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Enhancing Traffic Incident Management

Coordinated Traffic Incident and Congestion Management (TIM-CM):

Mitigating Regional Impacts of Major Traffic Incidents in the Seattle I-5 Corridor

by

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16. ABSTRACT

Within the Seattle metropolitan area, traffic incident management (TIM) operations provide a multi-jurisdictional and coordinated strategy to detect, respond to, and clear traffic incidents so that traffic flow can be restored quickly and safely. There is a need to extend TIM to include congestion management (CM), a complex activity for managing incident-generated congestion and for mitigating regional impacts after the actual incident has been cleared.

This project identified challenges and opportunities for the enhancement of regional TIM to incorporate CM processes and operational coordination, supported by innovative technologies. The researchers engaged regional stakeholders in a series of iterative scoping and participatory design activities to identify and articulate desired enhancements to the regional management of major incidents on the Seattle I-5 corridor. These activities were used to identify TIM and CM stakeholders, identify and review relevant policy, work with stakeholders to model the "as-is" TIM and CM processes and procedures, use the as-is model to facilitate stakeholders in identifying current pain points and opportunities for system enhancement, and articulate desired interventions made possible by innovative applications of emerging technology. The report includes recommendations for enhancing regional TIM to incorporate CM and a five-stage approach for conducting Phase 2 of this research.

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Executive Summary

The economy and infrastructure of Seattle are growing rapidly, with the population and commuter volume expanding in tandem. As a result, the city of Seattle regularly ranks within the top 5 cities with the worst traffic congestion across the nation. Within this major metropolitan area, traffic incident management (TIM) operations provide a multi-jurisdictional and coordinated strategy to detect, respond to, and clear traffic incidents so that traffic flow can be restored quickly and safely. There is a need to extend TIM to include congestion management (CM), a complex activity for managing incident-generated congestion and for mitigating regional impacts after the actual incident has been cleared. In comparison to stand-alone TIM, CM involves a wider, more-diverse group of stakeholders, covers a greater portion of the freeway, as well as the interconnected arterials and alternative modes of transportation, and the people, facilities, and services that rely on this infrastructure for mobility.

This project identified challenges and opportunities for the enhancement of regional TIM to incorporate CM processes and operational coordination, supported by innovative technologies. The research approach for this project was to engage regional stakeholders in a series of iterative scoping and participatory design activities to identify and articulate desired enhancements to the regional management of major incidents on the Seattle I-5 corridor. These activities were used to (1) identify TIM and CM stakeholders, (2) identify and review relevant policy documents and related work, (3) work with stakeholders to model the "as-is" TIM and CM processes and procedures, (4) use the as-is model to facilitate stakeholders in identifying current pain points and opportunities for system enhancement, (5) articulate desired interventions ("to-be" model) made possible by innovative applications of emerging technology, and (6) capture results, models and proposed interventions in a final report. The research team also worked with regional

stakeholders on non-technical aspects of potential system enhancements, such as issues of adoption, stakeholder buy-in, policy and structural implications.

The research team conducted regular working group meetings and sponsor meetings dedicated to documenting congestion management workflows, and identifying the information and partnerships needed to develop and execute a coordinated congestion management strategy. The following are the main ideas elicited by these meetings: (1) the Seattle Area Congestion Management Joint Operations Group (SAJOG) charter, (2) strategies for communicating with the "on-road" driver, (3) strategies for affecting "future" driver behavior, and (4) strategies for proactive data collection and sharing. The research team also conducted two "use case exercises": an "as-is" exercise, and a "to-be" exercise. Based on the two use case exercises several recommendations for enhancing regional TIM to incorporate CM were identified:

a) Create the appropriate TIM-CM joint operations command structure
b) Enhance the information-sharing environment across TIM and CM processes
c) Gather insight into current Seattle commuter behaviors and preferences

Finally, this report outlines a five-stage approach for phase 2 of this research, based on the aforementioned recommendations. The stages are as follows:

Stage 1: Formalize, empower and facilitate the SAJOG

Stage 2: Analyze the opportunity space

Stage 3: Understand the Information Sharing Environment

Stage 4: Iterative design of prototype solutions

Stage 5: build and test prototype solutions

I. Introduction

According to the latest U.S. Census Bureau figures, between July 2015 and July 2016, Seattle was the fastest growing city in the U.S., with a net gain of nearly 21,000 people (57 per day) on average. (Guy, 2017) With this considerable influx of residents comes an increased volume of vehicular traffic, further exacerbated by a geographically restricted mobility infrastructure. Rush hour times have become extended, with Seattle recently ranked fourth among U.S. cities for the worst overall congestion levels, with commuters spending about 40 extra minutes per day (152 hours per year) sitting in traffic congestion. ("TomTom Traffic Index," n.d.)

With the growing strains on regional infrastructure and increasing demands on transportation-related agencies, entities such as regional planners, governmental leaders and nonprofit organizations are exploring alternatives for alleviating the impact of traffic congestion on the region. The focus of this research, however, is not on normal, daily congestion, but rather on the under-studied area of traffic incident-related congestion. Traffic incidents create congestion that occurs in unexpected times and places where travelers do not expect delays. Nationally, roughly 25% of total congestion is due to traffic incidents. (FHWA 2012)

As a general rule, every minute of lane blockage due to a traffic incident results in 4-10 minutes of travel delay after the incident is cleared. (FHWA, 2012) Additionally, incident-related congestion contributes to secondary collisions, increased fuel consumption, and air pollution. FHWA estimates that the U.S. loses 1.3 billion vehicle hours of delay due to incident-related congestion each year, at a cost of almost $10 billion annually (2012 estimates).

The Federal Highway Administration (FHWA), through its Emergency Transportation Operations (ETO) program, provides tools and guidance for Traffic Incident Management (TIM). TIM is defined as "a planned and coordinated multi-disciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible." (U.S. Department of Transportation, n.d.) However, major highway incidents---such as the recently overturned propane truck that blocked both direction of the Seattle I-5 corridor for about eight hours ("Propane Truck Rollover," 2017) ---have major regional impacts from the associated congestion. These impacts must be addressed in coordination with TIM operations, but may have little to do with clearing the incident itself. These related but separate operational activities are referred to as congestion management (CM).

Like TIM, CM is a complex multi-agency, multi-jurisdictional activity. Unlike TIM, managing incident-generated congestion and mitigating the regional impacts continues after the incident is cleared and involves a wider more-diverse group of stakeholders. Furthermore, CM covers a greater portion of the freeway, as well as the interconnected arterials and alternate modes of transportation, and the people, facilities and services that rely on this infrastructure for mobility. This wider CM perspective must not take away from the urgent life-saving and incident-clearing activities of TIM, but it does call for greater coordination across TIM and CM operations.

Understandably, the focus of activity after a major freeway incident is to rapidly address the urgent needs stemming from the incident itself, such as clearing the blockage so responders can reach life-threatening accidents, fires, and environmental hazards. While this is necessary, the management of wider regional impacts stemming from major incidents has received less attention. Impacts such as long-term congestion and economic immobility are less focused and coordinated, with congestion management processes often waiting for critical information and direction from the incident managers.

Especially within the environment of a major metropolitan area, there is a need to extend TIM to include CM. The CM strategy must be aligned with the incident management strategy, but does not need to be put on hold while incident managers conduct their critical tasks. Moving forward, TIM can build upon joint incident response and site management protocols to include the understanding and mitigation of subsequent impacts of an incident on our transportation system and regional priorities.

The research reported here was facilitated by the University of Washington (UW) Mobility Innovation Center (MIC), and conducted by the UW Center for Collaboration for Security, Safety and Regional Resilience (CoSSaR), but was initiated, owned and driven by regional transportation management agencies. This project identifies opportunities for enhancement of regional incident response to incorporate congestion management processes via enhanced strategic and operational coordination, supported by innovative technologies. We label this direction as "TIM-CM" and view this work as Phase 1 of an ongoing TIM-CM effort.

While the research reported here takes a significant new strategic and technological direction, it is helpful to first review related ongoing projects that aim to improve the transportation infrastructure, reduce low-occupancy vehicle use, and enhance utilization of public transportation. Leading these efforts are the Washington State Department of Transportation (WSDOT) and the Seattle Department of Transportation (SDOT).

Washington State Department of Transportation (WSDOT)

WSDOT is the lead agency responsible for the State transportation system. It has a long history of operational innovations to help ensure that people and goods move safely and efficiently in Washington State. Many of these efforts are relevant to TIM-CM, and are outlined below.

Traffic Management Centers (TMCs)

WSDOT maintains six TMCs located around the state (Shoreline, Tacoma, Vancouver, Wenatchee, Yakima and Spokane) with a winter operations center on Snoqualmie Pass. These centers are the backbone for information management crucial to State transportation operations, including incident management. ("Traffic Management Centers," 2016) TMC personnel are key stakeholders in this TIM-CM project.

Figure 1: WSDOT Traffic Management Center

The Incident Response Program

WSDOT's Incident Response Program (IRP) supports Incident Response Teams (IRTs) to help reduce the time it takes to safely clear an incident and associated congestion. With a biennial budget of nearly $12M, this program runs 24/7 with 59 full time employees and 69 dedicated vehicles, ready to respond to incidents on highways or major corridors across the state (3,400 lane miles in total). IRT personnel participated in the TIM-CM research as key operational stakeholders.

WSDOT's IRT presence and assistance at incident scenes provided nearly $23M in regional economic benefits during the second quarter of 2017 alone. ("Gray Notebook," 2017) These economic benefits are measured by: (1) reducing the time and fuel that motorists waste in incident-induced traffic delay, by clearing incidents quickly, and (2) by helping to prevent secondary incidents though the proactive management of traffic incident scenes. Based on the WSDOT budget for incidence response, every $1 spent on the IRP provided drivers around $15 in economic benefit. ("Gray Notebook," 2017)

Web-based Traveler Information and Twitter Feed

Building on early research with the University of Washington, WSDOT was among the first State DOTs to capture real-time traffic data from freeway sensors and make it available to the commuting public. The goal of these early projects was to "improve traffic flow by influencing commuter behavior and decisions concerning alternate routes, departure times, and transportation modes." (Haselkorn, 1991) Accompanying this work to develop innovations for a web-based traveler information system were companion studies of Seattle commuters and the details surrounding their commuter-based decision-making and related behaviors. This holistic approach to understanding both the human and technical aspects of our regional transportation system (the "socio-technical system") was continued in the TIM-CM project research.

Today, this early research has evolved into an interactive website that displays maps of regions across the state with traffic information layered onto mapping tools. In addition to freeway sensors, these maps incorporate a vast array of closed circuit television (CCTV) cameras that users can select and view. The maps also show congestion, construction, traffic incidents and other variables, allowing users to construct a rich view of the traffic situation in any area at any time (see Figure 2 below). ("Seattle Area Traffic," n.d.)

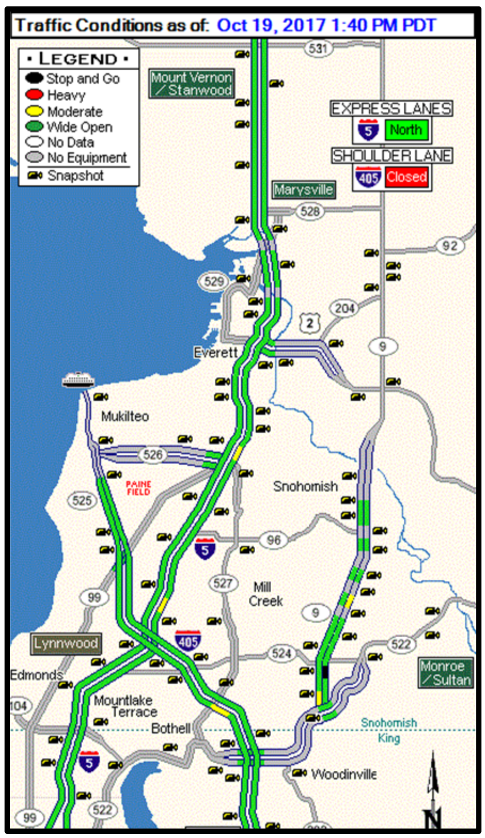

Figure 2: Regional Map from WSDOT Interactive website for traffic mapping

WSDOT uses Twitter to help keep commuters informed about happenings around Washington State. The Twitter messages regularly include "Know Before You Go" feeds to provide commuters with the information needed to make good travel decisions before getting into their vehicles. WSDOT Twitter feed currently has 263,000 followers.

Other WSDOT Systems

WSDOT offers “511”, a voice-based service for accessing live traffic-related information. By using the phone keypad or hands-free voice dialing options, 511 users can receive information about:

- Statewide traffic and road incidents, including construction and maintenance activities
- I-90 and I-5 express lane status
- Mountain pass weather, road conditions and restrictions
- Washington State Ferry information
- Statewide emergency messages and alerts
- Access to the 511 systems in Oregon, Idaho and Montana (“511 Travel Information,” 2017)

Other systems have been enhancements of the WSDOT traveler information website. WebFLOW32 is a Windows-based program that allows users to create traffic maps similar to those found on the WSDOT website. Users can also see CCTV, displays of variable message signs, and the status of the ramp meters. “Traffic Products: WebFLOW32,” n.d.)

WSDOT also developed a mobile app for smart devices, as a tool to assist travelers with information concerning regional transportation issues. The app provides a live traffic map, which shows congestion across interstates and highways as well as major thoroughfares, providing information on traffic accidents, weather advisories, with the ability to view live cameras. Furthermore, the app provides ferry information, mountain pass information, toll information, Canadian border wait information, and Amtrak data for the region (see figure 3 below).

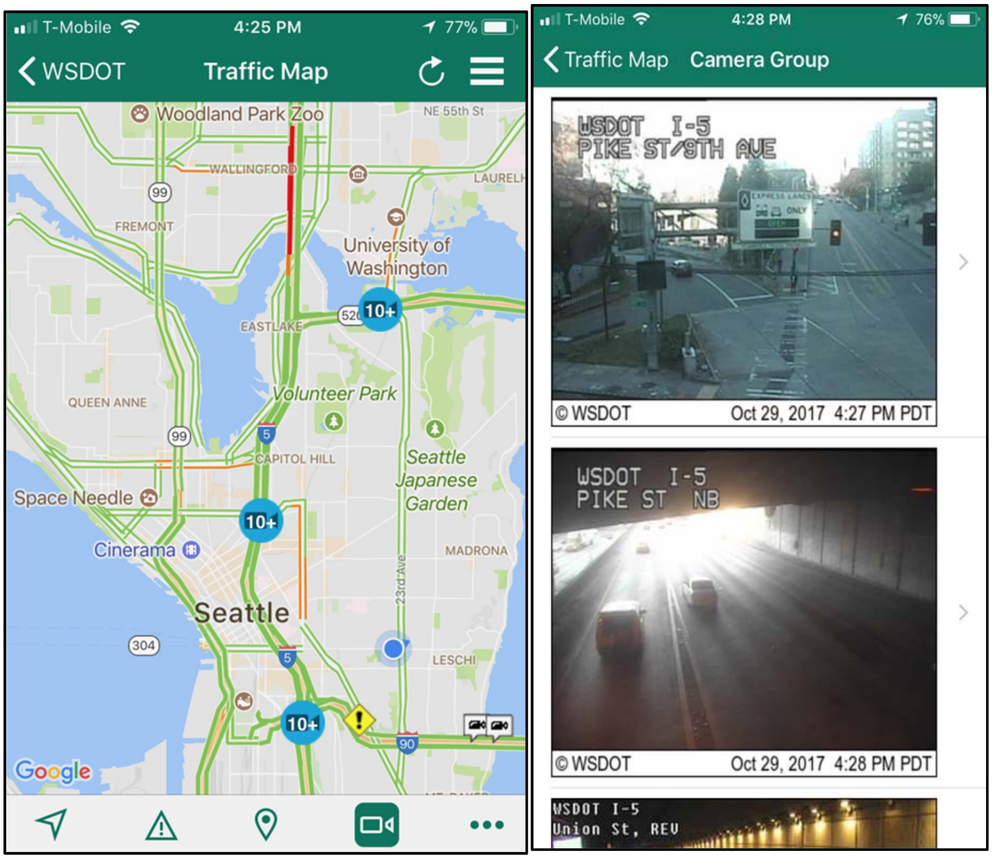

Figure 3: WSDOT Mobile App Display for Apple Devices

Seattle Department of Transportation

While WSDOT takes the lead in State transportation system management, SDOT focuses on transportation within the city of Seattle. Like WSDOT, SDOT uses several technologies to enhance multi-modal transportation across the city. The SDOT "Intelligent Transportation System" (ITS) operates out of the Transportation Operations Center (TOC) at SDOT headquarters. This ITS works to improve transportation safety and mobility by integrating technology into the existing local transportation infrastructure. Similar to WSDOT, information is gathered in the field via sensors (traffic detectors, CCTV, ramp meters and information service providers), and is transmitted to a computer located in the field (i.e. at an intersection) or to the TOC for processing and related action. ("Technology Program," n.d.) Some of the beneficial components of the SDOT ITS include: (a) portable changeable action signs, (b) dynamic messaging signs, (c) traveler information website, (d) SDOT twitter, (e) traffic signal management, (f) transit signal priority and more. The sections below provide a brief overview of some of the SDOT technological components most relevant to TIM-CM.

Figure 4: SDOT Transportation Operations Center

Dynamic Messaging Signs and Portable Changeable Action Signs

SDOT operates many Dynamic Messaging Signs (DMS) throughout the city, through which the TOC distributes electronic messages to travelers who are on the roadway. These signs send out information relating to traffic incidents, bridge closures, travel times, congestion and lane closures. There are currently 30 DMS operated by the TOC around Seattle, with more to come. ("Seattle Traffic Map," n.d.)

Similar to the DMS, SDOT employs Portable Changeable Message Signs (PCMS), which are electronic signs that can be strategically placed and moved to intersections or roadways where there are no DMS. Many of these signs have the capability of being programmed remotely from the TOC, and others are programmed remotely in the field. ("Technology Program," n.d.)

Traveler Information Website and Twitter Feed

The SDOT TOC uses strategically placed CCTV cameras across Seattle to monitor congestion, incidents, closures and other related issues. The ability to see traffic lanes and vehicles, live, helps TOC operators provide relevant, timely and accurate information to the public. The TOC offers a "traveler information website" that displays congestion / traffic flow rates (red, yellow and green indicators) across major highways and thoroughfares throughout the city. ("Seattle Traffic Map," n.d.) This website also offers the public open access to the CCTV cameras, as a live video stream or as a camera still. Currently, SDOT has installed 166 cameras across the city, and is in process of adding more. ("Seattle Traffic Map," n.d.)

SDOT also offers two Twitter feeds: the SDOT main Twitter feed, and the SDOT "Bridges" Twitter feed. The 265,000 users who follow the feeds receive real-time "Tweets" regarding traffic conditions, incidents, travel times, congestion, and bridge operations. ("Twitter: seattledot," 2017)

Traffic Signal Management and Transit Signal Priority Function

SDOT employs sensing technology and detectors that allow the TOC to manage traffic signals. When traffic volumes are high (congestion), the traffic signal control system can adjust timing plans accordingly. Many of the signals' operational systems are based on historic data for the time of day, and in some areas the signal timing will change automatically when traffic demand exceeds a certain threshold.

Similarly, SDOT uses wireless communications to allow buses and traffic signals to communicate at certain intersections. This process, known as Transit Signal Priority, functions by detecting an approaching transit vehicle, and adjusting the timing of light (i.e. extending the green time or shortening the red time) to facilitate transit vehicles. ("Technology Program," n.d.)

Best Practices and Procedures

Finally, SDOT is working on a Memorandum of Understanding (MOU) among Seattle transportation-related agencies for implementation of TIM best practices and procedures to facilitate safe and efficient clearance of incidents that impact Seattle's roadways. This MOU identifies programs and actions for sustaining the commitment to expanding TIM in Seattle. Participating agencies include SDOT, Seattle Police Department (SPD), Seattle Fire Department (SFD), the Seattle Office of Emergency Management, and the Seattle Office of Finance and Administrative services. SDOT, SPD and SFD are key partners in this TIM-CM project.

III. Review of Previous Work

Considerable transportation research, much of it funded by FHWA in partnership with State DOTs, focuses on various TIM aspects, such as planning, operations and evaluation; however, less work is focused specifically on CM resulting from traffic incidents. Some of the TIM research has implications for CM, such as studies on methods and best practices for traffic management. These methods include strategies such as: (1) ramp metering, (2) lane management, (3) variable speed limits, (4) shoulder use, (5) pricing options, (6) driver behavior and (7) traveler information tools. Below is a brief overview of some of this research.

A number of studies have focused on TIM planning and operations, as well as evaluation of incident impact. Some, like the 2012 report by the FHWA, have related previous TIM-focused research to CM. This study provides "a synthesis of analysis, modeling, and simulation (AMS) methods for incident impacts… to assist practitioners in the planning and development of TIM and the evaluation of the performance of TIM strategies." The project focused on the effects of traffic incidents on congestion, route reliability and secondary incidents, with the overall goal of estimating benefits and evaluating programs and proposed strategies. It included a survey of TIM practitioners which found that of 11 agencies who responded, 45% have conducted studies of incident impacts on congestion, 36% have conducted studies of secondary crashes due to incidents, 45% routinely measure and report secondary crashes and 73% have either developed or used software tools to estimate incident congestion impacts or secondary crashes. While the FWHA study measured the impact of traffic incidents-related congestion, the focus was on improving incident response during the incident, it did not address the need for a holistic approach to incident management where teams responsible for TIM and CM work together in a strategic and coordinated manner to address the long-term congestion and economic impacts of traffic incidents.

Driver decision-making and behavior is another area where research has provided guidance on CM and the design of CM tools. Early studies of Seattle commuter behavior by the University of Washington were used to inform future CM strategies and the design of Washington State traveler information systems. (Conquest, 1993) These studies identified four unique types of commuters, based on the decisions they made and their use of traffic information. These findings were applied to the development of innovative CM strategies such as early dynamic ridesharing systems (Michalak, 1995) and the delivery of real-time freeway data (Wenger, 1990) and transit information to the public. (Dailey, 1997)

In the area of transit information, this research at the University of Washington led to the OneBusAway project (2008). The OneBusAway mobile app is now available for the following U.S.-based areas: Puget Sound (Washington state), Rogue Valley (Oregon), San Diego (California) and Tampa Bay (Florida), with branded versions available in New York City (New York), and Washington DC. (Onebusaway, 2017)

In 2013, the U.S. Department of Transportation conducted a study to examine driver reaction to congestion pricing. Conducted in Orlando and Atlanta, participants (outfitted with GPS devices in their automobiles) made choices between a tolled and a non-tolled, but congested route during AM / PM commutes. These same participants also participated in a drive simulator task used to assess the risk attitudes of drivers and any characteristic biases in how they form beliefs about travel time experiences. The goal of the study was to examine how driver risk preferences influenced choices regarding routes and travel times. The study found that risk attitudes are important determinants for route choice and departure times.

In the State of Washington, the public has been generally supportive of roadway pricing initiatives to reduce congestion. For example, the public support for roadway pricing greatly assisted in getting the SR 520 bridge outfitted with variable toll lanes and enhanced HOV lanes (SR 520 Bridge Replacement Project, 2010-2015). This process was supported by a "tolling implementation committee" (established in 2010) to build public support and to provide guidance to the legislature.

There are, of course, numerous other state-based research and development projects to implement CM strategies. The following examples from California and Minnesota indicate a commonality with efforts in Washington State.

California- A RAND corporation study (2008) identified congestion reduction strategies in the Los Angeles (LA) area which found that: (1) Severe congestion around LA is from the great imbalance between road space supply and demand; (2) Prospects for "building the way out of congestion" are very limited; (3) Many strategies for congestion relief are often short-term strategies, or do not remain effective over time; and (4) Pricing strategies must be accompanied by alternative transportation improvements. (Sorensen, 2008) With these factors in mind, California State Department of Transportation (Caltrans) has initiated dozens of freeway congestion reduction projects since 2008, including lane widening, creating truck-only lanes, adding HOV lanes and connecting HOV lanes to exit ramps. Caltrans established the "QuickMap" tool, an online interactive platform and application for smart devices offering real-time traffic information for state highways. This system offers users the ability to display information about traffic incidents, construction, weather and other information. This system also offers live-view access to Caltrans traffic cameras (CCTV). (Caltrans, n.d.)

Minnesota- In the Twin Cities, the Metropolitan Council and the Minnesota State Department of Transportation (MnDOT) conducted a multi-phase study of an enhanced system of express lanes, auxiliary lanes, turn lanes, dynamic shoulders, modifying interchanges, and improving transit accessibility and travel options for transit. Phase two of the study (completed February 2017) included opportunities for the public to provide feedback on the proposed improvements (from phase 1) to I-494 and highway 62. Feedback from over 3,700 respondents indicated that the three key priorities for the public were: (1) minimal congestion, (2) overall travel time, and (3) a reliable and predictable trip, respectively (Czech, 2017). Recent MnDOT projects to reduce congestion include conversion of a priced dynamic shoulder lane on I-35 into a permanent MnPass lane[1], and construction of a new MnPass lane. Similar to other states, MnDOT offers a web-based interactive platform for users to acquire information related to traffic conditions, such as construction projects and related closures; weather information; traffic incident information; congestion information and more. MnDOT plans to use this tool to develop a transportation app for smart devices, to further assist travelers across the state to mitigate congestion and to effectively plan their travel. (MnDOT, n.d.)

[1] During rush hour periods, MnPass lanes provide a congestion-free travel option for those who ride bus transit, motorcycles, vehicles with 2+ passengers or those driving alone who are willing to pay a fee. Visit http://www.dot.state.mn.us/rtmc/reports/congestionreport2015.pdf for more information.

IV. Research Approach and Procedures

The general research approach for the TIM-CM project was to engage key regional stakeholders in a series of iterative scoping and participatory design activities to identify and articulate desired enhancements to the regional management of major incidents on the Seattle I-5 corridor. These activities were used to (1) identify TIM and CM stakeholders (see Appendix A.1 for complete list of project participants); (2) identify and review relevant policy documents and related work; (3) work with stakeholders to model the "as-is" TIM and CM processes and procedures; (4) use the as-is model to facilitate stakeholders in identifying current pain points and opportunities for system enhancement; (5) articulate desired interventions ("to-be" model) made possible by innovative applications of emerging technology; and (6) capture results, models and proposed interventions in a final report. The research team also worked with regional stakeholders on non-technical aspects of potential system enhancements, such as issues of adoption, stakeholder buy-in, policy and structural implications. These activities are described below.

Review of Policies and Related Work

The technical team conducted background research on current policies and procedures for regional TIM, and collected other necessary background information regarding congestion management along the Seattle I-5 corridor (see the Appendix A.2 for a list of relevant documents). Relevant information included Joint Operations (JOPS) protocols and Regional TIM interagency agreements.

The research team visited regional TMCs and engaged with the I-5/Joint Base Lewis-McChord Corridor Joint Operations Working Group (JBLM JOG). The JOG effort to the south enabled us to explore a related project in a different geographical area in the state of Washington.

In addition to shedding considerable light on similar relevant issues, a leader of the JBLM JOG joined the TIM-CM stakeholder working group and the planning team.

Working Group Meetings

The research team identified stakeholder agencies and representatives to be included in the working group (Appendix A1). Agencies included: WSDOT, SDOT, Seattle Police Department (SPD), Seattle Fire Department (SFD), Washington State Patrol (WSP), Challenge Seattle, Co-Motion's Mobility Innovation Center (MIC), 9-1-1 Dispatch (SPD and WSP), and the King County Metro Transit (KCMT). The research team facilitated bi-weekly meetings with agency representatives to achieve project goals. Alternate week meetings were held with the "planners" (the research team and representatives from the sponsoring agencies) to guide future activities and ensure a focus on TIM-CM priorities was maintained.

Use Case Exercises

In a conference room at the University of Washington, police, fire, transit, State Patrol, state and city departments of transportation (DOTs) and other key regional TIM and CM leaders gathered to engage in a two use case exercise. The goal was for this TIM community to reexamine how it manages major incidents in the Seattle I-5 corridor, and identify opportunities for enhancing this highly complex and collaborative operation. The use case, extrapolated from actual occurrences, began with a broken down school bus on I-5 near Safeco Field. Then, after traffic had backed up for 15 minutes, a secondary incident was introduced - an open topped truck carrying animal parts, known as a rendering truck, swerved to avoid the building congestion and overturned, spreading its contents across the freeway under the Convention Center (see Appendix A.3 for details on both incidents). The first step in improving a complex system is understanding how the current system works. As TIM and CM leaders worked this simulated sequence of incidents, facilitators modeled the “as-is” system and, later, led group discussion to refine the model and identify opportunities for enhancement (i.e., a “to-be” model).

Having worked together to clarify what the current TIM system “is” and the opportunity spaces that existed, the team turned to the design challenge of conceiving what the system “ought to be.” TIM and CM leaders discussed the current “pain points” and opportunities for system enhancement. They explored possible interventions to enhance the system. While innovative technology was not assumed to be that intervention, it was ever present in the minds of participants.

In weekly meetings following the use case exercise, the research team and exercise planners met to discuss and analyze the results. These findings are presented in Section V below.

V. Findings and Discussion

Working Group Meeting Findings

The project began with a kick-off meeting of all stakeholders in March 2017 to discuss improvements to traffic incident clearance in the I-5 corridor through the Seattle core. After the second meeting, the working group agreed that bi-weekly meetings of all stakeholders would occur for the duration of the project. Unlike tabletop exercises and after action reviews, which are focused on specific incidents, these working group meetings allowed stakeholders to take a more holistic, multi-agency, system approach to incident management.

After several meetings focused on TIM, the working group came to the conclusion that the focus must shift from incident response and clearance, which is already well established and functioning efficiently, to one of managing incident-generated congestion, which was far less established and understood. The working group agreed that a focus on mitigating congestion resulting from a major incident along the I-5 corridor was highly innovative and could greatly enhance mobility while reducing social and economic impacts to Seattle area residents and businesses. At this point the project sponsors agreed to meet with the University of Washington research team on the off-weeks, when the working group was not meeting.

The next several working group meetings and sponsor meetings were dedicated to documenting congestion management workflows, and identifying the information and partnerships that are needed to develop and execute a coordinated congestion management strategy. Below are several ideas that emerged from the working group and sponsor meetings.

1) Seattle Area Congestion Management Joint Operations Working Group (SAJOG)

The stakeholders quickly realized that a coordinated congestion management response would require a joint regional framework for operations, information sharing, technical environment, and policies. Several working group meetings were devoted to the development of a Seattle Area Congestion Management Joint Operations Working Group (SAJOG) charter, which defines and implements a joint regional framework in support of coordinated TIM-CM.

The UW research team modeled the SAJOG charter after the 2015 Charter of the JBLM JOG. Members of the UW research team and the sponsor team visited JBLM to learn firsthand from the stakeholders how the JBLM JOG supports multi-agency emergency response for all types of freeway incidents on the corridor of I-5 through JBLM. The working group approved the SAJOG charter in July 2017 and it is currently being routed to participating agencies for signatures.

2) Communicating with the "On-Road" Driver

There was considerable discussion of strategies for communicating with drivers who are already part of the incident congestion, as well as the limitations on what can be said to them in terms of affecting their choices and behaviors. The methods discussed and their advantages and disadvantages are briefly presented below:

- *Commercial radio* broadcasts are a traditional, longstanding, cooperative effort between public agencies and radio stations to inform on-road drivers. However, radio reports are limited by time allotted to them so often details are not provided, or the information is not timely or too general to be of immediate use to the driver.

- *Highway advisory radio (HAR)*, permanently installed at fixed locations or mounted on trailers or trucks, allows continuous focused incident information, but motorists need to tune into the particular frequency to get the information, and credibility is diminished if the information is not kept up to date. In addition, HAR has no technology path for the future.
- *Variable Message Signs (VMS)* can be used to display critical information about downstream incidents. Their use in recommending alternate routes is limited, however, as downstream VMS may not be available to provide further detour information. In addition, reading the signs may take driver's eyes away from the road and could result in distracted driving issues, which are a known cause of secondary traffic accidents (Stutts et al., 2005).
- *Telephone information systems (511)* provide up-to-date traffic information; however, calls may lead to distracted driving, especially if they are not hands free.
- *Commercial in-vehicle route guidance systems* can provide hands-free mobile access to information, usually for a subscription fee.
- *Commercial and public TV traffic reports* are useful for planning a trip, but not useful once on the road.
- *Social media via mobile devices* (e.g., WSDOT Twitter which has 446,000 users as of October 20, 2017) may provide incident information, but the message is restricted by the 140-character Twitter limit. Distracted driving issues are a concern when using these applications while driving.
- *Google Maps/Waze/Apple Maps/Other smartphone traffic apps* may provide drivers with alternate routes around incidents; however, these tools do not

evaluate the system as a whole, and as such may simply move the problem, or result in sending vehicles to areas not intended for additional traffic, causing further congestion and issues.

3) Affecting "Future" Driver Behavior

For those drivers who are not yet on the road, communicating the impacts of the incident and persuading them to remain at their current location until after congestion clears, or to use alternative modes of transportation, can help to reduce the congestion that results from major traffic incidents. For example, during the overturned propane tanker incident that occurred on February 27, 2017 the email below was sent to all employees of the University of Washington, Applied Physics Laboratory:

> *All Hands,*
> *I've just been informed that all lanes (both directions) of I-5 are closed between I-90 and the West Seattle Bridge exit due to an overturned tanker truck. There is no estimate as to a reopening time according to Seattle DOT. Please take this information into account and work with your supervisor as appropriate in planning your evening commute.*

While providing guidance can impact commuter behavior, further incentives may be useful in persuading drivers to stay off the roads during major incidents. These incentives might include: partnering with local restaurants to offer free or discounted menu items to encourage drivers to postpone their trips; partnering with employers to pay for extended parking and encourage the use of public transit or ridesharing; partnering with transit agencies to provide commuters with free rides and enhanced pick-ups during the incident; and partnering with ride-hailing services to provide discounts on their services. All of these incentives can be facilitated by online delivery.

4) Proactive Data Collection and Sharing

Inter-agency sharing of transportation data has the potential to improve the congestion management process; however, there are barriers to that information sharing that must be overcome. During one of the working group meetings, the group learned of the UW Transportation Data Collaborative, an initiative led by Dr. Jan Whittington, Associate Professor in the UW Department of Urban Planning. This project is working with public and private transportation providers to create a protected and linked data repository of sensitive information. The working group agreed that maintaining contact with this group to explore how best to leverage this data collective should be explored in future congestion management projects.

Exercise Findings

The final months of the project were spent conducting and analyzing the 'as-is" and "to-be" use case exercises to identify pain points and opportunities for enhancement to the current congestion management process. Two teams were established: (1) a TIM team consisting of players from WSP, SFD, WSDOT (IRT) and WSP (9-1-1 dispatch) and (2) a CM team consisting of players from WSDOT Traffic Management Center (TMC), SDOT Traffic Operating Center (TOC), SPD (Traffic), and SPD (9-1-1 dispatch). Below are the findings related to the As-Is and To-Be exercises. A summary of these findings can be found on figure 5, on the following page.

#	As-Is Findings	To-Be Findings
1	TIM and CM occurred largely in isolation from one another	TIM and CM worked in a coordinated fashion
2	There were limited options for information sharing across TIM and CM	A “just in time” information sharing mechanism enhanced coordination
3	Information sharing systems for CM did not generally support feedback	Facilitating feedback enhanced coordination
4	CM had less defined command structures and processes than TIM	CM was improved by pre-defined processes and ways to implement them
5	CM team postponed actions until TIM provided updates and information	CM initiated actions as events unfolded
6	TIM’s focus on urgent incident needs rarely considered CM	TIM team worked in parallel with CM team
7	Barriers to information sharing and coordination between law enforcement (LE) and non-LE agencies inhibited coordination	Exposed the LE / non-LE barriers to be primarily about resources and priorities that could be negotiated with CM

Figure 5: Summary of Findings from Use Case Exercises

As-Is Exercise Findings

During the As-Is Exercise, the TIM team immediately began operations to manage the incident scene. They were guided and driven by pre-existing operational protocols and structures that enabled them to act swiftly and collaboratively. They assessed the situation, reviewed their options, derived an operational plan, and launched into its execution. The CM team could not immediately devise and launch an operational plan for managing congestion because it lacked key information, such as the predicted duration of the incident.

WSDOT TMC indicated that it was receiving information from its onsite IRT and from monitoring cameras and WSP CAD. In some cases, the CM team was stalled waiting for needed information from the TIM team. The TIM team was not proactively providing information to the CM team, in part because they were so busily engaged in managing their part of the situation. While the CM team has access to WSDOT cameras and can monitor these in real-time, they did not have access to the WSP CAD, which contains incident-related data needed for CM decision making. The CM team also does not have access to the SPD CAD, which may provide information on what is happening on arterials affected by the incident and allow the CM team to respond sooner. The entire group agreed that allowing the CM team access to relevant information from these two CAD systems could improve their CM decisions and allow them to act quicker to congestion buildup. Barriers to information sharing and coordination between LE and non-LE agencies must be overcome in order to provide the CM team with access to these sources of information.

In discussion, the group learned that CM information flow is organized primarily in a hub-and-spoke model with WSDOT TMC at the center, pushing out information to SDOT TOC and other stakeholders. TMC's information sharing is primarily in one direction (i.e. there is no formal feedback loop) and assumes that agencies will use that information for their particular needs. While this is generally appropriate, in the case of a major long-term incident more coordination and linkage with the TIM operations may be needed. Presently there is no formal cross-agency mechanism on the CM side for establishing a strategic regional plan to manage extreme congestion and its impacts.

In addition to observations concerning the lack of a coordinated congestion management structure, other issues were identified. First, the CM team expressed a need to have better communication with Metro Transit, private transportation agencies (e.g., those operated by Microsoft and Google), and ride hailing companies to allow for easier and faster dissemination of incident congestion. In addition, there was not an effective means to notify employers of incident impacts to their employees. At the appropriate time, the Challenge Seattle partnership could be leveraged to reach out to the Downtown Seattle Association (https://downtownseattle.org/about/) to survey their members about ways WSDOT and SDOT can help their members during a major traffic incident along the I-5 corridor.

Low cost solutions were also identified during the as-is exercise. One solution was to purchase additional VMS/DMS for use in directing the traffic that was rerouted from I-5 to arterials and city streets. Currently, VMS/DMS are used primarily to notify drivers of an incident (e.g., stalled school bus at James St. Exit), but do not provide any detours because once drivers leave the I-5 corridor there is no means of providing them with further reroute directions. The working group cautioned that, prior to purchasing additional signs, additional exercises to identify reroute options should be conducted to identify locations where additional signs could be used.

After the as-is exercise the working group met several times to discussion the vision for an automated, data-driven approach to CM that included a decision aid tool to provide pre-planned reroute options based upon a congestion index algorithm. Three new innovations were proposed for use in the to-be exercise: 1) Congestion Analysis Engine (CAE) providing real-time congestion status, 2) Enhanced Information Sharing System (EISS) for real-time data acquisition and data sharing across the TIM and CM teams, and 3) Pre-Planned Options indicating reroutes or actions to be taken to alleviate congestion.

The following rules and procedures for conducting the to-be exercise were finalized:

- An SDOT representative would serve as the Congestion Analysis Engine, providing congestion status throughout the exercise.
- Players could approach the congestion analysis engine at any time during the exercise to clarify congestion related questions or issues.
- A representative from WSDOT played the role of the EISS.
- Players could approach the EISS at any time to ask for incident data.

In addition, nine pre-planned options were developed. Players could use the cards to propose a specific action (e.g., re-route northbound or southbound traffic via ________ street) to reduce congestion (see Appendix A.4 for a list of all pre-planned options). If an individual (or the congestion analysis engine) played one of these cards, the rest of the players could vote on the option card, or abstain from voting. The exercise planners evaluated the votes, and came to a conclusion about whether or not the action was to be implemented during the exercise.

To-Be Exercise Findings

The same organizational entities from the as-is exercise came together to work the same two-part scenario from the first exercise (see appendix A.3). While the first exercise involved the players working in two teams (a traffic incident management team and a congestion management team), this exercise was more of a group effort, with all players concentrated around one large table. The collective group worked together to process the initial release of information about the incident (see Appendix A.3 for more details on the exercise prompts). The Washington State Patrol dispatch (WSP Comms) was tapped by the SPD dispatch to take incoming information from on-scene callers. The WSP representative relayed that WSP would be first to the scene, and would conduct the initial incident assessment, secure the scene, and report back to WSP Comms.

While congestion was mounting, the group was notified by the EISS that traffic was becoming congested at the Convention Center, the central district (CD) and that traffic in lanes 1, 2 and the shoulder had become stopped. With this information, the teams worked to identify options for relocating the bus passengers to a more safe location, as the bus is "not pushable." The WSP representative reported that they would likely call Metro (KCMT) to see if there was an empty bus on SB I-5 that could serve as a tool for relocating the passengers, at which time the EISS reported that a secondary school bus had been sent by the school district to pick up the passengers in the stalled bus. WSP Comms coordinated with the WSDOT TMC about the on-scene situation and with IRT to get the bus towed once the passengers are removed.

Shortly after learning of the secondary incident (rendering truck turned over under the convention center), SFD and WSP are sent by WSP Comms to the secondary scene, where WSP follows on-scene protocols for HAZMAT based on the WSP HAZMAT guidebook. At this point in the exercise, a WSDOT representative played a "pre-planned option" card, directing WSDOT IRT to close SB I-5 at Denny / Stewart exit, using the PIO to communicate with the public to use Mercer exit. The group unanimously approved this action, as the Congestion Index confirmed that surrounding congestion had reached the trigger level for such an action. The group noted that while this action was approved, it would take around 45 minutes for this action to be fully implemented, as there would be many resources involved. About an hour after the initial 9-1-1 call about the stalled bus, the second school bus arrived, and the passengers were relocated safely. WSDOT IRT successfully towed the stalled bus, clearing the incident at the initial location.

The group transitioned focus to managing the incident and congestion associated with the secondary incident. At this time, the group tried to reach consensus about how to keep the southbound flow of traffic going around the incident at the Convention Center. A WSDOT IRT representative played a “pre-planned option” card, seeking to re-route to northbound SR 99 via 15th / Elliot ramp for inbound traffic. After review, the group voted against such an action. Another “pre-planned option” card was also played at this time, calling for the WSDOT TMC to re-route the I-5 express lanes to be southbound instead of northbound, allowing for drivers to get off at Montlake or 42nd Avenue, bypassing the scene of the secondary incident. The group reviewed this option, and after realizing that northbound I-5 traffic was running smoothly, decided that re-routing the express lanes in such a manner would create congestion for drivers trying to leave Seattle, further exacerbating traffic in the northbound direction; therefore, the option was rejected.

Overall, the operation went from two groups operating fairly independently to a single group collaboratively considering the impact of their operations on both TIM and CM. Below are additional impacts of the innovations introduced in the “ought to be” use case:

The Congestion Analysis Engine: The CAE was available to both CM and TIM stakeholders, but it was primarily used by CM stakeholders as it met their critical need for real-time congestion status updates and alleviated their dependence on the TIM participants for information. This indirectly benefited the TIM stakeholders who were busy responding to the incident, while allowing the congestion managers to be proactive rather than wait on information from incident responders.

An Enhanced Information Sharing System. The EISS facilitated coordination between the TIM and CM components of the team. There were several instances where participants needed information on items such as congestion status, assets en-route to the scene, or environmental factors. The EISS tool proved to be useful in clarifying such items, and minimized the amount of time that would have been expended trying to clarify these details with partners who were busy with their own tasks.

Pre-Planned Options for Congestion Relief. The CM stakeholders took particular advantage of playing "pre-planned option" cards to request possible courses of action during the exercise. When they did, the ensuing dialog among all participants was effective in exploring the impacts of these possible courses of action on the operations of other stakeholders. In particular, those responsible for TIM were better able to understand how their actions affected upstream congestion management, while CM participants were better able to see the impacts of their desired options on the incident response operations. This dialog also emphasized that pre-planned option must not limit the flexibility of operations in response to a complex, dynamic situation.

Finally, interactions among incident and congestion managers were greatly enhanced by the operational enhancements of the second exercise. In subsequent discussion, the TIM-CM team agreed that a second phase to design and test working enhancements was desirable.

VI. Recommendations

This section presents recommendations for enhancing regional TIM to incorporate CM via strategic and operational coordination, supported by innovative technologies.

Create the appropriate TIM-CM joint operations command structure. Both incident and congestion management are complex multi-agency, multi-jurisdictional activities that are interdependent yet with distinct goals, methods, and stakeholders. Historically, the focus of post-incident operations has been on the urgent needs stemming from the incident itself, such as clearing the incident blockage to address life-threatening injuries, fires, and environmental hazards. While this certainly is necessary, the management of wider regional impacts stemming from major incidents, such as long-term congestion and economic immobility, has been less organized or coordinated, and has had to wait for critical information and direction from the incident managers.

CM involves numerous entities beyond those who operate at the incident site and affects not only the freeway itself, but also the interconnected arterials and alternate modes of transportation, as well as the facilities and services that depend on this mobility. Transportation and emergency agencies need to widen their understanding of post-incident actions and strategies, so as to coordinate within the larger context of TIM-CM activity by allied agencies and stakeholders.

A coordinated CM response requires a joint regional framework for operations, information sharing, technical environment and related policies. One regional example is the I-5/Joint Base Lewis-McCord Corridor Joint Operations Working Group. This working group supports multi-agency emergency response for all types of freeway incidents on the corridor of I-5 through JBLM. The research team recommends that the stakeholder agencies responsible for

TIM and CM along the I-5 Seattle corridor ratify the Seattle Area Congestion Management Joint Operations Working Group (SAJOG) charter drafted during this project. This charter defines and implements a joint regional framework in support of coordinated TIM-CM.

Enhance the information-sharing environment (ISE) across TIM and CM processes. Inter-agency sharing of transportation data has the potential to improve the TIM-CM process; however, there are barriers to information sharing that must be overcome. These barriers are not only due to technical issues such as the lack of an enterprise architecture, but also to practices and policies such as those that inhibit non-LE agencies from gaining access to useful LE information.

Begin by conducting further analysis of the current ISE--you cannot improve a complex system without first knowing how it currently works. Then identify opportunity spaces and engage in an iterative and participatory co-design process to design ISE enhancements for those spaces. Co-design methodologies should consider the entire TIM-CM socio-technical system and environment.

Consider implementing an enterprise architecture to support enhancements. This architecture should allow each agency to participate under their own rules of engagement, yet enable increased operational information sharing. Other desirable features include: feedback loops for real-time cross-agency collaboration, a component that facilitates communication to the public, integration with existing commercial traffic information providers, and interoperability with current information sharing systems (e.g. systems used at SDOT and WSDOT Transportation Management Centers).

Consider policy enhancements in support of interagency sharing (e.g. memorandum of agreement across law enforcement and non-law enforcement entities so that during an incident, certain potentially sensitive information can be shared as needed.

Develop and implement pre-planned options. Pre-planned options indicating reroutes or actions to be taken to alleviate congestion can be developed ahead of time, including interagency policies and agreements necessary to operationalize them. These options could be triggered by a combination of human and computational analysis. For instance, a congestion engine could indicate when a given threshold is reached at a point on I-5, and then prompt the implementation of pre-planned management options. The process of implementing pre-planned options should be both flexible enough for the various TIM-CM stakeholders to accommodate a dynamic situation, yet streamlined enough to reduce the time for a coordinated response to rapidly growing congestion. In addition, pre-planned options can support timely prepared notifications to businesses and the driving public via various technologies, giving these partners faster and more targeting information for planning alternatives to contributing to the growing congestion.

Gather insight into current Seattle commuter behaviors and preferences. Build on similar studies of Seattle commuter behavior and decision-making conducted by the University of Washington (Wenger, Spyridakis, Haselkorn, Barfield, & Conquest, 1990; Conquest, Spyridakis, Barfield, & Haselkorn, 1993) to better understand how commuters currently get information about traffic (e.g. mobile apps, social media, television), the factors influencing route choices, use of multi-modal transportation preferences, etc. Include representative commuters in the co-design of future TIM-CM enhancements. Where possible and appropriate, build on existing TMC tools and strategies.

Consider enhancements that will help keep drivers (e.g. PM commuters) off the roads after an incident has occurred. While changing behaviors of some drivers will not be possible (e.g., those who need to pick up children from school or childcare may need to depart regardless of incident-related congestion), there may be opportunities to affect those behaviors of those drivers with more flexibility.

Explore partnerships with major Seattle area employers and private information providers such as Google Maps and Waze. For those drivers who are not yet on the road, communicating the impacts of the incident and persuading them to remain at their current location until after congestion clears, or to use alternative modes of transportation, can help to reduce the congestion that results from major traffic incidents.

While providing guidance can impact commuter behavior, further incentives may be useful in persuading drivers to stay off the roads during major incidents. Working with city employers to develop and promote these incentives is an area Challenge Seattle could help to facilitate. These incentives might include: partnering with local restaurants to offer free or discounted menu items to encourage drivers to postpone their trips; partnering with employers to pay for extended parking and encourage the use of public transit or ridesharing; partnering with transit agencies to provide commuters with free rides and enhanced pick-ups during the incident; and partnering with ride-hailing services to provide discounts on their services. All of these incentives can be facilitated by online delivery.

VII. The Way Forward

Managing incident-generated congestion and mitigating its regional socio-economic impacts requires an enhancement of regional traffic incident management to incorporate congestion management processes. Phase 1 of the TIM-CM effort has been extremely successful, largely due to the creation of an extended regional TIM-CM community that is ready to enhance and increase coordination of its efforts during major incidents. A follow-up Phase 2 will build on the momentum generated by this community. Below is an outline of suggested activities under the next TIM-CM Phase.

Stage 1—Formalize, Empower and Facilitate the Seattle Area Joint Operations Group (SAJOG): Finalize agency approvals of the SAJOG Charter produced under TIM-CM Phase 1. Establish SAJOG structure and facilitate activities of working groups in support of TIM-CM Phase 2 (e.g. give ownership of Phase 2 Stage activities to the SAJOG working groups). Stage 1 will be ongoing throughout all stages of Phase 2.

Stage 2—Analyze the Opportunity Space: Engage the commuting public to understand how they currently get and use information about daily congestion and major incident-related congestion (e.g., mobile apps, social media, television), factors influencing route choices, use of multi-modal transportation preferences, decision processes, etc. Engage the broader business community to explore employer-based programs that provide incentives to employees to avoid the central business district (CBD) not only during major traffic incidents, but also during high-impact days (events, holiday season, etc.). A coordinated approach that can lighten the demand load on typical days, will also benefit the area when the transportation system is compromised by major traffic incidents. These efforts should address significant system issues and are likely to include technical, organizational, policy and legal issues. Select the one or two most promising opportunity spaces and conduct further analysis to expand our understanding of the payoffs and challenges of these selected opportunities.

Stage 3—Understand the ISE: Building on the findings of TIM-CM Phase 1, continue working with the stakeholder group (expanded to include non-governmental partners and commuters) to complete and analyze the system model of current work processes and information-sharing associated with regional congestion management during major freeway incidents. How does the TIM-CM community acquire, analyze, share, use and store information? How does this community attempt to move backed up vehicles through and around the congested areas? How does it try to keep people from adding to the problem? How does it attempt to minimize economic and other negative regional impacts? The system model should integrate work processes and information flows, not only of public agencies, but also of relevant non-governmental stakeholders.

Stage 4—Iterative Design of Prototype Solutions: Working with all stakeholders, iteratively co-design prototype system enhancements that address the opportunities selected in Stage 2. Work with the SAJOG Policy working group to address interagency policy issues such as those identified in TIM-CM Phase 1 (i.e. appropriate sharing of Law Enforcement information; information sharing solutions that support agency-specific rules of engagement).

Stage 5—Build and Test Prototype Solutions: Build/enact prototype solutions and test under simulated conditions.

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Appendix A.1 - Complete List of Project Participants

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

Appendix A.1.1 Use-case Exercise #1 Planners and Players

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Appendix A.1.2 Use-case Exercise #2 Planners and Players

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Players
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Brian Smith, 9-1-1 Dispatch, SPD
Fred Olander, TCC Coordinator / Acting TCC Chief, KCMT
Jim Danninger, Traffic Maintenance Superintendent, WSDOT
Morgan Balogh, Assistant Traffic Engineer- Regional Operations, WSDOT
Sayuri Koyamatsu, Transportation Engineer, WSDOT
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Saran Becker, Senior Civil Engineer, SDOT
Willie Barrington, Captain, SFD
Zach Elmore, Lieutenant, WSP

Appendix A.2 - Relevant Interagency Documents

Seattle Department of Transportation (2016). "2016 Traffic Report". Retrieved from: https://www.seattle.gov/Documents/Departments/SDOT/About/DocumentLibrary/Reports/2016_Traffic_Report.pdf

Washington State Department of Transportation (2016). "2016 Corridor Capacity Report". Retrieved from: http://wsdot.wa.gov/publications/fulltext/graynotebook/CCR16.pdf

Washington State Department of Transportation. "WSDOT's Handbook for Corridor Capacity Evaluation". Retrieved from: http://wsdot.wa.gov/publications/fulltext/graynotebook/CCR_methodology_2nd_edition.pdf.

Washington State Department of Transportation, Washington State Patrol and Washington State Fire Chiefs (2016). "JOPS: A Joint Policy Operations Policy Statement". Retrieved from: https://www.wsdot.wa.gov/sites/default/files/2017/07/19/WSDOTWSPWFCJOPS.pdf.

Washington State Department of Transportation (2015). "Major Incident Tow (MIT) Handbook". Retrieved from: http://www.wsdot.wa.gov/NR/rdonlyres/3C1F7E19-2557-4117-98DE-CA410ACE6A39/0/MITHandbook.pdf.

Washington State Department of Transportation (2016). "The Gray Notebook: WSDOT's Quarterly Performance Report on Transportation Systems, Programs, and Department Management". Retrieved from: http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun16.pdf#page=33.

Washington State Department of Transportation (2012). "Integrated Corridor Management: Implementation Guide and lessons Learned". Retrieved from: https://ntl.bts.gov/lib/47000/47600/47670/FHWA-JPO-12-075_FinalPKG_508.pdf.

Seattle Department of Transportation (2017). "SDOT Traffic Incident Management Manual Draft".

Seattle Department of Transportation (2015). "Traffic Incident Management in Seattle: Observations and Recommendations". Retrieved from: http://murray.seattle.gov/wp-content/uploads/2015/07/Traffic-Incident-Management-Report-2015.pdf .

Washington State Department of Transportation (2014). "WSDOT Incident Response Program Standard Operating Guidelines".

Washington State Patrol and Washington State Department of Transportation (2012). WSP Agreement No. C120500GSC, Tow Incentive Program Interagency Agreement.

Washington State Patrol (2014). " District 2 Standard Operating Procedures Manual".

Appendix A.3 - Use Case Exercise Scenario

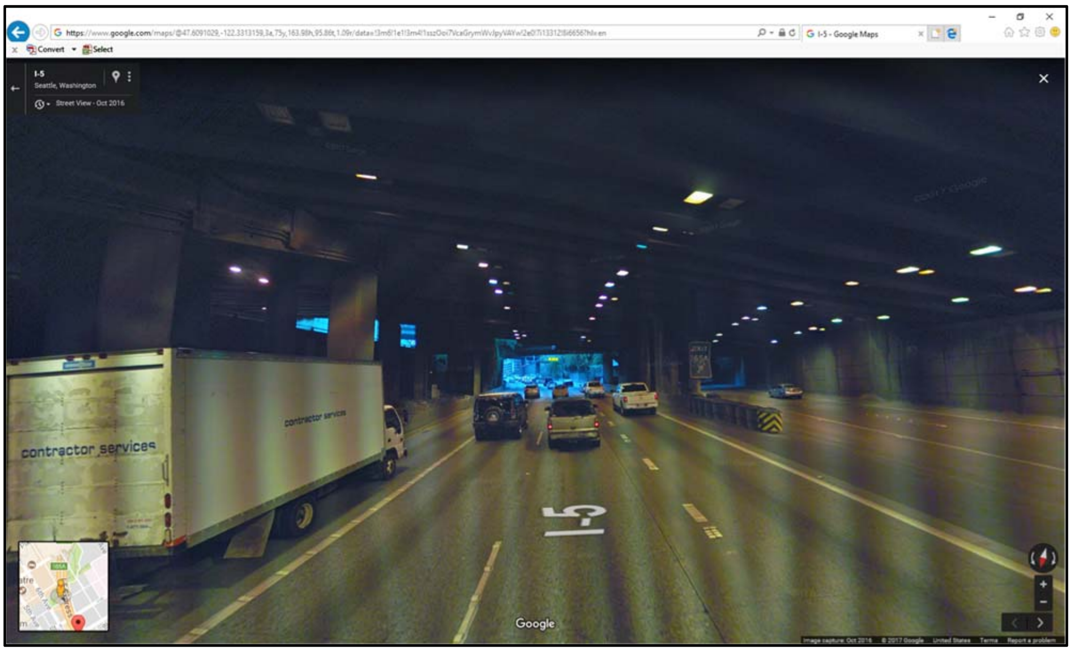
The exercise began with both exercise teams receiving an initial prompt, which consisted of the following:

> *On Thursday August 10th 2017 at 3PM a school bus driver calls 9-1-1 from the highway to say that the school bus, filled with children, has broken down on Southbound I-5 between exits 166 and 165. The driver reports that the bus is not "pushable." There is a Mariners baseball game at 7:10PM.* **Note: The photo below was projected during the exercise to help players visualize the scene.**

Following this first notification, each of the two exercise teams were given approximately 30 minutes to discuss and simulate their order of operations, protocols, processes and triggers. Each team used whiteboards, notepads, area maps, and sticky notes to map the processes and information flows.

After 30 minutes, the planners announced that a secondary incident had occurred, greatly complicating the situation. As the southbound backup from the primary incident spread to under the Convention Center, a vehicle attempted to cross lanes to exit at Union, forcing a rendering truck to swerve. The result was:

> *Another 9-1-1 call comes in, indicating that a rendering truck (traveling Southbound on I-5) has spun out under the convention center, slightly past the Union Street exit. The truck overturned, spilling its contents onto the freeway.* **Note: The photo below was projected to give players a sense of where the second incident occurred.**



Appendix A.4 - Pre-Planned Options (Use-case Exercise)

The pre-planned options were developed by the "planners" for use-case exercise #1 (see appendix A.2.1). The figure below shows the pre-planned option "cards" which were to be filled out by exercise participants during exercise #2. Note: Option cards #1 - #6 offered options for rerouting general traffic, and option cards #7 - #9 offered options for rerouting KCMT buses.

Pre-planned Option #1: Reroute I-5 SB Traffic

Action #: ________

Exit At: ______________________________

Proceed Via: ______________________________

Trigger: Congestion index above threshold

Pre-planned Option #2: Reroute I-5 NB Traffic

Action #: ________

Exit At: ______________________________

Proceed Via: ______________________________

Trigger: Congestion index above threshold

Pre-planned Option #3: Close Exit Ramps

Action #: ________

Ramp(s): ______________________________

____

____

Trigger: Congestion index above threshold

Pre-planned Option #4: Close Entrance Ramps

Action #: ________

Ramp(s): ______________________________

____

____

Trigger: Congestion index above threshold

Pre-planned Option #5: Adjust Traffic Signal Timing

Action #: ________

On Street/Area: ____________________________

Facilitate Flow: ____________________________

Trigger: Congestion index above threshold

Pre-planned Option # 6: Wild Card

Action #: ________

Do: ________________________________

____

____

Trigger: Congestion index above threshold

Pre-planned Option #7: Reroute I-5 SB Buses

Action #: ________

Exit At: ______________________________

Via: ______________________________

Trigger: Congestion index above threshold

Pre-planned Option #8: Reroute I-5 NB Buses

Action #: ________

Exit At: ______________________________

Via: ______________________________

Trigger: Congestion index above threshold

Pre-planned Option #9: Send Deadhead Buses

Action #: ________

To: ______________________________

Via: ______________________________

Trigger: Congestion index above threshold