questions during tasks to obtain more objective, unbiased assessments of activities.

Relevant Incident information

People use a wide variety of approaches and information sources to identify and understand emerging incidents, and often find ways to adapt protocols to better fit their own information-seeking preferences and needs. People contend with both too much and too little information: there is always a deluge of information coming in, but none of it is comprehensively complete. Major incidents often start as one type of situation, and often turn into something else, and handling these dynamic demands continually injected information. The Project Team noticed the broad importance of "overhearing" to manage this information overload: ambient visual and auditory information was constantly being processed both in control rooms and in vehicles on the road. Planning actions during incidents, especially for people at the SDOT TOC and

WSDOT TMC, is sometimes done in reference to known or perceived incident commander intent, so a better ongoing understanding of this key data point would be highly valuable.

Procedures and Jurisdiction

While most people the team observed maintained extensive documentation on procedure and protocol, people also rely on each other to know what to do, particularly in more complex or uncommon situations. People benefit from personal relationships with trusted parties, both inside and outside their own agency, to evaluate the feasibility and acceptability of a particular option. Important work sometimes happens between procedures or through negotiation, so knowing how much a procedure can flex in a given situation is important. Jurisdiction is also complicated and can require judgment calls to address. All of this suggests that the VCC would not function optimally if it simply imported existing standard operating procedures; rather, its procedures need to develop over time through the thoughtful collaboration of its users.

Pre-VCC Impressions of Interagency Coordination

People expressed a variety of perspectives on the current (pre-VCC) state of interagency coordination during large incidents. Interagency coordination became more important when people's own tools (two-way radio, camera feeds, etc.) were having problems. Interagency coordination could thus be seen partly as a fallback or resilience strategy for intra-agency work. However, agencies working on a shared problem sometimes have work objectives that can come into tension with each other, such as a stalled bus driver's need to adhere to a clear and orderly hierarchy and wait for a supervisor to arrive on scene, versus an incident response driver's need to get traffic moving quickly by any means necessary. Tools like the VCC that enable everyone to do their own tasks as effectively as possible, and communicate more clearly about their reasoning and intent, may help with managing this tension. Considerable effort is sometimes needed to convey the same information to different audiences, since people in different settings do not all use the same terminology to describe the same things. At the time of these observations, future VCC users were already discussing the importance of creating common vocabulary in the VCC that all the disparate parties could understand and act upon. Ultimately, interagency coordination is carried out by human beings; their own relationships and personalities play a large role. If people are not currently getting valuable information from others and feel that they're being kept in the dark, interagency coordination problems can exacerbate that frame of mind.

Technology and Tools

The Project Team learned a great deal about how people effectively and tactically use the technologies at their disposal to manage incidents and congestion. In particular, various agency-specific and third-party mapping tools such as Google Maps came up frequently; accurate, timely, rich information about location is core to the work of nearly every interviewee. One VCC capability people expressed interest in was a shared map whiteboarding and annotation tool, which was eventually built into the VCC in the form of Map Annotations. Others wanted to see responding units' locations. In addition, people often use personal devices such as smartphones, or personally crafted tools outside of procedure, often as workarounds for perceived gaps in the capabilities of the tools and technologies prescribed by procedure. Some types of lower-IT-resourced stakeholders like the incident response teams expressed that "just the basics" of the VCC's functionality could be immensely helpful. Later, during model deployment, their prediction came true, as the VCC's Integrated Dispatch Feed and mapping tools alone helped incident response personnel do their jobs more effectively and efficiently.

3.6.2 Baseline Survey

The baseline survey was hosted on Qualtrics, a cloud-based survey platform that provides tools for creating, distributing, and analyzing surveys and research data. Post-deployment surveys were also hosted on Qualtrics, and these results will be discussed in 3.7. Appendix K includes all the questions and their response formats for the baseline and post-deployment surveys. The baseline survey was sent to those identified as future users of the VCC (see 3.4), and was available beginning November 2, 2022, and closed on February 22, 2023. Participants were asked to provide their agency, number of years with their agency, job title, role in incident response, and number of years in this role. Next participants were asked 21 questions concerning inter- and intra-agency communication and coordination during incident response. Finally, they were asked to indicate their role in the development of the VCC, the level of familiarity that those within their agency had with the VCC, their name, email, phone number, and any comments they wanted to provide regarding the survey.

The 120 participants who responded to the baseline survey represented all seven public agencies and had an average survey completion time of 13 minutes and 21 seconds (Standard Deviation=14 minutes, 10 seconds). Respondents had an average of 12.78 years (Standard Deviation=11.54 years) of service with their agency, and an average of 7.38 years (Standard Deviation=8.04 years) experience in incident response. More than half of respondents (57.50%) had participated in some way with the development of the VCC.

Participants were asked to rate their ability to obtain information, communication, and coordination using a visual analog scale[4] (VAS) with endpoints as indicated in the Survey Question column of Table 3.3 below by moving the slider to a location between the endpoints. The location of the marker was then converted by Qualtrics to a number out of 100. For example, the location to the far left on the difficulty scale for Question 1 in Table 3.3 would be converted to zero while the location on the far right would be converted to 100; therefore, a rating closer to zero would indicate it was more difficult to get information while a rating closer to 100 would indicate that it was easier to get information.

[4] Visual Analog Scales (VAS) have been used for various psychometric assessments, including those related to subjective experiences, emotions, and perceptions, and have demonstrated validity and reliability. We used VAS as we believe them to be more intuitive for participants, require less cognitive effort than providing a numeric value, and reduce bias as participants may be less likely to choose an arbitrary number. Participants did not see any numbers when they selected their desired spot on the visual analog scale. This was intentional as we believed that showing participants the value that corresponded to the spot would negate the advantages described above and would be no different than allowing them to enter a number between 0 and 100 into a numeric write-in field.

Based on the ratings in Table 3.3, participants had more difficulty obtaining information from those outside their agency as well as more difficulty communicating and coordinating with those outside their agency. All 120 participants responded to each of the questions in Table 3.3.

The questions in Table 3.3 were repeated on all three post deployment surveys (see Appendix K. Baseline and Post-Deployment Survey Instruments) and we show the mean responses with standard deviations (SD) in brackets. All 120 participants responded to all five questions. Comparisons between ratings on the baseline and ratings on the post-deployment surveys are reported in 3.7.

Table 3.3 Baseline Survey Questions

Number	Survey Question	Mean (SD)
1	In conducting your work, how difficult is it to get necessary information about an active VCC-level incident from others within your agency? Very Difficult … Very Easy	66.18 (20.88)
2	In conducting your work, how difficult is it to get necessary information about an active VCC-level incident from others outside your agency? Very Difficult … Very Easy	49.87 (20.77)
3	Rate your overall satisfaction level with communication and coordination within your agency during an active VCC-level incident. Very Dissatisfied … Very Satisfied	68.84 (20.18)
4	Rate your overall satisfaction level with communication and coordination between your agency and external partners during an active VCC-level incident. Very Dissatisfied … Very Satisfied	54.64 (20.14)
5	During a VCC-level incident, how often do you reach out to someone outside your agency to coordinate work? Never … Always	58.40 (29.52)

3.6.3 Baseline Interviews

Researchers augmented surveys with baseline interviews that provided greater nuance and context on VCC-relevant issues. These interviews provided a good picture of the pre-VCC operational environment. Interviewees represented a balance among operational roles, agencies, and work experience level. Twenty-one users (14%) with traffic incident management, congestion management, or public information officer (PIO) roles were selected from the 152 users identified as VCC users. These 30-minute semi-structured, online interviews included six core interview questions asked of everyone. Those primarily in a Congestion Management role were asked one additional question; those primarily in a Population Movement role were asked four additional questions. Across all operational communities, those who had indicated on the baseline survey that they were involved with post-incident reporting were also asked two questions about this topic. When possible, each interviewee was asked to describe what technology systems they used to support their work, and what their usage was like. These system usage questions are not reported in detail here; only general points of interest are described, when applicable. The full protocol, with each of its variations, is described in Appendix I.

Eighteen of the 21 users participated in interviews between December 6, 2022, and January 5, 2023. There were five interviewees from WSDOT and SDOT, and two interviewees each from SPD, SFD, KCM, and Sound Transit. Five of the interviewees had roles in incident management, four from congestion management, four had roles as PIOs, and an additional five had other roles in incident response. Half of all interviewees had between three and 10 years of experience in incident response, eight interviewees had two or fewer years of experience, and one interviewee had more than 21 years of experience.

Following are some key insights from interviewees, grouped by question set. We also offer some comments on the measures that were used during the evaluation to measure the impact of the VCC on these areas.

Internal Communication and Coordination

Interviewees described many positive aspects of their communications with internal partners during a VCC-level incident. Positive factors of internal communications were often related to personal characteristics: people working hard, being intentional and thoughtful, and being flexible. Structural factors included effective division of labor, after action reviews that enable continued learning, and strong established communication procedures within an operational community.

Negative aspects of internal communication were varied–both too much and too little information can be problematic. The most common factors were lack of clarity or of well-established procedures and roles; and logistical or other difficulties in obtaining information from relevant parties. Even when it is clear whom to contact, people are still sometimes hesitant to bother them, knowing that they are busy. Additionally, since so many groups of people, processes, and information flows are active during an incident, without putting in active effort to monitor and question, it can sometimes be easy to get out of the loop. On the other hand, multiple people described some version of an information overload, which without careful management issues can, at times, get blown out of proportion, or someone can get drowned in extraneous details. At the time of baseline interviews, it was observed that a challenge for the VCC would be to strike a balance between making it easy to stay in the loop while avoiding information overload.

External Coordination and Communication

Regarding positive experiences with external communication, participants typically called out specific agencies they had especially effective communication with. This is not unexpected, since participants across many engagements and contexts have described high-skill, trustworthy relationship-building as a major outcome of good coordination. Beyond these specifics, participants also mentioned that having well-established protocols and direct, easy-to-maintain communication channels were helpful. Some participants further mentioned that during major incidents, having more agencies involved promoted a valuable sense of interdependence between different parts of the operational community, showcasing what unique value each agency and role could contribute or that communication tends to get better over time during a long incident.

The most common theme in people's negative experiences with external communication was excessive time and/or effort involved in obtaining information or access to the right people: essentially, the opposite of the most common positive factors in external communication. Underdeveloped relationships or procedures with external partners were also mentioned multiple times.

When physical assets are impacted by an incident, it is not always immediately obvious who maintains or owns them, such as a downed light pole, and it can take time to ascertain and contact the correct party. Logistical obstacles were another key factor; incompatible radio frequencies or low staffing levels/turnover at partner agencies kept people from upholding their agreed-upon communication or coordination tasks. The VCC should provide users across all areas of incident response with a common operating picture, thereby reducing the time and/or effort involved in obtaining information or accessing it from the right people. The impact of the VCC on external communication and coordination will be measured via post-deployment surveys and interviews.

Population Movement Questions

When asked how quickly they were able to get messages to the public after an incident had started, the four PIOs reported that although speed in getting messages out to the public is important to them, speed is not the only concern. In fact, three participants mentioned using some deliberate form of slowing of messages or inserting a delay in the process. That is because the goal is not just speed but care, appropriateness, and accuracy–an incorrect, overly revealing, or insensitively worded message can cause more harm than a few more minutes of delay. When it came to accuracy, direct reports from trusted people on scene were often considered more valuable and reliable than information from computer-aided dispatches and can be a major factor in both the speed and accuracy of messages. Most participants said they are likely to get messages out within 30 minutes of when the incident occurred.

When describing what factors stopped them from getting messages out faster, most people mentioned some form of confirming that information is accurate or complete, which may also require that the message be reviewed by a supervisor during complex incidents. It was also common for people to talk about phrasing challenges; particularly when the incident involved sensitive topics such as fatalities, they did not want to put out information until it's carefully and appropriately worded. Informational obstacles, such as not knowing whom to contact to receive updates, or even physical obstacles, such as traffic congestion slowing the arrival on scene of personnel who were expected to report on conditions; could also slow down information transmission. Finally, as dispatch event types were not standard across agencies, interpreting another agency's dispatch event type could slow the creation of messaging for the public.

Most participants said that it was difficult to assess the impact of their messages, or that people's true reactions were hard to infer. It is also hard to know the impact of a negative message (such as "avoid this area"). Two PIOs mentioned the possibility of using secondary statistics to infer impact (e.g., ridership statistics and congestion analytics, respectively). Also common were observable responses from the public via media (e.g., impressions, engagements, angry complaints) or the media voluntarily carrying their message forward. Given the difficulty of measuring the impact of the VCC using quantitative performance metrics such as demand characteristics or sentiment analysis on social media, post-deployment surveys and interviews were used instead.

Congestion Management from the Propane Tanker Rollover Questions

Participants with a primary role in congestion management undertake qualitatively different kinds of congestion management activities. King County Metro, for example, can reroute buses impacted by major incidents and monitor the progress of buses along their routes. Departments of transportation, on the other hand, have less control and can only shape the environment via congestion management strategies such as signal timing changes, express lane redirection, ramp metering, etc. However, according to one interviewee, these actions have "no significant impact [on mobility]," but it is not clear what counts as a significant impact, and how much that assessment of significance is connected to measurable changes.

Congestion Management interviewees appeared to have both primary and secondary (direct and indirect) methods of assessing the impact of their actions, based on the sensing and analysis tools at their disposal and the level of resolution those tools permit. A WSDOT interviewee claimed that they could not measure the impact of congestion management strategies "in the flow of things," but only afterward. Yet even this participant described the necessity of making tactical tweaks to such things as express lane direction, even though he wasn't sure how to measure the benefits of such interventions. The VCC includes a Mobility Strategies component, but given the above comments from interviewees, measuring the success of this component using quantitative performance measures (e.g., highway detection loops) will be replaced with qualitative measures gathered from post-deployment interviews.

Reporting Questions

Participants undertook a wide variety of reporting tasks, which happened on very different rhythms. Some reporting is a regularly scheduled aggregation of all incidents in a specific period (weekly, quarterly, etc.), whereas for others it is precipitated by a major incident or a major planned event, such as a significant construction project. Two interviewees mentioned that their agency often creates several different reports for a major incident, each focusing on one specialized source of information. These interviewees hoped that the VCC would be helpful for creating reports that aid them in synthesizing information from multiple sources into one single, coherent report. Post-deployment surveys and interviews were used to assess the impact that the VCC has on report preparation and these results are in 3.7.1.

3.7 Evaluation Results

Results in this section are organized by the FAST Act goals addressed by the VCC. Each goal has one or more evaluation questions that indicate a desired outcome or impact. These evaluation questions include quantitative and qualitative performance metrics. Table 3.4 below shows the evaluation questions and measures of effectiveness from the approved Evaluation Plan (see 3.1). For a description of the performance metrics, see Appendix J Data Definitions. In some cases when quantitative data were not available, qualitative data were collected using surveys, interviews, and observations. If the desired impact or outcome was not demonstrated, potential reasons are discussed. When testing for statistically significant differences between pre- and post-deployment or between Phases was appropriate, Mann Whitney U tests with a significant p-level of 0.05 were used to assess the meaningfulness of any observed differences, such that any p-value less than 0.05 indicated that the difference between the groups was statistically significant.

Table 3.4 Evaluation Questions & Measures of Effectiveness

Number	Evaluation Question	Measures of Effectiveness
1	How satisfied are you that the VCC has improved your ability to obtain accurate information from other agencies?	Subjective rating on post-deployment survey.
2	How satisfied are you that the VCC has helped you to do your job better during a VCC-level incident?	Subjective rating on post-deployment survey.
3	How satisfied are you that the VCC has increased collaboration among agencies or operation groups during a VCC-level incident?	Subjective rating on post-deployment survey.
4	How does performance in the corridor improve during incident conditions?	Approximate time difference between when an incident occurs and when intelligent transportation system devices are activated? Approximate time difference between when an intelligent transportation system device is activated, and users are made aware that this has occurred because it appears in the VCC. Time between incident notification and arrival of tow truck. Time to incident clearance (after-deployment)
5	Do the VCC user groups trust the incident model as represented in the VCC?	VCC Users trust rating for the incident model
6	Can the TIM team leverage other agency resources (e.g., people, equipment) when needed?	Perceived benefit of being able to leverage other agency resources.
7	Is there a reduction in the effort required to prepare management reports and after-action reports?	Subjective judgments of perceived effort to produce reports
8	Is the quality of management reports and after-action reports improved?	Subjective judgments of report quality on post-deployment surveys
9	For those events where there is an incident command post, was an incident commander or designee added to the Incident Model?	Percent of time an incident commander or designee was added to the Incident Model. For those incident models without an incident commander, we will check that one was assigned before including that record in the count.

Number	Evaluation Question	Measures of Effectiveness
10	How have interactions with legacy systems changed since we deployed the VCC?	Qualitative responses during post-deployment interviews.
11	What additional data sources should be added to the VCC to improve shared situational awareness?	Observations of VCC users and responses on post-deployment surveys
12	What additional groups could benefit from access to the VCC?	Observations of VCC users and responses on post-deployment surveys
13	Has communication between the VCC user groups improved (e.g., is there less reliance on phone calls to verify incident details)?	Number of calls logged during an incident Subjective judgments of number of calls needed to verify or clarify incident information
14	Do users feel sufficiently confident about the accuracy of the incident clearance time *estimates* to include them in the VCC?	Number of times a clearance time estimate was entered/updated divided by the total number of VCC Incident models.
15	Is the CM team able to leverage shared data to assess the effectiveness of response strategies and make future improvements?	Approximate time between incident notification and response vehicle and tow truck arrival at the incident
16	Does the incident model improve the CM team's ability to monitor and manage I-5 corridor operations during a major incident?	Subjective ratings on post-deployment surveys
17	Does the VCC improve mobility during major incidents in the Seattle/Central Puget Sound Area (see Figure 2.1)?	Maximum throughput speed threshold (85% of posted speed) Percent of person-miles traveled on the Interstate system On-time performance for transit providers
18	Is the rules engine making "good" decisions in terms of auto-generating incident models for VCC-level incidents?	Percentage of auto generated VCC Incident Models that are verified Percentage of launched Incident Models that were not auto generated Percentage of historical incidents that lasted over 90 minutes but would not have been identified by the rules engine
19	What lessons were learned to reduce the demand on the I-5 corridor during major incidents that can benefit future VCC deployments in other regions?	Responses during post-deployment interviews

Number	Evaluation Question	Measures of Effectiveness
20	Do PIOs perceive that their messages to the public are getting out more quickly and are more actionable?	Approximate time between when an incident occurs and when the first message is delivered to the public Subjective ratings by PIOs regarding message responsiveness and content
21	How does using the VCC use impact your development of public messages related to VCC-level incidents?	Responses collected during post-deployment interviews
22	What lessons were learned to facilitate the creation of a unified, timely, and actionable message to members of the traveling public?	Responses collected during post-deployment interviews
23	What lessons were learned about how to engage major private employers in assisting with the distribution of messaging during a major incident response.	Responses collected during post-deployment interviews
24	Does deployment of the VCC reduce incident clearance times?	Incident clearance times

3.7.1 Institutional or Administrative Benefits

In this section we identify seven objectives that align with the FAST ACT institutional or administrative benefits goal and present the results to each of the evaluation research questions within the objective.

Satisfaction with the VCC

Three questions were included on the evaluation plan to assess satisfaction with the VCC:

Question 1. How satisfied are you that the VCC has improved your ability to obtain accurate information from other agencies?

Question 2. How satisfied are you that the VCC has helped you to do your job better during a VCC-level incident?

Question 3. How satisfied are you that the VCC has increased collaboration across agencies or groups during a VCC- level incident?

For Questions 1[5] and 3, participants responding to the post-deployment surveys were asked to rate their satisfaction on a scale from *Very Dissatisfied* to *Very Satisfied,* where a score closer to 0 indicates very dissatisfied while a score closer to 100 indicates very satisfied. For questions

[5] Question 1 was asked twice in error. Average ratings were calculated and reported on Figure 3.4.

about getting accurate information from other agencies, the average rating went up from the Phase 1 surveys to the Phase 3 surveys, indicating that VCC users were more satisfied over time. The improvement in getting accurate information from other agencies was more than just a random change as evidenced by results of the Mann Whitney U test, U=372, p=0.014. While the average satisfaction rating for increased collaboration also increased from Phase 1 to Phase 3, this increase was not statistically significant (Figure 3.2).

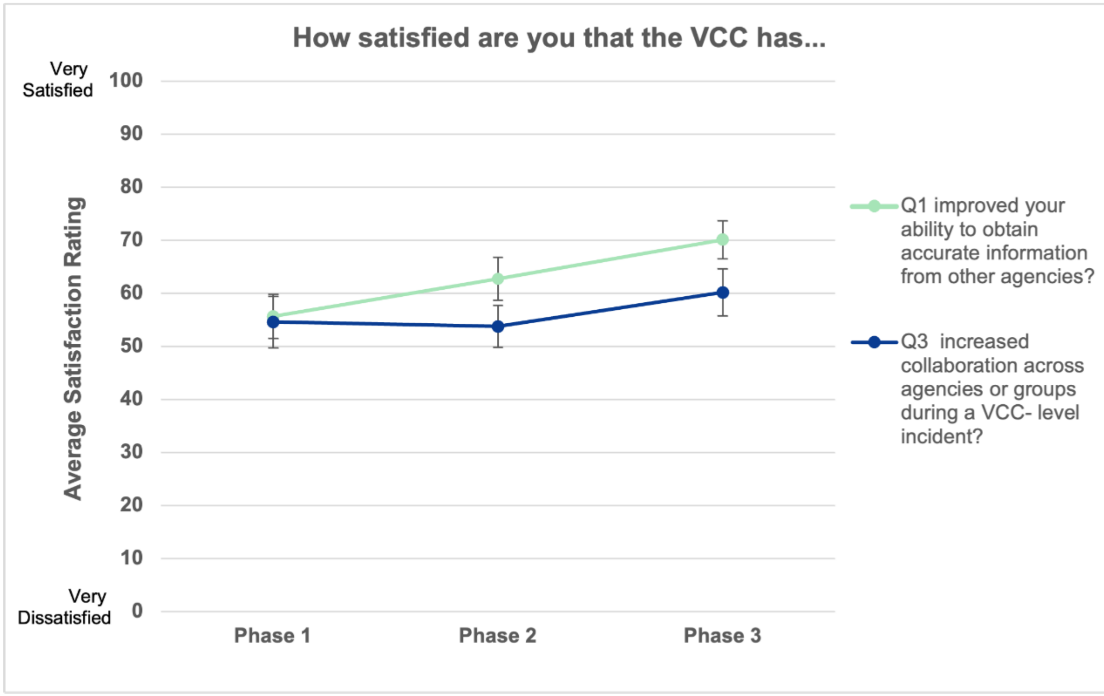

Figure 3.2 Mean Satisfaction Ratings for Evaluation Questions 1 and 3

In addition to specific questions about satisfaction with the VCC, we also asked users to report their overall satisfaction with communication and coordination with individuals within their agency and those outside of their agency. These questions were asked in the baseline survey and then again in the three post-deployment surveys (see Table 3.3, Questions 3 and 4). As seen in Figure 3.2 mean satisfaction scores were significantly higher in the Phase 3 post-deployment survey than mean satisfaction scores in the baseline survey for both communication and coordination with individuals within (Mann Whitney U test, U=1694, p=0.003) and outside of their agency (Mann Whitney U test, U=1878.5, p=0.02), suggesting that the VCC was contributing to the satisfaction with internal and external communication and coordination of large, complex incidents.

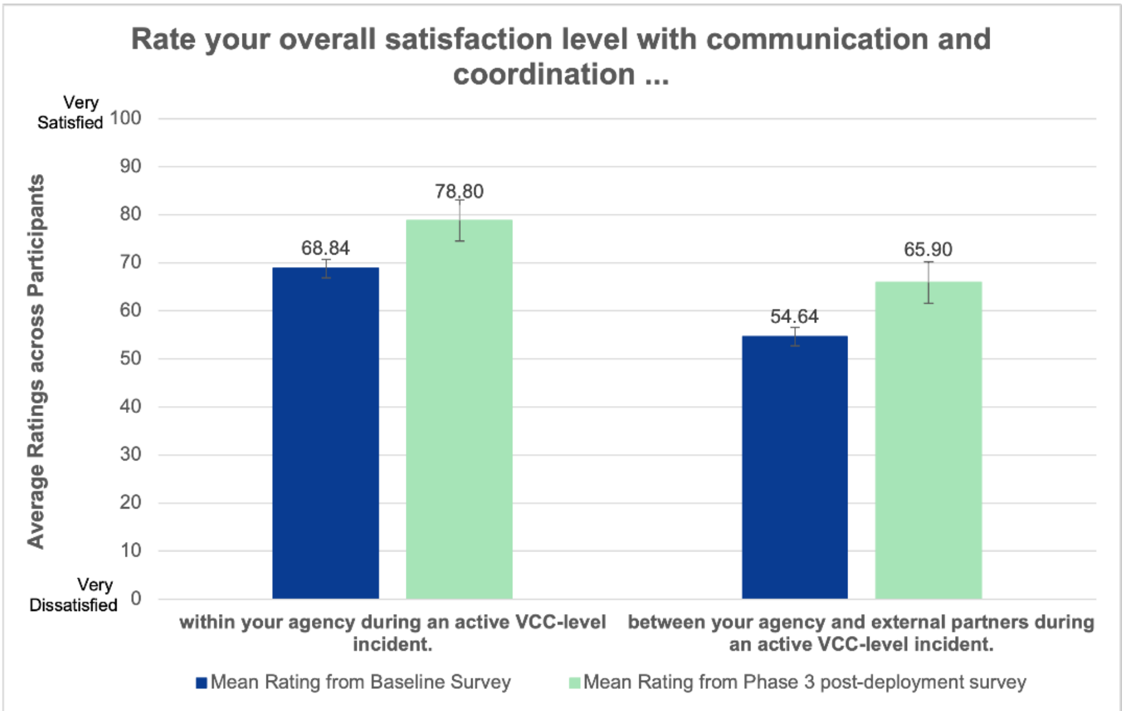

Figure 3.3 Communication and Coordination Satisfaction Ratings

To examine whether individuals with higher baseline satisfaction scores were more likely to be satisfied post-deployment, we conducted a correlational analysis. For this analysis we compared the baseline satisfaction of communication and coordination with those inside and outside their agency to scores from these measures on the Phase 3 survey including only those individuals who responded to both surveys. We found a weak positive correlation of 0.22 between pre-deployment and post-deployment satisfaction with communication and coordination with individuals inside the organization, suggesting satisfaction levels before deployment are only mildly indicative of the satisfaction levels after deployment. With regards to satisfaction with communication and coordination with individuals outside their agency we found a very weak positive correlation of 0.07, such that satisfaction levels before deployment are not a reliable predictor of satisfaction levels after deployment. In practical terms, these weak correlations imply that individuals with higher baseline scores are not substantially more likely to be satisfied post-deployment.

We did not specifically ask users Question 2, rather we analyzed use of the VCC to assess satisfaction with the VCC. User Analytics were used to measure basic user engagement and interaction with the VCC. The data and insights help to identify areas for VCC improvement and help quantify the general success of the VCC.

Data was collected during Phases 2 and 3 of the evaluation periods. The user analytics dataset contains a variety of fields that indicate use of the VCC (e.g., open Incident Model details page, annotated Situation Map, open Mobility Strategies page, etc.). Additionally, all the Incident Model reports in the VCC were collected to retrieve relevant data to complete analysis. The Incident Model report data contains fields, such as Incident ID, Incident Type, Location, etc.

Figure 3.4 shows the daily number of unique users that logged into the VCC during Phase 2 and Phase 3 of the post-deployment period. The dotted vertical lines represent the end of Phases 2 and 3. There is an overall slight increasing trend with the lowest number of users on the weekends and the busiest days on Tuesdays through Thursdays.

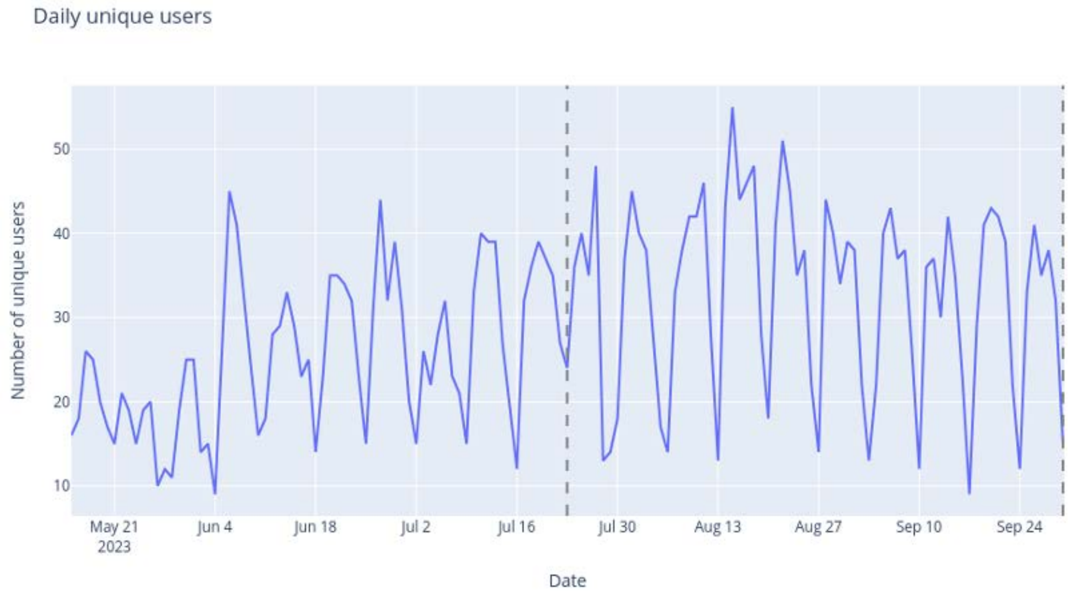

Figure 3.4. Unique Number of Users by Day

Access to all agency dispatches contributes to a common operating picture and shared situational awareness; therefore, it is not surprising that the Integrated Dispatch Feed was the most utilized area of the VCC. User analytics shows that there was a total of 6,539 interactions where the user opens a dispatch event from the Integrated Dispatch Feed of the VCC Dashboard, with a total of 25.13 events opened per user.

Provide a Clear, Accurate, and Timely Common Picture of an Incident

The ability to provide a clear, accurate, and timely common picture of an incident is key to achieving shared situational awareness. While improved awareness is not sufficient for improved performance, it is a prerequisite. The Project Team considered two associated evaluation questions:

Question 4. How does performance in the corridor improve during incident conditions?

Question 5. Do the VCC user groups trust the Incident Model as represented in the VCC?

To assess evaluation Question 4, the team collected baseline data from the SDOT TOC call logs and WSDOT's Washington Incident Tracking System (WITS) data systems for the ten-year period prior to the deployment of the VCC. Within these data sets, the following performance measures were identified in the Evaluation Plan:

a) Approximate time difference between when an incident occurs and when intelligent transportation system devices (e.g., electronic message signs, traffic signals) are activated.
b) Time between incident notification and arrival of tow truck.

The initial plan was to compare this baseline data to the post-deployment measures available in the VCC. However, the team found that these performance measures, which were entered manually into the SDOT and WSDOT systems, were not available on a consistent basis, and as such were not an appropriate performance measure to answer Question 4.

There was a third performance measure identified in the VCC data:

c) Approximate time difference between when an intelligent transportation system device is activated, and users are made aware that this has occurred because it appears in the VCC.

Of the 302 Closed Incident Models in the VCC, nine (2.9%) included one or more Mobility Strategies. In addition, four (1.3%) additional Incident Models included a mobility strategy in the Note field. Of the Mobility Strategies entered, eight involved activating an electronic message sign, four involved changing signal timings or closing ramps, and one involved diverting traffic (see Table 3.5).

It is not surprising that so few Incident Models included Mobility Strategies as it was expected that they would only be used for longer duration incidents. In fact, the average duration of all 302 incidents was five hours and 22 minutes, while the average duration for the nine incidents that included one or more Mobility Strategies was 19 hours and 11 minutes. The average time difference between when an Incident Model was created and a Mobility Strategy was entered into the VCC, was two hours and 34 minutes with a median time of 37 minutes. If the ramp closure (#10 in Table 3.5) is removed, which had a duration greater than six days, then the average time decreases to 32 minutes. While this is interesting, intelligent transportation system activations may not be an appropriate measure because it says more about the length and complexity of an incident than it does about the mobility in the corridor during an incident. It is only known when a VCC user is made aware that a mobility strategy was launched because it appeared in the VCC. The advantage of having these Mobility Strategies in the VCC is that they are viewable to all VCC users as soon as they appear in the VCC, providing a common operating picture for shared situational awareness, and as stated by one user on the Phase 3 survey:

> *Using the mobility strategy tab, we could see what has been done by other agencies for us to act on it, especially for incidents that are on interstates and state routes.*

Combining separate data streams from separate agencies to evaluate improved corridor performance during incidents proved challenging. However, the team believes that the data in the VCC which is provided by all participating agencies will lead to better evaluation of performance. Note: MP is a milepost. DMS is a dynamic message signs, an electronic message sign. MVI is a motor vehicle incident, MVC is a motor vehicle collision, and COLUNK is collision injury unknown.

Table 3.5 Mobility Strategies included with Incident Models

#	Incident Type	Location	Mobility Strategy	Notes	Duration
1	Tunnel MVI	SB SR99 TUNNEL AT TUNNEL	Activated DMS at SB SR 99 at Ward.	n/a	1 hour 5 minutes
2	Wires Down	RAINIER AVE S S NORMAN ST	DMS at NB Rainier at S College St activated	n/a	1 hour 22 minutes
3	COLUNK	I-5 NB at SR 516	n/a	['SHOOTING // ALL LANES BLOCKED NB I-5 // SR 516 RAMPS TO NB I-5 CLOSED //', 'BLOCKING TWO RIGHT LANES AFTER SR 516 // SR 516 TO NB I5 OPENED //']	15 hours 25 minutes
4	COLLISION INJURY	I-5 Express Lanes	SDOT ACTIVATED DMS FOR EXPRESS LANES CLOSURE; SDOT SIGNAL OPERATIONS TEAM MADE SIGNAL TIMING CHANGES MADE ALONG EAST MARGINAL WAY TO ACCOUNT FOR INCREASING TRAFFIC VOLUMES	n/a	6 hours 9 minutes
5	COLLISION PERSONAL INJURY	1st Avenue South Bridge, Seattle, Washington 98108, United States	Received Call from WSDOT and retweeted post. Actively Monitoring incident.	n/a	1 hour 9 minutes
6	WIRES DOWN (PHONE, ELECTRICAL, ETC.)	East Marginal Way S at S Michigan St - 4th Ave S	DMS ACTIVATED	n/a	4 hours
7	Fire in Building	4331 5TH AVE NE	DMS POSTED ON NE 45 ST AT UNION BAY	n/a	3 hours 37 minutes
8	COLLISION PROPERTY DAMAGE	S405 (JS) COALCREEK MP10-2	n/a	No mobility strategies applied.	3 hours 42 minutes

#	Incident Type	Location	Mobility Strategy	Notes	Duration
9	Fire in Building	14001 LAKE CITY WAY NE	n/a	Signal timing modified to provide more eastbound through/left and southbound left green at LCW/145th.', SIGNAL TIMING ADJUSTMENTS MADE AT 11:00 (DUE TO SIGNALS TEAM BEING OUT IN FIELD). MODIFIED EB LEFT AND SB LEFT GREEN AT LCW/145TH	24 hours 1 minutes
10	Ramp Closure	West Seattle Freeway Eastbound to SR 99 Northbound	Signal Operations Team Optimizing Signal Timing on Alternate Routes	n/a	152 hours 25 minutes
11	TRAFFIC HAZARD DEBRIS, NO LIGHTS, ETC	E90 (FM)RAINIER MP3-3	n/a	SDOT activated DMS on Rainier Ave S at S College St	49 minutes
12	COLLISION	AURORA AVE N AT ALOHA ST	DMS ACTIVATED	n/a	2 hours 25 minutes
13	MVC - WITH INJURIES (INCLUDES HIT AND RUN)	AURORA BRIDGE AT MIDSPAN	DMS ACTIVATED ON AURORA AVE N	n/a	29 minutes

To answer Question 5 VCC data was collected from VCC users at three separate times post-deployment. Users were asked to mark on a visual analog scale (VAS) their answer to the question, "How much do you trust the information that is available in an active VCC indent model?" The left endpoint on the VAS was *No Trust* and the right endpoint was *Full Trust*. These were then converted to scores out of 100 with zero indicating no trust and 100 indicating full trust. Table 3.6 shows the means and standard deviations of the trust ratings in all three post-deployment surveys. Trust was high in all three post-deployment surveys, and while there was a decrease in trust in Phase 2 compared with Phase 1, a Mann Whitney U test showed no statistically significant difference. Similarly, a Mann Whitney U test revealed no significant difference between mean trust in the Phase 1 and Phase 3 ratings, indicating that trust remained the same across the three phases of the post-deployment period.

Examining trust ratings on an individual level, we found that there were only nine participants who responded to all three post-deployment surveys with four individuals reporting greater trust over time and five individuals reporting lower trust over time. Examining the average change over time, of those reporting higher trust, ratings increase on average by 24 points, while those reporting lower trust decreased their rating by only 9 points on average. Given the importance of trust in continued use and adoption of the VCC, we recommend a future assessment of trust in the incident model.

Table 3.6 Trust in Incident Models and Trust in Dispatch Data Mean Ratings

Questions	Phase 1 (N=28)	Phase 2 (N=41)	Phase 3 (N=41)
How much do you trust the information that is available in an active VCC Incident Model?	81.39 (18.96)	75.80 (27.11)	80.66 (21.37)
How much do you trust the information in the VCC agency dispatches?	81.56 (19.13)	75.07 (24.27)	83.15 (20.26)

The Project Team also asked users on the post-deployment survey how much they trust the information in the VCC dispatches. Ratings were like those for trust in the Incident Model. As with the trust in Incident Model question, trust decreased in Phase 2, however, again this difference was not statistically significant according to a Mann Whitney U test. Nor was the difference between trust ratings in Phase 2 and Phase 3.

In the Phase 1 survey participants were also asked to explain their reasoning behind their ratings of these trust measures. In general, users trusted the information because they trusted the information source (i.e., agency computer-aided dispatch). However, six of the 28 users (21%) said that while they trusted the information in the dispatches, it tends to improve over time as more information arrives from the scene. One participant credited the VCC with improving the speed at which the information is updated:

> *Information coming in from various CAD systems is always the best information they have at the time, that tends to improve over time. The VCC allows for much quicker improvement on the information/data quality, but I know it is initially more relative as incidents develop.*

Similarly, when asked to provide an explanation for their rating of trust in the Incident Models, 12 of the 27 participants (44%) who answered this question said that they trusted the source of the data (i.e., the trained professionals entering the data into the VCC Incident Model). One participant commented that “as more agencies add to the incident, the information will be even more reliable.”

Considering that agency dispatches are generally considered a high-quality source of truth for working incidents, the comparable level of trust for VCC Incident Model information should indicate that the VCC’s Incident Models are considered quite trustworthy. The Project Team believes this is a marker of success in both creating the VCC Incident Model structure and the willingness of users to contribute broadly useful information to it. That trust in both agency dispatches and Incident Models did not significantly change over the course of the evaluation period may support a few possible conclusions, which are not necessarily mutually exclusive, and which bear further investigation in the future. Because each agency has unique expertise and access to information, and because incidents are extraordinarily complex and not fully representable in any system, it is possible that there is a ceiling of trustworthiness for the VCC that has already been achieved. Another possibility is that more users from all agencies and workgroups are needed for the VCC to achieve its full potential in terms of information richness and trustworthiness – users might be too busy to fully verify, record, and update key information in the VCC due to the demands placed on them by their jobs. In addition, the user community is still developing shared work processes around the VCC that may gradually enable more trustworthy and complete information to be recorded in the VCC.

Leverage the Resources of All Agencies

Knowing the location of agency resources contributes to shared situational awareness and allows agencies to leverage these resources in a major incident. In one-on-one online interviews conducted post-deployment from July 18 to August 11, 2023, VCC users were asked:

Question 6. Has the VCC helped you to leverage other agency resources (e.g., people, equipment) when needed?

Of the 18 users interviewed, 11 had sufficient experience with the VCC to be asked this question. Of those 11 who responded, five said that the VCC has helped them to leverage other agency resources. One participant suggested an improvement to the VCC that would allow users to leverage other agency resources, they said: "If [our SDOT Seattle Response Team] knew there was an [WSDOT Incident Response Team] nearby we could get them to help us. If the [WSDOT TMC] and [SDOT TOC] could see incident response team locations, then we could leverage them more."

Given that SDOT Seattle Response Team and WSDOT Incident Response Team units have automatic vehicle location systems, their locations could be displayed on the VCC Situation Map, thereby showing their proximity to an incident to all users of the VCC and allowing them to leverage these nearby assets when needed.

There is another way to view leveraging other agency resources. Because the VCC brings together data and people from multiple agencies, it offers new ways for a user from one agency to leverage a data resource from another agency. For example, an SDOT traffic manager at the Seattle TOC used a WSP dispatch to launch an Incident Model because it was a response to a fire that impacted city traffic. To date users are still discovering ways that the VCC can help them leverage other resources. The Project Team believes that supporting users to use the Mobility Strategies tab of the VCC more fully and effectively, easier user-to-user communication in the VCC, and the incorporation of additional data sources such as maintenance databases, can increase the VCC's ability to support this goal.

Improve the Ability to Make Informed Decisions

The value of after-action and management reports lies in their ability to capture a thorough analysis of an incident, promote continuous improvement, enhance preparedness, and ultimately contribute to better decisions in future incidents. To measure the impact of the VCC on this objective, the following questions were included in the Evaluation Plan:

Question 7. Is there a reduction in the effort required to prepare management reports and after-action reports?

Question 8. Is the quality of management reports and after-action reports improved?

Data to answer these two questions were collected using post-deployment surveys and interviews. In the post-deployment surveys, participants were first asked if they were responsible for the creation of after-action or other management reports. Those who had report creation responsibilities were then asked to rate on a VAS with endpoints *Strongly Disagree* to *Strongly Agree* the statement, “The VCC reduced the effort required to complete my reports.”

In the Phase 1 post-deployment survey, 12 of the 28 respondents indicated that they were responsible for report creation, and on average, they somewhat agreed that it was less work to create these reports (Mean =33.42, Standard Deviation=31.35). In Phase 2, 20 of the 41 respondents reported having responsibility for report creation, and they tended to have a higher agreement that it was less work to create reports (Mean = 39.50, Standard deviation = 31.50); however, this increase was not statistically significant. In Phase 3, the average agreement level increased to a mean rating of 76.60 (Standard Deviation=39.09), which was a statistically significant increase from the Phase 1 average rating, Mann Whitney U=40, p=0.002.

Report quality (Question 8) also was assessed during the Phase 2 interviews. While none of the eight interviewees responsible for creating reports had the opportunity to use the VCC to create an after-action report yet, these users did indicate that they were beginning to see the value of the Incident Model for report creation. According to one interviewee, many of their after-action reports have to do with creating a timeline, and understanding why and how decisions were made, “so having those inputs [in the Incident Model], I see the value in that.” Another interviewee commented on the value of the records management reports, which “wraps everything up into a tight little report and we can ship it off if needed.”

In conclusion, there has not yet been a representative opportunity to understand the value of the VCC for after-action and management reports, since there has not been a widely significant major incident since the VCC’s deployment. However, users are already identifying functional aspects of the VCC’s information that they can map to their known reporting needs and workflows, so the team expects that if the VCC remains in common use and those who prepare after-action and management reports are aware of the information that is recorded, success on these measures is very likely.

Changes in Incident Command Behaviors and Interactions with Legacy Systems

The Project Team expected that the VCC would result in some changes in incident command behaviors and changes to how the community interacted with their legacy systems. To assess these changes, data was collected to answer the following questions:

Question 9. For those events where there is an incident command post, was an incident commander or designee added to the Incident Model?

Question 10. How have interactions with legacy systems changed since we deployed VCC?

To answer Question 9, the team reviewed the 302 Incident Models that were created during the post-deployment period, only one included the name and agency of the incident commander. In addition to the Incident Commander field, there is a separate Incident Commander Agency field, where users can indicate which agency is currently in command of the incident, without being required to name an individual if this information is unavailable. In total 24 incidents included the incident commander’s agency. All 24 incidents were created by WSDOT personnel. Of these

24, 15 indicated WSDOT as the incident commander agency; six indicated WSP, and one each indicated SFD, and Whatcom Fire. As of the writing of this report, WSP, SPD, and SFD responders have not used the VCC during incident response, and Whatcom Fire is not a VCC member agency. However, it is expected that when more complex incidents occur that these agencies will have more need for the VCC and will either enter the incident commander and incident commander agency fields or provide the information to SDOT or WSDOT VCC users to enter the information.

Question 10 was asked during the Phase 2 Interviews. Of the 18 interviewees, eight shared how their interactions with legacy systems changed since the deployment of the VCC. The majority of interviewees had access to some dispatch data via other systems. For example, WSDOT TMC personnel have access to a WSP CAD client, while SDOT TOC has Viewpoint, which has dispatches from SPD and SFD. For WSDOT TMC personnel, the additional information that is available in their existing WSP CAD client results in their continued use of the CAD client as their primary source of information. WSDOT Incident Response Team, however, does not have access to the WSP CAD client and as a result have come to rely on the VCC and use it daily. According to one responder, “we've created an addiction to this [VCC].”

At the SDOT TOC, interaction with their legacy system, Viewpoint, has not changed. Again, this is primarily due to the additional information in Viewpoint that is not in the VCC. According to one interviewee, the Situation Map in the VCC is superior to the Viewpoint map because the map populates with dispatch events faster than they do in the Viewpoint map. Interviewees at KCM also said their interactions with legacy systems have not changed, primarily because they use those systems for major transit system disruption, which are not necessarily caused by traffic incidents.

For Question 9, the team cannot draw any significant conclusions yet, as there is not enough information to reason about. The team believes further analysis will be possible when a more robust first responder user base is interacting with the VCC, since first responders tend to be incident commanders most frequently. It is also likely that to learn more about the use of this information if a very large, serious incident occurs that implicates a multi-agency incident command structure. The team observed that having a separate incident commander agency field seems useful and might itself be actionable/helpful information, since this field was used significantly more often than the Incident Commander field. The team recommends learning more about the unique value of indicating an individual Incident Commander, or possible drawbacks if there are long incidents where who the acting Incident Commander is can change, and the information can get stale faster than some other fields.

Interactions with legacy systems have not changed for the most part; however, for an incident that involves agencies across jurisdictions there are tools, such as the Mobility Strategies, which would be utilized to notify all agencies of something like the activation of an electronic message sign or signal timing change. Changes in use to existing systems, where they do occur, seem to depend on perceived information or functionality gaps in existing systems. These gaps are not the same agency to agency, so the unique value of the VCC for overall sensemaking and work are not the same. More can be learned about this by adding and incorporating a wider variety of users who have different relationships with their systems.

Share Project Insights Regarding Shared Situational Awareness

To understand what project insights were learned regarding shared situational awareness during the evaluation, respondents were asked on surveys and during interviews the following two questions:

Question 11. What additional data sources should be added to the VCC to improve shared situational awareness?

Question 12. What additional groups could benefit from access to the VCC?

During observations and interviews throughout the evaluation several additional data sources were suggested that could improve the Situation Map, including tow truck locations, DOT maintenance vehicles, construction equipment, electronic message sign locations, and weather data. Knowing the location of these resources could allow for improved timing to arrive at the scene by deploying nearby resources, while weather information could be used to alert responders to poor driving conditions that could impact their estimates of arrival times to the incident scene. Additionally, if agencies know the location of their resources, they can request them specifically, if necessary. Congestion managers responsible for state roads also wanted milepost markers indicated on the Situation Map.

One city employee also requested that more accurate construction information be displayed on the Situation Map as some projects were missing entirely while others did not include important information such as estimated length of closure. Currently the VCC includes construction event data from INRIX, and while this is valuable, it is not always complete. SDOT also has construction data; however, it is not always up to date either as there are many challenges involved in maintaining current construction data. For example, sometimes construction is postponed, or it does not take up a whole lane, which is not always reflected even in the SDOT system. Knowing if an entire city street is closed due to construction or a long-term closure is essential for developing detour plans. In addition, interviewees also requested adding a layer on the Situation Map for flammable cargo restrictions and planned events (e.g., a Seattle Mariners home game today at 11am). Including icons on the Situation Map for the location of responders with a check in/checkout box that shows that if an agency is on the scene would also be useful congestion management information.

Transit partners suggested that having a map layer showing bus routes could help to quickly identify which transit routes could be impacted by an incident, allowing them to begin planning reroutes earlier. In addition, they suggested that transit and Link light rail alerts could be included because an incident involving a bus that breaks down on I-5, even if it’s on the shoulder, could impact traffic because passengers must be transferred to another bus, which would require a trooper from WSP to block a lane to ensure the safety of the passengers.

When asked Question 12 on the post-deployment surveys, approximately half of participants suggested one or more groups who could benefit. VCC users suggested a wide range of federal, state, county, and city entities that could benefit from the VCC, including:

- Railroads, Airports
- United States Coast Guard
- Port of Seattle

- Washington State Department of Ecology Spill Response Team
- State Contractors
- WSDOT and SDOT Maintenance and Construction crews
- Transportation Management and Operations Centers across Washington State
- Pierce and Community Transit
- Elementary and secondary schools
- SDOT Commercial Vehicle Enforcement
- City of Seattle Office of Emergency Management
- Construction Crews
- Seattle City Lights
- Stadium and arena management offices
- King County Sheriff

With respect to questions 11 and 12, it was found that users are thinking broadly and proactively about how much more the VCC could benefit them and others. They can readily imagine how additional data sources, such as the locations of incident response teams, could be added to the Situation Map, indicating that the system's features are clear and useful to them in the development of shared situational awareness. However, this does also mean that there are some ways to go before it fully and robustly supports shared situational awareness. It is also evident from the extensive list of suggestions for new user groups that Seattle area users see the benefits of the VCC and want others in the area to receive those benefits as well. The team speculates that additional user groups' participation would also contribute to the general perception of usefulness of the VCC, since users have indicated that the VCC will be more generally useful the more fully others are using it.

Improve Intra-agency and Inter-agency Coordination

Below are the results for the three research questions included in the evaluation to assess the effect of the VCC on intra-agency and interagency communication and coordination:

Question 13. Has communication between the VCC user groups improved (e.g., is there less reliance on phone calls to verify incident details)?

Question 14. Do users feel sufficiently confident about the accuracy of the incident clearance times to include them in the VCC?

Question 15. Is the Congestion Management team able to leverage shared data to assess the effectiveness of response strategies and make future improvements?

VCC users were asked on the baseline and post-deployment surveys to mark on a visual analog scale from *Never* to *Always* how frequently they used cell phones and landlines to communicate with people in their agency and outside of their agency. The markings on the scale were converted to a number out of 100 and then the three post-deployment survey ratings were averaged across surveys for each respondent. While the team hypothesized that users may rely less on phone calls to coordinate their responses, it was also possible that given the additional information that users had access to via the VCC, they may have more questions and a need to communicate more. Indeed, in post-deployment interviews, respondents said that increased phone calls were not a negative outcome and that overall communication improved.

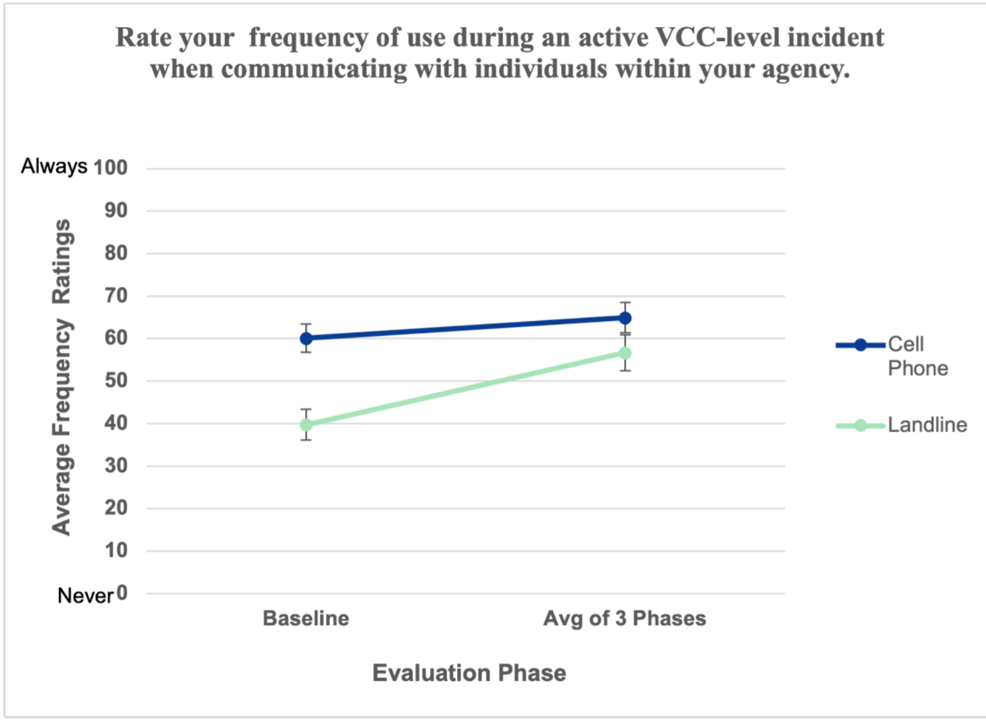

Figure 3.5 Internal Communication Frequency Ratings

When comparing the average rating across the three post-deployment phases to the baseline rating, there was no statistically significant difference in the frequency of cell phone use (See Figures 3.5 and 3.6). However, one Phase 2 interviewee with a WSDOT incident response team member remarked that “People are starting to get information without making as many phone calls.” With respect to using landlines to communicate during incidents, there was a significant increase in the frequency of landline use both internally (Mann Whitney U=3570, p<.001) and externally (Mann Whitney U=2688, p<.001). This may be a result of traffic engineers in WSDOT TMC and SDOT TOC using landlines to communicate and coordinate now that they share a common operating picture.

On the Phase 3 post-deployment survey we also asked participants with a role in congestion management to rate their level of agreement with the statement, “Now that I have the VCC, I am coordinating with more people outside of my agency.” The average rating for the 11 participants who responded was 45.91 out of 100 and a median rating of 59 out 100.

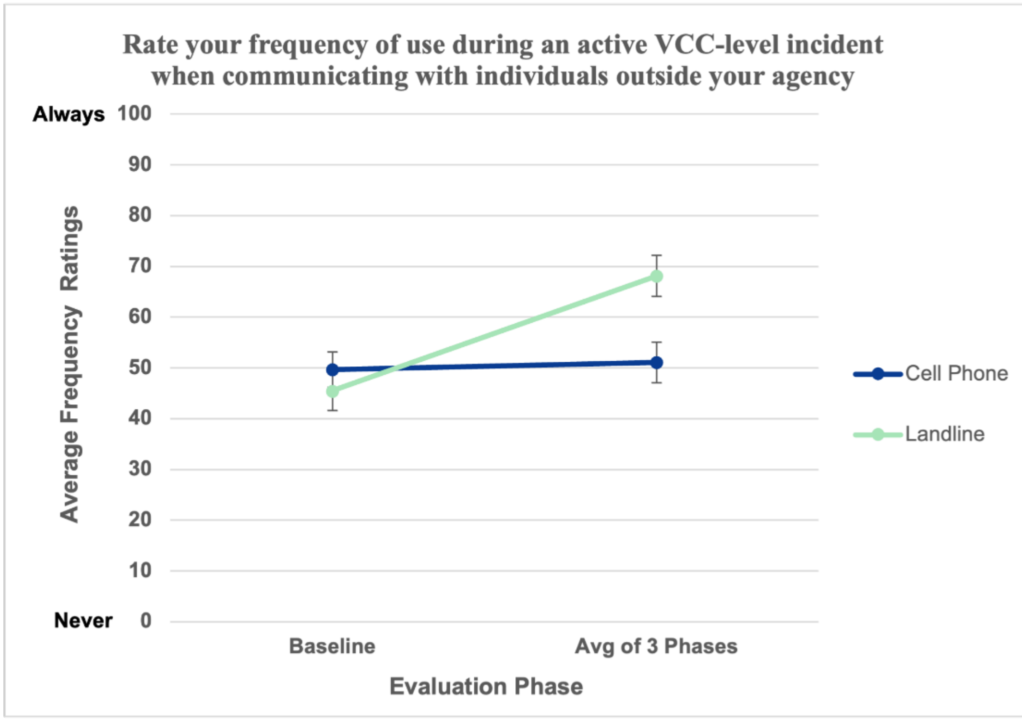

Figure 3.6 External Communications Frequency Ratings

We also asked participants in both the baseline and post-deployment surveys, "During a VCC-level incident, how often do you reach out to someone outside your agency to coordinate work?" (see Table 3.3, Question 5). As information was now available in the VCC via the incident model, we expected that the mean participant rating from the Phase 3 post-deployment survey would be less than the mean participant rating from the Baseline survey. Indeed, we found that the mean rating across all 41 responses in the Phase 3 survey (mean = 55.29, standard deviation = 33.68) was less than the mean responses of the 120 baseline respondents (mean = 58.40, standard deviation = 29.52); however, this difference was not statistically significant making it difficult to draw and clear conclusions. Furthermore, there was a large diversity of responses (high standard deviation) in both the pre- and post-deployment survey, which could be due to various factors such as role in incident response, personal preferences, or incident factors. An analysis of rating by role did not reveal any additional information, suggesting that the diversity of responses may be due to the incident itself, and therefore not a robust measure of communication and coordination.

To answer Question 14, we examine the Incident Models in the VCC. Of the 302 VCC Closed Incident Models, only 18 (6%) included an estimated clearance time. This is not surprising, given that in the baseline interviews and surveys VCC users preferred not to give estimates as they believed them to be unreliable. As seen in Table 3.7, three of the estimated clearance times were overestimated, while seven were underestimated, and only one included updated clearance times. Interestingly, Table 3.7 shows that the VCC was being used for more than traffic incidents. Eight (44%) of the incidents were special events, construction events, road closures or restrictions, and maintenance. In these VCC incidents clearance time estimates were provided, perhaps because they were easier to estimate.

Table 3.7 VCC Incident Models with Estimated Clearance Times

Incident Type	**Location**	**Estimated Clearance Time**	**Duration in Hours and Minutes**
Collision	I- 5, Seattle, Washington 98108, United States	['90 minutes to 2 hours']	1 hours 19 minutes
COLLISION INJURY UNKNOWN	N5 (JS)SR18	['2 to 4 hours']	4 hours 25 minutes
COLLISION FATAL	S405 (JN)SR167	['2 to 4 hours']	4 hours 52 minutes
COLLISION PERSONAL INJURY	S509 (TO)W Marginal Way	['4 to 6 hours']	2 hours 48 minutes
Emergency Maintenance	Ship Canal Bridge, Seattle, Washington, United States	['13:00 hours']	2 hours 33 minutes
Delayed opening of I-5 Express Lanes	I-5 Express Lanes	['90 minutes to 2 hours']	4 hours 21 minutes
Closure	I 5 Express, Seattle, Washington 98102, United States	['6 to 8 hours', 'More than 8 hours', '8pm', 'see notes']	20 hours 14 minutes
Construction closure	Northbound I 5 Mainline, Seattle, Washington 98102, United States	['4 to 6 hours']	20 hours 33 minutes
FLAMMABLE CARGO RESTRICTION	I 90, Mercer Island, Washington 98040, United States	['April 12th']	64 hours 7 minutes
INCIDENT	N5 (FM)DEARBORN MP164-6	['90 minutes to 2 hours']	1 hours 26 minutes
Special Event	Sr 99 Tunnel, Seattle, Washington 98109, United States	['2 to 4 hours']	2 hours 54 minutes
Special Event	Washington Highway 99, Seattle, Washington 98109, United States	['2 to 4 hours']	3 hours 9 minutes
Structure FIRE	SR539 E LAUREL RD	['90 minutes to 2 hours']	7 hours 36 minutes
Roadway maintenance	Southbound I-5 just south of NE 45th St	['90 minutes to 2 hours']	1 hours 9 minutes
MVC - UNK INJURIES	3501 East Marginal Way South, Seattle, Washington 98134, United States	['20:07']	1 hours 34 minutes
Ramp Closure	West Seattle Freeway Eastbound to SR 99 Northbound	['Unknown']	152 hours 25 minutes

Incident Type	Location	Estimated Clearance Time	Duration in Hours and Minutes
Collision	I 5 Express, Seattle, Washington 98102, United States	['less than 30 minutes']	0 hours 9 minutes
COLLISION PROPERTY DAMAGE	N9 (JN)MP91	['90 minutes to 2 hours']	2 hours 55 minutes

To answer Question 15, VCC users with congestion management responsibilities were asked on the post-deployment surveys, how likely they were to make alterations to their congestion management strategies in future incidents after seeing the information from partner agencies in the VCC. Again, participants were asked to mark their rating on a visual analog scale with endpoints, *Very Unlikely* and *Very Likely* and then this was converted to a score out of 100. Fourteen participants answered this question on Phases 1 and 2 surveys, while 11 responded to it on the Phase 3 survey. Ratings increased from a mean of 44.57 (Standard Deviation=31.72) in Phase 1 to 55.36 (Standard Deviation=32.69) in Phase 3 (Figure 3.7). While this difference is not statistically significant, this is likely due to the small number of participants responding to this question.

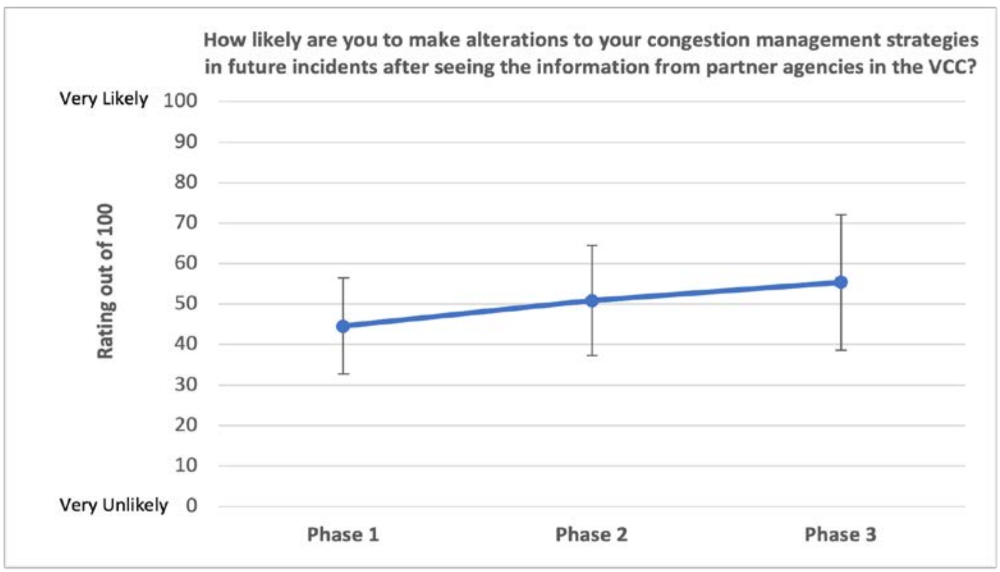

Figure 3.7 Altering Mobility Strategies Likelihood

In addition, participants were asked on the Phase 3 survey to explain their reasoning for their rating. Of the eleven participants who responded, six were from WSDOT, three from SDOT, and one each from KCM and SPD. Three of the participants responded that there was not yet enough experience with the VCC or data available in the VCC to make a substantial impact on their mobility strategies during a response to a major incident, and the respondent from KCM said that they did not utilize the VCC for congestion management. The remaining seven respondents, however, provided higher ratings (lowest rating was 58 out of 100 while the highest was 100 out of 100) and indicated that they were likely to make changes in mobility strategies in future incidents given the information in the VCC. Below are quotes from two participants:

> *The information flow in VCC to other agencies is far faster than any other means we currently use. The more that operators become familiar with it, the more impactful it will become.*
>
> *Can make faster decisions on the fly. Easier to pivot on the fly.*

It is particularly challenging to draw clear conclusions from the assessment of these evaluation questions given the small number of respondents and the lack of complex incidents during the post deployment period. However, at least some VCC users, particularly those at the DOTs with existing histories of interagency collaboration, find the VCC a way to enrich their interaction with each other even if the mode of that interaction (e.g., telephone) does not entirely shift to the mode of the VCC.

Overall, the evaluation demonstrated that the VCC provided many institutional and administrative benefits. The trusted data available in the VCC provided a common operating picture of an incident thereby increasing shared situational awareness and improving intra-agency and inter-agency coordination for users of the VCC. As discussed above, these VCC users are gradually learning to use the VCC and to incorporate it into their work, and protocols and processes are still being created and refined. Since no significant major incident occurred that required extensive, ongoing collaboration between agencies since the deployment of the VCC, it has not had the opportunity to be fully stress-tested with respect to institutional and administrative benefits. Therefore, the Project Team strongly recommends reassessing this suite of evaluation questions after a longer period of VCC adoption and learning curve.

3.7.2 Reduced Congestion and/or Improved Mobility

We identified three objectives that align with the FAST ACT goal of reducing congestion and/or improving mobility, and present below the results of the evaluation questions for each objective.

Provide Agencies with Access to Trusted, Secure, and Actionable Data to Quickly Respond to Congestion Resulting from Major Roadway Collisions

To measure the VCC's ability to improve mobility during a major incident the evaluation plan included one qualitative and one quantitative question:

Question 16. Does the Incident Model improve the Congestion Management team's ability to monitor and manage I-5 corridor operations during a major incident?

Question 17. Does the VCC improve mobility during major incidents in the Seattle/Central Puget Sound Area?

On the post-deployment surveys, VCC users whose primary role was to manage the congestion resulting from major incidents were asked to use a visual analog scale with endpoints of *Strongly Disagree* on the left and *Strongly Agree* on the right to rate their level of agreement with the following statements.

- The VCC Incident Model has improved my ability to monitor and manage I-5 corridor operations during a major incident.
- I feel I have more information about an incident now that I have access to the VCC.

There were 14 VCC users who responded to this question on the Phase 1 and Phase 2 post-deployment survey and 11 on the Phase 3 survey. As seen in Figure 3.8, agreement with the above two statements was approximately 50 out of 100 for both questions and increased to approximately 54 and 58; however, this increase was not statistically significant.

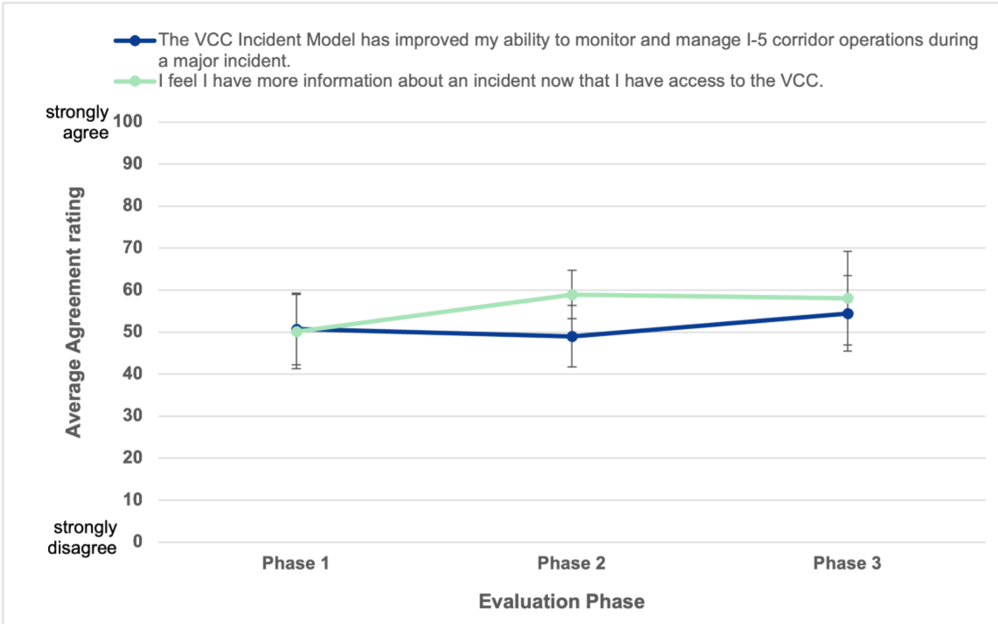

Figure 3.8 Impact on Mobility Ratings by Congestion Managers

To increase participation in the evaluation, those users who had activated their VCC login were asked to respond to a series of one-minute surveys during Phase 3 of the post-deployment period. These surveys included one question requiring a *Yes* or *No* response. Table 3.8 shows the questions asked, the percentage of respondents answering *Yes*, and the number of respondents who indicated that they had enough experience with the VCC to answer this question. While the response rate was like the above questions on the longer post-deployment surveys asked only of congestion managers, these respondents also included first responders and public information officers. This suggests that the VCC has valuable information, saves them time when working an incident or managing congestion, provides them with information that they cannot find elsewhere, and improves their ability to coordinate with other agencies across all incident management roles.

Table 3.8 Phase 3 One-Minute Survey Questions

One-minute Survey Question	Answered Yes (%)	# of Participants
Has the information in the VCC been useful to your work?	93%	14
Has the VCC saved you any time when working an incident or managing congestion?	56%	16
Has your ability to coordinate with other agencies improved since using the VCC?	69%	13
Has the VCC provided relevant information you could NOT have easily obtained elsewhere?	83%	18

Access to trusted, secure, and actional information is a key component of managing the congestion from a large, complex incident; therefore, we expected participants would find it easier to obtain information during a large, complex incident one they became familiar with using the VCC. On both the baseline and post-deployment surveys we asked participants to rate their level of difficulty in obtaining necessary information about an active VCC-level incident both from others internal to and external to their agency. As expected, we found that participants rated their ability to get information from those external to their agency as easier post-deployment than pre-deployment; however, this difference was only marginally significant, Mann Whitney U=2026.5, p=0.09 (see the two bars on the right in Figure 3.9). Somewhat surprisingly we found an even greater, and significant, improvement in the ability to get information from those within their own agency, Mann Whitney U=1532, p=0.0003. This improvement may be a result of individuals outside of the WSDOT Traffic Management Center and SDOT Traffic Operation Center, such as incident response team members and executives, getting access to incident data via the VCC rather than having to call into these centers to get information. A review of the individuals responding to the Phase 3 survey confirms this hypothesis. Approximately 60% of the respondents were from one of these two groups and they had a mean rating of 85.21 compared with a rating of 70.47 for those participants in roles within the centers.

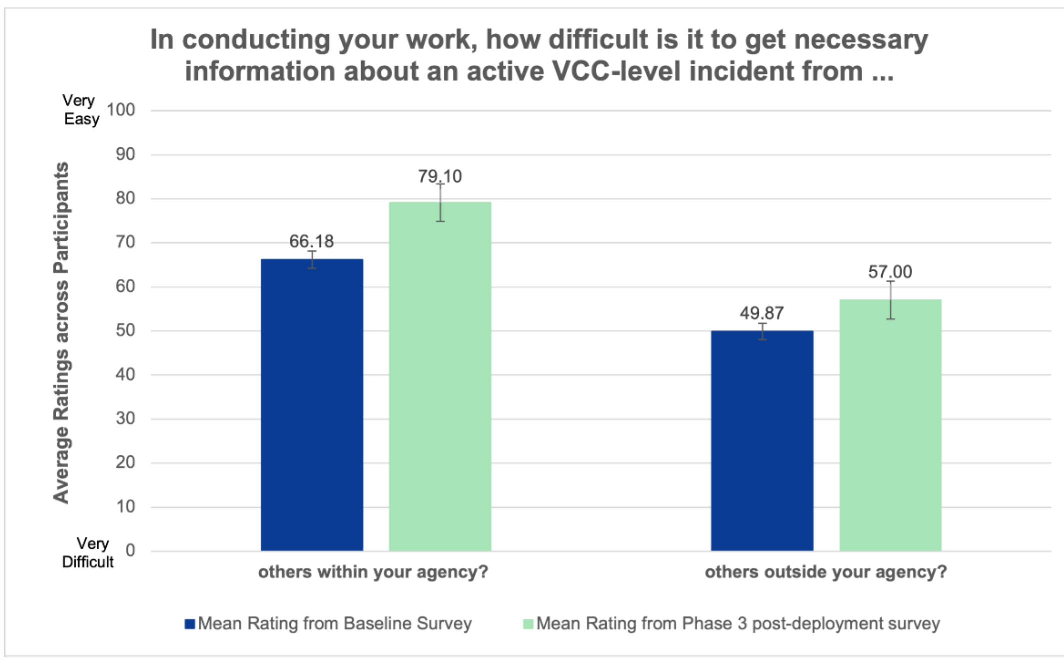

Figure 3.9 Obtaining Information Ratings

Answering Question 17 using quantitative measures such as maximum throughput, percent of person-miles traveled on the interstate, and on-time performance for transit providers was much more difficult. For example, while on-time performance for transit providers is available from KCM, finding comparable incidents of similar complexity pre- and post-deployment was challenging as KCM does not include incident data along with their performance records. In addition, assigning a causal relationship to any increase or decrease in on-time performance to the VCC was not possible, primarily because VCC use at KCM and Sound Transit was limited due to staffing shortages. Despite the slow adoption of the VCC, those VCC users in the KCM Transit Control Center who were using the VCC found certain capabilities to be very useful. For example, the Situation Map was frequently used to see which incidents could impact transit routes. They also made use of the camera layer on the Situation Map as they previously had only limited access to WSDOT cameras and found the cameras on the VCC easier to use than those on the public feeds. According to one VCC user from KCM:

> *It's [the VCC] the best tool we've seen for traffic camera visuals. Seeing an event unfolding is very important for us. VCC is very intuitive for people who are visual – better than some list-based systems.*

The lack of very large major incidents may be affecting the strength of the survey responses as well as the ability to evaluate mobility using the above quantitative measures. As more users adopt the VCC, measuring mobility improvements during incidents will be better and easier. It may also be the case that the learning curve of the VCC is taking longer than we would have hoped for some users. To that end, the Project Team proposes some user experience enhancements and additional data sources in Appendix F. In the future these questions should be evaluated again to determine if additional users, improved familiarity with the VCC, or the planned improvements have had the desired effect on mobility.

From the one-minute survey results, the high percentage of respondents (83%) who said they did get information they could not have easily obtained elsewhere seems to contradict the more neutral responses on the evaluation survey. As previously indicated, this may be due to slightly different demographics; those who reply to the one-minute survey are likely those who are more active users, so they might be already aware of the benefits of the VCC to them. The Project Team wants to ensure that the VCC has value for as wide a range of users as possible, so we would ideally prefer to have similar ratings from both instruments. Further, almost all one-minute survey respondents said that the VCC has been useful, but only about half have said it saved them time. This echoes interview findings that time saved is sometimes less important than information density or quality of time spent.

System Alerts of Major Incidents

Another way to reduce congestion is to provide users with system alerts that give them earlier awareness of evolving major incidents. This awareness enables them to get an earlier start on coordinated actions to ameliorate the situation. This was evaluated by focusing on the VCC rule-engine, and asked the following evaluation question:

Question 18. Is the rules engine making good decisions in terms of auto-generating Incident Models for VCC-level incidents?

As dispatches come into the Integrated Dispatch Feed, they are evaluated by transportation managers who can launch an Incident Model if they are seen as indicating a likely VCC-level incident. In addition to this human review, the VCC applies these rules to identify possible VCC level incidents:

- Events from Seattle Fire Department that include "Tunnel MVI", "Car Fire Freeway", or "Fire Response Freeway" in event type.

- Events from Washington State Patrol in Area “I5” that include “Road Closure”, “Fatal Traffic Collision”, “Disabled Vehicle Fire”, or “Possible suicidal pedestrian on bridge or overpass” in event type.
- Events that include “*bridge”* in location and *“blocking”* in event type.

If a dispatch meets these criteria, the VCC auto-generates an Incident Model based on the dispatch, and an email alert of a system generated Incident Model goes out to users. All system-generated Incident Models must be verified by a human Incident Manager.

While the rules engine provides some early notification of potential major incidents, there are many cases where VCC-level incidents are not automatically classified as such in the VCC system. This is due both to limitations of the rules and to the nature of incidents, some of which appear to be relatively common occurrences but evolve into more complicated situations. The analysis of large amounts of data from dispatch events and incident logs, as well as other relevant data sources, can provide useful insight into the characteristics and patterns of events and responses, enabling both enhanced and improved rules for auto-detection that provide early awareness of evolving incidents. An analysis of the rules engine and Incident Models can be found in Appendix G.

The team found that the rules engine generates several false positives, which requires additional labor on the part of users because they must manually delete these misidentified incidents. However, these system-generated false positives have not been increasing in number over time as the number of total incidents has increased, indicating that the *relative* burden of managing them is decreasing. In addition, because of an unexpected increase in complexity, a small number of false positives may not be entirely avoidable.

There are also quite a few false negatives in terms of human-generated incidents based on collision-focused dispatch events. The incident types of such human-generated incidents often include the term *collision* (such as COLLISION INJURY UNKNOWN), but since that is such a common dispatch event type indicating early uncertainty about a given situation, it on its own would not be significant enough to lead to a system-generated Incident Model. Further analysis of such incidents is needed to determine what *additional* characteristics of such dispatch events might be automatically detected and lead to a system-generated Incident Model. It is also possible that such additional characteristics tend to be added later in the life cycle of a dispatch event, or are correlated with non-dispatch information, and thus *would not be recorded by the originating dispatch systems* before a human VCC user would detect them anyway. It may well be that their curation and evaluation as VCC incidents by human users is already happening as quickly and efficiently as possible. Further research is needed to determine this, or if there are methods of detecting relevant information beyond an individual dispatch event’s data (such as geographic proximity to other dispatch events recording similar information).

Closed incident models can provide us with a deeper understanding of how the rules engine performed in the automatic classification of dispatches as VCC-level incidents. Every incident model in the VCC can be either (1) *closed* when the situation is cleared or (2) *deleted* if it was created incorrectly, was a test, or was system generated and never verified. Table 3.9 shows the number of Incident Models that were both closed and deleted, how many of them were created by users versus the system, and how many had a duration greater than 90 minutes.

The closed system generated Incident Models represents 28.15% of all closed Incident Models, while the deleted system generated Incident Models are 44.23% of all deleted models. This higher likelihood of system-generated incident models being "incorrect" was expected, as the rules engine is still quite simple and may inaccurately classify some dispatches as Incident Models, which are later deleted as unverified. However, out of all the system-generated Incident Models (108), only 21.29% were deleted, suggesting that almost 80% of all these Incident Models were verified by a user or at least worthy of closing (which maintains a record). This suggests that the initial design of the rules engine was a promising start, as it was able to identify about four out of five real incidents.

User generated incident models can also be used to assess the rules engine. While 217 incident models were generated by a user, that is the rules engine failed to identify them first, we must also consider that 14% (30) of these were Flammable Cargo restricts (11) and Maintenance Closures (19) that were planned events which are not recorded by any of the agency dispatches. Taking this into consideration, we see that the rules engine failed to identify 62% of incident models. In addition, 27% of incident models were correctly identified by the system. In Appendix G, we present proposals to reduce these missed incident models based on user input and analysis of Incident Models to identify patterns that might lead to more specific and accurate rules.

Finally, we can look at duration of the incident models to assess the rules engine. From Table 3.9 we see that 50% of the incident models generated by users had durations greater than 90 minutes compared to 54% generated by to the rules engine. While the rules engine was slightly better at identifying longer duration incidents, we must keep in mind that incident models may not have been closed immediately upon the clearance of an incident as VCC users may have been occupied with other tasks (see 3.5 for additional details) so we should be careful to draw too many conclusions from this performance measure.

Table 3.9. Incident Models with Closed or Deleted Status and longer than 90 minutes

Incident Model Final Status	Created by	Number of Incident Models	Duration longer than 90 minutes
Closed	User	217	109
	System	85	46
Deleted	User	29	n/a
	System	23	n/a
TOTAL	n/a	354	155

From this analysis, we can draw the conclusion that the identification of major incidents is a subtle and complex issue that will benefit from ongoing iteration: both in terms of updates to the rules engine, and thoughtful discussion with users as they learn to incorporate the VCC's information into their workflows.

Lessons for Demand Reduction

To benefit future deployments of the VCC to other regions, participants were asked the following question:

Question 19. What lessons were learned to reduce the demand on the I-5 corridor during major incidents that can benefit future VCC deployments in other regions?

During the post-deployment interviews VCC users were given the opportunity to discuss what they learned when using the VCC for traffic and congestion management and how it might benefit future deployments. One interviewee suggested that having a common set of event types would make it easier for users from different agencies to quickly scan the Integrated Dispatch Feed to decide which events to monitor. For example, an event involving a motor vehicle sometimes uses the acronym MVC in the event type, while other agencies use COLUNK, which stands for "Collision, Injury Unknown."

Another interviewee suggested using the VCC for planned events, such as the Taylor Swift concert and the Major League Baseball All-Star game in Seattle in July 2023, because they require extensive coordination between agencies prior to, during, and after the event. While the VCC's Incident Model was designed using unplanned, traffic-related use cases, VCC users found ways to use it for planned events, such as closures and maintenance discussed in 3.7.1, demonstrating that its use could be expanded to planned events.

Additionally, beginning to plan for how to use the VCC to manage major, catastrophic events such as earthquakes was suggested by an interviewee. Knowing what's still operational (rather than what is not) would help with the rerouting of commuter traffic as well as the routing of emergency responders to critical areas.

During the deployment period, VCC users demonstrated that the VCC provided value even in those less severe, less complex incidents. The above examples all speak to how the VCC can provide value across the severity spectrum for both planned and unplanned events and can have a positive impact on congestion and mobility. In addition, while there was insufficient time to make changes to the rules engine based on data analysis and user feedback, we believe that rules engine was a good first step towards a smarter approach to the early identification of large incidents that would severely impact mobility and we encourage future research in this area.

3.7.3 Effectiveness of Providing Integrated Real-Time Transportation Information to the Public to Make Informed Decisions

While the VCC does not include a public-facing portal, we believed that the Public Information Hub (see 2.1.5) would enhance messaging provided to the public allowing them to make informed decisions. To measure the VCC's impact on this goal, we present the results of the evaluation questions that align with the objectives below.

Improve Timing, Accuracy, and Consistency of Messaging to the Public and Major Employers

Question 20. Do Public Information Officers perceive that their messages to the public are getting out more quickly and are more actionable?

Public information officers (PIOs) did not have many opportunities to engage with the Public Information Hub given the lack of large-scale, complex incidents during the post-deployment period. However, as one public information officer wrote on the Phase 3 post-deployment survey, *For high-level incidents requiring coordination, the POP-MO [population movement] group members would use this [Public Information Hub] to coordinate messaging or share what messaging we are issuing. Thankfully while we remain likely to engage, large scale incidents have not been prevalent.*

In the two Incident Models where PIOs did use the Public Information Hub, they shared links to Twitter posts and provided updates on closures. For example, for an Incident Model created for a maintenance closure on the Seattle Ship Canal Bridge, the public information officer wrote,

SEATTLE From 9 a.m. to 1 p.m. Wednesday, March 8, two right lanes on the southbound Interstate 5 mainline will be closed at the Ship Canal Bridge (milepost 168) in Seattle. Washington State Department of Transportation bridge maintenance crews will be repairing potholes. To alleviate backups, the I-5 express lanes will remain southbound until work is completed before reversing to northbound for the afternoon commute. Commuters should anticipate significant delays on I-5 in Seattle.

Despite the lack of opportunities, one VCC user during the Phase 2 interviews said that the VCC could help to get actionable messages out faster since they can see the initial scope of the incident without having to call the WSDOT TMC, and that the initial alert helps them to understand how big the incident is going to be and how much they need to message it out.

In conclusion, the lack of existing engagement with PIOs, but their general interest in how the VCC might be useful to them during major incidents, highlights the need to continue proactively engage them. This way, when a large, complex incident requiring careful and deliberate public messaging does arise, PIOs who are VCC users feel ready to confidently take advantage of the VCC's features for their work.

Impact on Public Messaging for Improve Decision Making

Providing alternative travel options and encouraging travelers to use those options or delay their trips can reduce the congestion resulting from a major incident. The VCC, however, supports a trusted operational community and does not include a public-facing portal that directly provides travelers with congestion and alternative options. Rather, there is a Public Information Hub that is intended to enhance messaging and coordination among agency public information officers. Therefore, we focused our question on how the VCC impacted public information officers by asking:

Question 21. How does using the VCC impact your development of public messages related to VCC-level incidents?

Agency public information officers were interviewed and surveyed about their use of the VCC for developing public transportation messages. While there was no data to confirm direct VCC impact on the development of public messages related to major incidents, there was encouraging anecdotal information that indicated both general benefit and likely future use. The Public Information Hub was the last major feature developed for the VCC model deployment, and public information officers may still be figuring out how it best fits into their shared workflow. Despite this, public information officers described the VCC as "an aid in understanding the magnitude of incidents," and indicated they continued to see the benefit of the Public Information Hub to make all VCC users aware of their communications.

Lessons for Population Movement

Question 22. What lessons were learned to facilitate the creation of a unified, timely, and actionable message to members of the traveling public?

Question 23. What lessons were learned about how to engage major private employers in assisting with the distribution of messaging during major incident response?

In the time spent with Public Information Officers in the design and development of the Public Information Hub and during post-deployment activities, a lesson learned that care must be taken to create messages that were accurate, and that the most trustworthy information comes from the incident scene. When VCC design first began, there was a belief that the VCC could be used at the scene to record details such as key decisions, actions taken, and resource allocations. While there was not an opportunity to test this during the post-deployment period, there was some evidence of WSDOT IRT entering information directly into the VCC. However, for the VCC to be used by those with smaller displays such as laptops and tablets, the VCC must be enhanced to provide responsiveness and mobile compatibility. See 4.2.7, Ongoing Co-Evolution of Use and Technology.

Early work on the VCC was much more directly connected to the needs and constraints of major employers, both because of the partner participation of entities like Challenge Seattle, and the recognition that large employers' presence in downtown Seattle can significantly impact traffic patterns, especially during morning and evening peak hours. Major employers such as Amazon and Microsoft take direct actions to manage their employees' single occupancy vehicle traffic in Seattle, such as in the form of company shuttles and financial support of commuter-heavy Metro bus routes. The team initially planned to include major employers as possible read-only VCC users, so they could proactively use its information to send out messaging to employees requesting they delay heading home in the event of a major traffic incident and thus avoid contributing significantly to the incident's congestion or any secondary incidents. Engagement with representatives of major employers had begun prior to VCC development. However, these plans were altered by the pandemic. The Project Team, as all others, saw the complex impacts of hybrid and remote work during the early months of the pandemic, largely negating major employers' traffic impacts for some time. Most recently, many companies are attempting to bring workers back to their downtown offices. Thus, there is a lack data or an analytical through-line to assess this question. Now that commute and in person work patterns have begun to normalize, the team recommends re-establishing contact with major employers to learn more directly how information from the VCC could be of mutual benefit to them and to the VCC's member agencies.

In conclusion, despite the lack of large-scale incidents that would have provided public information officers with opportunities to engage with the VCC, there was some evidence that the information available in the VCC combined with the incident notification email could help to get actional information out to the public faster to inform their travel decisions.

3.7.4 Improved Safety

The VCC was designed to support the management of high-impact situations that put unusual stress on the Seattle-area transportation corridors. As such, we believed that one way to evaluate the goal of improved safety was to include Question 24 because the faster an incident is cleared, the sooner incident responders could remove themselves from the potential dangers experienced at the crash site.

Question 24. Does deployment of the VCC reduce incident clearance time?

To answer this research question, the team reviewed the Washington Incident Tracking System (WITS) and the SDOT TOC Call Logs for incident clearance times pre-deployment to compare them to similar sized incidents among the 302 incidents in the VCC that occurred post-deployment. However, this research question turned out to be difficult to answer as the WITS data had only incident date and type to compare, but was lacking location, updates, units, or other information that could assess the size of the incident. The SDOT call log data has more data, but both datasets are very large (34,000 rows and 21,000 rows, respectively) indicating that each row would be a dispatch event and to be able to compare to the 302 VCC Incident Models, there would need to be an incident detection algorithm, which is being worked on in order to improve the rules engine, and given the limited data is not yet possible.

3.8 Benefit-Cost Analysis

A Benefit-Cost Analysis is an evaluation technique that systematically identifies and compares the benefits and costs of implementing a new project. Since the benefit-cost analysis incorporates all the benefits and costs arising from a project or program with a societal perspective, its result can guide transportation professionals to make the most economically advantageous decisions for society (i.e., choosing the alternative that maximizes the net societal benefits). There are multiple benefit-cost analysis guidelines and evaluation examples performed in the context of traffic incident and safety management systems (Guin et al., 2007). The Project Team's analysis follows their approaches within the limitations of data availability.

3.8.1 Measuring Benefits

To calculate benefits, three types of savings were considered that the implementation of the VCC would bring into a society: 1) savings from additional time spent on the road due to delay, 2) savings from additional fuel consumption due to slowed traffic or waiting, and 3) savings from additional emissions of pollutants due to delay.

1) Savings from additional time spent on the road due to delays were calculated by first determining the total number of vehicle hours of delay (VHD) caused by the incidents. We employed the following formula to attain this objective.

$$VHD = F \times R \times T$$

Equation 3-1

where F is normal traffic flow at the incident site and time, which implies the average hourly traffic volume. R is reduction capacity due to incident, and T is duration of incident (hours). The data pertaining to the average hourly traffic volume (F) was obtained from the WSDOT traffic count database system (TRACFLOW). We then matched it to each incident record based on the time of the incident and its proximity to the nearest mile post. Roadway reduction factors (R) for incidents on freeways, established by the US Federal Highway Administration, were incorporated into our analysis (Bertini et al., 2004).

Time costs reflect the value of labor loss due to incident delay, accounting for the largest portion of incident delay costs. The cost of delayed time was estimated using the following model.

$$Total\ Cost_{delay-time} = LC_{hour} \times VO \times VHD$$

Equation 3-2

where LC_{hour} is hourly labor cost. VO is vehicle occupancy. VHD is vehicle hours of delay adopted from the prior analysis.

Following the USDOT guidance, we used $17.90 (i.e., general travel time saving per person-hour) as a reference for the hourly labor cost. For the base case scenario of the BCA, we assumed a vehicle occupancy rate of 1.15.

2) Savings from additional fuel consumption due to slowed traffic or waiting was calculated by first converting the measure of VHD into vehicle miles of delay (VMD) using the formula below. We assumed an average speed of 20 miles per hour during the incident.

$$VMD = VHD \times Average\ Speed\ during\ the\ Incident$$

Equation 3-3

Then, we calculate the amount of extra fuel consumption (gallon) as follows. We obtained the information regarding average fuel consumption per mile from all vehicle types in the US[6].

$$Additional\ consumption(gallon) = VMD \times 0.04016\ gallons\ per\ mile$$

Equation 3-4

Lastly, we estimated the associated costs by multiplying the additional fuel consumption with the average gas price per gallon in Washington[7].

$$Total\ Cost_{fuel} = Avg.P_{fuel} \times Total\ gallon$$

Equation 3-5

3) Savings from additional emissions of pollutants due to delay was calculated by adopting the method used by Guin et al. (2007) to estimate the costs associated with extra emissions of pollutants due to incident delay. Three different types of pollutants, i.e., HC (hydrocarbons), CO (carbon monoxide), and NO (nitrogen oxides), were considered for estimation of the costs. The

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[6]Source: US Environmental Protection Agency https://www.epa.gov/automotive-trends/explore-automotive-trends-data#DetailedData

[7]Average gas price per gallon in WA by years: 2017- $2.91; 2018 - $3.27; 2019 - $3.18

hourly emissions of these air pollutants were calculated to be $25.676/10^6$ tons for HC, $338.69/10^6$ tons for CO, and $36.064/10^6$ tons for NO. Reducing 1 ton of emissions would result in cost savings of $6,700 for HC, $6,360 for CO, and $12,875 for NO. We applied the following model to each pollutant separately to obtain total cost savings associated with extra emissions.

$$Total\ Cost_{emission} = VHD \times Emission_{hour} \times price_{gas/ton}$$

Equation 3-6

3.8.2 Measuring Costs

The costs of the VCC are based on the Federal Highway Administration award of $3,424,361 for the development of VCC in 2020, the cash match of $1,410,000 from WSDOT, the in-kind match of $3,769,000 from the private and public sectors, and the $1,600,000 estimated yearly operating expenses of the VCC, which includes staff, ongoing software licenses, and maintenance costs. A 5% discount rate was applied for both benefit and cost outcomes over the period of 10 years.

Below is a summary of the results of the benefit-cost analysis and offer conclusions based on the team's analysis. Details concerning the literature review conducted prior to performing the benefit-cost analysis, the data sources used, and the methodology can be found in Appendix H - Benefit-Cost Analysis.

3.8.3 Benefits and Costs

Total benefit includes both current and future benefits, with the latter calculated as the sum of present values of expected benefits over a 15-year period. Reducing incident duration by 30 seconds and one minute for all incidents covered by VCC would yield a benefit of approximately $9-17 million, depending on the amount of time the incident was reduced. The total cost of VCC comprises the initial investment and yearly operating expenses. The total costs are estimated to be approximately $27 million for 15 years.

3.8.4 Benefit-Cost Ratio

The benefit-cost ratio is calculated by dividing the total benefits expected from a project/program by its total costs. A ratio greater than one indicates that the expected benefits of the project/program exceed the costs, implying that the project is likely to generate a positive return on investment. The results of the benefit-cost-ratio for the VCC across the different levels of incremental delay savings are presented in Table 3.10 below. The analysis demonstrates that a three-minute decrease in incident delay would result in a benefit-cost ratio of 1.07. A severe incident is defined as an occurrence requiring more than 20 minutes for the clearance of affected lane(s).

Table 3.10 Results of the Benefit-Cost Ratio. (unit: US dollar)

Delay time savings	Total benefit	Total cost	Benefit-cost ratio
30 seconds	4,736,677	26,554,492	0.18
1 minute	9,487,199	26,554,492	0.36
2 minutes	18,923,943	26,554,492	0.71
3 minutes	28,391,762	26,554,492	1.07
4 minutes	37,843,047	26,554,492	1.43
5 minutes	47,269,955	26,554,492	1.78
6 minutes	56,769,410	26,554,492	2.14
7 minutes	66,261,545	26,554,492	2.5
8 minutes	75,714,945	26,554,492	2.85
9 minutes	85,201,483	26,554,492	3.21
10 minutes	94,683,061	26,554,492	3.57

The findings suggest if the time to clear lanes is reduced by approximately three minutes on average after the introduction of the VCC, the benefits would exceed the costs (Table 3.10). Analysis did not account for incidents that occurred in the major arterials of the region, as sufficient data was unavailable. Consequently, one can expect that extending the geographical coverage of the VCC is likely to result in an increase in the benefits.

3.9 Overarching Conclusions from Evaluation

There are two major overarching conclusions from the VCC evaluation effort. Together, these conclusions are potential future game changers for the understanding and assessment of integrated corridor management.

- An evaluation plan for a community-centered, agilely designed operational environment must itself be agile even into the post-deployment period if it is going to evaluate the innovative activity that this new environment engenders.
- The data available in the VCC (and other future VCC-like operational environments) provide a major opportunity to analyze and evaluate multi-agency integrated corridor management in new and far more effective ways.

The Project Team learned that the evaluation plan needs to be agile beyond the launch of model deployment if it is going to adequately assess the innovative collaborations evolved in this new virtual environment. Not only are the community's use of new features and capabilities still being evolved by the partner agencies, but also the data being generated is still being determined. Key VCC milestones in the processes of integrated corridor management, such as the launch and closure of an Incident Model, were still only general ideas when the evaluation plan was already completed and approved. By employing an agile evaluation plan, new and critical measures of impact and effectiveness can be evolved in parallel with the evolution of innovative operational processes and new interagency data.

This leads to the second point. The VCC brings together existing agency data such as dispatch records and new multi-agency data such as the information entered into an Incident Model, all organized around the management of incidents. This combination and organization of existing agency data and new VCC data provides an intriguing opportunity for new measures and analyses of regional incidents and how they are managed. It is as yet unclear what the agencies are doing with the new multi-agency data beyond retaining for compliance with public records laws.

The team recommends thoughtful consideration of how the new combination of data in the VCC can be used to analyze and evaluate multi-agency integrated corridor management in new and far more effective ways, while still meeting the records retention and management needs of the individual partner agencies.

Chapter 4 Lessons Learned and Recommendations

The final chapter of this report is not the final chapter of the VCC. The model deployment of the VCC, developed with significant support from FHWA, is now a state-funded program managed by WSDOT. The program is funded to maintain the existing system and also to expand it. There is much the Project Team learned and is still learning that will help to manage the future of the VCC program.

In addition, the VCC in its current form is a model for other VCC-like efforts that could help other regions and cities, especially about the creation, nature, management, governance, and evaluation of a virtual collaborative environment for integrated corridor management.

Following are these lessons and recommendations from the VCC model deployment, organized by: (1) Community-Centered Design and Development, (2) Features and Capabilities, (3) Policy and Governance, (4) User Management, (5) Future Enhancements, and (6) Moving Forward.

4.1 Community-Centered Design and Development

Over six years of co-creation with a diverse community of agencies, three under FHWA funding, the VCC team has learned a number of lessons associated with the management of a community-centered design, development, and implementation project. The goal was to develop and evaluate a collaborative operational environment that was designed by the transportation management community, for the transportation management community. Partner stakeholders were diverse agencies with different but overlapping missions, policies, jurisdictions, standard procedures, systems, data, and cultures. There were city, county, and State agencies with law enforcement, freeway, arterial, and transit focuses.

Given these goals and the diversity of partner agencies, the most critical management activity was community building. Expanding and reenforcing the operational community was the secret ingredient for everything from data integration and feature design to incident detection and operational updates. A shared operational environment is built upon existing relationships and grows by expanding those relationships.

Some key community building and community-centered design takeaways were:

- Sharing a new operational environment will impact how people work together, but you cannot jump right to a new collaborative vision; you must start by recognizing and building on the different ways that agencies and operational roles currently interact.
- Many new features seemed to call for new shared standard operating procedures, but this is an extremely sensitive issue that must be community owned and addressed over time. The project team was very sensitive about not telling agencies how to do their jobs.
- The community adopted change more through collaborative use, feedback, and refinement, than through formal agreement.
- VCC had to be an environment that produced value when needed and didn't add work when it wasn't. The community would not accept another system or tool that required additional care and feeding that distracted from their already demanding work.
- The community did not want a specialized application that they would only use during rare, high-impact, complex incidents. They wanted an environment that provided value on a daily basis yet enabled them to adjust and expand their activities as required by the complexity of the situation.

- Multi-jurisdictional areas were a sweet spot for VCC use that led to community building. For example, SR 99 is both a state highway and a city street. Incidents involving SR 99 called for shared community awareness of evolving situations and associated multi-agency dispatches and actions. These natural interagency incidents were a driving force behind VCC adoption and use.
- The project team presented options, but the community set priorities. This could require the project team to reduce its ambitions and scope. For example, the project team initially prioritized efforts to meet Section 508 accessibility guidelines and to develop a mobile version of VCC, but the operational community was focused on core CAD and Incident Model features. As always, the community ruled.
- The cost of community buy-in and time was more significant than dollars. Any direction that lost engagement and buy-in of the operational community was too costly, no matter how seemingly beneficial or economical the effort.

4.2 Features and Capabilities

There have been numerous lessons associated with the current VCC features and capabilities. This is not surprising as these have been co-created over time with the operational community. Continued and expanded use of these features and capabilities will continue to generate new lessons, leading to ongoing enhancement and improvement.

4.2.1 Interface and Display of Incident Data

As a model deployment, the current display of data from dispatches and within Incident Models has been extremely successful. However, the lack of uniformity in content and format of dispatches from different agencies was challenging, and often was handled by allowing the differences within the display. Unique formats, like that of the TMC Log, were presented as is and appended to associated WSP dispatches. While this was a vast improvement for agencies who, before the VCC, did not already have ready access to this useful information, it was not optimal for future possible interface options such as supporting user searches or integrating displays. As VCC expands geographically, these issues are likely to become even more important. New partners will mean new and more types of data to be understood and integrated; additional focus on incidents outside the immediate Seattle area will mean more regions to be represented and accessible in support of new collaborations.

Appendix F presents an extensive review of possible VCC interface and display enhancements that could improve user ability to identify and manage data of interest for future interagency management of incidents and mobility.

4.2.2 System-generated Incident Models and Alerts

The VCC provides an environment for supporting agency operators by learning from the vast amount of data on events that impact the transportation system. During model deployment, the Project Team explored using available data to determine if an event, such as a traffic accident, is likely to develop into a major incident – a VCC-level incident. Early detection and prompt notification of such incidents can facilitate collaboration among the community of agencies, both to respond to the incident and manage the resulting congestion.

As an initial effort, the Project Team collaborated with the community to develop a set of rules that would enable the VCC to automatically generate an Incident Model. Every dispatch event received by the VCC is evaluated against these rules. If the rules are satisfied, the system generates an Incident Model and sends out an alert to all users. If the incident is worthy of people's attention, then this automatic detection and alert enables users to collaborate as quickly as possible. If it is not worthy of their attention, it is an unwanted distraction.

See Appendix G for a quantitative analysis of Incident Models and a plan moving forward for improving the rules that produce system-generated Incident Models, based on this data analysis and interviews with users.

4.2.3 Records Management

The Records Management feature described in 2.1.7 is working well but is still part of a learning process. The general approach sends the same information to each agency, leaving them to store and manage this information according to their own policies. Since each agency employs different data and records management systems, this approach seems efficient and equitable.

The records management reports and the Records Management feature generated value beyond meeting the formal records requirement for which they were created. The reports neatly encapsulate a wide variety of incident data, which can be used for analysis and to prepare reports for management. Moreover, the table of closed incidents reflected in the Records Management feature makes it easy to refer back to recently closed incidents for those with access. This raises the question of appropriate usage since the Records Management feature and functionality were originally viewed as being restricted. The Project Team recommends exploring the usefulness of this functionality beyond this original intention, including ways users can access this information for their management reports without requiring them to download records management reports.

Finalization of records within the VCC prior to their being sent to agency records managers proved to be more onerous for users than expected. Expectations had to shift for how much human-in-the-loop was required to adequately monitor the VCC's data. Initially, the plan called for each closed Incident Model to be reviewed by a VCC Records Managers within 72 hours of incident closure to ensure that it did not contain any errors. The person who closed the incident was considered the ideal person to review and finalize it, but this was not enforced by the system. Any user with the VCC Records Manager role could finalize an incident. This was to increase the likelihood that someone would be available to confirm data quality and accuracy before moving the records on to individual agency systems.

In practice, this workflow did not work well. The assignment of a Record Manager to a given incident record was not straightforward. Since the system does not require any one person to finalize the report or send any individual reminders, report finalization often became out of sight, out of mind. Many incident records remained in the system for far longer than desired: months, in some cases. The Project Team adjusted by creating a script that automatically finalized incident records 96 hours after incident closure. Users were still encouraged to manually finalize reports, but if they did not, the system would do this task for them.

Many different solutions to distribute finalized incident records were examined, including the possibility of creating a secure link between the VCC and agency records retention systems. While this would be a more robust solution, only WSDOT had the existing capability, and each agency wanted to host and maintain records on their own agency's system. As such, it would have required considerable resources and time to vet, build out, and fully test this approach with all stakeholders. However, further VCC development efforts may wish to investigate this more robust option.

4.2.4 Pre-Planned Actions

One early project goal was for the VCC to support some form of pre-planned actions, perhaps through flexible templates of incident and/or congestion responses that could be used during common kinds of scenarios. One motivation for this was the success of pre-planned detours in the area south of Seattle around Joint Base Lewis-McChord. In early 2022, members of the project team and VCC users attempted to work toward design concepts for these pre-planned actions. Users were particularly interested in the possibility of establishing alternate routes/detours, along with associated interagency lane management and messaging strategies, which could be readily reused under well-understood incident conditions. For more about the role of the Concept of Operations in community-centered, agile development process, see Appendix E.

To support these activities, the Design and Development team worked with the Concept of Operations team to create operational scenarios that were used during design activities to identify (1) responses that could be planned in particular types of complex incidents, (2) information that would typically be shared among agencies, and, if possible, (3) design features in the VCC that would best support these planned actions. This work was supplemented with one-on-one and small group interviews with a subset of users, to better understand the details and nuances of their strategic responses to complex incidents.

The Project Team found that people in different roles and at different agencies had very different perspectives on the feasibility of creating planned actions. Some, particularly those working at transit agencies, actively created and maintained internal planned actions and had extensive procedures for enacting and monitoring them, both from control centers and on scene. This may relate to the more fixed nature of transit operations. Others, typically those who managed congestion on a more macro level, thought major incidents were too nuanced, with too many inputs and moving parts, to create truly effective and applicable planned responses. These users also pointed out that Seattle's unique and challenging geography make it hard to identify specific tactics or detour routes that can be meaningfully repeated between incidents. For this reason, the team decided to pivot away from planned responses for the time being and adjusted the project deliverables accordingly.

While the team did not directly develop pre-planned actions during the course of designing and developing the VCC model deployment, the time spent working on this proposed capability was still well spent and had unanticipated benefits. Several design insights from user engagements fed into other aspects of the VCC, particularly the Mobility Strategies tab of the Incident Model page. Additionally, the operational scenarios created were used in developing the Concept of Operations and were much richer and more detailed since they'd been tested out with a variety of real users.

Interestingly, in the time since this exploration of pre-planned actions was wrapped up, users have employed the VCC for uses that resemble pre-planned actions. These uses go beyond managing unanticipated traffic incidents. Users sometimes create VCC Incidents when they are planning to restrict the passage of flammable cargo in a tunnel or are planning to close off major roads for an extended construction period. These non-incident uses approach some of the goals of planned responses but arose naturally. This was an instance where the community-centered development approach allowed users to gain unexpected benefit and for the design team to continue learning about use cases for parts of the system that were not able to be developed during the original development period.

In general, the team still believes that planned responses are a worthy area of inquiry and development, and as VCC expands may be more easily applied to areas where the geography is more favorable or where the possibilities for ingress and egress near an area are more like the Joint Base Lewis-McChord case. The team expects that as VCC users in the Seattle area gradually develop their own shared processes and preferences, there may come a time when creating true pre-planned actions makes more sense.

4.2.5 Features with Location

There were useful lessons associated with features that included the description of location. For example, one value of the Integrated Dispatch Feed is related to its ability to give rich information about what is going on in specific locations. Of four dispatch feeds, not including the TMC Log, two provide less location information, partly due to variations in data creation/representation, and partly due to agency constraints based on their perceived need for information security. The challenge of providing useful location information is emblematic of many other complexities in creating a system for shared use that draws upon a variety of agency systems that were originally developed for other purposes.

Another example of a location challenge arose from pulling in the King County Metro's bus management and communication system. This system contains records created when KCM bus drivers contact the coordinators at KCM's Transportation Control Center. These records encompass a wide variety of issues drivers face, some of which involve reporting on traffic-impacting incidents in progress. However, because of the way the buses' vehicle location technologies report location back to the system, and the very nature of a bus as a moving object, the VCC was unable to pull in meaningful latitude/longitude data from these records. Records usually do include a street address, which appears in the Location column, but not a latitude/longitude, so there are no map pins for KCM events. This can make it more challenging for a user to associate a KCM dispatch event with a VCC event than it is for agency dispatches with latitude and longitude.

A third location challenge pertains to data security. While SPD's CAD system does produce both latitude/longitude and street address information, SPD chose not to include street address information in the records they push to the VCC for internal operational security reasons. While SPD dispatches can still be associated with Incident Models, it makes the glanceability of these records within the Integrated Dispatch Feed table more difficult. At present, the Location field for SPD records always shows "NA.” Hopefully over time, the trust in the security of the VCC community will grow and encourage agencies to be more open in their information sharing.

4.2.6 User Interactions with VCC Features

Lessons could be drawn from user interactions with VCC features. For example, information fields in the Incident Model were not used uniformly. The Incident Commander field was only used once, while the Incident Commander Agency field was used in 29 Incident Models. There are several possible reasons why this may have occurred, including:

- Commanding Agency is more generally known than individual Commander
- Commanding Agency is more useful than individual Commander
- Users are unsure about or reluctant to name an individual
- It is not clear which users have the authority to announce the Incident Commander

Depending on the motivations behind this uneven use of information fields, it may be useful in the future to adjust the composition of Incident Model fields.

The Notes tab on the Incident Model was extremely popular. In many cases, information was shared in notes even when there was a field that was specifically included for that information. For example, users tended to indicate closures, detours, changes in signal timing, and variable sign messages under the Notes tab, even though there was a Mobility Strategies tab designed specifically for this information. The likely lesson is that users prefer a more conversational exchange of information rather than a more formatted constrained list of items.

Another lesson from the use of the Incident Model was a change in the concept of when an incident ended. As a shared collaborative space, it was originally thought that the Incident Model would be closed when the last active agency closed the Incident Model. The team learned that users view a VCC-level incident as less about specific agency participation and more about traffic management. This means that the Incident Model is closed when the incident is cleared, and the traffic is flowing. This perspective is reinforced by the primary users who are at the WSDOT Traffic Management Center and the SDOT Transportation Operations Center. These users usually drive the evolution of Incident Models and close them when they are no longer engaged, even if, for example, the law enforcement agencies still have open active dispatches associated with the incident.

A related lesson was that agencies with missions that extend beyond transportation were less likely to use the VCC than agencies whose primary mission is to operate and manage the transportation system. SFD, SPD, and WSP were extremely cooperative in sharing their data for the benefit of the transportation community, but far less likely to fit VCC use into their existing workflows. This may be because transportation management is only a part of their law enforcement and emergency response mission.

Finally, transit agencies are still exploring their usage of VCC. Sound Transit is even considering what a VCC-like environment designed specifically for their needs would look like. What benefits and drawbacks would an agency-specific VCC provide? Could a VCC focused on transit enable transit agencies to better serve the traveling public? The Project Team looks forward to exploring these and related questions.

4.2.7 Ongoing Co-Evolution of Use and Technology

It is important to remember that current patterns of VCC use are not permanent. In its early stages, VCC use has continually evolved and for many new users is still an act of discovery. For example, law enforcement and fire agencies are currently infrequent users, but WSDOT Incident Response Team members with laptops in their vehicles and managers have recently been adopting the VCC, and SDOT Response Team dispatchers are beginning to incorporate VCC into their workflows. How this use plays out among the response community, including the evolution of technology access and possible mobile versions of the VCC, should be closely monitored and facilitated in the future.

Along these lines, SDOT and WSDOT are currently working to create a shared standard operating procedure for VCC usage. This is an extremely important initiative and likely to have considerable impact on patterns of VCC use. This impact should be investigated once the new procedures have had a chance to be completed and instituted. This information should also be shared with other DOTs who may use the VCC in the future.

There is a close connection between the evolution of VCC use and the evolution of the VCC itself. Every new incident managed with the VCC is a potential learning experience, and while clear and impactful lessons are not common, they should not be lost when they are available. For example, recently an SDOT TOC user launched the following Incident Model:

- VCC Incident (8ab-b2) was created by Jane Doe (alert 13:48) using WSP dispatch (type: fire, start 13:10, close 14:14). SFD dispatch added (type: encampment fire, start 13:10, close 14:06). Location: NE 50th St at 5th Ave NE (WSP dispatch location: S5 50TH Milepost 169-6). Contributing Factors: Fire
- Notes: (1) Signals were in flash. Signals are now dark. Fire has departed. SPD UPOs are no longer directing traffic. SDOT Signal Shop has been notified. (14:03) Posted by XXXX. (2) Traffic signals are back operational. (15:04) Posted by John Doe.

There are a number of potential lessons to consider in this incident. First, the SDOT user launched the Incident Model using a WSP dispatch, and then later added the SFD dispatch. This was unusual and cool to see a city user use a state dispatch to launch an Incident Model. What was their thought process? Did they consciously appropriate the WSP dispatch for city purposes, or has the VCC successfully built an operational community that transcends the particular jurisdiction and mission of a specific agency?

Second are potential lessons associated with the signal repair process. A note that the signal shop had been notified of the dark signals was posted at 14:03, and by 14:14 both relevant dispatches had been closed. However, the Incident Model was still open until a second city user associated with the signal repair team posted a note at 15:04 that the signals were operational. After John Doe posted this note, he closed the Incident Model. For an hour or so, the status of the Incident Model hinged on the status of the repair process, and this was unclear.

Should VCC incorporate a mechanism, perhaps an interim note, to facilitate reporting on the progress of signal repair? Should the evolution of the Incident Model leader from Jane Doe to John Doe be more explicit and clarify for the community the shift from an incident about fire to an incident about signal repair? These and other questions, stimulated by the operational community's use of VCC to manage incidents, are central to the future of VCC.

The Project Team is still learning about the evolving perception and use of the VCC. Possible future enhancements in both use and system capabilities are likely to focus on improved understanding of the status of incident clearance, improved user identification of useful information, and improved usability of the Mobility Strategies feature to encourage wider use.

4.3 Policy and Governance

The governance of VCC has been an ongoing balance of WSDOT leadership and individual agency autonomy and collaboration. WSDOT leadership stems largely from its role as a state transportation agency and the recipient of funding that has been essential for making the vision of VCC a reality. However, respecting and supporting individual agency autonomy is equally essential since without the engagement and contributions of partner agencies the VCC collaborative vision is unattainable.

Interagency agreements and charter work have together established the foundation for the collaborative VCC effort. The VCC charter established the Steering Committee that helped govern the project during design, development, and operational testing. Operational agreements allowed partner agencies to use the VCC to manage congestion for real life incidents. Data sharing agreements formalized details about the sharing of agency data feeds with the VCC community, including clarification of retention and rules for data use. While many interagency VCC practices evolved within less formal operational relationships, these more formal agreements were the foundation that empowered operators and emergency responders to explore innovative collaborations.

Funding of VCC design, development, and implementation has been through WSDOT, either with State funds or Federal funding awarded by FHWA. Now funding for maintenance and expansion of VCC is coming to WSDOT from the State Legislature. Throughout the six-year VCC journey, WSDOT has exercised its fiscal and policy authority with an eye towards respecting the various missions, jurisdictions, policies, processes, and cultures of the partner agencies. This benevolent leadership, predicated on the value of self-motivated collaboration, has been essential to the success of VCC.

The VCC interagency Steering Committee, established by WSDOT, has been a critical component of shared governance and policy making. It has not, however, been the apex of a top-down organizational structure. Rather than govern VCC development and use, the Steering Committee has primarily been a forum for information sharing and a sounding board for ideas and strategies. Nevertheless, the Steering Committee assures that partner agencies have a forum where they can make their needs known and negotiate priorities.

4.4 User Management

From the project team's perspective, user management encompassed three interdependent activities: (1) fostering operator engagement in the design and development process, (2) encouraging and facilitating user adoption of the VCC system, and (3) supporting active users. For details on these activities, see Appendix C. VCC User Adoption, Training, and Support.

While operators engaging in the design and development of VCC were not yet technically system users, they were taking the first step on the road to active VCC use. The busy transportation management community did not want yet another system dropped into their laps. By taking a community-centered, agile approach to VCC design and development, the virtual collaborative environment evolved under the guidance of the operational community. As the product evolved, so did the operators' shared sense of ownership and trust that their perspectives would be represented and respected. Operators began to look forward to the next iteration of their system so they could see how their input impacted the design of the VCC, and eventually so they could begin using it in their work.

Fostering operator engagement in this design and development process was key. Agencies needed to be engaged at the management level so that operators would be encouraged to participate. Once operators took part, it was critical to design user engagements to make maximum use of their time and revolve design around real-world cases that would be of interest to the transportation management community. Most importantly, the community had to be the driving force behind design and development decision making, not the project team.

User adoption evolved from this design and development process. Operators who had been most active in guiding the design decisions became the first and most active users. These tended to be WSDOT and SDOT congestion managers working at transportation centers as the VCC was most aligned with their existing workflows.

Thus, success was not a simple matter of numbers; rather it was a matter of identifying and supporting those users who were driving the development of VCC strategies that would be incorporated into regional transportation management. Eventually, 302 potential users received invitations to create a VCC account. Of those, 160 users created and confirmed their accounts. In actual use, however, about 30 users on a daily basis became the core group who employed the model deployment of VCC as a new and uniquely useful component of regional transportation management. Figure 3.4 shows daily usage during the evaluation period. This usefulness was focused on sharing information on incidents and management activities that crossed jurisdictional and mission boundaries.

Once active, users needed support to handle various types of problems that they encountered in navigating a new operational environment with multiple capabilities. As anticipated, there were unintended outcomes. Issues uncovered during operational use were recorded by users in a log that was immediately available to the project team. Some issues were classified as bugs and moved to a bug log where they were prioritized and addressed. Some issues were classified as ideas that would enable the VCC to better serve the needs of its users. These were maintained in an ideation log.

Items in the ideation log did not only come from operational use. Throughout the VCC's design, development, and evaluation, additional features and capabilities were identified that could bring value to users. Much of this took the form of user stories created by the design and development team through the course of development; others arose from documenting user input across a variety of user engagements. The Project Team was not able to address all of these ideation user stories during the period of the demonstration project funding, but carefully documented and prioritized them so that when future capacity and funding are available, work can begin efficiently and in a principled fashion. The number and variety of these ideation items are an indication of the potential depth and value of the VCC.

Following are categories that can be used to prioritize the ideation log and advance the goals of the VCC:

Going from Model Deployment to Product

Ideas that contribute to the process of turning the VCC model deployment into a production version that can be put to widespread use. This would encompass additional work to assure that the VCC rests on a firm foundation for future expansion of scope and functionality.

User Administration and Communication

Ideas that reduce the manual effort on the part of system and agency administrators to manage and support users. The current level of effort has been acceptable during the period of high-effort development and assessment of the VCC, and where the total number of users is relatively low. However, both of these conditions are likely to change, and there are a number of additional features that would facilitate how users are added, managed, and supported in a consistent and maintainable way. Foremost of these would be an improved administrative interface for filtering and bulk actions. While the current administrative interface contains several filters that can be used to produce a subset of users (e.g., based on status, name, agency), this should be expanded to become a full-featured administrative tool that supports more sophisticated filtering, sorting, and administrative actions, such as: (1) granting or revoking user permissions to multiple users at once, (2) looking up and confirming user roles (currently roles do not save until the user has confirmed their account, causing difficulty when looking up and verifying user roles), (3) establishing a common tool for system administrators to communicate with users and user groups.

Responsiveness and Mobile Compatibility

Ideas that would benefit users, especially those not in operations centers with the benefit of large desktop displays to interact with the VCC's content. These users must use smaller displays such as laptops or mobile devices that are currently less satisfactory for showing the VCC's content. Some response vehicles have laptops that exhibit occasional performance issues, such as flickering, when displaying content. In addition, many users rely on mobile devices and tablets in their daily work, and the VCC is currently not mobile friendly. As a first step, the design team has drafted several mobile and responsiveness-related user stories that build on community input.

Accessibility

Ideas that would make the VCC fully accessible to all its potential users, both to meet regulatory requirements and to realize core design values. This will be increasingly salient as the user base grows and changes, and the range of abilities that needs to be supported grows along with it.

Data Integrations and Reliability

Ideas that contain technical, process, and partnership aspects, such as the maintenance and expansion of the key data streams that feed the Integrated Dispatch Feed. Future expansions or scaling of the VCC will require modifications to existing data integrations and would be benefit by a thoughtful onboarding process for incorporating new data integrations. This could include procedures for ensuring that the data source owners are active participants in not only setting up integrations but maintaining their value and reliability.

General Requests for Improvements

Some of the more frequently requested user-driven improvements include:

- Customization of the Dashboard – Users want to have custom settings for how their Dashboard displays. This could include choosing which columns in the Integrated Dispatch Feed are visible by default, saving filters as individual defaults, and changing the placement and size of elements. Options for customization could enable users to adjust the display to meet the constraints of their screen size and type.
- Updates to the Situation Map – (1) Content. Users requested additional information be added to the map, such as an overlay of transit routes, state road mileposts, and impactful weather conditions. (2) Interaction. Users requested an always-accessible full-page map and a user-set default zoom level.
- Support for enhanced user interaction – Users wanted more effective ways to interact with other users and user groups, such as an in-system user directory page, indicators of who is currently online/using the VCC, and a direct inter-user messaging system.

Other Usability Improvements

In addition to the discussion and examples in Appendix F, the ideation log recorded some additional features and adjustments that could improve the VCC user experience. These included:

- Adjust the default zoom on the Incident Model Situation Map to always show all related dispatches (rather than using a fixed radius around the incident location).
- Enable agency and/or distance filters to the lookup modal used to add related dispatch events to an Incident Model.
- Add a visual indicator on the Integrated Dispatch Feed to show which WSP events have attached TMC Log comments.

4.5 Future Enhancements

As shown in Chapter 4.4, lessons learned from this model deployment and operational evaluation naturally lead to recommendations for future improvements and enhancements. Beyond user issues, there are lessons learned associated with design and development processes, such as how best to align the different perspectives of users in different roles and at different agencies.

The expansion of the VCC into new geographical areas and operational environments will also drive future enhancements of the VCC. New agency partners will bring new data sources that need to be adopted within the VCC and may require innovative ways to present that information and integrate it with current information. Additional geographical areas may require an enhanced map interface and new collaborative combinations to be supported. The future addition of agencies in rural areas will also drive new use cases to be addressed within the VCC environment.

Another motivator for enhancement may be the opportunity to apply VCC to the operation of a bi-state corridor, such as between Vancouver, Washington and Portland, Oregon. The additional issues introduced by interstate travel could drive future enhancements of the VCC environment.

Another possible area for future enhancement might be the creation of a public facing VCC portal that does not affect the security of the trusted operational VCC environment. Given the participation of law enforcement agencies, this topic would have to be approached with extreme caution. Nevertheless, the benefits to the public of direct access to relevant VCC information, coupled with increased trust in the secure environment, might make this effort worthwhile.

Finally, the future may bring the possibility of new partners who are not government agencies, such as large employers and institutions. Here again, the VCC may need to support a separate version that keeps secure information from non-governmental partners.

4.6 Moving Forward

The VCC project was an operational evaluation of an innovative model deployment of a virtual collaborative environment for integrated corridor management. Now with the success of the VCC and adoption by the State of Washington, the state is prepared to work with Federal partners to enhance and expand VCC both regionally and for national use. The management of an interstate corridor with VCC is a logical next step. An excellent candidate would be the Vancouver, Washington to Portland Oregon Corridor. In addition, VCC-like projects have already begun in other city corridors across the nation, and the Project Team would look forward to helping these projects learn from what was accomplished in the Seattle area. It is the team's hope that VCC will enable other regions to be more resilient in the face of major disruption such as the collapse of the I-95 interstate freeway in Pennsylvania in June 2023. Breaking down operational silos and building operational collaborations are critical components of a resilient regional mobility system.

May this report serve as a valuable resource for future projects that build on what has been accomplished here.

As the Project Team was completing this final report, the new WSDOT VCC Program Manager sent the team an email from a Research Scientist at a major Transportation Institute.

> *I'm working on similar technology… but it's not exactly at the same level yet as your system. I'm assuming we're all working under the same approaches – unless you're blessed with everyone using the exact same CAD system (I'm dealing with 15 different ones).*
>
> *I would appreciate the opportunity to chat with you about the system. While I'm curious about the technology, I'm actually more curious about the recruitment effort for the system. I've found that the technology component was relatively simple compared to dealing with the various agencies to play along (I was read the Riot Act for even asking one agency what CAD system they used).*

Yes, the agency "recruitment" component is more difficult than the technology component, but No, we're not "all working under the same approaches." The difference in approaches, however, has nothing to do with the number and diversity of CAD systems. It has to do with whose system this is and how it comes into being.

In the VCC, agencies do not get recruited and play along – they partner and are empowered to drive the creation of the system. Long before instituting a technical solution for integrating multiple agency CAD systems, agencies came together as an operational community to decide what they wanted the VCC to be and how they would achieve it. Community building and participatory design before technology integration–that is the difference in approach. There is no "Riot Act" to read because agencies know that if something is not to their liking, they can collaborate with their partners to change it. It is theirs.

The foundational lessons of VCC are community-centered design coupled with agile, iterative development that is driven by the feedback of the operational community. Without this community, as our fellow Research Scientist is learning, there are no technology solutions. With this community in the driver's seat, the VCC is an operational program even before the funded research is complete.

Model Deployment of the Virtual Coordination Center for Multimodal Integrated Corridor Management

Appendices

Final Report

for the Advanced Transportation and Congestion Management Technologies Deployment Program

Washington State
Department of Transportation

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Appendix A Project Management and Governance

VCC project management and governance were critical components of achieving the community ownership, trust, and collaboration necessary for achieving a successful VCC.

A.1 Oversight and Governance

A Steering Committee composed of senior agency leadership addressed issues that spanned multiple agencies, departments, and functional areas, including oversight on VCC decisions that impacted scope, schedule, or budget. Figure A-1 illustrates the organizational structure of the VCC Project Team, with oversight roles at the top two levels and project management at the third level. The fourth level of the figure contains seven boxes representing the workstreams that made up the Project Team. Table A-1 which follows describes the oversight and governance roles and responsibilities; Table A-2 describes the workstreams and their responsibilities.

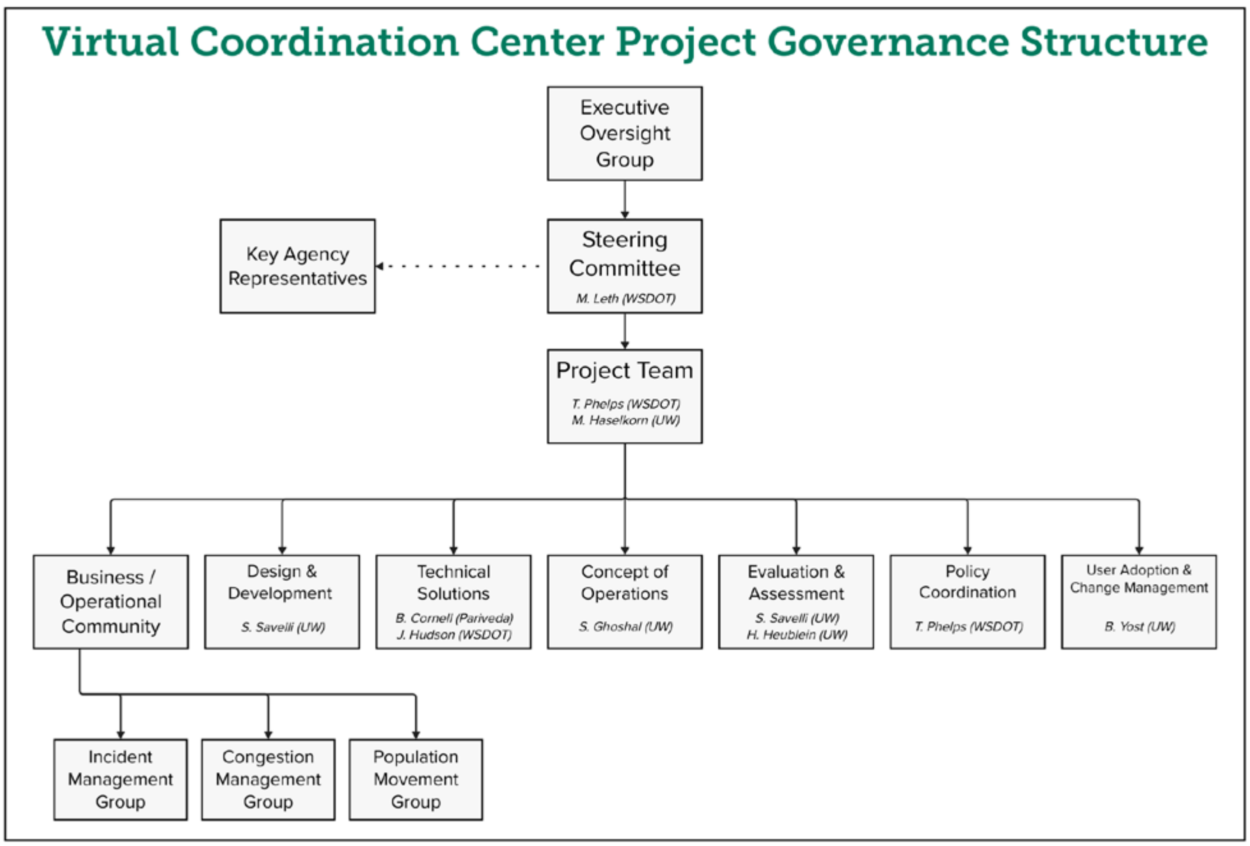

Figure A.1. VCC Project Governance Structure

Table A.1. Governance Roles and Responsibilities

Role	Who	Responsibilities
Executive Oversight Group	Composed of an executive from each of the public agency partners.	Evaluates the strategic direction of the project to align with the intent of the partner entities, ensure agency participation in the VCC program, endorses or responds to formal Steering Committee requests, ensure staff awareness of VCC Program and ownership of responsibilities, and mandate business and policy process alignment where necessary.
Steering Committee Chair	Elected by the Steering Committee members.	Acts as the primary point of contact and coordinator between the Steering Committee and Executive Oversight Group, and the Project Team, while also performing typical committee chair duties.
Steering Committee	Composed of senior management from each of the public agency partners who can address issues that may span multiple programs and functional areas.	Shares joint accountability for the success of the new system by providing timely and informed guidance on project decisions, business issues, policy, and/or agency related issues. Makes recommendations to the Executive Oversight Group for issues arising to that group's level of attention.
Key Agency Representative	Agency staff assigned by Steering Committee members to represent their agency.	Identifies agency resources and personnel as needed for time-sensitive decisions related to project delivery.
Project Team	Composed of UW, WSDOT, and Pariveda personnel.	Leads workstreams and ensures alignment across workstreams and up the organizational chain. Achieves program goals and objectives. Delivers a VCC that meets the cost, time, risk, scope, and quality expectations to the satisfaction of the Steering Committee, WSDOT program managers, and the FHWA Cooperative Agreement.

Table A.2. Project Workstreams and Responsibilities

Workstream	Responsibilities
Business / Operational Community	Provide business and subject matter expertise to the Project Team from the perspectives of three working groups: Incident Management, Congestion Management, and Population Movement. Participate in design, user adoption, and evaluation activities, and become users of the VCC. Each group is co-led by one WSDOT and one SDOT member of the group. Co-leads represent their working group to identify resources, provide input, and suggest group members to support design and development.
Design and Development	Use agile development, human-centered design, and community-centered design methods to design and develop the VCC. Work with the operational community to identify functional requirements in facilitated design scrums, observations, and other engagements. Generate user stories and wireframes that were used to design the VCC. Manage the use, feedback, refine cycles and documented outcomes from each cycle. Prioritize design work and bug fixes. Contribute to training and user support documentation, materials, and processes.
Technical Solutions	Implement the overall technical architecture and produce and integrate design elements created by the Design and Development team. Manage the release of each software update, bug fixes, and software testing.
Concept of Operations	Work with public agency partners to identify and articulate the concept of operations for working within the VCC environment. Provide a framework that the operational community can use to define standard operating procedures, all while considering existing agency policies and standards of practice.
Evaluation	Design and implement an evaluation plan. Gather and validate data and measurements about the VCC. Evaluate the VCC in the final year of FHWA funding, gathering data and documenting lessons learned for future consideration.
Policy	Identify, establish, and update business processes and policies to support use of the VCC in the year of testing and evaluation as well as lay a foundation for a state-funded VCC. Facilitate interagency and data sharing agreements.
User Adoption and Change Management	Design and implement a user adoption plan to manage the change introduced by the project and the VCC product. Design and facilitate user adoption engagements, a suite of training materials, and user support processes. Develop and execute a transition plan to manage the transition of the technical infrastructure, leadership, and day-to-day operations of the VCC to WSDOT. Ensure alignment across workstreams during the adoption and transition processes.

A.2 Project Team Structure

Project Management was a collaborative undertaking by WSDOT, UW, and the UW subcontractor, Pariveda. The Project Team was responsible for designing, developing, and implementing the VCC as well as meeting all requirements as outlined in the FHWA Cooperative Agreement. Pariveda managed the project's technical solutions from September 2020 to September 2022, when technical solutions management was transitioned to WSDOT's Technology Services Division, who managed technical solutions through the end of the funding period, September 30, 2023, and beyond. Tables A-3, A-4, and A-5 lists individuals who worked on the Project Team, by work affiliation.

Table A.3. Project Team from Washington State Department of Transportation

Name	Role
Travis Phelps	Project Director
Annie Johnson	Deputy Project Director
Tony Leingang	Acting State ITS Operations Engineer Incident Management and Operations Administrator
Mark Leth	Steering Committee Chair
Deanna Brewer	VCC Program Manager
Joshua Hudson	Technology Services Division
Ryan Hilton	Technology Services Division
Adam Leuin	Project Team Member
Hannah Britt	Project Team Member

Table A.4. Project Team from University of Washington

Name	Role
Mark Haselkorn	Project Manager, Faculty
Sonia Savelli	Design and Development Lead Evaluation and Assessment Lead Research Scientist
Sucheta Ghoshal	Concept of Operations Lead, Faculty
Brie Yost	Program Operations, User Adoption Lead
Hannah W. Heublein	Program Support Supervisor Evaluation Co-Lead
Gaia Borgias	Strategic Advisor Mobility Innovation Center Liaison
Bart Treece	Strategic Advisor Mobility Innovation Center Liaison
Ridley LeDoux	Graduate Research Assistant
Meg Moldestad	Graduate Research Assistant
Mariah Farris	Graduate Research Assistant
Bianca Johnson	Graduate Research Assistant
Donghoon Lee	Graduate Research Assistant

Name	Role
Andrea Figueroa	Graduate Research Assistant
Sushmidha Jawahar	Graduate Research Assistant
Quilla Graves	Graduate Research Assistant
Gi Lee	Graduate Research Assistant
Woo Young Kim	Undergraduate Student
Mishti Dhawan	Undergraduate Student
Charlotte Lee	UW Faculty
Layla G. Booshehri	UW Faculty
Jerome A. Dugan	UW Faculty
Cecilia Aragon	UW Faculty
Susan Carpenter-Brandt	Grants Manager
Laura Davis	Grants Manager

Table A.5. Project Team from Pariveda Solutions

Name	Role
Kent Corley	Vice President, Seattle
Bill Cornell	Technical Solutions Lead
Josh Kendrick	Lead Developer
Sam Peterson	Developer
Andrew Perkins	Developer
Brett Merrill	Developer

A.3 Public Agency Partners

The community of public agencies engaged in managing the Seattle transportation corridor is highly diverse. It includes agencies responsible for traffic and transit management, emergency services, and law enforcement, with city, county, and state jurisdictions. Since each major incident is unique, some incidents may require the participation of agencies not usually directly associated with transportation management, such as public utilities and the Washington State Department of Ecology. Primary current public agency partners are:

- Washington State Department of Transportation (WSDOT)
- Washington State Patrol (WSP)
- King County Metro Transit (KCM)
- Seattle Department of Transportation (SDOT)
- Seattle Police Department (SPD)
- Seattle Fire Department (SFD)
- Sound Transit

A.4 Private Sector Partners

Private sector partners were an important component of the VCC project, especially AWS as our cloud partner. Pariveda is listed as a development partner because, in addition to being a subcontractor, they contributed matching services. Partners contributed subject matter experts, staff time and resources, technology services, and credits for use of software applications. Their contributions to the VCC were instrumental in the successful building and launching of the VCC environment. Table A-6 provides an overview of the roles and contributions of the VCC private sector partners.

Table A.6. Private Sector Partners, Roles, and Contributions

Organization	Role	Contributions
Amazon Web Services (AWS)	Cloud service provider	AWS Promotional Credits, AWS subject matter experts, and AWS resources contributed to the development of the project, as well as machine learning and data analytics support and services.
Challenge Seattle	Initiation and Funding	Contributed $330,000 over the three-year life of the project.
INRIX	Data and services provider	INRIX services contributed to the development, implementation, and evaluation of the project. Roadway Analytics, and Real Time Traffic, which includes Construction Events.
Microsoft	Azure DevOps services	Azure DevOps credits contributed to the development of the project.
Pariveda Solutions, Inc.	Technical development	Provided the Technical Solutions team who developed the VCC platform in concert with the UW Project Team.
ReadyOp	Technical development	Contributed products that were integrated into the VCC platform.
Schema	Design and development collaboration	Contributed staff and resources to the design of the VCC. Assisted with the look of the user interface.
Siemens (Yunex Traffic)	Data and services provider	Contributed to the project by upgrading SDOT’s Incident Management system, Concert, from v8.1 to v8.3.
ThoughtExchange	Design and development collaboration	Provided use of ThoughtExchange, an engagement platform that was used to collect and prioritize users' ideas and feedback.
WSP USA	Concept of Operations and Evaluation review support	Provided expertise and best practices for the development of the concept of operations and program evaluation.

Appendix B Systems Engineering and Agile Development Methodologies

This Appendix provides details on the design and systems engineering processes and frameworks that the Project Team used to define project requirements, accomplish technical work, and verify and validate our work. Additional descriptions of these frameworks and processes can be found in the *Systems Engineering Management Plan*, submitted to the FHWA on September 22, 2021.

B.1 Implementing Community-Centered Design

Given the multiple agencies with diverse missions, jurisdictions, policies, technologies, practices, and perspectives, it was important for the VCC to be designed with the community's needs and workflows at the center of the design work. The complexities of existing interagency collaboration on all matters relating to traffic incidents had a significant impact on what was desirable and feasible for a new collaboration environment, and what would best support the relationships in our growing operational community. Since our operational community is large and diverse, it was also important to get an understanding of which subsets of that community would most effectively incorporate the VCC into their roles, and which would likely be less frequent users.

University partners at the department of Human Centered Design and Engineering specialize in studying and developing technologies with human-centered design, participatory design, co-design, and community-centered design perspectives. These approaches entail the use of structured, iterative design engagements with the widest possible range of involved stakeholders to understand their needs, hopes, and constraints as they imagine a preferable operational environment supported by the new technology. We complemented these engagements with human-centered approaches from qualitative social science such as ethnographic observation in the workplace, and semi-structured interviews with individuals. These latter design techniques allowed developers to build new technologies based on an understanding of intricate social and technical arrangements obtained from rich, detailed accounts of how people do their work, what they think and believe about that work, and what might be possible for their future collaboration that might be hard to obtain otherwise.

Following is a summary of the project team's primary human-centered design engagements with the VCC's operational community:

- Design scrums/workshops in 2018 and 2019: pre-design engagements with members of the operational community to understand their general preferences for VCC functionality and interfaces. These workshops generated early wireframes that have been used as design references throughout VCC development.
- Workplace observations, ride-alongs, and interviews: Summer 2019 workplace observations, sit-alongs, and ride-alongs with users of agency CAD systems to better

understand how these records are created and used. These observations provided key early input into the development of shared situational awareness functionality and a cross-agency inventory of technology systems used by the operational community in concert with CAD systems.

- Ongoing meetings with VCC users, which both allowed project team members to gather perspectives on a frequent basis, and helped team members adjust their strategies and plans for other forms of user engagement.
- Use, Feedback, Refine Cycles 1-4: During active system development, the project team led a wide variety of activities to learn more about the user community's perspectives on evolving functionality. These group activities included: (1) playing through potential VCC interactions with selected prospective users from different agencies; (2) conceptual tabletop exercises to simulate incidents, and (3) scenario development complemented with intensive one-on-one interviews with people in relevant roles.
- The use of Mural boards and Figma wireframes as collaborative design artifacts; this was made more feasible by Zoom meeting participation, as the VCC design and development team could readily share their screen to the Zoom meeting participants and explore granular aspects of in-development VCC interfaces, taking dynamic notes as we obtained user perspectives.
- One-on-one interviews to explore evaluation results and conclusions.

These engagements were not just intended to help the Project Team identify and understand the user community's problems. More importantly, community-centered design methods were community building activities that facilitated, empowered, and enabled the user community to identify its own problems and implement its own solutions. In this sense, our data-gathering activities were often the same as, or very closely related to, the VCC's community development activities. Importantly, they also gave us venues to better understand the critically important perspectives of front-line workers who would have daily interactions with the VCC and would be most impacted by its success or failure. The cycles of Use, Feedback, Refine employed during development gave the project team the opportunity to notice and correct our own misunderstandings about users' preferences, thereby preventing costly missteps in the future.

B.2 Employing an Agile Framework

FHWA typically uses the traditional "V" diagram, shown in Figure B-1, to illustrate project systems engineering requirements. While this diagram is sufficient for physical construction or installation projects, building and evolving functional software requires a more iterative approach. Instead of the traditional "V" systems engineering approaches, the Project Team used an Agile approach and performed the activities described by the "V" diagram in multiple phases of the project on a cyclical basis. This approach allowed the Project Team to deliver an initial capability of the product early while continuing to iterate on the overall functionalities of the VCC.

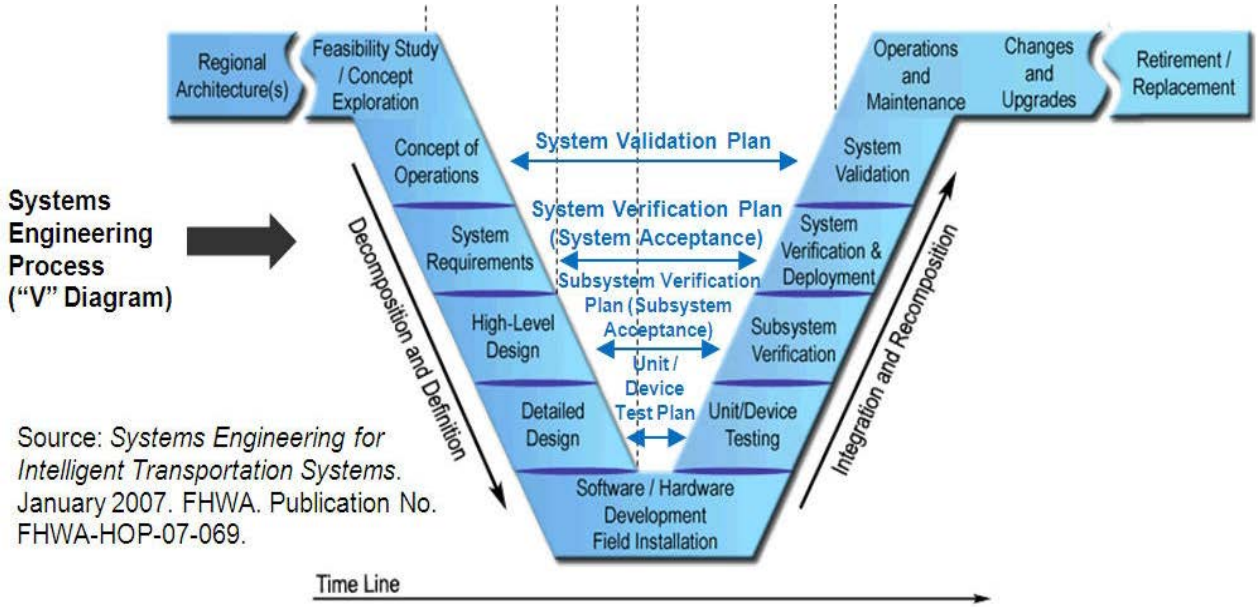

Figure B.1 FHWA Systems Engineering Process "V" Diagram

B.3 Agile Design and Development

The Project Team used agile frameworks, guided by the Agile Manifesto[1], for managing the project and developing the product in order to iteratively design, build, use, and refine the VCC. Agile is both a software development practice and a framework used in project management. The project's concept of operations is aligned with this Agile development process.

Agile is an industry-standard approach within the field of software development that plans work in short sprints, allows for adaptation through iterative processes, and evolves requirements and solutions through collaboration among group members with expertise in different areas, all working toward a common goal.[2]

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[1] Agile Alliance. Manifesto for Agile Software Development, 2001. https://agilemanifesto.org/. The Agile Manifesto (and the Agile 12 Principles referred to later in this section) is original source material for Agile Software Development. The Agile Manifesto is the basis for the Agile methodology within the software development industry as well as many other industries.

[2] What is Agile? What is Scrum?, cprime. https://www.cprime.com/resources/what-is-agile-what-is-scrum/

The VCC project began with a general idea of what the VCC should be and should do but did not have specifics on what it would look like and how users would interface with it. The agile process allowed the team to incrementally define the VCC and build its functionality, employing user feedback to drive the changes and updates. Figure B-2 illustrates the cyclical nature of agile and describes the team's development and refinement process.

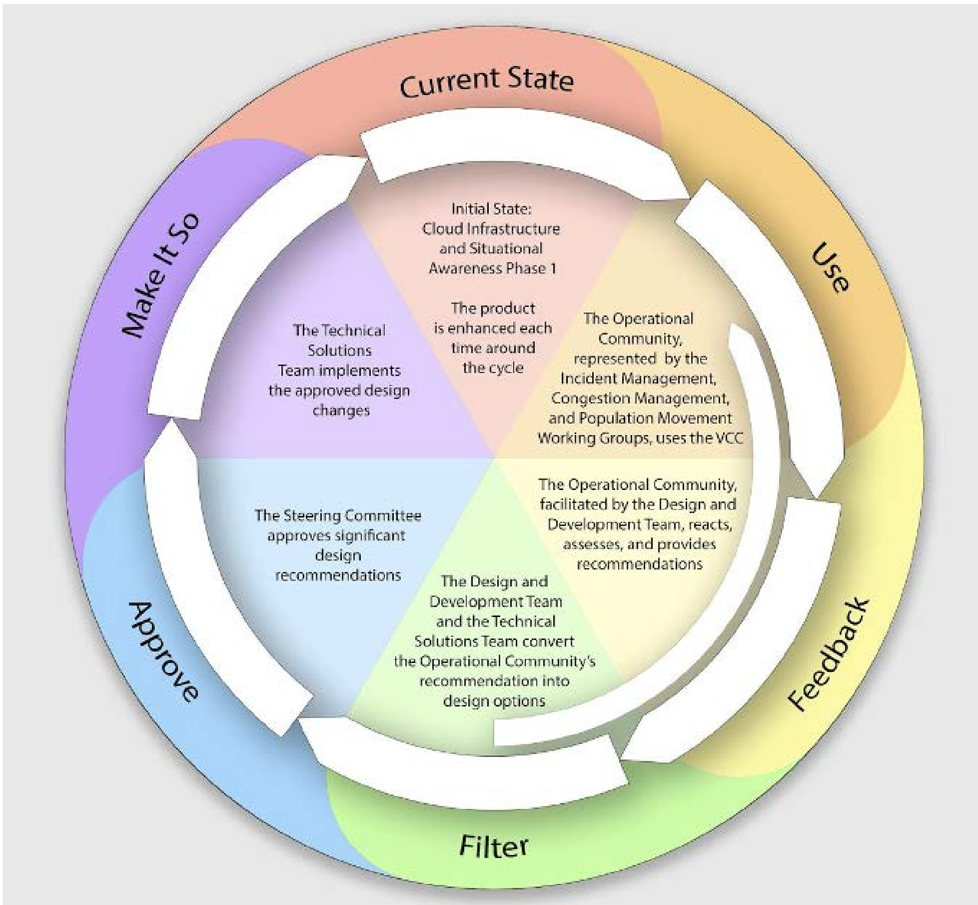


Figure B.2. Iterative Development and Refinement Model (Pariveda)

B.4 Agile Concepts used in the VCC Project

Agile concepts used in the VCC Project Team were:

- Wave: Within the VCC project, a wave is a defined period that is made up of multiple Sprints.
- Sprint: A block or cycle of activity during which design and development takes place. The VCC Project Team used two three-week sprints in each cycle.
- User Stories: A brief description of deliverable value for a specific user. Describes the type of user, what they want, and why they want it.

- Features: The product functionality being developed. Made up of groups of user stories.
- Epics: Made up of multiple features that align thematically.
- Acceptance Criteria: A set of conditions that is required to be met before deliverables are accepted.
- Use, Feedback, Refine: The process of verifying that user stories were turned into features that met user expectations, and that where this was not the case the features were refined. The Project Team engages with users through interviews, surveys, workshops, and other activities to learn what users like and dislike about the current stage of the product. The Project Team then compiles this feedback and refines the next iteration of the product.
- Quality Assurance (QA): The process of verifying that the software performs as specified. Bugs and issues are identified.

B.4.1 Agile Team, Roles, and Responsibilities

Table B.1. Agile Roles and Responsibilities

Role	Description
Product Manager	Ensures that the needs of the users / customers are met. Owns the vision of the product. Defines and prioritizes features and sets the roadmap for design work. Defines problem statements relating to the design of the product.
Technical Product Manager	Ensures that the vision defined by the Product Manager is technically feasible. Leads the developers in building the VCC platform. Defines and prioritizes the technical features and sets the roadmap for technical work. Defines problem statements relating to technical development.
Product Owner	Drives the Sprint Planning and Backlog Grooming meetings through a design lens. Leads prioritization of the backlog of work items. Decomposes features into user stories. Leads sprint planning and ensures stories are ready for development.
Technical Product Owner	Drives the Spring Planning and Backlog Grooming meetings through a technical lens. Determines the velocity of the development team and assigns story points to each user story. Facilitates completing and refining stories by providing software requirements and design aspects.
Business Analysts	Works with the operational community to define system feature requirements, test design interface ideas, and gather feedback to improve the user experience. Writes user stories and acceptance criteria, creates mockups and wireframes, and performs user acceptance and regression tests.
Developers	Performs system architecture, development, and deployment of the VCC product.

B.4.2 Agile Processes and Activities

Agile processes and activities practiced by the Project Team are described in Table B-2. The Project Team held six-week sprints with three-week A and B cycles. E.g., in Sprint 9A, the Project Team would plan 9A work and review Sprint 8B work. Figure B-3 illustrates the Project Team's sprint cadence.

Table B.2. Agile Processes and Activities

Activity Name	Description of Activity
Sprint Planning	Plan work for the current sprint. Define user stories and align on what will be included in the sprint. Review sprint themes and goals. Review stories and ensure a high level of understanding of what should be accomplished within each user story.
Sprint Review and Demo	Recap the theme and goals for the previous sprint with a focus on the product. Provide a system demo of the new features that were completed in the last sprint. Capture feedback on the demo that will inform future stories and features. Demos may be translated into a format the Project Team can share with the Steering Committee as a video or live presentation.
Backlog Grooming	Review the near-term backlog and reassess the priority of stories. Identify and tag stories that are ready for story point estimation by developers. Add high-level scope and clarification to stories so that they can be ready for estimation. Flesh out additional story requirements. Document any questions, dependencies, risks, etc. Decompose large stories into smaller stories. Remove user stories that are no longer relevant. Create new user stories in response to new discoveries.
Sprint Retrospective	Explore Project Team processes from the previous sprint with the purpose of improving process and product. Record what the team did well, what the team wants to improve, what the team learned. Celebrate successes and identify problems to tackle. Implement action items that are outcomes of these meetings.

Figure B.3. VCC Sprint Cycle Cadence

B.4.3 Design and Development Workflow

Before a VCC feature can be deployed, it must go through the following steps:

- Define in Concept of Operations
- Identify policy implications
- Gather requirements and identify problem statements
- Create high-level user statements. “As a __ user, I want to __.”
- Define the value the feature will deliver
- List the Inputs/building blocks needed to move to the next step
- Write user stories
- Write acceptance criteria for each user story
- Create mockups of the design
- Develop the design
- Facilitate Use, Feedback, Refine cycle(s) with users
- Perform quality assurance testing of built features

B.5 Quality Management

The Twelve Principles of Agile,[3] part of the Agile Manifesto, support quality management of the project. Using agile processes and principles allowed daily testing of our product, whereas traditional or waterfall project management approaches perform testing as a last phase of a project before a product is deployed. As a result of our iterative work and daily testing, we were able to discover problems and solve them in much earlier phases of the project, at lower cost and risk to the overall project.

Agile software development builds quality control into the sprint process. The Project Team’s activities and meetings, listed below, supported high quality standards. (Full descriptions of these activities can be found in the Systems Engineering Management Plan.)

- Weekly Team Check-ins
- Virtual Stand-Up Meetings
- Sprint Reviews
- Sprint Retrospectives
- Quality Assurance (QA) Testing
- Use, Feedback, Refine cycles
- Debriefs of user engagements, workshops, Steering Committee meetings, etc.

B.6 Quality Assurance

Before any software was released into the production environment, a member of the Project Team performed quality assurance testing. The quality assurance process was designed to validate that the newly designed software performed as specified. Multiple parties tested the software before updates were released to users. The Project Team also performed regression testing, which is a robust set of end-to-end tests that are performed manually to validate the health of the VCC application.

Quality assurance and regression testing allowed the Project Team to capture bugs in the system, prioritize, and fix them. Regression testing allowed the Project Team to create documentation on how the VCC is intended to work so that new developers working on the VCC in the future can safely maintain and add new features without the risk of accidentally breaking

[3] Agile Alliance. Manifesto for Agile Software Development, 2001. https://agilemanifesto.org/principles.html

existing functionality. The Project Team performed both quality assurance and regression testing using the Azure DevOps Test Suite, which enabled us to integrate any bugs or other work items that were outcomes of testing directly into the backlog.

The Project Team prioritized bugs with these criteria:

Table B.3. Bug Type, Description, and Action

Bug Type	Result of Bug	Action
Critical	Causes core functionality to fail with no workarounds	Must be fixed immediately
High Priority	Core functionality fails with workarounds	Prioritized to be fixed
Medium Priority	2nd Tier functionality fails with workarounds	Ideal to fix, might not be prioritized
Low Priority	Non-core functionality fails with or without workarounds	Not intended to be fixed

Appendix C User Adoption, Training, and Support

The Project Team began planning user adoption and training work in January 2022, initially focusing on what needed to be in place for users to participate in operational testing and evaluation of the VCC, and subsequent evaluation. The Project Team held a series of brainstorming sessions to identify the work that needed to be done with each workstream, questions that needed to be answered, and tasks that needed to be aligned with the project timeline.

The team's initial focus was on early adopters of the VCC. We anticipated that the first people who would use the system would work in control centers: WSDOT's Transportation Management Center, SDOT's Transportation Operations Center, and KCM's Transit Control Center. Many of these users had participated in design and development through the Use, Feedback, Refine cycles. Supporting early adopters was critical as they would naturally take on the role of promoters and champions of the VCC system. We made intentional choices about users to include in early testing and training opportunities based on observations of users during earlier Use, Feedback, Refine cycles.

Goals for the early adopters were:

- Understand their roles in both the VCC Program and the VCC Product.
- Prepare for onboarding and training for operational testing of the VCC.
- Understand how to give feedback and report issues to the Project Team.
- Prepare to participate in the formal evaluation of the VCC Product.

Goals for the Project Team during early adoption phase were:

- Integrate workstreams.
- Align internally as a team and externally with users, agencies, and technology partners.
- Identify early adopters from each agency.
- Acquire user contact information and the roles they will be assigned in the VCC.
- Assemble a Master User List.
- Identify Agency Trainers and Site Administrators from each agency.

Table C.1. User Adoption Activities

Date	Activity Name	Activity Purpose	Audience
5/18/2022	User Adoption Leads Intro	Identify Trainers at each Agency	User Adoption Leads
5/24/2022	User Adoption Introduction	User Adoption Process and Use Cases	All Users
7/21/2022	Feature Complete Review and Demo	Demo and Review	All Users

Date	Activity Name	Activity Purpose	Audience
8/18/2022	Guidelines and Operational Principles	Prepare for changes in business practices, review the agreements	All Users
9/15/2022	Training and Support	Training for View Only / Executive Level	Steering Committee, Key Reps, Executives
10/20/2022	Evaluation Launch	Introduce Users to the Formal Evaluation of the VCC	All Users

C.1 Train the Trainers Approach

The Project Team trained a group of trainers in each participating agency. These trainers would be responsible for training and supporting that agency's VCC users. The Steering Committee assisted the project team in identifying people who would be Agency Trainers. These people had visible roles and the ability to be "change leaders." They would promote and support innovative use of the VCC by their colleagues. Agency Trainers were given specialized training and resources to aid them in championing the VCC and training users at their agency. They also provided valuable leadership in defining how their agency would use the VCC in a way appropriate to their agency's specific needs.

After Agency Trainers were identified we followed the below plan, providing access to training materials and facilitating three sessions to prepare Agency Trainers for their upcoming work.

Table C.2. Train the Trainers Activities and Goals

Date	Activity/Meeting	Goals/Outcomes
9/26/22	Email to trainers: Intro, Calendar invite for meeting series, links to videos 1-4 and user guide V1.0. 1. Training Overview 2. Operational Principles and Guidelines 3. VCC Introduction 4. Access, Getting Help, Login	Agency Trainers get training schedule and time commitment expectation, successfully login to the VCC, and watch videos 1-4
10/5/22	Kickoff Meeting: review videos 1-4 and intro videos 5-8 5. Profile 6. Dashboard 1: Integrated Dispatch Feed and Map 7. Dashboard 2: VCC Incidents 8. Incident Model details and notes	Agency Trainers learn expectations, how to provide feedback for both training materials and the VCC system. Trainers ask questions for videos 1-4 are introduced to videos 5-8 materials.
10/5/22	Email to trainers: Links to videos 5-8	Agency Trainers watch videos 5-8
10/12/22	Meeting 2: Review videos 5-8 and intro videos 9-13	Agency Trainers ask questions for videos 5-8 and are introduced to videos 9-13 materials

Date	Activity/Meeting	Goals/Outcomes
10/12/22	9. Map Annotation 10. Public Information Hub 11. Mobility Strategies 12. Records Management 13. Permissions and Roles Email to trainers: Links to videos 9-13	Agency Trainers watch videos 9-13
10/19/22	Meeting 3: Review videos 9-13 and finish training series	Agency Trainers ask questions for videos 9-13 Discuss next steps
10/19/22	Email to trainers: Video library, Next Steps, Feedback processes	Agency Trainers have an email full of helpful info they can save for quick reference
TBD	Begin Onboarding Users at Agencies Dependent on Execution of Operational Testing Agreement and Data Sharing Agreement.	

We discussed with agency trainers that at the completion of training they should understand:

- Each functionality of the VCC
- How to use the training materials
- How to give feedback on training materials and get user support
- How to train others on how to use the VCC
- How to be a resource to the VCC users at their agency

Agency Trainers received a suite of tools to prepare them for their role as agency trainers during the onboarding and training period including:

- VCC Onboarding and Training Timeline
- Agency Trainers and Site Administrators To-Do Lists
- VCC Training Checklist to distribute
- Customizable Email Templates
- PowerPoint slide decks and video recordings from the Train the Trainer series of meetings
- User Support Resources to upload to an agency specific location

An onboarding preparation meeting was held 1/11/2023 to review Agency Trainer roles, the onboarding timeline, and the steps Trainers would take to onboard users at their agencies.

C.2 Site Administrators

In addition to Agency Trainers, another important agency role in the onboarding process was Site Administrator. Site Administrators had the following role expectations:

- Establish agency account request protocols and user tracking processes.
- Track all VCC users at their agency. Add, subtract, edit users and their roles as required.
- Work with Agency Trainer(s) to onboard new users.
- Ensure new users get their invitation to the VCC and can login successfully.

Working with agency Site Administrators, the team established onboarding protocols. Before a user could receive an invitation to the VCC:

- Agency agreements had to be complete
- The VCC production environment had to be stable and secure
- User lists and assigned roles had to be current and updated
- The User Guide had to be ready and distributed
- Feedback processes had to be updated and in place

Once the above requirements were met, then invitations were sent using these steps:

- Only users who had completed Baseline Survey got an invite
- Agency Trainers sent an introductory email to the agency's users, including a suite of videos, a user guide, and agency trainer contact information
- A formal VCC invitation was sent by the agency's Site Administrator

C.3 Training Materials

The following training materials were created for the VCC:

- Training Videos: A series of 13 training videos, about 100 minutes total, that cover how to use all features and capabilities of the VCC.
- VCC User Guide: An in-depth document that a user may refer to if they have any issues or want to explore any advanced features of the VCC (e.g., launching a VCC Incident model, annotating an incident model situation map, etc.).
- VCC Quick Start Guide: A set of instructions to help users set up and start using the VCC quickly. Provides a high-level overview of what the VCC is and how it works, and helps a user quickly learn to navigate the VCC and understand its fundamental features.
- Getting Started with the VCC: This one-pager contains information on how to set up a VCC account and how to login to the VCC. Sent by site administrators with their user welcome message.

- VCC Glossary (5 pages): A list of terms pertaining to the VCC that may not be recognized by all users of the VCC. The Glossary is a standalone document, but it is also included in the VCC User Guide.

C.4 User Engagement

The Project Team created a User Engagement Plan with strategies for use during the Operational Evaluation of the VCC system. The goals of the user engagement plan included:

- Successful integration of the VCC into everyday work at partner agencies
- Regular use of the VCC by the majority of users
- Regular use of helpful features of the VCC

User engagement objectives were:

- Provide regular opportunities for users to learn from each other, agency trainers, and the Project Team
- Identify and address issues and questions affecting the user community
- Increase the number of regular users as well as VCC usage
- Have invited users confirm their VCC accounts by June 6, 2023

We identified these unique audiences for user engagements:

- Regular Users: Those who use the VCC for their work on a regular basis. Within this group we have subgroups:
  - Congestion Managers
  - Incident Managers
  - Public Information Officers
- IT and Records Managers: These have VCC accounts for administrative purposes only and do not use the VCC on a regular basis for incident/congestion management.
- Executives and/or Passive Users: Personnel at agencies with leadership roles or have other reasons to access the VCC, but who do not personally use the VCC for integrated corridor management. They may or may not have a VCC account, and if they do, they do not use it regularly for their job, but rather just to check in and see the current situation. These users generally have a Basic User role in the VCC system.
- Investors: Those who provide significant funding and/or material support for the VCC.
  - Public Agencies
  - Private Partners
  - Challenge Seattle
  - UW
  - FHWA
  - State Legislators
- Other audiences who have interest in the VCC:
  - WSDOT and WSP staff in other regions

- Agencies in potential expansion regions.
    - Transportation community - regional, WA state, and U.S. communities
- The core user engagement messages were:
- More engagement across agencies will lead to a richer experience for all.
- This is your system. If something isn’t working for you, together we will fix it.
- Increased use will prepare you for enhanced collaboration when the situation calls for it.
- The Project Team is ready and excited to support you as much or as little as needed.
- There are many ways to get value from the VCC; the power is yours to decide!
- You can help make the VCC better by providing feedback with detailed suggestions.

C.5 User Support

With the launch of operational testing and evaluation of the VCC, users had to be able to request and receive support in a timely fashion. The Project Team created tools and processes to support this need, focusing on bugs that were priorities for evaluation purposes. All other bugs and requests were recorded and put in a backlog.

When a user is logged into the VCC they can click on the question mark button to open a side modal with User Support info. At the top of the modal a Request Help link appears. This link opens a new window with the Feedback Form.

When a user fills out the form and submits it, the form populates in a Bug Register and team member(s) receive automated notifications. A team member reads the submission, categorizes it, adds a short title, adds the user's name to the Submitted by column, and moves the item into the appropriate group:

- Active Bugs: It's a bug! And it goes into the backlog to be prioritized and fixed at a future date.
- Not a Bug / Discussion Needed: It's not a bug in the VCC system. But there is still an issue that the team needs to discuss and address. Communications to the user who submitted the issue should be discussed.
- Move to Ideation: It's not a bug. It's an idea for future development, enhancements, or other ideas for a future time.

The team discusses priorities for these items at a weekly Bug Meeting. If communication is required with the submitter outside of automated emails, a team member sends the appropriate email communication regarding the issue or feedback submitted. After review, a team member logs the bug into Azure DevOps. The bug is then addressed using the regular development, QA, and release to production processes.

After submitting their form, users receive an automatic message thanking them for their submission and letting them know the team will be in touch when there are updates regarding their request. When the status of the request changes, the person who submitted the request receives an automated email to let them know what that status is. A status of Coming in Next

Release or Implemented would generate an email. Other issues or feedback can necessitate a manual email from a team member.

A user can also click the link on the feedback form that opens up the VCC User Support Landing Page (Figure C-1). This landing page links users to the VCC Users Resources Google folder, which includes the below list of resources and their descriptions.

- Training Videos: In-depth video tutorials on using the VCC.
- User Guide: A complete and comprehensive guide to using all features of the VCC.
- Quick Start Guide: A guide to help you get started fast.
- Known Issues Log: Issues we know about and suggested work-arounds.
- Help Ticket Form: Have an issue or need support? Fill out a form and one of our team members will contact you soon.

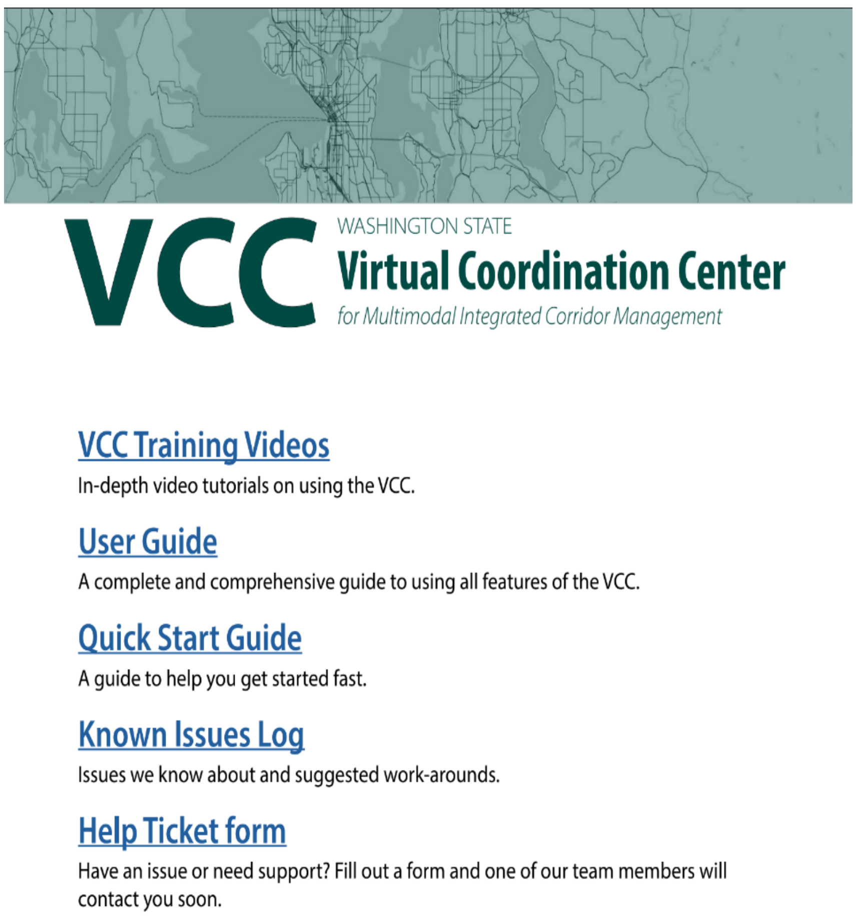


Figure C.1. User Support Landing Page

Appendix D Transition from Model Deployment to an On-going Program

D.1 Transition Goals and Objectives

- Transfer technology solutions management from Pariveda to WSDOT Technical Services Division by October 1, 2022.
- Transfer day-to-day WSDOT leadership of the VCC from the Management of Mobility Division to the Traffic Operations Division by July 1, 2023. Management of Mobility staff will remain engaged in the VCC project to provide strategic advice and close out the USDOT ATCMTD grant and any other grant related tasks.
- Transfer day-to-day operations of the VCC from the UW to WSDOT by September 30, 2023.
- Transfer ongoing project activities from UW to WSDOT by September 30, 2023.

D.2 Transition Key Dates and Activities

Table D.1. Key Transition Date and Activities

Key Date	Transition Activity
October 1, 2022	WSDOT assumes the management of technical solutions.
July 1, 2023	WSDOT assumes VCC leadership. State funding for operations and expansion becomes available.
September 30, 2023	ATCMTD grant-funded work on the VCC ends. UW work on the VCC operations ends.
October 1, 2023	WSDOT assumes day-to-day operations of the VCC.
December 30, 2023	Final ATCMTD report due to FHWA. UW research task order ends.

Transition planning began alongside user adoption planning in January of 2022. The first thing to handoff was management of the technical solutions which required planning and alignment with the WSDOT Technical Services Division and AWS. In Summer of 2022, WSDOT began working with Pariveda and AWS to transition the management of the development and architecture work. Pariveda then transitioned off the project October 1, 2022. Bug fixes and development work were then performed by the WSDOT team members.

The second major transition occurred in July 2023 when state funding became available and WSDOT was able to assume leadership responsibilities including managing Steering Committee meetings and activities, public agency and private partner engagement, and working with Seattle Area Joint Operations Group. Key personnel from partners were introduced to the new WSDOT Program Team and we met with AWS, INRIX, and ReadyOp to ensure the services that are critical to VCC operations would operate with no interruptions during the transition.

The technical and design work was transitioned to the WSDOT Program Team over the course of September 2023. Management of bug fixes, quality assurance processes, the CAD feed, and the ideation backlog were all major work areas that were successfully transitioned to WSDOT ownership by October 1, 2023.

The final workstream to transition to WSDOT was User Adoption and Change Management. While most of the transition of this workstream was complete by October 1, 2023, the user support processes had not yet been established at WSDOT and UW personnel continued to manage those processes for another two weeks. User engagements, training and onboarding, communication strategies, user support documentation, and the master user list were all major work areas that were transitioned to WSDOT between June and October 2023.

In summary, the close collaboration, long-term planning, team adaptability, and alignment of workstreams and partners during the transition of the VCC ensured a smooth and successful transition of the Virtual Coordination Center from the Project Team to the permanent WSDOT Program Team, thereby securing the VCC's continuity, and setting the stage for future enhancements and expansion.

Appendix E Use of an Agile Concept of Operations

The Concept of Operations is a key component of the systems engineering development process. Traditionally, a concept of operations document is completed prior to starting the development process. The goal of this traditional concept of operations is to guide development by articulating system requirements based on the operational communities' needs, as well as to capture a shared understanding of how the new system will be operated and maintained. This up-front approach has been effective in the development of systems whose features and use cases can be described in advance, for example a ramp metering system or bridge tolling system.

The VCC is not such a traditional system. It is an evolving, shared, multi-agency operational environment that links physical and digital infrastructure in support of enhanced human approaches to integrated mobility management. VCC is a *socio-technical* system, encompassing the interplay of technology enablers with human organizations and their policies and procedures. Therefore, rather than be completed up front, the VCC Concept of Operations was evolved along with the VCC itself.

Work on the VCC's Concept of Operations began in 2019, before the receipt of the ATCMTD grant. Members of the UW design team created a Concept of Operations working group that employed a relatively informal, exploratory methodology, but one which solicited interest and engagement from a wide range of stakeholders. During this period, the Project Team spent time exploring different Concept of Operations methodologies and types. Workplace observational data about future users and how they interacted with their current information technology systems for traffic management was also gathered, with a focus on Computer-Aided Dispatch (CAD) systems. The team was laying the groundwork for a human-centered design process by learning as much as possible about how current stakeholders worked.

After obtaining the grant, the Project Team formalized our Concept of Operations methodology and format to conform to grant deliverable expectations but were able to build upon the work already completed. After discussions with our FHWA contact to ensure our process would be acceptable, the team embraced aspects of agile development to create our agile Concept of Operations that could flexibly grow and adapt along with product development. Work began in earnest in autumn 2021 and continued until early 2023.

Our process began with an initial set of mobility management enhancements described by the operational community through early ideation activities, design exercises, and workshops. These initial operational concepts were taken as a starting point, not the end goal. During the Concept of Operations work period, members of the UW Concept of Operations team interfaced extensively with the design and development team, allowing for some shared information-gathering activities to capture user insights and preferences efficiently yet richly. In particular, the Concept of Operations and Design and Development teams collaboratively created operational scenarios that would help users think through what a world with the VCC might look like. These scenarios were developed iteratively through several engagements with users, to ensure their accuracy and richness, and were used in design workshops to work toward feature development as well as being included as key content in the Concept of Operations.

In January 2023, the Project Team completed a Concept of Operations of four primary chapters:

1. An introductory chapter laying out the scope and history of the project and the complexities of the socio- technical challenges it seeks to face;
2. An in-depth description of and rationale for features of the VCC that support shared situational awareness;
3. An in-depth description and rationale of features of the VCC that support shared mobility management; and
4. An in-depth description and rationale of features of the VCC that support coordinated Population Movement tasks.

Chapter 4 also briefly portrays the desired relationship between the Concept of Operations and the VCC, one of iteration and adaptiveness: a true living document as the VCC continues to be a living system. This Concept of Operations was approved by the VCC steering committee in January 2023 with assistance from WSDOT VCC project leaders and FHWA contacts.

The use of an agile Concept of Operations was generally successful. Shared learning through the process of creating the Concept of Operations was valuable and especially in the first year, the Concept of Operations was a venue for a wide variety of stakeholders to think together about how they wanted to transform their collaboration. However, there were areas for improvement.

When writing the Concept of Operations and pursuing its approval, the team aimed to create a relationship between the Concept of Operations and the operational community that was relatively active. In short, the Concept of Operations was to be a living document, guiding practice in an effective, accountable, useful way, but also growing and changing with system use. Over time, however, the Concept of Operations became more a requirement to be met than an evolving representation of the community's thinking. The Project Team recommends that processes be developed for more closely linking the evolving Concept of Operations with agile design processes.

Much of the challenge of preparing the Concept of Operations was developing an adequate understanding of the current state that the VCC would putatively improve. Current state was extremely complex to understand and represent, since the operational community's practices are so diverse, as are traffic incidents themselves. Clarity and directness kept us from representing this current state as fully as it might be. Representations of the current state of operations using diagrams and scenarios ended up being more challenging to complete the more detailed and faithful to life they became. Further, because the Concept of Operations was written over such a long period, the current state itself changed somewhat from the beginning of

Concept of Operations work to the end. A lesson learned is that this part of the Concept of Operations is not straightforward to create and is very much time dependent.

Trying to use similar Agile-type rhythms when creating the Concept of Operations, as a parallel to our Agile-style project development, was a challenge. The traditional Concept of Operations would certainly have been unable to capture the dynamic, changing approach used in the VCC project; but trying to write an Agile Concept of Operations was also logistically difficult because it is, fundamentally, a planning document. The ideal cadence and level of structure likely would have fallen somewhere in between the usual Systems Engineering pre-writing, and the Agile-style flexibility that was used. However, it's unclear whether it would have been possible to predict this ideal balance when work on the Concept of Operations began. In any case, the team found that Concept of Operations development structure and project design and development must work together to avoid confusion and redundant work among partners.

Operational scenarios are a key part of any Concept of Operations. The Concept of Operations team got considerable value from developing several of these scenarios in concert with the Design and Development team, who were using versions of them during design engagements with stakeholders. This double-usage of scenarios enabled the Concept of Operations team to learn more about what aspects of the VCC would provide value for users in the rich context of complex incidents. It also provided additional avenues for ensuring the scenarios felt authentic and natural, since many members of both the Concept of Operations and Design and Development teams do not have direct traffic incident and congestion management experience. Further, the Design and Development team benefited from being able to use this shared work to consider the conceptual and policy implications of designs developed within the Concept of Operations when proposing and designing features.

While the VCC project has been carefully planned since its inception, the evolving environment has been built in a way that iteratively adapts and responds to the expressed needs of the users for whom it is being created. Therefore, both the VCC itself and the Concept of Operations were developed using an agile approach. The Project Team recommends that an agile Concept of Operations be a standard option for evolving community-centered development projects like the VCC.

Appendix F Enhancing Interface and Display of Incident Data

The current implementation of the Virtual Coordination Center (VCC) has been well received by its current user groups. Functioning as an increasingly important tool for a wide variety of users, VCC is designed with the primary goal of fostering shared situational awareness, enabling collaborative planning, and facilitating the strategic coordination of mobility efforts in and near the City of Seattle. As WSDOT considers the extension of VCC to new jurisdictions and served by additional agencies, it may be necessary to enhance VCC's core functionality as the number and diversity of dispatch events and incident models increase. This document is focused on refining key aspects of the VCC, not only to make existing critical actions and tasks more efficient, but also to ensure adaptability and scalability for seamless expansion.

F.1 Design Recommendations for Expansion of the VCC

The proposed expansion of the VCC in terms of jurisdictions is recommended to occur in a modular fashion. Each jurisdiction will function as an independent system within a decentralized framework, yet all linked for interaction on an as-needed basis. Figure F-1 illustrates the modular nature of the VCC. This is represented by individual clusters of dispatches forming distinct VCC systems, autonomously yet interconnectedly operating.

These decentralized clusters operate adjacent to one another, allowing for efficient interactions, data sharing, and the establishment of privacy policies based on the level of dependencies between them. This modular approach enhances the flexibility and scalability of the VCC, facilitating seamless integration with new jurisdictions while maintaining operational autonomy.

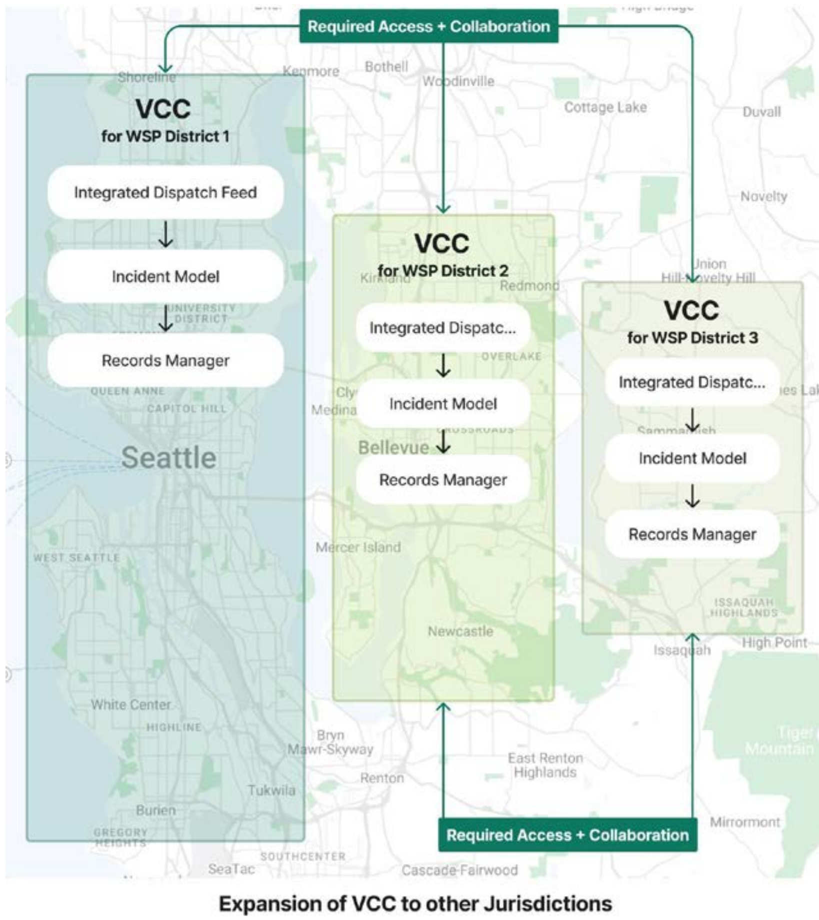


Figure F.1. Expansion Jurisdictions

F.2 Jobs To Be Done Analysis: Derived from Evaluation Objectives and Research

The Jobs To Be Done framework presented here offers a valuable perspective for understanding the fundamental needs and motivations of users engaged with the VCC. Instead of concentrating on the platform's features and functionalities, the framework allows us to delve into the core jobs users are seeking to fulfill. By recognizing and addressing these jobs, we improve the user experience and the overall success of the VCC.

The identified jobs to be done serve as the goals that VCC users aim to achieve. Derived initially from evaluation objectives and the user roles identified during VCC iterative design, these pointers are utilized as a foundation for this framework. The evaluation objectives were instrumental in assessing the system's success; hence they are adapted here to initiate the identification of overarching goals for which the VCC was developed. Crafting design recommendations based on these goals considers the necessary factors to enhance the system's ability to achieve its primary objectives.

Following are the primary goals of VCC:

- Enhancing Shared Situational Awareness
- Facilitating Intra-agency and Inter-agency Coordination
- Strengthening the capacity for Informed Collaborative Decision-Making
- Increasing Coordination of Response
- Granting Agencies Access to Trustworthy, Secure, and Actionable Data for Rapid Responses to Congestion Arising from Major Roadway Collisions
- Enhancing Incident Messaging – Improving Timing, Accuracy, and Consistency of Communication to the Public and Major Employers
- Offering Insights into Traffic Incident Management and Congestion Management
- Providing Insights into Population Movement

Here are the jobs to be done by specific user roles in VCC:

- Basic User:
    - A View Only role. Allows users to view the Dashboard, Integrated Dispatch Feed, and open Incident Model pages and view details. Also allows users to view all map layers, details of other users, and all notifications. Allows users to update their profile and notification preferences. All users receive the basic user permission, but this is primarily geared towards keeping higher-level management informed.
- Incident Manager:
    - Incident Managers can create VCC incident models based on dispatch events or from scratch, if a dispatch event does not exist. They are also responsible for updating these VCC incident models with trustworthy, secure, and actionable data. This is essential to assigning responsibilities, analyze situations effectively, and to keep the community informed. The contributions of these VCC users facilitates informed conversations and the derivation of strategies for optimizing mobility.
- Incident Contributor:
    - Allows users to add notes to Incident Models and pin dispatch events to their private view of the Dispatch Feed. Primarily for operational personnel with selected views of an incident, but not the big picture.
- Incident Records Manager:
    - Allows users to create, edit, close incidents, annotate incident situation maps, and create and edit mobility strategies. Allows users to view and re-open closed incidents, but not deleted incidents. If a user is set as an Incident Manager, they should also be set as an Incident Contributor. Primarily for operational managers with a big picture of an incident.
- Public Information Officer:

    - Allows users to create, edit, and close Scheduled Outreaches and Talking Points in the Public Information Hub of the VCC. Primarily for PIOs and other personnel with public information responsibilities.
- Site Admin:
    - Allows users to view the Admin page, add, remove, or edit any VCC users, and update user roles.

F.3 Feedback from the Operational Community

Throughout the evaluation period, the community was encouraged to provide extensive feedback on the utility of the VCC environment. The dialogues conducted during interviews and UFR sessions emerged as a primary source of research for the UX recommendations.

Furthermore, the team compiled all the feedback and suggestions received during this period into an Ideation Backlog, which was also leveraged for generating recommendations.

F.3.1 Use, Feedback, Refine Findings and Recommendations

The Use, Feedback, Refine (UFR) recommendations presented here originated from UFR sessions held during the evaluation period, as detailed in Appendix B. Below is a priority list derived from user feedback and recommendations, emphasizing the most crucial and immediately addressable aspects discussed during the session.

- A running log that effectively displays changes in the dispatch record, allowing for the tracking of incident evolution over time.
- Convenient links to the cameras closer to a given location of interest within the Incident Management system for quick access and situational awareness.
- Three-dimensional terrain on the situation map to provide a more thorough analysis of both under and aboveground areas, with specific attention to entry and exit points of bridges and flyovers.
- Contextual understanding of the relationships between different dispatch events, such as geographic proximity or connection to the same incident.
- Position of the command post on the situation map, along with summarized information about the location, number, and types of units dispatched.
- A curated list of related incidents within the incident model for a comprehensive understanding of ongoing situations.
- Automation of certain actions in the VCC to improve efficiency and responsiveness such as automatically pinning dispatches with a significant number of active units.
- Ability to draw regions on the map to capture and associate all map pins in a specified area for detailed analysis.
- A layer for Dynamic Messaging signs on the situation map, enabling the display of messages related to ongoing incidents.

- Ability to easily upload photos directly from the incident site to provide visual context and enhance communication.
- A section within the incident model to request assistance or respond to a "more assistance needed."
- A more robust notes field that allows for comprehensive documentation and information sharing.
- The ability to mention or tag an agency overall for effective communication and coordination.
- Allow users to customize their data view according to personal preferences for a more user-centric experience.
- Reorganization of the dashboard view to see more dispatch events, enhancing overall situational awareness.
- The ability to easily identify the party responsible for opening an incident, along with the ability to track recently closed incidents for comprehensive analysis.

F.3.2 Ideation Backlog Conclusions

The development team documented and addressed community feedback through weekly bug meetings and design and development sprints. Any outstanding items that were not promptly resolved were placed in the ideation backlog, a consistently maintained repository throughout the entire VCC development process. Presented below are the curated and high-priority entries from this ideation backlog, reflecting crucial insights derived from the maintained data.

Data Improvement

- Incorporate data related to the number of units responding and the status of units in the active dispatch feed.
- Monitor and notify users about dispatches extending beyond a duration of two hours.
- Provide insight into dispatch event duration.
- Make it easier to identify and access Transportation Management Center (TMC) logs currently attached to Washington State Patrol (WSP) Dispatches.
- Aggregate updates from various sources such as notes, mobility strategy, Public Information Officer (PIO) outreaches, and situation map changes.
- Offer additional information during the creation of the Incident Model (IM).
- Consider integrating a PIO social media timeline and access to PIO resources.
- Enhance the quality of TMC log information.
- Enrich mobility strategies by adding images.

Customization Options

- Utilize screen space for dispatch feed details instead of pop-up windows.
- Permit the relocation of all pop-up windows.
- Develop user-friendly customization features and provide guidance on how to use them.

- Enable users to customize columns in tabular views and guide them through the process.

User Interface Controls

- Improve pinned dispatches, with reasons displayed as a separate column.
- Give users the option to merge Incident Models for clarity and organization.
- Add the capability to include hyperlinks within notes for quick reference.
- Give users the ability to delete notes when necessary, with validation to prevent accidental deletions.
- Address user confusion regarding the distinction between closed and deleted items.
- Incorporate Machine Learning and System Intelligence:
- Enhance the rules engine, as elaborated in Appendix G.
- Develop and employ a VCC incident severity scale to inform the creation of a revamped user flow for alerts, appearance, and interactions with system-generated incidents.
- Consider introducing system-generated suggestions, such as automatically pinning dispatch events based on specified criteria.
- Explore providing insights into associated dispatches and estimated clearance times, especially when location and other key information is missing in the dispatch feed.
- Leverage system intelligence to read information from TMC logs and automate the filling of the Incident Model.
- Address record management issues, providing error resolution and maintenance assistance.
- Implement a smart search feature for enhanced user efficiency.

User Access and Control

- With the expansion of the VCC, define newer attributes to the set of role-based permissions to include access to other jurisdiction's VCC modules.
- Clearly indicate disabled features for users at the lower end of the hierarchy.
- Enable cloud-based collaboration by displaying user avatars and identities while performing actions like editing or deleting notes.
- Facilitate communication among users by providing a user directory with roles and contact information.
- Enable bulk notifications and user-to-user communication via the VCC.

Enhancing Adoption

- Provide comprehensive descriptions for features, supported by helpful icons and clear explanations.
- Enhance error messages and prompts to guide users effectively.

Design and Visual Elements

- Establish a visual design system that includes a dark mode for flexible aesthetics.
- Ensure accessibility and maintain a style guide and layout for consistency.

F.4 Other important considerations for design recommendations

Design recommendations need to accommodate the expected growth in the VCC. This growth is likely to include the introduction of new agencies and the expansion into new regions. As a consequence, there will be an increase in the number and type of users that will in-turn affect other considerations such as response time and user permissions.

Furthermore, the expansion of the VCC will introduce more data and information into the system. To ensure that users can navigate this increased data effectively, it becomes imperative to provide customization options. These options should be designed to create a well-organized personal view of the information in VCC. This arrangement can be tailored to align with the specific jurisdiction of the agencies involved, making it easier for users to access the information they need.

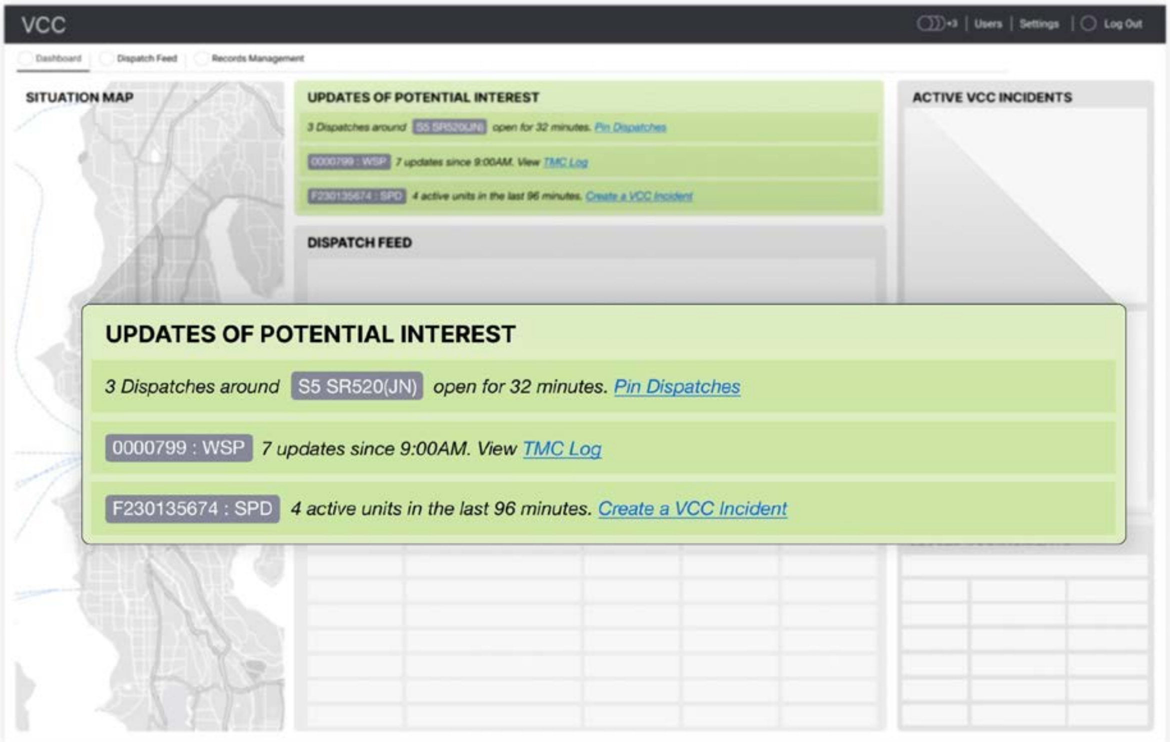
It is essential to prioritize the satisfaction of our existing users who have generously offered feedback which are guiding these recommendations. Additionally, addressing and resolving the identified gaps in the VCC sets the stage for a seamless expansion.

F.5 Design Recommendations

F.5.1 Insights on Open Dispatches

If, as proposed in Appendix G, the rules engine is enhanced to better characterize the nature and severity of incidents, this enhancement can also be used to provide more insights than to just identify VCC-level incidents. Users desire more complete understanding of evolving situations, and this could be provided by giving them access to the rules engine's reasoning to enhance their own. This future integration should be done thoughtfully, ensuring that it doesn't interfere with the user’s experience or create misconceptions about the capabilities of the rules engine. Further, it is crucial to establish a more frequent and transparent connection through feedback or dialogue with users (for example see Figure F-2).

Considering the iterative and generative nature of this idea, it's essential to view it as a step in a larger process rather than an endpoint. This approach is particularly important in addressing system problems and latency issues, acknowledging the varying speeds at which events unfold.



Wireframe Representing Insights from Rule Engine on Dashboard

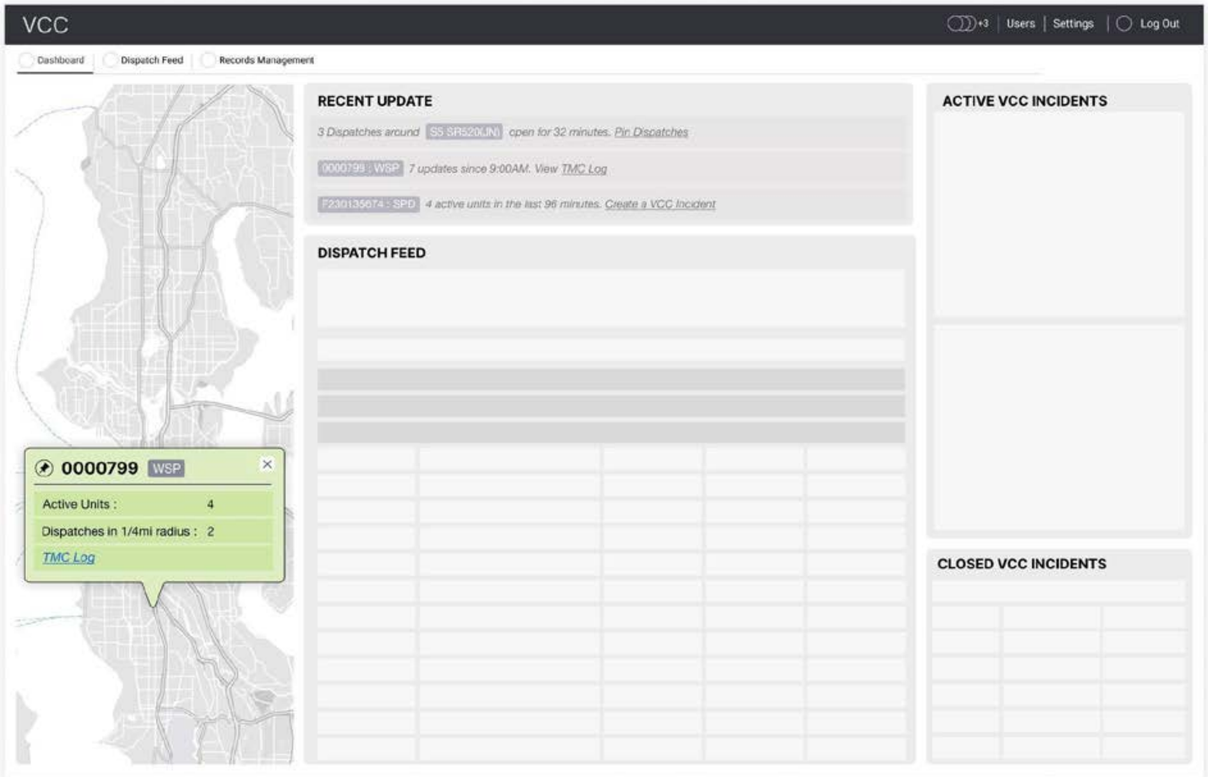
Figure F.2. Dashboard Insights

F.5.2 Use of Map as a Reference

The map can serve as the primary source of information for users. The dashboard and incident model can display relevant data on the map in a consistent manner, improving the understanding of traffic conditions, population movement, and other dispatches at the scene. Incorporating additional customizable map information layers could empower users to selectively view data based on their specific needs, providing control over the amalgamation of information relevant to diverse tasks. This should be based on thorough research to identify the most valuable data for users that the map could provide.

F.5.3 Map Widget

A map widget could present essential information alongside the location pin, providing high-value information to users quickly. The widget could facilitate a more efficient journey for individuals interested in a specific incident due to its location. Additionally, highlighting the dispatch on the feed when clicked or hovered over can enhance the engagement with dispatch events in the dashboard. This feature would likely require substantial adjustments to accommodate various screen sizes.

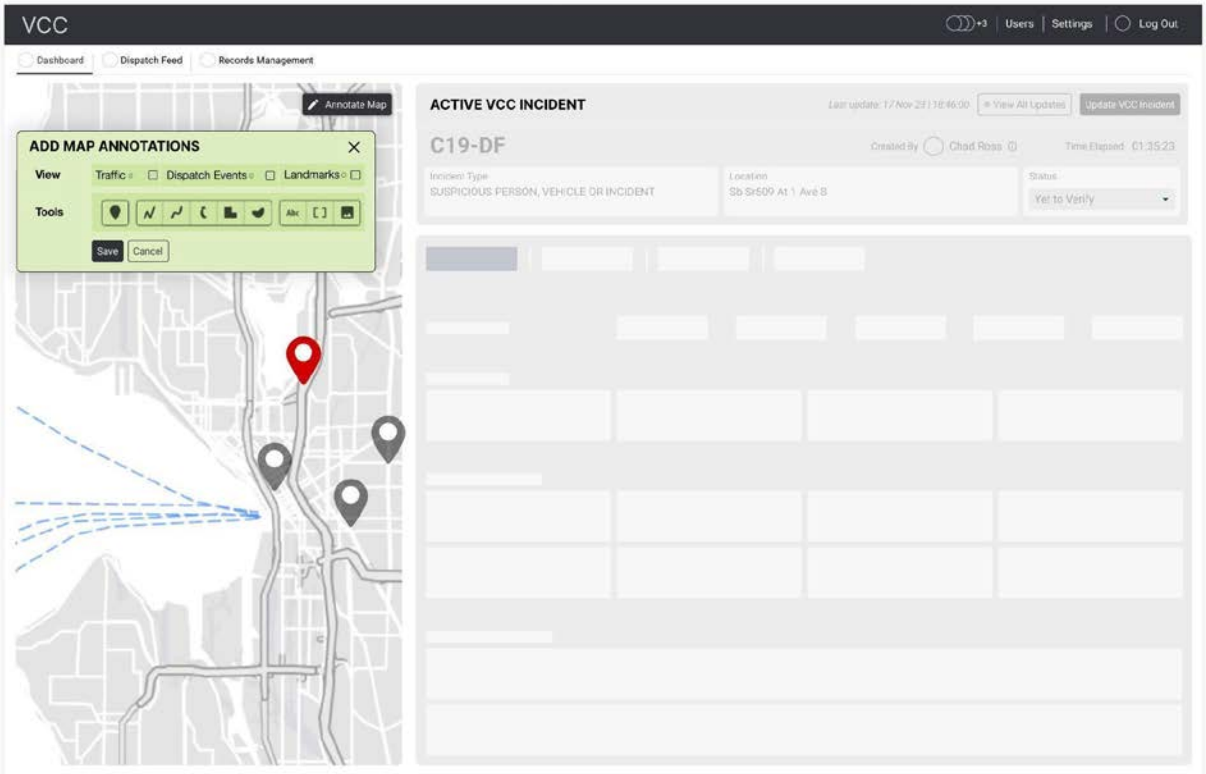


Wireframe Representing a map Widget on the Situation Map

Figure F.3. Situation Map Widget

F.5.4 Map Annotations

Integrating additional map annotation capabilities, such as enabling users to place signs and messages on the map, could enhance strategic planning. Users could also impact areas during major VCC incidents for various perimeters, such as impact areas and investigation zones in case of fatality or crime. Including options to specify a precise command post location could be another helpful map feature. Each of these annotation features requires thorough testing and observation of VCC incident-level emergency situations to ensure optimal UX.



Wireframe Representing map annotation options

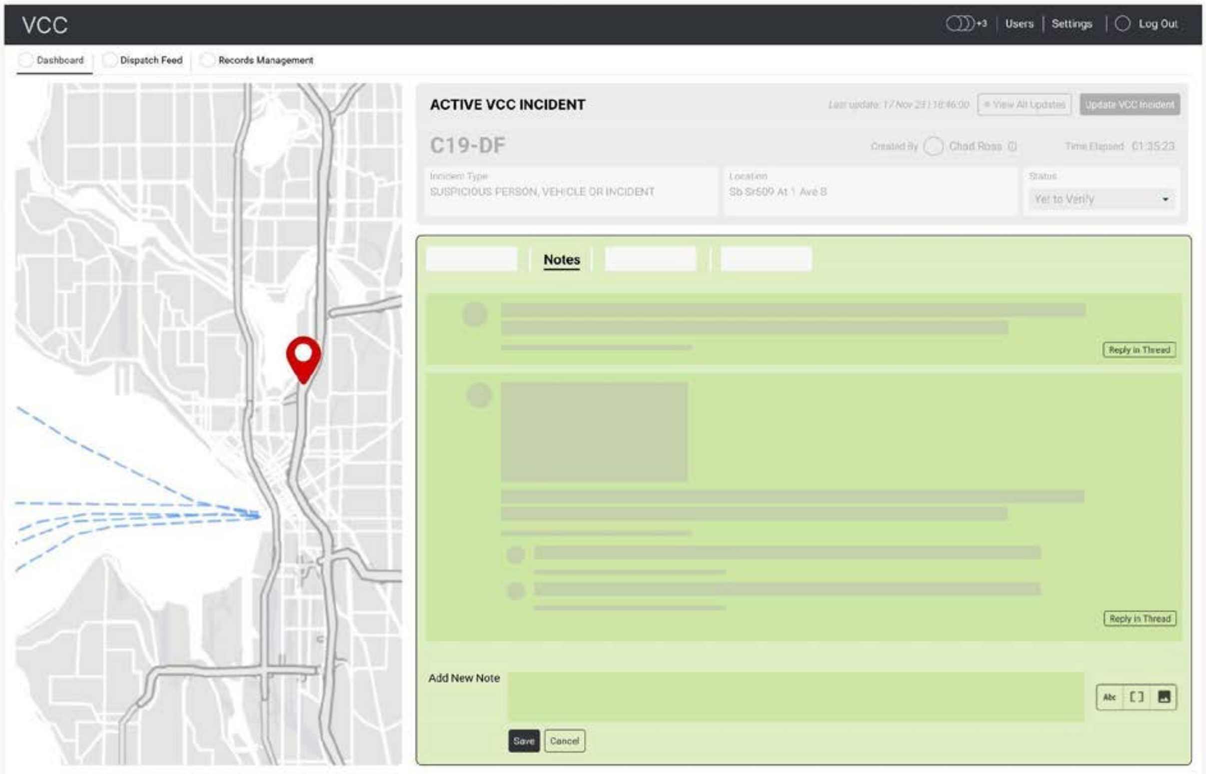
Figure F.4. Map Annotation Options

F.5.5 Incident Model for Situational Awareness

Implementing a fixed header in the Incident Model can enhance accessibility to critical information, including incident ID, location, incident type, status, and creation time. Additionally, this feature can motivate incident managers to prioritize furnishing or editing crucial incident details, ensuring the community stays well-informed.

F.5.6 Notes for Collaboration

The Incident Model "Notes" tab has proven to be one of the most popular user features. To enhance this feature, users should have the ability to attach and view images, links, and descriptions within notes. Moreover, the option to add replies and threads to a single note would facilitate smoother collaboration, helping users understand how their use of the Notes feature connects them with the actions and reasoning of other users.



Wireframe Representing notes used for collaboration

Figure F.5. Incident Collaboration Notes

F.5.7 More Collaborative Incident Model Management

Incident models could be made more collaborative and aware of what other users are doing. For example, when one user is in the act of editing the Incident Model, the "Update the Incident Model" button could be disabled for other users. This would reduce potential disruptions or corruption of information if more than one user is updating a field at the same time. Users could still provide updates through map annotations and notes without causing significant downtime for other Incident Managers.

F.5.8 Bulk Onboarding of Users

Onboarding and management of user groups could be much more powerful. For example, user groups could be uploading using a CSV file in a specific format. This format could include roles, permissions, and user information that would be highly beneficial for site administrators, especially when they are onboarding or managing large numbers of agency users who need to be integrated into the system. Additionally, associating agency information with user groups would support the development of features that enable people to tag an entire responding agency for notifications.

F.5.9 Customization with Modular Designs

Users should be able to customize the width and position of different sections on the dashboard, providing added convenience for those using screens of varying sizes and orientations, including extended screens. However, there could be challenges with excessive or undesirable customization. To address this, there should be an option to revert to the default state of customizations or to select predefined customization options.

F.5.10 Role-Based Access Control

User roles and their corresponding responsibilities are instrumental in enhancing users' interaction with the operational community. Clarifying this framework can help establish expectations for collaborative incident management within the VCC. It would be helpful to indicate user roles more clearly as operators interact within the Incident Model.

In addition, future welcome messages to new users can include details about the roles-based permission system and emphasize the new user's access capabilities and expectations within the VCC (for example, Figure F-6).

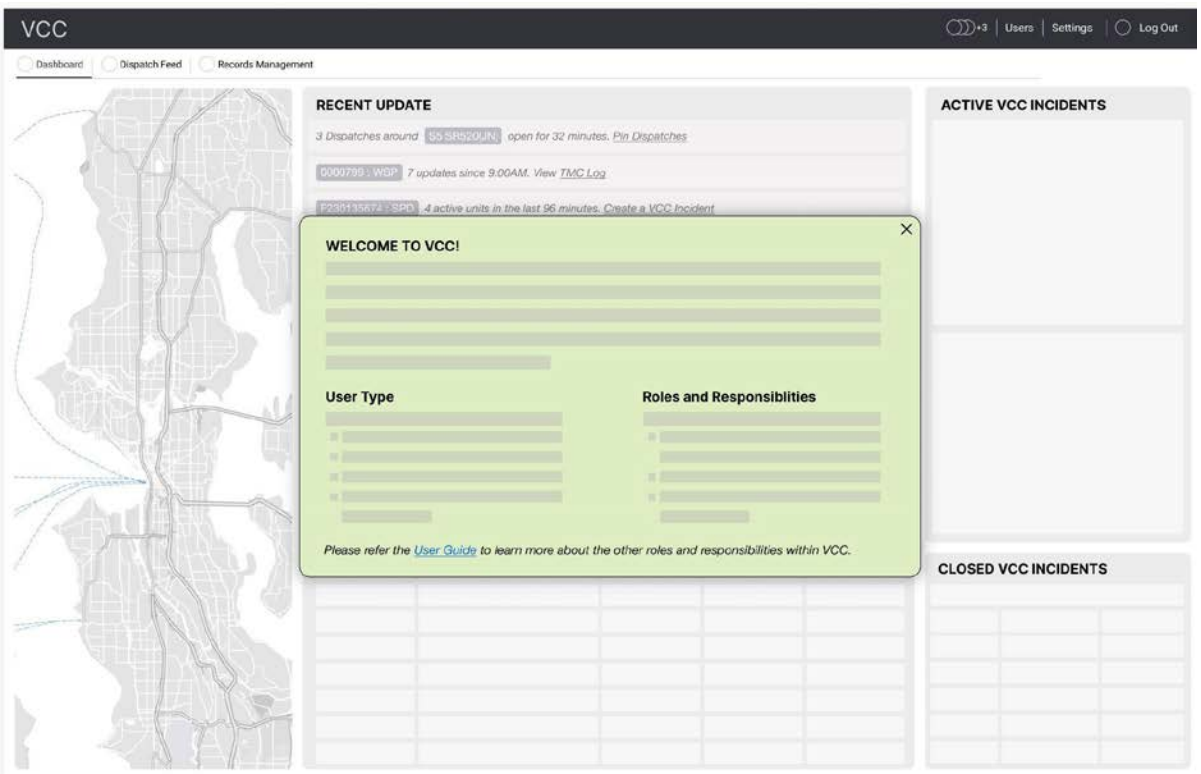
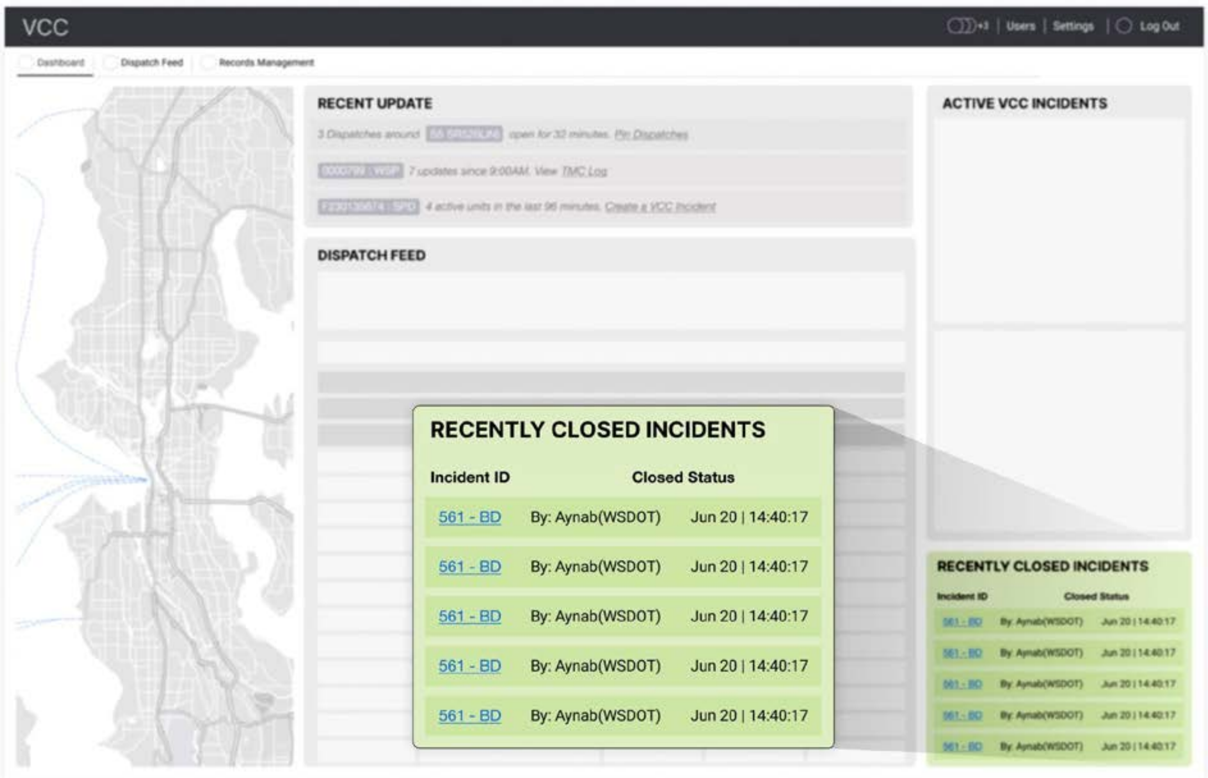


Figure F.6. Welcome Message

F.5.11 Making Better Use of Blank Space

Since the number of active incidents over time can be fairly minimal, the right hand column of the dashboard is often blank. This blank space on the dashboard could be used to show additional information, such as recently closed incidents.



Wireframe Representing Closed Incidents on Dashboard

Figure F.7. Dashboard with Recently Closed Incidents

F.6 Conclusion

Guided by a Jobs to be Done framework and closely collaborating with the operational community are the keys to effectively co-designing additional VCC interface features. This UX design methodology should facilitate conversations with the right stakeholders throughout the process, ensuring the successful development of an evolving user experience for the VCC.

Appendix G Enhancing System-generated Incident Models and Alerts

G.1 Introduction

The Virtual Coordination Center (VCC) is a shared digital operational environment where diverse agencies engaged in transportation management can share data, communicate, and collaboratively manage stresses on the regional transportation system. Partner agencies currently include King County Metro (KCM), Seattle Police Department (SPD), Seattle Fire Department (SFD), Washington State Patrol (WSP), Seattle Department of Transportation (SDOT) and Washington State Department of Transportation (WSDOT). As an initial goal, we propose here to support VCC operators by learning from the vast amount of data on events that impact the transportation system. Specifically, we will enhance the VCC's ability to help operators determine if an event, such as a traffic accident, is likely to develop into a major incident – a "VCC-level incident" (i.e., worthy of launching an incident model).

Early detection and prompt notification of such incidents can facilitate collaboration among the community of agencies, both to respond to the incident and manage the resulting congestion. Currently, a set of rules was obtained from operators and implemented to achieve this goal. Every dispatch event received by the VCC goes through this "rules engine" to be evaluated and, if it satisfies a rule, launches a system-generated incident model. This automated detection of different VCC-level incidents supports early awareness of operators and encourages early collaboration as necessary. This Appendix evaluates the effectiveness of the current rules engine and propose an enhancement of rules based on data analysis and interviews with operators.

G.2 Rules Engine

As dispatches come into the integrated dispatch feed, they are evaluated by transportation managers who can launch an Incident Model if they are seen as indicating a likely VCC-level incident. In addition to this human review, the VCC applies a set of rules to identify possible VCC level incidents. These rules, developed based on operator input, automatically categorize dispatches as possible VCC-level incidents if they are:

- Events from the Seattle Fire Department that include: "Tunnel MVI", "Car Fire Freeway", or "Fire Response Freeway" in the event type
- Events from the Washington State Patrol in Area "I5" that include: "Road Closure", "Fatal Traffic Collision", "Disabled Vehicle Fire", or "Possible suicidal pedestrian on bridge or overpass" in the event type
- Any event that includes "bridge" in the location and "blocking" in the event type.

If a dispatch meets these criteria, the VCC auto-generates an "Incident Model" based on the dispatch, and an email alert of a system-generated Incident Model goes out to all users. All system-generated Incident Models are marked as unverified until confirmed by a human Incident Manager.

While the rules engine provides some early notification of potential major incidents, there are many cases where significant VCC-level incidents are not automatically classified as such in the VCC system, and even more cases where a system-generated incident model is not viewed as sufficiently serious to warrant VCC-level status. This is due both to limitations of the rules and to the nature of incidents, some of which appear to be relatively common occurrences but evolve into more complicated situations. The analysis of large amounts of data from dispatch events and incident logs, as well as other relevant data sources, could provide useful insight into the characteristics and patterns of events and responses, enabling both enhanced and improved rules for auto-detection that provide accurate early awareness of evolving incidents.

G.3 Results from Quantitative Analysis of Incident Models

To understand how the rules engine and the automatic classification of potential major events worked after it was implemented, all incident model reports were collected from February 22, 2023 until September 30, 2023. Each one of these reports contains information about the incident such as location, type of event, start time, dispatches associated, who created it, along with every operator update, time of clearance, collaborative actions, map annotations, and others. Figure G-1 shows the distribution of incident models during the period of data collection.

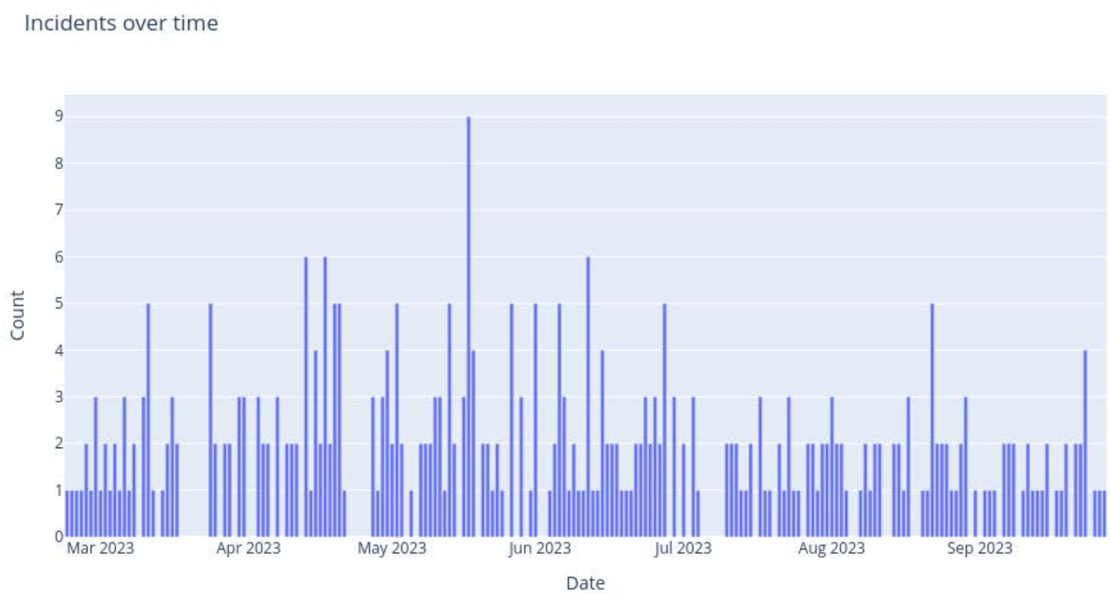


Figure G.1. Incident count over time

Figure G-1 shows that incident models were not created every day and that some days have far more incidents than others. There was an average of 42.43 incidents per month; 30% of all the days of data collection had 0 incidents while 30% had only one incident. There were no major changes in the number of incidents per month, except for the month of May when there were 60 incident models launched.

Every incident model in the VCC can be either (1) *closed* when the situation is cleared or (2) *deleted* if it was created incorrectly, was a test, or if it was system generated and never verified. This last type of incident can provide us with a deeper understanding of how the rules engine performed in the automatic classification of dispatches as VCC-level incidents. Figure G-2 shows the cumulative count of all Incident Models created over time. Human generated incidents are represented with blue, while system generated incidents are represented with red. Dashed lines are deleted incident models. From this visualization, observe that the number of deleted incidents has stayed relatively constant in the last months. At the same time, the number of closed incidents, both human and system generated, has been increasing almost linearly.

Figure G.2. Closed and Deleted Incident Models

Table G-1 shows the exact number of Incident Models that were both closed and deleted, as well as how many of them were created by users versus the system. The closed system generated Incident Models represent 28.15% of all closed Incident Models, while the deleted system generated Incident Models are 44.23% of all deleted models. This higher likelihood of system-generated incident models being “incorrect” was expected, as the rules engine is as yet quite simple and will inaccurately classify some dispatches as Incident Model, which were later deleted as unverified.

However, out of all the system-generated Incident Models (108), only 21.29% were deleted, suggesting that almost 80% of all these Incident Models were verified by a user or at least worthy of closing (which maintains a record). This suggests that the initial design of the rules engine was a promising start, as it was able to identify about 4 out of 5 real incidents.

Table G.1. Number of closed and deleted Incident models

Incident Model Final Status	Created by	Quantity
Closed	User	217
	System	85
Closed Sub-Total	n/a	302
Deleted	User	29
	System	23
Deleted Sub-Total	n/a	52
TOTAL Incident Models	n/a	354

Even though the design of the rules engine has been a fairly successful start to the automatic classification of incidents, the Project Team aims to have a smarter system based on the information and analysis gathered from the users as well as the data that VCC has generated through these months. There are still about 72% of Incident Models that are not detected by the system, as well as 27% that are incorrectly identified. Below, are proposals to enhance the rules engine based on user input and analysis of Incident Models to identify patterns that might lead to more specific and accurate rules.

G.4 Enhancing the Rules Engine

G.4.1 User interviews

Users of the VCC system create and verify incidents and are the human component in the design of the Rules Engine. These users have extensive operational knowledge, experience, and insights that must guide our understanding of what constitutes an incident and when to classify an event as one. Data must be viewed in the context of humans and their work, and operators must participate in designing the model and guiding the ML process.

As a starting point, the team gathered additional expert knowledge on incident classification from the operators in the different agencies involved. The team learned about the variables they use to assess the urgency of dispatches, what other information would be helpful to them, and how the rules engine could enhance their use of the VCC environment. These interviews also served as a learning opportunity to understand the concepts, terms, and overall operations of the agencies involved in the VCC.

The Project Team used semi-structured interviews lasting one hour each and consisting of a set of initial questions followed by a sample of actual incidents that were considered to be VCC-level in order to better understand the classification process. Do they consider these to warrant the launching of an Incident Models? Why do they think others consider them to be VCC-level?

The main lessons learned in the interviews were:

- Each agency has different variables of interest when assessing a dispatch event.
- Location is the most important variable as they use this to identify if the incident is in a zone that is relevant for their agency.
- Type of event and units assigned are the next most important variables of interest in assessing the size and importance of an incident.
- There are external variables that are also taken into consideration, such as weather, time of day, and the presence of construction events.
- Operators shared needs for decision support on alternative management options.
- Future goals beyond the identification of incident severity, such as suggesting incident strategies for managing major incidents, were desirable and can be achieved by building on this initial effort.

Based on these interviews with operators, the team then analyzed every variable they mentioned as important in the Incident Model data collected.

G.4.2 Location

The location of a dispatch event is one of the most important variables for operators. Figure G-3 displays all the Incident Models in the Seattle Area, with user and system generated incidents shown in blue and red, respectively. The Incident Models are spread across different areas from Seattle to Everett, mostly on highways. The system-generated incidents seem to be closer to the I5 freeway, as expected based on the current rules.

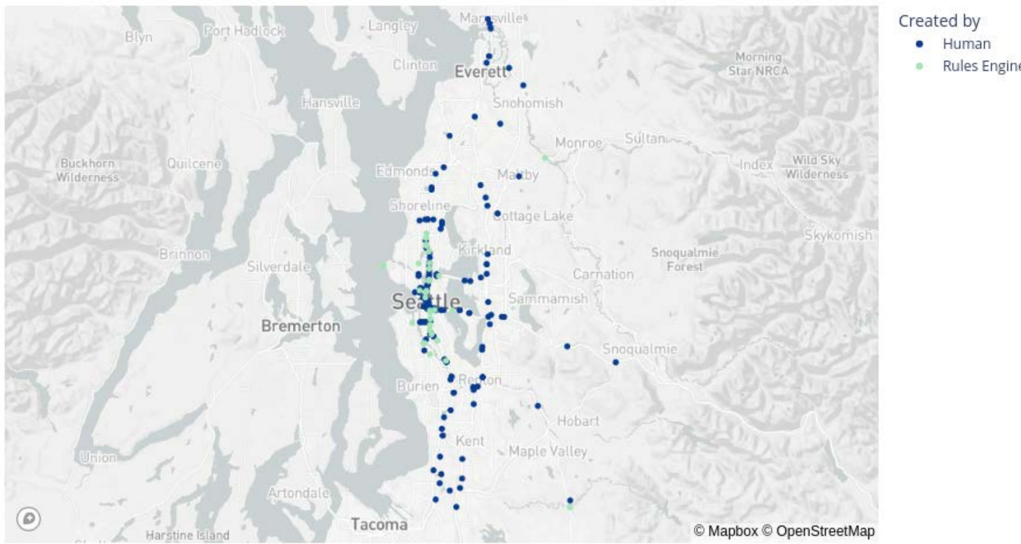


Figure G.3. Incident Models in the Seattle Area

It appears that the current rules restrict system generated incidents to a specific area and it may be more beneficial to have wider criteria for location. Figure G-4 is a heatmap of the locations of Incident Models showing which areas have the most density of Incident Models.

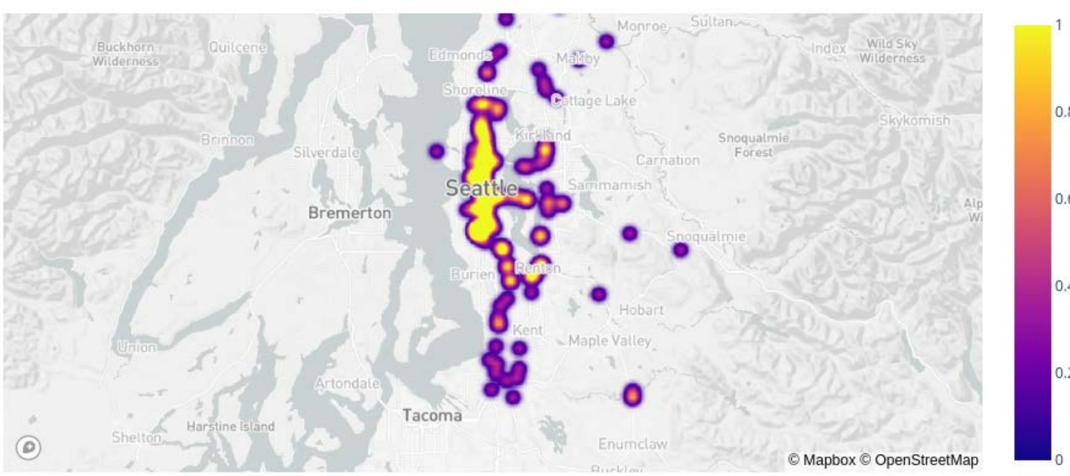


Figure G.4. Heatmap of Incident Models

This information can be used to create a function based on the density of Incident Models of the specific location of a dispatch. As dispatch events come into the system, they can be assigned a score to the location of the event from 0 to 1, representing the density of Incident Models that have happened in the past at that point. This would quickly indicate if the incident has occurred in a common "trouble spot."

G.4.3 Type of event

Given the current design of the Rules Engine, most system-generated incidents have event types such as Traffic Hazard Blocking Roadway, Car Fire Freeway, Fire Response Freeway, Road Closure, Fatal Traffic Collision, and Disabled Vehicle Fire. System-generated incidents are usually closed or deleted within 20 to 30 minutes of creation, indicating that the current VCC rules engine is not accurately identifying a VCC level incident, which generally lasts 90 minutes or more. Common system-generated incident types such as Fire Response Freeway, Car Fire Freeway, and Disabled Vehicle/Traffic Hazard Blocking are not of serious concern unless there are additional circumstances that increase the impact of these incidents significantly.

Figure G-5 shows the most common event types for user and system generated incidents. For user-generated incidents, the most common types are all collisions: Collision injury unknown, collision property damage, and collision personal injury. For system-generated incidents, the most common types are as expected given the rules.

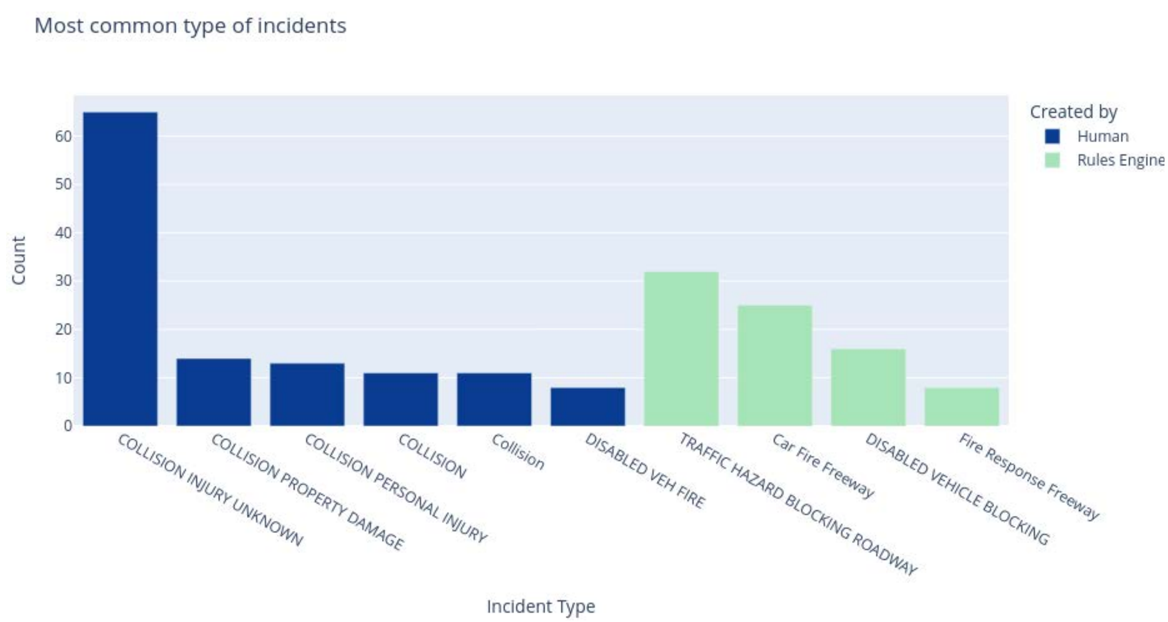


Figure G.5. Most Common Incident Types

Given that "Collision Injury Unknown" and multiple event types including "Collision" are the most common in user generated incidents, the Project Team proposes to include more of these types of events in the rules engine and assign a score based on how frequent this event type appears in past Incident Models.

G.4.4 Time of day

From expert knowledge gathered through interviews and qualitative analysis of the Incident Models, the team learned that the time of the day when the event happens plays an important role in the urgency it has. This is not surprising given the difference in traffic at different times in the day. Figure G-6 shows the frequency of Incident Models at different hours of the day.

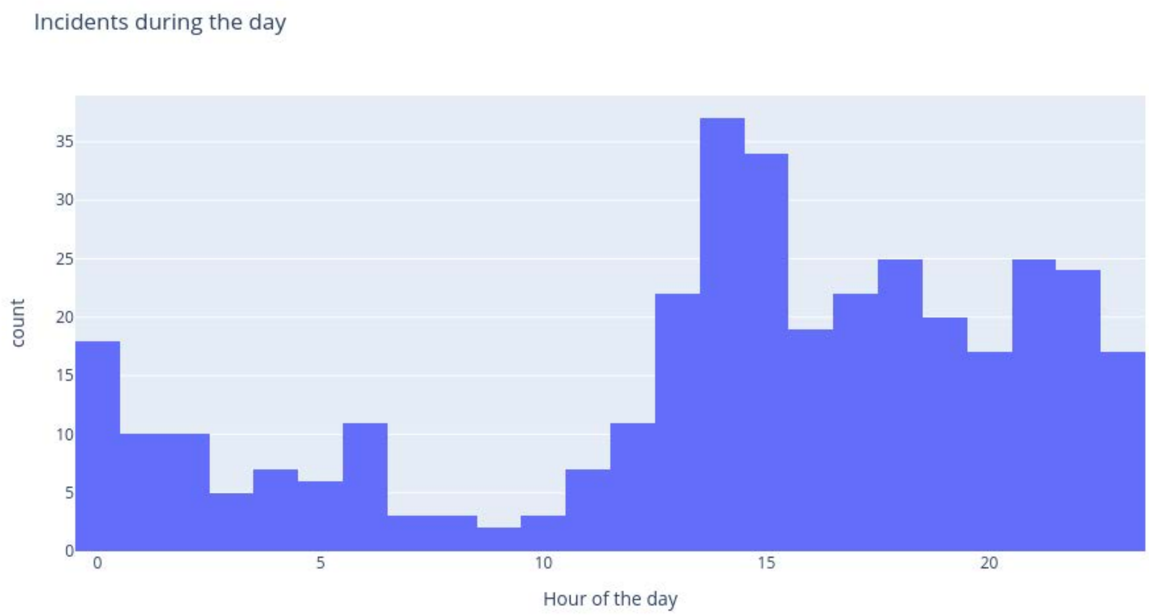


Figure G.6. Frequency of Incident Models

The period of time between noon and midnight had the most significant number of incident models. Based on this information and continuing gathering of incident model times, one can determine the probability of an Incident Model being at a given time and assign a score based on the past Incident Model data. It is not yet clear whether incidents that occur at unusual times are more or less likely to be of VCC-level.

G.4.5 Additional Variables

Based on our qualitative analysis of incident models, the Project Team found additional fields and variables that can give an indication of the seriousness of an incident.

Multiple Dispatches

During interviews, operators informed us that when a big incident starts, multiple dispatches referring to the same event might come in at the same time or in a small window of time. These dispatch events can be from different agencies and from varying but near locations. Based on this, the team evaluated past events and incident models, and identified ranges of time and distance that can help recognize whether a group of dispatches belong to the same event, increasing the probability of that event being of a VCC-level.

Duration of the Dispatch

The duration of the dispatch (i.e., how long the dispatch event is open) is an important factor in determining the likelihood of the dispatch indicating a VCC-level incident. This has not been part of the rules engine and we propose to include this as an important factor. As events come into the system, we can track their duration and as this duration increases, it should also increase the probability of it being a VCC-level incident.

Number of Updates

While the duration of a dispatch is an important factor, the duration of an incident model may not be. Some past incident models have been kept open for long periods of time even after the incident has been cleared. With this in mind, the team looked into the characteristics of incident models that have a long duration to determine whether this was because it hadn't been closed or because the incident itself hadn't been cleared. Where long duration was due to the incident model not being closed, the tea found that updates to the dispatch were rare. However, where the incidents themselves were ongoing, the need for more resources and collaboration led to a higher number of updates. We propose to include this variable as another important factor in the rules engine.

G.4.6 Point System

As already indicated, we propose a point system that would augment the current rules engine. These points would be based on the variables discussed above. The engine would assign a score to each dispatch event, representing the likelihood of it being a VCC-level incident. Each one of the variables discussed would add to the final score of the event, and each variable would have a different weight.

As there is no continuous evaluation of the events by the rules engine, whenever an event is updated it should trigger a recalculation of the score. The weight of each variable should be refined through extensive analysis. Collected dispatch data in which we are able to identify the dispatches that were considered VCC-level incidents should be used to calibrate, test, and evaluate the proposed enhanced rules engine.

G.5 Results from Qualitative Analysis of Incident Models

The following findings on incident models were gathered from operator interviews. While these do not necessarily pertain to the rules engine, they provide potentially important context.

Include Reasons for Deletion

Understanding the motivations for deleting incidents is important for improving incident management practices. Adding a field requiring the reason for deleting a VCC level incident could provide valuable information for users and designers alike. A menu could provide frequently used reasons for deleting.

Improve How Users Handle Incidents that are not Linked to the Map

Without proper location information (e.g., SPD dispatches), incidents cannot be linked to the map. This can lead to confusion and discrepancies, as in use-cases where the incident location is updated, but the subsequent update on the map is missing.

Leverage the Information in Notes

Notes in incident models share critical information among agencies. Notes are used not only to add new information, but also to communicate (e.g., "We are aware and tracking.") Other examples include ongoing estimation of reopening a closure and indication of participation of non-VCC units such as maintenance crews.

Clarify Criteria for Deletion and Closure

Criteria for when an incident should be deleted versus when it should be closed are not always clear. This is crucial for maintaining consistency in incident management records and developing useful historical data for future rules engine enhancements.

Establish Standard Operating Procedures for Collaborative Use of VCC Capabilities

While standardizing procedures across agencies can be a sensitive issue, operators indicated that standard operating procedures for VCC incident management could help ensure consistency and lead to more efficient practices among agencies. Again, this could also contribute to better historical data for enhancing system-generated support.

G.6 Future work

This proposal is intended as a starting point for the improvement of the rules engine. There are important steps that should be taken next. The calibration of the rules engine will consist of varying the weights and scores assigned to each of the variables discussed above. There needs to be extensive testing of different options for implementing and evaluating a point system that uses dispatch and IM data to enhance how the system identifies VCC-level situations.

Scores for the functional variables should be based on past data. It is important to obtain, store, and analyze this data without exposing sensitive information from the events or disrupting agency record management systems and strategies. If necessary, we can begin by using the already collected IM data as a starting point to identify the most common patterns for each variable.

G.7 Conclusion

The rules engine was implemented as an initial effort to support operators in the identification of dispatches that are likely to indicate a VCC-level incident requiring collaboration across agencies and/or the need for more resources. The Project Team determined that the initial Rules Engine was a good starting point, and it was able to detect a significant portion of the VCC-level incidents that occurred during the evaluation period. The team was also able to identify areas of improvement for this engine.

Based on interviews with users, the team focused on the most important variables that play a role in their determination of the seriousness and complexity of events. We then analyzed each of these variables to propose an enhanced design based on point systems that will assign a score to each dispatch event and calculate the likelihood of it being an incident based on past data. This calculation can be updated as new dispatch information arrives.

This is a first step towards a smarter approach to the identification of events that should result in the launch of an incident model. Calibration, testing, and evaluation, using past data, should be the next steps. In the future, the use of AI tools such as natural language processing should also be considered to improve the recognition of the types of events even when they are described differently by different agencies.

Appendix H Benefit-Cost Analysis

H.1 Literature Review

Traffic incident management (TIM) plays a critical role in improving public safety and population health, as well as achieving economic development of communities. Many studies have documented the potential impact of TIM on society using a variety of methodologies measuring benefits and/or costs (Guin et al., 2007). In particular, while cost measures are relatively straightforward to estimate, the methods used for estimating benefits in the studies have shown heterogeneity, especially in terms of their scopes and data sources. We briefly outline the evaluation methods employed in two different TIM projects and examine their respective findings.

Guin et al. (2007) examined the benefit-cost of Georgia's intelligent transportation system (ITS), Georgia NaviGAtor. The type of benefits included in their analysis is the reduction in delay, decrease in additional fuel consumption, improved air quality resulting from the ITS, and prevention of secondary incidents. Specifically, they refined the methodology of measuring the duration of incident delay that occurred in multiple lanes. They provided tutorials that included detailed formulas for measuring the incident duration, as well as other benefit measures. Additionally, their analysis was primarily based on incident logs and actual operation data obtained from the ITS. This approach allowed them to minimize the use of simulation models to obtain parameter values for their benefit-cost model, thus reducing uncertainty associated with the parameters. Their analysis yielded a benefit-cost ratio of 4.4 over a period of 1 year, suggesting that 4.4 times of benefits are generated for each unit of cost incurred.

Bertini et al. (2004) investigated the benefits of the freeway incident management program, COMET, in Portland, Oregon, focusing on its capacity to decrease incident delay. The researchers incorporated two types of benefits into their analysis, such as savings on fuel consumption and reduction in waiting time in the queue during incidents. In contrast to the method employed by Guin et al. (2007), Bertini et al. (2004) used a less data-intensive approach when estimating the benefits of the program. In particular, using the archived data of the program, they initially established vehicle hours of delay for each incident case, which played a critical role in calculating the remaining benefit measures. The evidence from the study suggested that if 100% of incidents in the Portland region were covered by COMET, reducing the delay by 1.1 minutes per incident would serve as a threshold that can generate a positive return on investment.

H.2 Data Sources

The data sources of the parameter information for benefit-cost analysis (BCA) can be categorized as follows: 1) the Washington State Department of Transportation (WSDOT) annual traffic incident log, 2) the WSDOT traffic count database system, and 3) information of average gas price and wage.

H.2.1 Traffic Incident Database

WSDOT publishes a regular report (i.e., Gray Notebook) about the agency's overall performance and functioning of the traffic management system of the state. We were able to access the incident log, which is the source of the report. The time period of the log used for the BCA is from 2012 to 2021 (10 years in total). The incident log contains detailed information of traffic incidents: basic tracking records (e.g., unique ID, date/time, incident response unit type), time to arrival/clear scene/clear lanes, road lane blocking status and primary lane involved, incident type and action taken, location (state route (SR) ID, direction, milepost (MP)), incident involved with fire, hazardous materials, or heavy truck. Note that we restricted the incident records based on the information of SR ID and MP to reflect the potential coverage areas of the VCC. Thus, the incidents that were included occurred on I-5 between MP 140 (near to Federal Way) and MP 200 (near to Everett).

H.2.2 Traffic Volume Database

WSDOT operates the vehicular traffic data monitoring program and publishes an annual report (i.e., multimodal corridor capacity report) based on the collected information. The examples of data provided in the report are vehicle volume (by various time periods), incident classification, speed, and frequency of congestion. Particularly, we used the TRACFLOW system (https://tracflow.wsdot.wa.gov/contourdata/brainscan) including the information on traffic volumes of freeway corridor by every 0.5 miles. In the same manner as above, we retrieved data from the Seattle metropolitan area.

H.2.3 Other Sources

Incidents induce unnecessary waiting times and gas consumption on the roads. To convert the delay caused by an incident into monetary value, we used the annual average gas price[4] (per gallon) and wage[5] (per hour) in Washington State.

H.3 Method of Benefit-Cost Analysis

A BCA is an evaluation technique that systematically identifies and compares the benefits and costs of implementing a new project. Since the BCA incorporates all the benefits and costs arising from a project or program with a societal perspective, its result can guide transportation professionals to make the most economically advantageous decisions for society (i.e., choosing the alternative that maximizes the net societal benefits). There are multiple BCA guidelines and

[4]Source: U.S. Bureau of Labor Statistics, Average Price: Gasoline, All Types in Seattle-Tacoma-Bellevue WA (https://www.bls.gov/regions/west/news-release/2022/averageenergyprices_seattle_20220614.htm)

[5]Source: Washington State Employment Security Department (https://esd.wa.gov/labormarketinfo/median-hourly-wages)

evaluation examples performed in the context of traffic incident and safety management systems (Guin et al., 2007). Our analysis follows their approaches within the limitations of data availability.

H.3.1 Measuring Benefits

To calculate benefits, we consider three types of saving that the implementation of VCC would bring into a society – 1) savings from additional time spent on the road due to delay, 2) savings from additional fuel consumption due to slowed traffic or waiting, and 3) savings from additional emissions of pollutants (e.g., carbon dioxide, hydrocarbon, and nitrous oxide) due to delay.

Estimation of Delay

To ensure accurate calculation of the aforementioned benefit measures, it is essential to first determine the total number of vehicle hours of delay (VHD) caused by the incidents. We employ the following formula to attain this objective.

$$VHD = F \times R \times T$$

Equation H-1

where *F* is normal traffic flow at the incident site and time, which implies the average hourly traffic volume. *R* is reduction capacity due to incident, and *T* is duration of incident (hours). It is worth noting that not every incident on freeways results in delays to the traffic flow. For the purpose of our analysis, we have defined the incidents that cause delay as those that exceed a minimum threshold of one minute and are located either on a lane or on a shoulder of the freeway.

The data pertaining to the average hourly traffic volume (*F*) is obtained from TRACFLOW. We then matched it to each incident record based on the time of the incident and its proximity to the nearest mile post. Roadway reduction factors (*R*) for incidents on freeways, established by the US Federal Highway Administration, were incorporated into our analysis (Bertini et al., 2004). For the base case scenario of the BCA, we assumed that the average number of lanes on freeways within the VCC coverage area was four. Please note that we performed a sensitivity analysis that involved varying the number of lanes (up to 6 lanes) to enhance the robustness of this assumption. To determine the duration of each incident, we added the time taken to arrive at the scene and time to clear the lanes using the WSDOT incident logs.

Estimation of the Cost of Incident Delay

1) Time cost: Time costs reflect the value of labor loss due to incident delay, accounting for the largest portion of incident delay costs. The cost of delayed time was estimated using the following model.

$$Total\ Cost_{delay-time} = LC_{hour} \times VO \times VHD$$

Equation H-2

where LC_{hour} is hourly labor cost. VO is vehicle occupancy. VHD is vehicle hours of delay adopted from the prior analysis.

Following the USDOT guidance, we used $17.9 (i.e., general travel time saving per person-hour) as a reference for the hourly labor cost. For the base case scenario of the BCA, we assumed a vehicle occupancy rate of 1.15.

2) Additional fuel consumption: To calculate the costs resulting from additional fuel consumption, we first need to convert the measure of VHD into vehicle miles of delay (VMD) using the formula below. We assumed an average speed of 20 miles per hour during the incident.

$$VMD = VHD \times Average\ Speed\ during\ the\ Incident$$

Equation H-3

Then, we calculate the amount of extra fuel consumption (gallon) as follows. We obtained the information regarding average fuel consumption per mile from all vehicle types in the US[6].

$$Additional\ consumption(gallon) = VMD \times 0.04016\ gallons\ per\ mile$$

Equation H-4

Lastly, we estimated the associated costs by multiplying the additional fuel consumption with the average gas price per gallon in Washington[7].

$$Total\ Cost_{fuel} = Avg.P_{fuel} \times Total\ gallon$$

Equation H-5

3) Additional emissions during incident delay: We adopted the method used by Guin et al. (2007) to estimate the costs associated with extra emissions of pollutants due to incident delay. Three different types of pollutants, i.e., HC (hydrocarbons), CO (carbon monoxide), and NO (nitrogen oxides), were considered for estimation of the costs. The hourly emissions of these air pollutants were calculated to be $25.676/10^6$ tons for HC, $338.69/10^6$ tons for CO, and $36.064/10^6$ tons for NO. Reducing 1 ton of emissions would result in cost savings of $6,700 for HC, $6,360 for CO, and $12,875 for NO. We applied the following model to each pollutant separately to obtain total cost savings associated with extra emissions.

$$Total\ Cost_{emission} = VHD \times Emission_{hour} \times price_{gas/ton}$$

Equation H-6

4) Calculating benefits: The estimated total costs of incident delay consist of three components: 1) time costs, 2) the costs from increased fuel consumption, and 3) the costs of reducing air

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[6]Source: US Environmental Protection Agency https://www.epa.gov/automotive-trends/explore-automotive-trends-data#DetailedData

[7]Average gas price per gallon in WA by years: 2017- $2.91; 2018 - $3.27; 2019 - $3.18

pollutants. We transform these cost estimates into benefits by calculating the incremental value of reducing incident delay by VCC. For example, if the increased coordination facilitated by VCC among traffic agencies resulted in one-minute reduction in incident delays, we can estimate the benefits by comparing the costs between two hypothetical scenarios: the baseline case without VCC and the alternative scenario where VCC improved incident response time by one minute for all incidents. For the BCA, we only used data from the three most recent years prior to the Covid-19 pandemic, specifically 2017, 2018, and 2019, to address potential biases stemming from the impact of the pandemic.

H.3.2 Measuring Costs

The costs of the VCC are based on the Federal Highway Administration (FHA) award of $3,424,361 for the development of VCC in 2020, the cash match of $1,410,000 from WSDOT, the in-kind match of $3,769,000 from the private and public sectors, and the $1,600,000 estimated yearly operating expenses of the VCC, which includes staff, ongoing software licenses, and maintenance costs. We applied a 3.1% discount rate for both benefit and cost outcomes over the period of 15 years.

H.4 Results

H.4.1 Seattle Metro Area Summary Incident Statistics

Table H-1 presents descriptive statistics of the incidents that occurred on I-5 (MP range: 140-200 in the state of Washington) between January 2012 and December 2021. The table includes data on the proportions of the incidents across hour groups (e.g., morning, afternoon), incident types (e.g., collision, disabled), lane blockage types (e.g., single, shoulder), and clear groups (e.g., < 15 min). The average number of incidents per year in the coverage area is 17,000 – 9,000 occurred on the north bound, whereas 8,000 occurred on the south bound. The incidents across the quarter were evenly distributed. A majority of incidents occurred during the peak commuting hours. The statistics also reveal that over 50% of incident reports in the area were attributed to disabled cars on the roadway, followed by collisions (~13%) and abandoned vehicles (~12%). Regarding the types of lane blockage, approximately 80% of incidents involved a shoulder or median blockage, while 17% resulted in a single lane blockage. About 80% of incidents were cleared from the roadway within 15 minutes. We visualized these incident statistics through pie charts (Figures H-1, H-2, H-3, and H-4).

To provide a more targeted view of incident data, we narrowed our focus by including only incidents with a delay of one minute or more in Table H-2. Furthermore, we restricted the data including incidents that occurred in downtown Seattle (MP range: 160-170) only. From Tables H-2 and H-3, we identified that the proportion of incidents related to debris removal more than doubled. Furthermore, incidents occurring on either single or multiple lanes were more likely to contribute to the lane blockage. There has been a two-fold increase in both the time to arrive and time to clear the scene. Additionally, Table H-4 shows the same data by clear groups. We noticed that as the time required to clear the scene increased, incidents with casualties and greater lane blockage were more likely to occur.

H.4.2 Results of Benefit-Cost Analysis

Benefits and Costs

The benefits and costs associated with reducing incident delay are presented in Tables H-5, H-6, H-7, H-8, H-9, and H-10, respectively. Total benefit includes both current and future benefits, with the latter calculated as the sum of present values of expected benefits over a 15-year period. For example, in Table H-5, we observed that reducing incident duration by 30 seconds and 1 minute for all incidents covered by VCC would yield a benefit of approximately 9 and 17 million dollars, respectively. The total cost of VCC comprises the initial investment and yearly operating expenses. The total costs are estimated to be approximately 27 million dollars for 15 years.

Benefit-Cost Ratio

The benefit-cost ratio is calculated by dividing the total benefits expected from a project/program by its total costs. A ratio greater than 1 indicates that the expected benefits of the project/program exceed the costs, implying that the project is likely to generate a positive return on investment. The results of benefit-cost-ratio for VCC across the different levels of incremental delay savings are presented in Table H-8, H-9, and H-10. Note that each table presents results for different scenarios varying the operational definition of a severe incident based on the clearing time of incidence. Our analysis demonstrates that a 3-minute decrease in incident delay would yield a benefit-cost ratio exceeding 1.

H.4.3 Sensitivity Analysis

To test the robustness of our findings, we performed sensitivity analysis varying some of parameters in the benefit-cost model. Specifically, we selected five parameters: vehicle occupancy factor, average speed during the incidents, the number of lanes, discount rate, and the study period. The alternative values employed in the sensitivity analysis are presented in Tables H-11, H-12, and H-13, along with their corresponding outcomes. The results of the sensitivity analysis indicate that the variation in our parameter assumptions has negligible effects on the results from the base case scenario. This evidence supports the robustness of our initial assessment.

We conducted a benefit-cost analysis of implementing the VCC in the Puget Sound region. Our findings suggest if the time to clear lanes for severe incident (Table H-10) is reduced by approximately 3 minutes on average after the introduction of VCC, the benefits would exceed the costs. Our analysis did not account for incidents that occurred in the major arterials of the region. Consequently, we expect that extending the geographical coverage of the VCC is likely to result in an increase in the benefits.

H.5 References and Tables

Bertini, R., Rose, M., & El-Geneidy, A. (2004). *Using Archived Data to Measure Operational Benefits of ITS Investments, Volume 2: Region 1 Incident Response Program*.

Guin, A., Porter, C., Smith, B., & Holmes, C. (2007). Benefits Analysis for Incident Management Program Integrated with Intelligent Transportation Systems Operations: Case Study. *Transportation Research Record*, *2000*(1), 78–87. https://doi.org/10.3141/2000-10

Table H.1. Summary statistics for the incidents on I-5 2012 to 2021 (unit: %)

I-5 MP range: 140-200	**Northbound**	**Southbound**
Number of incidents	89,965	81,674
Quarter		
Q1	26	25
Q2	27	26
Q3	26	26
Q4	22	23
Weekdays		
Yes	86	86
No	14	14
Hour group		
Early morning	1	1
Morning commute	37	36
Afternoon	33	32
Evening commute	29	30
Night	0.2	0.2
Incident type		
Abandoned vehicle	11.4	12.0
Collision - Fatality	0.1	0.1
Collision - Injury	2.8	2.7
Collision - Other	10.2	10.8
Debris	8.6	9.5
Disabled	56.9	57.1
Police activity	0.4	0.4
Other	9.7	7.5
Lane blockage		
Single lane	16.2	17.0
Multiple lane	3.3	3.4
Shoulder/Median	75.5	74.6
HOV	2.8	2.8
Ramp	1.7	1.7
All travel lanes	0.2	0.2
Total closure	0.2	0.3
Other	0.1	0.1
Clear group		
< 15 min	78.0	77.1
< 30 min	14.5	15.1
< 60 min	5.8	6.0
< 90 min	1.1	1.2
≥ 90 min	0.6	0.6
Time to arrive (SD)	2.49 (13.49)	2.66 (16.24)
Time to clear lane (SD)	10.37 (30.34)	10.22 (35.52)
Time to clear scene (SD)	11.18 (18.33)	11.48 (18.85)

Table H.2. Summary statistics for delays causing incidents (> 1 min) on I-5, 2012 to 2021 (unit: %)

I-5 MP range: 140-200	**Northbound**	**Southbound**
Number of incidents	22,158	21,092
Quarter		
Q1	25	25
Q2	26	25
Q3	25	25
Q4	24	25
Weekdays		
Yes	85	84
No	15	16
Hour group		
Early morning	2	2
Morning commute	33	33
Afternoon	32	33
Evening commute	32	32
Night	0.6	0.5
Incident type		
Abandoned vehicle	2.8	2.6
Collision - Fatality	0.2	0.3
Collision - Injury	9.5	8.9
Collision - Other	22.1	22.9
Debris	25.3	26.3
Disabled	34.5	33.3
Police activity	1.3	1.1
Other	4.4	4.6
Lane blockage		
Single lane	58.2	57.5
Multiple lane	11.9	11.8
Shoulder/Median	12.5	14.0
HOV	9.8	9.4
Ramp	5.9	5.8
All travel lanes	0.6	0.5
Total closure	1	1
Other	0.1	0.1
Clear group		
< 15 min	51.4	52.4
< 30 min	28.3	27.8
< 60 min	14.7	14.3
< 90 min	3.4	3.4
≥ 90 min	2.2	2.0
Time to arrive (SD)	5.19 (10.03)	5.04 (6.66)
Time to clear lane (SD)	11.34 (25.75)	11.33 (29.38)
Time to clear scene (SD)	21.22 (29.63)	20.97 (30.01)

Table H.3. Summary statistics for the incidents near downtown Seattle on I-5 2012 to 2021 (unit: %)

I-5 MP range: 160-170	**Northbound**	**Southbound**
Number of incidents	3,448	3,082
Quarter		
Q1	26	26
Q2	26	24
Q3	26	25
Q4	22	25
Weekdays		
Yes	83	83
No	17	17
Hour group		
Early morning	3	3
Morning commute	31	29
Afternoon	32	30
Evening commute	34	38
Night	0.4	0.5
Incident type		
Abandoned vehicle	3.4	2.6
Collision - Fatality	0.1	0.3
Collision - Injury	7.4	7.9
Collision - Other	21.1	24.5
Debris	20.3	18.9
Disabled	41.5	40.1
Police activity	1.5	1.2
Other	4.7	4.5
Lane blockage		
Single lane	66.5	64.0
Multiple lane	7.9	9.2
Shoulder/Median	9.9	9.2
HOV	5.9	7.2
Ramp	9.1	8.9
All travel lanes	0.3	0.3
Total closure	0.4	1.0
Other	0.1	0.1
Clear group		
< 15 min	53.7	50.2
< 30 min	29.5	30.6
< 60 min	13.5	15.4
< 90 min	1.9	1.9
≥ 90 min	1.3	1.9
Time to arrive (SD)	5.03 (14.56)	5.19 (6.84)
Time to clear lane (SD)	8.31 (17.15)	9.64 (26.13)
Time to clear scene (SD)	18.55 (24.77)	19.96 (24.72)

Table H.4. Summary statistics for the incidents on I-5 by clear groups 2012 to 2021 (unit: %)

	<15	**>=15 - <30**	**>=30 - <60**	**>=60 - <90**	**>=90**
Number of incidents	22,434	12,145	6,282	1,471	918
Incident type					
Abandoned vehicle	2.7	2.7	3.2	2.1	1.3
Collision - Fatality	0.0	0.0	0.1	0.2	9.8
Collision - Injury	1.0	8.5	29.6	37.9	34.5
Collision - Other	12.3	34.3	34.2	31.2	21.8
Debris	41.9	11.7	4.1	3.4	3.1
Disabled	37.8	37.1	21.0	14.7	13.8
Police activity	0.7	1.1	1.9	3.6	5.9
Other	3.6	4.6	5.9	6.9	9.8
Lane blockage					
Single lane	64.4	57.9	45.4	33.8	21.9
Multiple lane	7.0	10.8	21.9	32.6	43.9
Shoulder/Median	13.8	12.8	13.2	12.6	7.4
HOV	8.3	11.5	10.8	10.7	5.9
Ramp	5.7	5.7	6.4	5.2	8.7
All travel lanes	0.5	0.4	0.4	1.0	2.7
Total closure	0.3	0.8	1.7	3.9	9.0
Other	0.1	0.1	0.2	0.3	0.4
Time to arrive (SD)	1.97 (3.05)	7.35 (5.75)	9.24 (8.33)	10.33 (11.62)	15.57 (38.81)
Time to clear lane (SD)	2.96 (2.63)	7.42 (6.24)	21.67 (15.7)	48.42 (27.65)	137.53 (107.12)
Time to clear scene (SD)	7.02 (3.85)	20.54 (4.2)	40.6 (8.41)	70.85 (8.3)	159.32 (100.89)

Table H.5. Scenario 1: Benefits from reduced time of clearing the severe incidents on I-5 MP 140-200 (unit: US dollar)

Delay time saving	Vehicle hours of delay	Time cost	Fuel cost	Emission reduction cost	Total cost	Benefit	Future benefit	Total benefit
Base case	2,055,652	71,910,849	5,152,177	5,502,892	82,565,918	0	0	0
30 seconds	2,072,782	72,510,081	5,195,110	5,558,592	83,263,783	697,865	7,829,666	8,527,531
1 minute	2,089,913	73,109,382	5,238,047	5,613,229	83,960,658	1,394,740	15,648,225	17,042,965
2 minutes	2,124,175	74,307,919	5,323,919	5,707,847	85,339,685	2,773,767	31,120,160	33,893,927
3 minutes	2,158,434	75,506,389	5,409,785	5,798,606	86,714,780	4,148,862	46,547,979	50,696,841
4 minutes	2,192,696	76,704,927	5,495,658	5,894,240	88,094,825	5,528,907	62,031,334	67,560,241
5 minutes	2,226,955	77,903,392	5,581,519	5,987,246	89,472,157	6,906,239	77,484,251	84,390,490
6 minutes	2,261,217	79,101,934	5,667,393	6,088,700	90,858,027	8,292,109	93,032,960	101,325,069
7 minutes	2,295,479	80,300,470	5,753,266	6,196,594	92,250,330	9,684,412	108,653,844	118,338,256
8 minutes	2,329,740	81,499,008	5,839,139	6,298,351	93,636,498	11,070,580	124,205,896	135,276,476
9 minutes	2,364,000	82,697,471	5,925,003	6,403,322	95,025,796	12,459,878	139,793,065	152,252,943
10 minutes	2,398,261	83,896,011	6,010,875	6,499,036	96,405,922	13,840,004	155,277,329	169,117,333

Note. A severe incident is defined as an occurrence requiring more than 10 minutes for the clearance of affected lane(s).

Table H.6. Scenario 2: Benefits from reduced time of clearing the severe incidents on I-5 MP 140-200 (unit: US dollar)

Delay time saving	Vehicle hours of delay	Time cost	Fuel cost	Emission reduction cost	Total cost	Benefit	Future benefit	Total benefit
Base case	1,487,052	51,996,419	3,731,766	4,110,971	59,839,156	0	0	0
30 seconds	1,499,444	52,429,705	3,762,864	4,149,185	60,341,754	502,598	5,638,877	6,141,475
1 minute	1,511,837	52,863,041	3,793,962	4,189,108	60,846,111	1,006,955	11,297,488	12,304,443
2 minutes	1,536,622	53,729,666	3,856,160	4,253,868	61,839,694	2,000,538	22,444,950	24,445,488
3 minutes	1,561,405	54,596,240	3,918,355	4,321,422	62,836,017	2,996,861	33,623,153	36,620,014
4 minutes	1,586,190	55,462,863	3,980,553	4,386,948	63,830,364	3,991,208	44,779,186	48,770,394
5 minutes	1,610,973	56,329,435	4,042,742	4,452,833	64,825,010	4,985,854	55,938,574	60,924,428
6 minutes	1,635,758	57,196,062	4,104,943	4,527,435	65,828,440	5,989,284	67,196,514	73,185,798
7 minutes	1,660,542	58,062,684	4,167,142	4,603,145	66,832,971	6,993,815	78,466,807	85,460,622
8 minutes	1,685,327	58,929,309	4,229,338	4,672,440	67,831,087	7,991,931	89,665,126	97,657,057
9 minutes	1,710,110	59,795,880	4,291,532	4,745,336	68,832,748	8,993,592	100,903,219	109,896,811
10 minutes	1,734,895	60,662,506	4,353,729	4,813,768	69,830,003	9,990,847	112,091,878	122,082,725

Note. A severe incident is defined as an occurrence requiring more than 20 minutes for the clearance of affected lane(s).

Table H.7. Scenario 3: Benefits from reduced time of clearing the severe incidents on I-5 MP 140-200 (unit: US dollar)

Delay time saving	Vehicle hours of delay	Time cost	Fuel cost	Emission reduction cost	Total cost	Benefit	Future benefit	Total benefit
Base case	1,154,775	40,368,848	2,900,221	3,214,325	46,483,394	0	0	0
30 seconds	1,164,397	40,705,240	2,924,389	3,241,399	46,871,028	387,634	4,349,043	4,736,677
1 minute	1,174,021	41,041,674	2,948,558	3,269,563	47,259,795	776,401	8,710,798	9,487,199
2 minutes	1,193,268	41,714,501	2,996,896	3,320,670	48,032,067	1,548,673	17,375,270	18,923,943
3 minutes	1,212,513	42,387,289	3,045,231	3,374,362	48,806,882	2,323,488	26,068,274	28,391,762
4 minutes	1,231,760	43,060,117	3,093,571	3,426,656	49,580,344	3,096,950	34,746,097	37,843,047
5 minutes	1,251,005	43,732,904	3,141,903	3,477,004	50,351,811	3,868,417	43,401,538	47,269,955
6 minutes	1,270,252	44,405,733	3,190,243	3,533,239	51,129,215	4,645,821	52,123,589	56,769,410
7 minutes	1,289,499	45,078,560	3,238,582	3,588,878	51,906,020	5,422,626	60,838,919	66,261,545
8 minutes	1,308,745	45,751,387	3,286,919	3,641,349	52,679,655	6,196,261	69,518,684	75,714,945
9 minutes	1,327,991	46,424,173	3,335,254	3,696,575	53,456,002	6,972,608	78,228,875	85,201,483
10 minutes	1,347,237	47,097,002	3,383,593	3,751,348	54,231,943	7,748,549	86,934,512	94,683,061

Note. A severe incident is defined as an occurrence requiring more than 30 minutes for the clearance of affected lane(s).

Table H.8. Scenario 1: Results of benefit-cost ratio (unit: US dollar)

Delay time saving	Total benefit	Total cost	Benefit-cost ratio
30 seconds	8,527,531	26,554,492	0.32
1 minute	17,042,965	26,554,492	0.64
2 minutes	33,893,927	26,554,492	1.28
3 minutes	50,696,841	26,554,492	1.91
4 minutes	67,560,241	26,554,492	2.54
5 minutes	84,390,490	26,554,492	3.18
6 minutes	101,325,069	26,554,492	3.82
7 minutes	118,338,256	26,554,492	4.46
8 minutes	135,276,476	26,554,492	5.09
9 minutes	152,252,943	26,554,492	5.73
10 minutes	169,117,333	26,554,492	6.37

Note. A severe incident is defined as an occurrence requiring more than 10 minutes for the clearance of affected lane(s)

Table H.9. Scenario 2: Results of benefit-cost ratio (unit: US dollar)

Delay time saving	Total benefit	Total cost	Benefit-cost ratio
30 seconds	6,141,475	26,554,492	0.23
1 minute	12,304,443	26,554,492	0.46
2 minutes	24,445,488	26,554,492	0.92
3 minutes	36,620,014	26,554,492	1.38
4 minutes	48,770,394	26,554,492	1.84
5 minutes	60,924,428	26,554,492	2.29
6 minutes	73,185,798	26,554,492	2.76
7 minutes	85,460,622	26,554,492	3.22
8 minutes	97,657,057	26,554,492	3.68
9 minutes	109,896,811	26,554,492	4.14
10 minutes	122,082,725	26,554,492	4.6

Note. A severe incident is defined as an occurrence requiring more than 20 minutes for the clearance of affected lane(s).

Table H.10. Scenario 3: Results of benefit-cost ratio (unit: US dollar)

Delay time saving	Total benefit	Total cost	Benefit-cost ratio
30 seconds	4,736,677	26,554,492	0.18
1 minute	9,487,199	26,554,492	0.36
2 minutes	18,923,943	26,554,492	0.71
3 minutes	28,391,762	26,554,492	1.07
4 minutes	37,843,047	26,554,492	1.43
5 minutes	47,269,955	26,554,492	1.78
6 minutes	56,769,410	26,554,492	2.14
7 minutes	66,261,545	26,554,492	2.5
8 minutes	75,714,945	26,554,492	2.85
9 minutes	85,201,483	26,554,492	3.21
10 minutes	94,683,061	26,554,492	3.57

Note. A severe incident is defined as an occurrence requiring more than 30 minutes for the clearance of affected lane(s).

Table H.11. Scenario 1: Results of benefit-cost ratio from sensitivity analysis (unit: US dollar)

Parameters	Delay time saving	Total benefit	Total cost	Benefit-cost ratio
Base case	1 minute	17,042,965	26,554,492	0.64
Vehicle occupancy factor: 1.15	1 minute	12,482,713	26,554,492	0.47
Average speed: 10 mph	1 minute	16,518,335	26,554,492	0.62
Number of lanes: 6 lanes	1 minute	20,864,466	26,554,492	0.79
Discount rate: 5%	1 minute	15,200,770	24,441,187	0.62
Covered years: 10 years	1 minute	12,203,872	21,003,243	0.58
Base case	2 minutes	33,893,927	26,554,492	1.28
Vehicle occupancy factor: 1.15	2 minutes	24,773,434	26,554,492	0.93
Average speed: 10 mph	2 minutes	32,844,617	26,554,492	1.24
Number of lanes: 6 lanes	2 minutes	41,748,899	26,554,492	1.57
Discount rate: 5%	2 minutes	30,230,291	24,441,187	1.24
Covered years: 10 years	2 minutes	24,270,257	21,003,243	1.16

Table H.12. Scenario 2: Results of benefit-cost ratio from sensitivity analysis (unit: US dollar)

Parameters	Delay time saving	Total benefit	Total cost	Benefit-cost ratio
Base case	2 minutes	24,445,488	26,554,492	0.92
Vehicle occupancy factor: 1.15	2 minutes	17,850,733	26,554,492	0.67
Average speed: 10 mph	2 minutes	23,685,474	26,554,492	0.89
Number of lanes: 6 lanes	2 minutes	30,803,479	26,554,492	1.16
Discount rate: 5%	2 minutes	21,803,145	24,441,187	0.89
Covered years: 10 years	2 minutes	17,504,560	21,003,243	0.83
Base case	3 minutes	36,620,014	26,554,492	1.38
Vehicle occupancy factor: 1.15	3 minutes	26,728,058	26,554,492	1.01
Average speed: 10 mph	3 minutes	35,479,975	26,554,492	1.34
Number of lanes: 6 lanes	3 minutes	46,180,603	26,554,492	1.74
Discount rate: 5%	3 minutes	32,661,712	24,441,187	1.34
Covered years: 10 years	3 minutes	26,222,313	21,003,243	1.25

Table H.13. Scenario 3: Results of benefit-cost ratio from sensitivity analysis (unit: US dollar)

Parameters	Delay time saving	Total benefit	Total cost	Benefit-cost ratio
Base case	2 minutes	18,923,943	26,554,492	0.71
Vehicle occupancy factor: 1.15	2 minutes	13,803,930	26,554,492	0.52
Average speed: 10 mph	2 minutes	18,333,316	26,554,492	0.69
Number of lanes: 6 lanes	2 minutes	24,215,102	26,554,492	0.91
Discount rate: 5%	2 minutes	16,878,431	24,441,187	0.69
Covered years: 10 years	2 minutes	13,550,775	21,003,243	0.65
Base case	3 minutes	28,391,762	26,554,492	1.07
Vehicle occupancy factor: 1.15	3 minutes	20,711,882	26,554,492	0.78
Average speed: 10 mph	3 minutes	27,505,765	26,554,492	1.04
Number of lanes: 6 lanes	3 minutes	36,303,738	26,554,492	1.37
Discount rate: 5%	3 minutes	25,322,861	24,441,187	1.04
Covered years: 10 years	3 minutes	20,330,349	21,003,243	0.97

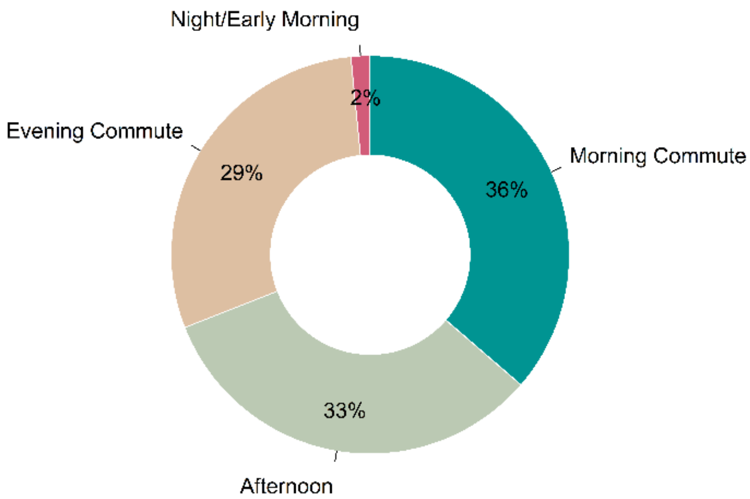

Figure H.1. Incident by Hour Group

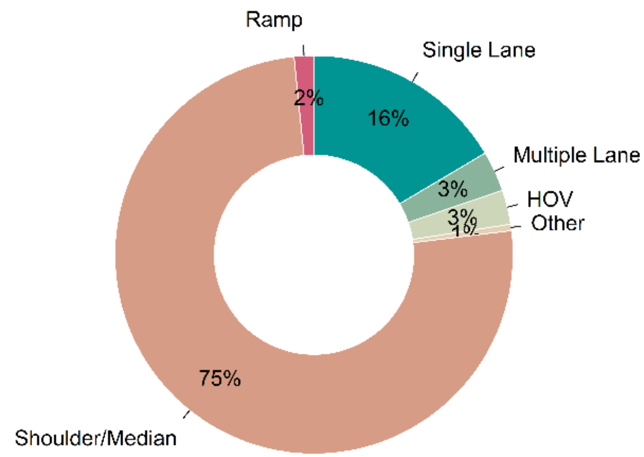

Figure H.3. Lane Blockage Type

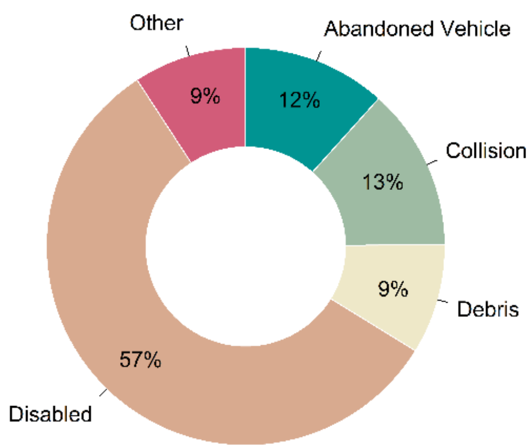

Figure H.2. Incident Type

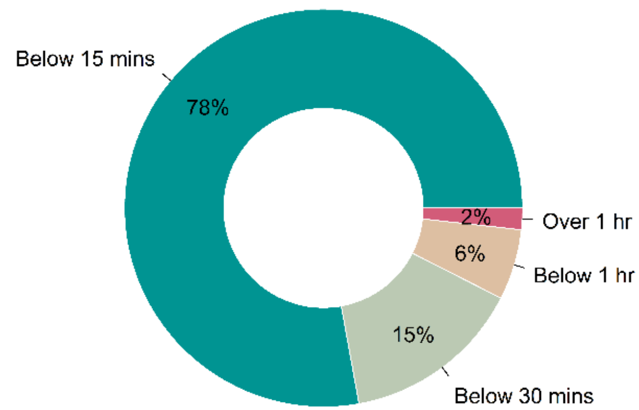

Figure H.4. Incident by Clear Group

Appendix I Interview and Observation Protocols

Below we provide the protocols used to conduct interviews and workplace observations during the Evaluation period. The interviews typically drew upon a subject's evaluation survey responses in order to add context and depth to their answers.

I.1 Baseline Interview Protocol

I.1.1 Preparation

- Create copy of this document in SharePoint
- Add interviewee name to header
- Review their survey responses
- Add Job title to question 1
- Add response to survey questions 9 and 13 to interview question 2
- Remove irrelevant traffic management systems from the below list
- Remove irrelevant survey questions

I.1.2 Preamble

- Greetings and thanks for agreeing to a follow-up interview to the pre-deployment survey.
- Introduce yourself (if you do not know them)
- Provide context (read aloud): This interview is part of a larger effort to gather baseline data for the evaluation of the VCC. The information you share will be used to evaluate the system. Once completed, the Virtual Coordination Center will be a cloud-based platform to enhance the collaborative management of the Seattle area's transportation system. I ask that you frame any responses around the criteria of a Virtual Coordination Center-level incident:
    - 'A VCC-level incident refers to a transportation situation that requires extensive collaboration across agencies and roles to resolve. Some examples of these complex incidents include but are not limited to motor vehicle collisions on freeways that block multiple lanes, extended road closures, crime scenes, hazardous material spills, fatality collisions, rollover collisions, and blocking incidents estimated to require more than 90 minutes to resolve.'
- Brief overview of the list of questions (how many, try our best to get through all the questions)
- Share that interview responses or other materials will not be shared outside of the evaluation team and will only be used to help us evaluate the VCC. Some comments may be used or paraphrased in the final report. Your role in an incident may be referenced but we will not share identifying information.
- Confirm permission to record and start recording (do you have any questions for me? Is it alright if I start recording the conversation?)

I.1.3 Questions

- Can you tell me more about what you do as a [insert job title]?
- What do you do during a major traffic incident?

- When asked to rate your overall satisfaction level with communication between your agency and internal partners during an active VCC-level incident, you answered [insert their answer]. Can you tell me more about that?
- And your overall satisfaction level with communication with external partners was [insert their answer]. Can you tell me more about that?
- It is our understanding that your agency uses [systems mentioned in the appropriate table below] to manage traffic. Which systems do you tend to use to help you manage a major traffic incident?
- How do you use them?

Table I.1. King County Metro Systems

Typical User	**Systems**
KC Metro coordinators	MobileITCS Google Maps Twitter Motorola Radio System
KC Metro CITRS	ATIS Twitter Virtual Machine EmVista Drupal Shared network drive Cameleon GovDelivery TransitAlerts

Table I.2. Seattle Department of Transportation Systems

Typical Users	**Systems**
TOC Operators	Cameleon Google Maps Access Database Alert Seattle Camera inventory Excel sheet Traveler Information Map Twitter Data Manager Bing Maps Hansen (aka InforPublic Sector) Viewpoint Web Flow 32 Email Teams ATMS: Concert, Tactics, SCOOT Possible future application: PagerDuty

Typical Users	Systems
Seattle Response Team	Hansen (aka InforPublic Sector) Twitter Cameleon Fillable timesheet pdf Incident log

Table I.3. Seattle Police Department Systems

Typical Users	Systems
Dispatchers	Versaterm [CAD] Call queue monitor Radio Case lookup application
Officers in the field	Versaterm [CAD] Sector Body camera application Onboard GPS Mark43

Table I.4. Seattle Fire Department Systems

Typical Users	Systems
Fire alarm center	Move-up modules Respond CAD Cameleon RapidSOS
Field Units	Respond CAD ESO Google Maps Locutian

Table I.5. Washington State Department of Transportation

Typical Users	Systems
TMC Operators	TMS Google Maps Twitter WSPCAD Table of intersections Radio Cameleon
PIO	Twitter GovDelivery ROADS
Incident Response Team	Phone camera WITS Radio

Typical Users	Systems
Others	HATS Workzone database Consolidated system (in development, grant funded) PRMS Here.com

Population Movement Questions

- How quickly do you feel you can get a message with basic details about a traffic incident out to the public?
- What, if anything, prevents you from getting these messages out more quickly?
- Do you have any way of measuring the impact that your messages have on mobility or mode-switching during a major incident? That is, how do you know if your messages are having the desired effect?
- If yes, can you provide more detail on how you measure this impact?
- How likely are you to be able to get a suggested action in a message to the public within the first 30 minutes of an incident?

Congestion Management Specific Questions

- Do you have any way of measuring the impact that your mobility strategies have on mobility during a major incident? That is, how do you know that your actions are having the desired effect?
    - If yes, can you provide more detail on how you measure this impact?

Records Retention-specific questions

- Can you tell me more about how you prepare the reports for your agency about an incident?
- Do you ever feel the reports are lacking important information? How often?
- Final Question - Ask everyone: Is there anything else you would like to tell me about your work?

Conclusion

- End recording.
- Thank them for their time and participation.
- Provide your contact information to contact you with questions.

I.2 Phase 2 Interview Protocol

I.2.1 Preparation

- Create copy of this document in SharePoint
- Add date, time, and interviewer and interviewee name to header
- Review Interviewee's baseline interview videos and notes, if available

- Review Interviewee's survey responses (check baseline and post-deployment Phase 1 and Phase 2 surveys)
- Add Job title to question 1
- Add any questions that you may want to ask based upon past interviews and survey responses (aks only if time permits)
- Remove irrelevant survey questions

I.2.2 Preamble

- Greetings and thanks for agreeing to an interview
- Introduce yourself (if you do not know them)
- Provide context (read aloud)
- This interview is part of a larger Virtual Coordination Center evaluation effort. Your responses will not be shared outside of the evaluation team. Some comments may be used or paraphrased in the final report and while your role may be referenced we will not share any other identifiable information.
- This interview will be no longer than 45 minutes and will include X questions. Brief overview of the list of questions (how many, try our best to get through all the questions)
- I would like to record this interview so that I can be sure to accurately capture your responses. Is it okay if I start recording now?

I.2.3 Questions

Questions to ask if NOT part of baseline interviews.

- As a [insert job title] can you tell me more about your role during major traffic incidents?

General questions for everyone

- How often do you use the VCC (e.g., daily, only when notified of a VCC-level incident, etc.)?
- Where do you rate your familiarity with VCC (0 - 100) *compared to others in your agency*?) 0 would indicate no familiarity while 100 would indicate the most familiarity.
- What areas of the VCC or information in the VCC are most helpful to you during major incidents? E.g., integrated dispatch feed, Incident Model, situation map, etc.
- Provide some examples of how/when you've used this information.
- Are there any features of the VCC that you don't use or don't find useful?
- Has the VCC changed the way you interact or collaborate with:
- Others within your agency. If yes, can you provide an example. If not, why not?
- Others outside of your agency. If yes, can you provide an example. If not, why not?
- Have you found other uses for the VCC outside of collaborating on major incidents?

Questions from the Evaluation plan

- Has use of the VCC changed how you interact with any of your other traffic management systems? Please explain or provide an example. (Q1-10)
  - Has the VCC helped you to leverage other agency resources (e.g., people, equipment) when needed? Please explain or provide an example. (Q1-3)? An

example here would be if you are SDOT does VCC help you to leverage WSDOT IRT or vice versa if you are WSDOT can you more easily contact SDOT SRT?

Questions for Public Information Officers or those Responsible for Communication of Incidents

- Do you communicate with the public, if yes:
  - Has the VCC helped you to get messages about major incidents out to the public more quickly? (Q3-1)
  - If yes, can you provide more detail or an example?
  - If not, why not?
- Has the VCC helped you to put out more actionable messages about major incidents out to the public? (Q3-1)
  - If yes, can you provide more detail or an example?
  - If not, why not?
- Has the VCC had any impact on how you develop public messages related to major incidents? (Q3-2)
  - If so, please explain
  - If not, why not?

Questions on Evaluation Plan Concerning Report Preparation

- Are you involved in the preparation of any management or after-action report? If yes, then ask Q18, otherwise skip to next section)
- Has the information in the VCC been used in your preparation of management reports or after-action reports? (Q1-4)
  - If yes,
    - Was there a reduction in the effort required to prepare these reports? Please provide an example, if possible.
    - Did the information in the VCC have any impact on the quality of the reports? Please provide an example, if possible.
  - If not, do you think the VCC will have an impact on report preparation in the future? Please explain.

Questions for Congestion Managers Concerning Specific Incident Models (IMs)

- Are you sensitive to the difference between “closing” and “deleting” an IM?
  - If yes, how do you decide which IMs to delete rather than close?
- Have you used the mobility strategy page?
  - If yes, what information have you added?
  - If not, why not?
- Have you used the Notes?
  - If yes, what have you used them for?
  - If not, why not?
  - Optional: Why did you use the Notes for IM #XXX rather than put it in the mobility strategy tab?

- Are you sensitive to the difference between “human launched” and “system generated” IM?
- Do you view and treat them differently? If so, explain.
- Have you ever launched an IM without a dispatch? Explain the situation.
    - If yes, did you enter a location and link it to the map? If not, why not?
    - Have you ever later gone back and associated a dispatch with that IM?
- When launching an IM from a dispatch, have you ever replaced the automatically inserted dispatch location with your own location? If so, why?
- Did you link it to the map?

Final Question

- Ask everyone: Is there anything else you would like to tell me about your experience with the VCC?
- Additional questions if time permits:
    - Are you aware of the various ways to get help with the VCC?
        - If so, how has this process been for you?
        - If not, how do you get help when needed?

Conclusion

- End recording.
- Thank them for their time and participation.
- Provide your contact information to contact you with questions.

I.3 Evaluation Phase 1 Observations

I.3.1 Logistics

Dates: April 17 - May 12, 2023

Locations: WSDOT TMC, SDOT TOC, KCM TCC

People: Mark (later in the week), Sonia, Hannah (first two weeks), Brie

Schedule: Mondays/Wednesdays - 7:00-9:00 AM; Tuesdays/Thursdays - 4:00-6:00 PM

I.3.2 Goals from the Evaluation Plan

Observations of the traffic incident management team, congestion management team, and public information officers performing tasks pre- and post-VCC deployment will be conducted. Observers will be co-located with staff. Real-time probes (queries posed concurrent with the task) may be used for a more objective, unbiased assessment. Real-time probes will only be used after careful review with the user groups to ensure they do not negatively impact incident response and that they comply with any COVID-19 safety measures.

I.3.3 Questions to Ask

- How would you define a VCC-level incident?
- What are key characteristics that would lead you to believe the VCC would be beneficial to use when monitoring and responding to an incident?

- During a VCC-level incident, how often do you go off shift and need to update your replacement (or go on shift and need to be updated)? How is this done? Did this change with the deployment of the VCC?
- When you join a response for an existing VCC-level incident, are you able to quickly get up to speed on all the details of the incident?
- When transitioning off an active VCC-level incident, are you able to quickly provide the person taking over with all the information they will need?
- Does your agency have any Standard Operating Procedures (SOP) related to VCC? If so, what are they?
- Do you feel ownership of the IMs you launch?

I.3.4 Evaluation Interests

- Where is the VCC located in the physical space?
- Is it in more than one work area so that each user is logged in and monitoring the VCC?
- What's the setup of the VCC?
- Does it take up the entire monitor or is it on a shared monitor?
- Is the VCC sized so they can see the entire Dashboard screen?
- Are they viewing the Dashboard or the Feed?
- Do they have any filters on? Which dispatch streams are they viewing?
- What's the timeframe they are using?
- Are they viewing All dispatches or only Noteworthy?
- Are they sorting by any particular column on the Integrated Dispatch Feed either on the Dashboard or the Feed?
- Is there an Incident Model on the Dashboard? If so, are they viewing the IM Detail page or the Dashboard IM card?
- Did users pin any dispatches? If not, ask if they are aware of this capability and if they find it useful.
- Observe an operator as they carry out their normal tasks.
- Record their name, role/title, years in this role.
- Take notes about what they are doing and with which systems they are interacting, including. Record:
- # of phone calls they make, time spent on phone
- Communications with others in their space
- Communications with other agency personnel (if possible, ask who they are speaking with and their agency)
- Any other tools they use to communicate.
- Do you notice any points of frustration - how to determine if someone shows signs of frustration (*either with the VCC or when they are interacting with other systems or people*).
- Observe an operator as they are interacting with the VCC. Record name, etc. if multiple operator observations.
- During the 2-hour observation, how often are they using the VCC? This may be difficult to quantify - it could be a count of the number of times they turn their attention to the

VCC or a percentage of time they are interacting. Let's see how this goes and then we can modify it for Phase 2 if necessary.

- How is VCC being used in connection to availability of other available CADs? Do they look at CAD (WSDOT = WSP Client, SDOT = Viewpoint) first and then verify on the VCC, do they look at VCC first and then confirm on CAD?
- What do you do when a system generated VCC is launched? I.e., How are users verifying a system-generated Incident Model? Without the VCC, Verification of an incident currently involves locating the incident (once they are aware of it) on a CCTV camera. Once they see it, then it's verified.
- Does this change with the VCC. For example, if they can't find it on a camera do they sift through the dispatch records to see if they can find other instances of this incident from another CAD?
- How is the lead decided for a system generated IM? For human generated IM?
- If an IM is launched by an operator:
- Who at your agency launched the IM? Is this part of your SOPs and documented?
- Are they entering any information into the VCC and if so, how do they obtain this information (e.g., cameras, phone calls to others, etc.)?
- Incident clearance times
- Incident clearance time estimates
- Additional questions:
- How do you identify secondary incidents? Without the VCC? With the VCC?
- Get copies of any of the following:
- Blank management reports used (as about frequency, distribution lists)
- Standard Operating Procedures

I.4 Evaluation Phase 2 Observations

I.4.1 Logistics

Dates: June 26 - July 16, 2023

Locations: WSDOT TMC, SDOT TOC, KCM TCC

People: Sonia, Ridley, Brie, Mishti

Schedule: Tuesday 8:00-10:00 AM; Thursday 4:00-6:00 PM

I.4.2 Goals from the Evaluation Plan

Observations of the traffic incident management team, congestion management team, and public information officers performing tasks pre- and post-VCC deployment will be conducted. Observers will be co-located with staff. Real-time probes (queries posed concurrent with the task) may be used for a more objective, unbiased assessment. Real-time probes will only be used after careful review with the user groups to ensure they do not negatively impact incident response and that they comply with any COVID-19 safety measures.

I.4.3 Questions to Ask

- How would you define a VCC-level incident?
- What are key characteristics that would lead you to believe the VCC would be beneficial to use when monitoring and responding to an incident?
- During a VCC-level incident, how often do you go off shift and need to update your replacement (or go on shift and need to be updated)? How is this done? Did this change with the deployment of the VCC?
- When you join a response for an existing VCC-level incident, are you able to quickly get up to speed on all the details of the incident?
- When transitioning off an active VCC-level incident, are you able to quickly provide the person taking over with all the information they will need?
- Does your agency have any Standard Operating Procedures (SOP) related to VCC? If so, what are they?
- Do you feel ownership of the IMs you launch?

Evaluation Interests

- Where is the VCC located in the physical space?
- Is it in more than one work area so that each user is logged in and monitoring the VCC?
- What's the setup of the VCC?
- Does it take up the entire monitor or is it on a shared monitor?
- Is the VCC sized so they can see the entire Dashboard screen?
- Are they viewing the Dashboard or the Feed?
- Do they have any filters on? Which dispatch streams are they viewing?
- What's the timeframe they are using?
- Are they viewing All dispatches or only Noteworthy?
- Are they sorting by any particular column on the Integrated Dispatch Feed either on the Dashboard or the Feed?
- Is there an Incident Model on the Dashboard? If so, are they viewing the IM Detail page or the Dashboard IM card?
- Did users pin any dispatches? If not, ask if they are aware of this capability and if they find it useful.
- Observe an operator as they carry out their normal tasks.
- Record their name, role/title, years in this role.
- Take notes about what they are doing and with which systems they are interacting, including. Record: # of phone calls they make, time spent on phone.
- Communications with others in their space.
- Communications with other agency personnel (if possible, ask who they are speaking with and their agency).
- Any other tools they use to communicate.
- Do you notice any points of frustration? - how to determine if someone shows signs of frustration (*either with the VCC or when they are interacting with other systems or people*).

- Observe an operator as they are interacting with the VCC. Record name, etc. if multiple operator observations.
- During the 2-hour observation, how often are they using the VCC? This may be difficult to quantify - it could be a count of the number of times they turn their attention to the VCC or a percentage of time they are interacting. Let's see how this goes and then we can modify it for Phase 2 if necessary.
- How is VCC being used in connection to availability of other available CADs? Do they look at CAD (WSDOT = WSP Client, SDOT = Viewpoint) first and then verify on the VCC, do they look at VCC first and then confirm on CAD?
- What do you do when a system generated VCC is launched? I.e., How are users verifying a system-generated Incident Model? Without the VCC, Verification of an incident currently involves locating the incident (once they are aware of it) on a CCTV camera. Once they see it, then it's verified.
- Does this change with the VCC. For example, if they can't find it on a camera do they sift through the dispatch records to see if they can find other instances of this incident from another CAD?
- How is the lead decided for a system generated IM? For human generated IM?
- If an IM is launched by an operator:
- Who at your agency launched the IM? Is this part of your SOPs and documented?
- Are they entering any information into the VCC and if so, how do they obtain this information (e.g., cameras, phone calls to others, etc.)?
- Incident clearance times
- Incident clearance time estimates
- Additional questions:
- How do you identify secondary incidents? Without the VCC? With the VCC?
- Get copies of any of the following:
- Blank management reports used (as about frequency, distribution lists)
- Standard Operating Procedures

Appendix J Data Definitions

Data definitions are provided for the performance metrics in the Evaluation Plan.

VCC-level Incident: A transportation situation that may require enhanced collaboration across agencies and roles to address. The existence of a VCC-level incident is indicated to users by the initiation of an Incident Model.

Incident Model: See Chapter 2.1.3.

Dispatch Event: Data from SPD, SFD, or WSP 911 computer-aided dispatch (CAD) systems or from the KCM Customer Service Record system that represents a collision, crash, or event that is impacting traffic or is traffic-related.

Dispatch Event Start Time: The time when the call resulting in a dispatch record is logged into the agency CAD system.

Dispatch Event Close Time: The time when a dispatcher changes the status of a dispatch event to closed. Dispatches may not be closed immediately upon an agency leaving the scene as dispatchers may be involved in other tasks and may be delayed in changing the status to closed.

Dispatch Event Duration: The difference between the time when the agency CAD record's status is changed to Closed and the Event Start Time.

Incident Model Start Time: Is arrived at in one of two ways: 1) If the VCC Incident is based on one or multiple agency dispatches, then it is the Event Start Time for the earliest of the dispatches; or 2) If the VCC Incident is not based on an agency dispatch and has been entered manually by a user, then the Incident Model Start Time corresponds to the time when the VCC Incident was initially entered into the VCC.

Incident Model Launch Time: The time when a VCC user or the system creates an Incident Model. If a VCC user creates an Incident Model from scratch (i.e., without an associated agency dispatch event), the Incident Model Launch Time and the Incident Model Start Time will be the same.

Incident Model Closed Time: The time when a VCC user changes the Status of the Incident Model to Closed. A VCC user with the Incident Manager role closes the Incident Model if they determine that the last responder has left the scene, and the roadways are cleared of responders, debris, and vehicles. A roadway is considered cleared if all responding units have left the scene or if all vehicles are pulled over to the shoulder of the roadway such that they are no longer blocking traffic. As is the case for dispatch events, VCC users may be delayed in changing the Status of the Incident Model to closed because they are tending to other responsibilities, which may in turn affect the Incident Model Duration.

Incident Model Duration: The difference between the Incident Model Closed Time and the Incident Model Start Time. This is referred to as Time to Incident Clearance in the Evaluation Plan. As agency clearance times may differ because they learn about incidents at different times and leave the scene at different times, we used Incident Model Duration as our performance measure in Chapter 3.5.

Incident Mobility Strategy Start Time: The timestamp created when a user entered a mobility strategy into the VCC or the timestamp from when a user entered a mobility strategy into the Notes section of the VCC.

Estimated Clearance Time: This estimate is entered by a VCC user to indicate how long they predict it will take for all incident responders to clear the roadways. Anyone with the Incident Manager role can add an estimated clearance time.

Appendix K Baseline and Post-Deployment Survey Instruments

All surveys were hosted on Qualtrics. Participants were sent a link to the survey that included a brief description of the survey, the approximate time required to complete the survey, a deadline for completing the survey, and a name and contact email should a participant have any questions. The baseline survey and Phase 1 post-deployment surveys were estimated to require between 20 and 30 minutes to complete due to the number of open-ended responses that were required. Phase 2 and Phase 3 post-deployment surveys were estimated to take approximately 15 minutes to complete.

Each survey also included this definition of a VCC-level incident as several questions referenced this type of incident.

> *A VCC-level incident refers to a transportation situation that requires extensive collaboration across agencies and roles to resolve. Some examples of these complex incidents include but are not limited to motor vehicle collisions on freeways that block multiple lanes, extended road closures, crime scenes, hazardous material spills, fatality collisions, rollover collisions, and blocking incidents estimated to require more than 90 minutes to resolve.*

Table K-1 shows the survey questions, the response format, and which survey the question appeared on. Some questions required that participants use a visual analog scale (VAS) to provide a rating. VAS have been used for various psychometric assessments, including those related to subjective experiences, emotions, and perceptions, and have demonstrated validity and reliability. We used VAS as we believe them to be more intuitive for participants, require less cognitive effort than providing a numeric value, and may reduce bias as participants may be less likely to choose an arbitrary number. Figure K-1 below shows the VAS used for Question 12 on Table K-1. Participants clicked on the blue marker and dragged it to the desired spot. The visual analog scales had endpoints that were appropriate to the survey question (see column 3 in Table K-1). Qualtrics converted the VAS to a number between 0 and 100 depending upon where the participant put the blue marker. In the VAS in Figure K-1, the blue marker at the very left of the scale was converted to 0 to reflect Very Difficult while the blue marker to the extreme left of the scale was converted to 100 to reflects Very Easy. Participants did not see any numbers when they selected their desired spot on the visual analog scale. This was intentional as we believed that showing participants the value that corresponded to the spot would negate the advantages described above and would be no different than allowing them to enter a number between 0 and 100 into a numeric write-in field.

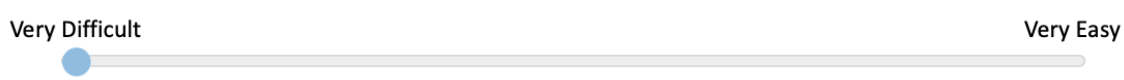

Figure K.1 Visual Analog Scale used in Table K.1 Survey Questions

Table K.1 Survey questions, response modes, and the survey in which they appeared.

No.	Question	Response Mode	Included in
1	Select your agency	Choose one from: King County Metro Transit, Port of Seattle/Northwest Seaport Alliance, Seattle Department of Transportation, Seattle Fire Department, Seattle Police Department, Sound Transit, Washington State Department of Transportation, Washington State Patrol, Other [write-in]	All surveys
2	How long have you been with your agency? Round to the nearest year.	Numeric write-in	Baseline
3	How many years have you been in your current role? Round to the nearest year.	Numeric write-in	All surveys
4	Job Title	Text write-in	All surveys
5	What is your current role in an incident? If your position could fall under multiple responses, choose your primary role.	Choose one from: Congestion Management - individuals responsible for managing traffic flow (e.g. TOC/TMC operator, Traffic Enforcement Units, Traffic Engineers, etc.), Incident Response - individuals responsible for onsite management of an incident (e.g. IRT, SRT, Fire, Police, etc.), Population Movement - individuals who communicate with the public or media and agency executives (e.g. Public Information Officers, public affairs, customer service, etc.), Executive - individuals responsible for bigger picture planning and communication (e.g. regional administrators, public officials, directors, etc.), Other, please explain [with write-in]	All surveys
6	How long have you been working in the area of incident response you indicated above? Round to the nearest year.	Numeric write-in	Baseline
7	Have you logged in and explored the VCC?	Yes/No	All post-deployment surveys
7a	Please describe why you have not logged in and explored the VCC.	Asked only if respondent selected No to Q7. Open-ended text field	All post-deployment surveys
8	In general, how much do you trust the information in the VCC agency dispatches?	VAS with endpoints No Trust on the left and Full Trust on the right	All post-deployment surveys

No.	Question	Response Mode	Included in
8a	Please explain your reasoning to Question 8: "how much do you trust the information in the VCC agency dispatches?"	Open-ended text	Phase 1
9	How much do you trust the information that is available in an active VCC incident model?	VAS with endpoints No Trust on the left and Full Trust on the right	All post-deployment surveys
9a	Please explain your reasoning to Question 9: "how much do you trust the information that is available in an active VCC Incident Model?"	Open-ended text	Phase 1
10	How satisfied are you that the VCC has improved your ability to obtain accurate information from other agencies?	VAS with Very Dissatisfied on the left and Very Satisfied on the right	All post-deployment surveys
10a	Please explain your reasoning to Question 9: "how satisfied are you that the VCC has improved your ability to obtain accurate information from other agencies?"	Open-ended text	All post-deployment surveys
11	For each of the following communication tools, rate how frequently you use them during an active VCC-level incident when communicating with individuals **within** your agency: Cell phone calls, Landline phone calls, Text messages, VCC [asked only on post-deployment surveys], Online messaging software (Skype, Teams, etc.), Emails, Face-to-face discussions, Phone/video conference software (Teams, Zoom, etc.), Social Media platforms (Facebook, Twitter, etc.), Radio, Other – please define.	VAS with endpoints Never on the left and Always on the right	All surveys
12	In conducting your work, how difficult is it to get necessary information about an active VCC-level incident from others **within** your agency	VAS with Very Difficult on the left and Very Easy on the right	All surveys
12a	Please explain your reasoning to Question 12: "in conducting your work, how difficult is it to get necessary information about an active VCC-level incident from others **within** your agency?	Open-ended text	Phase 1
13	Rate your overall satisfaction level with communication and coordination **within**	VAS with Very Dissatisfied on the left and Very Satisfied on the right	All surveys

No.	Question	Response Mode	Included in
	your agency during an active VCC-level incident.		
14	For each of the following communication tools, rate how frequently you use them during an active VCC-level incident when communicating with individuals **outside** your agency (see Q11 for list of communication tools).	VAS with endpoints Never on the left and Always on the right	All surveys
15	During a VCC-level incident, how often do you reach out to someone **outside** your agency to coordinate work?	VAS with endpoints Never on the left and Always on the right	All surveys
16	In conducting your work, how difficult is it to get necessary information about an active VCC-level incident from others **outside** your agency?	VAS with Very Difficult on the left and Very Easy on the right	All surveys
16a	Please explain your reasoning to Question 16: “in conducting your work, how difficult is it to get necessary information about an active VCC-level incident from others **outside** your agency?”	Open-ended text	Phase 1
17	How satisfied are you that the VCC has improved your ability to obtain accurate information from other agencies?	VAS with Very Dissatisfied on the left and Very Satisfied on the right	All post-deployment surveys
18	Rate your overall satisfaction level with communication and coordination between your agency and **external** partners during an active VCC-level incident.	VAS with Very Dissatisfied on the left and Very Satisfied on the right	All surveys
19	How satisfied are you that the VCC has increased collaboration among agencies or operation groups during a VCC-level incident?	VAS with Very Dissatisfied on the left and Very Satisfied on the right	All post-deployment surveys
20	How likely are you to add information into the VCC?	VAS with Very Unlikely on the left and Very Likely on the right	All post-deployment surveys
20a	Please explain your reasoning to Question 22: “how likely are you to add information into the VCC?”	Open-ended text	Phase 1 survey, Phase 3 survey
21	How would you rate the usability of the VCC?	VAS with endpoints Very Difficult to Use on the left and Very Easy to Use on the right	All post-deployment surveys
22	What additional internal workgroups and external agencies could benefit from access to the VCC?	Open-ended text	All post-deployment surveys

No.	Question	Response Mode	Included in
23	How often do you get an estimated clearance time for an incident?	VAS with endpoints Never on the left and Always on the right	Baseline
24	When you get an estimated clearance time, how accurate does that estimate turn out to be?	VAS with endpoints Never on the left and Always on the right	Baseline
25	During a VCC-level incident, how often do you go off shift and need to update your replacement (or go on shift and need to be updated)?	VAS with endpoints Never on the left and Always on the right	Baseline
26	When you join a response for an existing VCC-level incident, are you able to quickly get up to speed on all the details of the incident?	VAS with endpoints Never on the left and Always on the right	Baseline
27	When transitioning off an active VCC-level incident, are you able to quickly provide the person taking over with all the information they will need?	VAS with endpoints Never on the left and Always on the right	Baseline
28	Are you responsible for creating or contributing to any reports (including reporting to executives, after-action reports, etc.) associated with a VCC-level incident?	Yes/No	Baseline, Phase 1, 2
28a	What kinds of reports do you create or contribute to?	Open-ended text field [Asked only if responded Yes to Q28]	Baseline
28b	What kinds of information do you contribute to the reports?	Open-ended text field [Asked only if responded Yes to Q28]	Baseline
28c	In general, how easy is it to gather the information for the report?	VAS with Very Difficult on the left and Very Easy on the right [Asked only if responded Yes to Q28]	Baseline
28d	Is the information contained in these reports valuable?	VAS with Not at all Valuable on the left and Very Valuable on the right [Asked only if responded Yes to Q28]	Baseline
29	I have used the information in the VCC to help me create reports about incidents.	Yes/No	All post-deployment surveys
29a	Rate your level of agreement with: I have used the information in the VCC to help me create reports about incidents.	VAS with Strongly Disagree on the left and Strongly Agree on the right [Asked only if responded Yes to Q29]	Phase 1, 2
29b	Rate your level of agreement with: The VCC reduced the effort required to complete my reports.	VAS with Strongly Disagree on the left and Strongly Agree on the right [Asked only if responded Yes to Q29]	All post-deployment surveys
30	Rate your level of agreement with: The VCC Incident Model has improved my ability to monitor and manage I-5 corridor operations during a major incident.	VAS with Strongly Disagree on the left and Strongly Agree on the right [Only asked if selected “Congestion Management” role in Q5]	Phase 1, 2

No.	Question	Response Mode	Included in
31	Rate your level of agreement with: I feel I have more information about an incident now that I have access to the VCC.	VAS with Strongly Disagree on the left and Strongly Agree on the right [Only asked if selected “Congestion Management” role in Q5]	Phase 1, 2
32	Rate your level of agreement with: The tools I currently use to manage congestion provide me with all the information I need to manage a VCC-level incident.	VAS with Strongly Disagree on the left and Strongly Agree on the right [Only asked if selected “Congestion Management” role in Q5]	Baseline
32	Rate your level of agreement with: “I can accurately, quickly, and efficiently collect all the information I need to manage congestion caused by a VCC-level incident.”	VAS with Strongly Disagree on the left and Strongly Agree on the right [Only asked if selected “Congestion Management” role in Q5]	Baseline
34	How likely are you to make alterations to your congestion management strategies in future incidents after seeing the information from partner agencies in the VCC?	VAS with Very Unlikely on the left and Very Likely on the right [Only asked if selected “Congestion Management” role in Q5]	All post-deployment surveys
	Please explain your reasoning to Q34: "How likely are you to make alterations to your congestion management strategies in future incidents after seeing the information from partner agencies in the VCC?"	Open-ended text	Phase 3 survey
35	During a VCC-level incident, how aware are you of the information other agencies share with the public regarding that incident?	VAS with Not all Aware on the left and Very Aware on the right [Only asked if selected “Population Movement” role in Q5]	Baseline
36	When you hear information from another agency shared with the public, how often does it conflict with what you know?	VAS with endpoints Never on the left and Always on the right [Only asked if selected “Population Movement” role in Q5]	Baseline

No.	Question	Response Mode	Included in
37	How have you been a part of the Virtual Coordination Center's development? Select all that apply.	Options: Participated in early brainstorming sessions (prior to September 2020), Member of a committee (Steering, Executive Oversight), Member of a workstream (Business, Evaluation & Assessment, Policy, Design & Development, Technical Solutions, Concept of Operations), Attended at least one workshop (workstream meetings, training or user adoption meetings), Participated in Use, Feedback, Refine (UFR) activities, I have not participated in the Virtual Coordination Center's development, Other-please explain [write-in field]	Baseline
38	How familiar do you think your coworkers are with the Virtual Coordination Center?	VAS with endpoints Not Familiar at all on the left and Very Familiar on the right	Baseline
39	Name, email address, phone number	Collected so we could review responses during Interviews	All surveys
40	What have you done in the VCC? Select all that apply.	Options: Viewed Dispatch Events, Viewed Incident Models, Created/edited Incident Models, Viewed/added Incident Model Notes, Annotated an Incident Model, Pinned Dispatch Events, Viewed/added to Public Information Hub, Viewed/finalized VCC Records Management Reports, None of the Above	All post-deployment surveys
41	Was there anything in the survey that was confusing or that you would like to share with the project team?	Open-ended text field	All surveys