SYSTEMS ENGINEERING CONCEPT OF OPERATIONS (ConOps)

for:

RAILROAD-HIGHWAY GRADE CROSSING

MINNESOTA DEPARTMENT OF TRANSPORTATION

Contract Number:

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1.0 PURPOSE AND SCOPE OF APPLICATION PACKAGE

This document provides a ***Concept of Operations*** (*ConOps*) for various types of active railroad-highway grade crossing protection that may apply to a particular project. Active protection means the use of some type of device that is activated to warn motorists of an approaching train, either flashing-light signals, or flashing-light signals and gates. Static protection with signing only is *not* included. Please see the corresponding *Minnesota Statewide Regional ITS Architecture and Systems Engineering Checklist* (*Checklist)* for the project to identify which type(s) apply.

Regardless of the type, all implementations of active grade crossing protection include the operational concepts for the flashing-light signals (item .1). Following are the name and numbering identifiers for the various protection types:

.1 – Flashing-Light Signals (FLS, common to all forms of active protection)
.2 – Cantilever Flashing-Light Signals (CFL)
.3 – Standard Railroad Gates (SRG)
.4 – Four Quadrant Gates (FQG)
.5 – Traffic Signal Preemption (TSPr)
.6 – Other

For each section of this document where information is distinguished by optional feature, the section follows the numbering scheme per the above. For example, Section 1.5 covers the purpose and scope for Traffic Signal Preemption from the railroad system perspective. A separate document addresses Railroad Preemption *ConOps* from the traffic signal perspective.

The stakeholders, as per the *Minnesota Statewide Regional ITS Architecture* (March 2009; *Statewide Architecture* for short) for grade crossing protection will be all or nearly all of the following depending on the site:

- Travelers: private vehicle drivers and passengers, transit operators and passengers, commercial operators, school bus operators and passengers, pedestrians (including those with disabilities), and bicyclists
- Minnesota Department of Transportation (Mn/DOT) and associated entities:
    - District Offices
    - RTMC (Regional Transportation Management Center), plus Transportation Operation and Communication Centers (TOCCs)
    - Office of Freight and Commercial Vehicle Operations (OFCVO)
    - Office of Traffic, Safety, and Technology (OTST; formerly OTSO)
    - Office of Maintenance, and
    - Office of Transportation Data and Analysis (TDA)
- Minnesota Department of Public Safety (DPS)
- Local Agencies: counties, cities, towns, villages, and townships
- (Local) Traffic Management Centers
- Local Maintenance and Construction Management (MCM) Agencies
- Local Transit Providers with light rail vehicle operations through grade crossings
- Railroad Companies

- Federal Highway Administration (FHWA)
- Federal Railroad Administration (FRA)

Notes to Stakeholder list:

- Only Travelers is listed in the *Statewide Architecture,* but has been expanded above to explicitly list the various types of Travelers.
- The list of Local Agencies has been similarly expanded from the *Statewide Architecture.*
- Local law enforcement has been added in the MSP group.

An important overall aspect is that railroad-highway grade crossing protection planning, design, and operation must be a cooperative effort involving the railroad operating entity, the local municipality or unit of government, and where applicable the regulatory agency with statutory authority. Planning, design, and construction are the responsibility of Mn/DOT, railroad companies, and local government units, while maintenance of the protection equipment is the responsibility of the railroad company. The local municipality or unit of government is responsible for maintenance of approach roadways and signing plus adjacent traffic signals and may share in maintenance of warning devices for Quiet Zones. In all cases, a high level of cooperation and coordination must be established and maintained between the involved public agencies and the railroad company.

1.1 Railroad Flashing-Light Signals (FLS)

Basic FLS consist of (see Figure 1):

- A pole with "RAILROAD CROSSING" crossbuck sign at the top
- A pair of red flashing lights mounted in a horizontal line that flash in alternating sequence.

FLS as shown are always included with both versions of gates (SRG and FQG) as well. Post-mounted flashing light signals are normally located on the right side of the highway on all highway approaches to the crossing. Flashing light signals are generally post-mounted, but where improved visibility to approaching traffic is required, cantilevered flashing light signals (CFL) are used. .

The FLS are activated by the approach of a train that closes a track circuit. Two basic operational modes are used that affect initiation of alternating light display. In the first mode, activation of active protection is programmed to occur a fixed time before the arrival of the railroad vehicle at the crossing. Typically the lights flash for 20 seconds (minimum prescribed in *2005 MN MUTCD* and by the FRA) or more, but the constant warning time is set at a nearly uniform value. To accomplish this, circuit controllers must be able to accurately measure the speed of the approaching train and estimate the arrival time to the crossing to meet the constant warning time requirement.

In the second mode, the approach of a train at the circuit terminal point unconditionally activates flashing-light protection and speed of the train is not taken into account. Active crossing protection time thus is variable as a function of the speed of the approaching train and the location of the circuit terminus. With either mode, flashing operation continues until the train or trains fully clear the grade crossing area.

Ideally the crossing protection equipment is monitored by both a rail operations center and a road MCM center for an alarm in case of a device failure so that a repair crew can be immediately dispatched.

1.2 Railroad Cantilever Flashing-Light Signals (CFL)

CFL are essentially the same functionally as FLS except that the flashing-light signals are suspended over the approach roadway to increase conspicuity and driver recognition (see Figure 2). As noted in Section 1.1, post-mounted FLS are typically installed as well, as included in the Figure 2 example. CFL may be appropriate when any of the following conditions exist:

- Multilane highways (two or more lanes in one direction).
- Highways with paved shoulders or a parking lane that would require a post-mounted light to be more than 10 feet from the edge of the travel lane.
- Roadside foliage obstructing the view of post-mounted flashing light signals.
- A line of roadside obstacles such as utility poles (when minor lateral adjustment of the poles would not solve the problem).
- Distracting backgrounds such as an excessive number of neon signs (conversely, cantilevered flashing lights should not distract from nearby highway traffic signals).
- Horizontal or vertical curves at locations where the extension of flashing lights over the traffic lane will provide sufficient visibility for the required stopping sight distance.

1.3 Standard Railroad Gates (SRG)

SRG are the common active protection devices at grade crossings in urban and suburban areas across the US (see Figure 3 and Figure 4). Figure 3 shows SRG protection for vehicles only while Figure 4 adds pedestrian gates. The gates include flashing red lights that are activated at the same time that the post-mounted flashing lights are activated. The lights serve as an initial warning to drivers that a train is approaching, and the gates cannot begin to come down until the lights have been activated for at least three seconds. The gates must reach the horizontal position at least five seconds before the arrival of the train, though longer lead times are often used. The flashing lights remain active and the gates down until the train(s) leave the grade crossing. As can be seen in Figure 5, sometimes a median is constructed to discourage drivers from trying to “beat the train” by driving around lowered gates, an obviously dangerous maneuver.

1.4 Four Quadrant Railroad Gates (FQG)

FQG are the same in function as SRG but with the added protection on the departing, or exit, side of grade crossing approaches (see Figure 6), for the purpose of more positively discouraging gate running by drivers. Gate activation is more complex in that there is a need to delay the times the gates on the departing side come down, with exit gate arm activation and downward motion based on detection or timing requirements established for each site. This operation allows motorists on the tracks when flashing light activation begins to avoid becoming trapped in the grade crossing area because of the downstream gates. Another aspect at sites where vehicles might queue from a downstream intersection into the grade crossing area is use of dynamic exit gate operating mode. This mode has detection devices to control exit gate operation based on vehicle presence within the grade crossing area. In short, design of FQG timing must be carefully considered on an individual site basis to implement the best possible protection.

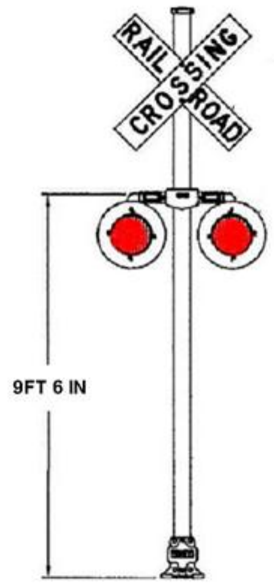

Figure 1 Typical Flashing-Light Signals

(Source: Public Utilities Commission of Ohio Grade Crossing Inventory, http://www.ohiorail.ohio.gov/crossings.php)

Figure 2 Typical Cantilever Flashing-Light Signals

(Source: Public Utilities Commission of Ohio Grade Crossing Inventory, http://www.ohiorail.ohio.gov/crossings.php)

Figure 3 Standard Railroad Gates
(Source: Public Utilities Commission of Ohio Grade Crossing Inventory, http://www.ohiorail.ohio.gov/crossings.php)

Figure 4 Standard Railroad Gates with Pedestrian Gates
(Source: (Source: Mn/DOT photo files)

Figure 5 Standard Railroad Gates – With Median
(Source: Public Utilities Commission of Ohio Grade Crossing Inventory,
http://www.ohiorail.ohio.gov/crossings.php)

Figure 6 Four Quadrant Railroad Gates
(Source: Mn/DOT photo files)

1.5 Traffic Signal Preemption (TSPr)

When railroad-highway grade crossings are in near proximity to traffic signals, the two systems are directly connected so that the highest possible level of grade crossing protection is provided. The overall objective is to clear the crossing and maintain it that way while the train(s) passes to avoid a collision between the train(s) and vehicles or people (see Figure 7). The application scope here is heavy rail, i.e., operations in which the train can not be expected to stop in time to avoid a collision with an object on the grade crossing. Light rail transit is considered a non-standard application that must be treated on a case-by-case basis. The approach of a train near a TSPr signal always preempts normal signal operation to clear the crossing and avoid a collision. In all cases, the train system sends a preempt message to the traffic signal controller, which then takes appropriate action to clear the crossing and hold the "crossing closed" preemption state. The railroad hardware side includes the track sensing circuitry and the interconnection to the traffic signal up to the point where the preempt message is handed off to the traffic signal.

The basic operational mode as described in Section 1.1 critically affects traffic signal clearance timing. With constant warning time, traffic signal clearance timing must be related to the specific warning time for activating crossing protection. In the mode with non-constant warning time, the variable detection time of the train relative to when it reaches the crossing must be factored into site design and subsequent signal timing. In either case, the pre-emption response of the traffic signal controller is site specific and depends on the physical configuration of the railroad-highway grade crossing and the location of adjacent traffic signals. The control logic must clear vehicles, bicyclists, and pedestrians off the railroad tracks by special pre-emption phasing and timing. Figure 8 is an example of phase sequencing for railroad preemption of a traffic signal.

Signal operation with preemption may also include turning signals further downstream of a crossing to green to allow queued vehicles to leave the crossing area. Under all circumstances, preemption treatment of traffic signals is complex and must be carefully considered and designed to provide the greatest possible protection for the individual site conditions.

The railroad side must provide clear and precise information to the involved traffic signals. Related materials for the traffic signal(s) are presented in *Systems Engineering Concept of Operations for: Standard Traffic Signal.*

Figure 7 Grade Crossing with Traffic Signal Preemption
(Source: Public Utilities Commission of Ohio Grade Crossing Inventory, http://www.ohiorail.ohio.gov/crossings.php)

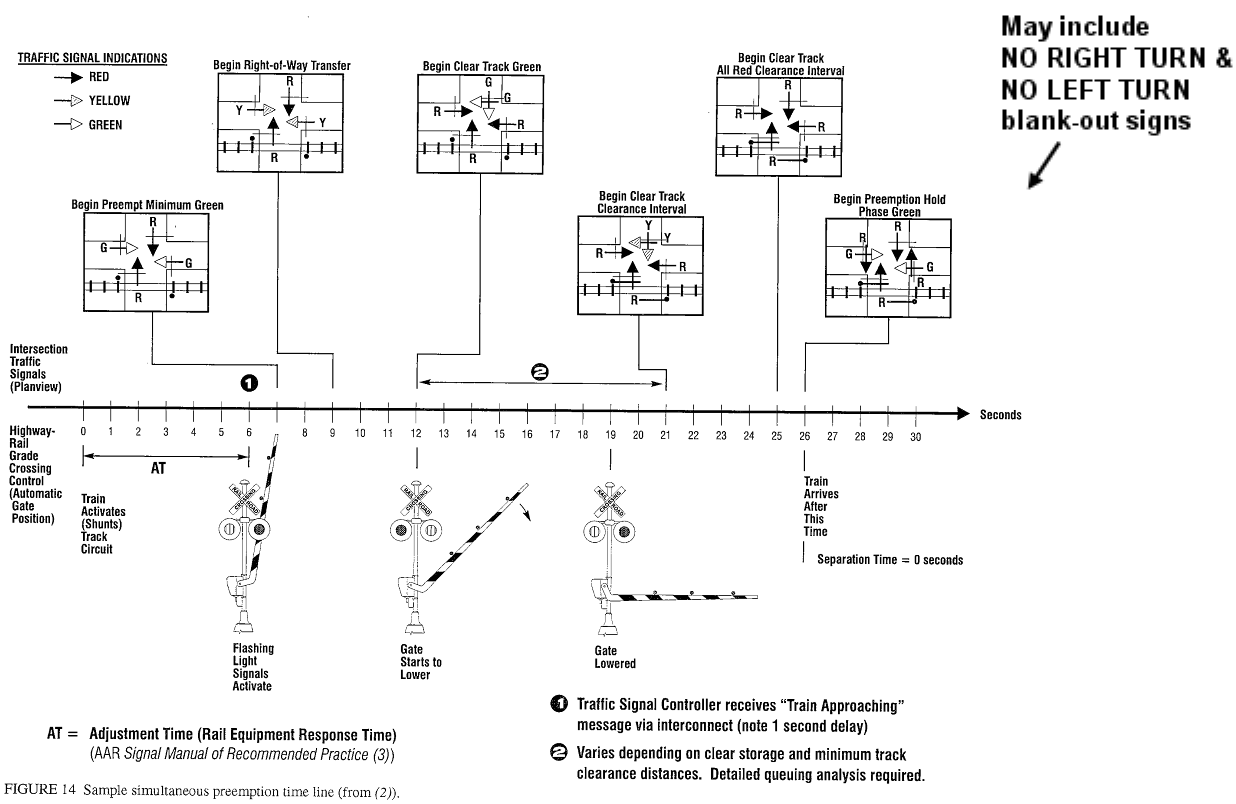

Figure 8 Traffic Signal Sequencing for Railroad Preemption
(Source: *Traffic Signal Operations Near Highway-Rail Grade Crossings*, NCHRP Synthesis 271)

1.6 Other

[Reserved for new grade crossing features and their characteristics. Please consult with appropriate MnDOT, FHWA, or local staff to develop needed scope description.]

With all of these standard grade crossing protection types, there is no absolute way to prevent an errant motorist from either running the gates or crashing through gates into the grade crossing area. Limited experimentation has taken place in the US with positive barriers based on the nets used on aircraft carriers to catch aircraft overrunning the landing area. If high-speed rail is deployed in Minnesota, this type of advanced protection should be considered for implementation. This is an example of another type of grade crossing protection that would require further research, design, and testing.

2.0 REFERENCE DOCUMENTS

Reference sources, including traffic signal design and operation documents, follow. The latest adopted version of each document should apply.

- "Intelligent Transportation System Architecture and Standards," (*CFR 940*), Federal Highway Administration (FHWA) Final Rule, 23 CFR Parts 655 and 940
- *Minnesota Statewide Regional ITS Architecture,* March 2009
- *MnDOT Intelligent Transportation System (ITS) Design Manual*, Fall 2009
- *Minnesota Traffic Engineering Manual*
- *Minnesota Statutes 2009,* Chapter 219, "Railroad Safety and Employment"
- Various traffic signal planning, design, and operations references cited at http://www.dot.state.mn.us/trafficeng/designtools/index.html
- *2005 MN MUTCD*, particularly "Part 8. Traffic Control Systems for Railroad-Highway Grade Crossings," and Section 4D.13.
- *Mn/DOT Traffic Signal Timing and Coordination Manual,* March 2009
- *Railroad-Highway Grade Crossing Handbook,* FHWA*,* available at http://www.fra.dot.gov/Elib/Document/1464
- The American Railway Engineering and Maintenance-of-Way Association (AREMA) standards, available at http://www.ihs.com.au/standards/arema/
- Local agency grade crossing practices and design guidelines, as applicable
- *The Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)*, latest edition.

3.0 BACKGROUND AND SYSTEM CONCEPT

3.1 Railroad Flashing-Light Signals (FLS)

Grade crossing protection is overseen and directed by the Mn/DOT Commissioner of Transportation, as indicated in *Minnesota Statutes 2009*, Chapter 219, "Railroad Safety and Employment." The Commissioner is charged with determining the most appropriate form of protection at grade crossings and with investigating associated issues. This duty has evolved in response to the development of the rail system across the US over the past 150+ years. Railroads were originally given land grants in return for developing long distance rail service and generally granted absolute rights to operate on their right-of-way as they deemed necessary. Grade crossing protection has been an obvious basic issue from the start, with a major emphasis on safety at this critical interface between highway and rail systems. Since rail companies are charged with maintaining protection devices, the protection requirements are essentially uniform across the country so that the companies do not have to deal with differing rules by state.

3.2 Railroad Cantilever Flashing-Light Signals (CFL)

As discussed in Section 1.2, CFL add to conspicuity of grade crossing warning for added protection.

3.3 Standard Railroad Gates (SRG)

Railroad gates were first patented in the 1860s. With the advent of the automobile and increasing mileage of roads and thus grade crossings in the 20th century, gate protection became much more widespread. Standardization of design and application across the US has been the norm for several decades. Critical needs and guidance are provided in the *2005 MN MUTCD*, particularly Part 8.

3.4 Four Quadrant Railroad Gates (FQG)

Section 1.3 discusses the expanded role and operation of FQG relative to SRG.

3.5 Traffic Signal Preemption (TSPr)

The major thrust of interconnecting railroad track circuits to nearby traffic signals and preempting their normal red-yellow-green operation is the need to clear the crossing area of conflicting objects and persons before the train arrives. This need leads to fairly complex communications and traffic signal sequencing to provide as much protection as possible.

3.6 Other

Given the maturity of active grade crossing protection, potential other features, such as communication of train approach to individual vehicles, can be expected to evolve. These will require substantial documentation to justify and explain new technologies and applications.

4.0 OPERATIONAL DESCRIPTION

The major operational aspects of grade crossing protection have been discussed in Section 1.1 through 1.5 and Section 3.1 through 3.5. The connection and interface between the rail system and the highway system are critical to assuring safe operation when such interconnection has been deemed appropriate. The railroad company and the public agency must work cooperatively in planning, designing, implementing, and managing grade crossing protection.

5.0 OPERATIONAL NEEDS

The needs of grade crossing protection for the various stakeholders are presented in Table 1.

Table 1 Grade Crossing Protection Needs by Stakeholder

STAKEHOLDER	GRADE CROSSING PROTECTION NEEDS
Travelers: private vehicle drivers and passengers, transit operators and passengers, commercial operators, school bus operators and passengers, pedestrians (including those with disabilities), and bicyclists DPS	FLS-1 Deployment of active grade crossing protection at railroad-highway grade crossings that have historically high incident rates and have deficient sight distances.
	FLS-2 Highly conspicuous warning to travelers that they are approaching a grade crossing
	FLS -3 Clear, unambiguous display of an active warning that a train is approaching and subsequently occupying the crossing
	FLS -4 Safe and efficient clearance of the grade crossing of vehicles, pedestrians, and bicyclists
	FLS-5 Safe and efficient termination of protection device once the train(s) has left the crossing area
	Additional Needs and Functions by grade crossing protection feature:
	CFL-1 Accentuated display of an active warning that a train is approaching and subsequently occupying the crossing.
	SRG-1 Fail-safe gate operation that minimizes the possibility of vehicles, objects or persons entering the grade crossing area from approach lanes. Separate pedestrian crossing gates from those for vehicles may be needed.
	FQG-1 Fail-safe gate operation that minimizes the possibility of vehicles, objects or persons entering the grade crossing area from approach lanes or by attempting to run the gates by using opposite direction exit lanes
	FQG-1 Fail-safe gate operation that minimizes or eliminates the possibility of vehicles becoming trapped in the grade crossing area by exit gates.
	TSPr-1 Positive conveyance of track circuit message to adjacent traffic signal(s) in timely manner that train is approaching and subsequently occupying the crossing
	Other – *[Please consult with appropriate Mn/DOT, FHWA, or local staff to develop needed Needs and Functions]*
All Stakeholders share in above to varying degree. Further specific Needs and Functions follow:	
Mn/DOT, Mn/DOT District Offices, Local Agencies, FHWA, and FRA	FLS-6 Planning, design, and implementation of grade crossing protection that meets agency and railroad performance standards or guidelines for operations and safety, and which is reliable and easily maintained.

Table 1 (continued)

	FLS-7 In coordination with railroad company, planning, design, and implementation of protection device monitoring of performance and device failures plus communications links, as required by site plans.
Mn/DOT Office of Maintenance, RTMC, OTST, TDA, OFCVO, and TOCCs; Local MCM Agencies and Traffic Management Centers	FLS-8 Communications links and failure alarms as required by site plans FLS-9 Archiving of equipment failure records for further analysis as required by site plans TSPr-2 Clear, unambiguous communications link with the traffic signal(s) that is preempted
Railroad Companies, Local Transit Providers with light rail operations	FLS-10 Proactive operation and maintenance of protection equipment on a continuous basis.
	FLS-7 See above, in coordination with responsible governmental unit

The Needs and Services plus associated ITS Development Objectives, per the *Statewide Architecture*, are presented in Table 2. For reference, the complete list of ITS Development Objectives is presented in Appendix A.

Table 2 Grade Crossing Protection Needs/Services & ITS Development Objectives by Grade Crossing Protection Feature

ID	Feature	Needs/Services		ITS Development Objectives
GCP-FLS	*Railroad Flashing-Light Signals*	TM28	Provide railroad flashing light signals and gates	O-9
		TM38	Provide health monitoring of rail crossings	O-9
GCP-CFL	*Railroad Cantilever Flashing-Light Signals*	TM28	Provide railroad flashing light signals and gates	O-9
GCP-SRG	*Standard Railroad Gates*	TM28	Provide railroad flashing light signals and gates	O-9
GCP-FQG	*Four Quadrant Railroad Gates*	TM28	Provide railroad flashing light signals and gates	O-9
TS-RRP	*Traffic Signal Preemption*	TM28	Provide railroad flashing light signals and gates	O-9
TS-Oth	*Other*			

Needs/Services and ITS Development Objectives per *Minnesota Statewide Regional ITS Architecture* (March 2009).

Needs/Services Key:
TM - Traffic Management

See Appendix A for detailed list of ITS Development Objectives.

6.0 OPERATIONAL SUPPORT ENVIRONMENT

6.1 Railroad Flashing-Light Signals (FLS)

The operational support environment will use standard maintenance of railroad companies. Railroad technicians will operate and maintain the grade crossing protection using industry operational guidelines along with routine and emergency maintenance procedures that are well established. Grade crossing protection sequencing and timing is to be in conformance with the *2005 MN MUTCD* and AREMA standards.

With respect to operational scenarios, the most important maintenance aspect once protection sequences and timing have been prepared and implemented is to have defined quick response procedures for trouble calls. Trouble calls will typically originate from various sources: the general public, police, railroad company personnel, and Mn/DOT or Local Agency personnel who drive through the subject approach*[es]* either as a part of assigned work, or as a private citizen, e.g., while commuting to and from work.

Preventive maintenance on the grade crossing protection will be scheduled to occur frequently as a part of routine maintenance. Review of operations can be expected to occur periodically or in response to changing conditions at the crossing, in terms of either rail activity or vehicle activity. Safety data (crash and “near miss” experience) plus vehicle delay data from each site should factor into site review, along with field observations and citizen complaints.

FLS sites may include central monitoring of grade crossing protection health by the railroad company, the local government entity, or both. In this case, system architecture and communications system configuration will need to be developed on an individual site basis, ideally including redundant network design.

Specialized training is required to handle operations and maintenance.

6.2 Railroad Cantilever Flashing-Light Signals (CFL)

CFL operational scenarios are essentially the same as for FLS, but with a greater focus on confirming that the desired level of conspicuity is achieved by the grade crossing warning equipment.

6.3 Standard Railroad Gates (SRG)

The basic SRG operational scenario is as described in Section 1.3 above to provide standard, readily understood warnings and protection of each grade crossing. Uniform national standards are the basis for operations so that any non-local driver can immediately comprehend the layout and appropriate response action when flashing lights and gates are activated.

6.4 Four Quadrant Railroad Gates (FQG)

Section 1.4 describes the basic operational scenario that affords additional protection to minimize the likelihood of gate running. The most important aspect is the programmed or controlled delay in lowering the exit side gates, to avoid trapping vehicles on the grade crossing. The dynamic exit gate operating mode with appropriate detection in the grade crossing area help to address this issue.

6.5 Traffic Signal Preemption (TSPr)

Section 1.5 describes the basic operations. The interface between the track circuit and the traffic signal plus the associated signal preemption timing are critical aspects that must be carefully developed and fine tuned as necessary. TSPr also requires regular routine maintenance and quick response in case of performance failure or trouble call. Although the operations of each site is standalone, remote monitoring of the preemption circuitry that sends alarm messages to both the railroad and the local highway agency in the case of a malfunction is desirable. The system architecture and associated communications for this are dependent on characteristics of both the rail system and the traffic signal operation. Periodic operational and safety reviews need to be conducted, potentially leading to adjustment in TSPr activation sequencing and timing.

6.6 Other

[Reserved for new features and their scenarios].

7.0 SUMMARY OF IMPACTS

7.1 All Grade Crossing Protection

For all forms of grade crossing protection, the goal is elimination of all grade crossing crashes. The protection should alert and warn all drivers, including those who are impaired and distracted, of the dangers associated with grade crossings. The consequences of failing to abide by the warnings and protection are almost always severe, hence the safety benefit is of the highest importance. Grade crossing incident history and site characteristics should be the basis for determining the most appropriate form of protection.

Secondarily, grade crossings cause stopping and delays to motorists, such that sequencing and timing should aim to limit flashing-light and gate down times to just those durations that are required to protect travelers. The time that a crossing is blocked by a train depends on the operational characteristics of the railroad company. Railroad companies in general wish to be good corporate citizens and aim to limit individual gate down times.

7.2 Other

[Reserved for new feature impacts.]

APPENDIX A. ITS DEVELOPMENT OBEJCTIVES

Source: ***Minnesota Statewide Regional ITS Architecture*** *(March 2009)*

General Purpose: Create a system that enhances transportation through the safe and efficient movement of people, goods, and information, with greater mobility and fuel efficiency, less pollution, and increased operating efficiency in Minnesota.

A. Improve the Safety of the State's Transportation System

A-1. Reduce crash frequency (*ATMS, ATIS, APTS, CVO, EM, MCM & AVSS*)

- O-1 Reduce crashes due to road weather conditions
- O-2 Reduce crashes due to unexpected congestion
- O-3 Reduce secondary crashes
- O-4 Reduce incident clearance time
- O-5 Reduce crashes due to red-light running
- O-6 Reduce crashes due to unsafe drivers, vehicles and cargo on the transportation system
- O-7 Reduce lane departure crashes
- O-8 Reduce crashes due to roadway/geometric restrictions
- O-9 Reduce crashes at railroad crossings
- O-10 Reduce crashes at intersections
- O-11 Reduce speed differential
- O-12 Reduce crashes due to driver errors and limitations
- O-13 Reduce crashes involving pedestrians or non-motorized vehicles
- O-14 Reduce violation of traffic laws

A-2. Reduce fatalities and life changing injuries (*ATMS, ATIS, CVO, EM, MCM & AVSS*)

- O-5 Reduce crashes due to red-light running
- O-9 Reduce crashes at railroad crossings
- O-10 Reduce crashes at intersections
- O-11 Reduce speed differential
- O-15 Reduce emergency/incident response time
- O-16 Enhance emergency/incident response effectiveness
- O-17 Safeguard public safety personnel while they are at roadway incidents and emergencies
- O-18 Reduce speed violations

A-3. Safeguard the motoring public from homeland security and/or Hazmat incidents (*ALL*)

- O-15 Reduce emergency/incident response time
- O-19 Reduce security risks to transit passengers and transit vehicle operators
- O-20 Reduce security risks to motorists and travelers
- O-21 Reduce security risks to transportation infrastructure
- O-22 Reduce exposure due to Hazmat & homeland security incidents
- O-23 Enhance tracking and monitoring of sensitive Hazmat shipments

A-4. Reduce crashes in work zones (*ATMS, ATIS, EM & MCM*)

- O-4 Reduce incident clearance time
- O-11 Reduce speed differential
- O-24 Reduce congestion and delay
- O-25 Enhance safety of workers

B. Increase Operational Efficiency and Capacity of the Transportation System

B-1. <u>Reduce overall delay associated with congestion *(ATMS, ATIS & MCM)*</u>
- O-4 Reduce incident clearance time
- O-15 Reduce emergency/incident response time
- O-16 Enhance emergency/incident response effectiveness
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow
- O-27 Reduce incident detection and verification time

B-2. <u>Increase average vehicle occupancy and facility throughput *(ATMS & APTS)*</u>
- O-28 Increase transit ridership
- O-29 Enhance transit operations efficiency
- O-30 Increase carpoolers
- O-31 Increase throughput of roadways

B-3. <u>Reduce delays due to work zones *(ATMS, ATIS, EM & MCM)*</u>
- O-4 Reduce incident clearance time
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow

B-4. <u>Reduce traffic delays during evacuation from homeland security and Hazmat incidents *(ALL)*</u>
- O-24 Reduce congestion and delay

B-5. <u>Enhance efficiency at borders *(ATMS, CVO, EM & AVSS)*</u>
- O-32 Reduce delays at border crossings
- O-33 Keep travelers informed of travel conditions

C. Enhance Mobility, Security, Convenience, and Comfort for the Transportation System User

C-1. <u>Reduce congestion and incident-related delay for travelers *(ATMS, ATIS & APTS)*</u>
- O-4 Reduce incident clearance time
- O-15 Reduce emergency/incident response time
- O-16 Enhance emergency/incident response effectiveness
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow
- O-27 Reduce incident detection and verification time
- O-34 Enhance parking facility services and management

C-2. <u>Improve travel time reliability *(ATMS)*</u>
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow

C-3. <u>Increase choice of travel modes *(APTS & ATMS)*</u>
- O-33 Keep travelers informed of travel conditions
- O-35 Inform travelers of travel mode options

C-4. <u>Enhance traveler security *(APTS & EM)*</u>
- O-19 Reduce security risks to transit passengers and transit vehicle operators
- O-20 Reduce security risks to motorists and travelers
- O-21 Reduce security risks to transportation infrastructure

C-5. <u>Reduce stress caused by transportation *(ATMS, ATIS, APTS, EM & MCM)*</u>
- O-3 Reduce secondary crashes
- O-11 Reduce speed differential
- O-14 Reduce violation of traffic laws
- O-18 Reduce speed violations
- O-24 Reduce congestion and delay
- O-29 Enhance transit operations efficiency

O-33 Keep travelers informed of travel conditions
O-34 Enhance parking facility services and management
O-35 Inform traveler of travel mode options

D. Enhance the Present and Future Economic Productivity of Individuals, Organizations and the Economy as a Whole

D-1. Reduce travel time for freight, transit and businesses *(ATMS, ATIS, APTS & CVO)*
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow
- O-29 Enhance transit operations efficiency
- O-33 Keep travelers informed of travel conditions

D-2. Improve the efficiency of freight movement, permitting and credentials process *(ATIS & CVO)*
- O-33 Keep travelers informed of travel conditions
- O-36 Enhance asset and resource management
- O-37 Enhance credential process automation
- O-38 Reduce freight movement delays due to inspection

D-3. Improve travel time reliability for freight, transit and businesses *(ATMS, APTS & CVO)*
- O-26 Maintain smooth traffic flow
- O-29 Enhance transit operations efficiency
- O-33 Keep travelers informed of travel conditions
- O-38 Reduce freight movement delays due to inspection

D-4. Increase agency efficiency *(ATMS, APTS, AD, CVO, EM & MCM)*
- O-29 Enhance transit operations efficiency
- O-36 Enhance asset and resource management
- O-39 Enhance garage operations efficiency

D-5. Safeguard existing infrastructure *(CVO, EM & MCM)*
- O-21 Reduce security risks to transportation infrastructure
- O-36 Enhance asset and resource management
- O-40 Reduce commercial vehicle size and weight violations

D-6. Aid in transportation infrastructure and operations planning *(ALL)*
- O-36 Enhance asset and resource management
- O-41 Enhance planning with better data
- O-42 Enhance investment decision making

D-7. Reduce vehicle operating costs *(ATMS, APTS, CVO & AVSS)*
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow

E. Reduce Energy Consumption, Environmental Impacts and Costs of Transportation

E-1. Reduce emissions/energy impacts and use associated with congestion *(ATMS, ATIS & CVO)*
- O-24 Reduce congestion and delay
- O-33 Keep travelers informed of travel conditions
- O-43 Enhance compliance of air quality standards

E-2. Reduce need for new facilities *(ATMS,CVO & MCM)*
- O-31 Increase throughput of roadways
- O-36 Enhance asset and resource management
- O-37 Enhance credential process automation

E-3. <u>Reduce negative impacts of the transportation system on communities *(APTS, ATMS, EM & MCM)*</u>

- O-14 Reduce violation of traffic laws
- O-28 Increase transit ridership
- O-30 Increase carpoolers
- O-44 Reduce environmental impacts of de-icing material use

AD:	Archived Data Management	AVSS:	Advanced Vehicle Safety Systems
APTS:	Advanced Public Transportation Systems	CVO:	Commercial Vehicle Operations
ATIS:	Advanced Traveler Information Systems	EM:	Emergency Management
ATMS:	Advanced Traffic Management Systems	MCM:	Maintenance and Construction Management