m **DEPARTMENT OF TRANSPORTATION**

Systems Engineering Analysis for Weigh-in-Motion System

System Requirements

May 2020
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Revision History

This document will be used for design of MnDOT's new weigh-in-motion 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	8/10/2019	Initial version
1.1	5/21/2020	Revisions per MnDOT comments
1.2	5/28/2020	Final version

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Introduction

This document provides **Functional Requirements** (*FRs*) for standard Weigh-in-Motion (WIM) systems. A WIM installation uses in-pavement sensors to measure the weights and speed of any vehicle passing over them at highway speed, as well as the number and spacing of axles. A roadside processor then instantly classifies the vehicle and determines whether or not it is likely legal in gross vehicle weight, individual axle weight, and axle group weight, focusing on commercial vehicle trucks. The action at the site then depends on the type of WIM installation, as summarized in the *Concept of Operations*. Installations may also include a video camera viewing trucks as they pass over the road section near the sensors, or a camera to take still images of the passing trucks.

The WIM system records information on all vehicles passing over the sensors, thus the detailed data can be archived to compute pavement vehicle loads in, usually, equivalent single axle loads (ESALs). This information is very useful in analyzing expected pavement life and needed rehabilitation, and in evaluating of how well particular pavement designs withstand wear-and-tear for general design purposes. If the site is standalone, the data are stored locally for later transfer to other MnDOT (or FHWA) offices. If the site connects to a control center, the data are typically transferred via the communications network in real time. Current MnDOT WIM sites are standalone and are not connected to a control center.

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 WIM 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 WIM system must do as the basis for further design, procurement, installation, testing and operation. It also presents an assessment of how the WIM system fits within the Minnesota Statewide Regional ITS Architecture.

ITS Architecture Assessment

As an Intelligent Transportation System, it is necessary to assess where the WIM system fits within the [Minnesota Statewide Regional ITS Architecture (Version 2018)](#). As it is envisioned in the concept of operations, the WIM system is part of the [Commercial Vehicle Operations Service Area Package (Volume 5)](#). The system addresses numerous needs/potential solutions identified in the architecture and are noted below.

- CVFO 01: Minimize delays at weigh stations through additional automation
- CVFO 12: Permit and route commercial vehicle operators of oversize and overweight loads to routes that accommodate size and weight requirements
- CVFO 18: Provide multi-state oversize/overweight permitting
- CVFO 02: Provide mobile weight enforcement
- CVFO 03: Target enforcement at locations with history of violations

The WIM system is further identified in Commercial Vehicle Operations 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). WIM system service packages are provided in Table 1 below.

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

System/Element	Service Package	Description
Weigh in Motion (WIM) Stations Roadside Equipment	• CVO08: Smart Roadside and Virtual WIM • CVO03: Electronic Clearance	This element represents WIM systems that measure and record axle weights and gross vehicle weight without requiring the vehicle to come to a stop.

Based on the architecture references identified, it is confirmed that the WIM system is adequately addressed in the *Minnesota Statewide Regional ITS Architecture.*

Functional Requirements

Functional requirements are verifiable details that define what the WIM 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 WIM 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 WIM Installation

ID	Functional Requirement
WIM	**Weigh-in-Motion for CVO Inspection with Enforcement**
WIM-1	The roadside check facility equipment shall detect the presence of commercial vehicles and freight equipment approaching a facility. Sensors can differentiate between different types of vehicles and determine the number of axles, gross vehicle weight, weight per axle, and axle spacings.
WIM-2	The roadside processor shall check weight compliance per Minnesota statutes in terms of gross vehicle weight, individual axle load, and axle group load within the time period and level of accuracy specified in the plans.
WIM-3	When specified in the plans, the WIM installation shall include a CCTV camera or still digital photography to capture and instantly make available video or snapshot images of vehicles passing over the WIM sensors.
WIM-4	The installation shall store detailed records of 1) all vehicles passing over the WIM sensors for use in vehicle classification and post-processing of weight compliance trends and patterns, plus 2) status indicators and alarms.

ID	Functional Requirement
WIM-5	As specified in the plans, the roadside check facility equipment shall operate as a standalone facility. Parameters and settings shall be changeable to alter the sensitivity and operating characteristics of the WIM equipment at the site.
WIM-5a	(Optional) As specified in the plans and as a control center for WIM exists, the roadside check facility equipment shall be supervised by the control center. Parameters and settings shall be changeable to alter the sensitivity and operating characteristics of the WIM equipment from the control center.
WIM-6	The field processor shall generate WIM equipment operational status indicators and failure alarms on the field processor.
WIM-6a	(Optional) As specified in the plans and as a control center for WIM exists, the field processor shall send WIM equipment operational status indicators and failure alarms on the field processor to the control center.
WIM-7	When specified in the plans, the roadside check facility equipment shall send a pass/pull-in notification to the commercial vehicle and its driver based on the information received from the vehicle and the measurements taken. The message may be sent to the driver using equipment such as dynamic message signs, red- green lights, flashing signs, etc.
WIM-8	When specified in the plans, the roadside check facility equipment shall display truck weight compliance information on a dynamic message sign at the site as an information item to drivers.
WIM-9	When specified in the plans, the roadside check facility equipment shall transmit the information over the internet via a secure web site, for use by weight enforcement officers.
WIM-10	WIM design shall consider whether nearby CAV roadside units (RSUs) will require direct data feeds from the WIM.
WIM-11	WIM design shall consider whether nearby CAV roadside units (RSUs) will benefit from shared power or communications with the WIM.
WIM-12	When specified in the plans, WIM shall communicate pass/pull-in messages to the applicable CAV Infrastructure System.
WIM-Oth	**Other**
WIM-Oth-1	[Develop as appropriate]

Table 3. Mapping of WIM Needs/Services to Functional Requirements

Feature	Needs/Services	ITS Functional Requirements
Weigh-in-Motion for CVO Electronic Clearance with Enforcement	CVFO 01: Minimize delays at weigh stations through additional automation	WIM-1, -2 and -5 thru -9
	CVFO 12: Permit and route commercial vehicle operators of oversize and overweight loads to routes that accommodate size and weight requirements	WIM-1, -2 and -7 thru -9
	CVFO 18: Provide multi-state oversize/overweight permitting	WIM-5, -7 thru -9
	CVFO 02: Provide mobile weight enforcement	WIM-3, -10
	CVFO 03: Target enforcement at locations with history of violations	WIM-2, -4, and -10
Other	[Develop as needed]	