SYSTEMS ENGINEERING
CONCEPT OF OPERATIONS (ConOps)

for:

WEIGH-IN-MOTION
INSTALLATION

MINNESOTA DEPARTMENT OF TRANSPORTATION

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1.0 Purpose and Scope of Application Package

This document provides a ***Concept of Operations*** (*ConOps*) for standard Weigh-in-Motion installations. 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 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 described in Section 1.1.

Due to the dynamics of weight load and transfer at speed, the weights from a WIM installation are used as a screening tool of weight compliance only and cannot be used directly for enforcement. The WIM equipment, for example, is required to be accurate on gross vehicle weight to within 10%, 95% of the time. Legal weight can only be established by static scales that the truck needs to pull onto at a weigh station, or by portable static scales carried by weight enforcement personnel. Static scales must be periodically checked and recertified for accuracy.

Figure 1 illustrates typical piezo quartz sensors used in the pavement, which is the only type of sensor used by the Minnesota Department of Transportation (Mn/DOT). Figure 2 illustrates loop detectors installed as a “speed trap” to measure speed very accurately. Accurate speed is needed so that axle spacings can be measured to within one-half foot accuracy. This is needed to check compliance for axle groups based on the FHWA “bridge formula,” which is a function of weight by axle spacing. Installations may also include a closed circuit television (CCTV) camera viewing trucks as they pass over the road section near the sensors, or a camera to take still images of the passing trucks and license plate to monitor compliance.

Since the WIM system records information on all vehicles passing over the sensors, 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 Mn/DOT (or FHWA) offices. If the site connects to a control center, the data are typically transferred via the communications network in real time.

This *ConOps* focuses on the field element WIM that are fairly standard, but also mentions oversight and monitoring from a control center. WIM sites may be either standalone or connected to a control center. In the second case, communications are needed, but WIM communications are typically a small part of a larger network that is outside the scope of this *ConOps.*

PIEZO QUARTZ SENSOR INSTALLATION

INSTALLED SENSOR

Figure 1 Typical WIM Site Sensors
(Source: Mn/DOT files)

Figure 2 Typical WIM Site Speed Trap
(Source: Mn/DOT files)

Please see the corresponding *Minnesota Statewide Regional ITS Architecture and Systems Engineering Checklist* (*Checklist)* for the project locations.

Mn/DOT and the Minnesota State Patrol are responsible for planning, designing, operating, and maintaining weight enforcement systems, while the FHWA oversees the overall weight enforcement plan. The complete list of potential stakeholders, as per the *Minnesota Statewide Regional ITS Architecture* (March 2009; *Statewide Architecture* for short), is 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 Traffic, Safety, and Technology (OTST; formerly OTSO)
  - Office of Maintenance
  - Office of Transportation Data and Analysis (TDA)
  - Office of Freight and Commercial Vehicle Operations (OFCVO)
- Minnesota Department of Public Safety (DPS)
- Minnesota State Patrol (MSP)
- Local Agencies: counties, cities, towns, villages, and townships
- Federal Highway Administration (FHWA)

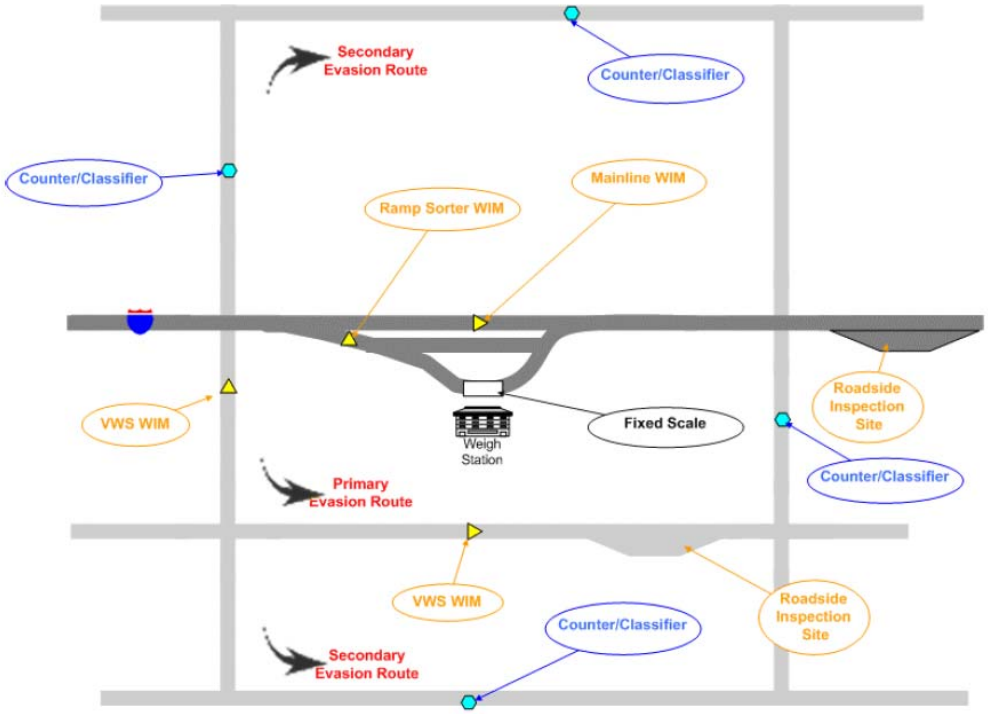
Notes to Stakeholder list:

- 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*.

1.1 WIM for CVO Electronic Clearance with Enforcement

WIM measurements are part of electronic clearance for commercial vehicle operations (CVO), typically resulting in expedited processing of vehicles that have been already certified. These CVO trucks carry an electronic tag that identifies at least the truck and its cargo. The roadside equipment must be able to read the electronic tag, but the WIM equipment independently screens trucks for compliance with legal limits. The WIM sensors might be placed only in the outside lane from which trucks enter a CVO inspection station. ***(STILL NEED VERIFICATION TAGS IN USE IN MN)***

An advanced concept for a "virtual weigh station" is presented in Figure 3 from the cited statewide plan for weight enforcement. In this concept, there are several WIM sensors and other detectors strategically placed on the road network so that trucks cannot easily avoid inspection. Virtual weigh stations may also use a dynamic feedback system that presents a weight compliance message to vehicles immediately after they have passed over a WIM scale. This is similar to speed signs with a message "YOUR SPEED IS xx ", instead saying, for example, "YOUR VEHICLE IS OVERWEIGHT." In other words, the sign would apply peer pressure, as opposed to actual enforcement.



VWS – Virtual Weigh Station

Figure 3 WIM Installation at "Virtual Weigh Station"

(Source: *Minnesota Statewide Commercial Vehicle Weight Compliance Strategic Plan*, 2005)

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CCTV camera views or still images afford a tool for CVO inspection personnel to identify non-compliant trucks that ought to be pursued and issued a ticket for avoiding a CVO electronic clearance/inspection station. The CVO station may include static scales to check vehicle weight. CVO inspection personnel thus are the primary initial users of the information from the WIM site.

The WIM system typically has an 8-10% tolerance built in so that an apparent violation is signaled only when the truck is very likely to be in violation. Only trucks exceeding the tolerance value typically are directed to proceed to the site static scales, while within tolerance trucks are allowed directly back onto the highway. Overweight truck fines can run into the thousands of dollars.

In another version of WIM operation, a picture of the likely offending vehicle and weight information is posted on a real time web site to enforcement officers downstream of the site. Those officers would use a snap shot picture of the vehicle to identify it as it approaches, then they would stop the truck and again perform a static weigh-in using portable scales ("mobile weight enforcement"). Figure 4 illustrates the type of information displayed on a web page with a series of truck pictures, one of which is identified as potentially overweight ("Warning: Over GVW threshold").

Virtual Weigh Station Display

Figure 4 WIM Enforcement over the Internet – Web Page Display
*(*Source: *Virtual Weigh Station System Overview*, p 4, International Road Dynamics, used by permission)

For enforcement purposes, it is important that site data be archived for post-processing. With archived data, trends in violation behavior by location, day of week, and time of day can be investigated. Targeted enforcement can then aim to address the times and places most in need of enforcement.

1.2 Other

[Reserved for new WIM features and their characteristics. Please consult with appropriate Mn/DOT, FHWA, or local staff to develop needed scope description.]

2.0 Reference Documents

Reference sources are as follows:

- "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
- *Mn/DOT Intelligent Transportation System (ITS) Design Manual*, Fall 2009
- Various traffic engineering planning, design, and operations references cited at

http://www.dot.state.mn.us/trafficeng/designtools/index.html ***(VERIFY KEEP)***

- *Minnesota Statewide Commercial Vehicle Weight Compliance Strategic Plan*, URS for Mn/DOT and Minnesota State Patrol, June 30, 2005
- *Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods*, American Society for Testing and Materials Specification 1318-02, 2002.

3.0 Background and System Concept

3.1 WIM for CVO Electronic Clearance with Enforcement

WIM technology has progressed a long way in the last 20 years in step with advances in electronic processing and communications system development. CVO electronic clearance was a concept that evolved from the original Intelligent Vehicle Highway System program in the early 90s, though WIM technology was already under development at the time. The benefits of speeding up truck processing at state ports of entry and at inspection/weigh station are obvious in terms of more productive commerce, and WIM is one important part of expediting truck movements.

One of the best ways to preserve and protect the pavement infrastructure as well as improve overall safety is to make every effort to keep overweight trucks off road facilities. WIM enforcement is a very important tool that allows the state to monitor for compliance with load limits, assessing fines to drivers who do not comply with the law. Load limits on interstates across the US for the most part are the same or very similar, so that enforcement in one state often has benefits for other states as well. The technology behind WIM is complex and sophisticated, yet functions at a remarkably high level of accuracy as long as the equipment is well maintained.

3.2 Other

[Reserved for new WIM features and their characteristics.]

4.0 Operational Description

The major operational aspects of WIM have been discussed in Section 1. As more WIM installations are implemented in Minnesota, it can be expected that all sites will be networked together to a control center so that trends and can be actively monitored across the state.

5.0 Operational Needs

The needs of WIM installations for the various stakeholders are presented in Table 1.

Table 1 WIM Needs by Stakeholder

STAKEHOLDER	WIM 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	WIM-1 Application of WIM data by appropriate authorities to enforce legal weight limits thus preserving the integrity and life of the key pavement asset and provide a safer operating environment.
	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 Needs and Functions follow:	
Mn/DOT, Mn/DOT District Offices, Local Agencies	WIM-2 Planning, design, and implementation of WIM sites that meet agency design and performance standards, are reliable and fairly easy to maintain. WIM-3 Access to WIM archived data for purposes of evaluating pavement performance and to help guide design.
Mn/DOT RTMC, TOCCs, and OTST	WIM-4 Communications links to WIM management centers when indicated. WIM-5 Remote oversight of WIM sites when they are linked to a center.
Mn/DOT OM	WIM-6 Proactive maintenance of WIM equipment.
MSP	WIM- 7 Accurate, reliable WIM equipment that can be used for CVO compliance, WIM enforcement, or speed enforcement as appropriate. WIM-8 Access to WIM archived data so that violation patterns can be documented to help target enforcement.
Mn/DOT OFCVO and TDA	WIM-9 Access to WIM archived data to help with CVO management, road safety, and facility planning.
FHWA	WIM-7 Accurate, reliable WIM performance that can be used to help manage the pavement asset.

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 WIM Needs/Services & ITS Development Objectives by WIM Feature

ID	Feature	Needs/Services		ITS Development Objectives
WIM-CVO	*Weigh-in-Motion for CVO Electronic Clearance with Enforcement*	CF01	Minimize delays at weigh stations through additional automation	O-26, O-32, O-38, O-40
		CF12	Direct commercial vehicle operators to routes that accommodate size and weight requirements	O-6, O-26, O-33, O-36, O-40
		CF18	Provide multi-state oversize/overweight permitting	O-36, O-37, O-40
		CF02	Provide mobile weigh enforcement	O-36, O-38, O-40
		CF03	Target enforcement at locations with history of violations	O-36, O-38, O-40
		CF04	Target enforcement on carriers, vehicles and drivers with history of violations	O-36, O-38, O-40
WIM-Oth	*Other*			

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

Needs/Services Key:
CF - Commercial Fleet

See Appendix A for detailed list of ITS Development Objectives.

6.0 Operational Support Environment

6.1 WIM for CVO Electronic Clearance with Enforcement

The operational support environment will use operations and maintenance procedures completed either by agency personnel or contracted private services. WIM equipment is complex and specialized and must be maintained at a high level to achieve satisfactory performance. Initially, the equipment is subject to rigorous testing, and some fine tuning of settings and parameters can be expected. Ideally, the parameters and settings can be monitored and changed remotely from a control center based on field operations.

Specially trained technicians maintain WIM installations using supplier recommended procedures at regularly scheduled intervals. This would include periodic checking and recalibration of sensors. Further specialized procedures may be needed if the WIM equipment is linked to other CVO electronic clearance equipment. In general, trouble calls on WIM sites are not as critical as with, for example, traffic signals or active grade crossing protection. Nevertheless, CVO inspection personnel rely on a high performance level so that they can fulfill their mission of assuring trucks operate within legal limits. Trouble calls will typically originate from alarms on standalone equipment that may be transmitted to the control center.

For WIM installations that connect to a control center, system architecture and communications system configuration will need to be developed during planning and design, ideally including redundant network design. Communications may be either wireline or wireless.

For enforcement purposes, WIM data needs to be archived for MSP personnel so that they can run reports that identify violation trends and patterns. These reports will then facilitate targeted enforcement.

6.2 Other

[Reserved for new features and their scenarios].

7.0 SUMMARY OF IMPACTS

7.1 WIM for CVO Electronic Clearance with Enforcement

The primary impact of WIM for electronic clearance is to help maintain a high level of operational compliance with legal weight limits on the state highway system. By keeping violations to a minimum, the system helps to preserve an expensive long term asset, namely the basic pavement structure. This in turn has economic benefits for the state by helping assure the full design life of facilities can be achieved. Keeping overweight trucks off highways should also have safety benefits, since overweight trucks generally are more difficult to stop in emergency conditions and tend to cause more severe crashes when involved in incidents. WIM stations also provide detailed vehicle classification data useful for a variety of planning and design purposes.

With regard to enforcement, fines for overweight trucks can be substantial, and where WIM sites are placed on high volume truck routes, in a relatively short time they net fines well in excess of installation and operating costs. This is a secondary benefit to the overall goal of and impact of preserving pavement structure.

7.2 Other

[Reserved for new WIM feature impacts.]

Appendix A. ITS Development Objectives

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. Reduce overall delay associated with congestion *(ATMS, ATIS & MCM)*
- 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. Increase average vehicle occupancy and facility throughput *(ATMS & APTS)*
- O-28 Increase transit ridership
- O-29 Enhance transit operations efficiency
- O-30 Increase carpoolers
- O-31 Increase throughput of roadways

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

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

B-5. Enhance efficiency at borders *(ATMS, CVO, EM & AVSS)*
- 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. Reduce congestion and incident-related delay for travelers *(ATMS, ATIS & APTS)*
- 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. Improve travel time reliability *(ATMS)*
- O-24 Reduce congestion and delay
- O-26 Maintain smooth traffic flow

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

C-4. Enhance traveler security *(APTS & EM)*
- 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. Reduce stress caused by transportation *(ATMS, ATIS, APTS, EM & MCM)*
- 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. Reduce negative impacts of the transportation system on communities *(APTS, ATMS, EM & MCM)*

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