Active Traffic Management Concept of Operations

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Preface

This document is the Concept of Operations (Con Ops) Report for the Washington State Department of Transportation's (WSDOT) Active Traffic Management (ATM) Program. This document is written for readers of all levels and provides information on the project justification, ATM design concepts, stakeholder and operational needs, and an overall concept of operations for the ATM program.

The format of this document is taken from the ANSI/AIAA-G-043-1992: Guide to the Preparation of Operational Concept Documents. Several sections have additional information to address the goals of this document.

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1.0 Scope

1.1 Identification

This document is the Concept of Operations Report (Con Ops) for the Washington State Department of Transportation (WSDOT) Active Traffic Management (ATM) Program. Specific revision information can be found in the Revision Table at the front of this document.

1.2 Document Overview

This document provides a description of ATM and its initial goals, vision, and high-level concepts. This document is written for readers of all levels and provides information on the project justification, stakeholder and operational needs, system overview, operations and maintenance budgeting and an overall concept of operations for the ATM program.

The purpose of this document is to communicate the current understanding of the user needs associated with the ATM program and to provide insight into how these systems might be implemented and procured. The descriptions contained within this document are at a high-level and do not include system details that are best left to systems designers. System details will be captured and documented in the appropriate phases of the project.

At the current time, there are no known security or privacy issues associated with the contents of this document.

This document contains the following sections:

1.0 Scope – Provides an overview of this document and the system to which it applies, identifies the intended audience, discusses the purpose for implementing the system, provides background information for the project and highlights the major goals and objectives (overarching vision for the system).

2.0 Referenced Documents – Contains the list of documents referenced in the Concept of Operations.

3.0 User-Oriented Operational Description – Contains a description of the intended system from a user vantage point. It also explains how organization/system-specific goals and objectives are accomplished. Emphasis is placed on who the users are and what the users do.

4.0 Operational Needs – Describes what is required by the region that the current system does not provide.

5.0 System Overview – Provides a high-level description of the interrelationships of key system components, their scope and interfaces. It describes all aspects of the integrated system at once (diagram).

6.0 Operational Environment – Contains information about operations and maintenance budgeting. This section will describe the mechanism for estimating the costs; provide a deployment or implementation scenario and discuss the system life cycle.

7.0 Support Environment – Describes what is needed for ATM that is complimented by the existing ITS elements and the impacts that users may experience during development.

8.0 Operational Scenarios – Contains high-level descriptions of common operational scenarios associated with ATM. It will highlight the improvements as well as constraints.

9.0 Acronyms – Contains an alphabetical list of all acronyms and abbreviations used within this document.

1.3 Purpose for Implementing Active Traffic Management Techniques

The transportation system, particularly the freeways, in the metropolitan areas of the State are congested. (The specifics of congestion, especially in the Seattle Metropolitan Area, are well documented elsewhere.) Collision rates normally increase in congested conditions. The purpose for implementing Active Traffic Management (ATM) is primarily to reduce the collisions that often occur on congested urban freeways and secondarily to address the congested conditions themselves.

The Washington State Department of Transportation (WSDOT) is already a national leader in managing freeway facilities efficiently using ramp metering, HOV lanes, providing traveler information, and managing incidents. However, the WSDOT is interested in implementing additional systems and strategies to address safety and congestion concerns. The WSDOT has recently undertaken a feasibility study to determine if European applications of ATM could be successfully applied to freeways in the Seattle Metropolitan Area. The European experience includes ATM strategies that improve safety and traffic flow using integrated systems and coordinated responses.

Active traffic management can be defined as dynamically managing and controlling traffic based on prevailing conditions in order to improve safety. These techniques target collisions that result from both recurrent and non-recurrent congestion. ATM is a tool that can maximize safety and improve throughput and may be used as an interim strategy to enhance the efficiency of corridors that may ultimately receive major capital investments.

The European ATM techniques could serve as additional tools to manage and utilize the region's freeway capacity effectively, efficiently, and safely. It should be recognized that the ATM techniques are evolutionary techniques – these are not brand new strategies, but rather a continuation of what this region has been doing for many years to effectively manage traffic.

1.4 Background

The ATM feasibility study was completed in three phases. Phase I qualitatively evaluated three major transportation corridors in the Puget Sound region to determine which corridor presented the best opportunity to test ATM techniques in Phase II. Figure 1 shows the Phase I corridors for consideration within the Puget Sound Area.

The Phase I qualitative corridor review used the following criteria: data availability, infrastructure, traffic conditions, implementation potential, implementation feasibility, near-term construction activities and impact of long-term construction. Based on the screening process and the identification of potential opportunities, I-405 appeared to be the facility most suited for quantitative analysis in Phase II, with I-5 being rated the next highest. However, there was not a wide rating variation amongst the corridors; revealing that all evaluated corridors would be conducive to analyzing and potentially implementing ATM strategies.

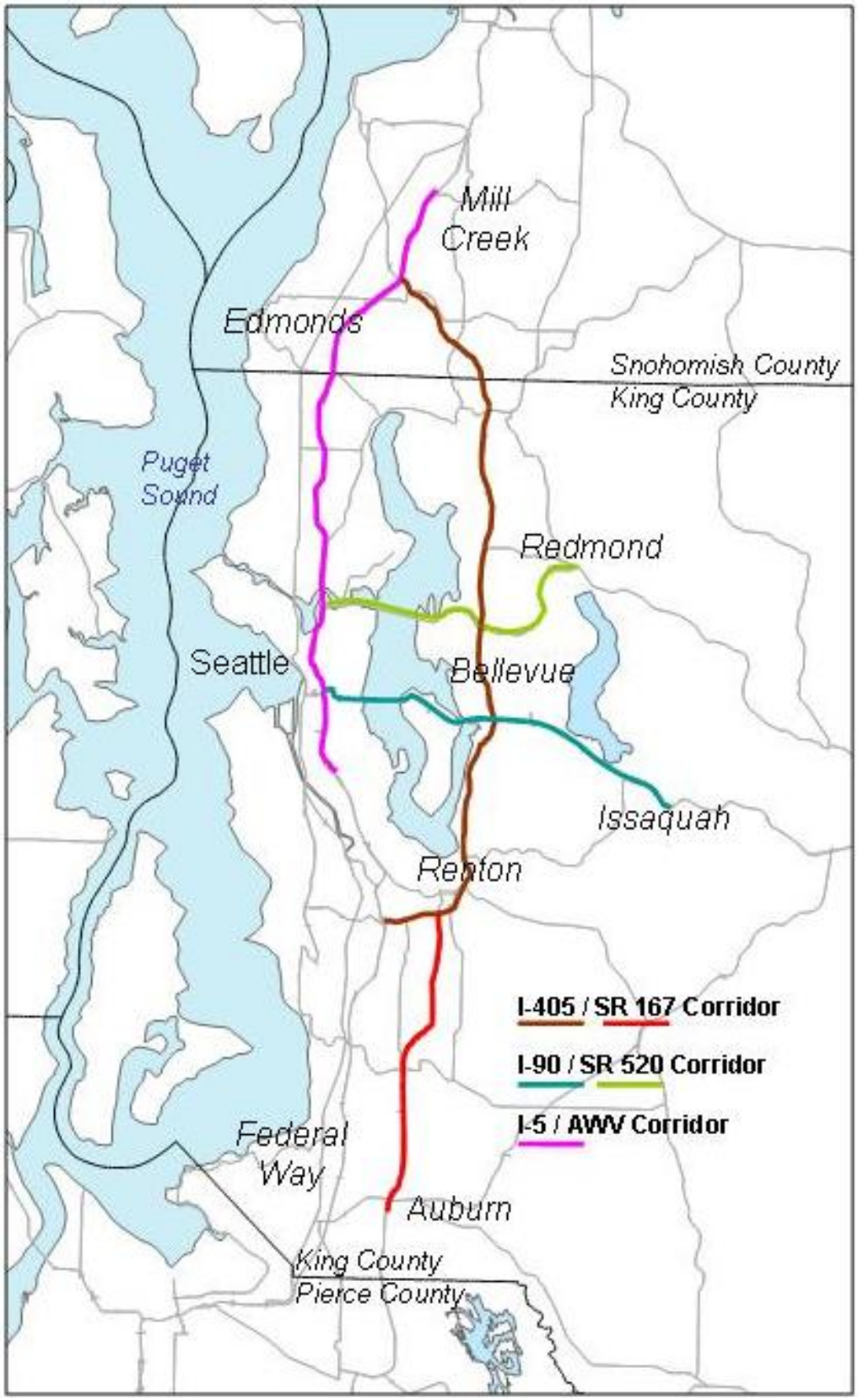


Figure 1. Phase I Corridors for Consideration

Phase II of the feasibility study quantitatively assessed six ATM techniques as they could be applied within the southern portion of the I-405 corridor. The quantitative analysis included concept level design; signing and operating plans for each technique; micro-simulation and conceptual benefits estimation (as feasible and appropriate); conceptual cost estimates; and conceptual operations and maintenance costs. Phase II also included an assessment of operational, policy and institutional issues that would need to be addressed or resolved prior to implementation of the various ATM techniques.

Phase III completed conceptual design, capital and operations and maintenance cost estimates for a variable speed limit/lane control/queue warning system on I-5 between Tukwila and Swamp Creek, on I-405/SR 518 from the North Airport Expressway to Swamp Creek, on SR 520 from Seattle to Redmond, and on I-90 from Seattle to Issaquah. Figure 2 shows the approximate extents of the roadways under consideration. Phase III also included the development of a Concept of Operations report for the proposed variable speed limit/lane control/queue warning system, as well as an update of the regional ITS architecture to include ATM concepts, and incorporation of the proposed ATM system into Washington's Highway System Plan and the Puget Sound Regional Council's Metropolitan Transportation Plan (MTP).

Based on the study results, the WSDOT plans to implement a combined variable speed limit/ lane control/queue warning system on a number of freeways in the Seattle Metropolitan Area. The application of the proposed system is expected to reduce collisions and their severity by reducing speeds in successive steps upstream of congestion or an incident. Implementing the proposed system, in conjunction with current WSDOT traffic management measures, is expected to reduce incidents and congestion associated with the incident as well as improve trip reliability.

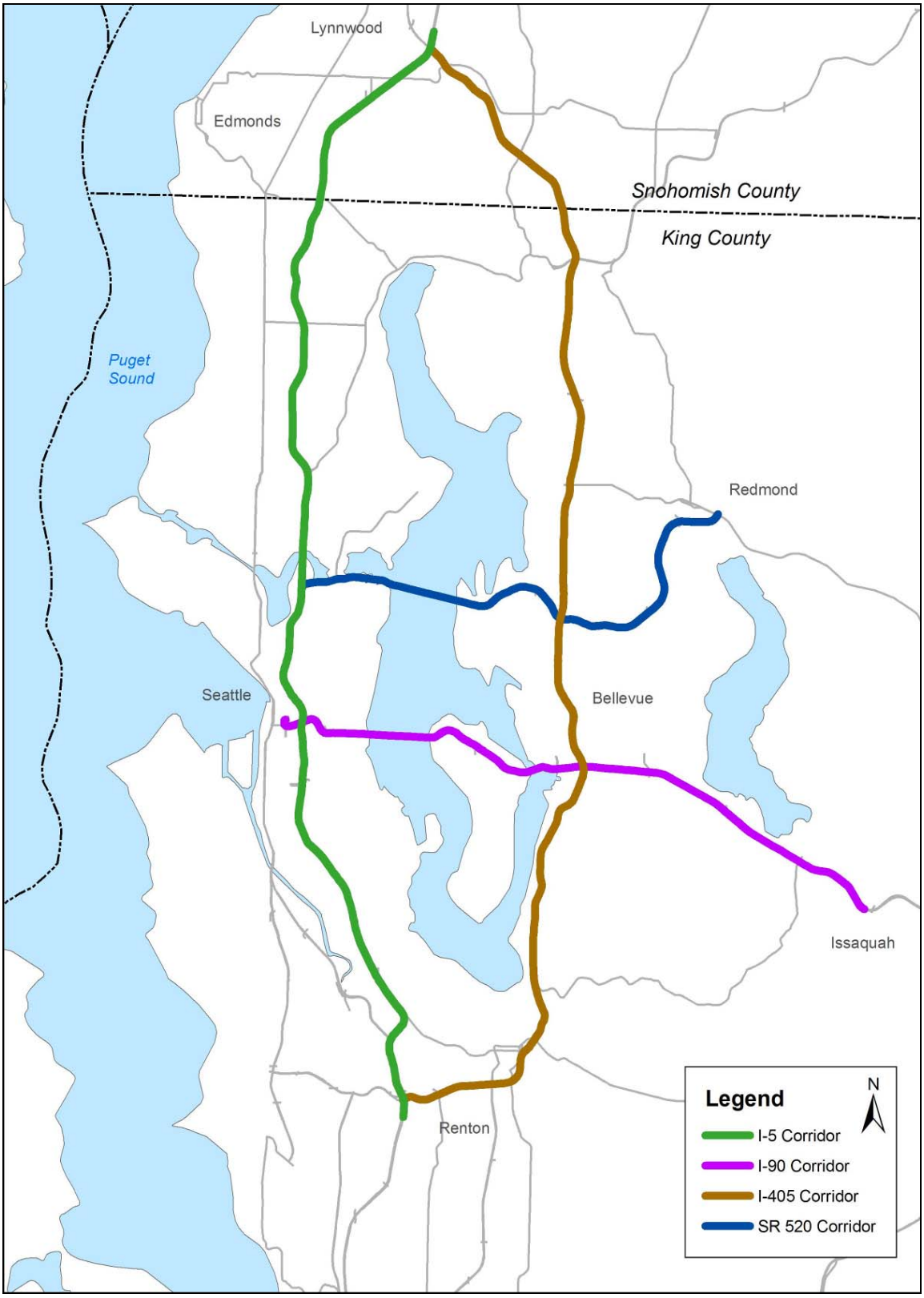


Figure 2. Phase III Corridors

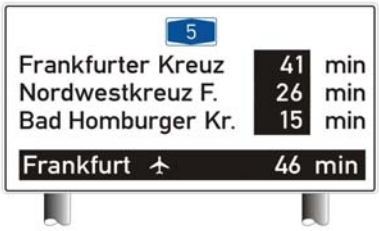
1.4.1 Active Traffic Management Techniques

This subsection provides a brief description of the individual ATM techniques considered in Phase II of the Feasibility Study. Sections 1.4.2 through 1.4.4 provide additional information on the design concepts that were developed for Phase II of the project [Reference 4]. While there were a number of different design concepts developed for each technique as part of Phase II, only the most promising are discussed. For additional information on the other design concepts, refer to the ATM Feasibility Study (November 2007).

- **Speed Harmonization** – to dynamically and automatically reduce speed limits approaching areas of congestion, accidents, or special events. Benefit – to maintain flow and reduce risk of collisions.
- **Queue Warning** – to warn motorists of downstream queues and direct through-traffic to alternate lanes. Benefit – to effectively utilize available roadway capacity and reduce the likelihood of speed differentials and collisions related to queuing.
- **Hard Shoulder Running** – to use the shoulder as a travel lane during congested periods or to allow traffic to move around an incident. Benefit – to minimize recurrent congestion and manage traffic during incidents.

Speed harmonization signing in the Netherlands (Dutch Department of Transportation).

Hard shoulder lane in England (UK Highways Agency)



Travel time signs in Germany (State of Hessen Germany)

- **Travel Time Signing** – to provide estimated travel time (and potentially toll information) to communicate travel and traffic conditions. Benefit – to allow for better pre-trip and en-route decisions by travelers.

- **Junction Control** – to use variable traffic signs, dynamic pavement markings, and lane use control to direct traffic to specific lanes (mainline or ramp) based on varying traffic demand. Benefit – to effectively utilize available roadway capacity and manage traffic flows to reduce congestion.

Junction control in the Netherlands (Managed Lanes in the Netherlands, AVV Transport Research Center, Ministry of Transport)

1.4.2 Speed Harmonization/Variable Speed Limits

Germany has used speed harmonization since the 1970s with the focus on improving traffic flow based on the prevailing conditions. It is typically deployed on roadways with high traffic volumes. In Denmark, speed harmonization is referred to as variable speed limits, and it is used to manage congestion during construction projects. Used since 1981 in the Netherlands, some deployments have been implemented during adverse weather conditions (e.g. fog), while others have been used to create more uniform travel speeds. The lane control displays are used for incidents, maintenance and construction. Most recently, they have used their system to reduce speed in a densely populated and environmentally sensitive area to reduce polluting elements. The ministry has also developed two powerful tools to assess their ATM efforts: a Sustainable Traffic Management Handbook to show local authorities how best to address accessibility problems and a Regional Traffic Management Explorer which is a sketch planning and modeling tool that quantifies benefits of ATM strategies. In 2001, England introduced a pilot project in response to motorists' demands for better service within the realistic limitations of widening and expanding the roadway network.

Variable Speed Limits on I-90 over Snoqualmie Pass

Since 1997, WSDOT has implemented and managed variable speed limits to account for changing and severe weather conditions, one of the few variable speed limits (VSL) in the entire nation. WSDOT has found the VSL to be very effective in creating a uniform traffic speed that increases the safety of travelers going across the pass.

1.4.3 Queue Warning

A key component of speed harmonization is the ability of the system to communicate to drivers why speeds are lowered, or to warn them of downstream queues (queue warning). In Germany, a congestion pictograph or icon is displayed on both sides of the gantries to alert motorists of queues or congestion ahead. Alternatively, the pictograph may be displayed on an overhead dynamic message sign (DMS). The value of the system lies in warning drivers of downstream queues so they take appropriate actions (e.g., slow down or change lanes) thereby reducing the occurrence of primary and secondary collisions caused by the congestion. The gantries in Germany are typically spaced 0.62 miles (1 km) apart and the system begins reducing speeds between three and four gantries before an incident. In the Netherlands, motorists are alerted of queues with flashing lights and speed signs activated on variable speed limits signs. The gantries are typically spaced every 0.31 miles (500 m).

Side mount queue warning signs as part of a speed harmonization system - Hessen Germany.

1.4.4 Hard Shoulder Running

In Germany, hard shoulder running is used with speed harmonization to address freeway capacity bottlenecks. It allows for additional capacity during congestion and has been in use since the 1990s. The Netherlands started using this strategy in 2003 as part of a larger program to improve use of the existing infrastructure. England's system utilizes the availability of the shoulder for travel rather than for emergency refuge only. To ensure its safe operation, emergency refuge areas are spaced every 0.31 miles (500 m intervals) with emergency call boxes.

1.4.5 Travel Time Signs

The WSDOT has a long history of providing traveler information. This technique would supplement the existing WSDOT tools by installing signs that are designed specifically to display travel times. The Germans and the Danes successfully use this approach in Europe.

1.4.6 Junction Control

WSDOT has, for nearly 30 years, managed freeway traffic by controlling, or metering, traffic entering at freeway entrance ramps. This has been one of the most effective traffic management programs put into operation to date. Ramp metering is a way to control traffic at interchanges, or junctions.

In some parts of Europe, an emerging technique to manage traffic at interchanges is termed junction control. Junction control is a method to dynamically change lane allocation at an interchange. It can be used at freeway on-ramps or off-ramps. The idea is that under some traffic conditions or times of day, it would be more effective to use existing lanes for one type of movement or for traffic coming from one facility while at other times of day it would be more effective to use the lanes in a different way. For example, when ramp volumes are relatively light or mainline volumes are very heavy, it might be most effective to have an entrance ramp merge into the right lane. However, there may be times that the volume on the ramp is extremely high while the mainline volumes are low. In this case, traffic merging from the on-ramp will have to find gaps in the mainline traffic. Even though the mainline traffic is relatively light, the hesitation needed at times to find a gap may be disruptive to ramp flows and may create a situation with higher rear-end collision potential on the ramp.

Junction control could be used to "close" the right lane of the mainline roadway upstream of the ramp, through the use of lane control signs in order to give ramp traffic a freer-flowing merge transition onto the mainline. This use of junction control provides priority to the facility with the higher volume and reduces priority to the lesser volume roadway. Junction control can also be used at off ramps, especially when hard shoulder running is used, to dynamically create a two lane off-ramp with a freeway drop lane and an option lane.

Junction control can only work at on-ramps when the mainline has spare capacity (giving priority to a higher merge volume). Junction control at an off-ramp can only work if an exit ramp has available width to accommodate an additional exit lane (giving priority to a higher exiting volume and/or downstream merging volume).

1.5 Major Goals and Objectives

The overarching vision for the installation of active traffic management techniques (either a combination of techniques or a single technique) revolves around the following parameters:

- Commitment to safety – Recognizing the link between congestion and safety
- Balancing mobility and the environment

- Limited resources to address congestion – Make best use of existing infrastructure
- Optimize performance of the facility through active management
  - Provide reliable trips
  - Reduce recurrent and non-recurrent congestion

2.0 Referenced Documents

A variety of documents are used as references within this report. The list is as follows:

1. ANSI/AIAA-G-043-1992: Guide to the Preparation of Operational Concept Documents, 1992.
2. 2007-2026 Highway System Plan, High Benefit Low Cost, Washington State Department of Transportation, December 2007. Accessed on 2/14/08 at http://www.wsdot.wa.gov/planning/HSP.
3. Destination 2030 Update, Regional Metropolitan Transportation Plan, Puget Sound Regional Council, April 5, 2007. Accessed on 2/14/08 at http://www.psrc.org/projects/mtp/pubs/D2030plan5.07.pdf.
4. Active Traffic Management Feasibility Study, PB Americas, Inc., Jacobs Carter Burgess, EarthTech, Inc., and Telvent Farradyne, November 2007.
5. Systems Engineering for Intelligent Transportation Systems – An Introduction for Transportation Professionals, US Department of Transportation, January 2007. Accessed on 2/14/08 at http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf.
6. Development of Guidance Materials to Support the Regional Concept of Operations, Guidance Document Annotated Outline, February 1, 2006. Accessed on 2/18/08 at http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Reg_ConOps_Final%20Draft%20Outline_02-01-06.doc.
7. Active Traffic Management: The Next Step in Congestion Management, Mirshahi, Mohammad, Jon Obenberger, et al, FHWA-PL-07-012, March 2007. Accessed on 5/12/08 at http://international.fhwa.dot.gov/pubs/pl07012/atm_eu07.pdf

3.0 User-Oriented Operational Description

This section contains a description of each ATM technique individually, as well as a description of the proposed variable speed limit/lane control/queue warning system from a user vantage point. Each individual technique is discussed separately, then a description of the proposed combined system is presented. This section also explains how organization/system-specific goals and objectives are accomplished. Emphasis is placed on who the users are and what the users do.

3.1 Variable Speed Limits

The design concept for a variable speed limit system includes over-lane speed signs as well as side-mount DMS and a general purpose VMS sign over the right shoulder. Sign spacing will be every one-half mile. This spacing is intended to allow the motorist to see a consistent message throughout the implementation area, as there will always be an overhead sign bridge in view. The consistent message is further reinforced because the signs are placed at consistent intervals. Figure 3 shows speed control displays mounted overhead, side-mounted iconic signs and the general purpose VMS.

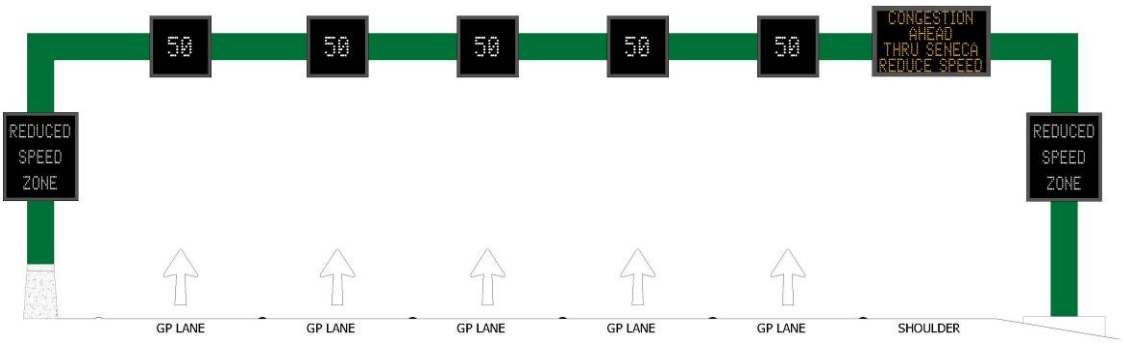


Figure 3. Variable Speed Limits, Lane Control and Message Signs

3.2 Queue Warning

A queue warning system is an effective means to alert motorists to downstream queues. The use a queue warning system in an area where congestion occurs consistently during a specific time period on a daily basis may not be highly effective, as drivers come to expect the queues. However, the end of a queue is not static, so even if daily drivers are accustomed to congestion and queuing, a queue warning system will alert drivers to these dynamic fluctuations. In addition, the system would alert unfamiliar motorists, familiar drivers traveling in off-peak hours, and weekend travelers to upcoming congestion and queues.

Figure 4 shows two examples of independent queue warning signing using either one or two variable message signs. It should be noted that the VMS, although more expensive, provides a higher level of flexibility with regard to providing motorist information. It should be noted that this would only be an independent system if the variable speed limit system were not also being proposed as part of the installation.

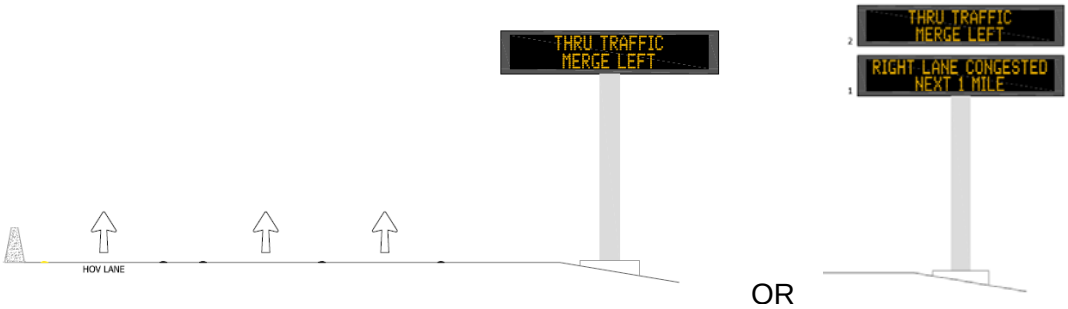


Figure 4. Queue Warning – VMS Sign

3.3 Hard Shoulder Running

Hard shoulder running is used to address capacity bottlenecks during congested periods and is a way to fully utilize existing roadway infrastructure. Hard shoulder running can be implemented as part of a variable speed limit system and can incorporate elements of junction control. Effective implementation of hard shoulder running requires that the installation continue beyond the bottleneck. Figure 5 shows lane control displays that are mounted on a typical mast arm pole and include side-mounted regulatory signs. Figure 6 shows an example of a ¾-mile advance guide signing modified with a VMS at the bottom. The side-mounted sign would be a DMS or blank-out sign. At the upstream entrance, changeable message signs could be used to alert motorists whether or not the shoulder is open for use as shown in Figure 7.

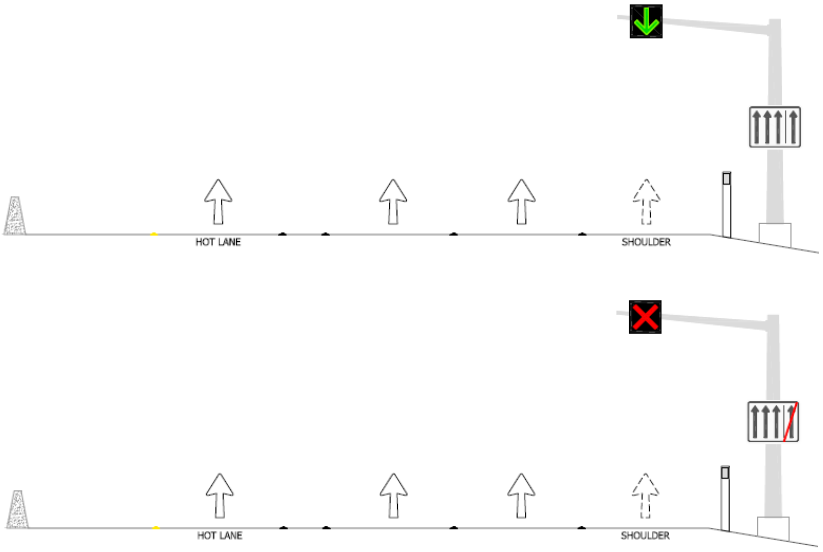


Figure 5. Hard Shoulder Running: Lane Use Mast Arm (Active & Inactive)

Figure 6. Hard Shoulder Running – ¾ Mile Advance (Active & Inactive)

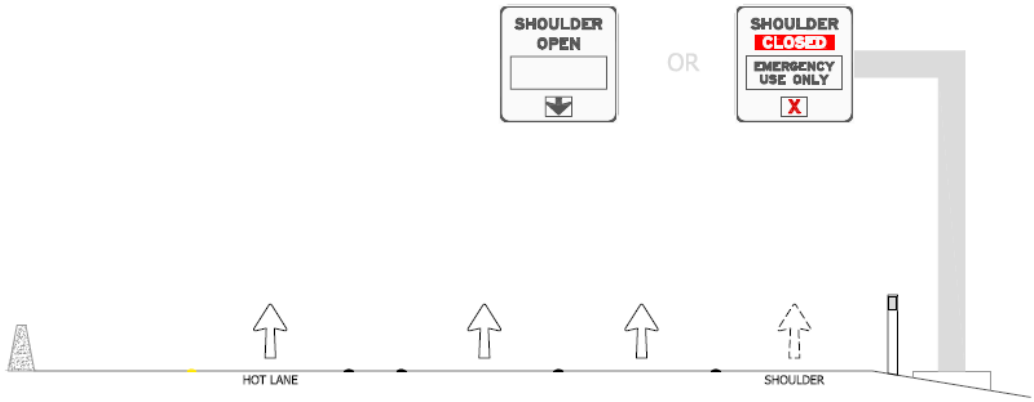


Figure 7. Hard Shoulder Running: Upstream Entrance – CMS (Active & Inactive)

3.4 Travel Time Signs

As was noted earlier, the WSDOT already provides travel time information using general purpose VMS. The use of dedicated or special purpose signs will provide motorists with an easily recognizable and consistent display of travel time information. Figure 8 shows an example of dedicated travel time signs and information for northbound I-5 travelers approaching the junction of I-405 during typical travel conditions. Figure 9 shows examples of what the signs might display for I-405 congestion in the Renton/Factoria corridor and I-5 congestion through Seattle. These graphics show dedicated hybrid DMS signing for travel times to Bellevue or Everett using the various corridors.

Figure 8. Traveler Information: Hybrid DMS Travel Time Sign – Normal Condition

Figure 9. Traveler Information: Hybrid DMS Travel Time Sign – Congested Condition

3.5 Junction Control

As previously described, the application of junction control dynamically allocates mainline and ramp lanes based on traffic conditions and volumes. While ramp metering (another form of junction control) controls the flow of vehicles onto a facility, this method of junction control, manages the use of roadway lanes within an interchange.

Figure 10 shows an example of junction control signing for SR 518 from upstream of the North Airport Expressway entry point near 24th Avenue South. Figure 11 shows sample advance exit ramp signing on I-405 northbound at SR 167 and Figure 12 shows sample signing beyond the exit ramp for the same location.

Figure 10. Junction Control – Upstream Entry Point (Active & Inactive)

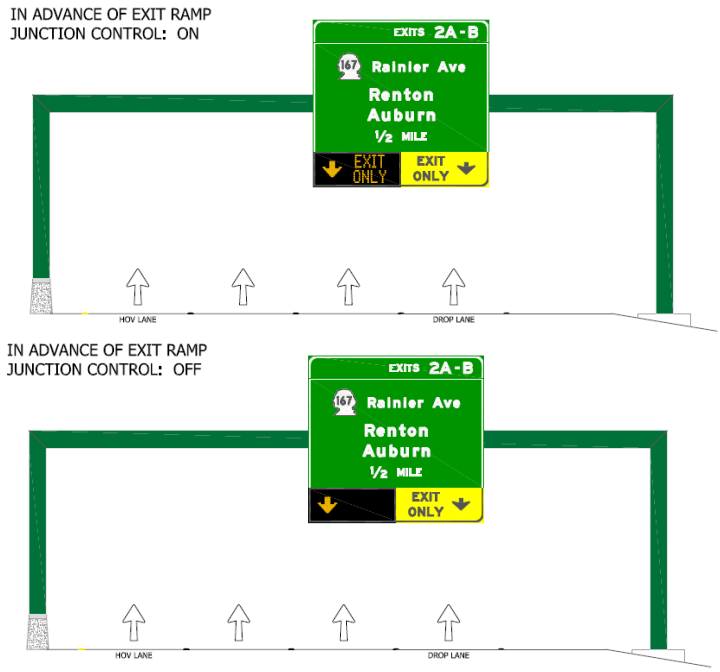


Figure 11. Junction Control – Advance of Exit Ramp (Active & Inactive)

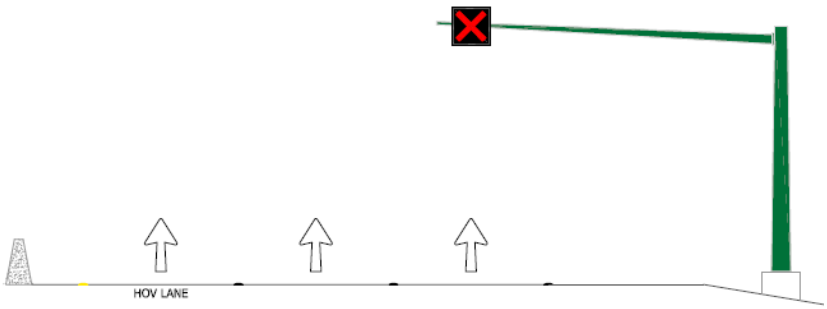


Figure 12. Junction Control – Beyond Exit Ramp (Active)

3.6 Proposed System – Variable Speed Limits/Lane Control/Queue Warning

The proposed ATM system combines the major elements of variable speed limits and queue warning, and also includes lane control measures.

Figure 13 shows the conceptual layout of the gantry-mounted over-lane speed displays that are the backbone of the variable speed limits system. The gantries should be spaced approximately every one-half mile and the general sign layout should reflect the figure below and the following guidelines.

- Over-lane speed and lane control displays should be situated over the travel lane that the sign is controlling. The over-lane display can either display the speed or lane control markings, or the two can alternate as separate phases of a message. The lane control displays would provide the additional functionality to use this to manage incidents or address maintenance during nighttime hours. In advance of an incident, the lane control displays can move traffic out of the blocked lane.

- The display situated over each lane should be capable of displaying numbers (such as speed) and various icons (such as a green arrow, red 'X,' white diamond, or yellow arrow). No supplemental message (such as "speed" or "speed limit" or red circle) around the displayed speed will be necessary. The color of the numbers will be white (on a black background) to reflect the regulatory nature of the system.
- The general purpose VMS should be on the right side (or in cases where no room is available on the right, the left side) of the gantry, preferably over the shoulder. This VMS will be used to warn drivers of downstream conditions and queuing that is the cause of the traffic congestion and slow moving traffic.
- Signs that provide additional detail or a supporting message can be placed on the gantry columns. Examples of the type of messages for these signs are ones that describe managed lane uses, posted speed limits, or traffic condition icons.

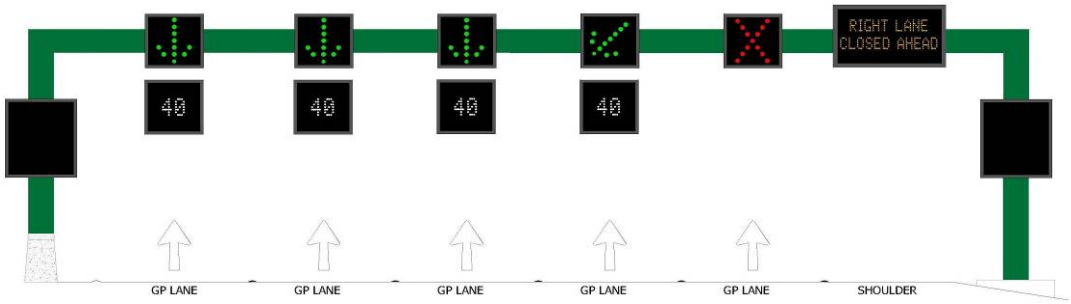


Figure 13. Gantry with Speed Displays/Lane Control and Supplemental Signs

Typically the signs for all general purpose lanes at a given location will display the same speeds. It will be possible to display different speeds above all the lanes, but the typical practice will be to have consistent speeds displayed for all general purpose traffic. Signs over managed lanes (e.g., HOV or HOT lanes) will be able to display speeds that are different from the general purpose lanes. The speeds over the HOV or HOT lane will reflect the conditions downstream in the HOV or HOT lane and will not be artificially constrained by conditions in the general purpose lanes, as it is important to maintain the travel time advantage in HOV/HOT lanes.

The operation of the proposed system under normal, incident, work zone/maintenance of traffic operations are discussed in detail in Section 8. The operational scenarios are presented for facilities both with and without managed lanes.

3.7 User Classes and Other Involved Personnel

This section describes the user classes associated with the operation, maintenance, and use of the ATM System. The selection of user classes was based on the ways in which each user class interacts with the proposed system. Factors that distinguish user classes include common responsibilities, skill levels, work activities, and modes of interaction with the system. The list below contains the initial user classes identified for the ATM System.

- **TMC Operations Staff** – This user class represents the personnel who will operate and monitor the ATM/freeway system.
  - TMC Manager
  - TMC Operators
- **ITS Engineers** – This user class represents the personnel who design, develop and deploy ITS systems.

- **Maintenance Staff** – This user class represents the personnel who maintain and service the ITS equipment.
  - Maintenance Technicians for Traffic Control and Repair
  - Bridge Inspectors (Structural Engineers)
- **Software Engineers** – This user class is responsible for the design and development of new features for the central software.
- **System Administrator** – This user class is responsible for the maintenance of the computer system including system software, network connections, and individual workstations. They are involved with OS and hardware installations, configurations and upgrades.

3.8 Stakeholder Needs

WSDOT realized that in order to ensure a successful implementation, it was important to gain approval and support from all levels of the organization and its regional partners. On March 5, 2008, a concept of operations workshop was held to discuss the various operational scenarios. The workshop purpose was to solicit operator and stakeholder feedback on how the ATM elements should operate in context of other existing and planned transportation system elements. Traffic, design, freeway operations, and tolling staff from the WSDOT Headquarters, WSDOT Northwest Region, WSDOT Olympic Region, Puget Sound Regional Council (PSRC), King County DOT, Federal Highway Administration (FHWA), and the consultant team were invited to attend. Appendix A contains a list of stakeholders in attendance at this workshop.

The workshop began with a brief summary of the various ATM techniques. Then, a focused discussion of the various freeway configurations was conducted. The four primary configurations were: 1) Basic Freeway Operation, 2) Managed Lane, 3) Tolled Freeway with No Managed Lane, and 4) Tolled Freeway with Managed Lane. For each freeway configuration, elements such as new field equipment; new responsibilities at the TMC; and changes to the current operations with respect to the existing systems was discussed. All of the systems were reviewed in terms of how they interact with each other and the operators for five different scenarios: normal operations, incidents, work zones, queue spillback and traveler information dissemination. During the workshop and subsequently when documenting the results, it became clear that the tolled and no toll configurations would operate the same from an ATM perspective. The above configurations were combined and became: 1) Basic Freeway Segment and 2) Managed Lane. Section 8.0 discusses the five operational scenarios for each of the two combined freeway configurations.

3.9 Operational Goals and Objectives for ATM

The following is a list of project goals and objectives as identified in our initial workshop from Phase I:

- Maximize both safety and traffic flow
- Optimize the existing infrastructure during recurrent and non-recurrent congestion with minimum operator intervention
- Use as an interim strategy to maximize the efficiency of the corridors that may receive major capital investments
- Place operations as a priority in planning, programming and the funding processes
- Focus on trip reliability and customer orientation

- Provide additional capacity during periods of congestion or incidents
- Use tools to support cost-effective investment decisions to optimize the benefit-cost ratio

4.0 Operational Needs

This section describes what is required by the region's freeway managers that the current system does not provide.

- Mechanism to reduce mainline speeds
- Sufficient density of traveler information
- Easy lane control and incident warning
- Ability to accommodate peak period capacity increases
- Constant real-time travel times at major decision points throughout the Puget Sound region
- Flexible lane use and control that would be appropriate for the varying conditions of the Puget Sound area

4.1 Staffing

The move to incorporate ATM into the operational structure will require additional staffing. Twenty-four hour staffed freeway management system operation will be required at the TMC in order to activate the techniques whenever they are needed. With the addition of variable speed limits, there will be a need for an additional operator in the TMC 24 hours a day, seven days a week. Since freeway management operators are currently on duty on weekdays for about 13 hours per day and on weekends eight hours per day, an additional 2.2 FTEs are needed to cover the remaining shifts. Accounting for the additional operator (1.6 FTEs) during the weekdays, this brings the need up to 3.8 FTE.

Additional equipment will require an increase in maintenance efforts as well. The additional maintenance would pertain to structural inspections of the gantries and regular maintenance for the data stations, detectors, VMS, VSL and DMS displays.

4.2 Data Support and Communications Structure

ATM techniques such as variable speed limits require a higher density of detectors than presently available. In addition, the ATM control algorithms may need detector data by lane. Current control algorithms (e.g., for ramp control) require detectors across all lanes at a single location be grouped a station of detectors. Furthermore, because the operational segments may cross from one WSDOT region to the next (e.g. VSL on I-5), there is a strong need for center-to-center communications. This requires data sharing between the Northwest Region and the Olympic Region TMCs.

There will be tremendous amounts of data coming into the TMC which will need to be archived. The current archive will continue to maintain and store the data, as well as post the data on the internet for public use.

5.0 System Overview

This section describes the concepts of the proposed ATM Program. These concepts are based on information gathered during a FHWA/AASHTO Scanning tour in Europe and subsequent research into the ATM techniques. The subsections that follow contain high-level descriptions

and discussions of the operational features with explanations of how the proposed system will operate. Items discussed in this subsection include:

- Context within the National ITS Architecture
- Integration with Current ITS Infrastructure and Programs
- Major System Components
- Interfaces to External Systems
- Proposed Capabilities or Functions

5.1 Context within the National ITS Architecture

The National ITS Architecture, maintained by the USDOT, is a comprehensive, common and mature framework for developing and integrating transportation systems at the State, Regional and local level (hereafter referred to as just the regional level). The National ITS Architecture therefore serves as a guide, available to ITS professionals for developing integrated transportation systems. Because it's a comprehensive, common, and mature framework; Regional Architecture development usually begins with the National ITS Architecture, and is thereafter customized based on regional characteristics (e.g., transportation needs, existing and planned ITS deployment, responsibilities, etc.). This customization typically occurs by mapping existing, planned and desires regional transportation systems to National ITS Architecture subsystems and services areas.

The National ITS Architecture (version 6.0) identifies a series of transportation services for which transportation systems apply. These transportation services are addressed through 91 unique Market Packages. A Market Package is a grouping of different subsystems and communication flows needed to deliver a desired transportation service (e.g., Surface Street Control or Electronic Toll Collection). Market Packages can work separately, or in combination to address the real-world transportation needs and desires identified through traditional planning activities. Table 1 provides a listing of the National ITS Architecture Market Packages selected as being applicable to the Active Traffic Management (ATM) and Electronic Toll collection (ETC) project architecture developed as part of this project. Following Table 1, each Market Package is described and a diagram illustrating system integration in the greater Puget Sound Region is provided. If not already included, Market Packages listed in Table 1 were added to the Puget Sound Regional Council Regional ITS Architecture, which was updated as part of this project to include a project-level architecture for ATM and ETC concepts and elements.

Table 1. National ITS Architecture Market Packages Applicable to ATM and ETC

Market Package	Market Package Name
AD1	ITS Data Mart
ATMS03	Surface Street Control
ATMS04	Freeway Control
ATMS05	HOV Lane Management
ATMS06	Traffic Information Dissemination
ATMS09	Traffic Forecast and Demand Management
ATMS10	Electronic Toll Collection
ATMS18	Reversible Lane Management
ATMS19	Speed Monitoring
ATMS21	Roadway Closure Management
EM09	Evacuation and Re-entry Management

5.1.1 ITS Data Mart

ITS Data Mart (Figure 14) provides a focused archive that houses data collected and owned by a single agency, such as the Washington State Department of Transportation, district, private sector provider, research institution, or other organization. This focused archive typically includes data covering a single transportation mode and one jurisdiction that is collected from an operational data store and archived for future use. It provides the basic data quality, data privacy, and meta data management common to all ITS archives and provides general query and report access to archive data users.

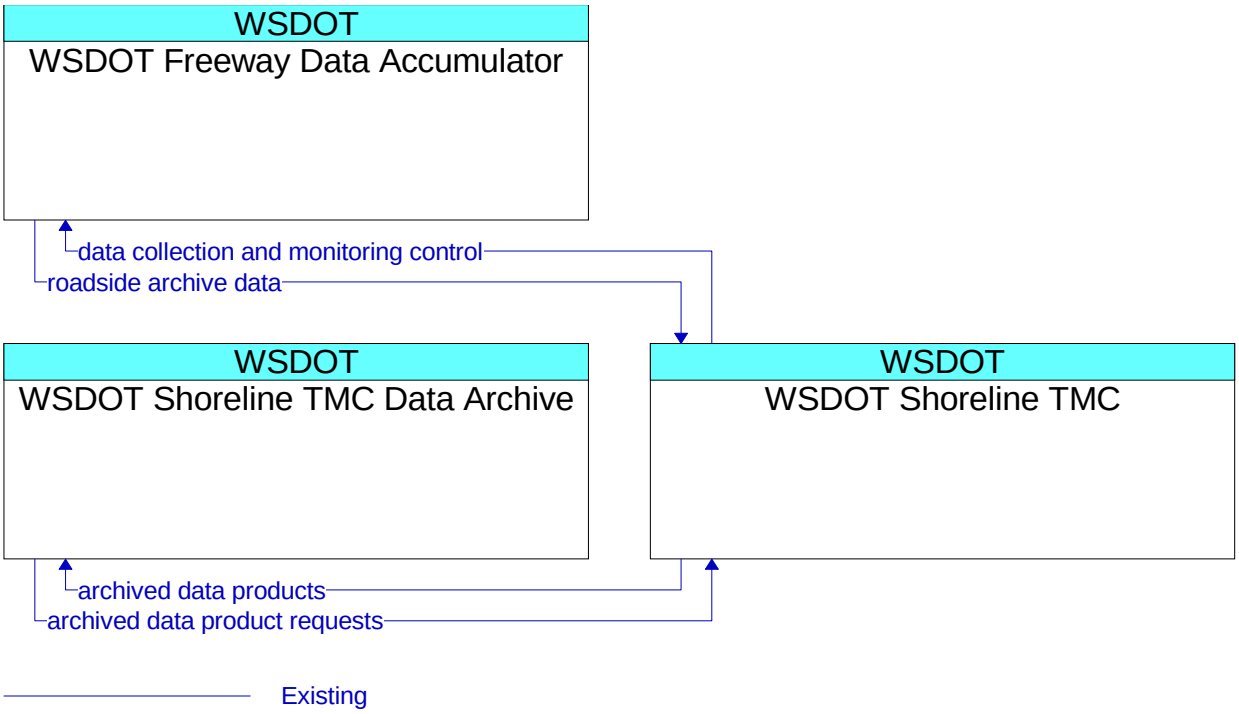


Figure 14. ITS Data Mart Market Package Diagram

5.1.2 Surface Street Control

Surface Street Control (Figure 15) provides the central control and monitoring equipment, communication links, and the signal control equipment that support local surface street control and/or arterial traffic management. A range of traffic signal control systems are represented, ranging from fixed-schedule control systems to fully traffic responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests. This service option is generally an intra-jurisdictional package that does not rely on real-time communications between separate control systems to achieve area-wide traffic signal coordination. Systems that achieve coordination across jurisdictions by using a common time base or other strategies that do not require real time coordination would be represented by this package. This is consistent with typical urban traffic signal control systems.

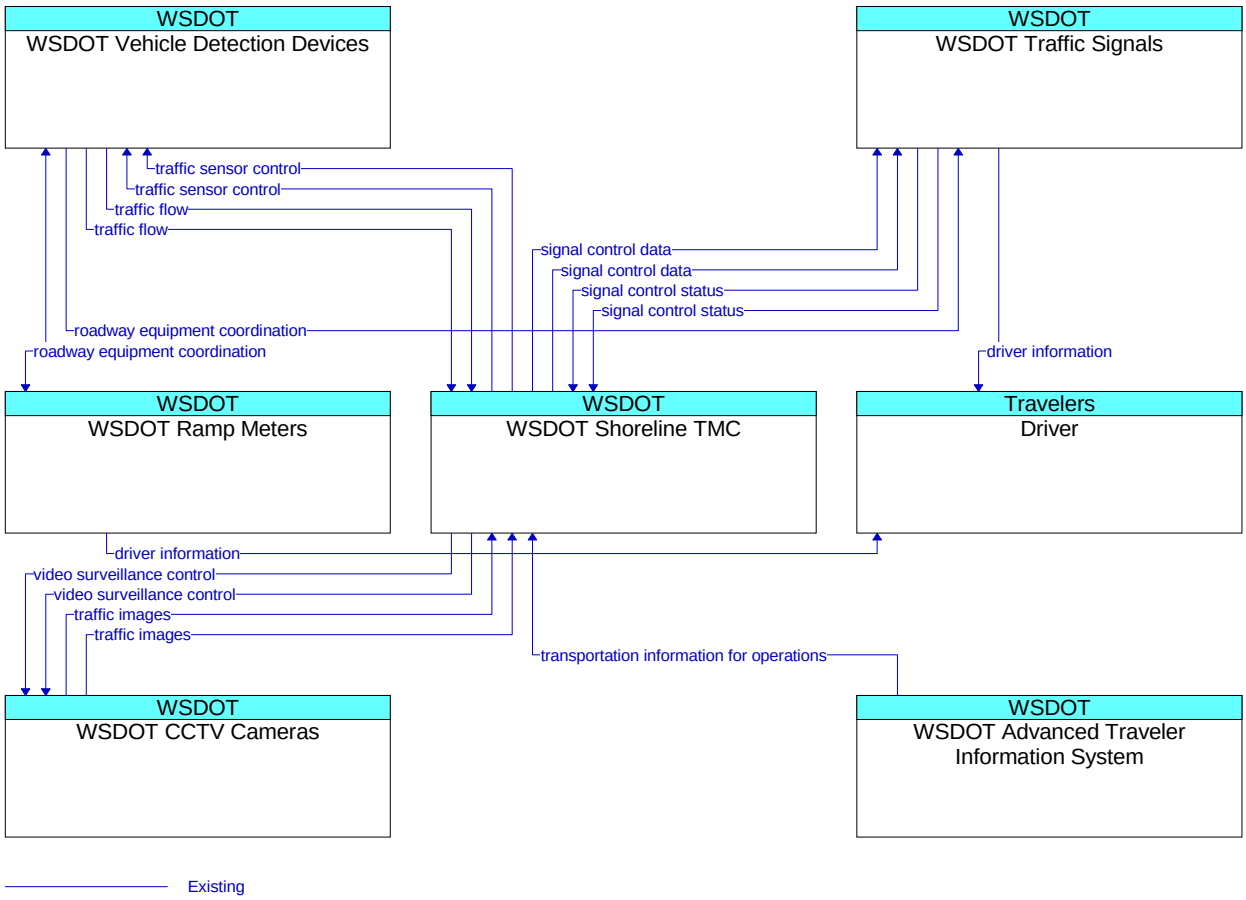


Figure 15. Surface Street Control Market Package Diagram

5.1.3 Freeway Control

Freeway Control (Figure 16) provides central monitoring and control, communications, and field equipment that support freeway management. It supports a range of freeway management control strategies including ramp metering, interchange metering, mainline lane controls, mainline metering, and other strategies including variable speed controls. This service option incorporates the instrumentation included in the Network Surveillance Market Package to support freeway monitoring and adaptive strategies as an option.

This also includes the capability to utilize surveillance information for detection of incidents. Typically, the processing would be performed at a traffic management center; however, developments might allow for point detection with roadway equipment. For example, a CCTV might include the capability to detect an incident based upon image changes. Additionally, this service option allows general advisory and traffic control information to be provided to the driver while en route.

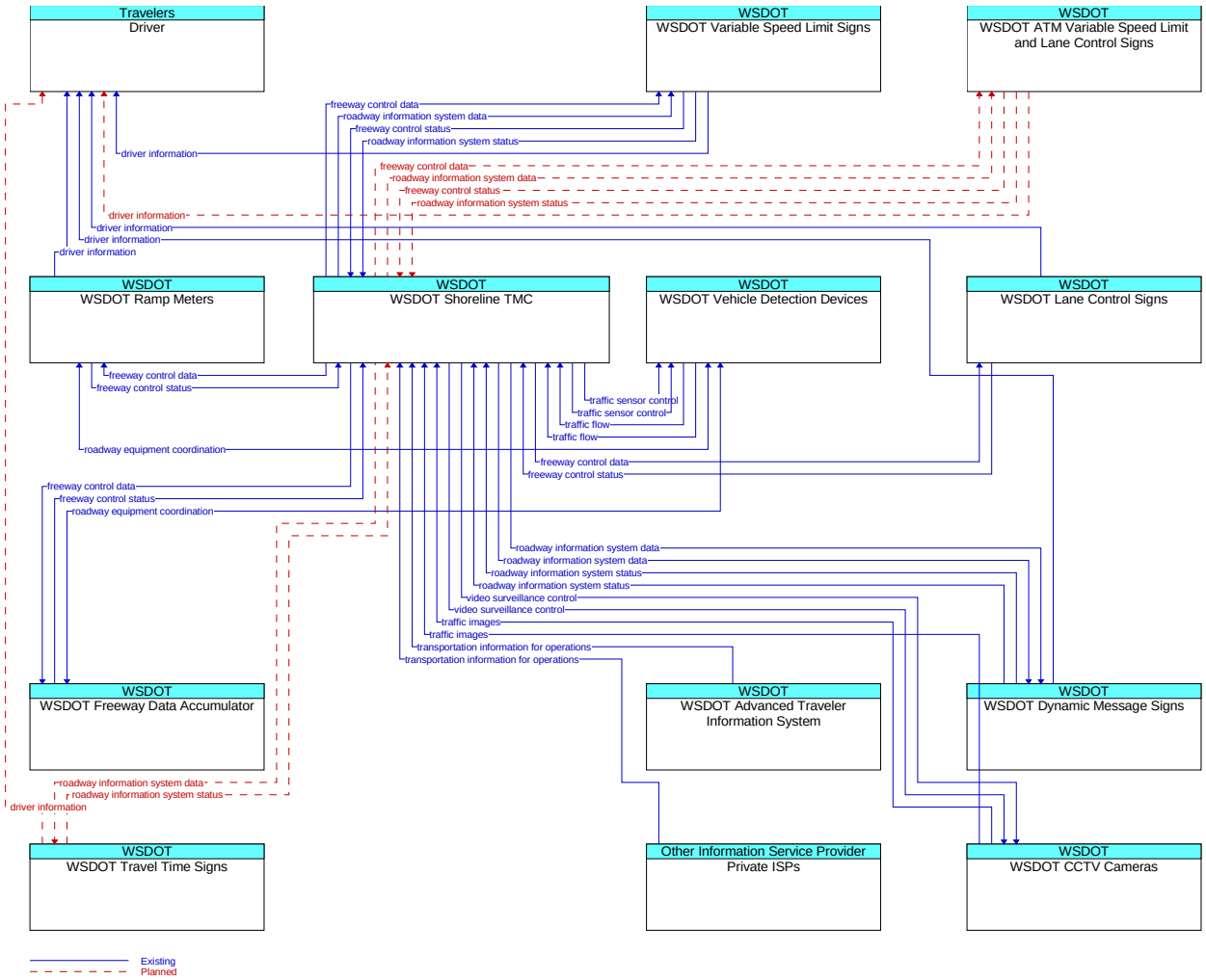


Figure 16. Freeway Control Market Package Diagram

5.1.4 HOV Lane Management

This market package manages HOV lanes (Figure 17) by coordinating freeway ramp meters and connector signals with HOV lane usage signals. Preferential treatment is given to HOV lanes using special bypasses, reserved lanes, and exclusive rights-of-way that may vary by time of day. Vehicle occupancy detectors may be installed to verify HOV compliance and to notify enforcement agencies of violations.

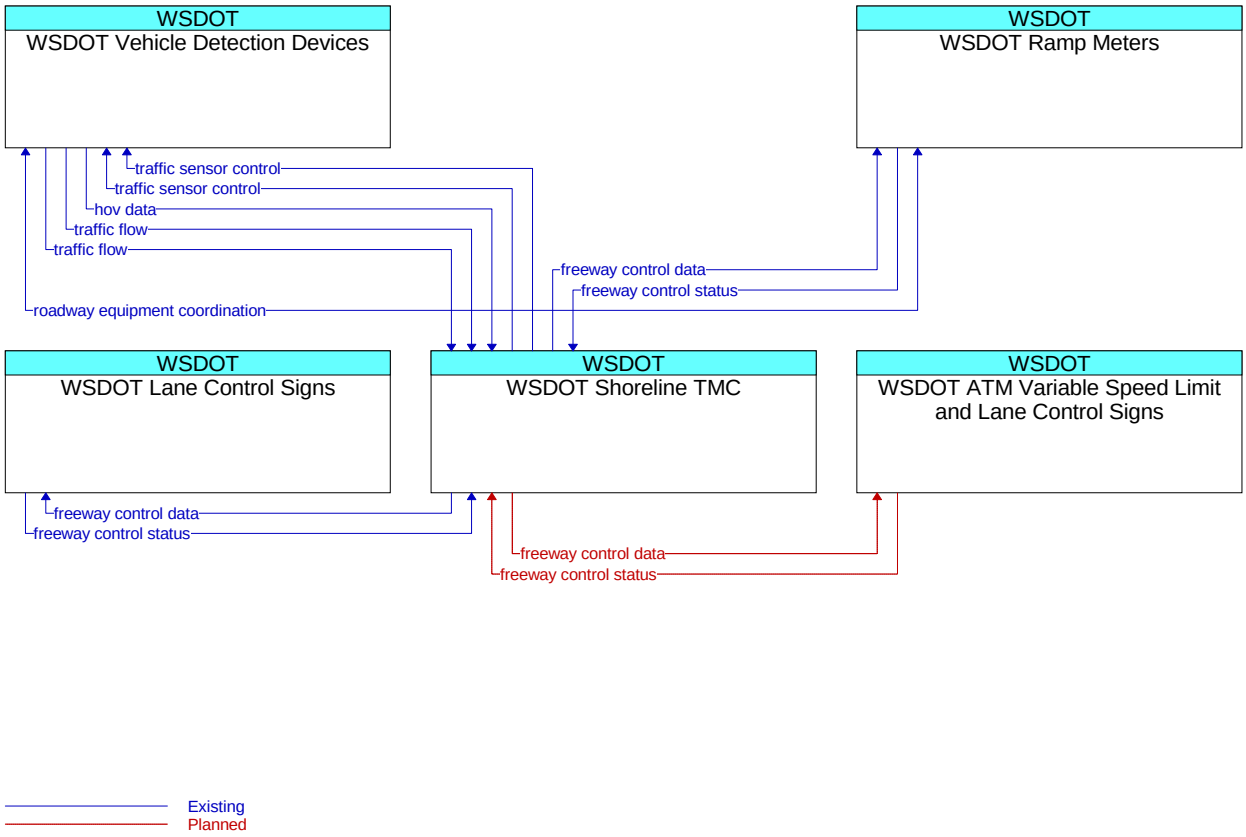


Figure 17. HOV Lane Management Market Package Diagram

5.1.5 Traffic Information Dissemination

Traffic Information Dissemination (Figure 18) provides driver information using roadway equipment such as dynamic message signs or highway advisory radio. A wide range of information can be disseminated including traffic and road conditions, closure and detour information, incident information, and emergency alerts and driver advisories. This package provides information to drivers at specific equipped locations on the road network. Careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package also covers the equipment and interfaces that provide traffic information from a traffic management center to the media (for instance via a direct tie-in between a traffic management center and radio or television station computer systems), Transit Management, Emergency Management, and Information Service Providers. A link to the Maintenance and Construction Management subsystem allows real time information on road/bridge closures due to maintenance and construction activities to be disseminated.

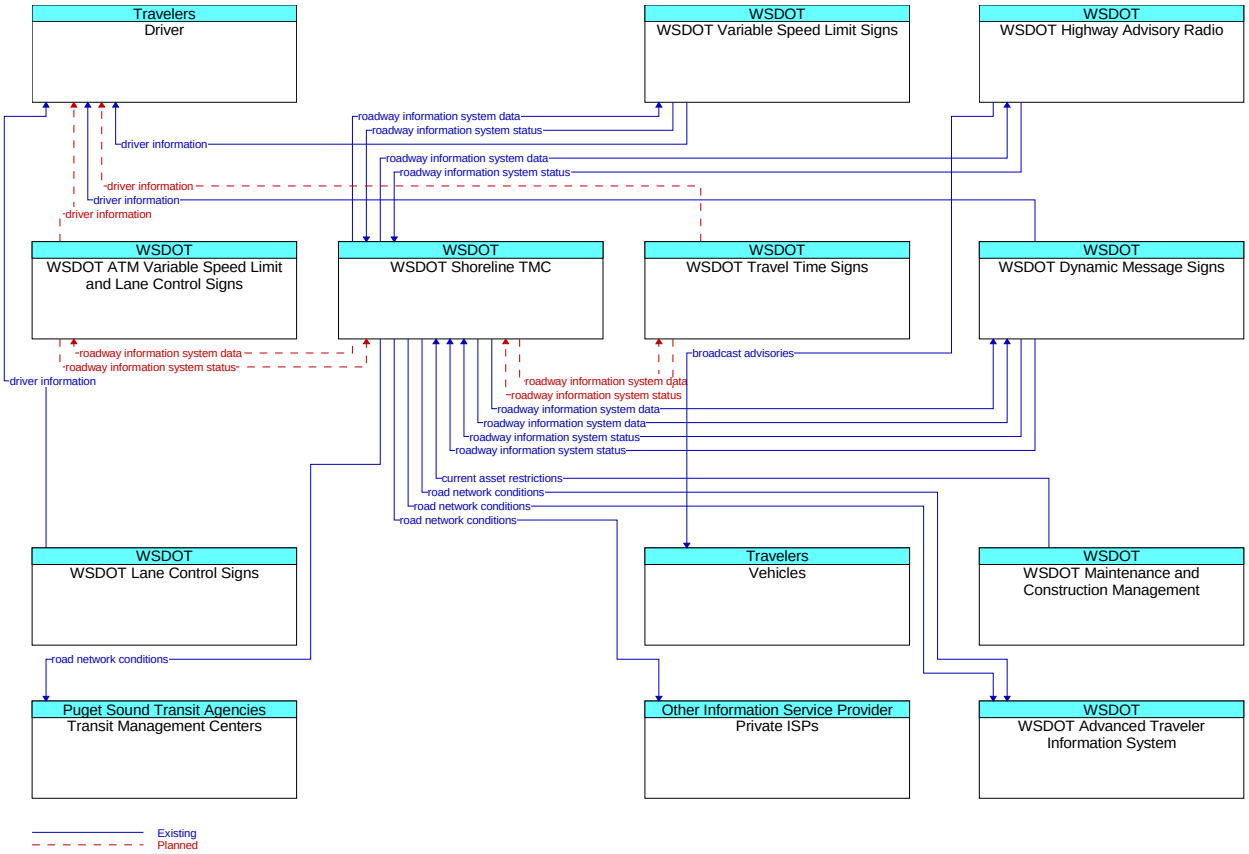


Figure 18. Traffic Information Dissemination Market Package Diagram

5.1.6 Traffic Forecast and Demand Management

Traffic Forecast and Demand Management (Figure 19) includes advanced algorithms, processing, and mass storage capabilities that support historical evaluation, real-time assessment, and forecast of the roadway network performance. This includes the prediction of travel demand patterns to support better link travel time forecasts. The source data would come from the Traffic Management Subsystem itself as well as other traffic management centers and forecasted traffic loads derived from route plans supplied by the Information Service Provider Subsystem. This market package provides data that supports the implementation of TDM programs, and policies managing both traffic and the environment. The package collects information on vehicle pollution levels, parking availability, usage levels, and vehicle occupancy to support these functions. Demand management requests can also be made to Toll Administration, Transit Management, and Parking Management Subsystems.

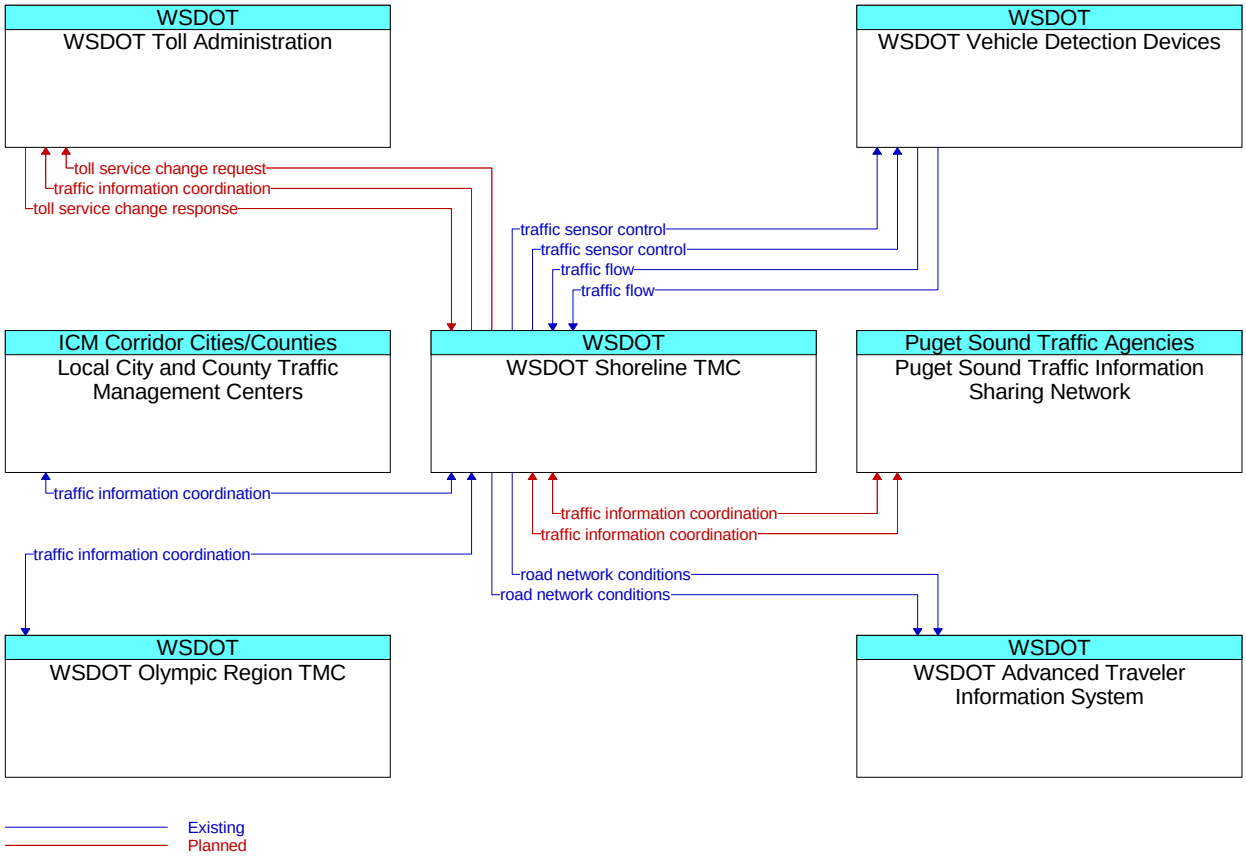


Figure 19. Traffic Forecast and Demand Management Market Package Diagram

5.1.7 Electronic Toll Collection

Electronic Toll Collection (Figure 20) provides toll operators with the ability to collect tolls electronically and detect and process violations. The fees that are collected may be adjusted to implement demand management strategies. Dedicated short range communication between the roadway equipment and the vehicle is required as well as fixed-point to fixed-point interfaces between the toll collection equipment and transportation authorities and the financial infrastructure that supports fee collection. Vehicle tags of toll violators are read and electronically posted to vehicle owners. Standards, inter-agency coordination, and financial clearinghouse capabilities enable regional and ultimately national interoperability for these services. Two other market packages, APTS04: Transit Fare Collection Management and ATMS16: Parking Facility Management, also provide electronic payment services. These three market packages in combination provide an integrated electronic payment system for transportation services.

The toll tags and roadside readers that these systems utilize can also be used to collect road use statistics for highway authorities. This data can be collected as a natural by-product of the toll collection process or collected by separate readers that are dedicated to probe data collection.

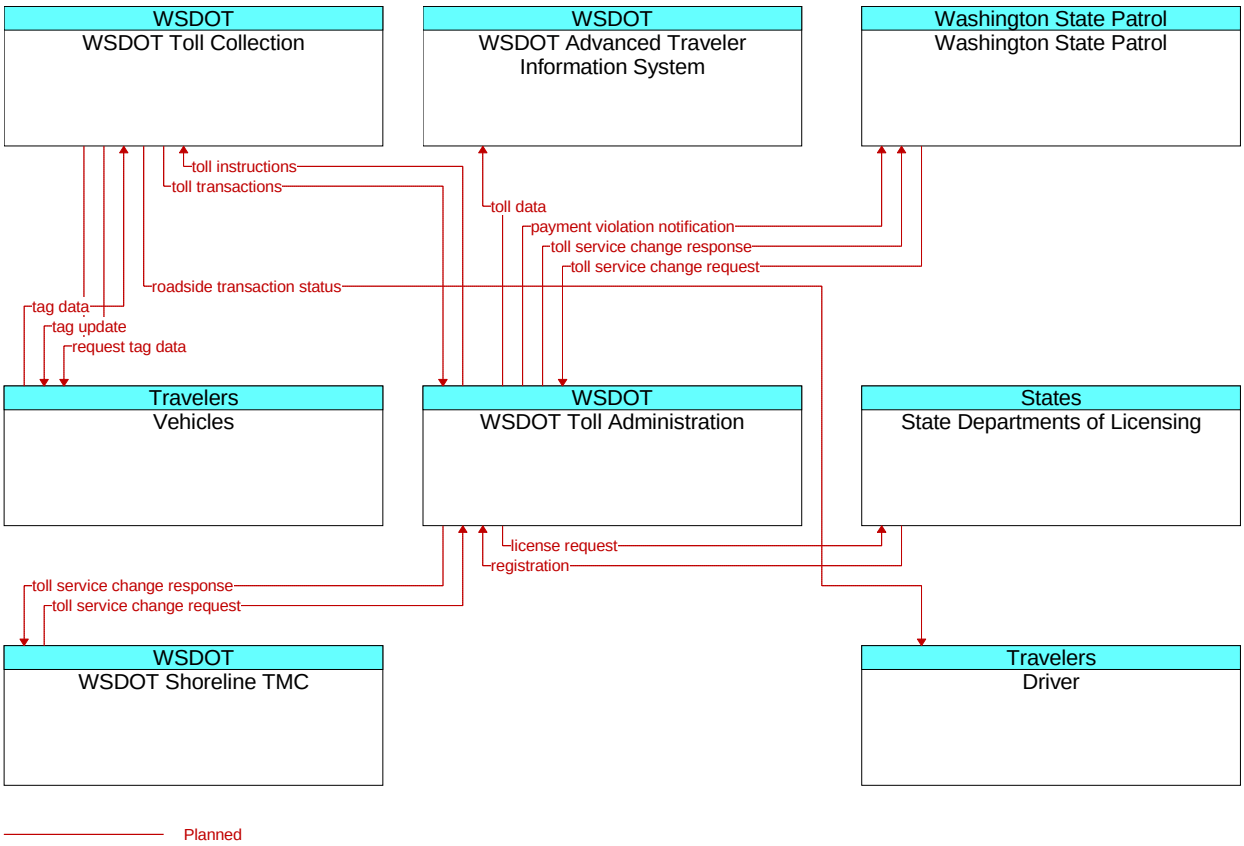


Figure 20. Electronic Toll Collection Market Package Diagram

5.1.8 Reversible Lane Management

This market package provides for the management of reversible lane facilities (Figure 21). In addition to standard surveillance capabilities, this market package includes sensory functions that detect wrong-way vehicles and other special surveillance capabilities that mitigate safety hazards associated with reversible lanes. The package includes the field equipment, physical lane access controls, and associated control electronics that manage and control these special lanes. This market package also includes the equipment used to electronically reconfigure intersections and manage right-of-way to address dynamic demand changes and special events.

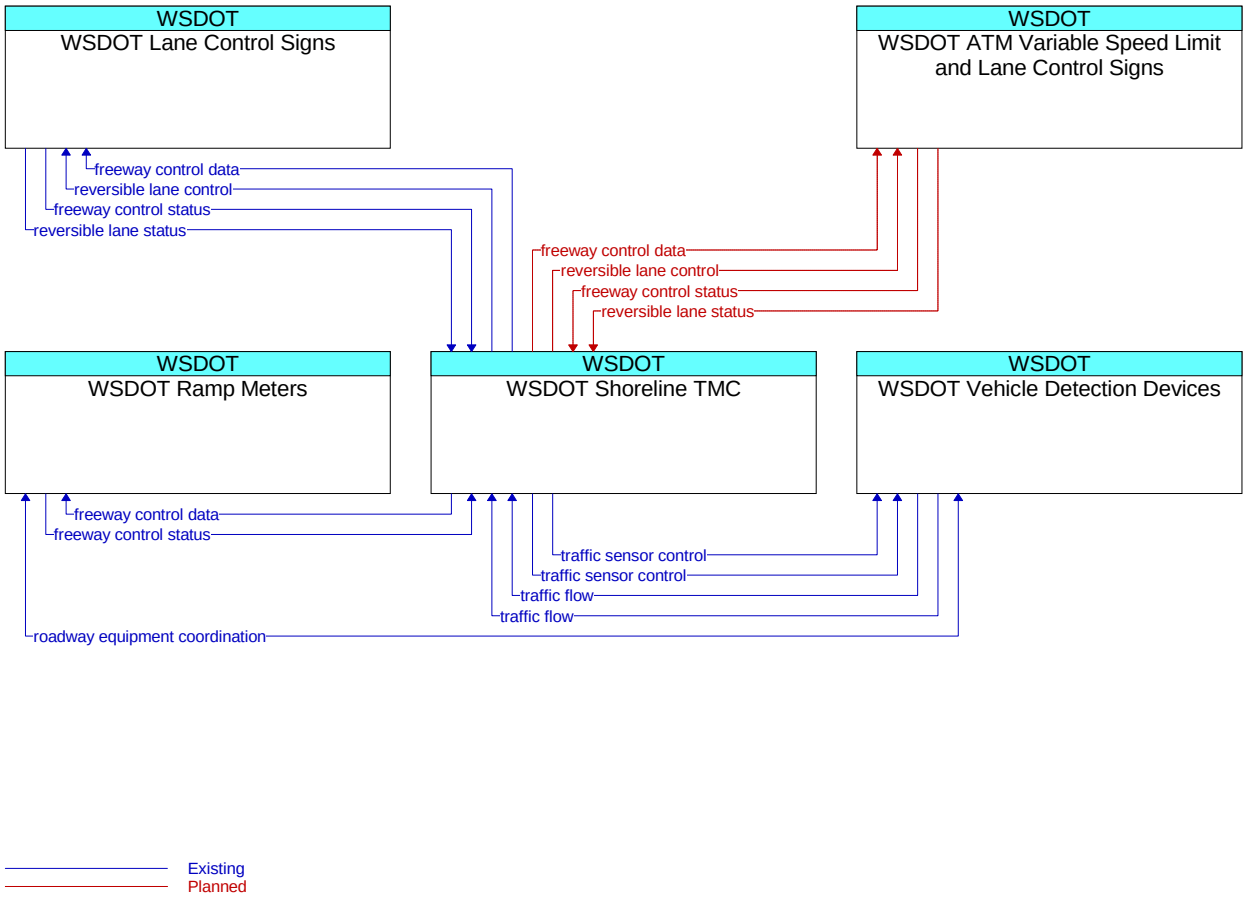


Figure 21. Reversible Lane Management Market Package Diagram

5.1.9 Speed Monitoring

This market package monitors the speeds of vehicles (Figure 22) traveling through a roadway system. If the speed is determine to be excessive, roadside equipment can suggest a safe driving speed. Environmental conditions may be monitored and factored into the safe speed advisories that are provided to the motorist. This service can also support notifications to an enforcement agency to enforce the speed limit on a roadway system.

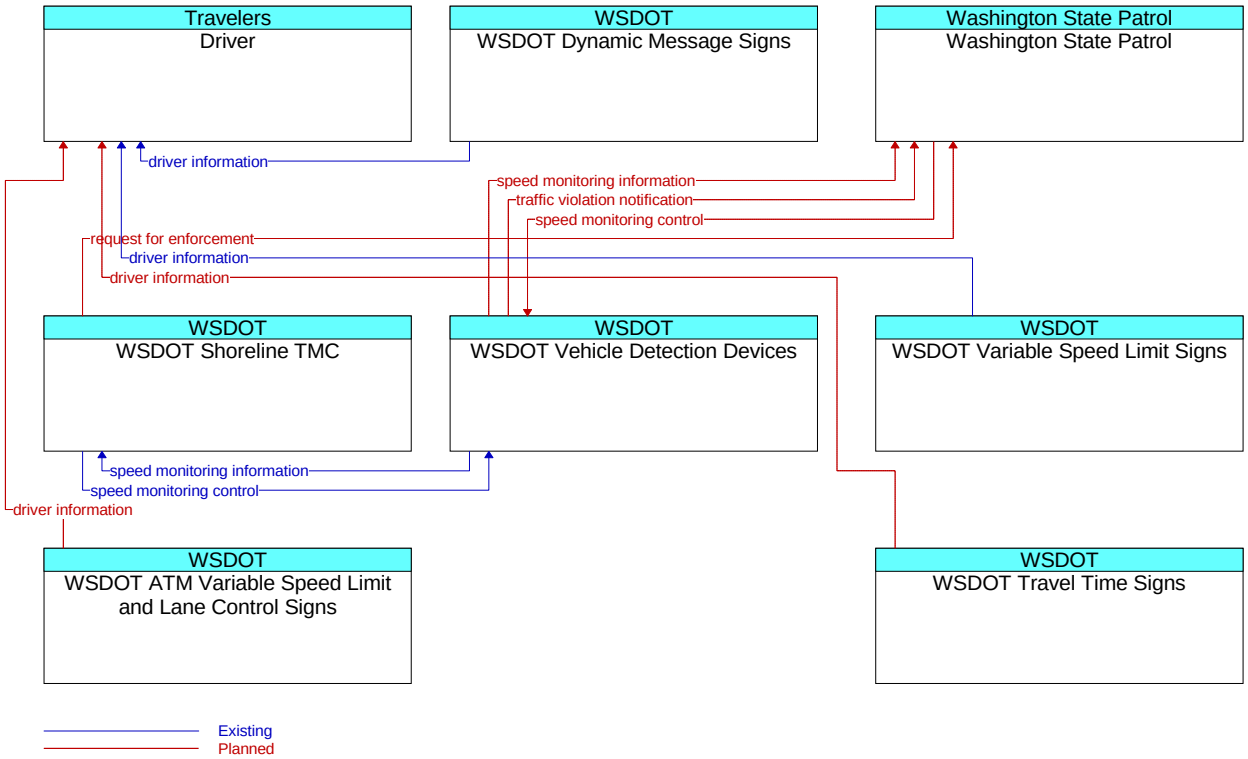


Figure 22. Speed Monitoring Market Package Diagram

5.1.10 Roadway Closure Management

This market package closes roadways (Figure 23) to vehicular traffic when driving conditions are unsafe, maintenance must be performed, and other scenarios where access to the roadway must be prohibited. The market package includes automatic or remotely controlled gates or barriers that control access to roadway segments including ramps and traffic lanes. Remote control systems allow the gates to be controlled from a central location or from a vehicle at the gate/barrier location, improving system efficiency and reducing personnel exposure to unsafe conditions during severe weather and other situations where roads must be closed. Surveillance systems allow operating personnel to visually verify the safe activation of the closure system and driver information systems (e.g., DMS) provide closure information to motorists in the vicinity of the closure. The equipment managed by this market package includes the control and monitoring systems, the field devices (e.g., gates, warning lights, DMS, CCTV cameras) at the closure location(s), and the information systems that notify other systems of a closure.

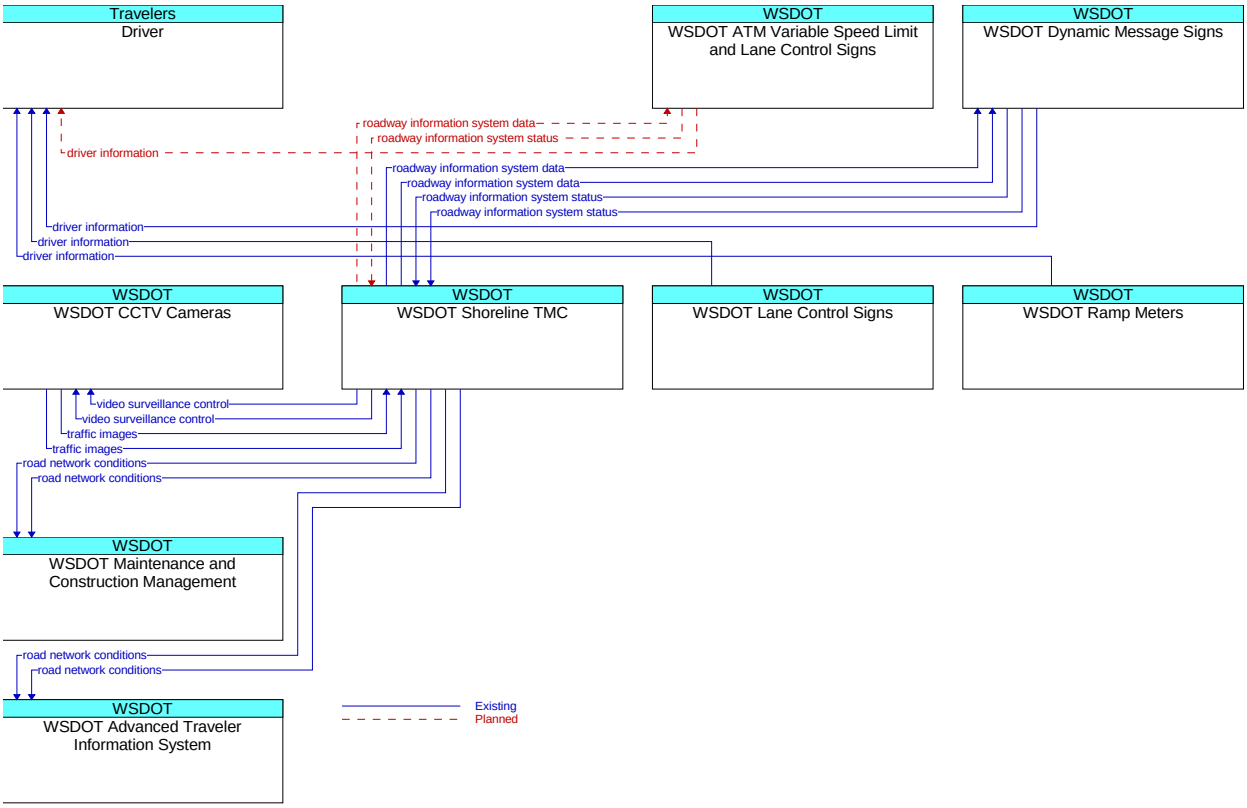


Figure 23. Roadway Closure Management Market Package Diagram

5.1.11 Evacuation and Re-entry Management

Evacuation and Re-entry Management (Figure 24) supports evacuation of the general public from a disaster area and manages subsequent reentry to the disaster area. The market package addresses evacuations for all types of disasters, including disasters like hurricanes that are anticipated and occur slowly, allowing a well-planned orderly evacuation, as well as disasters like terrorist acts that occur rapidly, without warning, and allow little or no time for preparation or public warning.

This market package supports coordination of evacuation plans among the federal, state, and local transportation, emergency, and law enforcement agencies that may be involved in a large-scale evacuation. All affected jurisdictions (e.g., states and counties) at the evacuation origin, evacuation destination, and along the evacuation route are informed of the plan. Information is shared with traffic management agencies to implement special traffic control strategies and to control evacuation traffic, including traffic on local streets and arterials as well as the major evacuation routes. Reversible lanes, shoulder use, closures, special signal control strategies, and other special strategies may be implemented to maximize capacity along the evacuation routes. Transit resources play an important role in an evacuation, removing many people from an evacuated area while making efficient use of limited capacity. Additional shared transit resources may be added and managed in evacuation scenarios. Resource requirements are forecast based on the evacuation plans; and the necessary resources are located, shared between agencies if necessary, and deployed at the right locations at the appropriate times.

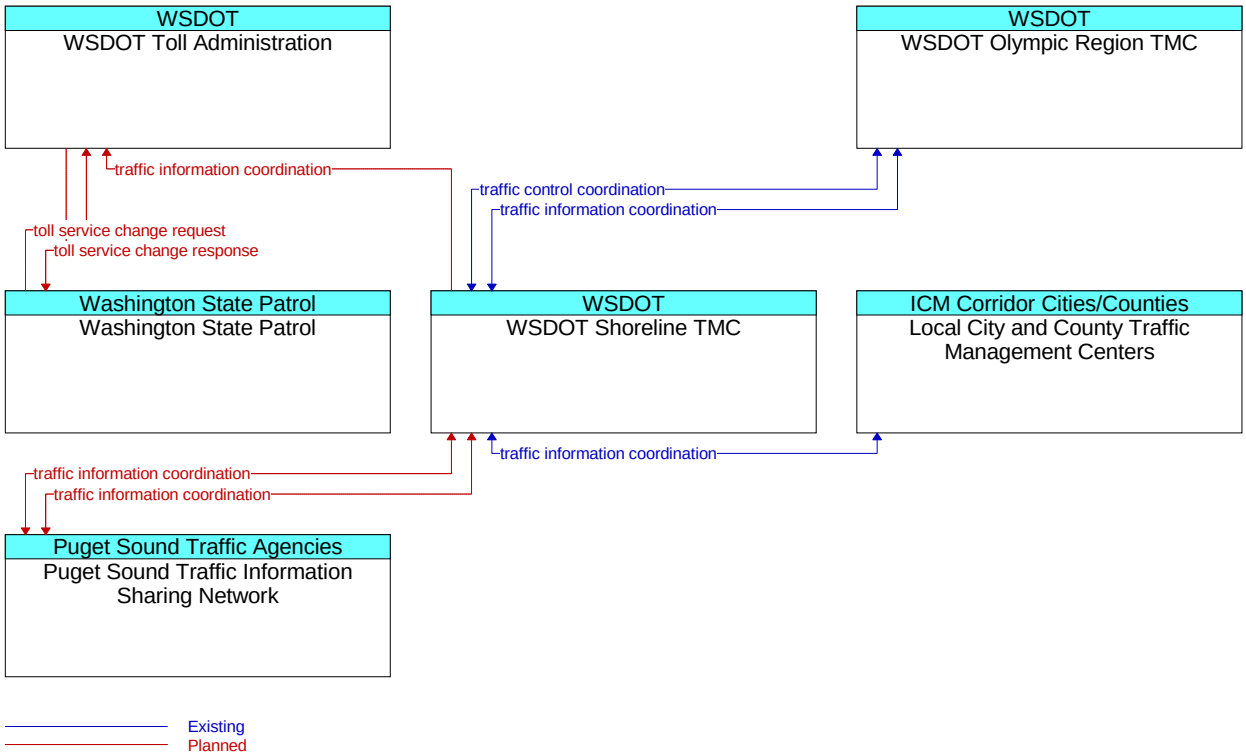


Figure 24. Evacuation and Re-entry Management Market Package Diagram

5.2 Integration with Current ITS Infrastructure and Programs

The ATM techniques discussed in this document are consistent with the WSDOT traffic management philosophy and the integrated corridor management program. They provide WSDOT with another set of tools to help them actively manage traffic conditions.

Further, the hardware required for variable speed limits fits in well with the existing ITS infrastructure. Communication will be needed to the controller equipment on the roadside. There is existing fiber optic communication cable throughout most of the Seattle area freeways.

Current traffic management systems require detectors and the same technology can be used for the variable speed limit detectors. In some locations, designers may find that existing detector stations can be used to provide the data needed for the variable speed limit system. Locations with a single loop detector in each lane would require additional detectors to enable speed measurement. Other technologies may be appropriate, especially radar detection as speed detection needs to be associated with every gantry. Detection should be ideally located within a few hundred feet downstream of the gantry.

It is desirable to implement a camera system that allows the operators to see all of the signs.

The variable message signs used to support these techniques are similar to signs used elsewhere by WSDOT. The new signs should be specified to be NTCIP™ compliant. The WSDOT TMS software can communicate with NTCIP™ signs, making integration much easier than if WSDOT used only proprietary communication protocols.

WSDOT currently orchestrates an incident management program with incident response patrols. These patrols can be used to help sweep the hard shoulder in addition to their other duties.

ATM techniques such as queue warning would work to compliment the existing ramp metering system when addressing mainline congestion.

Finally, WSDOT manages and maintains its own ITS central software. WSDOT software engineers will be able to integrate the software needed for speed harmonization onto existing computing platforms, especially considering WSDOT is working on the migration of its current software from a mini-computer environment to a server-based platform. The integration will take some effort and WSDOT may choose to hire contract software developers or even contract out the work. However, this should not pose a particular problem because WSDOT owns the source code and can build new versions of software.

5.3 Major System Components

The ATM system will be composed of several different ITS components. Each component provides specific capabilities required to meet the requirements of the system. ATM components include

- Dynamic message signs (DMS) capable of displaying speeds, lane control signals, or various words or icons
- Travel Time Signs
- Variable message signs for displaying messages regarding the reason for reduced speeds
- Traffic detectors
- Communication systems

The system will also work within the environment of the existing freeway management system. Existing freeway management components include:

- Closed circuit television (CCTV) cameras
- Ramp metering
- Dynamic message signs
- Communication systems
- Traffic detectors
- Travel Time Signs

5.4 Interfaces to External Systems

The following potential interfaces to external systems have been identified:

- Center-to-center communications with local jurisdictions such as the City of Seattle arterial signal operations as part of interchange signal integration for queue warning and ramp metering (to alleviate queue spillback on an off-ramp back onto the mainline)
- Center-to-center communications between the Northwest Region and Olympic Region's TMCs to operate speed harmonization across regional boundaries as the regional TMCs work together to enhance traffic operations throughout the state
- Center-to-center communications with transit agencies so they can be informed of traffic conditions that may affect their routes
- Center-to-center communications with enforcement so they can be informed of the prevailing speed limits with speed harmonization

Figure 25 shows the boundaries of the six WSDOT regions.[1] Each region has its own TMC for traffic operations.

Figure 25. WSDOT Region Map

[1] http://www.wsdot.wa.gov/mapsdata/TDO/NW_Loc_Logs.htm#

5.5 Proposed Capabilities or Functions

This subsection identifies the capabilities, functions and features of the proposed ATM system.

- Dynamically and automatically reduces speed limits in areas of congestion or incidents
- Provides advance warning of downstream queues
- Directs traffic to specific lanes based on varying traffic demand
- Allows use of the shoulder as a travel lane during congested periods or to move around an incident
- Provides estimated travel times and traffic conditions to the motoring public

6.0 Operational Environment

This section contains information about the system, operations, and maintenance costs. It will describe the mechanism for estimating the costs; discuss multi-year implementation scenario and address life cycle issues.

6.1 System Costs

Preliminary cost estimates were completed on a per ATM sign bridge basis for three-lane and five-lane freeway sections. The process of developing these cost estimates included three primary steps:

1. Identify major elements required as part of the speed harmonization/lane control/queue warning concept for each sign bridge
2. Develop individual costs of the major elements
3. Apply construction and design factors to create a conceptual level cost per sign bridge

6.1.1 Major ATM Elements

Of the five ATM concepts, detailed cost estimates for speed harmonization/lane control/queue warning were developed for this effort. The major elements of the concept were identified according to the FHWA ATM study (Active Traffic Management: The Next Step in Congestion Management, March 2007) and refined through WSDOT and consultant team dialogue of the major elements and the overall operation of the system.

The per ATM sign bridge conceptual cost estimate is based on quantities and assumptions applicable to the I-5 corridor from Tukwila to Swamp Creek estimates. Quantities were taken from three and five lane segments of I-5 then averaged based on the number of sign locations in those segments. The per sign bridge conceptual cost estimates should only be used as a rough guide. A thorough review of the various assumptions and notes associated with these estimates (Conceptual Design and Cost Estimate submittal, September 2008) is necessary to apply these estimates to other corridors. For example, the per sign bridge cost estimates do not include the cost to install a trunk line, as a trunk line was already in place on I-5 within the Phase III study area.

The conceptual sign bridge cost estimates include ATM element assumptions that are required for installation regardless of the corridor's specific attributes. These element assumptions are noted in Table 2.

Table 2. Common ATM Element Assumptions

Sign Bridge quantity is the span length of the sign structure (columns included in the unit price). Sign bridges installed approximately every ½ mile.
One overhead lane control DMS per each main line through lane (size is approximately 4-1/2 ft x 4-1/2 ft).
Two supplemental full color matrix side-mount DMS at each sign structure.
Height-restricted DMS is used where there are vertical clearance issues such as under structures, tunnels/lids.
One overhead VMS on each ATM sign bridge (size is approximately 4-5 ft tall x 8-9 ft wide).
Variable Speed Warning (VSW) ground-mounted shoulder sign are installed for select system interchange ramps connecting the major corridors (two VSW signs assumed for two-lane ramps).
One sign controller is required for each DMS/VMS/VSW sign.
One controller cabinet can house up to five controllers.
Data Feed is measured from nearest CCTV camera or hub location to sign structure location. Unit price includes conduit, fiber optic cable, trenching, pull boxes, and splicing, in place complete.
Power Feed is measured from nearest service drop or existing CMS/VMS location to sign bridge location. Unit price includes conduit, cable, trenching, pull boxes, and splicing, in place complete.
Where existing service is located >1/4 mile from sign, a new service drop will be provided. Where existing service is ≤ 1/4 mile from sign certain percentages of existing service drops shall be replaced.
HDD (horizontal directional drilling) unit price accounts for data cable lateral from trunk. Assumes data cable lateral from trunk equals sign bridge length. Where HDD is greater than sign bridge length, quantity includes additional boring for power feed.
Vehicle speed detectors installed approximately every 1/2 mile.
One non-intrusive speed detector is required per each sign bridge location. Unit price includes detector, cabling, interface device and communication device.
Additional CCTV camera relocation assumes up to 33% additional camera locations will be added to the I-5 corridor. This is assumed to account for existing camera conflicts as well as new service.
Approximately 75 LF of barrier/guardrail is required at each sign bridge in-ground footing location.
Approximately 50 LF of existing bridge rail requires reconstruction at each sign bridge on-structure footing location (except at wall-mount situations).
Corridor Fiber Optic Conduit consists of a 4-inch duct with inner ducts, in place complete.
Corridor Fiber Optic Cable consists of a 48-count fiber optic bundle, installed.
No major relocation of existing utilities is required.
Provision for "Basic Safety Improvements" accounts for unspecified roadside safety improvements.

The conceptual sign bridge cost estimates also include ATM element assumptions that will vary based on the specific attributes of the freeway corridor. These element assumptions for the I-5 corridor, which was used to develop the per ATM sign bridge conceptual cost estimate, are noted Table 3.

Table 3. ATM Element Assumptions Expected to Differ by Corridor

Service drops generally followed the above noted conditions; on I-5 it was assumed that 80% of existing service drops would be replaced. This will vary based on the existing conditions of the freeway corridor.
Approximately one existing overhead sign structure will require relocation for every 1 mile of corridor within the Seattle core area between I-90 and SR 520. Approximately one existing overhead sign structure will require relocation for every 1.8 miles of corridor outside of the Seattle core area.
New Fiber Optic data distribution line is required for the entire length of the I-5 corridor.

6.1.1.1 Individual Costs

Individual costs for the major elements were collected. These costs were informed by a variety of sources including FHWA's ITS Unit Costs Database, historical ITS estimate data from WSDOT Northwest Region, and product manufacturers and distributors. The individual materials purchase and installation costs are detailed in Table 4 for a three-lane section and Table 5 for a five-lane section. Software costs (development and implementation) are not included in these estimates, as this cost is captured by the first ATM installation. However, the cost to integrate subsequent corridors in the overall system has been included in the per lane conceptual cost estimates.

6.1.1.2 Construction and Design Factors

Construction and design factors were added to the estimates to create a conceptual cost estimate per sign bridge for a variable speed limit/lane control/queue warning system. These factors include: traffic control; mobilization; construction contingency; construction engineering; sales tax; environmental clearance and preliminary engineering; and final design and engineering. The construction and design factors are detailed in Table 4 and Table 5 below.

The conceptual per sign bridge cost estimate for a three-lane freeway section is $1.6 million, making the per directional mile cost approximately $3.2 million. The conceptual per sign bridge cost estimate for a five-lane freeway section is $2.0 million, making the per directional mile cost approximately $4.0 million.

Table 4. Per ATM Sign Bridge Location Three-Lane Section Conceptual Cost Estimate

Items	Quantity	Unit	Unit Price	Cost	Per Location Cost
Sign Bridges	900	LF (width)	$2,000	$1,800,000	$138,462
In-ground Foundations	22	Each	$12,500	$275,000	$21,154
On-structure Foundations	4	Each	$15,000	$60,000	$4,615
Dynamic Message Signs (DMS)	52	Each	$40,000	$2,080,000	$160,000
Variable Message Signs (VMS)	13	Each	$55,700	$724,100	$55,700
Sign Controllers	65	Each	$1,800	$117,000	$9,000
Controller Cabinets	13	Each	$10,500	$136,500	$10,500
Data Feed	3,875	LF	$20	$77,500	$5,962
Power Feed	900	LF	$25	$22,500	$1,731
New Service Drop	12	Each	$20,000	$240,000	$18,462
Horizontal Directional Drilling	150	LF	$65	$9,750	$750
Non-intrusive Speed Detectors	13	Location	$15,000	$195,000	$15,000
Exist. Sign Relocation[a]	39	Each	$44,500	$1,735,500	$28,925
Exist. Sign Bridge Relocation[a]	1	Each	$400,000	$400,000	$6,667
Additional CCTV Camera[a]	17	Each	$30,000	$510,000	$8,500
Traffic Barrier	1,650	LF	$180	$297,000	$22,846
Reconstruct Bridge Railing	100	LF	$215	$21,500	$1,654
					$509,928
Integration Expense	1	LS	$53,455	$53,455	$53,455
TESC	(5%)				$25,496
Provision for "Basic Safety Improvements"	(5%)				$25,496
Traffic control, mobilization, contingency	(50%)				$254,964
				Construction Subtotal	$869,340
Sales Tax	(8.9% of Constr. Subtotal)				$77,371
				Construction Subtotal incl. Tax	$946,711
Environmental Clearance & PE	(8% of Constr. Subtotal)				$69,547
Final Design and CE (12% + 15%)	(27% of Constr. Subtotal)				$234,722
				Project Subtotal per Sign Location	$1,250,980
General contingency (low level of investigation)	(30% of Project Subtotal)				$375,294
				Estimated Project Cost per Sign Location	$1,626,274

Note: This cost estimate is to be read in conjunction with attached itemized sheet.
[a] Corridor-wide item divided by total number of sign locations on the corridor.

Table 5. Per ATM Sign Bridge Location Five-Lane Section Conceptual Cost Estimate

Items	Quantity	Unit	Unit cost	Cost	Per Location Cost
Sign Bridges	3,640	LF (width)	$2,000	$7,280,000	$177,561
In-ground Foundations	71	Each	$12,500	$887,500	$21,646
On-structure Foundations	11	Each	$15,000	$165,000	$4,024
Dynamic Message Signs (DMS)	246	Each	$40,000	$9,840,000	$240,000
Variable Message Signs (VMS)	41	Each	$55,700	$2,283,700	$55,700
Sign Controllers	287	Each	$1,800	$516,600	$12,600
Controller Cabinets	82	Each	$10,500	$861,000	$21,000
Data Feed	6,250	LF	$20	$125,000	$3,049
Power Feed	6,300	LF	$25	$157,500	$3,841
New Service Drop	35	Each	$20,000	$700,000	$17,073
Horizontal Directional Drilling	870	LF	$65	$56,550	$1,379
Non-intrusive Speed Detectors	41	Location	$15,000	$615,000	$15,000
Exist. Sign Relocation[a]	39	Each	$44,500	$1,735,500	$28,925
Exist. Sign Bridge Relocation[a]	1	Each	$400,000	$400,000	$6,667
Additional CCTV Camera[a]	17	Each	$30,000	$510,000	$8,500
Traffic Barrier	5,325	LF	$180	$958,500	$23,378
Reconstruct Bridge Railing	300	LF	$215	$64,500	$1,573
					$641,916
Integration Expense	1	LS	$53,455	$53,455	$53,455
TESC	(5%)				$32,096
Provision for "Basic Safety Improvements"	(5%)				$32,096
Traffic control, mobilization, contingency	(50%)				$320,958
				Construction Subtotal	$1,080,521
Sales Tax	(8.9% of Constr. Subtotal)				$96,166
				Construction Subtotal incl. Tax	$1,176,687
Environmental Clearance & PE	(8% of Constr. Subtotal)				$86,442
Final Design and CE (12% + 15%)	(27% of Constr. Subtotal)				$291,741
				Project Subtotal per Sign Location	$1,554,870
General contingency (low level of investigation)	(30% of Project Subtotal)				$466,461
				Estimated Project Cost per Sign Location	$2,021,331

Note: This cost estimate is to be read in conjunction with attached itemized sheet.
[a] Corridor-wide item divided by total number of sign locations on the corridor.

The cost of implementing a speed harmonization/lane control/queue warning system as part of a larger construction project would reduce the per sign bridge costs as reported above, as some costs would be absorbed or shared with the larger construction project.

Travel time sign and ground-mount variable speed warning sign costs (located only at specific freeway-to-freeway ramps), are not included in the per ATM sign bridge costs. These two elements are not integrated into the proposed variable speed limit/lane control/queue warning system. Both travel time signs (location and number of destinations shown on the sign) and variable speed warning signs need to be accounted for individually based on the corridor in question.

6.2 Operations and Maintenance Costs

The operations and maintenance (O&M) costs are based on WSDOT's ITS Maintenance database of estimated annual costs for the various systems including variable message signs, changeable message signs, communication hubs, and closed circuit television cameras. The

estimated maintenance costs are based on WSDOT's work done by Northwest Region Maintenance personnel. Maintenance schedules for new devices like the non-intrusive speed detectors and variable speed warning signs, which are new to WSDOT, are estimated.

The original costs provided by WSDOT were based on the 2003-2005 biennium pay scales. These rates were increased by ten percent to reflect a pay increase in July 2007 and another two percent to reflect a pay increase in July 2008. Likewise, equipment costs have also been adjusted.

The unit rates in Table 6 were used for the various labor and equipment categories. Material costs may include replacement/repair parts, materials and other incidentals. In most cases, the Maintenance Technician category was used to handle traffic control, maintenance, and repairs. Total costs are rounded to the nearest two or three significant digits.

Table 6. Unit Rates

Work Activity	Details	Cost
Labor	Maintenance Technicians for Traffic Control and Repair	$41 / hour / person
	Bridge Inspectors (Structural Engineers)	$51 / hour / person
Equipment	Man Lift	$17 / hour
	Pickup	$6 / hour
	Van	$5 / hour
	Truck-Mounted Impact Attenuator	$4 / hour
Materials	Varies	Varies

6.2.1 Sign Bridge Structural Inspections

The WSDOT Bridge Preservation Office is required to inspect each sign bridge (gantry) and cantilever structure every five years. No inspections are allowed at night, so the inspections will need to be done early Saturday or on Sunday mornings. This translates into higher labor costs because it will most likely require overtime labor to achieve this. The number of hours allowed for this type of work will be small due to the high traffic volumes. Thus, maintenance for these inspections will require multiple sessions of setting up and removing traffic control, so the work will be inefficient.

The estimated time required to inspect one sign bridge is four hours (Table 7). This includes traffic control set up, inspection and traffic control removal.

Table 7. Structural Inspections

Work Activity	Qty	Details	Cost
Labor	4	Maintenance Technician for Traffic Control	$656
	2	Bridge Inspector (Structural Engineer)	$408
Equipment	1	Man Lift Truck	$68
	1	Pickup	$24
	2	Van	$40
	1	Truck-Mounted Impact Attenuator	$16
		Total Cost per Structure (every 5 years)	**$1,200**
		Total Cost per Structure (annually)	**$240**

Sign bridge gantries are spaced at approximately every ½ mile in both directions, so the annual maintenance per mile is $960.

6.2.2 Overhead Variable Message Signs

6.2.2.1 General

The recommended maintenance schedule for overhead VMS signs is one major preventative maintenance (PM) (Table 8) per year plus monthly minor PMs. Major PM for a sign over a traffic lane typically takes between six to eight hours (assume eight hours for the cost estimate). Traffic control is a major cost when the sign is over traffic. The traffic control requires about two hours to set up and one hour to take down. In addition, arrow board trucks, truck-mounted impact attenuators (one per closed lane) and numerous signs and barrels are needed. For signs located over the shoulder or off the road, the assumption is that the costs will be the same because the shoulder and at least one travel lane will be closed for safety reasons.

Table 8. Major PM for an Overhead VMS

Work Activity	Qty	Details	Cost
Labor	6	Maintenance Technician	$1,968
Equipment	2	Man Lift Truck	$272
	1	Pickup	$48
	1	Van	$40
	2	Truck-Mounted Impact Attenuator	$64
Materials			$500
		Total Cost per Sign (annually)	**$2,900**

Minor PM (Table 9) would be conducted on a monthly basis and require one hour of labor, except for the month when the major PM occurs. So, this translates into 11 minor PMs per year.

Table 9. Monthly Minor PM for Overhead VMS

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$41
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$5
	0	Truck-Mounted Impact Attenuator	$0
Materials			$0
		Total Cost per Sign (per visit)	**$46**
		Total Cost per Sign (annually)	**$510**

Repair Costs (Table 10) also need to be accounted for as some signs will need repair over time. For an overhead VMS sign, the cost includes traffic control set up and take down and is estimated at six hours per year per sign every three years.

Table 10. Repair (Overhead VMS)

Work Activity	Qty	Details	Cost
Labor	6	Maintenance Technician	$1,476
Equipment	2	Man Lift Truck	$204
	1	Pickup	$36
	1	Van	$30
	2	Truck-Mounted Impact Attenuator	$48
Materials		Repair parts and materials	$400
		Total Cost per Sign (every 3 years)	**$2,200**
		Total Cost per Sign (annually)	**$730**

6.2.2.2 Maintenance Summary Costs – Overhead VMS

The yearly maintenance cost for overhead VMS is approximately $5,600 per sign per year (Table 11). The annual maintenance cost for VMS off the roadway is the same.

Table 11. Overhead VMS Maintenance Summary Costs

Overhead VMS	Costs
Major PM	$2,900
Monthly Minor PM	$510
Repair	$2,200
TOTAL	**$5,610**

Overhead VMS are located on every ATM sign bridge which is spaced at approximately every ½ mile in both directions, so the annual maintenance per mile is almost $22,500. Additional VMS are sometimes added throughout the corridor and must be added to the annual maintenance per mile cost on a per sign basis.

6.2.3 Non-Intrusive Speed Detectors

6.2.3.1 General

The non-intrusive speed detectors are assumed to be mounted on luminaire poles, camera poles or sign bridge vertical members and they will not be located over traffic lanes. Therefore, no lane closures would be required for maintenance. The recommendation for maintenance of the non-intrusive speed detectors is twelve preventative maintenance (PM) visits per year. One would be a major PM (Table 12) and the other eleven would be minor PMs (Table 13). Major PM would require two hours of labor. Minor PM requires one-half hour per visit. Repairs (Table 14) are estimated to be needed every three years and will require approximately two hours.

Table 12. Major PM for Non-Intrusive Speed Detectors

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$82
Equipment	1	Man Lift Truck	$34
	0	Pickup	$0
	0	Van	$0
	0	Truck-Mounted Impact Attenuator	$0
Materials			$100
		Total Cost per Detector (annually)	**$220**

Table 13. Minor PM for Non-Intrusive Speed Detectors

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$21
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$3
	0	Truck-Mounted Impact Attenuator	$0
Materials			$0
		Total Cost per Detector (per visit)	**$23**
		Total Cost per Detector (annually)	**$250**

Table 14. Repair (Non-Intrusive Speed Detectors)

Work Activity	Qty	Details	Cost
Labor	2	Maintenance Technician	$164
Equipment	1	Man Lift Truck	$34
	0	Pickup	$0
	0	Van	$0
	0	Truck-Mounted Impact Attenuator	$0
Materials		Repair parts and materials	$500
		Total Cost per Detector (every 3 years)	**$700**
		Total Cost per Detector (annually)	**$230**

6.2.3.2 Maintenance Summary Costs – Non-Intrusive Speed Detectors

The total annual cost per non-intrusive speed detector is $700. The preliminary design requires one non-intrusive speed detector on every ATM gantry which is located at approximately every 1/2 mile in both directions, so the annual maintenance per mile is $2,800.

6.2.4 Overhead Lane Control Signs

6.2.4.1 General

The overhead lane control signs would not be full matrix VMS signs, but rather special purpose LED-type signs. Maintenance costs will be less than for full matrix and these types of signs should be more reliable. The assumption is that each sign bridge will one lane control sign over each lane mounted on the horizontal member of the sign bridge.

These signs will be fully enclosed and will not require maintenance above the ground unless they need to be replaced. The recommended maintenance schedule is one minor preventative maintenance (PM) (Table 15) per month. Minor PM requires one hour of labor per sign bridge, including the sign control cabinet. This translates into 12 minor PMs per year for an annual cost of $550 per sign bridge.

Table 15. Monthly Minor PM for Overhead Lane Control Signs

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$41
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$5
	0	Truck-Mounted Impact Attenuator	$0
Materials			$0
		Total Cost per Sign Bridge (per visit)	**$46**
		Total Cost per Sign Bridge (annually)	**$550**

Because some signs will require replacement (Table 16), the replacement costs need to be included. For signs over traffic, the cost includes traffic control set up and take down and is estimated at four hours every three years per sign bridge. If a sign is exhibiting signs of imminent failure and a lane closure is being conducted for another purpose, the sign will be replaced to save on maintenance costs.

Table 16. Replacement (Overhead Lane Control Signs)

Work Activity	Qty	Details	Cost
Labor	6	Maintenance Technician	$984
Equipment	2	Man Lift Truck	$136
	1	Pickup	$24
	1	Van	$20
	2	Truck-Mounted Impact Attenuator	$32
Materials		Repair parts and materials	$400
		Total Cost per Sign Bridge (every 3 years)	**$1,600**
		Total Cost per Sign Bridge (annually)	**$530**

6.2.4.2 Maintenance Summary Costs – Overhead Lane Control Signs

A summary of the overhead lane control sign costs per sign bridge are shown in Table 17. Given a ½-mile spacing for these sign bridges, the yearly maintenance cost per mile for the lane control signs in both directions is $4,320 per year.

Table 17. Overhead Lane Control Signs Maintenance Summary Costs (one sign bridge in one direction of travel)

Overhead Lane Control Signs	Costs
Monthly Minor PM	$550
Replacement	$530
TOTAL	**$1,080**

6.2.5 Side-Mount DMS

6.2.5.1 General

The side-mount DMS will be full color matrix and mounted on the vertical member of the gantry. The assumption is that each sign bridge will have two full color DMS signs per sign bridge. These signs will be able to display words, numbers, and symbols.

The recommended maintenance schedule is one major preventative maintenance (PM) (Table 18) per year and monthly minor PMs. The major PM requires up to three hours/sign bridge: one hour of maintenance for each DMS on the bridge and an hour to get to the location and setup. For major PM, the cost of $470 per sign bridge accounts for two side-mount DMS.

Table 18. Major PM for Side-Mount DMS

Work Activity	Qty	Details	Cost
Labor	2	Maintenance Technician	$246
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$15
	1	Truck-Mounted Impact Attenuator	$12
Materials			$200
		Total Cost per Sign Bridge (annually)	**$470**

Minor PM (Table 19) would be conducted on a monthly basis and require one hour of labor per sign, except for the month when the major PM occurs. So, this translates into 11 minor PMs per year at an annual cost of $510 per sign bridge.

Table 19. Monthly Minor PM for Side-Mount DMS

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$41
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$5
	0	Truck-Mounted Impact Attenuator	$0
Materials			$0
		Total Cost per Sign (per visit)	**$46**
		Total Cost per Sign (annually)	**$510**

Because some signs will require repair (Table 20), the repair costs need to be included. The cost includes traffic control set up and take down and is estimated at two hours every five years per sign bridge.

Table 20. Repair (Side-Mount DMS)

Work Activity	Qty	Details	Cost
Labor	2	Maintenance Technician	$164
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$10
	1	Truck-Mounted Impact Attenuator	$8
Materials		Repair parts and materials	$400
		Total Cost per Sign (every 5 years)	**$580**
		Total Cost per Sign (annually)	**$120**

6.2.5.2 Maintenance Summary Costs – Side-Mount DMS

A summary of the full color matrix side-mount DMS costs per sign bridge are shown in Table 21. Given a ½-mile spacing for these sign bridges, the yearly maintenance cost per mile for the side-mount DMS in both directions is $4,400 per year.

Table 21. Side-Mount DMS Maintenance Summary Costs (one sign bridge in one direction of travel)

Side-Mount DMS	Costs
Major PM	$470
Monthly Minor PM	$510
Repair	$120
TOTAL	**$1,100**

6.2.6 Variable Speed Warning Signs

6.2.6.1 General

The variable speed warning (VSW) signs are assumed to be ground mounted signs. There will be one sign per ramp located on the major ramps entering the Variable Speed Limit control area. They will be changeable message warning type signs that display the current speed limit on the mainline. The recommended maintenance schedule is one major preventative maintenance (PM) (Table 22) per year and monthly minor PMs. Minor PM (Table 23) would be conducted on a monthly basis and require one hour of labor, except for the month when the major PM occurs. So, this translates into 11 minor PMs per year. The major PM requires two hours and the minor PM requires one hour. Repairs (Table 24) would be conducted every five years and would require about three hours of labor.

Table 22. Major PM for VSW Signs

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$82
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$10
	0	Truck-Mounted Impact Attenuator	$0
Materials			$100
		Total Cost per Sign (annually)	**$190**

Table 23. Monthly Minor PM for VSW Signs

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$41
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$5
	0	Truck-Mounted Impact Attenuator	$0
Materials			$0
		Total Cost per Sign (per visit)	**$46**
		Total Cost per Sign (annually)	**$510**

Table 24. Repair (VSW Signs)

Work Activity	Qty	Details	Cost
Labor	1	Maintenance Technician	$123
Equipment	0	Man Lift Truck	$0
	0	Pickup	$0
	1	Van	$15
	0	Truck-Mounted Impact Attenuator	$0
Materials		Repair parts and materials	$500
		Total Cost per Sign (every 5 years)	**$640**
		Total Cost per Sign (annually)	**$130**

6.2.6.2 Maintenance Summary Costs – VSW

The yearly maintenance cost for a VSW sign is $830 per year (Table 25).

Table 25. VSW Maintenance Summary Costs

VSW	Costs
Major PM	$190
Monthly Minor PM	$510
Repair	$130
TOTAL	**$830**

6.2.7 Maintenance Costs

The information provided in the previous tables was used to calculate the additional FTEs to maintain each corridor of the entire ATM system (see Table 26 and Table 27). This information is broken out by labor category. Calculations accounted for the proposed number of gantries per mile in both directions, the number of miles in each study corridor, and the number of hours of labor per year for each of the maintenance functions. An FTE was considered to be 1,800 hours per year. Calculation assumptions can be found in Appendix C.

Table 26. Maintenance Technician FTEs

2.20	FTE	SR 520
2.82	FTE	I-90
9.48	FTE	I-405
9.63	FTE	I-5
24.13	FTE	Entire ATM System

Table 27. Bridge Inspector FTEs

0.027	FTE	SR 520
0.032	FTE	I-90
0.108	FTE	I-405
0.105	FTE	I-5
0.272	FTE	Entire ATM System

The potential for reduced maintenance labor exists when repairs can be done in place of regularly scheduled maintenance. As previously stated, if signs are exhibiting signs of imminent failure and a lane closure is being conducted for another purpose, the sign can be replaced at

the same time. Therefore, the total number of maintenance FTEs required for the entire system is a conservative number.

6.2.8 Operations Costs

With speed harmonization, there will be a need for an operator (Engineer/Intern) in the Traffic Management Center 24/7. There are currently operators on duty on weekdays about 13 hours per day and on weekends eight hours per day. Therefore, an additional 3.8 FTEs are needed to cover the remaining shifts for a cost of $52,500 per FTE or almost $200,000 per year.

6.2.9 Motorist Information Signing Maintenance

The motorist information signing (travel time information) can be used at the following sites:

- Southbound I-405 at I-90
- Southbound I-405 at SR 167
- Westbound I-90 at I-405 (2)
- Northbound I-5 at I-405
- Northbound I-5 at I-90
- Southbound I-5 at I-405 (2)
- Southbound I-5 at I-90
- Southbound I-5 at SR 520
- Southbound I-5 at I-405 (2)
- Westbound SR520 at I-405 (2)

The number of travel time signs varies between one to two signs per location. Annual maintenance can be calculated using the annual maintenance cost of $5,600 per VMS. There are no additional operations costs associated with this ATM technique.

6.2.10 Master Summary Operations & Maintenance Costs

The operations and maintenance costs for speed harmonization are summarized in Table 28. Annual maintenance for the structural inspections, VMS, non-intrusive speed detectors, overhead lane control signs and side-mount DMS can be calculated on a per mile basis. VSW and travel time signs must be accounted for on a per item basis because they are located at major interchanges. The increased operations costs must also be accounted for separately. Annual maintenance for speed harmonization will cost approximately $34,980 per mile. Additional savings could be realized if the entire maintenance for all devices on the same gantry could be completed at the same time.

Table 28. Annual O&M Cost for Speed Harmonization (both directions)

Work Activity	Cost
Structural Inspections	$960 / mile
Overhead VMS Maintenance	$22,500 / mile
Non-Intrusive Speed Detector Maintenance	$2,800 / mile
Overhead Lane Control Signs Maintenance	$4,320 / mile
Side-Mount DMS Maintenance	$4,400 / mile
Total Annual Maintenance	**$34,980 / mile**
Stand Alone Items	**Cost**
Variable Speed Warning Sign Maintenance	$830 each
Motorist Information (Travel Time) Signing Maintenance	$5,600 each
Added Operations Costs (for the entire system)	$200,000 / year

6.3 Deployment

It is also important to note that the ATM elements proposed for the Seattle area will be implemented in an environment with substantial traffic management infrastructure and systems already in place. On the freeway system in the Seattle area, the following systems are currently in place:

- ramp metering,
- incident response teams,
- freeway service patrols,
- variable message signs,
- traveler information systems (such as the WSDOT web-based traffic map and the 511 telephone system),
- HOV lanes,
- integrated corridor management, and
- closed circuit television (CCTV).

It is important to consider all traffic management systems and techniques when thinking of implementing ATM where there currently is limited or no other freeway management elements. All of these systems work well in concert with one another. Integration of ATM with these systems, operations, and maintenance is important to provide while deploying ATM. Further, careful consideration should be given to implementing ATM elements without these other systems either in place or in the program. The more traditional traffic management elements are very cost effective. Further, the primary ATM element being proposed for the Seattle area, variable speed limit/lane control/queue warning, primarily addresses safety improvement. Some of the other traffic management elements, particularly ramp metering, address safety as well congestion. It is important to plan for a system that will use the best combination of traffic management techniques to meet the needs of the region in which they will be deployed.

The implementation of Active Traffic Management on the freeways in the core Puget Sound region (greater Seattle/Bellevue area) and on I-5 from approximately Lakewood to Arlington is part of WSDOT's strategic plan goals to improve safety and mobility on the state highway system. Due to the geographic extent of this system vision, implementation will occur over many years and as stand-alone projects or as part of other highway projects. In all cases, the

deployment of the Active Traffic Management strategies will need to be done considering logical operating segments.

The first deployment of a variable speed limit/lane control/queue warning system will be the northbound I-5 section from approximately S. Boeing Access to the I-90 interchange (operational in 2010). As shown in Figure 26, this section of northbound I-5 has a high incidence of rear-end collisions, congestion occurrences and delay, making it an ideal location to implement a variable speed limit/lane control/queue warning system. In addition the Urban Partnership Agreement provides the opportunity to implement variable speed limit/lane control/queue warning on SR 520 and I-90 between I-5 and approximately I-405 (both installations extend slightly further east than I-405).

Deployment for the rest of the system based on the system conceptualization completed to date (core Puget Sound area freeways) and logical operational segments is recommended below. It should be noted, however, that a system conceptualization needs to be undertaken for the rest of the region and this process may result in segment deployment priorities that are higher than those listed.

- northbound I-5 from I-90 to SR 520/Ship Canal and southbound I-5 from SR 520/Ship Canal to S Boeing Access Road.
- southbound I-5 from Swamp Creek to SR 520/Ship Canal
- northbound I-5 from SR 520/Ship Canal to Swamp Creek
- northbound I-405/SR 518 from North Airport Expressway to I-90
- southbound I-405/SR 518 from I-90 to North Airport Expressway
- southbound I-405 from Swamp Creek to I-90
- northbound I-405 from I-90 to Swamp Creek
- eastbound and westbound I-90 from Eastgate/I-405 to Sunset Interchange
- eastbound and westbound SR 520 from I-405 to Redmond

In addition to the above noted segments, a fourth segment in the I-5 study area (northbound and southbound I-5 from Tukwila to Boeing Access Road) was assessed as well, but will likely be deployed as part of a longer segment to the south.

While full implementation of ATM is expected to occur over a relatively long time-period, incremental steps can be taken to begin addressing the work that needs to be accomplished. For example, near-term repaving projects can augment existing detection systems for future variable speed limit/queue warning system needs. As noted above a multi-year implementation scenario is most logical for this type of program given the uncertainty of dedicated funding sources.

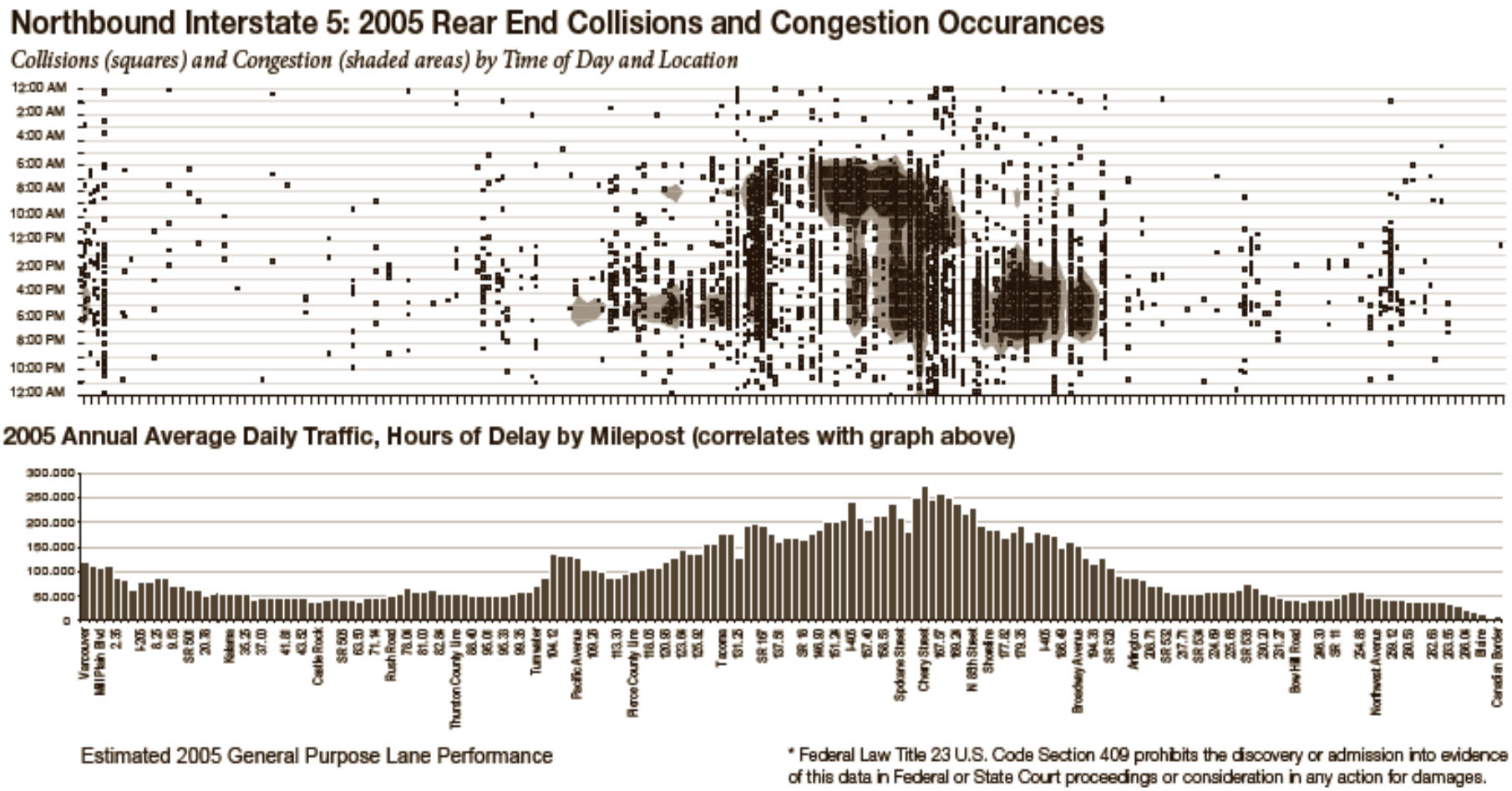


Figure 26. Rear-end Collisions, Congestion and Hours of Delay (Northbound I-5)

Table 29 shows a list of near-term and long-term construction projects on each freeway facility and adjacent facilities that could be leveraged to install various elements of the ATM system. Projects in each of the four primary corridors, and SR 167, are divided into those slated for the facility itself or adjacent to it.

Table 29. Core Puget Sound Area Construction Activities

Major Corridor	Facility	Near-Term Construction Activities (prior to 2011)	Long-Term Construction Potential (after 2011)
I-5: Corson Avenue S to 128th Street SW	On	None	- I-5 Pavement Reconstruction
	Adjacent	- Alaskan Way Viaduct & Seawall Replacement Project - I-405 Corridor Program projects (12 under construction)	- Alaskan Way Viaduct & Seawall Replacement Project - Sound Transit North LINK
I-405: Tukwila to Lynnwood	On	- I-405 Corridor Program projects (12 under construction)	- I-405 Renton to Bellevue (Sections 1-3)
	Adjacent	None	- I-5 Pavement Reconstruction
SR 167: Auburn (15th Street NW) to I-405	On	- HOT Lanes Project	- SR 167 RTID Package - SR 167 Priority 2 - SR 167 Priority 3 - SR 167 Priority 5
	Adjacent	None	None
I-90: I-5 to Issaquah (Sunset Interchange)	On	- Two-way Transit & HOV Operations, Stages 1 & 2	- Two-way Transit & HOV Operations, Stage 3
	Adjacent	None	- SR 520 HOV & Bridge Replacement Project - Sound Transit East LINK
SR 520: I-5 to Redmond (full length)	On	- W. Lake Sammamish to SR 202	- SR 520 HOV & Bridge Replacement Project
	Adjacent	- Two-way Transit & HOV Operations, Stages 1 & 2 - Sound Transit University LINK	- Sound Transit University LINK - Two-way Transit & HOV Operations, Stage 3

Implementation of a variable speed limit/queue warning system can be advanced by coordinating with the design and implementation teams of the projects noted in the previous table. In addition, outreach to elected and appointed officials providing information on the benefits of ATM implementation may aid in obtaining funding, as will the exploration of local and federal funding opportunities for capital project costs, as well as on-going system operations and maintenance costs. Lastly, coordination with local partners, especially law enforcement, could yield collaborative implementation opportunities.

6.4 Life Cycle

As technology advances, there will be a need to replace various components like the field devices or the central software. The lifecycle varies with technology obsolescence more so than actual wear and tear on the component (except perhaps the sign structures). Once in place, all of the components will be a part of WSDOT's preservation program and will be programmed into the budget according to the preservation model for its specific system type. Examples of the various types of system components include central servers, field signs, field controllers, detectors, communication media, and sign structures.

7.0 Support Environment

This information is provided to allow all affected organizations to prepare for the changes that will be brought about by the ATM system and to allow for planning of the impacts on WSDOT, user groups, and the support maintenance organizations during the development of, and transition to the new system.

The support environment for the ATM System will be one that compliments the existing support environment processes and capabilities of the client. Hardware and central software components will be replaced as determined by the support staff. Development and deployment of new components for the ATM System will be coordinated with the assigned support staff. Support of the system is anticipated to require additional TMC operations and maintenance support and must be considered for the full life of the ATM Project.

7.1 Impacts during Development

This subsection describes the anticipated impacts on the operations and maintenance staff during the retrofit process for the proposed system. Other impacts during development may be discovered during the remaining phases of the system lifecycle. The currently identified impacts during the retrofit process include the following:

- Involvement in studies, meetings, and discussions – In order to ensure the success of the project, there will be a need for client involvement in all aspects of the system lifecycle. This will necessarily require involvement in studies, meetings, and discussions that will occur throughout the development of the system.
- User and support involvement – There will also be a need for increased involvement by the user and support groups. This involvement will include participation in reviews and demonstrations, evaluation of initial operating capabilities and evolving versions of the system, development or modification of databases, and required training.

8.0 Operational Scenarios

This subsection describes the operational scenarios for potential ATM systems on a basic freeway segment as well as freeway segments that include high occupancy toll (HOT) or high occupancy vehicle (HOV) managed lanes.

The ATM techniques that are discussed are the variable speed limit/lane control/queue warning system, hard shoulder running, junction control and travel time signs. The proposed scenarios are:

- Normal Operation
- Incident Situation
- Work Zone / Maintenance of Traffic
- Queue Spillback
- Travel Time Signs

In each of these scenarios, the operation of the applicable ATM elements will be presented and the following freeway configurations are discussed.

- Basic Freeway Segment, tolled or untolled
- Managed Lane, within a tolled freeway or untolled freeway

However, it should be noted that the ATM operation for a Tolled Freeway with no Managed Lane is the same as Basic Freeway Segment. Similarly, the ATM operation for a Tolled

Freeway with Managed Lanes is the same as a non-tolled freeway with Managed Lanes. Therefore, the discussion of these scenarios is not discussed in detail, but rather references the appropriate Basic or Managed lane scenario.

8.1 Normal Operation

8.1.1 Basic Freeway Segment (with or without tolls)

A basic freeway section would include general purpose freeway lanes only (i.e., no HOV, HOT or other managed lanes included as part of the roadway). The operational scenario looks at how the existing traffic systems work with each of the above mentioned ATM techniques.

8.1.1.1 ATM Techniques

8.1.1.1.1 Variable Speed Limit/Lane Control/Queue Warning System

The variable speed limit/lane control/queue warning system is intended to assist driver reaction to unanticipated speed reductions, particularly those in excess of 10 mph. The system gradually slows traffic down as it approaches congestion, rather than have drivers suddenly come upon congested, slow-moving traffic. Figure 27 shows the conceptual layout of the gantry-mounted overhead lane control displays that should be spaced approximately every one-half mile.

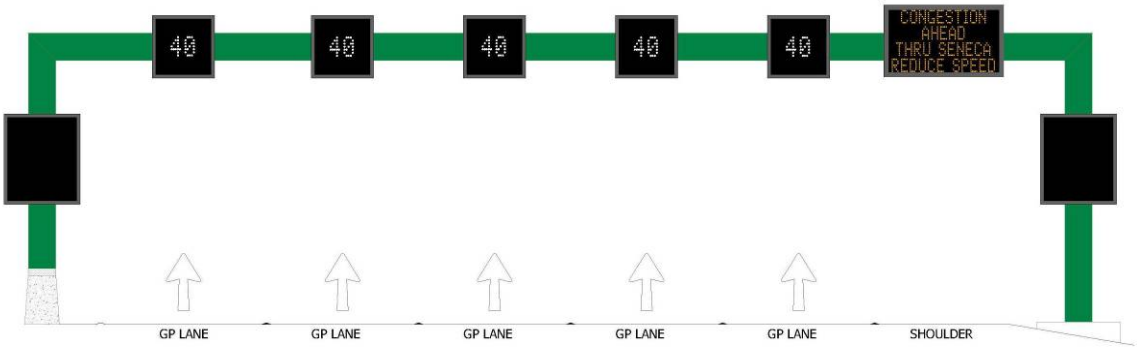


Figure 27. Gantry with VSL signs, side-mount signs and overhead VMS

Under free-flow or near free-flow conditions, all overhead lane control displays would be blank, not showing any speeds. When speeds that fall below a specified threshold are detected (for example 30 mph), the system would automatically activate to gradually reduce the speed of traffic approaching the congestion point to match that of the slowed traffic. For example, the signs nearest the back of the slow moving traffic might display 30 MPH, as would the signs immediately upstream of that gantry. The third gantry upstream might display a speed of 45 MPH. Similar sign activation could occur via operator control if necessary. However, operator override of the system is not considered to be effective for typical operations. Specific ATM system variables will be programmable, and the initial system activation threshold and algorithm will be determined during the system design process.

The overhead speed displays within the congested portion of the freeway and downstream of the congestion would be turned off. It is desirable to have the signs blank/off once the driver enters the queue to reinforce that speed transition should occur in advance of the needed driver reaction. As the back of the queue/congestion moves up and down the freeway, the overhead lane control displays would activate as necessary to maintain the operation described above.

When speeds can return to free flow, the system will display an increased speed limit on the shoulder mount signs downstream of the slowdown. The display of the posted speed limit at these locations is necessary in order to increase the legal speed limit back to the typical facility speed. The increased speed limit would be displayed on the side-mounted signs (typically on the gantry columns) while the overhead signs would be blanked. Displaying the increased speeds on the side-mounted sign would differentiate reduced speeds (because of congestion, incidents, or work zones which would only be displayed overhead) from the recovery speed limits.

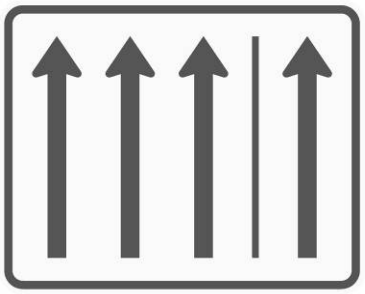
In the situation where the downstream speeds recover, but not to free flow conditions and then break-down again approaching additional congestion, the side mount signs would display an increased speed, but not 60 MPH. As drivers approach another slowdown, the system would respond in the same manner as for the initial slowdown.

Typically, the signs for all general purpose lanes at a given location will display the same speeds. It will be possible to display different speeds above all the lanes, but the typical practice will be to have consistent speeds displayed for all general purpose traffic. The speeds over the HOV or HOT lane will reflect the conditions downstream in the HOV or HOT lane and will not be artificially constrained by conditions in the general purpose lanes, as it is important to maintain the travel time advantage in HOV/HOT lanes (see Section **Error! Reference source not found.**).

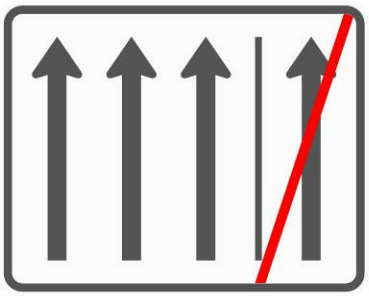
The system will be flexible in order to present speeds as either advisory or regulatory. However, it is intended that the system will be regulatory. Regulatory speed limits will be particularly important in work zones, in order to support WSDOT's work zone safety programs. The side-mount signs (shown in Figure 28 on the gantry columns) will be used to post the regulatory speed limit or a message to indicate that the overhead speed displays are the legal speed limit. The side-mount signs and overhead speed displays would replace existing static speed limit signs. Appendix C contains a series of possible signing scenarios for regulatory variable speed limit/lane control/queue warning system operations.

8.1.1.1.2 Hard Shoulder Running

Hard shoulder running would only be implemented in conjunction with the variable speed limit/lane control/queue warning system and use the same general layout as mentioned above. A sign will be displayed on the right column to indicate appropriate use of the shoulder. When the shoulder is open to traffic, the sign will signify it is open by an arrow, similar to the sign display shown at right.



When the shoulder is closed to traffic, the sign will signify it is closed by an arrow with a red diagonal line through it, similar to the sign display shown at right.



When the shoulder is open to traffic, the gantry will look something similar to Figure 28.

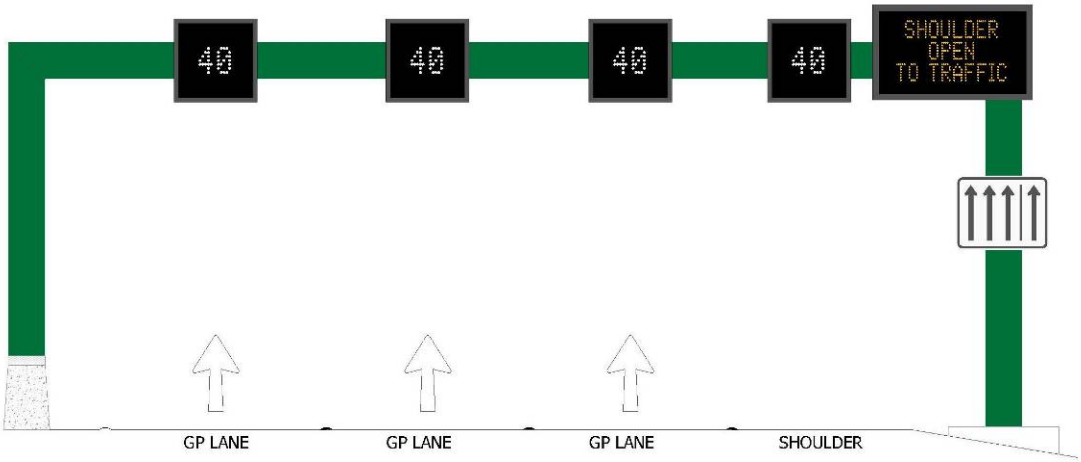


Figure 28. Gantry Showing Hard Shoulder Open

When the shoulder is closed to traffic, the gantry will look something similar to the graphic in Figure 29.

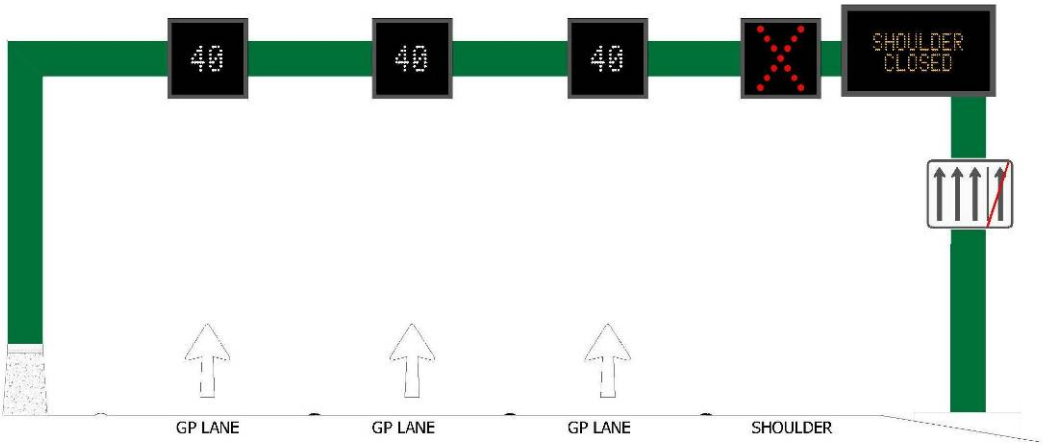


Figure 29. Gantry Showing Hard Shoulder Closed

At the upstream end of the hard shoulder section, signing will need to be installed to make it clear to drivers whether the shoulder is open or closed to traffic. The diagram in Figure 7 in Section 3.3 illustrates one possible signing concept.

Operation of the hard shoulder requires some safety measures prior to opening it to traffic. Incident response teams will be required to “sweep” the entire hard shoulder section to ensure that it is clear of any stalled vehicles, large debris or other obstacles. Closed circuit television should be used to ensure that the shoulder has remained clear after the sweep and prior to opening. Service patrols should also be available during the operation to quickly clear disabled vehicles or other incidents.

Striping of the hard shoulder must also be considered. If there is no shoulder on the right side, it is more difficult for the driver to determine how much space or clearance the vehicle has to the edge of pavement. As a result, there is an increased potential for drivers to run off the pavement

if it is not clearly marked. An acceptable shoulder treatment will need to be determined as part of the design process for individual implementation projects.

Continuous lighting may be required throughout the length of the hard shoulder if there is no outside striping, to make it easier for drivers to see the edge of pavement. Rumble strips may also be an appropriate measure to warn drivers if they stray near the edge of pavement. In addition, when shoulders are being used for hard shoulder running, disabled vehicles no longer have a place to pull over. Refuge areas should be incorporated to the right of the hard shoulder at appropriate intervals when reasonable and feasible.

Ending hard shoulder running at an exit ramp requires the consideration of a number of design elements. At exit ramps, if there is no hard shoulder running, there is a standard gore and taper in the diverge area. However, with hard shoulder running, traffic will be on the shoulder and geometrics of the ramp will need to be considered. If the geometrics of the ramp can handle a double lane exit and traffic patterns require one, then the shoulder lane will be an exit only lane and the adjacent lane is a an option lane. In-pavement lighted lane delineators may be required to illustrate this channelization. The hard shoulder lane would terminate at the ramp and could be introduced again at the on-ramp downstream.

If a double lane exit is not needed and for exit ramps within the hard shoulder running area, exit channelization must be designed for safe operation when the shoulder is open or closed to traffic. Standard exit striping would work when the shoulder is closed. However, when it the shoulder is open, standard exit striping would be confusing, making it look like drivers in the lane adjacent to the hard shoulder could exit, creating conflicts with the exiting traffic on the shoulder. In this case, lighted lane delineators should be used to indicate exit channelization when the shoulder is open and closed to traffic. Exit signing that could support this exit layout is shown in Figure 6 in Section 3.3. The top diagram of Figure 6 illustrates the state of the exit sign when hard shoulder is open and the bottom illustrates the state of the sign when closed. The exact layout of the exit channelization will need to be defined during the design process for each hard shoulder running project.

The use of lighted lane delineators to dynamically change the exit ramp configuration, either from a single lane exit when the shoulder is closed to a two lane exit when the shoulder is open, or from an exit from the lane next to the right shoulder to an exit from the hard shoulder, is an application of junction control. Ramp exit lanes and ramp diverges are dynamically assigned depending on the state of the hard shoulder operation.

To accommodate hard shoulder running, some construction may be needed at the interchanges, both on the ramps and the mainline within the interchange. Shoulder pavement would need to be full-depth throughout the hard shoulder section. Drainage and potential water quality issues may also need to be addressed.

Speed limits may need to be reduced when the hard shoulder is in operation. Typically, hard shoulder running is in operation under congested conditions and travel speeds are already reduced, however, sight distance may be a concern if there are structures or other visual obstructions next to the shoulder. The variable speed limit/lane control/queue warning system will be used to display appropriate speeds whenever the hard shoulder is open to traffic. The typical operating speed would be 60 MPH (or typical posted speed limit for the roadway) if there is no congestion downstream, unless the design speed for that lane should be lower or road conditions are such that the speeds need to be lowered for safe operation.

8.1.1.1.3 Travel Time Signs

The operational concept for travel time signs is straightforward. Signs dedicated to displaying travel times will be installed upstream of major decision points. The distance upstream of the decision point will be sufficient for drivers to see, comprehend, and decide what route they want

to take to their destination. The times will be automatically calculated based on data from the freeway management system. A possible sign design is shown in Figure 8 in Section 3.4.

The critical issue for the travel time signs will be how many destinations and routes can be displayed on the same sign. For example, Westbound I-90 approaching I-405 could have the following destinations and routes signed with travel times:

- SeaTac or Tukwila via I-405
- SeaTac or Tukwila via I-90 and I-5
- Seattle via I-90
- Seattle via I-405 and SR 520
- Everett or Lynnwood via I-405 / I-5
- Everett or Lynnwood via I-90 and I-5
- Everett or Lynnwood via I-405, SR 520, and I-5

Not all of these destinations and routes can be signed while keeping the signs and messages comprehensible to drivers. No more than one destination should be displayed per sign and no more than three routes per destination should be signed. Up to two travel time signs can be located in advance of any given interchange.

8.1.1.2 Enforcement

For the variable speed limit/lane control/queue warning system, providing accurate and detailed information via the signs on the gantries will help to ensure driver compliance over the long-term. The overhead variable message signs (VMS) would be used to post such messages as “Right Lane Blocked Ahead 1 Mile”. For consistency, these messages would be displayed on relevant gantries to alert drivers what is happening downstream. The posted speeds will reflect the downstream conditions so drivers will see the relevance of the signs and have confidence in the system. In this way, drivers will be more likely to understand the need for reduced speeds and comply.

The side-mount DMS also be capable of displaying symbols or icons to display information about conditions on the roadway ahead. The system would be capable of providing a text message on one gantry followed by an iconic message on the next one. The text vs. icon message could be alternated on every other gantry to more clearly explain the traffic condition. The design of the system will enhance compliance. The European experience indicates that if the system is reliable and drivers understand why they are asked to slow down (e.g., collision downstream or stop and go traffic downstream), they will comply. With an accurate and credible system, excessive monitoring or enforcement should not be required. If there is a need for heavy enforcement, then modifications to operation of the system should be considered.

The system will be able to send notification of speed limit changes to the Washington State Patrol. The communication will likely be to the WSP dispatch center where the information can be sent out to the WSP officers via means that are best suited to WSP needs (map displays on mobile terminals, pages, and email alerts are all possibilities). Discussions, agreements, and standard operating procedures are needed to ensure an orderly and safe operation of the variable speed limit/lane control/queue warning system. Issues such as where the speeds are to be enforced (e.g. after the final lowest speed has been posted) or the feasibility of automated enforcement should be addressed.

Enforcement of hard shoulder running is most important when the shoulder is closed. CCTV can be used to monitor the shoulder when closed to traffic on a spot check basis. Problem locations and times should be reported to WSP. Routine enforcement patrols would be the primary way to enforce the closed condition of the hard shoulder. Close coordination with WSP will be

important to make sure enforcement needs are addressed in the design phase of a hard shoulder. Coordination with WSP will also be needed during the operation of hard shoulder running to so problems areas can be identified and addressed.

8.1.1.3 Operations

WSDOT would like an automated variable speed limit system that utilizes tunable parameters to make adjustments as needed (e.g., to modify the size of the zones for the speed limit thresholds or implement different types of sequencing when needed). The key to the design is flexibility, modular software, and an incremental implementation approach. In this way, lessons learned by operating the system can be reflected in updates and modifications to the system.

The variable speed limit system will be consistent with the existing control system. When a slowdown persists for a specified duration, the system will automatically display recommended speeds without any response from the operators. However, since operators will be monitoring the system, they will have the ability to override the system at any time. Likewise, the system should automatically turn displays off when the speeds have returned to conditions above another specified threshold. In addition, there would also be a decision support system to help operators make key decisions when necessary.

It will be important to have the ability to provide speed displays and possibly lane control in the tunnels and lidded sections of Puget Sound area freeways. The displays will need to be smaller to fit within the restricted height of the tunnels and lids. Display of speed is the top priority. Traffic signals could be used in lieu of lane control signals to close lanes in the tunnel, if necessary. Because of the smaller displays, it is likely that the distance from one set of displays to the next will need to be shorter than on an open freeway.

8.1.1.4 Staffing

The variable speed limit system should be able to display reduced speeds at any time of day or night. As a result, staffing is needed 24 hours per day, 7 days a week for operators to monitor the system. In addition, the added duty of monitoring the variable speed limit system will likely require additional operators during hours when the TMC is usually staffed with traffic system operators.

At the present time, both regional TMCs (Shoreline and Parkland) have no space for additional operators during peak periods. There is no more space for additional workstations. Space requirements need to be analyzed and the expansion of the existing TMCs or construction of a new TMC should be considered.

8.1.1.5 Maintenance

Variable speed limit and the other ATM techniques will add field devices that will need to be maintained. In addition, there will be a higher level of urgency to maintain these devices because they are geared toward improving safety. Additional maintenance staffing will be needed to assure that the new devices, as well as existing ones, are adequately maintained.

Due to the added number of devices and the importance of maximizing efficiency in maintenance operations, the use of a Maintenance Management System (MMS) would be advantageous for maintenance staff and for maintenance staffing. The MMS would be used to track repairs using IP addressable devices so they will know which devices are down and the repair history for each device. If the system is self-aware, then it could automatically send out maintenance alerts. In addition, the MMS can assure the highest priority tasks are completed first, allowing the best use of maintenance staffing levels.

Maintenance work on the signs themselves will not occur over the freeway lanes, but rather off-site. Therefore, the signs should be designed to be easily installed, removed and replaced with a minimum of time. A special maintenance lifting device is used as part of England's M42

system, and may be required to expedite any movement of the signs. In addition, the signs will need to be highly reliable and require no to minimal maintenance to minimize replacement activities. In addition, back-up power options (UPS or redundant power) will need to be finalized during project design.

Freeway lanes often are realigned for construction activities. It is during construction that ATM techniques, especially variable speed limit, are most needed. It is important to plan for a system that will allow lanes shifts to occur with a minimum of disruption and expense to keep the system operational. In Denmark, the gantries are designed to allow movement of the gantry and repositioning of the signs along the gantry when needed because of construction or other lane realignments. It will be important to design in a method to move the signs on the gantry once the system is in place to take into account future or temporary lane alignment changes.

The software needs to be well documented so that it is maintainable. WSDOT would like the flexibility to add extra devices at any time, so the software/system needs to be able to do this incrementally. WSDOT will be developing the software in-house so that it is integrated with its existing TMS control software.

8.1.2 Managed Lane Segment (with or without tolls)

ATM strategies will operate much the same on freeway sections with managed lanes as they do with no managed lane (scenario 1 above). This section will describe the unique aspects of operating ATM systems in freeway sections with managed lanes.

8.1.2.1 ATM Techniques

8.1.2.1.1 Variable Speed Limit/Lane Control/Queue Warning System

A typical layout for a variable speed limit gantry in a freeway section with managed lanes is shown in Figure 30. The only difference between a typical variable speed limit gantry on a facility with a managed lane is how the side mount sign is used. The sign on the left column will display the restrictions on the managed lane (for example, the carpool definition for an HOV lane or pricing information for a HOT lane). Any type of managed lane could be treated in a similar way with the overhead lane control DMS providing speed information and displaying some information about the nature of the managed lane, with more detailed information displayed on the gantry column sign that is adjacent to the managed lane.

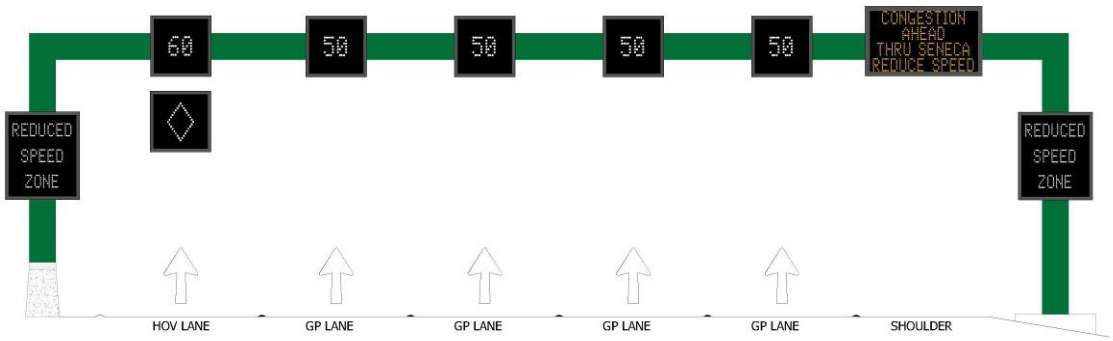


Figure 30. Managed Lanes Variable Speed Limit Gantry

The overhead signing would operate much the same as in the basic freeway scenario. The exception is that the DMS over the managed lane could display icons, numbers, or letters that could help reinforce the use of the lane. For example, the sign over the HOV lane could display

a diamond when speeds are not reduced. If speeds are reduced, the display over the HOV lane could alternate between the appropriate speed and the diamond.

With signs over each travel lane, there is the capability to post different speeds by travel lane. While each of the GP lanes should display the same speed, the HOV lane may have a different speed posted. The sign over the managed lane should display the appropriate speed for traffic in the managed lane. Appendix B includes a signing scenario for managed lanes.

The algorithm used to determine the GP displayed speeds should only consider conditions in the GP lanes. However, for the managed lane, the algorithm should be flexible to account for speeds in the GP lanes as well as in the managed lane or for the managed lane only. The weighting of GP lane conditions and managed lane conditions should be a variable and controlled by the TMC operators.

The operation of the variable speed limit system will need to be coordinated with the operation of any tolling system active on the same freeway section. Depending on the pricing algorithm, changing speeds in the managed lane may affect the tolls that are charged. Consideration of the tolling concept should be included in the operation of the ATM elements.

When the managed lane is tolled, the operation of the variable speed limit system would not compromise the objective of the tolled facility and the pricing algorithm would need to take into account the operation of the ATM elements. The speeds would not be posted lower than the prevailing speed in the congested area. So, if downstream speeds were already 30 MPH or lower, displaying speeds of 30 MPH on the two gantries immediately upstream of the slowdown would not compromise the objective of the tolled facility. It is important to note that only three or four gantries would normally display speeds at all. On the other hand, if congested conditions occurred downstream (e.g. stop and go traffic), but the system displayed no lower than 45 MPH, the correct information would not be displayed to drivers and WSDOT may take on liability in this situation.

With a tolled facility, it is imperative to provide traffic condition information at the ‘purchase’ decision point – whether there are single or multiple points of tolling. Since gantries are located approximately every ½ mile, opportunities to provide motorists with tolling information and affect their decision process are relatively plentiful. It might be considered less critical if there are multiple points of tolling because there would be several locations to buy-in or opt out.

8.1.2.1.2 Hard Shoulder Running

The operation of hard shoulder running on a roadway facility with a managed lane would not differ from those discussed for a basic freeway segment.

8.1.2.1.3 Travel Time Signs

Active traffic management utilizes travel time signs to provide motorists with information to make commuting decisions. For example, if both SR 520 and I-90 were tolled facilities, then providing motorists with the various toll prices would be useful. However, it is important not overwhelm the driver by providing too much information on a single sign that they can’t process the information. Combining both travel time and tolling information on a single sign is a decision that should be finalized during project design.

8.1.2.2 Enforcement

Enforcement of ATM elements on a roadway with managed lanes does not differ from that required for a basic or normal freeway segment.

8.1.2.3 Operations

A tolled facility with managed lanes provides for differential tolling within a tolled facility. Having a “value added” HOV or HOT lane does not require operation of ATM elements any differently from a normal freeway segment with managed lanes.

Tunnel operations of ATM elements on a roadway with managed lanes does not differ from that required for a basic or normal freeway segment.

8.1.2.4 Staffing

Staffing for the implementation and operation of ATM elements on a roadway with managed lanes does not differ from that required for a basic or normal freeway segment.

8.1.2.5 Maintenance

Maintenance of ATM elements on a facility with managed lanes does not differ from that required under the basic freeway segment conditions.

8.2 Incident Situation

8.2.1 Basic Freeway Segment

The variable speed limit/lane control/queue warning system would operate very similarly in incident conditions as in normal congested conditions. For incident conditions, speeds on the overhead displays would activate in advance of the slowed traffic queuing behind the incident, just as for recurring congestion. However, the displays would remain on within the queue/congested conditions and would move upstream from the incident location as congestion moved upstream. The displays would remain on throughout the congested portion of roadway to assure slower speeds protective of the incident scene and responders. Downstream of the incident, the overhead displays would be off and the side-mount signs would indicate the normal speed limit. In cases where both the variable speed limits and lane control displays are needed, the signs would be two-phase and alternate at a set interval determined by Operations.

During incident situations, the system could also help speed incident clearance by getting emergency response agencies to the scene when the traffic is completely blocked. For example, operators can put any customizable scenario into place that would execute a closure scenario “x” feet upstream from the incident as well as open a lane for emergency access. Decision support should be included in the system to help operators make the decisions needed when operating under incident or unusual conditions.

In the Netherlands, when an incident occurs, they use a cocked arrow, followed by a red “X” to move drivers out of the lane. In the UK, for emergency access, they close the lane with a red “X” and the red “X” moves back with the queue until all of the emergency vehicles have arrived at the incident scene. In many cases, the hard shoulder (8’ to 10’) could be opened for emergency vehicles to gain access to the incident scene. It is critical that at the point where life safety accesses the freeway that the traffic is cleared from that point to the incident scene. It is important to note that the lane wouldn’t be cleared to the back of the queue because queues can extend for several miles.

The system would react to an incident through the following steps:

- TMC operators are alerted to incidents through the WSP CAD system, the existing freeway management system, or by incident response people in the field.
- The appropriate incident management units and emergency response personnel respond to the situation.

- The variable speed limit system may automatically turn on because it detects the resulting slowdown or TMC operators will activate the system.
- Message signs will warn drivers of the reduced speed ahead. The TMC operator will add messages on the overhead VMS about why there is a slowdown.
- TMC operators will activate the lane control system if it is appropriate to clear a lane in advance of the incident to protect the incident scene and responders.
- TMC operators could use the lane control system to set up a clear lane that emergency service personnel can use to reach the incident scene. The system would allow operators to close the lane upstream of the incident at the point that congestion is present. As the slowdown moves upstream, the lane closure would also move upstream. The series of graphics in Figure 31 show how the lane closure moves upstream on the M42 motorway in England for a hypothetical two-lane collision on the right side of the diagram.

With the advanced warning given to motorists about incidents, there is a potential for drivers to divert to the arterial system. During these conditions, coordination with the local agencies' arterial signal operations should occur to help deal with traffic diversion. See Section 8.4 for a brief discussion of some possible techniques to address this. In addition, Appendix B contains a possible signing scenario for an incident or work zone situation.

8.2.2 Managed Lane Segment

For a right-side lane blocking incident that is not in the managed lane, the WSP (in consultation with the WSDOT personnel) would decide whether to open up the managed lane for GP traffic. Another management strategy for incident conditions could be to raise the price in the tolled managed lane in order to reduce traffic in that lane and allow emergency responders to utilize the managed lane to get to the incident more quickly. The signs that are part of the variable speed limit system could be used to provide supplemental information on the status of the managed lane in an incident situation. If necessary, the incident response team could supplement this information with portable VMS at appropriate locations.

If the incident is on the left side of the freeway, the managed lane could be closed to allow more rapid response by emergency responders using the lane control system, similar to the description in Section 8.2.

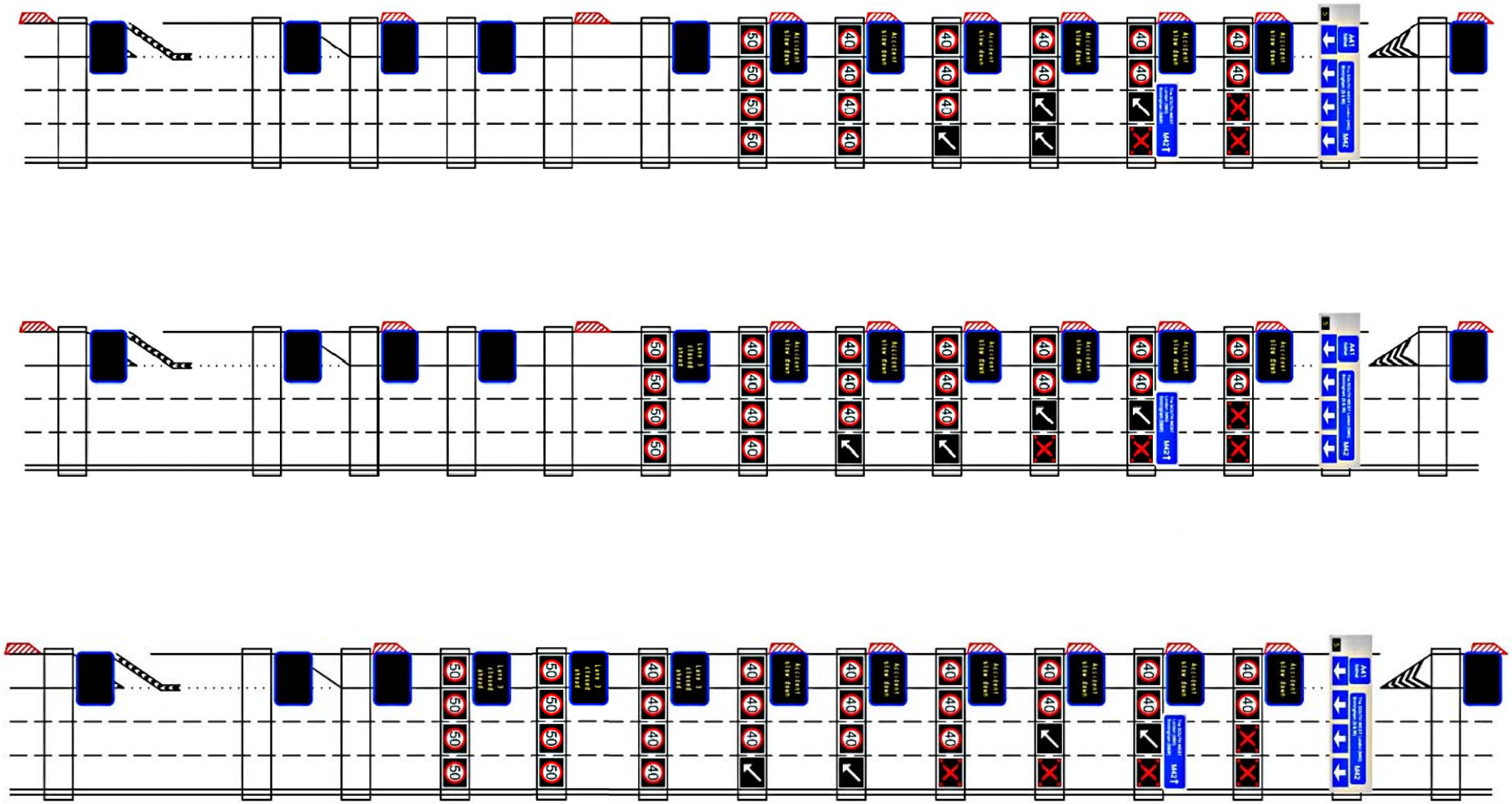


Figure 31. M42 Lane Closure Signing

8.3 Work Zone/Maintenance of Traffic

8.3.1 Basic Freeway Segment

In work zones, ATM elements would be operated similarly to the incident situation. The exception is that the lane control signs would be used to augment work zone traffic control and there would be no need to have a lane closure move upstream with the back of congestion. The lane control system will be flexible, simple to use, and able adapt to many situations.

Through a work zone, the overhead displays would display the speed limit in the work zone, if a reduced speed was needed. In advance of the work zone, the system would operate as in the incident situation: the speeds on the overhead displays would remain on within the queue and throughout the work zone. As with the incident scenario, this would be done to safeguard personnel in the work zone. The system would activate upstream as congestion moves upstream in order to protect vehicles in the back of the queue. Once past the work zone, the overhead displays would be off and the side-mount signs would indicate the normal speed limit.

8.3.2 Managed Lane Segment

The implementation and operations for work zone or maintenance of traffic on a freeway facility with managed lanes would be no different that those discussed for a basic freeway segment.

8.4 Queue Spillback

8.4.1 Basic Freeway Segment

There are occasions when traffic exiting the freeway spills back on to the freeway. In this situation, variable speed limits may be used to slow traffic down in advance of the off-ramp. In addition, the side-mount DMS on the right side of the gantry could be used to warn motorists of the queue and recommend that drivers merge left (or right in the case of a left hand exit) for through movements. When queue spillback is detected, arterial signal timing could be adjusted to alleviate the problem. Traffic-responsive signal control algorithms could be used to automatically adjust signal timing.

Staff responsible for freeway operations and those responsible for surface street operations will need to work together on a plan to integrate the freeway ATM system with the arterial management system. As mentioned above, signal timing for the arterials may be adjusted to help alleviate queue spillback or other freeway conditions. The increased ability to communicate with drivers afforded by the ATM system could also be used to improve arterial conditions. For example, if the arterial system is congested in the vicinity of one interchange, the overhead VMS on the variable speed limit/lane control gantries could be used to suggest an alternate exit. Likewise, for special events, TMC operations staff could work with the appropriate city or county to develop ATM plans to support the special event traffic control plans.

8.4.2 Managed Lanes Segment

The implementation and operations for queue spillback on a freeway facility with managed lanes would be no different that those discussed for a basic freeway segment.

8.5 Traveler Information

8.5.1 Basic and Managed Lanes Freeway Segments

Providing accurate traveler information has become increasingly important to the public. However, users can get lost with all of the information that is provided via the web and on the phone. The focus should be on the information that travelers need to know and give them specific menu choices to narrow down what they're looking for.

For these ATM techniques, WSDOT could provide a link on the web to all of the gantry information or an interface with the 511 phone system. E-mail alerts could also be disseminated for users when traffic conditions specifically affect their daily commutes.

WSDOT has direct ties to King County Metro, but not to the other transit agencies. By establishing relationships with other transit agencies, they could increase the amount of transit information they are able to disseminate as well.

8.6 Summary of Benefits

The European experience with active traffic management systems has shown a reduction in collisions to fall anywhere between 15 and 40 percent of total collisions. After consideration of the European experience, reduction rates of 16 percent for property damage collisions and 30 percent for injury collisions were assumed to apply for the proposed variable speed limit/lane control/queue warning system on I-5. The estimated collision avoidance percentage rates were then applied to the total number of collisions within the installation segment to determine the number of primary collisions estimated to be avoided as a result of the implemented system. For the purposes of this study, the collision reduction rates were applied to the selected I-5 corridor only (Tukwila to Swamp Creek).

The value of avoiding collisions was calculated in monetary terms by multiplying the number of collisions avoided (and the type) with the National Safety Council value for collision avoidance. The National Safety Council estimates that avoiding one property-damage-only collision saves $8,200 and avoiding one injury collision saves $119,650. The expected collision avoidance values for implementation of Phases 0 through 4 in the selected I-5 corridor are shown in Table 30, below.

Table 30. Collision Avoidance Values

I-5 Installation Segment	Estimated Per Year Collision Avoidance Values per Segment
Phase 0	$ 6.8 million
Phase 1	$12.3 million
Phase 2	$10.8 million
Phase 3	$ 6.6 million
Phase 4	$ 2.0 million

Secondly, the I-5 Pavement Reconstruction Project's VISSIM model was used to estimate the expected reduction in traffic delay as a result of collision avoidance due to the installation of a variable speed limit/lane control/queue warning system. The VISSIM model includes the I-5 corridor from the King County line (NE 205th Street) in the north to approximately Interurban Avenue in the south. The basic model parameters were not changed for the purpose of this study, but the model was coded and run to quantify the

accident reduction benefits realized in Europe as a result of speed harmonization systems.

To quantify the accident reduction benefits, a blocking incident was coded into the VISSIM model to determine the amount of delay reduced by the avoidance of both property damage only and injury collisions. Based on an anecdotal review of WSDOT incident data, a property-damage only collision was coded to result in a 15-minute blockage of a single lane and injury collisions were estimated to block a single lane for an average of 60 minutes. The lane adjacent to the collision was coded with a free-flow speed of 40 mph to reflect the lower vehicle speeds of drivers as they approach and pass an incident. Free-flow speeds on subsequent lanes were not modified.

The model was run without an incident to obtain baseline vehicle delay results and then run with an incident to obtain vehicle delay results when an incident is present (for either a 15 or 60 minute blockage). Model runs for all possible accident scenarios for all installation segments could not be completed within the timeframe, so in certain instances the results for a particular installation segment were determined to adequately represent expected results for a different installation segment.

Delay cost savings were developed using 2007 Washington State Employment Security Department annual employment and wage averages for King, Pierce, and Snohomish Counties to calculate value of time estimates. Value of time estimates are approximately half of the hourly average wage rate. The delay reduction estimates obtained from the VISSIM model were then multiplied by the calculated value of time estimates (estimated at $12.98 per hour). Collision avoidance delay reduction estimates are shown below in Table 31.

Table 31. Collision Avoidance Delay Reduction Estimates

I-5 Installation Segment	Estimated Collision Avoidance Values per Year
Phase 0	$550,000
Phase 1	$480,000
Phase 2	$880,000
Phase 3	$370,000
Phase 4	$180,000

Based on the expected benefits and conceptual cost estimates, expected cost recovery values were calculated. The estimated yearly benefit was compared to the estimated installation cost per Phase. Phase 0 and Phase 1 resulted in expected cost recovery values of 5 and 4.5 years, respectively. Phase 2 had an expected cost recovery of 5.5 years, while Phase 3 results in a cost recovery of nearly 8 years. Phase 4 cost recovery values were considerably higher at nearly 14 years. Again, the installation of I-5 Phase 4 is expected to include a segment that includes and extends south of the I-405 and SR 518 interchange, which will change the expected cost recovery.

8.7 Opportunities and Constraints

Table 32 is a summary of the opportunities and constraints associated with the proposed ATM system.

Table 32. Opportunities and Constraints

Opportunities	Constraints
• Improves safety while addressing congestion • Potentially adds center-to-center communications between WSDOT Region TMCs, transit agencies, enforcement and local jurisdictions • Integrates well with the existing ITS infrastructure • Maximizes efficiency of corridors that may receive major capital investments • Enhance TMC FLOW operations to 24 hours a day, 7 days a week • Enhances density of traveler information for motoring public • Provides ability to reduce mainline speeds • Provides flexible lane use and control as well as incident warnings • Accommodates increased peak period capacity during congested or incident conditions • Enhances real-time travel time information at major decision points • Provides enhanced traffic control for construction, maintenance, or incident management activities.	• Increased maintenance costs for additional devices and personnel • Increased operations costs to run TMC 24 hours a day, seven days a week and to cover freeway service patrols for hard shoulder running, if not currently available • ATM needs to receive priority in future programming and funding to be sustainable for operations, maintenance and expansion • Increased capital costs for equipment, communications, and an expanded TMC • Limited right-of-way available for improvements such as hard shoulder running

9.0 Acronyms

AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
ATM	Active Traffic Management
ATMS	Advanced Traffic Management System
AWVSRP	Alaskan Way Viaduct and Seawall Replacement Project
CAD	Computer-Aided Dispatch
CCTV	Closed Circuit Television
CMS	Changeable Message Sign
ConOps	Concept of Operations
COTS	Commercial-off-the-Shelf
DMS	Dynamic Message Sign
FHWA	Federal Highway Administration
FTE	Full-Time Equivalent
GP	General Purpose
GPS	Global Positioning System
HDD	Horizontal Directional Drilling
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HSR	Hard Shoulder Running
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IRT	Incident Response Team
ITS	Intelligent Transportation System
LCD	Lane Control Display
LED	Light Emitting Diode
MMIS	Maintenance Management Information System
MTP	Metropolitan Transportation Plan
MUTCD	Manual on Uniform Traffic Control Devices
NTCIP™	National Transportation Communications for ITS Protocol
NWR	Northwest Region
O&M	Operations and Maintenance
PM	Preventive Maintenance
PS&E	Plans, Specifications and Estimate

PSRC	Puget Sound Regional Council
SOP	Standard Operating Procedure
SOV	Single-Occupant Vehicle
TMC	Traffic Management Center
TMS	Transportation Management System
UPS	Uninterruptible Power Supply
US	United States
VMS	Variable Message Sign
VSL	Variable Speed Limit
WSDOT	Washington State Department of Transportation
WSP	Washington State Patrol

Appendix A – Concept of Operations Meeting (Phase III) Attendee List

Puget Sound Active Traffic Management, Wednesday, March 5, 9:00 AM to 12:30 PM

Federal Highway Administration
James Colyar

Jacobs Carter Burgess
Gina McAfee
Russ McCarty
Tyler Milligan
Katy Nees
Joe Sobleskie

King County Department of Transportation
Aileen McManus
Rob Fellows
Paul Takamine

Parsons Brinckerhoff
Keith Nakano
Liz Young

Puget Sound Regional Council
Stephanie Rossi

Telvent
Les Jacobson
Lisa Nelson
Jason Stribiak

Washington State Department of Transportation
Morgan Balogh
Mark Bandy
Dave McCormick
John Nisbet
Pasco Bakotich
Steve Kim
Tony Leingang
Mark Leth
Patty Rubstello
Craig Stone
Ted Trepanier
Ron Vessey

Appendix B – Maintenance FTE Calculation Assumptions

List of Assumptions for the FTE Calculations

FTE Calculation

Maintenance Technician

Assumptions:

Hours per FTE	1800	hours
I-5 study area	29.6	miles
I-405 study area	30.3	miles
I-90 study area	9	miles
SR-520 study area	7.6	miles

There is one gantry is each direction at each location

					Assumptions
		per sign bridge			
Structural Inspection		3.2	hrs/yr	4 techs, 4 hours, every 5 years	
Major PM, VMS		48.0	hrs/yr	6 techs, 8 hours, once a year	
Monthly Minor PM, VMS		11.0	hrs/yr	1 tech, 1 hours, 11 times a year	
Repair, VMS		12.0	hrs/yr	6 techs, 6 hours, once every 3 years	*assumes 1 VMS per gantry*
Major PM, non-intr spd		2.0	hrs/yr	1 tech, 2 hours, once a year	
Monthly Minor PM, non-intr spd		5.5	hrs/yr	1 tech, 0.5 hours, 11 times a year	
Repair, non-intr spd		1.3	hrs/yr	2 techs, 2 hours, every 3 years	*1 non-intr spd per gantry*
Monthly Minor PM, lane control		18.0	hrs/yr	1 tech, 1.5 hours (3 DMS), 12 times a year	*assume 3 lanes for 520*
			24	1 tech, 2 hours (4 DMS), 12 times a year	*assume 4 lanes for I-90, and 4 for I-405*
			30	1 tech, 2.5 hours (5 DMS), 12 times a year	*assume 5 lanes for I-5*
Replacement, lane control		8.0	hrs/yr	6 techs, 4 hours, every 3 years (per sign bridge)	
Major PM, side mt DMS		6.0	hrs/yr	2 techs, 3 hours, once a year	
Monthly Minor PM, side mt DMS		11.0	hrs/yr	1 tech, 1 hours, 11 times a year	
Repair, side mt DMS		0.8	hrs/yr	2 techs, 2 hours, every 5 years	
	Total	126.8	hrs/yr	for 3 lanes	
		138.8	hrs/yr	for 4 lanes	
		144.8	hrs/yr	for 5 lanes	

		per sign			*VSW: 1 sign per ramp located on major*	
Major PM, VSW		2.0	hrs/yr	1 tech, 2 hours, once a year	*ramps entering VSL control areas.*	
Monthly Minor PM, VSW		11.0	hrs/yr	1 tech, 1 hour, 11 times a year	*I-5: 6 for NB and 7 for SB*	13
Repair, VSW		0.6	hrs/yr	1 tech, 3 hours, every 5 years	*SR 520: 4 for WB and 4 for EB*	8
	Total	13.6	hrs/yr		*I-90: 4 for WB and 2 for EB*	6
					I-405: 11 for NB and 7 for SB	18

Take number of hours/year/sign bridge and multiply by 4 — 2 gantries in each direction per mile

507.3	hrs/year/mile	for 3 lanes on 520	108.8	hrs/yr	*for VSW for SR520*
3855.7	hrs/year	for 7.6 miles on 520	0.06	FTE	
2.14	FTE	(not including VSW)			
555.3	hrs/year/mile	for 4 lanes on I-90	81.6	hrs/yr	*for VSW for I-90*
4998.0	hrs/year	for 9 miles on I-90	0.05	FTE	
2.78	FTE	(not including VSW)			
555.3	hrs/year/mile	for 4 lanes on I-405	244.8	hrs/yr	*for VSW for I-405*
16826.6	hrs/year	for 30.3 miles on I-405	0.136	FTE	
9.35	FTE	(not including VSW)			
579.3	hrs/year/mile	for 5 lanes on I-5	176.8	hrs/yr	*for VSW for I-5*
17148.3	hrs/year	for 29.6 miles on I-5	0.10	FTE	
9.53	FTE	(not including VSW)			

FTE Calculation

Bridge Inspector

		per sign bridge	
Structural Inspection	1.6	hrs/yr	2 brdg insp, 4 hours, every 5 years
	6.4	hrs/yr/mile	
	48.64	hrs/yr	for 7.6 miles on 520
	0.027	FTE	
	6.4	hrs/yr/mile	
	57.6	hrs/yr	for 9 miles on I-90
	0.032	FTE	
	6.4	hrs/yr/mile	
	193.92	hrs/yr	for 30.3 miles on I-405
	0.108	FTE	
	6.4	hrs/yr/mile	
	189.44	hrs/yr	for 29.6 miles on I-5
	0.105	FTE	

Appendix C – Signing Concepts

NORMAL FREEWAY SECTION
NORMAL CONGESTION
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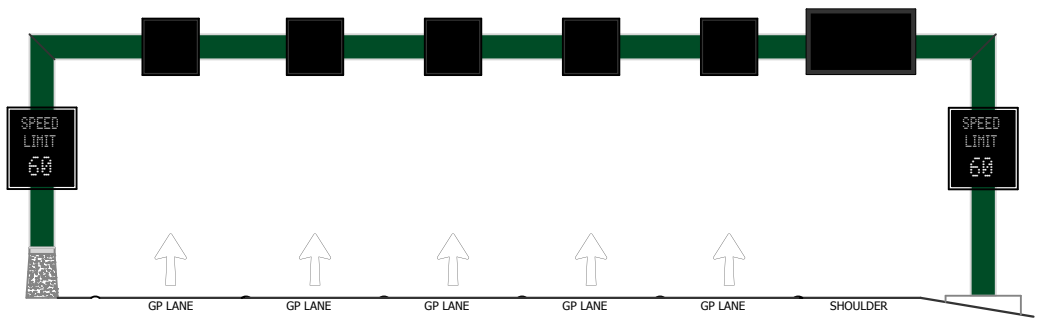

IN CONGESTION

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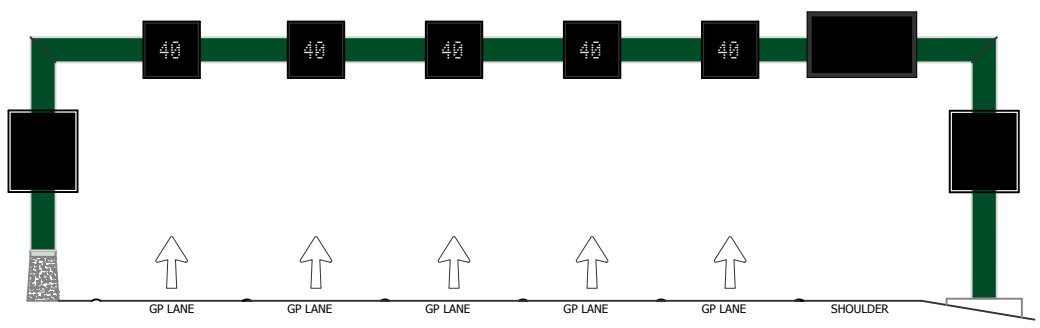
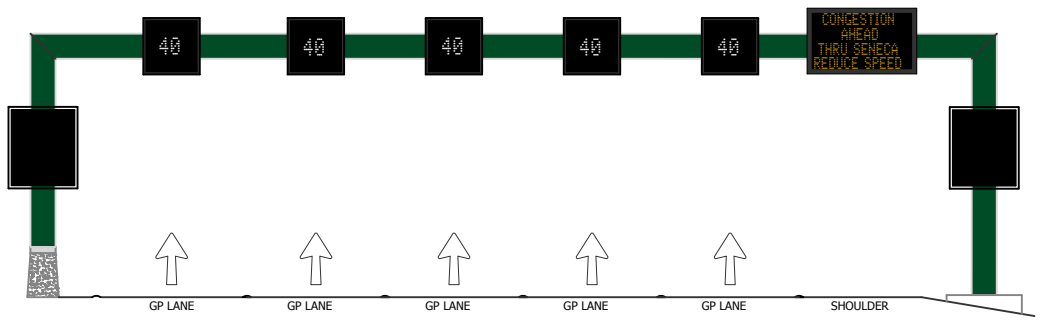


BACK OF QUEUE



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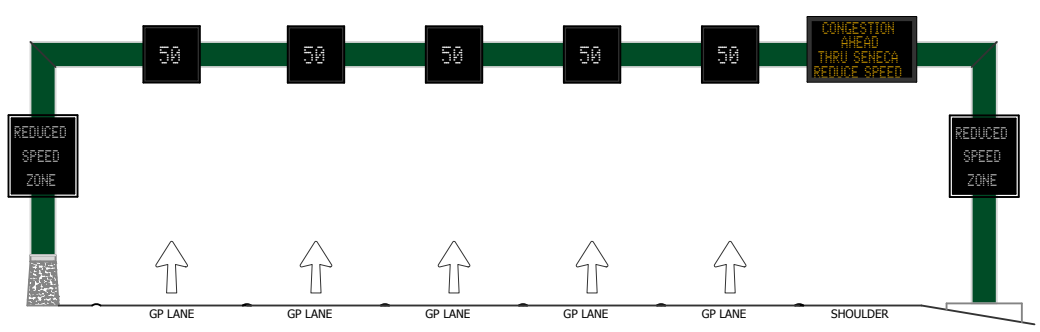

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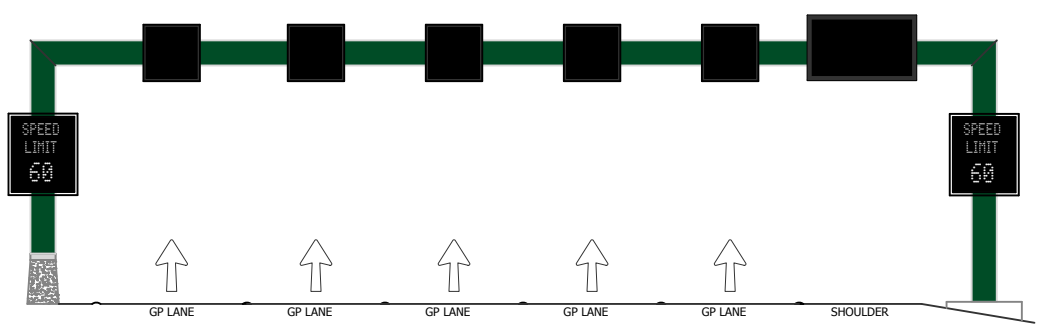
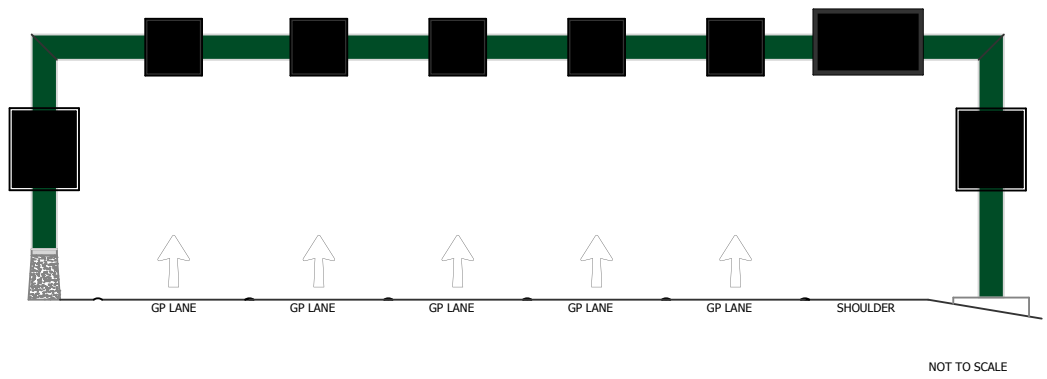


RESTING STATE

NORMAL FREEWAY SECTION
NORMAL CONGESTION
SPEED POSTING = ADVISORY



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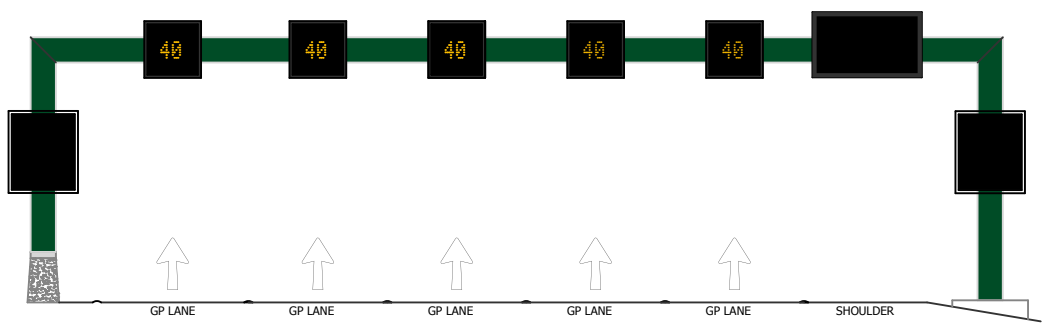
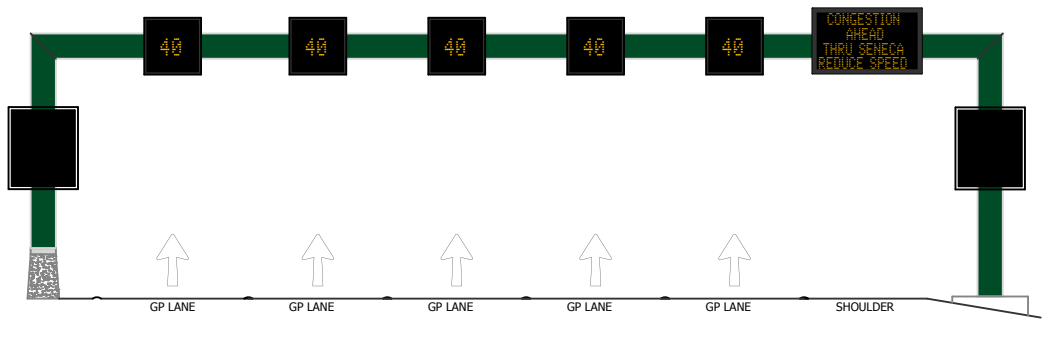


BACK OF QUEUE



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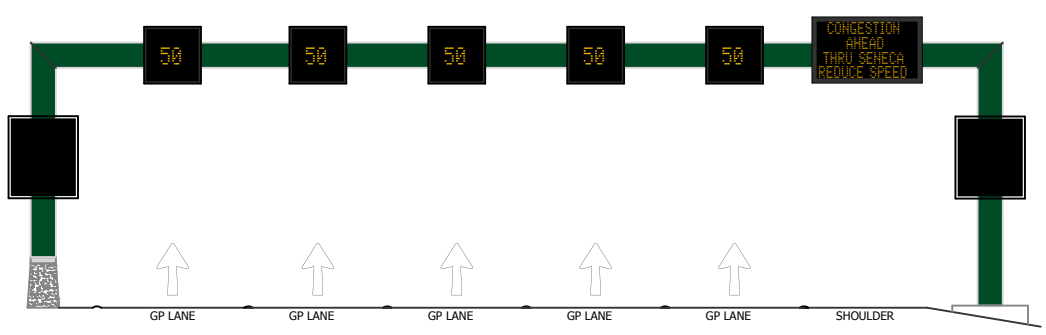

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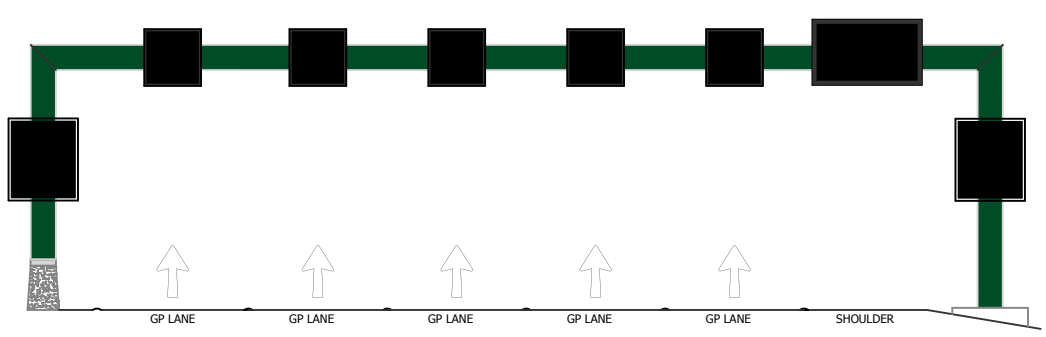
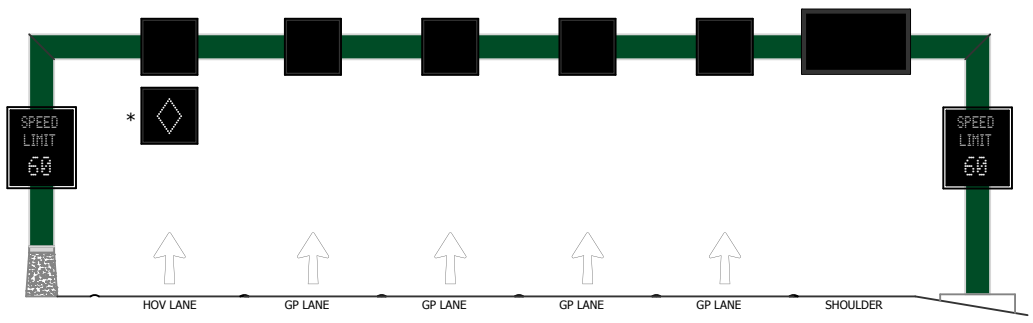


RESTING STATE

MANAGED LANE SECTION
NORMAL CONGESTION
SPEED POSTING = REGULATORY



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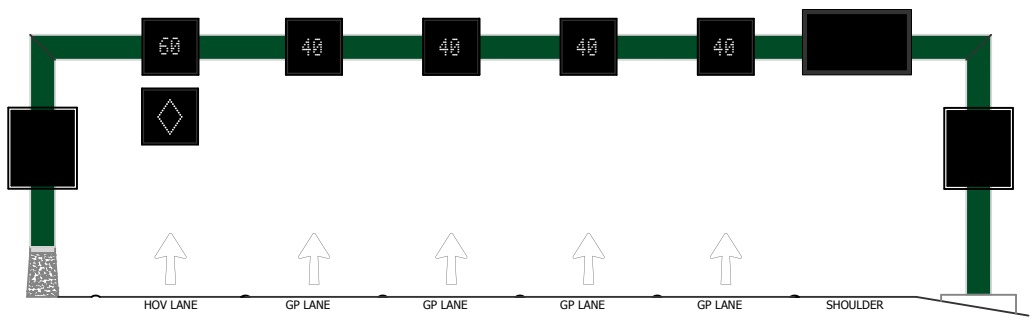
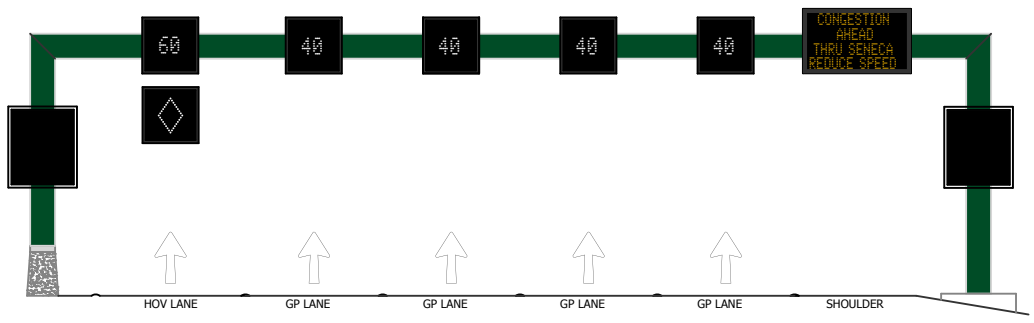


BACK OF QUEUE



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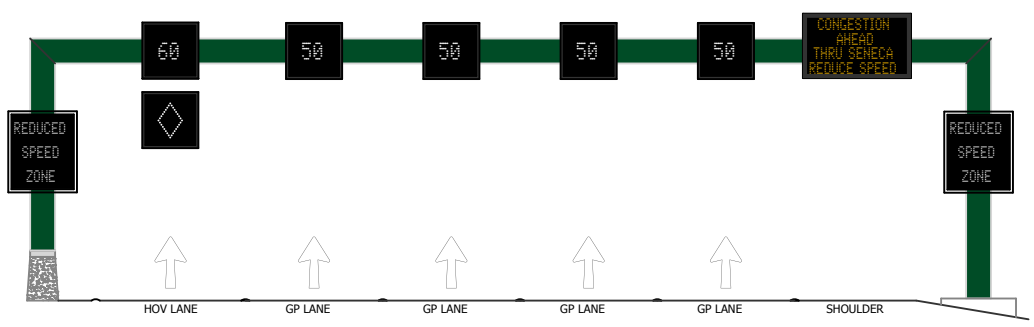

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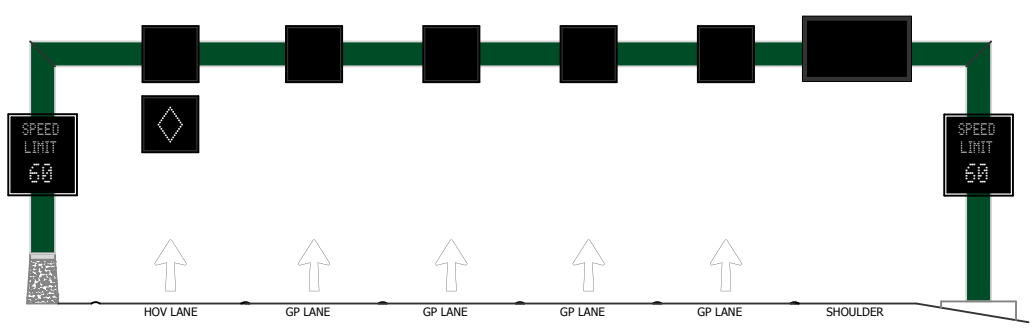

RESTING STATE

* represents a 2-phase message

MANAGED LANE FREEWAY SECTION
NORMAL CONGESTION
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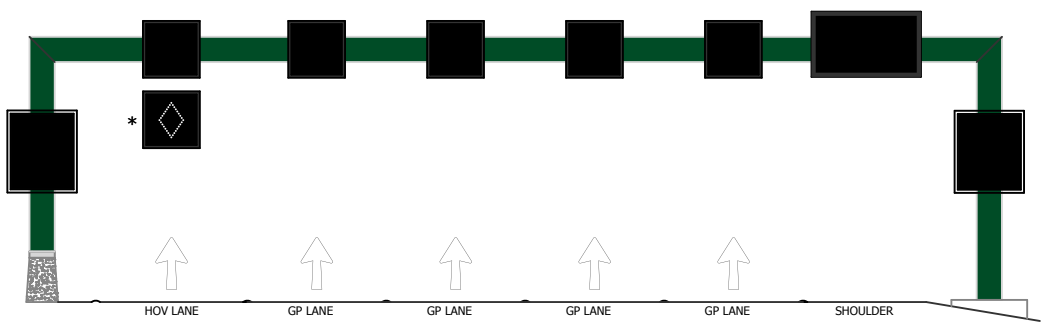

IN CONGESTION

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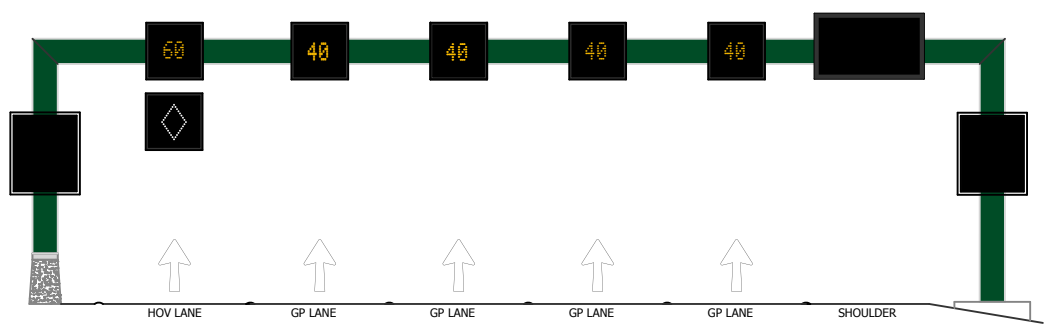
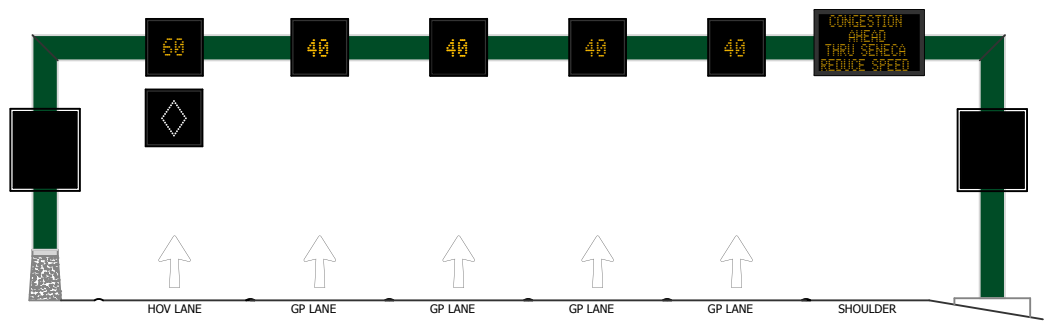


BACK OF QUEUE



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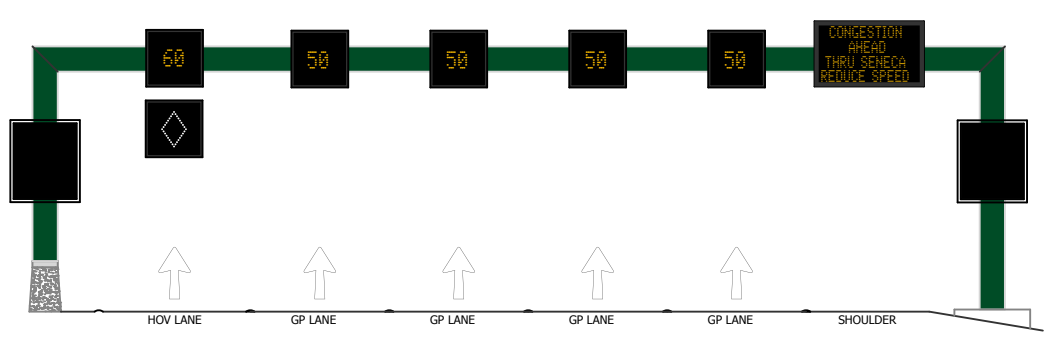

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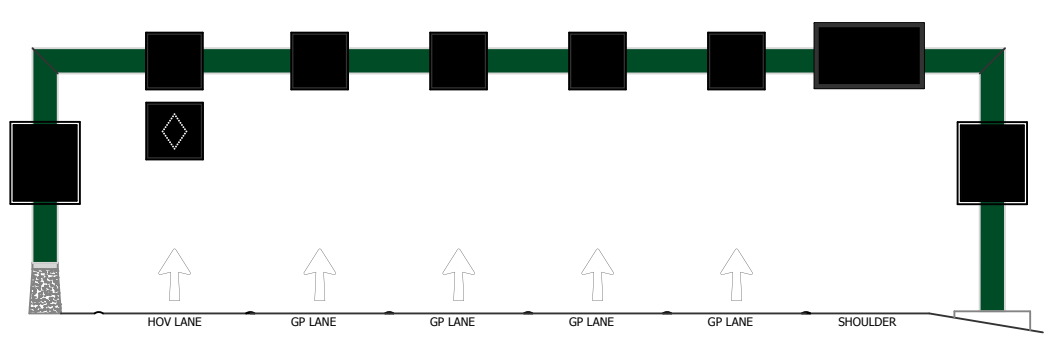
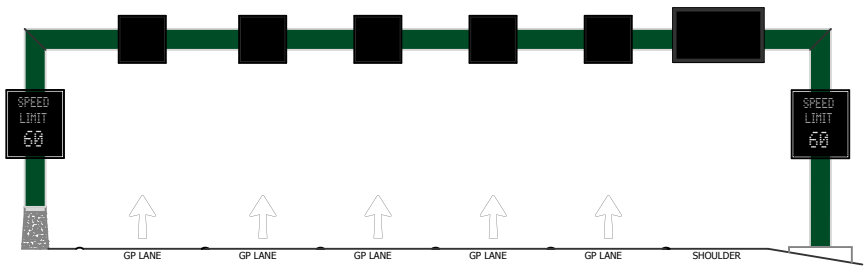


RESTING STATE

* represents a 2-phase message

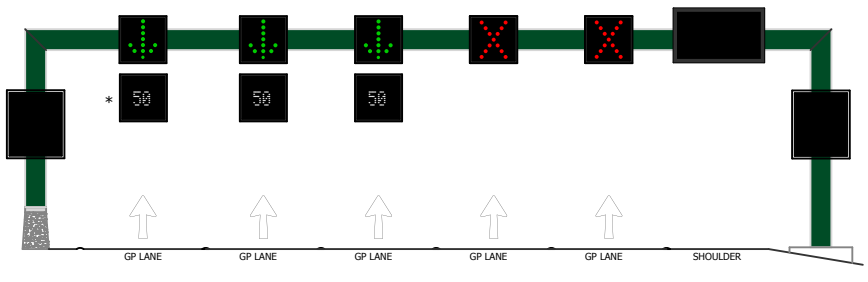
NORMAL & MANAGED FREEWAY SECTION
WORK ZONE OR INCIDENT
SPEED POSTING = REGULATORY

NO CONGESTION
WORK SPEED LIMIT = 50 MPH

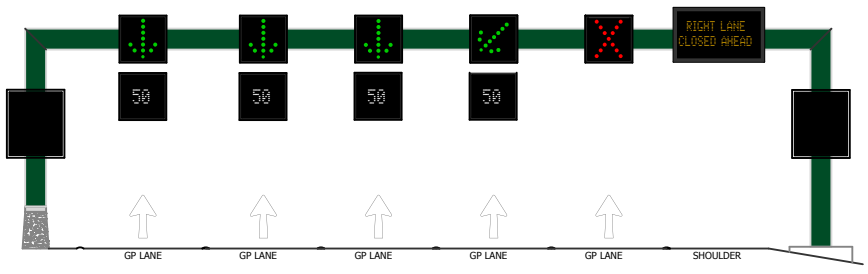


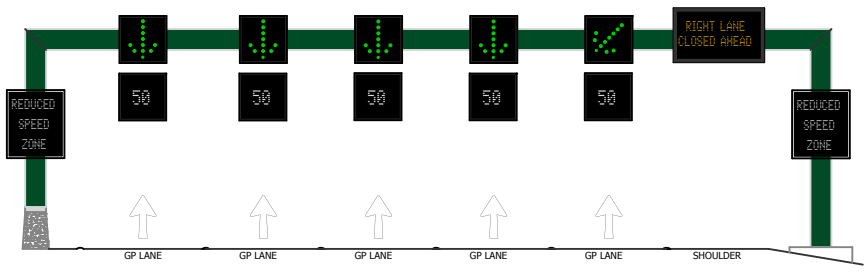
NORMAL TRAFFIC FLOW CONDITIONS

NOT TO SCALE

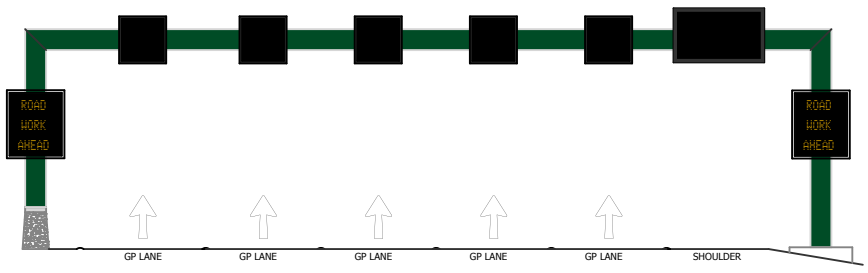


WORK ZONE/INCIDENT LOCATION

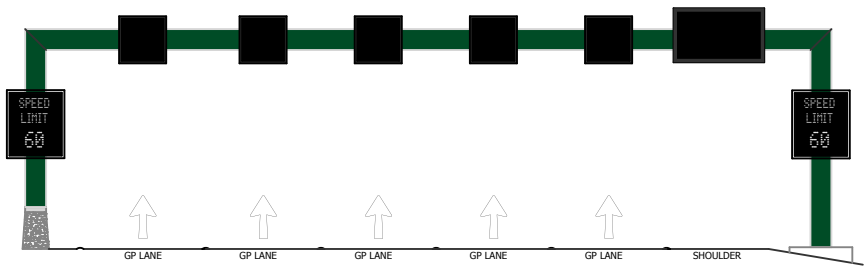




BEGIN TEMPORARY TRAFFIC CONTROL



INITIAL NOTIFICATION

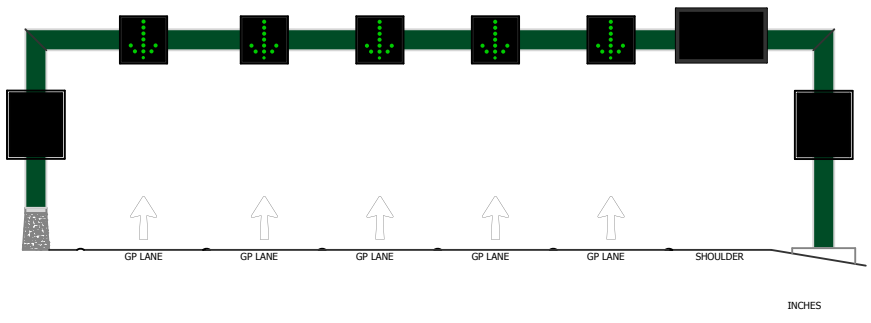


RESTING STATE

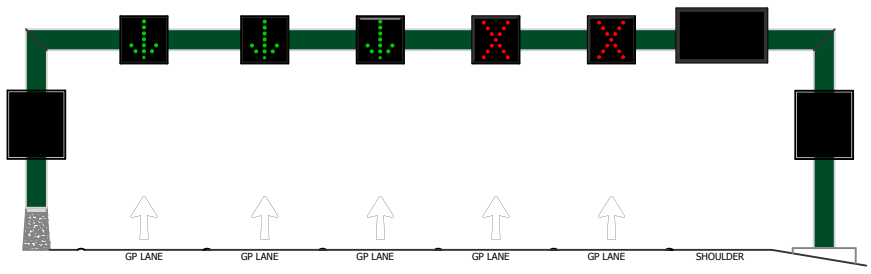
* represents a 2-phase message

NORMAL & MANAGED FREEWAY SECTION
WORK ZONE & INCIDENT
SPEED POSTING = ADVISORY w/ STATIC REGULATORY SIGNING

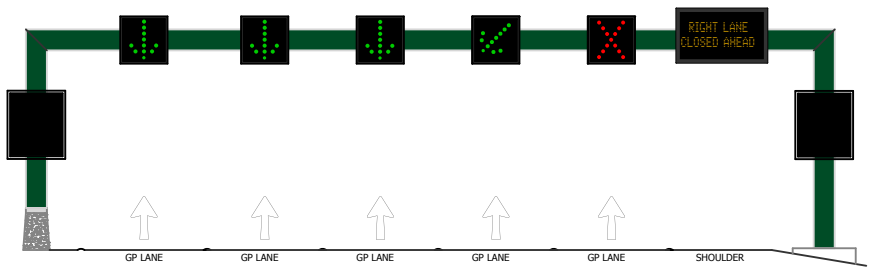
NO CONGESTION

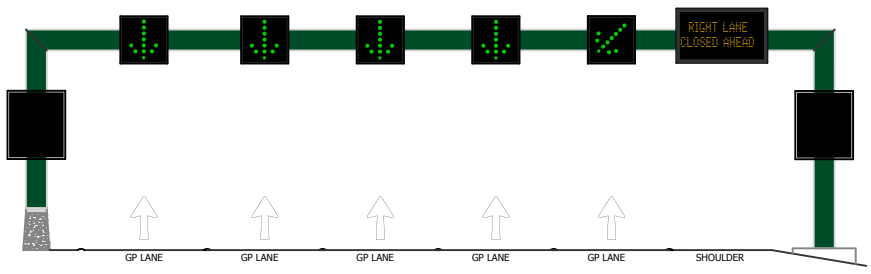


NORMAL TRAFFIC FLOW CONDITIONS

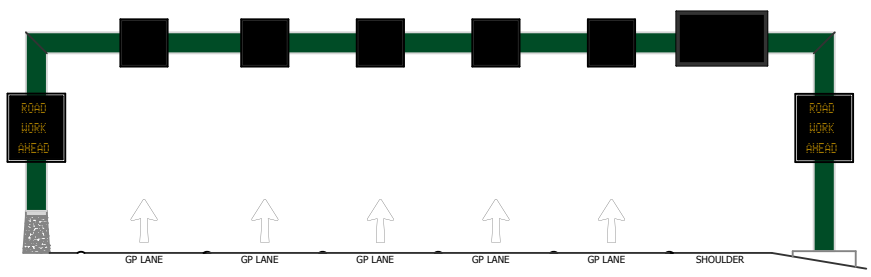


WORK ZONE/INCIDENT LOCATION

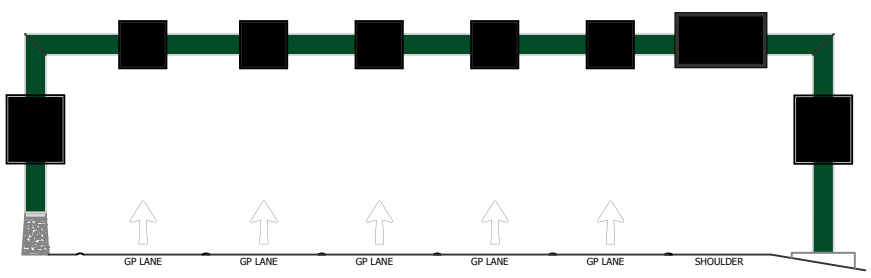




BEGIN TEMPORARY TRAFFIC CONTROL



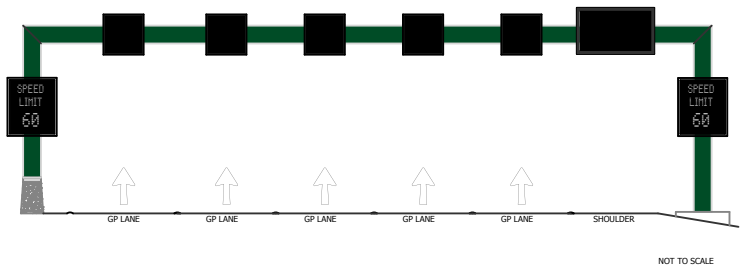
INITIAL NOTIFICATION



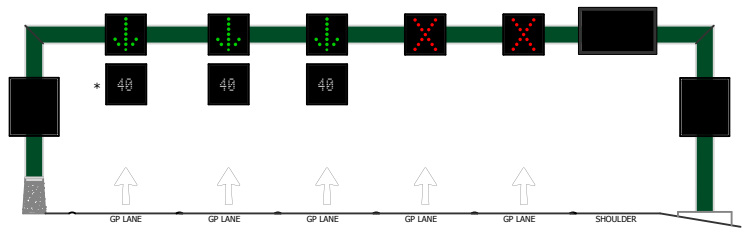
RESTING STATE

NORMAL & MANAGED FREEWAY SECTION
WORK ZONE OR INCIDENT
SPEED POSTING = REGULATORY

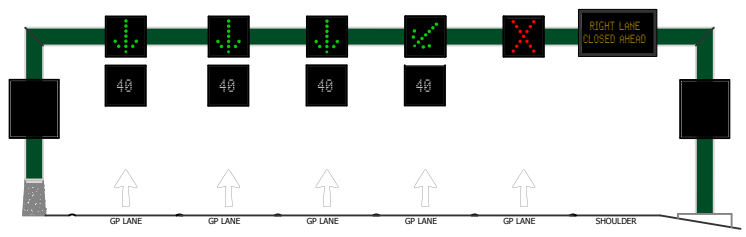
WITH CONGESTION
WORK SPEED LIMIT = 50 MPH



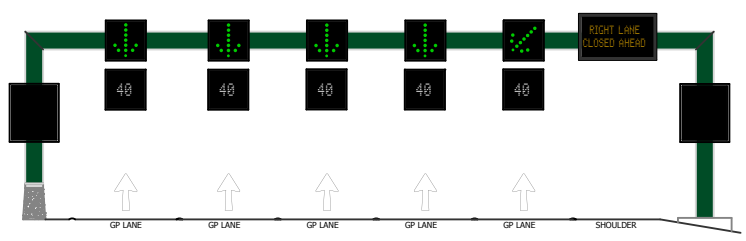
NORMAL TRAFFIC FLOW CONDITIONS



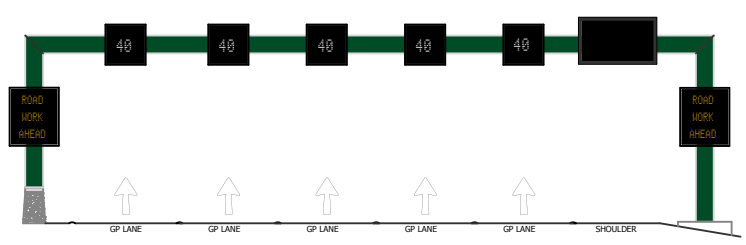
WORK ZONE/INCIDENT LOCATION
in CONGESTION



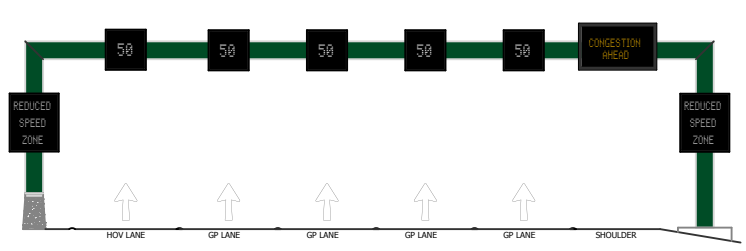
in CONGESTION



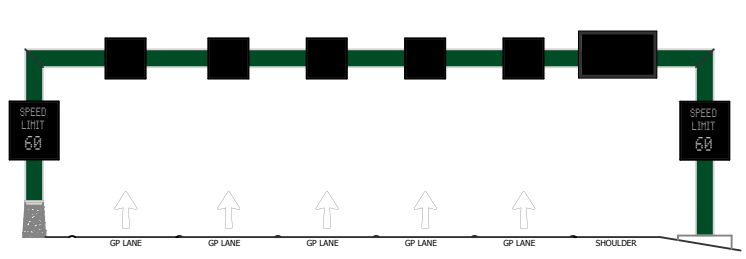
BEGIN TEMPORARY TRAFFIC CONTROL
in CONGESTION



INITIAL CONSTRUCTION NOTIFICATION
in CONGESTION



FIRST STEP DOWN



RESTING STATE

* represents a 2-phase message