



**Systems Engineering Analysis for Railroad-Highway Grade Crossing
System Requirements**

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Revision History

This document will be used for design of MnDOT’s new railroad-highway grade crossing system. As the system is developed, changes to requirements will be tracked and this document will be revised as needed. The following table provides the date and a brief description of each revision to document revision history.

Revision Number	Date of Revision	Description of Revision
1.0	8/23/2019	Initial version
1.1	5/11/2020	Revisions per MnDOT comments
1.2	5/29/2020	Final version

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Introduction

This document provides **Functional Requirements (FR)** for various types of active grade crossing warning that may apply to this project. Please see the corresponding *Minnesota Statewide Regional ITS Architecture and Systems Engineering Checklist (Checklist)* for the project to identify which specific types apply and other pertinent site details. Regardless of the types, all active grade crossing warnings include the FR for the flashing-light signals. Following are the names for the various warning types:

- Flashing-Light Signals (FLS, common to all forms of active warning)
- Cantilever Flashing-Light Signals (CFL)
- Standard Railroad Gates (SRG)
- Four Quadrant Gates (FQG)
- Traffic Signal Preemption (TSPr)
- Other

The FR are categorized by the above warning types. Illustrations of these are provided in the corresponding *Concept of Operations* document.

The concept of operations developed for this project presents an overview of the current environment, identifies the relevant stakeholders, translates current challenges into specific needs, outlines the envisioned operational concept, suggests likely roles and responsibilities, describes scenarios for operation of the new railroad-highway grade crossing system, and presents potential risks and recommended mitigation strategies associated with this effort.

This system requirements document contains the requirements necessary for addressing the needs identified in the concept of operations. The requirements describe what the railroad-highway grade crossing system must do as the basis for further design, procurement, installation, testing and operation. It also presents an assessment of how the railroad-highway grade crossing system fits within the Minnesota ITS Architecture.

ITS Architecture Assessment

As an Intelligent Transportation System, it is necessary to assess where the railroad-highway grade crossing system fits within the [Minnesota Statewide Regional ITS Architecture \(Version 2018\)](#). As it is envisioned in the concept of operations, the railroad-highway grade crossing system is part of the [Traffic Management Service Package Area \(Volume 3\)](#). The system addresses numerous needs/potential solutions identified in the architecture and are noted below.

- ATMS28: Provide railroad flashing light signals and gates
- ATMS38: Provide health monitoring of rail crossings

The railroad-highway grade crossing system is further identified in Traffic Management bundle as a series of existing architecture elements within several service packages. Service packages represent slices of the Physical View that address specific services (i.e. traffic signal control). A service package collects together several different physical objects (systems and devices) and their functional objects and information flows that provide the desired service. Individual service packages and the system functions they perform can be found in the [United States Department of Transportation National ITS Reference Architecture \(ARC-](#)

IT). Railroad-highway grade crossing system service packages are provided in Table 1.

Table 1. Applicable Service Packages from Minnesota Statewide Regional ITS Architecture

System/Element	Service Package	Description
Railroad Active Warning Roadside Equipment	<ul style="list-style-type: none"> • TM13: Standard Railroad Grade Crossing • TM14: Advanced Railroad Grade Crossing 	This element represents roadside equipment that alerts motorists of railroad crossings at at-grade intersections. Gates are activated and de-activated as trains are detected approaching and clearing the intersection.

Based on the architecture references identified, it is confirmed that the railroad-highway grade crossing system is adequately addressed in the *Minnesota Statewide Regional ITS Architecture*.

Functional Requirements

Functional requirements are verifiable details that define what the railroad-highway grade crossing system will do, how well it will perform or what conditions it must perform under. The requirements presented in this section are defined in relation to the needs that were identified in the concept of operations for the railroad-highway grade crossing system.

There are a series of functional requirements presented in Table 2 to describe the environment the system must operate within.

Table 2. Functional Requirements for Grade Crossing Warning

ID	Functional Requirement
GCP-FLS	Railroad Flashing-Light Signals
GCP-FLS-1	The field element shall close the railroad- highway grade crossing when a train is approaching with enough time for travelers to safely clear the crossing using post-mounted flashing-light signals at a minimum, plus other devices as specified in the plans.
GCP-FLS-2	The activation of the flashing-light signals shall be coordinated with the approaching train message from the track circuit to provide adequate warning in advance of train arrival at the crossing.
GCP-FLS-3	The activation timing shall provide either constant warning time or variable warning time in accordance with the plans.
GCP-FLS-4	Active grade crossing warning shall be in effect until the train(s) leave the grade crossing area.
GCP-FLS-5	To the maximum extent possible, active grade crossing warning shall use fail- safe design and operations principles.
GCP-FLS-6	The field element shall monitor the status of the railroad-highway grade crossing equipment, including the current state, mode of operation, equipment condition, and failure alarms. This information shall be forwarded to the rail wayside equipment.

ID	Functional Requirement
GCP-FLS-7	When specified in the plans, the field element shall transmit current state, mode of operation, equipment condition, and failure alarms to the rail operations center. This may include the current status of the tracks, whether a train is approaching, and how long the crossing will be closed.
GCP-FLS-8	When specified in the plans, the field element shall transmit current state, mode of operation, equipment condition, and failure alarms to the traffic management center. This may include the current status of the tracks, whether a train is approaching, and how long the crossing will be closed.
GCP-FLS-9	When specified in the plans, the field element shall control dynamic message signs (DMS) and other traveler information devices in the vicinity of the railroad-highway grade crossing to advise drivers, bicyclists, and pedestrians of approaching trains.
GCP-FLS-10	When specified in the plans, the field element shall determine whether the railroad-highway grade crossing is blocked by traffic in the roadway or by some other obstruction, then notify the traffic management center and/or the rail operations center.
GCP-FLS-11	When specified in the plans, the traffic management center and/or the rail operations center shall archive status data received on railroad-highway grade crossing equipment, including state, mode of operation, equipment condition, and failure alarms.
GCP-FLS-12	When specified in the plans, the field element shall collect pedestrian images and pedestrian sensor data, and respond to pedestrian crossing requests via display, audio signal, or other manner.
GCP-CFL	Railroad Cantilever Flashing-Light Signals
GCP-CFL-1	When specified in the plans, the field element shall close the railroad-highway grade crossing when a train is approaching with enough time for travelers to safely clear the crossing using cantilever-mounted flashing-light signals. Post-mounted flashing-light signals shall also be provided when also specified in the plans.
GCP-SRG	Standard Railroad Gates
GCP-SRG-1	When gates are specified in the plans, the field element shall close the railroad- highway grade crossing when a train is approaching with enough time for travelers to safely clear the crossing using approach side gates in addition to flashing-light signals.
GCP-SRG-2	When specified in the plans, pedestrian gates shall be included in addition to vehicle gates.
GCP-SRG-3	The lowering of the gates shall be coordinated with, and follow, the initiation of flashing-light signal activation.
GCP-FQG	Four Quadrant Gates
GCP-FQG-1	When four quadrant gates are specified in the plans, the field element shall close the railroad-highway grade crossing when a train is approaching with enough time for travelers to safely clear the crossing using approach side and exit side gates, in addition to flashing-light signals.
GCP-FQG-2	The lowering of the exit side gates shall lag the lowering of the approach side gates to allow vehicles to safely clear the grade crossing area.

ID	Functional Requirement
GCP-TSPr	Traffic Signal Preemption
GCP-TSPr-1	When Traffic Signal Preemption is shown in the plans, the field element shall close the railroad-highway grade crossing when a train is approaching with enough time for travelers to safely clear the crossing by preempting adjacent traffic signals with prescribed sequencing and timing.
GCP-TSPr -2	Preemption shall be in addition to other active grade crossing warning.
GCP-TSPr -3	When specified in the plans, the field element shall support the integrated control of adjacent traffic signals to clear an area in advance of an approaching train and to manage traffic around the grade crossing.
GCP-CAV	CAV Infrastructure Systems
GCP-CAV-1	When specified in the plans, the field element shall communicate crossing status to the applicable CAV Infrastructure System.
GCP-Oth	Other
GCP-Oth-1	[Develop as appropriate]

Table 3. Mapping of Grade Crossing Warning Needs/Services to Functional Requirements

Feature	Needs/Services	ITS Functional Requirements
Railroad Flashing-Light Signals	ATMS28: Provide railroad flashing light signals and gates	GCP-FLS-1 thru -5, -9 thru -12
	ATMS38: Provide health monitoring of rail crossings	GCP-FLS-6 thru -8
Railroad Cantilever Flashing-Light Signals	ATMS28: Provide railroad flashing light signals and gates	GCP-CFL-1
Standard Railroad Gates	ATMS28: Provide railroad flashing light signals and gates	GCP-SRG-1 thru -3
Four Quadrant Railroad Gates	ATMS28: Provide railroad flashing light signals and gates	GCP-FQG-1, -2
Traffic Signal Preemption	ATMS28: Provide railroad flashing light signals and gates	GCP-TSPr-1 thru -3
Other	[Develop as appropriate.]	