CONCEPT OF OPERATIONS
FOR
I-70 PEAK PERIOD SHOULDER LANE

Interstate 70 – US 40 at Empire Junction to Twin Tunnels
CDOT Project NHPP 0703-401 (19474)

Prepared for:

The Colorado Department of Transportation (CDOT)

Prepared by:

In Partnership with:

DRAFT Version 6.0

February 25, 2014

DOCUMENT VERSION CONTROL

Document Name	Submittal Date	Version	Comments
Concept of Operations – Working Doc (Apex Review)	August 27, 2013	0.0	Initial draft of Sections 1-2 for internal review by Apex
Concept of Operations – Working Doc (Apex Review)	September 12, 2013	0.1	Draft of Sections 1-2 for internal Apex QA/QC
Concept of Operations – Working Doc (HDR/FHU Review)	September 13, 2013	1.0	Draft of Section 1-2 for review by Consultant Team
Concept of Operations – Working Doc (Apex Review)	September 25, 2013	1.1	Draft of Section 3-4 for internal Apex QA/QC
Concept of Operations – Working Doc (HDR/FHU Review)	September 27, 2013	2.0	Draft of Section 1-4 for review by Consultant Team
Concept of Operations – Working Doc (Apex Review)	October 10, 2013	2.1	Draft of Section 5-6 for internal Apex QA/QC
Concept of Operations – Working Doc (HDR Review)	October 28, 2013	3.0	Draft of Section 1-6 for informal review by project team
Concept of Operations – First Draft (Project Team Review)	December 30, 2013	4.0	Draft for review by project team
Concept of Operations – Working Doc (Apex Review)	January 27, 2014	4.5	Draft for internal Apex QA/QC
Concept of Operations – Second Draft (CDOT Review)	January 31, 2014	5.0	Draft for distribution to CDOT (outside of project team)
Concept of Operations – Working Doc (Apex Review)	February 21, 2014	5.1	Draft for internal Apex QA/QC
Concept of Operations – Final Draft	February 25, 2014	6.0	Final Draft

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Abbreviation	Description
AADT	Annual Average Daily Traffic
AGS	Advanced Guide way System
ALPR	Automatic License Plate Recognition
ATM	Active Traffic Management
ATR	Automatic Traffic Recorder
AVI	Automatic Vehicle Identification
CBE	Colorado Bridge Enterprise
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CFM	Continuous Flow Metering
ChAPS	Chain Area Program System
CMCA	Colorado Motor Carriers Association
CSP	Colorado State Patrol
CSS	Context Sensitive Solution
CTMC	Colorado Transportation Management Center
CTMS	Colorado Transportation Management Software
DHV	Design Hourly Volumes
DMS	Dynamic Message Sign
DSMD	Dynamic Speed Monitoring Display
DSRC	Dedicated Short Range Communications
DTD	Division of Transportation Development
E-470	E-470 Public Highway Authority
EB	Eastbound
EJMT	Eisenhower-Johnson Memorial Tunnels
ELOM	Express Lanes Operations Manager
FHWA	Federal Highway Administration
FTE	Full-Time Equivalent
GP	General Purpose
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HPTE	High Performance Transportation Enterprise
HSM	Highway Safety Manual
HSR	Hard Shoulder Running
HTSU	Heavy Tow Service Units
ITS	Intelligent Transportation Systems
LUS	Lane Use Signals
MDSS	Maintenance Decision Support System
MPH	Miles Per Hour
MUTCD	Manual on Uniform Traffic Control Devices
MVRD	Microwave Vehicle Radar Detectors

Abbreviation	Description
NA	No Action
POE	Port of Entry
PPSL	Peak Period Shoulder Lane
RFID	Radio Frequency Identification
RMS	Ramp Meter Station
SOV	Single Occupant Vehicle
TEL	Tolled Express Lanes
TMC	Transportation Management Center
TMO	Transportation Management Organization
TTI	Travel Time Indicator
VMS	Variable Message Sign
VSL	Variable Speed Limit
VTMS	Variable Toll Message Signs
WIM	Weigh-In-Motion

ACKNOWLEDGEMENTS

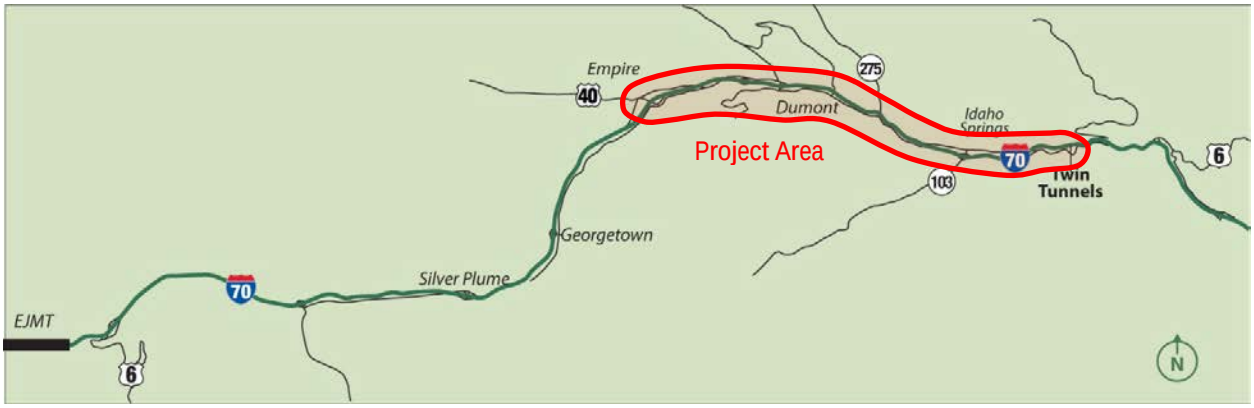
This report was developed in cooperation with the following stakeholders through the I-70 PPSL project leadership team and technical team:

- City of Idaho Springs
- Clear Creek County
- Clear Creek County Sheriff's Department
- Clear Creek Watershed Foundation
- Colorado Department of Transportation
- Colorado Motor Carriers Association
- Colorado State Historic Preservation Office
- Colorado State Patrol
- Colorado Trout Unlimited
- Colorado Parks and Wildlife
- Federal Highway Administration
- High Performance Transportation Enterprise
- I–70 Coalition
- Idaho Springs Police Department
- Jefferson County
- Summit County
- US Army Corps of Engineers
- US Forest Service
- Upper Clear Creek Watershed Association

1 INTRODUCTION

1.1 Purpose of Document

The I-70 Eastbound Peak Period Shoulder Lane (PPSL) project ("Project") will utilize the shoulder to provide a third, eastbound travel lane during peak periods along the I-70 Mountain Corridor from US 40 at Empire Junction to the Twin Tunnels. The peak period shoulder lane will serve as an extension to the third, eastbound lane that has recently been constructed through the Twin Tunnels, and operate as a tolled express lane.



Source: I-70 Peak Period Shoulder Lane Traffic Analysis Feasibility Study, Atkins, 2013

Figure 1-1: I-70 Mountain Corridor

The purpose of this Concept of Operations is to describe the characteristics of the proposed PPSL system from the perspective of the operator, the Colorado Department of Transportation, and the user. It will serve as a high-level conceptual guide for the design, implementation, and operation of the I-70 PPSL system. Due to the fact that this segment will be an extension of the recent reconstruction work at the Twin Tunnels, consideration will be given to maintain consistency in traffic operations between the two segments.

The Concept of Operations document will not provide guidance on pricing and revenue. These elements are being completed outside of this document effort.

1.2 Scope of Project

A Managed Lane can take on several different forms, including toll-free lanes for High Occupancy Vehicles (HOV), priced lanes open to all motorists that do or do not provide toll-exemptions to HOV traffic, priced lanes that institute variable pricing by time of day based on levels of congestion, bus-only lanes, hard shoulder running lanes, etc. This project will be utilizing a hard shoulder running lane during the periods of greatest congestion, which will be referred to as a Peak Period Shoulder Lane (PPSL). Several combinations of unmanaged lanes, also known as General Purpose (GP) lanes and priced lanes (referred to simply as "Tolled Express Lanes" or "TEL," hereafter) are being considered. Intelligent Transportation System (ITS) devices will be installed or upgraded to support the operation of the PPSL. This Concept of Operations document will focus on the operational characteristics of those various alternatives and how they affect the various stakeholders. Improvements along the entire corridor are not yet funded, so the intent of this project is to provide an interim operational improvement to help ease eastbound traffic congestion through the project area.

The Colorado Department of Transportation (CDOT) will be responsible for the design and construction of the Project as well as maintenance and operation of the facility. The High Performance Transportation Enterprise (HPTE) will oversee the management and operation of the managed lanes tolling system. It is presumed that the E-470 Public Highway Authority (E-470) will serve as the Tolling System Integrator and will provide the back office system and customer service center to process and issue tolls, as well as collect payment. A preliminary Traffic and Revenue Study was conducted by CDOT, HPTE and its consultants, but the final toll pricing structure has not yet been established. The final Traffic and Revenue Study will be coordinated with the development of the concept of operations to the greatest extent possible in order to balance the operational and financial aspects of this project.

The proposed PPSL along I-70 will provide a reliable travel time during peak travel periods for motorists returning to the Denver Metro Area from recreational activities in the mountains of Central Colorado and for regular I-70 users traveling eastbound during peak periods. The PPSL and toll rate structure will be designed to carry traffic all the way to from the junction of US 40 and I-70, 10 miles east to US 6 at the base of Floyd Hill, east of the Twin Tunnels.

1.3 Referenced Documents

The following are reference documents upon which this document is based:

- I-70 PPSL Safety Assessment (January 2014)
- I-70 Changeable Speed Limits Concept of Operations (June 2013)
- I-70 Reversible Lane Georgetown to Floyd Hill – Phase I Feasibility Study (August 2010)
- I-70 Mountain Corridor CSS – I-70 Reversible Lane – Phase II Feasibility Study (February 2011)
- I-70 Mountain Corridor Final Programmatic Environmental Impact Statement (March 2011)
- I-70 Mountain Corridor Record of Decision and Final Programmatic Environmental Impact Statement (June 2011)
- I-70 Mountain Corridor Mobility and Operational Assessment (August 2011)
- I-70 Mountain Corridor – Short Term Mobility Solutions (December 2011)
- I-70 Eisenhower Johnson Tunnel Continuous Flow Metering (CFM) Study (2012)
- Twin Tunnels Environmental Assessment Transportation Technical Memorandum (May 2012)
- Developing an Active Traffic Management System for I-70 in Colorado (September 2012)
- I-70 Peak Period Shoulder Lane Traffic Analysis Feasibility Study (March 2013)
- Advanced Guideway System (AGS) Feasibility Report (Draft)
- I-70 Mountain Corridor Traffic Incident Management Plan for Clear Creek County (April 2011)
- Mountain Corridor Incident Management Program Response Manual (February 2005)
- Manual on Uniform Traffic Control Devices (2009).
- A Policy on Geometric Design of Highways and Streets, 5th Edition, American Association of State Highway and Transportation Officials (2004)
- Highway Capacity Manual, Transportation Research Board (2000)
- Efficient Use of Highway Capacity Summary Report to Congress, American Association of State Highway and Transportation Officials (November 2010)
- Systems Engineering Guidebook for ITS v3.0, Federal Highway Administration
- CDOT/FHWA Memorandum of Understanding (Draft)

2 BACKGROUND

Section 2 provides a description of the existing conditions within the project area, as well as the basis of need for the concept of operations and proposed project.

2.1 Project Area

The section of I-70 between the Eisenhower-Johnson Memorial Tunnels (EJMT) and the Denver Metro Area experiences recurring peak period congestion on weekends and holidays during winter and summer peak recreational travel seasons. This 45-mile, four-lane section of I-70 is the primary access route from the Denver Metro Area to the mountains of central Colorado where there are numerous opportunities for outdoor activities, such as skiing in the winter as well as camping, hiking, biking, and sightseeing in the summer and fall. Consequently, this corridor experiences heavy flows of westbound traffic on Friday afternoons as well as on Saturday and Sunday mornings. Eastbound traffic is heavy later in the day, and the highest peak period congestion occurs on Sunday afternoons when both day and weekend visitors are returning for the start of the work week. The majority of this congestion happens in the segment between Georgetown and the Floyd Hill area for the following reasons (see Figure 2-1):

- Heavy traffic volumes enter and exit I-70 at U.S. Highway 40 (US 40)/Empire Junction just to the east of Georgetown; the interchange serves numerous recreational opportunities in Grand County that use Berthoud Pass.
- The roadway geometry through Idaho Springs is constrained, with narrow shoulders and tight curves.
- The Westbound Twin Tunnels (located in Idaho Springs) is operationally constrained because of the narrow shoulder widths, but the Transportation Commission is considering funding a project to widen the westbound bore, similar to the recent work on the eastbound bore.

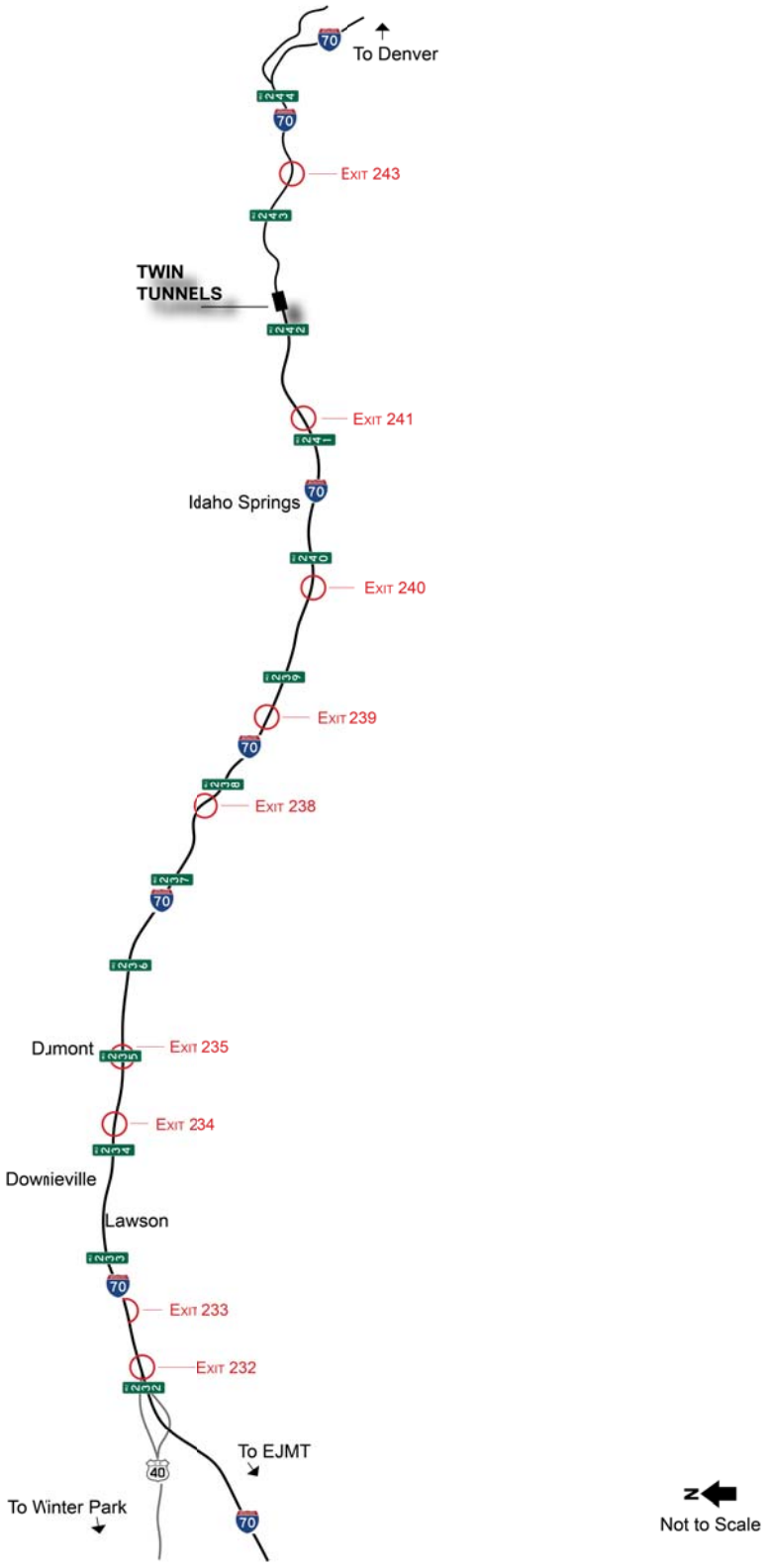


Figure 2-1: Project Corridor

2.2 Traffic Characteristics

I-70 currently carries two travel lanes in each direction within the Project corridor, with the exception of the Twin Tunnels segment to the east of the project which was recently widened to include a third eastbound lane. At least one, two-lane local road is also present through the entire corridor, running approximately parallel to I-70. The eastbound and westbound lanes of I-70 are separated by a narrow median with guardrail or concrete barrier. The speed limit is posted at 65 miles per hour (mph) entering the west end of project corridor, but is reduced to 60 mph at MP 238, and further reduced to 55 mph at MP 242. The corridor's Annual Average Daily Traffic (AADT) ranges from 39,000 to 45,000 vehicles per day (CDOT 2011), with Design Hourly Volumes (DHV) in the peak direction at approximately 7.5 percent of the AADT. Figure 2-2 depicts eastbound I-70 average hourly traffic volumes during the peak travel period, based on data from the 2013 No Action DynusT model of the corridor. There are a total of eight grade-separated interchanges along I-70 within the Project limits, including a Commercial Vehicle Weigh Station near milepost (MP) 234.

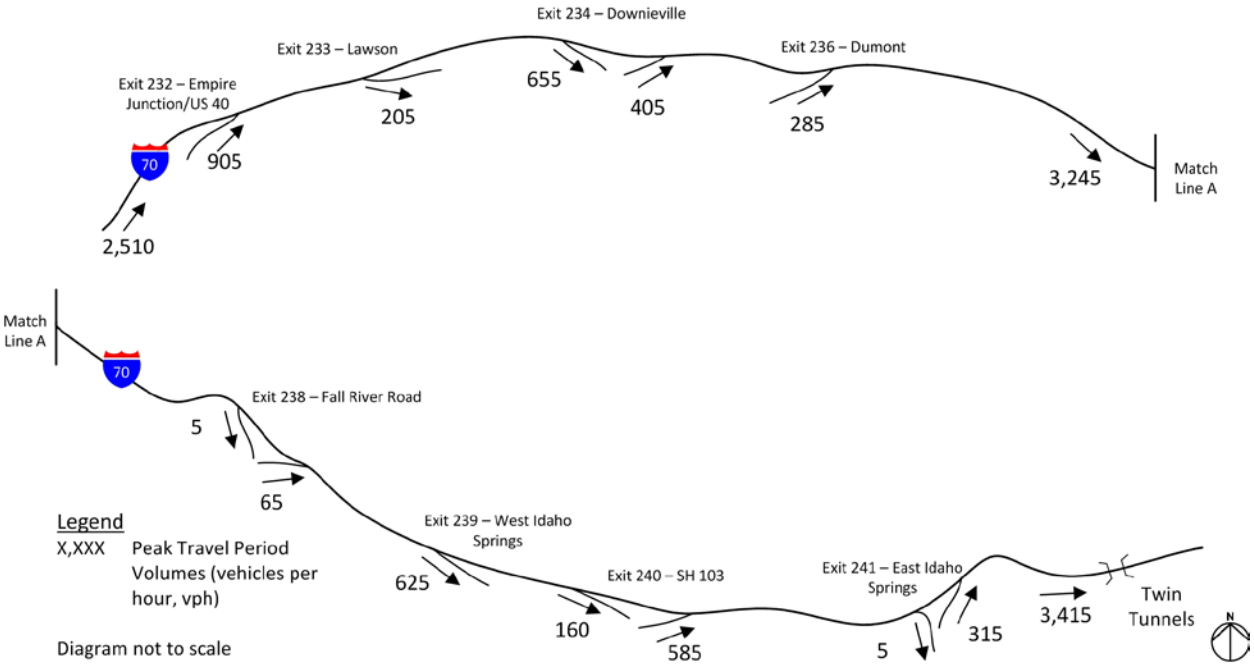


Figure 2-2: Eastbound I-70 Average Hourly Traffic Volumes (Peak Travel Period)

2.3 Existing Operational and Support Environment

2.3.1 ITS Infrastructure

A 144-strand fiber optic cable has been installed along I-70 through the entire length of the project corridor, in a duct bank with multiple conduits. The cable is owned by CDOT and serves as the ITS communications backbone, but Comcast Communications utilizes two strands on the cable and performs all the splicing and maintenance. The backbone cable is able to provide devices along the corridor with reliable, high-speed communications to both the Colorado Transportation Management Center (CTMC) and the EJMT control centers. In addition to the control centers, there are two CDOT ITS regeneration buildings (Copper Mountain Node and Hidden Valley Node) that serve as major hubs for the communications system along the mountain corridor.

A list of all the existing ITS field equipment along I-70 within the project limits from US 40 to the Twin Tunnels (between mile markers 231 and 242) is shown in Table 2-1. The summary includes all the devices that will be added along I-70 from Exit 241 to the EB entrance of the Twin Tunnels as part of the eastbound Twin Tunnels widening project which is currently under construction. At the time this report was written these devices had not been installed, but are anticipated to be in place by early 2014.

Table 2-1: Current ITS Devices within the Project Corridor

ITS Device	Westbound	Eastbound	Total
Automatic Traffic Recorder*	1		1
Closed Circuit Television (CCTV) Camera	5	4	9
Doppler Radar Units	3	2	5
Variable Message Sign (VMS)	2	2	4
Variable Speed Limit Sign (VSL)		1	1
Microwave Vehicle Radar Detector (MVRD)*	2	4	6
Travel Time Indicator (TTI)	3	3	6
Ramp Meter Station (RMS)		3	3

*Each ATR and MVRD site is reported based on the cabinet location, but covers both eastbound and westbound traffic

The project corridor also includes the following ITS devices in both directions of travel along I-70 in advance of the Dumont Port of Entry (POE) to support commercial vehicle enforcement:

- Weigh-In-Motion (WIM) stations
- PrePass readers
- Dynamic Open/Closed signs

In addition to the devices within the project limits, the following devices are located on eastbound I-70 within the five mile segment immediately west of the project area (between mile markers 227 to 231), and are utilized to provide traveler information for the project corridor.

- 3 CCTV cameras (providing coverage of eastbound, but located on westbound)
- 1 TTI
- 1 Variable Speed Limit (VSL) sign

See Figure 2-3 for a detailed layout of all the devices along the corridor.

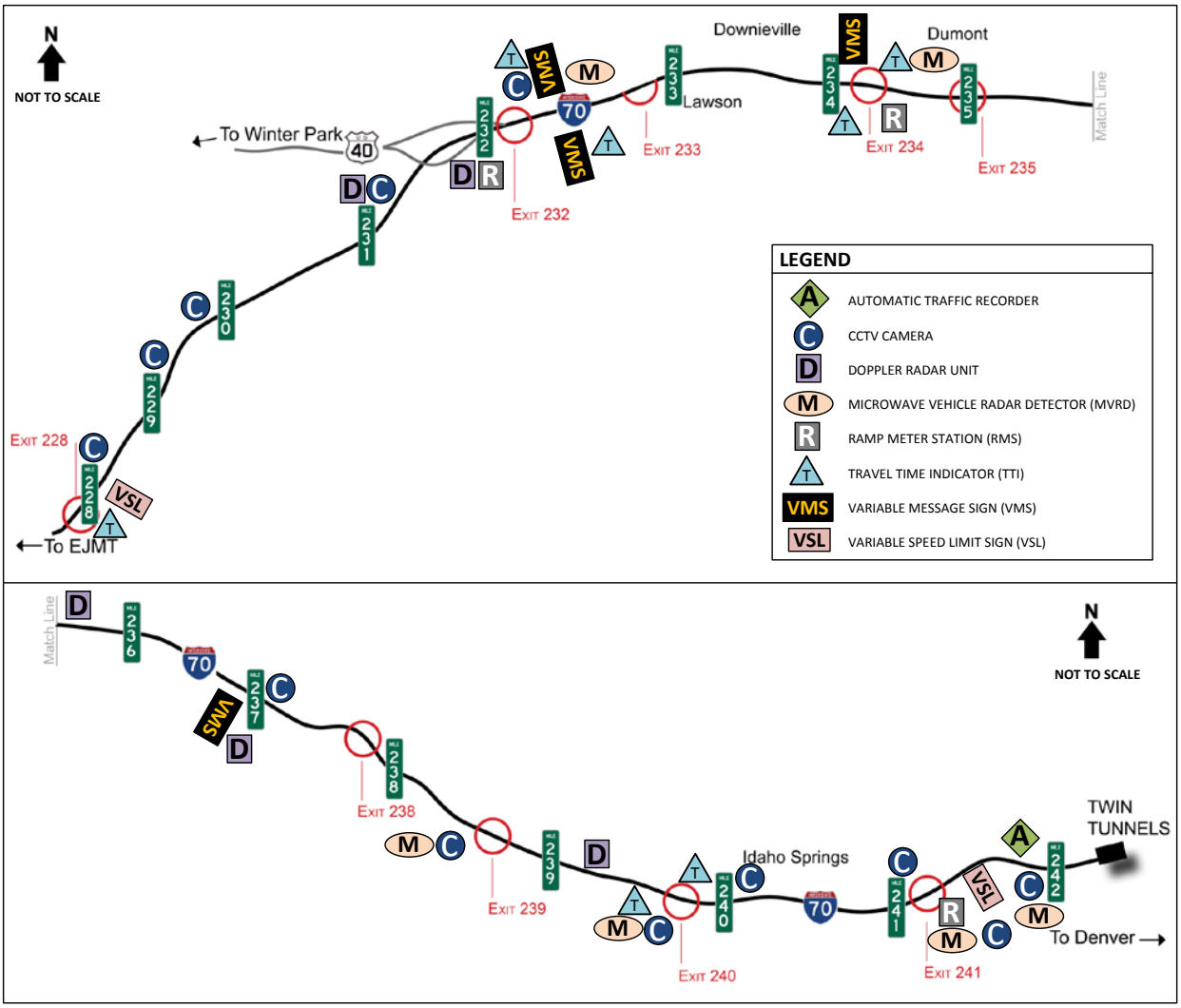


Figure 2-3: Current ITS Devices in Project Limits

2.3.2 ITS Software Systems

The following is a description of the existing software programs that are used to assist with ITS infrastructure maintenance and operations:

- Colorado Transportation Management Software (CTMS) - CTMS is a customized software application that integrates various ITS devices into a single program. The software resides at the CTMC, with a client at EJMT. CTMC operators use this program to post messages to VMS. The program is also used to collect and assemble the TTI, MVRD, and RMS data, and then disseminate this information to the traveling public.
- Camera Cameleon - Camera Cameleon is the software program used to view and control CCTV surveillance cameras. There are client versions of the program at CTMC and EJMT.
- Camera Cameleon ITS Client (HOV software) - Camera Cameleon ITS Client (HOV software) is a version of Camera Cameleon customized for the I-25 Express (HOT/HOV) Lanes. This software resides at CDOT Region 1 and Node 2. The software controls the HOV VMS and automatic gates.
- Chain Area Program System (ChAPS) - ChAPS is the chain area control system at EJMT. It is a customized software application used to monitor and operate the chain station equipment between

Genesee and Vail. Chain station equipment includes VSL, flashing beacons, lighting, and other associated infrastructure.

2.3.3 Commercial Vehicles

Commercial vehicles account for approximately 10.5% of the AADT (CDOT 2011) through this segment of the corridor. During the peak period of travel the percentage is much lower, but the commercial vehicles on this corridor have few other east-west options and can still have a significant effect on traffic operations due to the roadway geometry.

The Dumont POE is located within the project limits, and is operated by the Colorado State Patrol (CSP). In addition to the stationary scale within the POE, the advance weigh-in-motion stations, PrePass transponder readers, and "Open"/"Closed" VMS panels are also used to perform daily operations.

There is only one chain station within the project limits, which is located just west of the Twin Tunnels on eastbound I-70 (approximately mile marker 241). The chain station is currently being reconstructed as part of the Twin Tunnels widening project.

2.3.4 Transit

While no regional public transportation agency technically operates within the project limits, there are a variety of private shuttles and vanpools available for transportation through the corridor. Also, CDOT is in the early planning process for implementing a regional bus service through the corridor.

2.3.5 Transportation Management Center Operations

The CTMC, located in Golden, serves as the hub for CDOT's ITS network. The operators at the CTMC monitor ITS devices statewide, including the CCTV cameras and vehicle detectors within the project area. The operators are responsible for dispatching the Mile High Courtesy Patrol and disseminating traveler information via VMS, the 511 system and the CoTrip.org website. There are typically 2-3 operators staffed in the CTMC at any given time, with an additional two operators staffed during the winter peak periods to specifically focus on the I-70 corridor.

The EJMT operations center is located approximately 16 miles west of the project area, and controls the VSL and DMS that provide information to eastbound I-70 traffic leading into the project area. In addition, the EJMT makes the determination as to when chain law goes into effect for the entire I-70 mountain corridor.

2.3.6 Incident Management

CDOT developed an incident management program response manual (last updated in 2005) for the entire I-70 mountain corridor, including all of the steps, responsibilities and resources required to manage and clear an incident within the corridor. A detailed, county-specific traffic incident management plan was created in 2011 for Clear Creek County, and updated in 2012 as a project specific guideline for managing incidents during the construction of the 2012/2013 Twin Tunnels Construction Project. The incident management plans include closure points, detour plans, and standard operating procedures for a variety of situations.

In addition to a well-documented incident management program, the CTMC staffs additional operators during peak winter operations. The CTMC also dispatches courtesy patrol, Heavy Tow Service Units (HTSU) and push bumper trucks to assist stranded motorists and alleviate congestion.

2.3.7 Enforcement

Enforcement of traffic laws along I-70 within the project corridor is performed by the Colorado State Patrol (CSP), Clear Creek County Sheriff, or Idaho Springs Police Department. In general, traffic enforcement cannot be staged from the median because of the narrow width, grade differentials and almost continuous barrier/guard rail.

2.3.8 Maintenance

Maintenance of the roadway and snow removal along I-70 is currently performed by CDOT Region 1. All the ITS equipment along the corridor is maintained by CDOT ITS, with two exceptions: PrePass maintains the transponder readers in advance of the POE, and CDOT Division of Transportation Development (DTD) maintains the Automatic Traffic Recorders (ATR).

2.4 Existing Stakeholder Roles and Responsibilities

The project corridor includes a significant number of stakeholders that take a significant interest in any impacts to this segment of the I-70 mountain corridor.

2.4.1 I-70 Coalition

The I-70 Coalition is a Transportation Mangement Organization (TMO) made up of more than 30 political jurisdictions, whose mission is to enhance public accessibility and mobility in the I-70 Central Mountain Corridor and adjoining dependent counties and municipalities through the implementation of joint public & private transportation management efforts. The coalition serves as an advocate for transportation issues impacting the I-70 mountain corridor by getting involved in studies, providing education and outreach, seeking opportunities for transportation funding, and bringing state and national attention to the importance of transportation improvements along the I-70 Corridor. The coalition also manages a traveler information website for the corridor (www.GoI70.com). Within the project limits, Clear Creek County, Empire and Idaho Springs are all members of the coalition.

2.4.2 Federal Highway Administration (FHWA)

FHWA is involved in project leadership and oversight for any projects or improvements that impact the federally funded interstate system (e.g. I-70). FHWA also serves as a technical resource for operations and management of the I-70 corridor.

2.4.3 CDOT

CDOT Region 1 is responsible for roadway maintenance, including snow removal, and also covers the operations of the EJMT control center. The EJMT is responsible for determining when chain law goes into effect, operating the chain law equipment and VSLs, and for coordinating operations with the CTMC at the east end of the mountain corridor.

CDOT ITS is responsible for maintenance of all ITS devices, including traffic cameras, weather stations, MVRDs, TTIs, WIM stations, and ramp meters. CDOT ITS also covers the operations of the CTMC control center, which includes communication with the EJMT to coordinate the CTMC-controlled VMS messaging with the implementation of chain law, and for the management of major incidents or weather events.

CDOT DTD is responsible for maintenance of the ATRs along the corridor.

2.4.4 Colorado State Patrol (CSP)

The Golden Troop within District 1 of CSP is responsible for enforcing the traffic laws along this segment of I-70, in addition to maintaining and operating the Dumont Port of Entry. CSP maintains the stationary scale within the weigh station, but the equipment on I-70 is maintained by CDOT and PrePass.

2.4.5 PrePass

The PrePass program is responsible for maintaining the Automatic Vehicle Identification (AVI) equipment in the field, managing the distribution of the vehicle transponders, and operating the back office system that verifies whether or not an individual commercial vehicle meets the bypass criteria established by the State of Colorado.

2.4.6 Comcast Communications

Comcast currently manages the locates, splicing and maintenance of CDOT's fiber optic backbone through the project corridor.

2.4.7 Local Law Enforcement Agencies

Local law enforcement agencies, including the Clear Creek County Sheriff and the Idaho Springs Police Department, also enforce traffic laws along I-70 and respond to incidents along the corridor.

2.4.8 Emergency Responders

Emergency responders utilize this segment of I-70 to respond to incidents on and off the freeway in the project area, and have generally found I-70 provides a quicker overall response time than utilizing parallel local roads. EMS and fire response is generally staged from Georgetown, Dumont and Idaho Springs facilities, with an additional fire staging area in Empire. The typical emergency responders operating within the project corridor include:

- Clear Creek Fire Authority
- Clear Creek EMS
- Colorado State Patrol
- Clear Creek County Sheriff
- Georgetown Police Department
- Idaho Spring Police Department

2.4.9 Colorado Motor Carriers Association (CMCA)

The CMCA is the state trucking association in Colorado that represents the interests of the commercial vehicle stakeholders for the project corridor.

2.4.10 Local Motorists

Many residents use this segment of I-70 as a link between local destinations, in addition to commuting through the corridor to the Denver Metro Area for work. Commercial development in the area depends on the business from recreational travelers through the corridor.

2.4.11 Regional and Recreational Travelers

During the peak periods of congestion, the project corridor has a high percentage of seasonal and recreational traffic that may not be as familiar with the corridor as a local or regular commuter. The residents and businesses on the western slope of Colorado will also frequently use I-70 for purposes such as health care, shopping, etc.

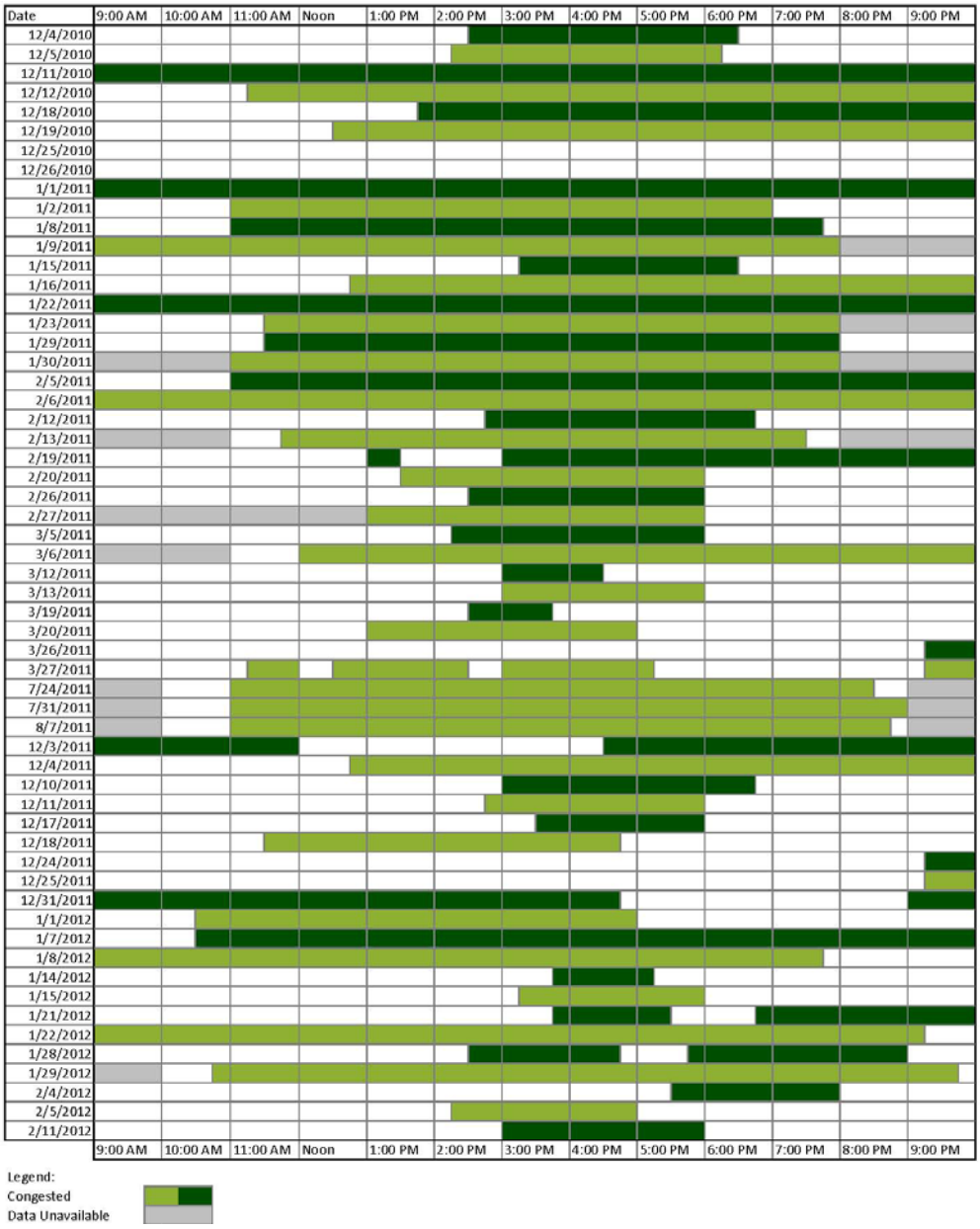
2.5 Operational Assessment

Increasing traffic demand and congestion continues to put pressure on I-70 corridor operations, serving as the primary link between the Denver Metro Area and the communities and recreational opportunities along the mountain corridor to the West.

2.5.1 Traffic Operations and Mobility

The section of I-70 between the EJMT and the Denver Metro Area experiences heavy flows of eastbound traffic on Saturday and Sunday afternoons when both day and weekend visitors are returning for the start of the workweek. The majority of this congestion happens in the segment between Georgetown and the Floyd Hill area. This is due to several reasons including the heavy traffic volumes that enter eastbound I-70 at the US 40/Empire Junction interchange and the constrained roadway geometry through Idaho Springs. Table 2-2 shows a sampling of eastbound I-70 congestion (extended periods below free flow speeds) on peak travel Saturdays and Sundays, for the segment between US 40 and the Twin Tunnels. As shown in the table, the congestion through this section of I-70 can last up to 12 hours.

Table 2-2: I-70 Eastbound Traffic Congestion Summary – US 40 to Idaho Springs (2010 to 2012 Winter Peak Saturdays and Sundays)



The Twin Tunnels project recently opened and has addressed many of the constrained areas in the vicinity of the tunnels, including the addition of a third eastbound lane. Figure 2-4 shows weekend average travel speeds along I-70 between US 40 and the Twin Tunnels after the eastbound Twin Tunnels project was completed and opened to traffic. Although it is a small sample, including only November 2013 through February 2014, the recently collected data already shows that peak period congestion remains a significant issue within the Project corridor.

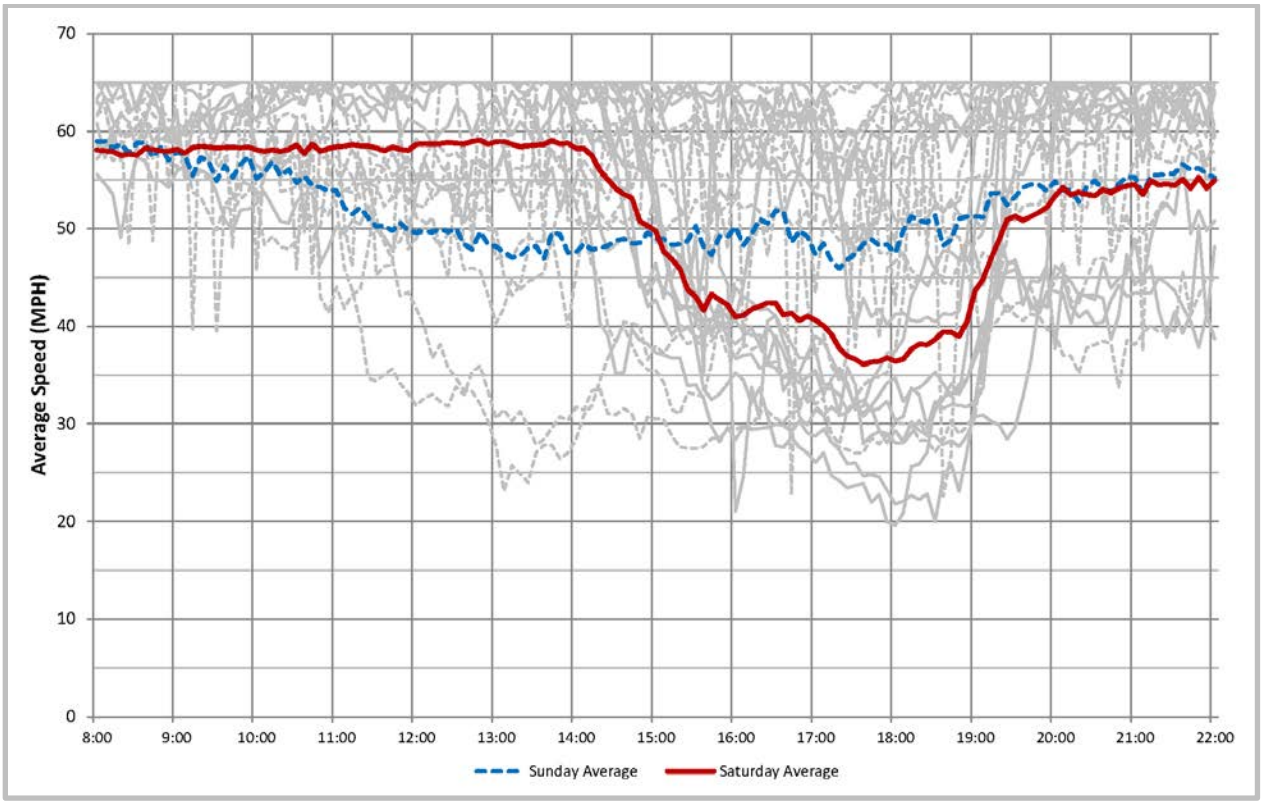
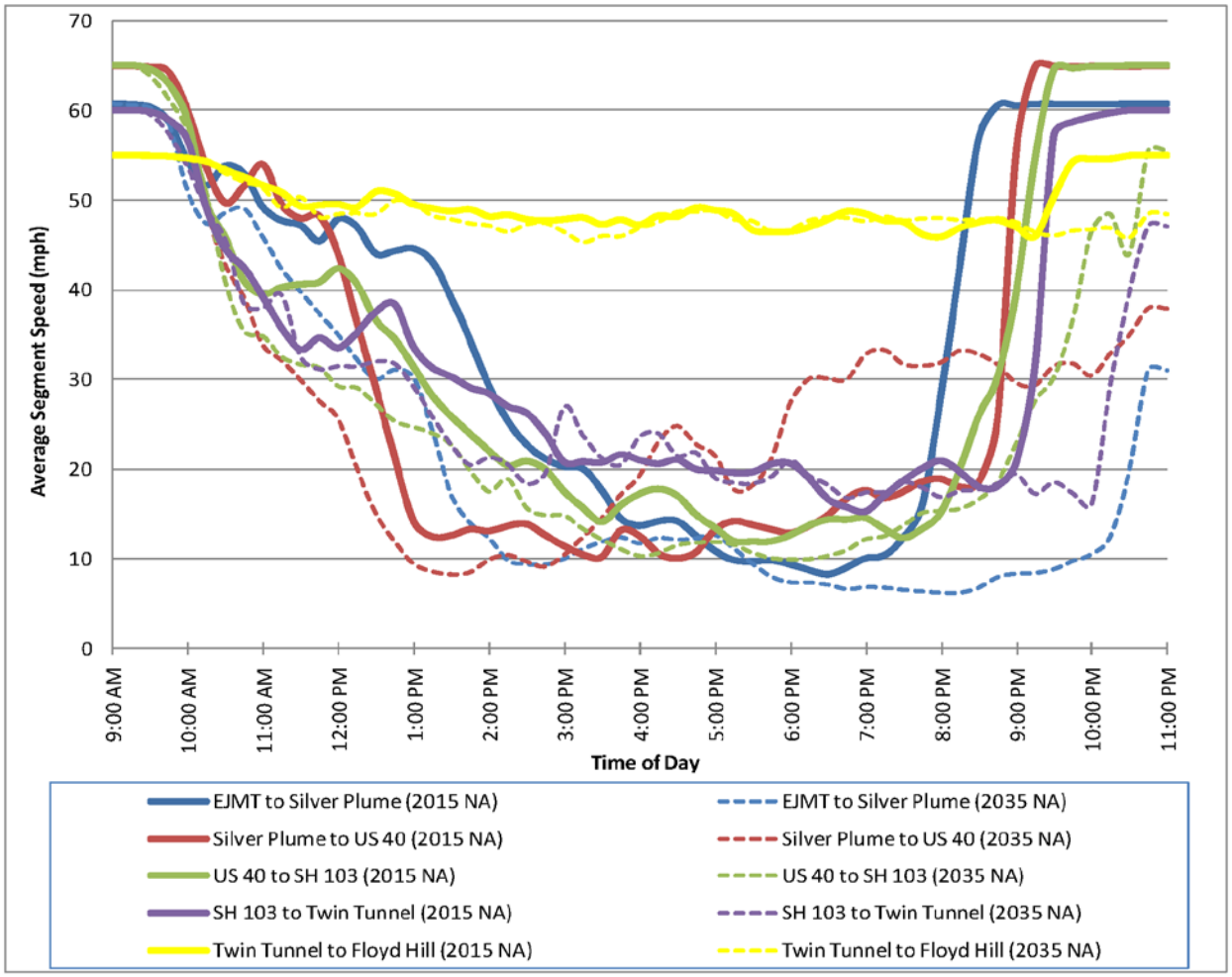


Figure 2-4: Eastbound I-70 Speeds – US 40 to Idaho Springs (2013/2014 Winter Weekends)

Future traffic conditions in this segment of I-70 were estimated in the I-70 Peak Period Shoulder Lane Traffic Analysis Feasibility Study performed by Atkins in 2013. The study utilized the DynusT mesoscopic analysis tool to evaluate the operations of the entire I-70 corridor between EJMT and the top of Floyd Hill under future conditions. To determine the impact of the Twin Tunnels widening project, the DynusT model was utilized to evaluate Year 2013 existing conditions without the Twin Tunnels widening and Year 2013 "Improved" conditions which assumed that the Twin Tunnels Widening improvements will be complete and open to traffic. Additional congestion due to increased travel demand was also modeled for Year 2015 and Year 2035 No Action (NA) scenarios, where no additional improvements (beyond the recently completed twin tunnel project) are implemented. Since the corridor already operates at capacity for many hours during peak weekend afternoons, the lower travel speeds are expected to remain generally unchanged (see Figure 2-5); however, the duration of the peak period will increase with the additional demand. Whereas congestion is expected to end between 7:00 p.m. and 8:00 p.m. during peak Sundays with the completion of the Twin Tunnels widening project, it is expected to extend to 9:00 p.m. in Year 2015 and beyond 10:00 p.m. by Year 2035. In order to shorten the peak period duration and improve travel times, additional improvements along this segment of eastbound I-70 will be required.



Source: I-70 Peak Period Shoulder Lane Traffic Analysis Feasibility Study, ATKINS, 2013

Figure 2-5: Eastbound I-70 Speeds for Year 2015 and 2035 Conditions

2.5.2 CTMC Operations

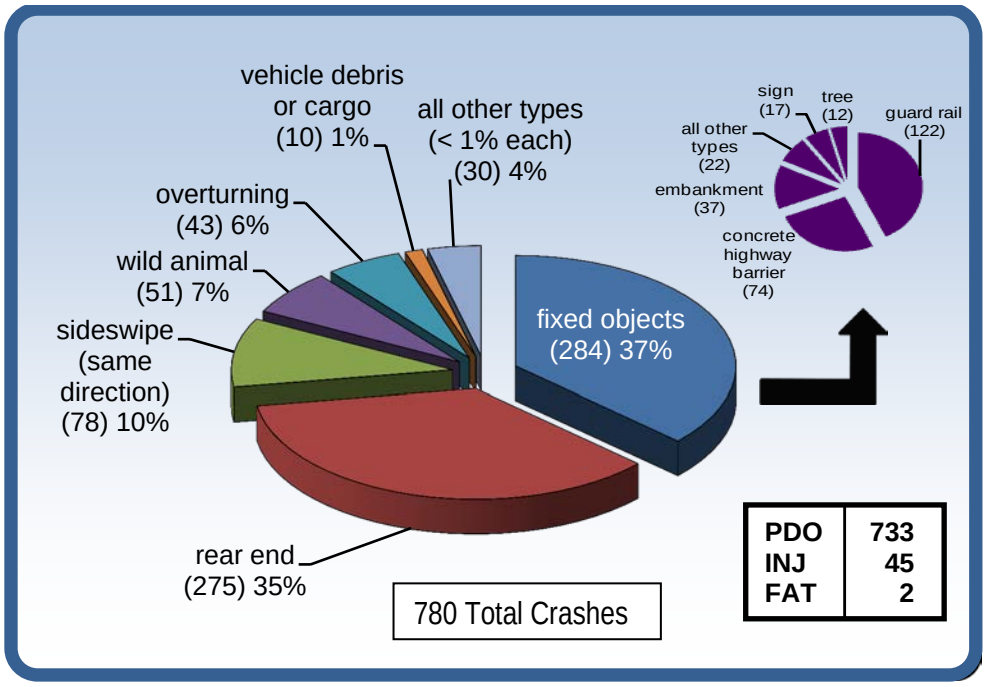
The CTMC is responsible for operating ITS devices throughout the entire state, and will be responsible for the additional proposed ITS devices to be installed for this project. Across the nation, ITS field devices are being installed at a faster rate than budgets for operating and maintaining the devices can keep up, and Colorado is no exception. The CTMC continually strives to improve efficiency, but would likely be burdened by the operation of any new systems without increased levels of staffing.

2.6 Safety Assessment

Under a separate study[1], crash history was evaluated for the five-year period, January 1, 2008 through December 31, 2012, between I-70 MP 230.00 and MP 242.00 to locate crash clusters and identify crash causes. There were 780 crashes reported within the study segment, and the most predominant crash types were fixed object type crashes (concrete barrier, guard rail, embankment and walls), rear end type crashes, and sideswipe same direction type crashes. These crash types comprise approximately 82

[1] I-70 Peak Period Shoulder Lane Safety Assessment, FHU, 2014

percent of the crashes along the corridor. A breakdown of the crash type distribution for the study is included in Figure 2-6.



Source: I-70 Peak Period Shoulder Lane Safety Assessment, FHU, 2013

Figure 2-6: Crash Type Distribution in 2008-2012 for I-70 (MP 230 – MP 242)

There are several factors that were determined to contribute to the cause of crashes along the study corridor. Some of the primary factors include; the horizontal curvature of I-70, travel speed, traffic congestion due to weekend traffic, and inclement weather / road conditions. For many of the crashes, more than one of these factors contributed. In order to better understand these factors and how they influenced crashes, the circumstances surrounding the most predominant three crash types along the corridor were reviewed in more detail. See separate study[1] for more detailed analysis, which break down the crash history based on directionality, season, day of week and type of crash.

The majority of the three predominant crash types on the study segment occurred during the winter season. The fixed object type crashes were more common on westbound I-70 on weekdays, while the rear end and sideswipe crashes were more common on eastbound I-70 on weekends when traffic congestion is more widespread. In fact, almost 50 percent of the eastbound rear end crashes occurred on Sundays.

In addition to the overall study, a detailed analysis was also conducted on sub segments that generally corresponded to each of the curves along the study corridor.

The following summarizes the final recommendations for the project corridor developed as a result of the safety assessment:

- Consideration should be given to installing dynamic speed monitoring displays (DSMD) to inform drivers of excessive speeds and encourage them to slow down.
- Consideration should be given to installing variable speed limit signs (VSL) within the project area and adjusting the speed limits based on road and weather conditions.

- Due to the high occurrence of crashes at night, consideration should be given to reviewing the existing lighting along the corridor to ensure that it is sufficient.
- Consideration should also be given to replacing all delineator post reflector buttons, rail reflector tabs and installing linear barrier delineation to provide better and consistent nighttime delineation throughout the corridor
- Along with any reconstruction work, "Safety Edge" methods should be used when paving the shoulders where the guardrail is not against the paved shoulder to help make it easier for vehicles to reenter the roadway in a controlled manner. "Safety Edge" can be found in Chapter 4 of the CDOT Roadway Design Guide.
- Consider installing rumble strips along the westbound outside shoulder which could help to reduce the number of run-off-the-road crashes along the corridor.
- Due to the frequency of wildlife type crashes, consideration should be given to installing wildlife warning signs with flashing beacons in the westbound direction near MP 233 and MP 242.
- Eastbound to Northbound Loop Ramp at Empire Junction (US 40) Interchange
    - Consideration should be given to adding additional signing to warn drivers of the sharp curve, or consider installing dynamic speed monitoring displays (DSMD) to inform drivers of excessive speeds and encourage them to slow down.
    - Consider clearing some of the vegetation off the right side of the ramp to make the sharp curve ahead more visible to drivers.
- Consider adding signing warning of congestion ahead before MP 232 in the eastbound direction.
- Finally, the construction of an eastbound peak period shoulder lane should help to reduce congestion and will likely help to reduce the number of rear end type crashes occurring in the eastbound direction.

2.7 Project Constraints and Assumptions

2.7.1 Operational Focus

The intent of this project is to make interim operational changes that improve mobility, without major infrastructure improvements. For example, it would be outside of the scope of this project to add 12 feet of pavement width along the entire length of the project for an additional lane.

2.7.2 Financial Limitations

The project is anticipated to be funded at approximately $35.6 million, with the following breakdown:

- $ 3.3 million Colorado Bridge Enterprise (CBE) funding
- $32.3 million non-CBE Funding

2.7.3 Schedule Limitations

In order to capture all the necessary funding, the following project milestones are anticipated:

- October 2013 - Draft Concept of Operations
- November 20, 2013 - FIR Plans
- May 14, 2014 - FOR Plans
- July 17, 2014 - Project Advertisement

2.7.4 Physical Limitations

The right-of-way for I-70 through the project limits is very narrow. In addition to a narrow median, the ability to build additional width is limited on the outside by rock slopes to the north and Clear Creek to the south. Several narrow bridge structures within the project limits also restrict the ability to increase the section width.

2.7.5 Context Sensitive Solution (CSS) Evaluation Criteria

The CSS process is defined by FHWA as a collaborative, interdisciplinary approach that involves all stakeholders in developing a transportation facility that complements its physical setting and preserves scenic, aesthetic, and historic and environmental resources while maintaining safety and mobility. With this process in mind, the technical team created the flow chart included in Appendix A to assist the technical team in translating core values and critical issues into actual evaluation criteria for the project, and to ensure the development of a design with features that fit into the I-70 mountain corridor.

3 System Overview

Section 3 provides an overview of the proposed PPSL concept, including discussion about other effective implementations and how they will be applied to the goals and context of this specific project corridor.

3.1 Project Goals and Objectives

The primary goal of the proposed concept is to improve mobility through the project corridor during peak periods, while maintaining safe operations and a context sensitive solution. A series of technical team meetings were held to collaboratively develop the design concept with input from all the stakeholders. The CSS evaluation criteria described in Section 2.7.5 were utilized throughout the concept development process as a guideline to compare against.

3.2 State of the Industry

3.2.1 UK Experience with Hard Shoulder Running (HSR)

3.2.1.1 Example

Over the last decade in the UK, the concept of Active Traffic Management (ATM) has developed to address traffic issues associated with the growing levels of congestion. In September 2006, the HSR concept was introduced on the M42 motorway in Birmingham, UK, between Junctions 3A and J7.

ATM (known as smart motorways in the UK) utilizes many existing and established highway technologies, which are presented in Figure 3-1. Key features include the use of the shoulder lane as an additional travel lane, Lane Use Signals (LUS) installed above each lane displaying the Variable Speed Limits (VSL), and emergency pull-outs for use in the event of a breakdown or emergency during HSR.

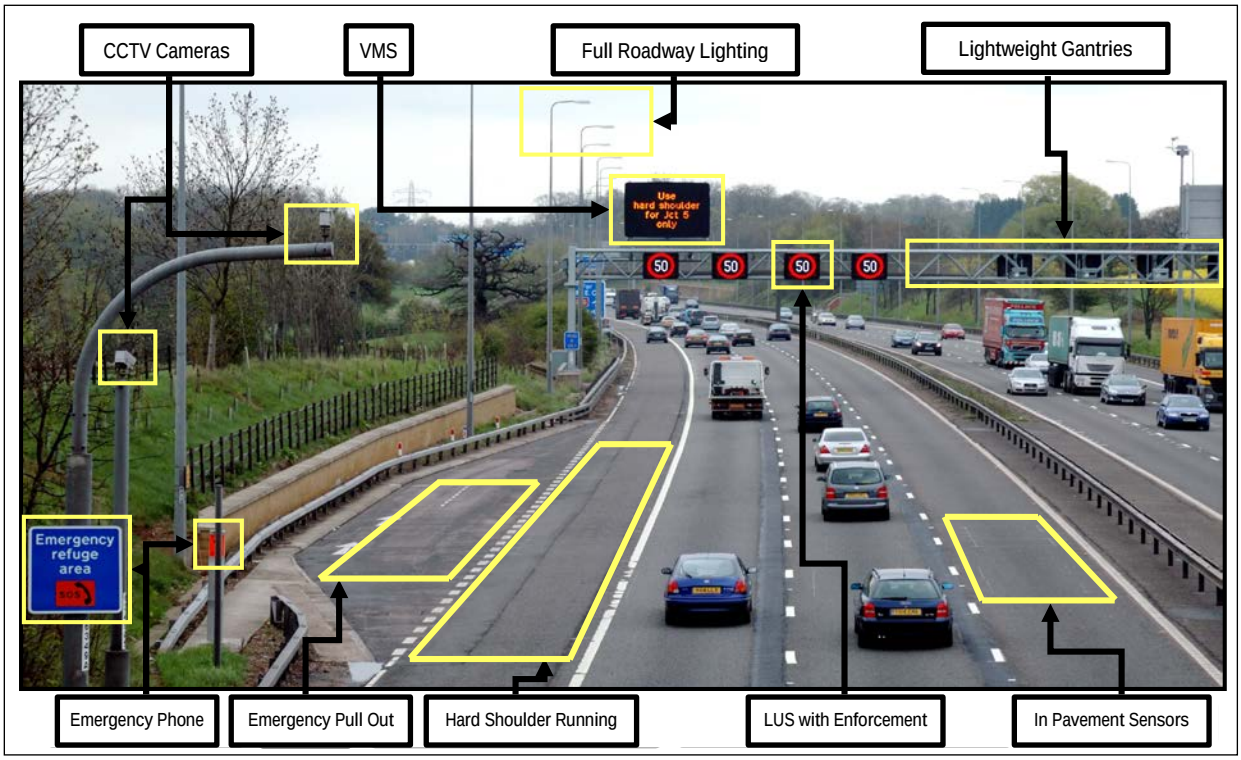


Figure 3-1: Components of a Typical UK Managed Lane

The standard lane width on a UK highway is 12 feet (3.65m), but lane widths are modified to between 10 feet and 12 feet to widen the shoulder lane for use as a travel lane.

Operational aspects

One of the aims of ATM in the UK is to smooth traffic flow during periods of congestion by using VSL to reduce the differential speed between lanes (i.e. more uniform flow). The settings and timings for the VSL signs are set in accordance with pre-determined thresholds and calibrated on a link-by-link basis, based on real-time traffic data. Highways Agency Digital Enforcement Camera System (HADECS), which are purpose-built enforcement cameras, are also in place to enforce the mandatory speed limits.

Prior to the opening of the shoulder lane, 3-Lane Variable Mandatory Speed Limits (3L-VMSL) is implemented to control flow through heavily congested sections of the roadway, without the use of the shoulder as an additional travel lane. 3L-VMSL operates automatically, although control room operators are able to intervene if necessary.

4-Lane Variable Mandatory Speed Limits (4L-VMSL) is implemented after 3L-VMSL has been implemented and the shoulder lane has been cleared as safe to be opened. When HSR was first introduced in the UK, a maximum 50 mph speed limit was introduced across all lanes of the smart motorways section of the M42 (reduced from the national speed limit of 70 mph for limited access freeways). After extensive monitoring and evaluation of the hard shoulder as a travel lane, HSR up to 60 mph was introduced in 2008 and has been the standard for ATM since that time.

3.2.2 Comparison of Standard Practices

Overall, the introduction of PPSL in various countries has been effective in addressing congestion concerns, providing additional road capacity and improving travel times (associated with improvements in traffic speeds) in an effective and efficient matter. The key features and observed benefits from a selected number of projects have been summarized in Table 3-3.

Table 3-3: Comparison of PPSL Projects in Various Countries

	UK	Netherlands	Germany
Emergency Pull-Outs	Every 1/3 to 1/2 mile	Every 1/2 mile	2/3 mile
Vehicle Detection	MIDAS loops every 1/3 mile (330 ft for M42 Pilot)	Every 1/3 mile for GP lanes, every 250 ft on the shoulder	Every 2/3 mile
Lane Widths	Standard highway: 12 ft HSR sections: Variable across lanes (10.5-12 ft)	12 ft	Standard motorway: 12.5 ft Minimum lane width: 10.5 ft (11.5 ft for heavy vehicles)
Gantry (sign bridge) Spacing	1/3 mile on M42-MM 1/2 to 2/3 mile	< 1/2 mile	2/3 mile
Operating Speed	No-HSR: 70 mph During HSR utilizes three speed limits (60 mph, 50 mph and 40 mph)	No-HSR: up to 80mph for highways, 60 mph for national roads During HSR utilizes three speed limits (55 mph, 45 mph and 30 mph)	No-HSR: 75 mph During HSR: between 60 mph and 80 mph
Travel Times	22% improvement	4% improvement (1-2 minutes/mile)	20%
Increased Capacity	7-9% (HSR at 50 mph)	7-22%	25%

Each project demonstrates improved traffic conditions when compared to the non-managed cases; however, there were instances where the benefits were not realized on all sections within the same project.

3.2.3 Tolling

The left, eastbound shoulder lane will be tolled when the PPSL is operating in order to manage demand and capacity. This section provides a high-level description of tolling alternatives, technologies, and the operational scheme.

3.2.3.1 Design Considerations

During periods of traffic congestion, the left shoulder of eastbound I-70 will be opened to traffic and operated as a tolled lane. Referred to as "hard shoulder running", this scenario is becoming general practice throughout the United States. There are three general design considerations that will comprise the PPSL: lane separation treatment; access (type and location), and lane signing and striping.

Separation Treatment – The MUTCD identifies three types of separation treatment for managed lanes: barrier-separated, buffer-separated and contiguous. Each treatment is described as follows, and depicted in Figure 3-2.

- Barrier-separated facilities use a physical barrier such as a concrete barrier or pylons to separate the tolled lanes from the general purpose lanes. The I-25 Reversible Express Lanes segment north of Downtown Denver and on US 36 between I-25 and Pecos are examples of barrier-separated facilities. A barrier separation was not considered for the PPSL given the interim nature of the project and the fact that the tolled lane is the shoulder when the PPSL is not in operation.
- Buffer-separated facilities use pavement markings and a buffer space, as opposed to a physical barrier, to delineate between the managed and GP lanes. This is the most common type of separation. The width of the buffer space can vary depending on the available pavement and right-of-way. For example, the US 36 Managed Lane will consist of a 4-foot striped buffer while the North I-25 Managed Lane from US 36 to 120th Avenue will provide a 2-foot striped buffer.
- A contiguous condition exists when the managed lane is directly adjacent to the GP lanes with only the width of the pavement markings separating the managed lane.

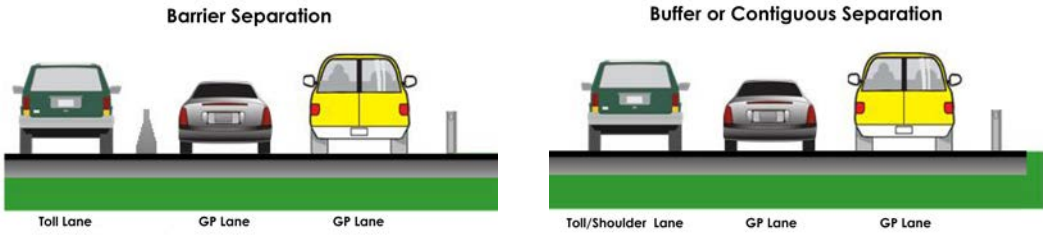


Figure 3-2: Separation Treatment Alternatives

Access

Access refers to the ability to ingress and egress (enter and exit) a managed lane. Access is a key design component of managed lanes, safely and efficiently guiding users in and out of the facility at desired locations. Access zones should be placed at logical points based upon trip origins and destinations, Traffic and Revenue Studies, geometric constraints and safety considerations. The frequency of access zones should consider the travel demands of the area, pricing strategy for the managed lane, length of managed lanes, and other factors.

Access types may consist of ingress only, egress only, or combined zones. There can be a mix of types within a given facility as desired.

As a general guideline, a minimum weave distance of 800 feet per lane should be given from the on-ramp to the start of an access zone, or from the end of the access zone to the next off-ramp. The FHWA recommends 600-800 feet per lane, while California recommends a minimum of 800 feet. A distance of 750-800 feet per lane change has generally been used on recent CDOT projects.

Recent published guidelines of managed lanes show a trend toward longer access zones and longer weave areas. Access zones should be 1,000 feet long at minimum and preferably 2,000 feet or longer, using a white broken 8-inch stripe as a divider to encourage ingress and egress to and from the PPSL. The state of California is now transitioning to a minimum 2,000-foot opening due to recent safety studies.

The access zone lengths mentioned above are minimum guidelines. Access zones can vary in length and be much longer depending upon the interchange density, roadway geometry, and desired operational scheme. For example, an access zone of 2500 feet or more may be used to spread out the weaving of vehicles and alleviate an otherwise concentrated access points. Some facilities have continuous access zones in which vehicles may enter and exit the managed lanes at any point.

Signing and Striping

Signing refers to the messaging used to convey regulations, warnings, guidance and current traffic conditions to road users. With respect to the PPSL, messaging will be essential to notify users of the:

- Limits of the toll lane
- Status; open or closed
- Lane eligibility and restrictions
- Price to utilize the toll lane
- Payment methods
- Destinations and allowable ingress and egress locations

Signage can be static (using fixed messaging) or dynamic (using electronic means to vary messaging). Commonly a mix of both static and dynamic signage is used for tolling.

The signing alternatives and concepts are discussed in detail in Section 4.2.2.

Striping refers to the pavement markings that delineate the freeway lanes, entries and exits. A detailed description of the striping concept can be found in Section 4.2.1.

3.2.3.2 Pricing Concepts

Static Pricing – A single, fixed price is charged regardless of congestion.

Variable Pricing - Price is based upon time of day for each day of the week, although in some circumstances it may also be established for certain days of the month or year.

Dynamic Pricing - Different price levels are triggered by traffic flow thresholds using real time traffic detection equipment. Prices fluctuate based on actual traffic conditions in the managed lane in order to maintain free flow speeds. While dynamic pricing is not intended for use during the initial implementation, it is possible that future traffic growth might make it a viable option.

3.2.3.3 Segmenting

Segmenting refers to dividing the toll lane into logical pieces to allow for access and destinations based upon user need. This important facet of managed lanes helps define the pricing scheme.

The PPSL could be treated as a single segment or divided into multiple segments that comprise the toll system. Segments should be derived from trip origin and destination needs and guided by the desired outcomes of the system, such as maintaining safety and maximizing the efficiency of the segment. The project area will have two types of lanes; GP and tolled. The two GP lanes will provide a non-tolled means of travel, along with access to and from interchanges within the corridor. The tolled lanes will be available during peak periods only; drivers may elect to use the toll lane during peak travel periods depending upon their willingness to pay for available capacity. Toll segmenting for the PPSL is detailed in Section 4.1.2.

3.2.3.4 Toll Rates

Toll rates are the prices that are charged for the segment(s) of the tolled facility. As mentioned, they may be fixed, variable by time-of-day, or dynamic based upon prevailing congestion. The rates should be determined through a pricing model as part of a Traffic and Revenue Study. Rates are set according to demographics and willingness to pay for capacity. The pricing models aim to achieve the desired lane use in order to keep the lane operating at a speed of 45-mph, typically. Based upon traffic engineering principles, that is the speed where you can maintain the highest volume and density (spacing between

vehicles) without experiencing congestion and compromising safety. Rates are expected to be refined and adjusted as necessary to meet the objectives of the system.

3.2.3.5 Enforcement

The goal of enforcement is to ensure safe operation throughout the corridor, while helping to maintain the desired speeds in the managed lane during the designated hours of operation. Toll payment and eligibility will not be an enforcement focus since virtually all users will be assessed a toll; very few vehicles will have exempt status. Enforcement efforts would focus on traffic violations, such as speeding, driving too fast for conditions, vehicles crossing the separation treatment when the PPSL is operational, and vehicle driving in the shoulder when the PPSL is closed.

All motorists using the managed lanes must properly pass through the tolling point, whether paying the toll or eligible for toll exempt status. The managed lane will not have a physical barrier separating it from the general purpose lanes, so vehicles could avoid paying the toll by bypassing the tolling point in the GP lanes and then reentering into the toll lane beyond the tolling point. Regulatory signs installed along the roadway may be installed to notify drivers that they are prohibited from crossing the solid white line when the PPSL is open.

To mitigate attempted willful violation, multiple toll points will be installed along the project corridor irrespective of the pricing scheme. The frequency of toll read points will ensure there are no long gaps in the toll lane where a toll tag transponder would not be read or a license plate image would not be captured.

On-site presence of a patrolling enforcement officer is the most effective means of enforcement, as automated means of enforcement are not available. CCTV surveillance could be used to review the frequency of violations (i.e., monitoring vehicles illegally crossing the separation treatment) and to determine specific areas for enforcement. Targeted enforcement by CSP or other local law enforcement agencies will be recommended by the project team and implemented by law enforcement as deemed appropriate.

3.2.3.6 Tolling in Colorado

There are several tolled facilities within the State of Colorado. Some are toll-only facilities and others are managed lanes allowing free use for carpools and tolling single occupant vehicles.

The toll-only facilities in Colorado include E-470 and the Northwest Parkway in the Denver Metro Area.

The other existing facility is the I-25 Reversible Lanes which tolls Single Occupancy Vehicles (SOV) and exempts High Occupancy Vehicles (HOV). Two other upcoming managed lanes projects include the north I-25 Express Lanes (extending north from US 36 to 120th Avenue) and the US 36 Managed Lanes (between I-25 in Denver and Foothills Parkway in Boulder).

3.2.4 Safety

3.2.4.1 Safety Findings for Similar Installations

While overall experience utilizing shoulders as additional travel lanes in the United States has been positive, research regarding documented safety benefits has been inconclusive. Factors that make it difficult to identify safety impacts include the small number of available sites with the treatment, the complexities due to unique geometries of each implementation, the limited number of years each treatment has been in use, the anticipated small magnitude of the safety effects, and the limited number of crashes associated with each specific treatment.

In Europe, part-time shoulder use is a congestion management strategy typically deployed in conjunction with complementary traffic management strategies such as speed harmonization and/or ramp metering. The intent is to reduce the speeds differentials along a corridor and reduce the likelihood of collisions. European agencies have realized both safety and mobility benefits as a result of these projects.

The following describes specific elements of implementations in both the United States and Europe.

I-35W (Minneapolis, Minnesota) – A segment of the left shoulder on I-35W has been converted to a priced dynamic shoulder lane open to all vehicles. Although safety statistics are not available, Mn/DOT personnel believe the facility is operating safely and as planned. Early results from variable speed limits in Minnesota show increased mobility, throughput, and safety resulting from improvement in the speed differentials approaching congestion and reduced shockwaves.

I-35, Minneapolis

I-66, Virginia

I-66 (Northern Virginia) – The segment of I-66 between US 50 and I-495 has been converted to include an HOV lane and a shoulder lane. Models associated with the project found no evidence that crash frequency was affected by any of the following factors when aggregated across all lanes: managed-lane strategy during peak hours, AADT volumes, merging and diverging influence areas, weather, light conditions, and existence of pull-off areas.

California – The safety effects of narrow lanes and shoulder use lanes were investigated using 490 sites in California where the freeway was converted from four to five lanes or five to six lanes. The evaluation found that projects converting four lanes to five lanes resulted in crash frequency increases of 10 to 11 percent. However, the observed increase could also be a result of the speed differential introduced by added HOV lanes. Also, the analysis results suggest that despite increasing crash frequencies within the project limits, crash frequencies upstream of the project may be reduced.

The Netherlands – Hard shoulder running is only deployed in conjunction with speed harmonization in the Netherlands. With implementations on six freeways, the Dutch have seen a reduction in incidents between 10 and 48 percent.

Germany – Hard shoulder running is also only deployed in conjunction with speed harmonization in Germany. Facilities with speed harmonization have seen a reduction of up to 29 percent in crashes with injuries, a reduction of up to 27 percent in crashes with heavy material damage, and a reduction of up to 3 percent in crashes with light material damage.

M 42 (Great Britain) – In Great Britain, M 42 combines speed harmonization with hard shoulder running. During the first 36 months of operations there was a reduction in personal injury accidents from 5.08 to 2.25 per month (55 percent) and a reduction in the “accident severity index” (ratio of fatal and serious accidents to all accidents) from 0.16 to 0.07 (54 percent).

3.2.4.2 Safety Concerns with PPSL

When comparing the proposed I-70 PPSL with other projects in the United States and Europe, significant differences should be kept in mind. These include:

- Other implementations generally address weekday peak period congestion concerns and therefore have everyday commuters that become very familiar with their operation and requirements.
- When the shoulder is used as a travel lane, it will be tolled. When the hard shoulder is free and open to all vehicles, there is more potential for vehicles to weave in and out of the shoulder lane which helps to reduce speed differentials between lanes, but increases the likelihood of crashes due to these maneuvers.
- The safety shoulder (during off-peak periods) will be on the left side of the freeway, whereas the normal location in the United States is on the right side.
- The PPSL will transition to the permanent third lane that has been constructed beginning at the East Idaho Springs Interchange, which means there will be no downstream bottleneck that might lead to crashes migrating from one section of the corridor to another.
- Only limited speed limit enforcement will be possible due to the high volumes and limited space for enforcement activities.
- The project will not utilize gantries that span all lanes and have specific dynamic message signs over each lane to inform motorists of speed limits and whether the lane is open to traffic.

Safety Analysis of Geometric Changes – The Highway Safety Manual (HSM) discusses crash modification factors which quantify the change in expected average crash frequency at a site caused by implementing a particular treatment, design modification, or change in operations. Four separate calculations were made using individual crash modification factors to analyze the total number of crashes during both off-peak and peak periods, and the number of single vehicle run off the road crashes during both off-peak and peak periods. As a result of these calculations, it was found that there is the potential for an additional 7.6 crashes per year related to geometric changes associated with the project.

Safety Analysis due to Congestion Reduction – A recent research paper prepared by CDOT staff members suggests that during hard shoulder running crash rates decline because of the lower traffic volume or density per lane. The I-70 Mountain Corridor was analyzed in this paper and it was forecasted that a decrease in total crashes of approximately 53 percent on Sundays would be seen as a result of PPSL implementation; an annual decrease in crashes due to congestion reduction would be between 9.4 and approximately 12.8.

When the forecasted crash reductions due to congestion relief are combined with the previously discussed increase related to geometric changes, the analysis shows an annual decrease of between 1.8 and 5.2 crashes. Therefore, the PPSL project should not result in a net increase in crashes, and, furthermore, it is likely that there could be a moderate decrease in crashes for eastbound I-70 traffic.

3.2.4.3 General Safety Observations Concerning PPSL Elements

While overall the conclusion is that the proposed PPSL project will not result in a decrease in safety, there should still be comprehensive monitoring of both peak and off-peak operations after implementation. The following discussion provides a qualitative assessment concerning the potential impacts to safety of various design elements and measures that should be included in the design of the PPSL that minimize potential adverse safety impacts.

Merge and Diverge Areas – Since the PPSL is on the left side, there will be no changes to how on-ramps and off-ramps operate between peak and off-peak conditions. Thus, the safety characteristics of these should remain the same as currently, with some possibility for minor improvement.

Intermediate Access and Egress Points – The number of access points should be limited in order to reduce the chance for the conditions that have been found to cause crashes at access points on buffer separated HOV lanes in Texas and California.

Variable Speed Limit (VSL) Signs – VSL signs are an important safety consideration and should be utilized through the PPSL corridor. They will serve to moderate speed differentials and harmonize traffic between the managed lane and general purpose lanes. Based on on-going experience once the PPSL is operational, a differential of up to 15-20 mph should not present undue safety concerns, especially with minimal lane changing.

Emergency Pull-outs – The number of emergency pull-outs and off-ramp locations should minimize disturbances to peak traffic operations due to breakdowns. The average spacing for emergency pull outs or interchanges is approximately 1 mile.

Monitoring of Operations by CDOT Staff – The PPSL corridor will have complete video coverage by closed circuit television cameras (CCTV). This will allow personnel at the CTMC to monitor traffic flow when the managed lane is operational.

Signs – The signing associated with the PPSL will be a critical component of the traffic control and operations of the lane.

Opening Procedures – The PPSL should only be opened after it has been determined that the shoulder lane is clear of stationary vehicles, debris, standing water, and snow.

Emergency Response – The project team has closely coordinated with emergency service providers in Clear Creek County, and a summary of emergency response procedures has been prepared.

3.3 Other Project Considerations

3.3.1 Relating the European Experience

Although the evaluation work carried out for the ATM projects in Europe has demonstrated benefits when compared to non-managed cases, the greatest benefits were realized when speed harmonization and automated speed enforcement were implemented along with hard should running. In Colorado, however, the legislature does not currently allow for automated speed enforcement in conjunction with variable speed limits on freeways.

3.3.2 Education and Outreach

User preference surveys conducted in the UK for the HSR projects have identified that despite its benefits, some motorists are reluctant to use the hard shoulder. The key issues appeared to be:

- On-going concern about availability of emergency refuge areas
- A need for more advance notice of changes in lane use
- Lack of confidence in variable speed limits

All three issues are related to familiarity with the system, and as such user acceptance may grow with time and perhaps with additional driver education.

3.3.3 Operations

HSR projects rely on a wide range of ATM systems and supporting ITS used for monitoring traffic flow, clearance of hard shoulder, and incident detection. While this technology is essential to the successful deployment of an HSR project, the additional workload on maintenance personnel and TMC operators due to the implementation of new field infrastructure must be considered.

4 Operational and Support Environment

Section 4 describes the technical details and the decision-making process for the preferred PPSL concept.

4.1 Traffic Operations

4.1.1 Typical Section

A series of meetings were held with the project technical team to develop the requirements for the typical roadway cross-section, which will be used to provide for safe operations and a context sensitive solution. The existing eastbound I-70 roadway section through the project limits varies from approximately 37 feet to 40 feet. The proximity of Clear Creek to I-70 within the project limits suggests that a narrow typical cross-section will have the least environmental impacts. This approach also follows the interim nature of the project. In order to minimize any negative impacts to safety along the corridor due to a narrow cross-section, the project technical team established the minimum lane and shoulder width requirements shown in Table 4-1.

Table 4-1: Minimum Lane and Shoulder Widths

Element	Minimum Width	Source
Left Shoulder (inside)	1 ft.	Safety Analysis
All Travel Lanes	11 ft.	FHWA Requirement, Safety Analysis
Primary Commercial Vehicle Lane	12 ft.	CMCA, Safety Analysis
Right Shoulder (outside)	4 ft.	FHWA Requirement

The most common type of separation treatment for managed lanes in Colorado is to create a buffer area with pavement markings, as opposed to a physical barrier. The width of the buffer area can vary depending on the available pavement and ROW. In keeping with the goals of an interim solution and due to the geometric constraints within the project limits, the recommended separation treatment between the PPSL and the GP lanes is only the width of the pavement markings.

Based on the requirements established above, the minimum typical cross-section recommended by the project team is depicted in Figure 4-1. This cross-section should be applied as a minimum template for the project corridor; however, a wider cross-section may be used as right-of-way allows and exceptions may need to be evaluated for short stretches with tighter geometry.

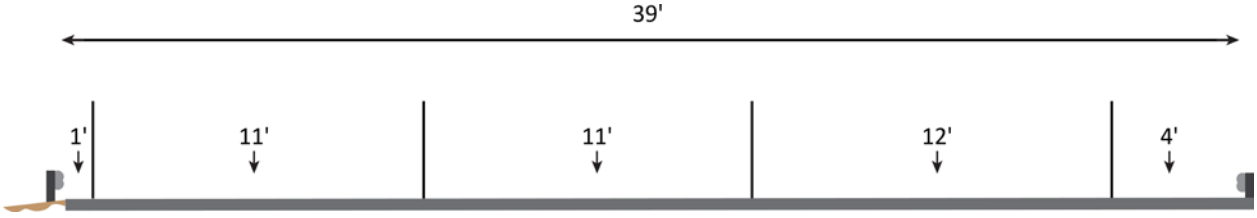


Figure 4-1: Minimum Recommended Typical Cross-Section

With the typical cross-section established, a determination had to be made as to which lane would be managed (tolled) during peak periods and which lane would serve as the full shoulder (breakdown area) during the off-peak periods.

Considering driver expectancy and the higher anticipated speeds, it was determined that the tolled lane would operate most safely and efficiently on the left side (inside) of the roadway. With this in mind, the project technical team evaluated the operation of a left-side versus right-side PPSL, and developed Table 4-2 to show the pros and cons of each alternative.

Table 4-2: Left-Side vs. Right-Side PPSL

	Pros	Cons
Left	● Managed lane clearly defined ● Consistent operations peak and off peak ● Reduces signing ● Ability to add rumble strip between GP and ML ● 12' lane is on the far right used by trucks	● Shoulder is wider on the left during off peak periods (unconventional)
Right	● Breakdown lane is on the right side of the roadway ● PPSL lane would be a continuous add lane at US 40 interchange	● Increases signing ● Managed lane is not clearly defined ● Peak and off peak operations differ ● 12' lane is in the middle, meaning you will need to pass trucks on the right ● Trucks have to weave right to reach port of entry ● No opportunity for rumble strip ● Inattentive drivers may end up in ML

Source: I-70 Peak Period Shoulder Lane Left vs. Right Side Operations, HDR White Paper

General driver expectancy would suggest that the right-side PPSL would provide a more standard break-down area during the off-peak conditions, but this option would create several operational concerns that the project team had to consider. With a right-side PPSL, the traffic in the GP lanes would have to shift one lane to the right during peak periods in order to operate the left-side toll lane, requiring extra signing and additional merging conflict points. The freeway ramps would also tie into the travel lanes at a different point during the peak and off-peak periods, creating potentially unsafe conditions. In order to allow slower moving commercial vehicles to operate in a full 12-foot lane and to stay to the right during both peak and off-peak periods with a right-side PPSL, the minimum cross-section (Figure 4-1) would have to be widened by one foot to accommodate the second 12-foot lane.

Through the evaluation of these operational concerns, lessons learned from other states, meetings with the emergency responders within the project limits, and the commercial vehicle operations representatives, it was determined that the left-side PPSL was the preferred alternative. Figure 4-2 depicts the typical cross-section and lane assignments for the preferred alternative.

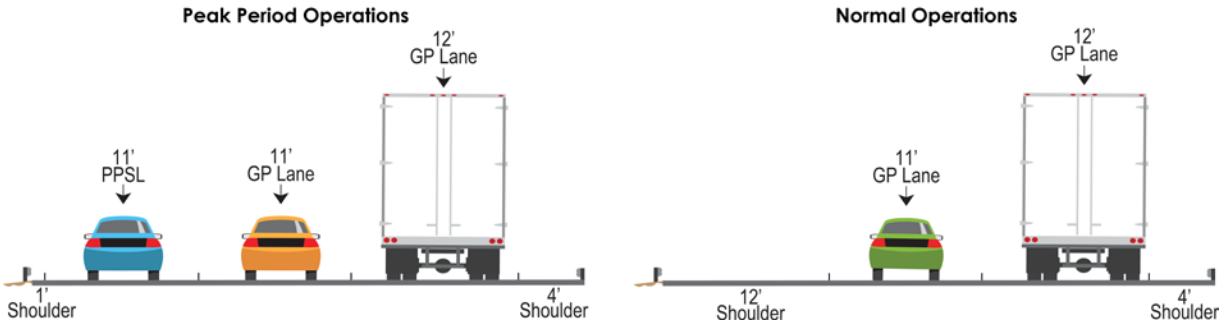


Figure 4-2: Typical Cross-Section with Lane Assignments

4.1.2 Peak Period Shoulder Lane (PPSL)

The proposed PPSL will utilize the inside shoulder of eastbound I-70 for hard shoulder running from US 40 to the tie-in point with eastbound I-70 widening at the Twin Tunnels. The PPSL lane will be tolled during peak periods of travel, and will function as a shoulder for emergency stopping during the off-peak periods.

Motorists will be able to operate in the PPSL continuously from beginning to end; however, intermediate access zones to accommodate ingress and/or egress movements were also considered. Access is a key design component of any type of managed lane, helping to safely and efficiently guide users in and out of the facility at desired locations. Access zone locations are determined based on the travel demands of the area, pricing strategy for tolled lanes, length of tolling area, and other factors.

In order to maintain free flow operations and minimize weaving/merging movements with the anticipated speed differential (see Section 4.1.5), no intermediate access zones are recommended between US 40 and the east side of Idaho Springs. However, an ingress-only access zone will be required between the east Idaho Springs interchange (Exit 241) and the Twin Tunnels, allowing entrance into the full-time managed lane that will continue to operate from the Twin Tunnels to US 6 when the PPSL is not in operation. Figure 4-3 shows a preliminary conceptual layout of the access zones within the study area.

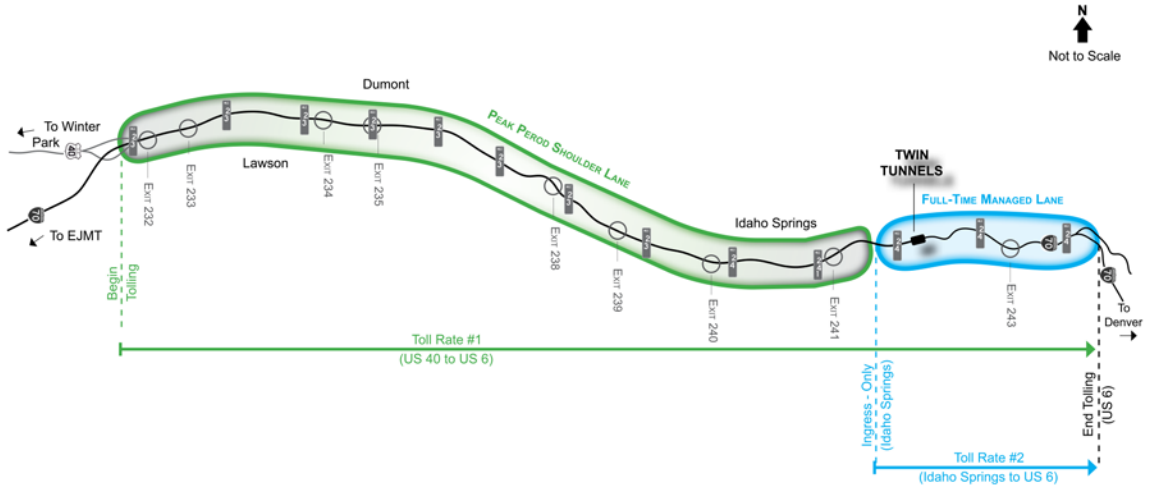


Figure 4-3: Tolling Segments and Access Zone Locations

In addition to general placement within the corridor, consideration must be given to the detailed layout of the individual access zones. It is recommended that each access zone is a minimum of 2000 feet in length, with a minimum separation distance of at least 1600 feet between the access zone and an upstream on-ramp or downstream off-ramp. These requirements have been found to provide adequate distance for vehicles entering and exiting the facility to safely maneuver to/from the access zones, but longer distances are desirable if they can be accommodated. See Figure 4-4 for a conceptual layout of an access zone.

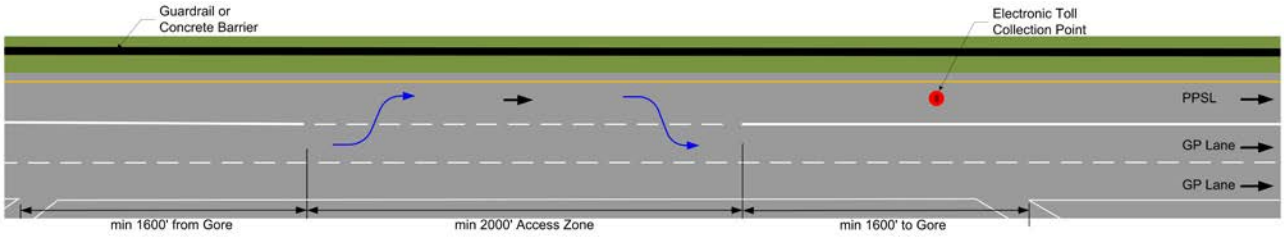


Figure 4-4: Access Zone Conceptual Layout

While Figure 4-4 shows a combined ingress/egress zone, access zones should be designed as ingress-only or egress-only for this project in order to reduce potential conflict points. The exact placement of the toll point relative to each access zone will be determined during the detailed design.

4.1.3 Emergency Pull-outs

Emergency pull-outs are essential to the reliable operation of any roadway segment that has been converted to utilize hard shoulder running, particularly in rural areas with a lower density of interchanges. The recommended spacing for emergency pull-outs (or interchanges) in this segment of I-70 is approximately every mile, and they will all be located along the outside shoulder. The initial concept for pull-out locations was presented and accepted through the CSS process.

4.1.4 Ramps

The geometry of each existing on and off ramp in the project area will need to be evaluated by the design team in order to account for the realigned travel lanes. Some widening may be required to provide adequate acceleration/deceleration length with the revised alignment.

4.1.5 Speed Limits

During peak period operations, the target speed for the PPSL will be at least 45 mph to optimize traffic flow and provide a reliable travel option through pricing. The GP lanes will likely be operating at a lower speed due to traffic congestion. Reducing the speed differential between the fastest moving traffic and the slowest moving traffic is generally found to increase safety by reducing the number of lane changes and the average crash severity. There are two main methods CDOT can actively employ to manage the speed differential between the two lane groups: toll rates and variable speed limits.

Toll rates can be set to achieve desired volumes in managed lanes, which in turn affects the speeds in that lane since speeds are related to the volume of traffic.

Variable speed limits could also be used to change the posted regulatory speed limit along the corridor. The speed limit for I-70 could be changed during PPSL operations in order to lessen the speed differential in the tolled and GP lanes.

Beyond these active methods for controlling speeds, the fact that the adjacent GP lanes will be congested and moving slowly may naturally lower the speeds in the toll lane due to driver discomfort.

Both active methodologies can be automated with algorithms based on input from field sensors; however, enforcement can be more challenging with variable speed limits and more field devices (beyond the base requirements of the PPSL project) would be required to achieve the same level of automation. Through a separate study[2], CDOT has previously investigated the potential benefits of dynamically controlling speed limits along this segment of the I-70 corridor based on traffic conditions. See Section 4.2 for more discussion on the field infrastructure required for variable toll rates and variable speed limits. For the PPSL, it is assumed that speed limits will be varied manually and not automatically.

4.2 Traffic Control

The traffic control for the proposed system will be used to clearly convey the status of the PPSL to the roadway users, so they can determine whether the shoulder is open to traffic or should only be used for emergencies. Toll rate information will also need to be provided so travelers are able to make a decision whether or not to utilize the PPSL. Once their decision is made, the signing and striping will need to guide them to enter or exit the PPSL at the proper locations. The following system elements will be utilized to accomplish these goals.

4.2.1 Roadway Striping

The PPSL will need to be separated from the general purpose lanes, which will be accomplished using pavement markings. The roadway striping will identify the appropriate locations where drivers can enter or exit the PPSL and should convey that the PPSL is a shoulder during non-peak periods. An 8-inch solid white line will be used to delineate the PPSL from the GP lanes.

Within access zones, the striping will change to an 8 inch dashed line to signify that vehicles are allowed to enter or exit. Figure 4-5 illustrates the proposed roadway striping for the PPSL at the beginning (US 40) and end (Twin Tunnels) of the PPSL segment. Because the PPSL will tie into the Twin Tunnels improvements, which includes the addition of a third lane, all three lanes will be able to continue east when the PPSL is open.

[2] *Changeable Speed Limits – Concept of Operations*, 2013 by NavJoy and Kritek

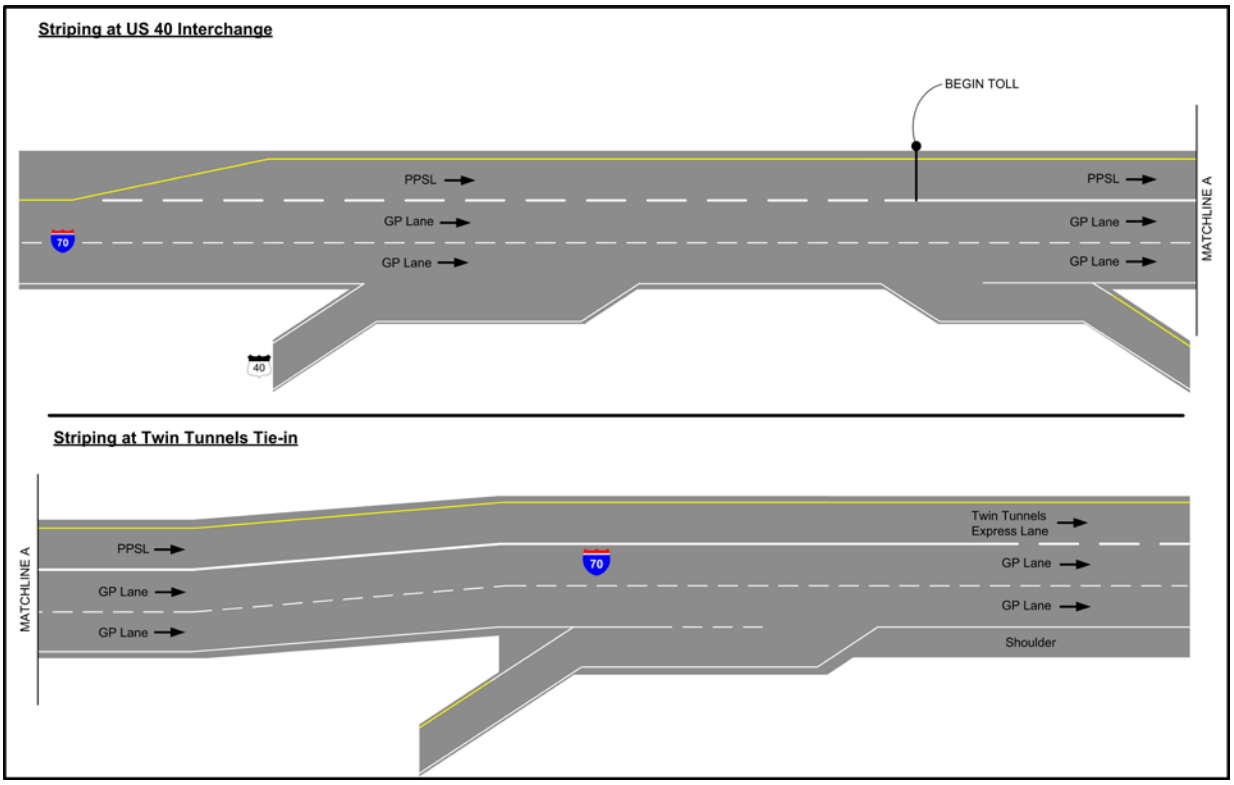


Figure 4-5: PPSL Striping Concept

There are eight interchanges between Empire Junction and Idaho Springs that will be impacted by the PPSL. The striping on the eastbound freeway ramps at each of these interchanges may need to be modified to accommodate PPSL operations. The following is a summary of the impacted freeway ramps:

- Empire Junction/US 40 (exit 232) – full movement interchange, eastbound on- and off-ramps
- Lawson (exit 233) – partial diamond interchange, eastbound off-ramp only
- Downieville (exit 234) – full diamond interchange, eastbound on- and off-ramps
- Dumont (exit 236) – partial diamond interchange, eastbound on-ramp only
- Fall River Road (exit 238) – full diamond interchange, eastbound on- and off-ramps
- West Idaho Springs (exit 239) – partial diamond interchange, eastbound off-ramp only
- State Highway 103 (exit 240) – full diamond interchange, eastbound on- and off-ramps
- East Idaho Springs (exit 241) – unique configuration interchange, eastbound on- and off-ramps

4.2.2 Roadway Signing

The signing associated with the PPSL will be a critical component of the traffic control and operations of the lane. Signing will need to clearly convey that the shoulder is only open to traffic during limited time periods, but is available for breakdowns or emergencies during the off-peak periods. Since this is an interim operational improvement, the focus of the signing will be to provide clear and concise messaging with a minimal number of signs. The following section provides an overview of the information that should be conveyed to drivers during both peak and off-peak periods, and conceptual signing layouts.

Since the PPSL will be tolled, signage will be necessary to provide toll rate information and the location of the access zones with enough advance warning to allow drivers to easily enter and exit the PPSL. Recent tolling projects in Colorado along US 36 and I-25 near Denver have included detailed coordination with

FHWA to develop the preferred signage to be used for toll lanes. Clear and consistent signing and striping will reduce confusion for drivers and minimize lane separation violations in which drivers enter or exit the PPSL at locations outside of the designated access zones. Figure 4-6 illustrates the series of signs that would be required at each ingress access zone.

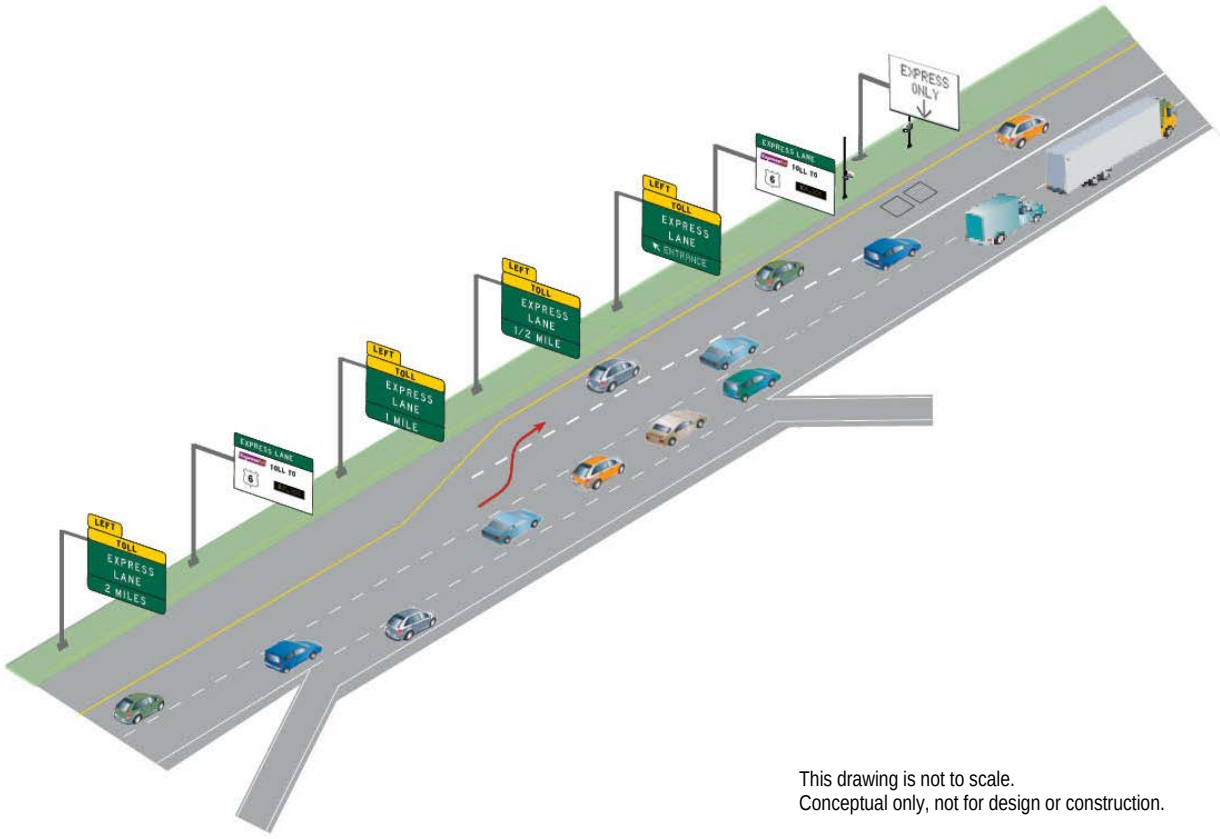


Figure 4-6: Conceptual Signing and Striping Plan for Ingress Access Zone

The signing for the PPSL will be a combination of static and dynamic signs to allow more flexible operations of the PPSL. In addition to the signing that is needed to provide toll information to travelers, lane use signals (LUS) are proposed at approximately ½ mile spacing over the PPSL only. The LUS will be used to display the status of the lane throughout the corridor and to close the PPSL for emergency responder access. The LUS are discussed in detail in Section 4.2.3. Figure 4-7 shows the proposed signing layout for key signing along the corridor when the PPSL is open and closed, respectively. Additional supplemental signs will be required (not shown in figures), but the exact details will be determined during the design.

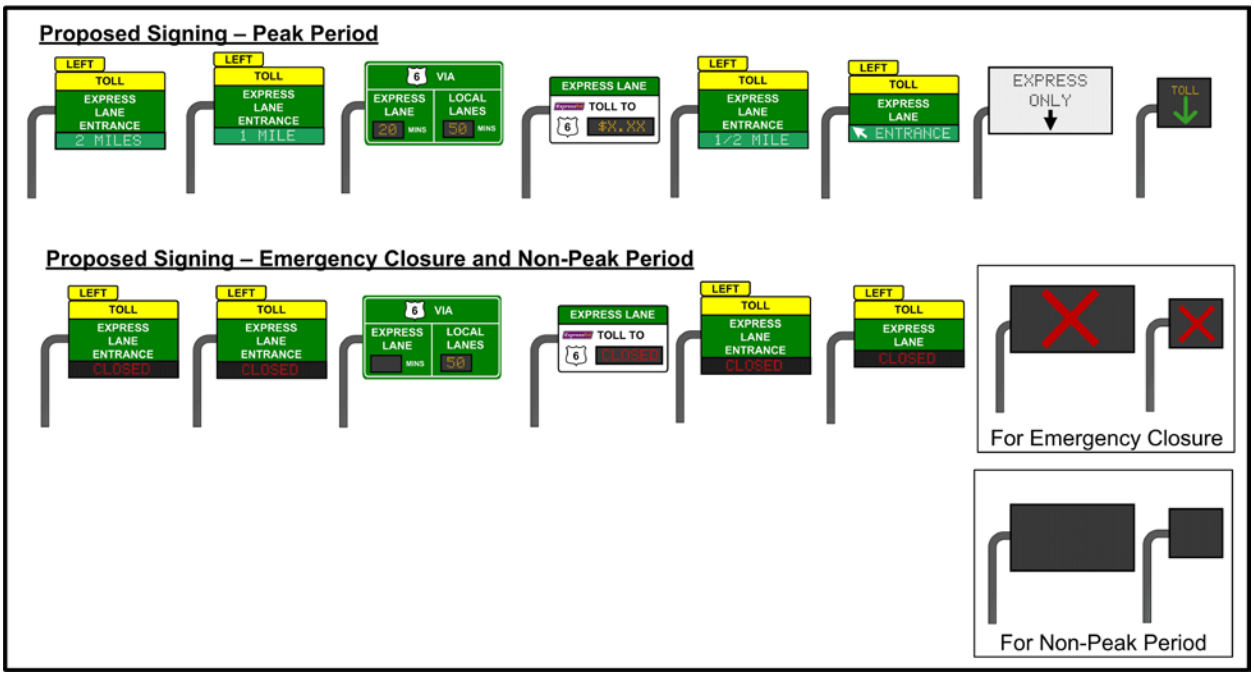


Figure 4-7: Proposed Signing Layout with PPSL Open

The signing concepts shown in Figure 4-8 were also considered as alternatives to the dynamic panels and full matrix ATM signs, but the concepts were eliminated due to the reduced flexibility for operational times and the overwhelming amount of text that had to be included on each sign to convey the appropriate messages to the motorists.

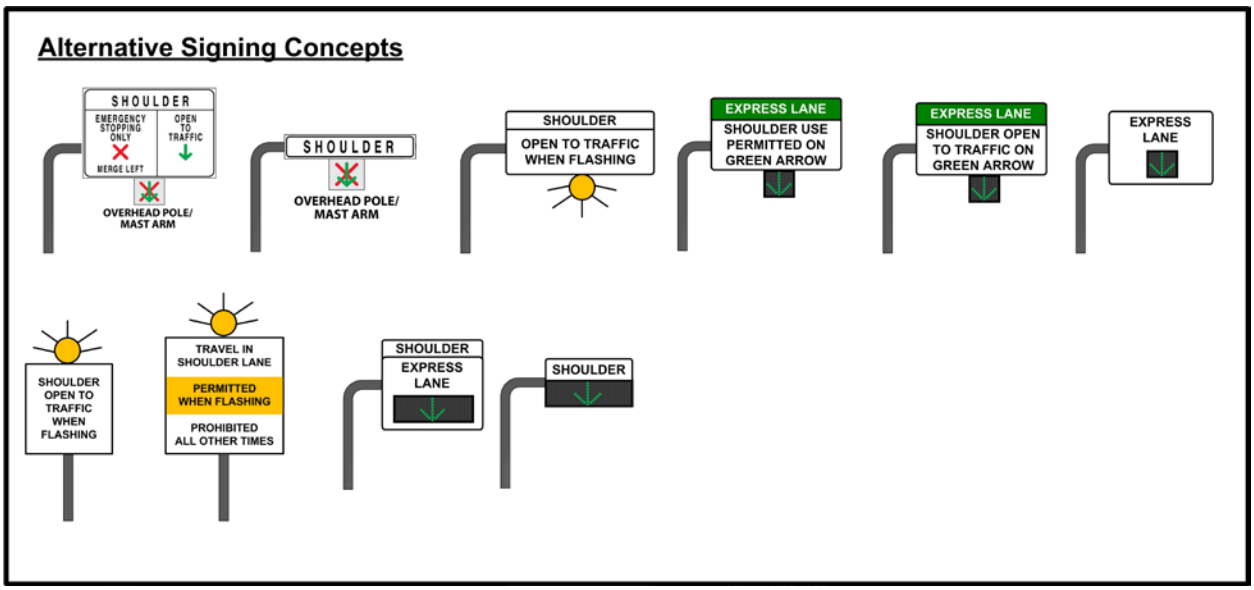


Figure 4-8: Proposed and Alternative Signing Concepts

4.2.3 ITS Infrastructure

The ITS infrastructure to be utilized for the PPSL will consist of ATM devices, which provide information to travelers; supporting ITS devices, which will monitor and collect traffic data; and ITS software, which will manage the ITS devices. ATM devices consist of those that dynamically manage traffic based on prevailing traffic conditions and disseminate information to travelers. The supporting ITS devices are used to monitor and collect real-time data on the current traffic conditions. The ITS software is the interface between the operators in the CTMC and EJMT and the devices located on the corridor. The data from the supporting ITS components will be used to measure the performance of the PPSL, make decisions on when the PPSL will operate, and automatically post travel times or other preset messages to the ATM devices. The ATM, supporting ITS devices and ITS software that will be evaluated for use with the PPSL are described as follows:

Active Traffic Management

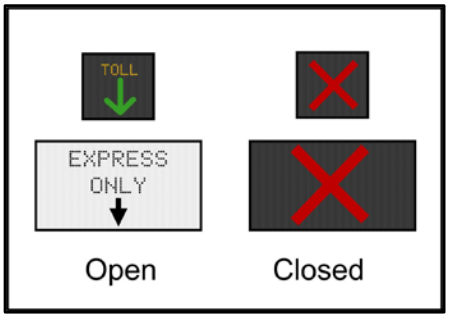
The following components will be evaluated as part of the ATM system for the PPSL and would be used to provide travel information, improve safety, and enhance mobility by increasing throughput and reliability:

- Variable Message Signs (VMS): There are two existing EB overhead VMS in the project area that will remain in place. These VMS are frequently used to provide travel time information along the corridor. They are also used for a wide range of other purposes, including providing weather advisories, amber alerts, and construction and incident notifications. No additional VMS have been proposed as part of this project, but the existing VMS will continue to be used to provide travel information to drivers.

Sample VMS Message

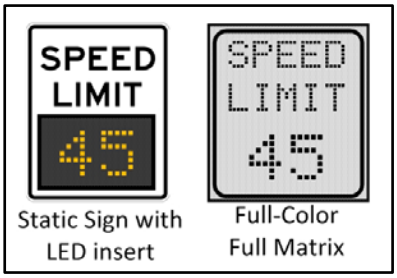
- Lane Use Signals (LUS): LUS are electronic message signs that will be located over the PPSL. They will be used to display lane status information to roadway users so that they know when the PPSL is open. For this project, there will be two sizes of electronic message signs that will function as LUS, and should have the capability to display various symbols or messages, including color graphics. The LUS are consistent with what has been used on other corridors in Colorado. These will be primarily used to display lane status information, such as a red "X" indicating lane closed, a green arrow pointing down indicating lane open, or a blank sign indicating no information. The LUS could be used to close the PPSL when it is in operation if emergency responders need to use the lane. It is generally recommended that LUS are installed to provide near continuous visibility for motorists, but the final layouts vary from project to project based on corridor needs, project goals and roadway geometry. In cases of extreme horizontal or vertical geometry, it may not be practical or beneficial to maintain continuous visibility.

  It is recommended that a mix of LUS and medium-sized VMS are installed within the corridor. The medium-sized VMS would serve as not only LUS, but also enhance ATM by providing the ability to display additional information. These ATM VMS would be useful for displaying MUTCD graphics or additional text, such as "CLOSED", "OPEN", "TOLL", "BREAKDOWN LANE", or "NO TOLL".



Examples of LUS and ATM VMS

- Variable Speed Limit (VSL) Signs: A VSL system was previously designed for deployment along I-70 EB within the PPSL project limits, and was also recommended for deployment as part of the *I-70 PPSL Safety Assessment*. A detailed concept of operations document and preliminary construction plans have been developed, describing how VSL would operate and identifying proposed locations. The documents recommend a semi-automated implementation of VSL, which would use an algorithm that monitors the real-time traffic data and would provide a suggestion to an operator at the CTMC when the speed limit should be changed. The operator would need to verify traffic conditions prior to implementation. This approach would also require additional ITS devices that collect speed, volume, occupancy and travel time information. The PPSL project will potentially install the additional ITS devices so the VSL signs can operate semi-automated, however the VSL software and algorithm would be developed outside of the PPSL project. There are currently two VSL signs deployed that could be utilized for PPSL operations – one is west of the project limits near Georgetown and the other is just west of the Twin Tunnels. The existing VSL are static signs with LED inserts. Alternatively, smaller full-color full matrix VMS or a scrolling-film sign could be used for VSL. The full-color full-matrix VMS should have the capability to display MUTCD regulatory and advisory signs, as well as other symbols and supplemental messages.

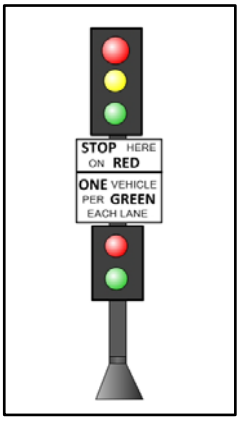


Examples of Digital VSL

- Variable Travel Time Information Sign (TTS): The TTS consist of a static message, with permanent travel time locations, and an LED insert where the variable travel time for that segment would be displayed. There is a travel time algorithm already in use by CDOT, and could be modified to display the travel times as calculated for the PPSL. To support the TTS, the additional devices that would be required are already in place along the corridor. Travel time displays are currently in use along the I-70 corridor, and in the project area; however the times and locations are displayed on full-matrix VMS signs. The TTS were eliminated from the final signing concept by the stakeholders due to the marginal perceived benefit and the desire to reduce any non-essential signing through the corridor.

Sample TTS

- Ramp Meters: There are three existing ramp meters along I-70 EB in the project area. These ramp meters are used to help control the number of vehicles entering the interstate during congested periods when the PPSL is open, and will remain in place. The existing ramp meters at US 40 and the Downieville interchange use in-pavement loops to measure speeds and volumes along both the on-ramp and mainline I-70. Since the mainline lanes will be shifted, the mainline detection will need to be replaced. The mainline detection for the third existing ramp meter in Idaho Springs has already been replaced with a non-intrusive sensor as part of the Twin Tunnels project. If the ramps are re-striped and the lanes shifted, the ramp detection may need to be replaced as well. All ramp meter detection will be evaluated during the design.



Ramp Meter

Supporting ITS Devices

ITS devices will be needed to monitor and collect traffic volume, speed, lane occupancy, and travel time information for the PPSL operations. The data from these devices will be used to evaluate the performance of the PPSL and may be used to decide when to open the PPSL for traffic. All existing serial-based ITS equipment in the project area should be upgraded and replaced with Ethernet-based devices. CDOT is also planning to replace the fiber backbone along I-70 from Bakerville to C-470, which all of the devices will tie into for communications. The following is a summary of the expected impacts and additions to the ITS infrastructure:

- Closed Circuit Television (CCTV) Cameras: A sufficient number of new cameras will need to be installed to supplement the existing CCTV cameras and provide full coverage within the corridor. Full CCTV coverage will be important to provide visual confirmation of traffic and weather conditions, verification of incidents, and for monitoring the PPSL. The cameras would also be used to verify that the PPSL is clear of debris or vehicles before it is opened.

- Microwave Vehicle Radar Detectors (MVRD): The existing MVRD units along the corridor will need to remain functional during construction. The locations of the MVRD units will be evaluated during the design and additional units may be added. MVRDs are used to measure volume, speed, and occupancy data. Additional MVRDs are recommended for the VSL algorithm to operate semi-automatically.

- Travel Time Indicators (TTI): While MVRD units give volume, occupancy, and speed data at a given point, TTI are used to track vehicle travel times across segments spanning from one TTI location to the next. The existing TTI antennas and readers within the project limits are currently being upgraded as part of another CDOT project which should be complete prior to the PPSL construction. The upgraded readers contain multi-protocol readers that can detect Title 21 and the ISO 18000-6C protocols. Additional TTI units were also recommended for the VSL project and are a source of information used in the VSL algorithm. Data for the PPSL will need to be separate from data for the general purpose lanes in order to provide a separate travel time for each. The existing TTI will need to be re-positioned to read only the general purpose lanes and additional units will need to be placed over the PPSL.

- Weigh-In-Motion System (WIM): The existing system operated by the CSP will remain, however the associated aspects of it (WIM stations, PrePass transponder readers, in-ground loops, and "Open"/"Closed" VMS panels) may need to be relocated over the lanes as part of the lane realignment segment of this project.

ITS Software

The following existing software programs will be evaluated as part of the ATM management system for the PPSL and could be used to control and manage ITS devices. See Section 2.3.2 for additional description of the software programs.

- Colorado Transportation Management Software (CTMS): This program is already in use at the CTMC and EJMT for VMS message population, and can be utilized for the VMS in this project. As part of the US-36 and North I-25 managed lane projects, an ATM interface is currently being written for CTMS to control LUS devices. This would need to be adapted for the PPSL project area; however the interface will be complete prior to the implementation of this project.

- Chain Area Program System (ChAPS): Currently, existing VSL signs in the project area are controlled through the ChAPS system by CDOT Region 1 EJMT staff out of the Eisenhower Tunnel control center. They are manually controlled, and speed limits are only lowered when chain laws are in effect. If the VSL are going to be automated, an algorithm for the CTMS can be written, however that is outside the scope of this project.

4.3 Tolling System Components

4.3.1 Tolling Parameters

As mentioned earlier, the PPSL will be a toll-only facility; meaning that all users in the lane, both SOV and HOV, will be tolled. The facility will be a cashless payment system for which all tolls are collected electronically. Users who wish to use the PPSL will either be equipped with a transponder or, as a secondary means of tolling, their license plate image will be captured and an invoice will be mailed.

Few vehicles will have exemptions from being assessed a toll. Vehicles anticipated to receive exempt status include law enforcement vehicles, emergency responders, and authorized maintenance vehicles.

Given the constrained roadway geometry and Dumont POE requirement for use of the right lane, commercial vehicles with more than two axles will not be allowed to utilize the toll lane.

4.3.2 Toll Tag Transponders

Once users are in the toll lane, the tolling system will need to identify them and assess tolls.

The primary means of electronic tolling involves the use of electronic toll tag readers that identify transponders mounted inside passing vehicles. Each transponder contains the necessary electronic components to be read by an over-lane or roadside toll tag reader and is set with a unique independent electronic signature that is linked to a specific user account. There are two main types of toll tag transponders in the industry today: form factor and sticker. Both types of transponders are actively being used by agencies throughout the United States and internationally, including the existing facilities in Colorado. A more detailed description of each type of transponders is provided as follows.

4.3.2.1 Form Factor Transponder

Form factor transponders are the more prevalent type of transponder, given that they have been in circulation longer, and because some of the new tolling schemes being implemented necessitate their use. These transponders are typically small, hard plastic cases that attach to the inside of the windshield via Velcro or suction cups.

4.3.2.2 Switchable Form Factor Transponder

Some form factor transponders have the ability to be read in multiple states (i.e., switched to HOV or SOV mode) or disabled (i.e., turned on or off). Switchable form factor transponders are expected to be introduced to the public in Colorado for use on the upcoming US 36 and North I-25 managed lanes projects in 2015.

Example of Switchable Transponder

4.3.2.3 Sticker Transponder

As the name implies, this type of transponder is contained in a sticker or thin plastic strip, instead of a hard plastic case. These sticker transponders have certain advantages over form factor transponders. They are smaller, less expensive (generally costing only a couple of dollars as compared to 20 dollars per unit for the hard case transponders), and are passive tags that do not require a battery. Also, they are not as prone to the adhesion problems which form factor transponders experience as the Velcro or suction cups wear out over time. Generally, sticker transponders are placed on a vehicle's windshield; however, there are variations that can be mounted outside on the vehicle's bumper or headlamp. In recent years, E-470 has transitioned to sticker transponders as their standard.

Example of Sticker Transponder

4.3.2.4 Communications Protocol

This section focuses on the two communications protocols used in Colorado: Title 21 and ISO 18000-6C. The Colorado Legislature requires interoperability between tolling facilities within the State. As a result, multi-protocol Radio Frequency Identification (RFID) tag readers will need to be used to allow for the deployment of different communications protocols while still keeping interoperability intact between facilities. Both protocols of RFID tags operate in the 860 MHz to 960 MHz Industrial, Scientific, and Medical band.

- Title 21 – The Title 21 protocol was developed by Caltrans in the early 1990's. Caltrans identified a frequency band that would be utilized strictly for electronic toll transponders and readers. Title 21 refers to the related section of the California Code of Regulations which describes compatibility requirements and data format for AVI equipment between vehicle-mounted tags and fixed-position roadside readers. Caltrans continues to use the Title 21 frequencies for electronic toll collection. Colorado followed suit and all toll facilities within the State currently operate under the Title 21 protocol.
- ISO 18000-6C – Similar to the Title 21 protocol, this International Standards Organization (ISO) protocol defines the air interface between the readers and the tags. E-470 is procuring ISO 18000-6C sticker transponders to replace the existing Title 21 form factor transponders. 6C is an open standard; however some manufacturers have developed modified versions that are proprietary.

4.3.3 Lane System

The lane system is comprised of all the field components within the tolling system, which are described in detail in the following sections.

4.3.3.1 Automatic Vehicle Identification (AVI) Reader

AVI antennas will be mounted directly above the managed lane and will read the toll tag information stored inside each transponder. The AVI reader will need to be multi-protocol (Title 21 and ISO 18000-6C) so that it is compatible with the newer ISO 18000-6C tags as well as the legacy Title 21 transponders. Once a toll tag is read, transaction information will be sent to the lane controller and forwarded to the Back Office System via the plaza controller.

4.3.3.2 Automatic License Plate Recognition (ALPR) Camera

In the event that a toll user does not have a transponder or if the transponder is not read, Automatic License Plate Recognition (ALPR) cameras will be used to obtain an image of the vehicle's license plate. Once the image is taken, an Optical Character Recognition system will process the image to identify the vehicle's license plate. The image and plate information will then be sent to the lane controller and forwarded to the Back Office System via the plaza controller for visual confirmation. The license plate numbers are collected and the name and addresses of the registered users are requested from the State Department of Motor Vehicles. Once address data has been obtained, bills for all the tolls incurred during a specific period are aggregated and sent out to collect payment. License plate tolling is more labor intensive to collect; and as a result, toll users incur a surcharge (currently 25% in addition to the posted toll rate) for license plate tolling.

4.3.3.3 In-Pavement Sensor Array

An array of in-pavement loops are installed at each tolling point. These loops detect each vehicle and are used to trigger the wayside forward-shot and rear-shot ALPR cameras. These loops also classify heavy vehicles to assess the appropriate toll surcharge, on facilities where heavy vehicles are allowed.

4.3.3.4 Lane Controller

The lane controller is the toll point's central processing unit and is located on-site. The lane controller interfaces with and controls all lane subsystems. The lane controller is responsible for much of the data and image processing and will transmit the transponder tag and license plate information via the fiber communications network to the back-office for processing.

The lane controller should be designed to provide a backup of the system in case of equipment or communications failure. The lane controller can accommodate this by storing and buffering transactions in the event that communications between the lane controller and the Back Office System are interrupted, ensuring that tolling operations will continue without interruption. Lane controllers can also be designed with redundancy by having a second controller that is used as a failover device. Having battery backup and redundant power supplies also provides a means for equipment protection.

4.3.3.5 Plaza Controller

A new plaza controller will be installed to accommodate the additional PPSL toll points. The individual lane controllers at each tolling point within the project area will communicate to a single plaza controller, which will then communicate with the back office server.

4.3.3.6 Toll Rate Signs

Toll rate signs are placed at decision points prior to each toll lane ingress point to notify motorists of the current toll rate. Toll rate signage can be static, but it typically includes dynamic components. The static portion of the sign displays the destination while the dynamic portion will be an LED display indicating the current toll rate for the appropriate destination to support the pricing approach for the segment. These hybrid signs are referred to as Variable Toll Message Signs (VTMS).

Sample Toll Rate Sign

4.3.4 Back Office System

The Back Office System is comprised of the Customer Service Center, account management, and transaction and violation processing, and the system receives all transponder tag and license plate

information from the lane controller by way of the plaza server. The working assumption for the PPSL is that E-470 will provide the Back Office System.

The role of the Customer Service Center is to set up toll user accounts, stock and distribute transponders, be the interface to the customers, mail invoices, and handle and track complaints. Account management includes the processes of debiting and crediting accounts, handling the balances and funds, credit card notification, and account status information. Transactions and violations are processed and handled by the Back Office System, including any notices that need to be sent to account holders or violators regarding account status updates, current and balances, adjustments, adjudications, and collections.

Due to the dynamic nature of congestion on the corridor, a firm schedule of days that the PPSL will be in operation cannot be set in advance. It is recommended that a direct interface be established between the proposed VTMS control software (CTMS) and the Back Office System, in order to automatically transfer posted toll rates to the lane controllers via the Back Office System. It is also recommended that transaction and violation processing be delayed, in order to allow time for HPTE to update the Back Office System with any revised toll rates or toll nullifications due to emergency use or other circumstances.

4.3.5 Toll Revenue

A separate traffic and revenue study will be conducted prior to opening day for the PPSL in order to determine the initial toll rates that will optimize the desired volumes of traffic in the tolled lane.

4.4 System Management

4.4.1 Standard Operating Procedures

The PPSL will be operated and maintained by HPTE, but CDOT and CSP will have the authority to suspend the operation of the PPSL for reasons such as incidents, shoulder blockage, weather event, or other unsafe conditions. It is recommended that as part of a larger staffing plan for tolling and managed lanes operations in Colorado, HPTE appoint a PPSL Operations Manager to oversee all system operations, incident management and maintenance activities. The Operations Manager will ensure that changes in toll collection, including transaction nullification, are in keeping with the process identified in this Concept of Operations document.

The Operations Manager will likely be based at the CDOT Transportation Management Center (CTMC) in Golden and will supervise all PPSL operations, including:

- Coordinating work between CDOT and other entities with a responsibility for PPSL operations
- Assisting with construction, maintenance, and capital equipment installation
- Monitoring PPSL level of service and conducting speed and travel time studies to meet Federal standards
- Providing recommendations to HPTE for improving PPSL performance
- Coordinating incident response strategies
- Monitoring operations by radio, cellular phone, or other voice communication mechanisms
- Logging all information pertaining to incidents or requirements for toll nullification
- Relaying information to traffic service entities and transportation agencies
- Managing contracts for inspection, rehabilitation, and other maintenance of the toll collection system

The Operations Manager will assign personnel to respond to field operations and maintenance repair issues. Since the PPSL will only be operational part-time, maintenance will be scheduled while the shoulder is not in use. Prior to opening the PPSL and during operations, CTMC operators will be responsible for checking the lanes for disabled vehicles, coordinating the removal of disabled vehicles from the lanes, coordinating the removal of hazardous debris from the lanes, and completing incident reports as required.

All PPSL personnel responsible for operations will have the capability to communicate with the Operations Manager and CTMC via radio, cellular phone, or other acceptable means of voice communication. Every operator by Operations Manager assignment will have a specific call number, to be used for communicating with various parties, including Operations Manager, CTMC, CSP police dispatch, and police on assignment.

4.4.2 Hours of Operation

The hours of operation for the Peak Period Shoulder Lane will be vital to the success of this project; implementing too late may not relieve queues that have already formed. However, implementing PPSL when volumes do not warrant it is not ideal and potentially introduces safety concerns, due to the lack of a shoulder. The heaviest flows of eastbound traffic are on Saturdays, Sundays and holiday afternoons during the summer and winter months. By examining the traffic volumes, average speed data and congestion data for identified segments of the corridor, a recommendation for initial hours of operation for the PPSL can be made. These recommendations should be reevaluated once the program has been implemented, and the hours/days of operation can be revised based on "lessons learned" from observations such as queue lengths and driver behavior.

Volume data selected for analysis in the *I-70 Peak Period Shoulder Lane Traffic Analysis Feasibility Study* is from Saturdays and Sundays in 2010, which represents the typical of peak travel conditions for the I-70 corridor during ski season. This data was also collected prior to any speed harmonization trials that were performed by CDOT that would have affected throughput volumes. Figure 4-9 and Figure 4-10 show CDOT ATR data from the two permanent recorders located within the study area; one located east of the Eisenhower Tunnel and the other west of the Twin Tunnels, on Saturdays and Sundays. Eight weekends in January and February 2010 were selected, as well as the two Monday holidays during those months (Martin Luther King, Jr. Day and Presidents Day). Traffic was equivalent on the Sunday and Monday of those holiday weekends, and was therefore included in this analysis. The average for each ATR is shown in bold color; the gray lines correspond to the daily data points.

On Saturdays in 2010, total volumes began to increase at the same rate at both locations, at about the same time. The Eisenhower Tunnel ATR measured the maximum traffic volume of over 2000 vph at around 2:00 pm at which point volumes began to decrease. At the Twin Tunnels ATR, volumes reached a peak of just below 3000 vph later in the day, at about 3:00 pm. On Sundays, total volumes began to sharply increase at the same rate at both locations, at about the same time. The Eisenhower Tunnel ATR measured the maximum traffic volume of over 2000 vph at around 12:00 pm at which point volumes began to decrease. At the Twin Tunnels ATR, volumes reached a peak of over 3000 vph later in the day, at about 1:00 pm. In general, the Saturday peak occurred slightly later than Sunday, and had lower total traffic volumes.

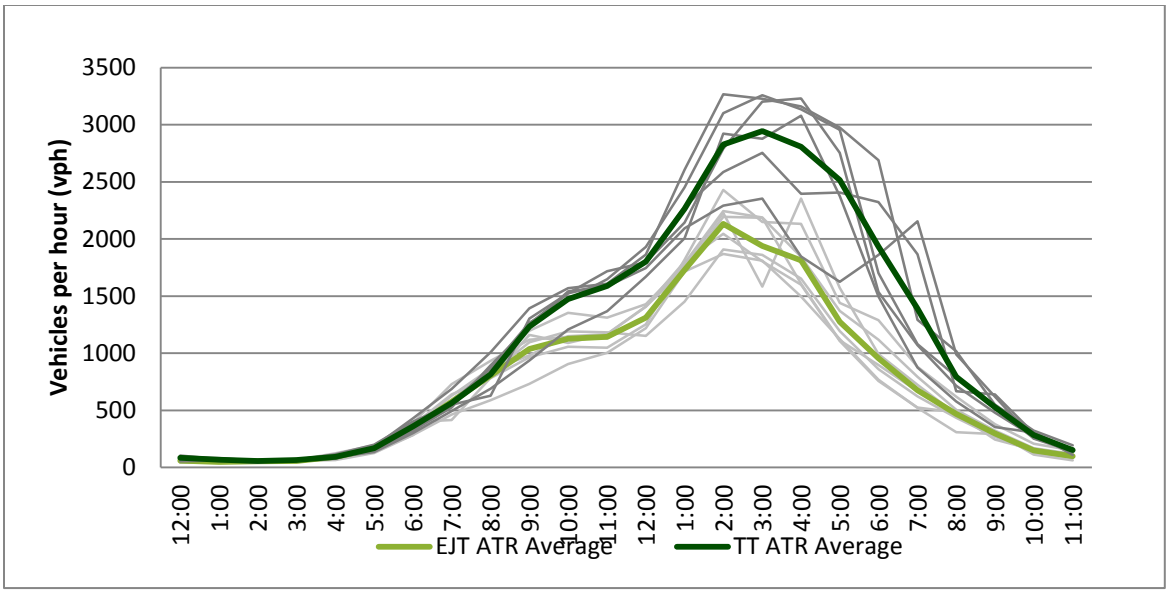


Figure 4-9: I-70 ATR Traffic Data (Saturdays in Winter 2010/2011)

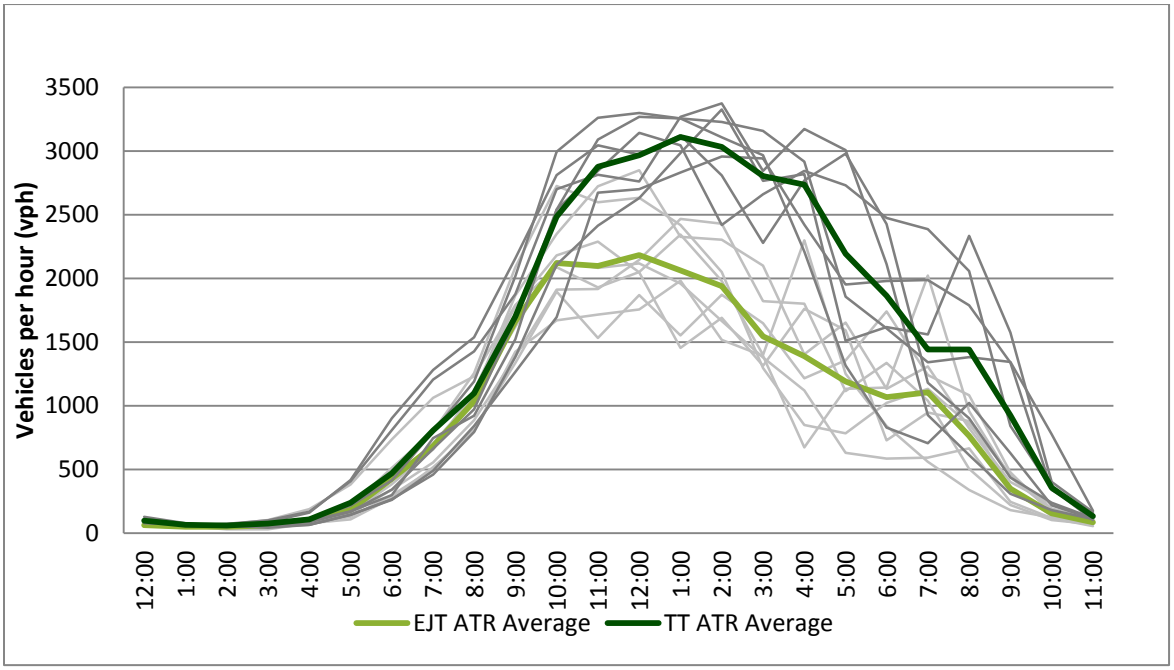


Figure 4-10: I-70 ATR Traffic Data (Sundays in Winter 2010/2011)

Using data collected by CDOT MVRD devices, average speeds for the eastbound I-70 segment from US-40 to Idaho Springs were plotted for Saturdays and Sundays during the Winter 2010-2011 season, between the hours of 9:00 am and 10:00 pm. Figure 4-11 and Figure 4-12 show the individual daily data in grey with the average data in bold color. In general, the average hours of congestion on Saturdays are shorter, beginning at about 2:00 pm and lasting until about 9:00 pm. In contrast, the hours of congestion on Sundays lasts from about 11:00 am until 9:00 pm. Both of these average speed curves correspond with the volume data from the same time period, i.e. volume increases closely correspond with average speed decreases over the same time period.

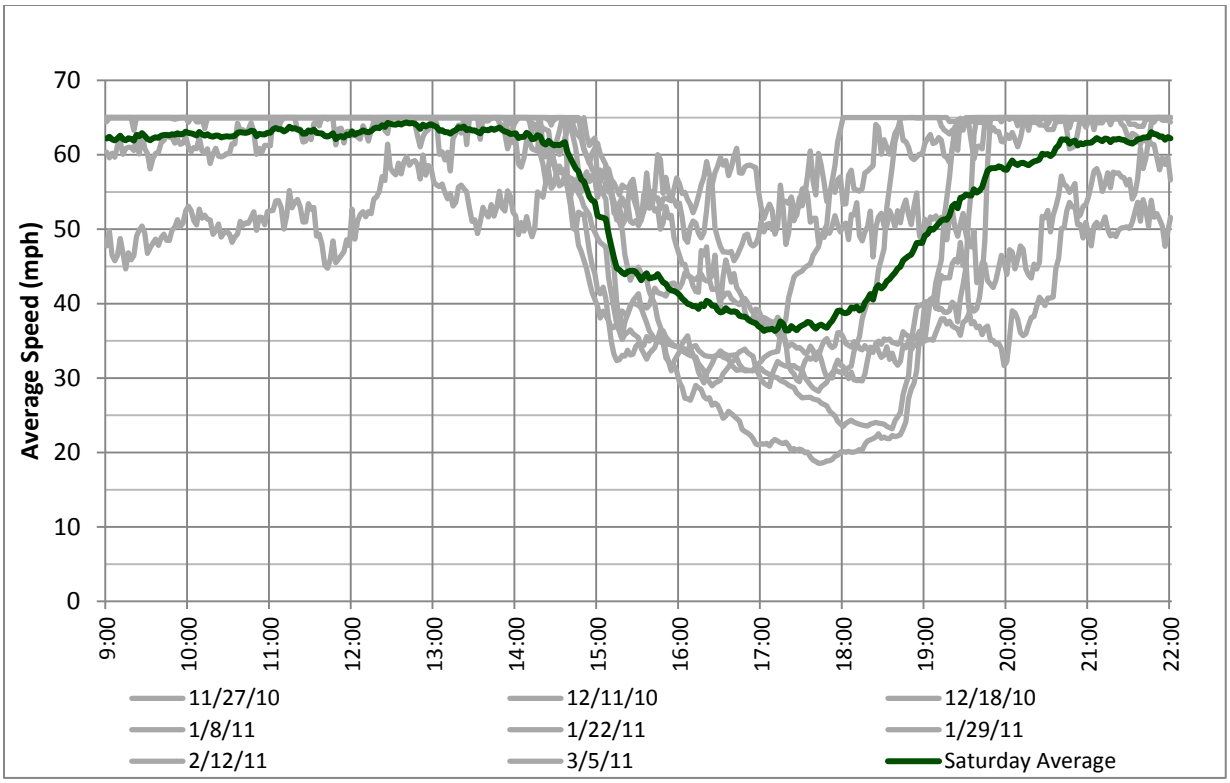


Figure 4-11: I-70 Average Speeds (Saturdays in Winter 2010/2011)

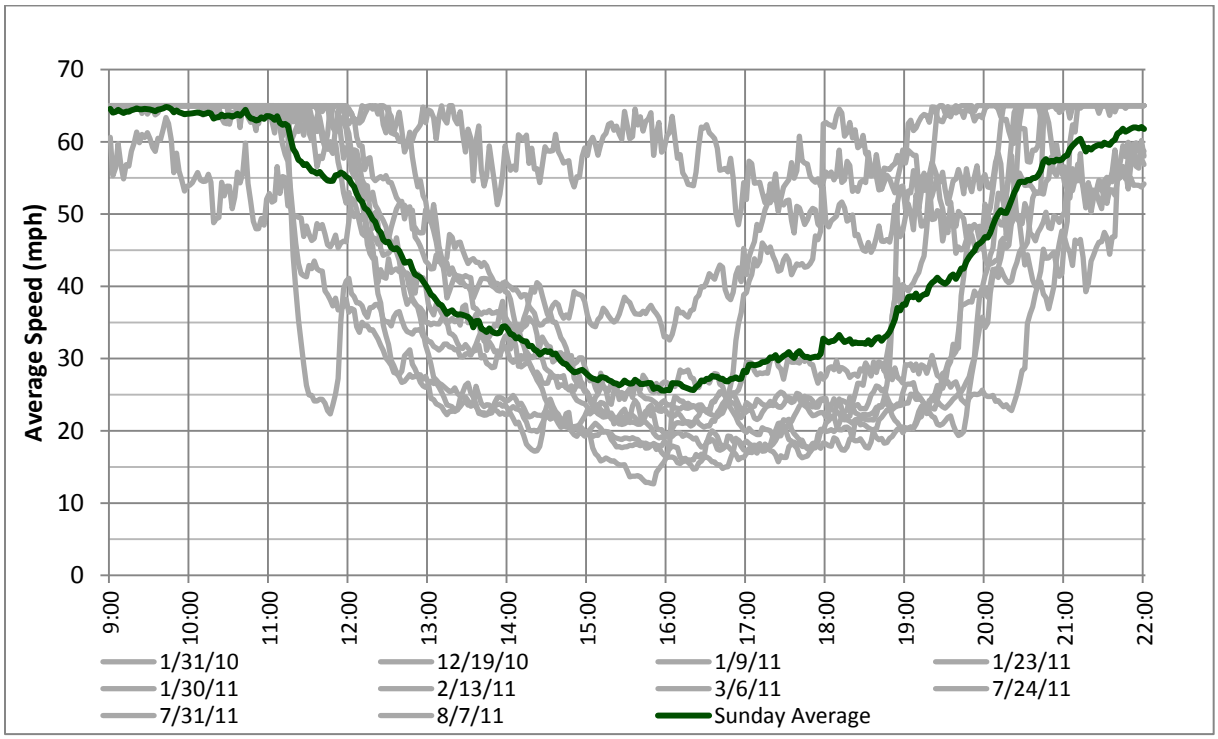
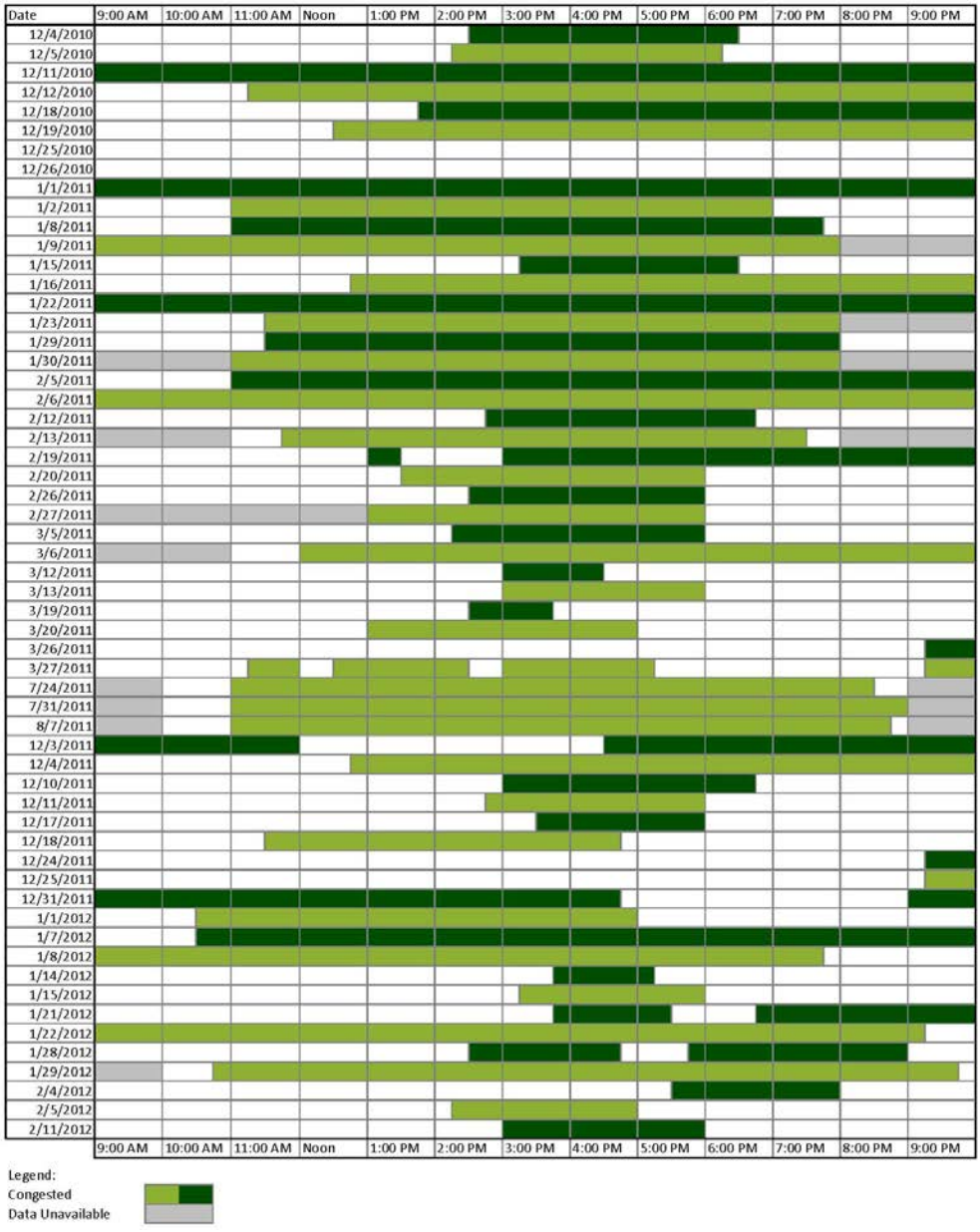


Figure 4-12: I-70 Average Speeds (Sundays in Winter 2010/2011)

Eastbound travel time segment data was analyzed as part of the I-70 Eisenhower Johnson Tunnel Continuous Flow Metering (CFM) Study in 2012. Segment data was collected along I-70 by CDOT MVRD devices and plotted by time. Segments were counted as congested when the average travel speed dropped below free flow speeds.

Table 4-3 shows data for Saturdays and Sundays during winters in 2010 through 2012, and three days in late July/August 2011, similar to proposed implementation dates for the PPSL. Weather information was not included in this data collection, so it is unknown if adverse weather conditions were the cause of any of these congestion events.

Table 4-3: I-70 Eastbound Traffic Congestion Summary – US 40 to Idaho Springs (2010 to 2012 Winter Peak Saturdays and Sundays)



The observations below, based on the data in Table 4-3, support flexibility with implementation of the PPSL which will allow the ability to adapt to traffic conditions as they evolve.

- Only five dates had little to no congestion during the entire time period. Four of those dates were in conjunction with Christmas, and one was in late March after peak ski season.
- Approximately 1/3 of the days showed congestion that lasted fewer than five hours.
- Approximately 1/6 of the days showed congestion that began prior to 11:00 am
- Approximately 1/3 of the days showed congestion that began at or after 11:00 am and continued for more than five hours, equally distributed between Saturdays and Sundays.

Predicting thresholds for volume, occupancy, or travel time in advance of project implementation and before the Twin Tunnels widening project is complete could be labor intensive and imprecise. In order to balance the semi-predictable nature of the I-70 mountain corridor traffic peaks with the uncertainties that come from adverse weather and tight geometry, a two-pronged approach to the PPSL hours of operation implementation is recommended. The initial implementation of the PPSL would follow a static schedule based on historical data showing the highest volumes and most congested travel times. The second step would be to add the flexibility to allow the shoulder lane to be opened earlier or remain open later based on observations from the CTMC operators and the Operations Manager. For example, if congestion builds up early, the shoulder lane can be opened early; or if it continues past the end of the static timing period the PPSL can be kept open until traffic in the general purpose lanes returns to free flow speed. A broad public outreach effort will be important to inform the travelling public of when PPSL will be in effect, but any additional "flex" hours would not need to be communicated to the public in advance.

Based on the information analyzed and other historical data, it is recommended that the PPSL be implemented at a minimum during the following periods:

- Weekends during July, August and December through March
- Holidays and Holiday Weeks
- Spring Break
- Special Events
- Emergency Operations (potentially without toll)

The PPSL is intended to open early enough to proactively delay the point in time when congestion begins to break down the flow of traffic, and as such it will be important to open the PPSL during additional periods when real-time or forecasted travel or weather conditions indicate significant congestion. Operators will be able to observe how weather and incidents affect PPSL operations; and patterns of traffic volumes, speeds and queues will become apparent. These observations will enable the operators and managers to draw conclusions about how to best implement the PPSL outside of the planned days.

Adjustments could also be made to reduce the hours of operation by opening the PPSL later in the day, or closing it once the GP lanes have returned to free flow speeds; however, these actions would have more potential for negative feedback from the public if the PPSL is not in operation during any of the expected hours.

4.4.3 Transition Procedure

The following list covers the opening and closing of the PPSL for planned periods of time and based on manual observation of need. If parameters such as volumes or occupancy will be used as triggers to determine PPSL opening, additional procedures will need to be developed. The transition procedure should be reevaluated and refined by the Operations Manager after observing several days of PPSL operations.

- The operators and Operations Manager should utilize the CCTV cameras from the CTMC to visually verify that the entire length of the PPSL is free of incidents, debris or other blockages. If any portion of the shoulder is blocked at this time, the Operations Manager will coordinate with the CSP and courtesy patrol to remove the blockages.
- Existing VMS in the proximity of this project may be populated with an approved message notifying motorists of the upcoming PPSL opening, if they are not already being utilized for other messaging.
- After all operators and CSP or municipal police supervisors have communicated to the Operations Manager that the shoulder is open, the Operations Manager will make the final decision that the lane is ready and safe to be opened. The Operations Manager will give direction to activate all VMS, VTMS and LUS signs involved in the PPSL system.
- While the PPSL is operational, the Operations Manager and operators at the CTMC will continue to closely monitor the corridor as discussed previously. The Operations Manager will adjust the toll rate based on the recommendations and guidelines provided by the Traffic and Revenue Study.
- When the PPSL is being closed, the first signs at the entrance of the lane need to be set to "CLOSED" and the LUS should be systematically turned off as traffic clears out of the lane.
- Designated personnel could enter upstream of the PPSL and drive the length of the shoulder to officially "close" the lane.
- While the PPSL is not in operation, operators at the CTMC should continue to monitor that there are no violators entering the closed shoulder lane. CSP should be notified of violations and any violation trends should be reported to the Operations Manager.

4.4.4 Enforcement

The primary concerns for enforcement with the PPSL will be different than other managed lanes in the Denver Metro area, as there will be no exemptions for HOV traffic. Outside of standard traffic violations, enforcement is likely to focus on safety where vehicles are illegally entering and exiting the PPSL outside of identified access zones or driving on the shoulder when the PPSL is not active. CSP and local law enforcement will have the authority to issue citations for these violations, and will direct vehicles to pull over at the nearest emergency pull-out or I-70 exit. If violations are observed by the operators in the CTMC or courtesy patrol, it should be noted and brought to the attention of the Operations Manager. The Operations Manager will make note of any patterns and contact CSP to increase targeted enforcement if necessary.

4.4.5 Performance Metrics Reporting

In order to accurately assess performance of the proposed PPSL concept, baseline conditions will need to be established for a variety of evaluation criteria. Table 4-4 lists suggested evaluation criteria and the data that will be needed to conduct an annual comparison.

Table 4-4: Recommended PPSL Evaluation Criteria and Performance Measures

Recommended PPSL Evaluation Criteria	Performance Measures (Annual Comparison/Comparison to "Before" Baseline)
Improve safety in the corridor by reducing the number of primary and secondary accidents	• Incident / crash rate (e.g., per person-hours or vehicle-miles of travel), and/or total number of crashes by segment o By type (e.g., primary/secondary) o By severity (e.g., fatal, injury) o By weather type (e.g., clear/dry, rain, snow, fog) o By lane type (PPSL, or general purpose lane)
Improve consistency and reliability of travel times for both managed lane and general purpose users	• *90th or 95th percentile travel times* - reported in minutes and seconds, and indicate how bad delay will be on the heaviest travel days. • *Buffer Index* - This uses the 95th percentile travel time to represent a near-worst case travel time. It is computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time. It represents the extra buffer time a traveler should allow to arrive on-time for 95 percent of all trips. • *Planning Time Index* - Computed as the 95th percentile travel time divided by the free-flow travel time, this measure represents the total travel time that should be planned when an adequate buffer time is included.
Reduce recurring congestion during peak periods	• *Average travel time / Average Delay per person* - can be segregated by segment as well as time of day/scenario/event. • *Travel Time Index* - the ratio of travel times in the peak period to a target or acceptable travel time (typically free-flow conditions). The travel time index indicates how much longer a trip will take during a peak time. • *Congestion levels by segment* - can be segregated by time of day/scenario/event. The duration of congestion and the average time of day the segment becomes congested can also be evaluated.
Enhance incident management activities	• Incident / crash rate • Emergency responder transport times • Incident clearance times

4.5 System Maintenance

System maintenance will be essential for proper operations of the facility, including both the roadway and the ITS and tolling equipment.

4.5.1 Roadway

Roadway maintenance will continue to be performed by CDOT Region 1; including snow removal, shoulder brooming and roadway repair out of the EJMT, and static sign repair and refreshing pavement markings out of Denver. Snow removal will become more challenging along the corridor because of the narrow median on one side and Clear Creek on the other side, compounded by a reduction in the shoulder width that can be used for temporary snow storage. Multiple passes will be required in order to clear the full roadway width, even when using two plows in tandem. Unless an additional plow can be obtained for use on this segment of roadway, it will be challenging to fully clear the roadway for PPSL operations in the event of a major snowstorm. The emergency pull-outs could also prove to be challenging for snow removal if they are not paved, as unpaved surfaces can cause damage to the snow plow blades.

4.5.2 Equipment

The majority of the field ITS and tolling equipment maintenance will occur during the off-peak periods when the PPSL is not in operation. CDOT ITS will continue to maintain the existing ITS equipment along the corridor, and will be responsible for maintaining any new ITS equipment installed with the PPSL project. The High Performance Transportation Enterprise (HPTE) will be responsible for contracting out the maintenance of the tolling equipment in the field and the back office. HPTE may elect to contract Level 1 maintenance (basic) and Level 2 maintenance (complex) separately, in order to optimize the use of existing maintenance staffing within the corridor and to minimize the potential for long response times for basic troubleshooting and repairs.

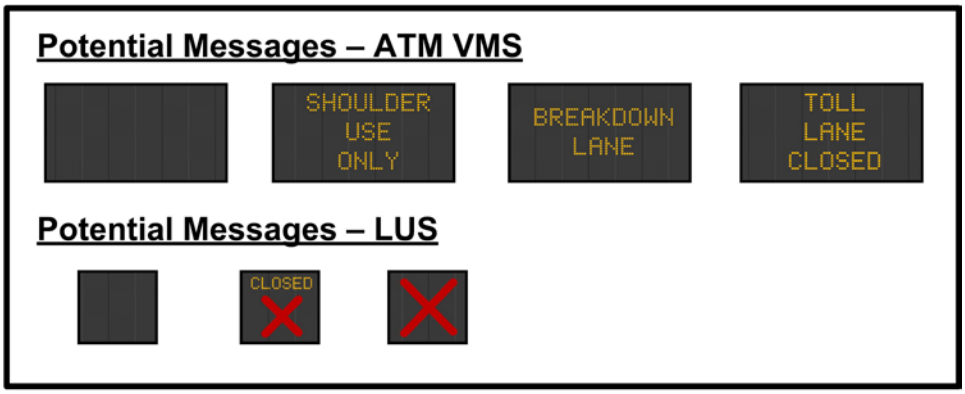
5 OPERATIONAL SCENARIOS

The following sections illustrate different operating scenarios for the PPSL. The selected scenarios are intended to cover situations that will be encountered during PPSL operation, increasing the level of consideration for the proposed system procedures.

5.1 Normal (Non-Peak) Operations

During normal operations, when the PPSL is not active, the corridor will operate much as it does in its present condition. See Figure 5-1 for a depiction of how the proposed dynamic signing could be used along the corridor during this scenario. All VTMS and LUS signs will display the default message (e.g., blank sign, "shoulder use only"). As drivers approach the access zone where the PPSL begins, they will not have to make any lane changes to remain in their GP lane, and the commercial vehicles will remain in the 12-foot wide primary commercial vehicle lane. Vehicles that cross the pavement markings into the PPSL shoulder for general travel and not for emergency purposes will be subject to receiving a moving violation.

As vehicles approach the tie-in to the Twin Tunnels Widening Project, the striping that separates the PPSL from the GP lanes will change from solid to broken, providing an access zone into a third GP lane through the Twin Tunnels. The VTMS will display a message indicating that there is no toll, and the LUS beyond this point will display a message, indicating that the lane is open to traffic.

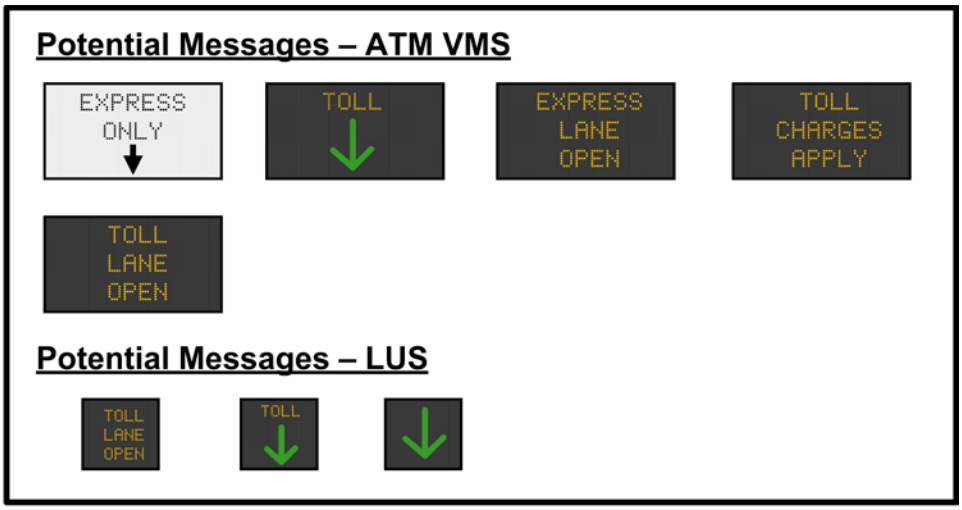


Sample Messages during Normal Operations

5.2 Peak Period Operations

The Operations Manager should be on duty at the CTMC, and all documented transition procedures should be followed prior to opening the PPSL to traffic. See Figure 5-2 for a depiction of how the proposed dynamic signing could be used along the corridor during this scenario. As part of the procedure, CSP and courtesy patrol should also be notified.

Once the PPSL is active, drivers travelling along eastbound I-70 will pass VMS with messages notifying them that the shoulder lane is open and VTMS with the current toll price. Drivers will have time to read the toll rate, and decide if they want to utilize the PPSL. As they approach the initial ingress point near US 40, the striping will identify the beginning of the PPSL. Following the access zone, the striping will change to a solid line, and access to/from the PPSL will be prohibited except at designated ingress/egress points.



Sample Messages during Peak Period Operations

5.3 Special Event Operations

The PPSL may also be opened to traffic outside of the standard hours of operation for holidays, peak summer weekends, or planned events that are anticipated to generate a large, concentrated number of return trips from the I-70 Mountain Corridor to the Denver Metro Area. In this situation, the Operations Manager should be on duty in the CTMC prior to PPSL implementation, and the procedures for peak period operations should be followed. As part of the procedure, CSP and courtesy patrol should also be notified.

5.4 Toll Exemptions

No toll reductions or exemptions will be provided for High Occupancy Vehicles (HOVs), and any vehicle using the managed lane without a transponder will be identified via Automatic License Plate Recognition Cameras. Emergency responders, courtesy patrol and maintenance vehicles may be provided transponders coded into the system as non-revenue tags, exempting them from paying tolls.

5.5 Heavy Vehicles

Given the constrained roadway geometry and due to the POE requirements, it is not expected that commercial vehicles with more than two axles will be allowed to utilize the shoulder lane.

5.6 Emergency Management

The I-70 Mountain Corridor routinely sees disruptions of traffic from incidents such as crashes, disabled vehicles, and roadside debris. It will be critical to provide emergency responders with a reliable travel path along I-70 for incident response. This section outlines the anticipated response when the PPSL is active and when it is closed.

5.6.1 Emergency Management when PPSL is Active (Peak Period Operations)

When an incident occurs while the PPSL is active, emergency responders or courtesy patrol will assess the incident and determine a course of action. The emergency dispatch or courtesy patrol should notify the CTMC and the Operations Manager of the incident. The CTMC operators will also be monitoring the corridor via CCTV, so they can assist emergency response dispatchers in identifying the exact location of incidents called in via 911. VMS messages will be used to notify the travelling public of the incident.

Any disabled vehicles should be moved to a safe location by Courtesy Patrol. If it is not possible to safely move the vehicles, the segment of the PPSL impacted by the blockage may need to be closed; particularly

if the blockage is within the PPSL or if emergency responders are utilizing the PPSL to reroute GP lane traffic around the blockage. The Operations Manager will be responsible for contacting E-470 to exempt tolls during any periods where the PPSL operations are significantly impacted. Any lane closures along eastbound I-70 during PPSL operation should be closely communicated with the Operations Manager and the CTMC, in order to ensure that the correct signing procedures and tolling system changes are followed.

In the case of an emergency PPSL closure, the CTMC operators will utilize the dynamic signing to clear traffic from the PPSL for emergency responder access by changing the dynamic panels on the advance guide signs to "CLOSED" and changing the green arrows on the LUS to red X's. See Figure 5-3 for a depiction of how the proposed dynamic signing could be used along the corridor during this scenario.

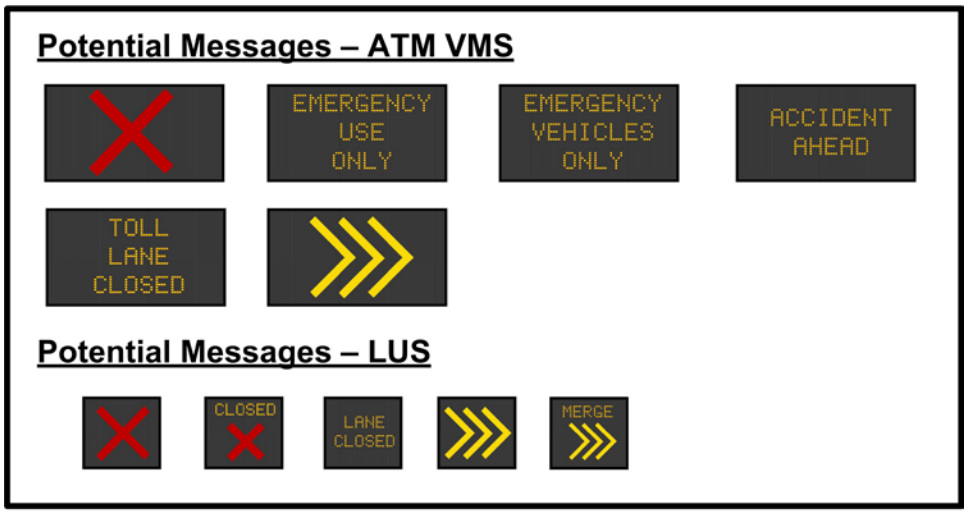
If an emergency closure is within the general purpose lanes and requires the use of the PPSL for general purpose eastbound I-70 traffic, the operators will implement a messaging scheme that indicates that no toll charges for use of the PPSL in the vicinity of the emergency closure.

In both cases, CDOT will also coordinate with the E-470 back office to ensure that motorists are not charged tolls during the time period when the emergency closure was in effect. This notification process has the potential to be automated if the VTMS control software is able to communicate overridden toll rates directly to E-470.

5.6.2 Emergency Management when PPSL is Closed (Normal Operations)

When the PPSL is not active, the inside shoulder can be utilized as a breakdown area or for emergency stopping; however, on days that the PPSL will be active, incidents should not be staged on the inside shoulder in preparation for the transition procedure. Emergency responders will be authorized to use the shoulder to access incidents even when the PPSL is closed.

If it is not safe to service a disabled vehicle on the inside shoulder and the vehicle cannot be moved to an emergency pull-out, CSP or Courtesy Patrol should follow standard procedures for securing the area. CSP and courtesy patrol should be in contact with the CTMC as soon as possible, so messages can be displayed on VMS signs alerting upstream traffic to the location of the incident. In some situations the inside shoulder (closed PPSL) may be utilized by law enforcement to reroute GP lane traffic around the incident.



Sample Messaging during Emergency Closure of PPSL

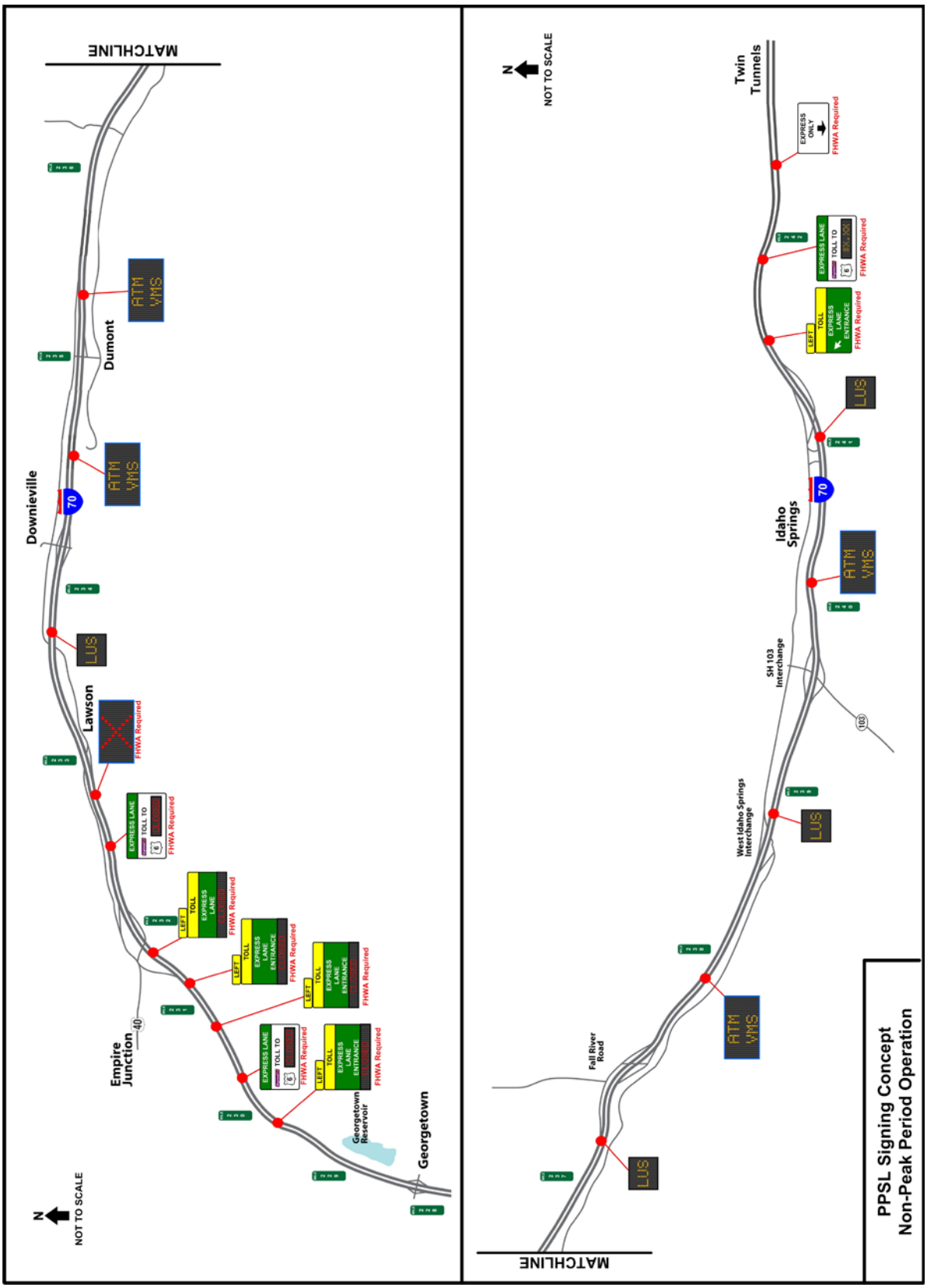
5.7 Weather Disruption

During winter weather events, CDOT snow-removal and winter maintenance protocol will be followed. Since the full width of the roadway will be utilized when the PPSL is active, the inside shoulder must be kept clear even when it is not in use. If the plows operate in tandem, with staggered overlapping plow blades, and the first plow is close to the inside shoulder, then I-70 can be kept clear and safe. The emergency pull-outs must also be kept clear of snow piles, which can only be done with snow plows if the pull-out surface is paved.

In advance of a winter snowstorm, CDOT will make a determination as to whether the PPSL should be opened. If an unexpected major winter weather event occurs, the Operations Manager and roadway section MTCE supervisor will also make the determination to delay the opening or to close the PPSL early. Considerations will be given to the current speeds and volumes on the roadway, the condition of the roadway surface, visibility, and the weather forecast. The CTMC has access to CDOT's Maintenance Decision Support System (MDSS), which can be used to help in decision making. The PPSL will only be opened if it can be operated safely.

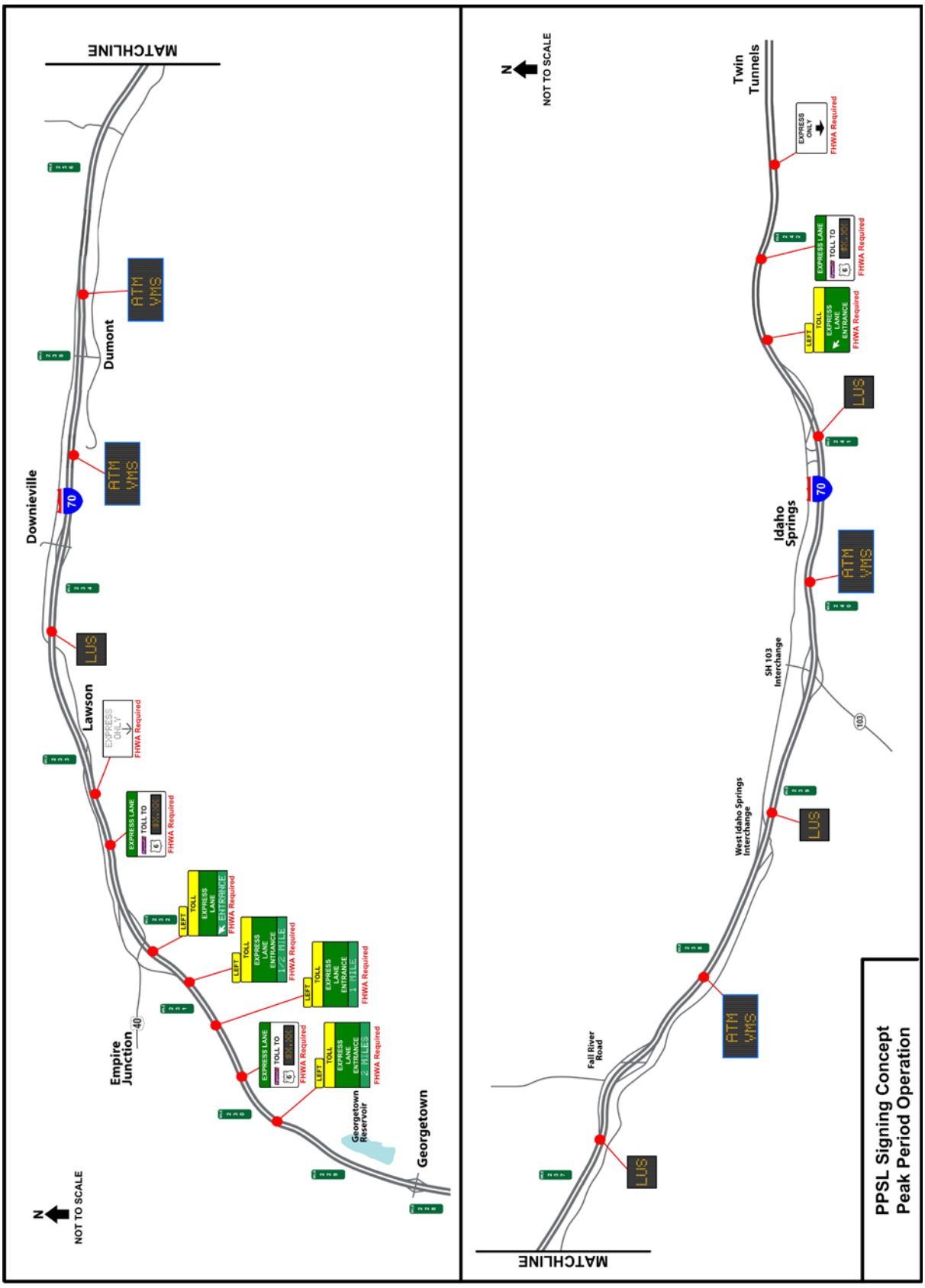
5.8 Maintenance

Special consideration will have to be given to the impact of roadway and equipment maintenance within the limits of the PPSL. A "policy" or "operations" manual should be developed to identify the procedure for scheduling and coordinating this work. The goal will be to ensure that maintenance procedures can be accomplished effectively without impacting operations, and to clearly define the steps, actions, and roles of all personnel. When closures are needed in the shoulder lane, such activities would be planned for non-peak periods whenever possible.



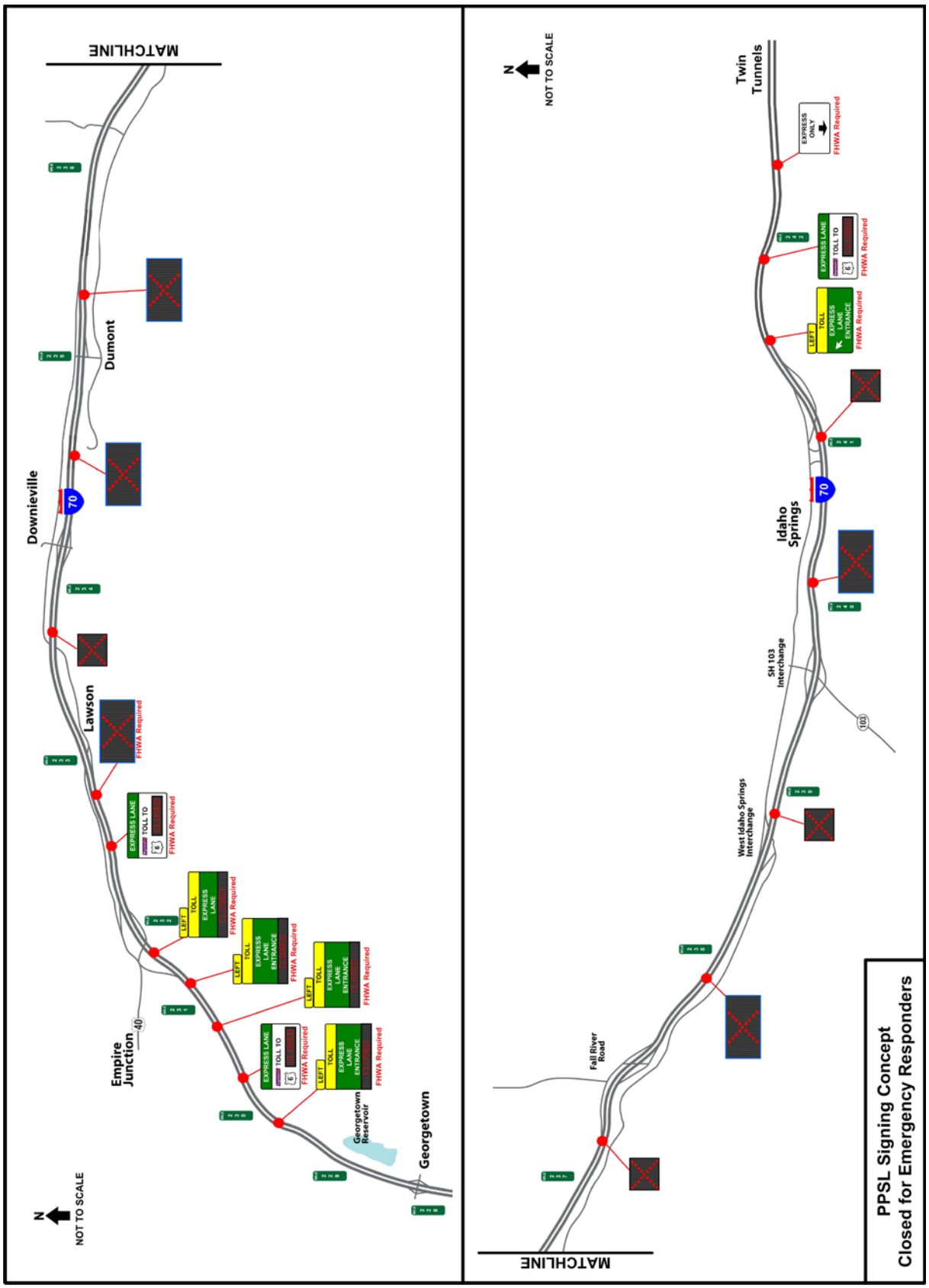
Note: Signing layout is conceptual and will be further refined through the CSS process and the design phase.

Figure 5-1: Dynamic Signing Concept during Normal (Non-Peak) Operations



Note: Signing layout is conceptual and will be further refined through the CSS process and the design phase.

Figure 5-2: Dynamic Signing Concept during Peak Period Operations



Note: Signing layout is conceptual and will be further refined through the CSS process and the design phase.

Figure 5-3: Dynamic Signing Concept during Emergency Closure

6 SUMMARY OF IMPACTS

6.1 Infrastructure

6.1.1 Additional Pavement

With a proposed cross-section of 39 feet, the existing pavement through the majority of the project corridor will accommodate the third lane. Minor widening will be required in some locations, with the largest increases occurring at the interchanges.

6.1.2 Structure Modifications

In order to accommodate the proposed cross-section, retaining walls will be required, with the majority of the wall locations at the interchange locations where the roadway widening is the largest.

Additionally, two of the existing bridges over I-70 will need to be replaced in order to provide adequate vertical clearance for the new roadway cross section. The proposed SH 103 bridge replacement is anticipated to include three lanes and a sidewalk, and the East Idaho Springs interchange bridge replacement is anticipated to include two lanes and a sidewalk.

6.1.3 Traffic Operations and Control

The following are the anticipated impacts to the existing traffic control along eastbound I-70 for the proposed PPSL concept, as detailed in Section 4.2:

- Restriping of eastbound I-70 from US 40 to the western limits of the Twin Tunnels widening project
- Installation of new static signs
- Installation of LUS
- Installation of CCTV cameras
- Installation of MVRD
- Installation of TTI
- Installation of VSL signs
- Reset Weigh-In-Motion Station
- CTMS Software modifications for LUS
- Reset Ramp Meters

6.1.4 Tolling System

The following are the anticipated requirements for the implementation of the tolling system, as detailed in Section 4.3:

- Installation of toll points
- Installation of plaza controller
- Installation of VTMS
- Required upgrade/expansion to back office system
- Interface between CTMS and back office system for providing updated toll rate information

6.2 Changes in Stakeholder Roles and Responsibilities

With the addition of the I-70 PPSL and associated infrastructure, stakeholder roles and responsibilities are expected to change as follows:

- HPTE: HPTE will have the responsibility for managing and operating the I-70 PPSL managed lane and toll facility. HPTE will likely contract other agencies to perform back office support, equipment maintenance, and corridor operations.
- CDOT ITS: The CDOT ITS Branch, including the CTMC, will operate and maintain the existing and proposed ITS infrastructure along I-70. This includes many of the ITS elements discussed in Section 4.2.3. CDOT ITS may also be contracted to assist with Level 1 (basic) maintenance of the toll equipment.
- CDOT Region 1: CDOT Region 1 will operate and perform general maintenance of the I-70 PPSL managed lane facility (under an agreement with HPTE) as well as continue with responsibility for the GP lanes on the rest of the I-70 facility. The EJMT will coordinate with the proposed PPSL Operations Manager for any incidents occurring along the corridor that may impact the PPSL operations. CDOT Region 1 may also be contracted to assist with Level 1 (basic) maintenance of the toll equipment.
- E-470: Through an agreement with HPTE, E-470 will provide back-office and customer service center support to HPTE for the I-70 PPSL managed lanes. In addition, they will provide, install, and operate the toll collection equipment. E-470 will provide Level 2 (complex) maintenance for the toll equipment, but may not provide Level 1 (basic) maintenance due to response times.
- CDOT HQ: CDOT Public Relations will be responsible for the public outreach and education associated with opening the PPSL ("Go Live").

It is recommended that HPTE, CDOT and E-470 develop operations, maintenance and Go Live plans that will include determination of the magnitude of impact the new system will have on personnel and equipment needs. These agencies should prepare a staffing plan to quantify these personnel and equipment needs. Considerations for this plan should include:

- Go Live: The Go Live plan should detail all up-front education and marketing, cover all issues associated with the initial opening of the facility, and address specific start-up needs.
- Contracted Services: New contracts or modifications of existing contracts will be necessary to address areas such as tolling enforcement and E-470 back office responsibilities.
- Travel: The travel distances from the CDOT dispatch points to the field for maintenance may include a significant amount of travel time just to arrive on-site.
- Region Responsibilities: Responsibilities should be designated and further defined for each CDOT Region and staff.
- Communication Infrastructure and Equipment: Personnel need to be trained and equipped to perform routine and emergency troubleshooting and repair.
- System Monitoring: The PPSL will only operate during peak periods and service will be of utmost importance given that drivers are paying a toll and will expect a certain quality of service for the system.
- Utility Locates: CDOT will be responsible for locating longitudinal and latitudinal crossings through the Utility Notification Center of Colorado and will need to have resources available to perform these functions.
- Equipment: Additional communications infrastructure and potentially new technology may create a need for new tools to perform maintenance.

- Vehicles: Appropriate vehicles are needed for installation, repair and testing of equipment. Vehicles will be needed to access toll rate signs, CCTV cameras, toll readers, and related equipment (vehicles may include aerial trucks and splicing vans.)
- On-Call Personnel: The PPSL will only operate during peak periods; however, these periods (weekends and holidays) typically fall outside of the normal work week for maintenance personnel. In addition, some of the traffic control infrastructure will be used 24 hours per day, seven days a week. Depending upon the frequency of maintenance patrolling and equipment failures, personnel may be needed to perform dedicated or rotational shifts for on-call duties.
- Integration of ITS Equipment: All ITS equipment will need to be integrated into the CTMC network, including CTMS, Camera Cameleon, and www.CoTrip.org.
- Training: All staff must be appropriately trained to handle routine and emergency maintenance response for the system.

These operations and maintenance considerations will require additional resources. Staffing could come in the form of CDOT personnel, contract employees, or a combination of both.

6.3 System Operations

As described in Section 4.4.1, it is recommended that a PPSL Operations Manager be assigned to the oversight of the proposed PPSL system. The exact details of this position will be determined as part of a larger staffing plan for tolling and managed lanes operations in Colorado.

The proposed system will also require modifications to the existing CTMS software in order to achieve full functionality and control of the PPSL. Similar modifications are being implemented for projects on I-25 and US 36, which will reduce the level of magnitude for the changes that will need to occur.

6.4 System Maintenance

The majority of the impacts to maintenance within the project corridor will be expansions of existing services, but there will be a few new services that will be required.

- Pavement: Although there is expected to be minimal expansion of the existing pavement footprint through the project corridor, travel on the shoulder will increase the wear on what was an occasionally used shoulder. Pot hole repairs, crack sealing and eventually pavement replacement will require more time and materials along the corridor.
- Roadside Safety: With new roadside infrastructure to support the PPSL, also comes the potential for new roadside safety features to maintain (e.g. guardrail).
- Snow Removal: The additional lane miles of snow removal will impact not only the demand on CDOT maintenance staff, but also increase the annual wear on plows and require more anti-icing product to be purchased each winter season.
- Support Structures: Structural inspection schedules and resources will need to be expanded to accommodate the new sign support foundations along the corridor.
- Static Signing: New overhead and median-mounted static signs will need to be added to CDOT's maintenance and long-term replacement schedule.
- ATM and Dynamic Sign Panels: The electronic overhead signs will require more routine maintenance than the static signs, and the dynamic signs providing mandatory MUTCD messages will also need to be incorporated into a long-term replacement schedule.
- Supporting ITS Devices: In addition to the dynamic signing, CDOT ITS will also have a significant number of new field devices to maintain, increasing the demand on the existing staff.

- Tolling Equipment: HPTE will be responsible for maintaining the tolling equipment, and will most likely outsource maintenance.

6.5 Public Outreach and Education ("Go Live" Plan)

A public relations and education campaign will need to be carefully developed and implemented prior to and during the initial deployment of the facility to ensure potential users understand how to properly use the facility. This effort could involve broadcast and print media, online information, special mailings to existing I-25 Express Lanes customers and E-470 transponder holders as well as a wide variety of targeted strategies to reach people in the communities most likely to use the facility. Also, E-470 customer service center personnel will need to be specifically staffed and trained to deal with these start-up issues.

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I-70 EB Peak Period Shoulder Lane
Project Criteria Flow Chart

Context Statement

The I-70 mountain corridor is Colorado's only east-west interstate and the primary access route from Denver to the mountains of western Colorado.

The segment of the I-70 corridor that runs from Empire Junction to the Twin Tunnels at Idaho Springs has spectacular view sheds and is one of the most heavily populated areas of Clear Creek County. It also is one of the narrowest sections in the corridor, with the roadway located on the canyon floor adjacent to Clear Creek. This segment of interstate is an important link for the community, acting as a major arterial throughout the area and also providing multi-modal forms of transportation. Improvements to the interstate in this area directly impact established communities as well as unique environmental, historic and recreational resources.

This segment of the corridor experiences heavy flows of eastbound traffic causing severe congestion and traffic delays during peak periods, especially at the I-70/US 40 interchange at Empire Junction.

Short term operational strategies need to be explored until sufficient funding can be obtained to implement the corridor's ultimate vision.

Core Values	Critical Issues	Evaluation Criteria
Safety	• Emergency Response • Safety of Travelling Public • Local and Tourist Driver Expectancy • Incident Management	1. Address Safety During PPSL Operations? 2. Maintain Safety During non-peak times?
Mobility	• Reliability • Operations • Maintenance • Active Management • Roadway Connectivity/Network	3. Improve mobility and reliability during peak times? 4. Minimize the effort required to maintain the option?
Constructability	• Fiscally Responsible Costs • Limit Throw Away Work • Adverse Impacts to Enviro/Community • Minimize Infrastructure Improvements • Keep to Operations Project • Adaptability	5. Enable the project team to achieve the goal of opening PPSL by July 1, 2015? 6. Create infrastructure investments that are reasonable to construct and provide the best value for their life cycle, function and purpose.
Community	• Recreation • Historical and Cultural Resources • Tourism and Economy • Local Access • Signing • Livability • Effects to low-income and minority populations	7. Allow for a process to engage and communicate with all the local, regional and national users of the I-70 Mountain Corridor? 8. Create opportunities to "correct past damage"? 9. Provide access and protect opportunities for enhancements to tourist destinations, community facilities, and interstate commerce? 10 Effects to low-income or minority populations in a high and disproportionate manner?
Environment	• Clear Creek • Wildlife Habitat and Movement • Mining and Metals • Water Quality • Sediment • Air Quality • Noise • Wetlands	11. Incorporate sustainability by using locally available materials and environmentally-friendly processes? 12. Protect or create unique features for the area as a gateway? 13. Protect wildlife needs? 14. Protect Clear Creek? 15. Protect the defining historical elements of Clear Creek County?
Engineering Criteria & Aesthetic Guidelines	• Balance Design Using CSS Guidance • Aesthetics Inspired By Surroundings • Adherance to ROD • Use of Most Recent Technology	16. Meet CDOT and industry standards? 17. Achieve the mountain mineral belt aesthetic guidelines? 18. Meet the I-70 Mountain Corridor design criteria?
Sustainability	• Blends with Future Possibilities (AGS, Transit, Greenway, etc.) • Definition of Interim • Idaho Springs Visioning	19. Preserve opportunities for the AGS and the ultimate preferred alternative? 20. Adaptable for future changes/projects (including Idaho Springs Visioning)?

Project No: NHPP 0703-401
Project Code: 19474

9/18/2013