

CHAPTER 5 - INTELLIGENT TRANSPORTATION SYSTEMS

Table of Contents

5-1.00 INTRODUCTION	5-3
5-1.01 Purpose	5-3
5-1.02 Scope	5-3
5-1.03 Chapter Organization	5-3
5-2.00 GLOSSARY	5-4
5-2.01 Definitions	5-4
5-2.02 Acronyms	5-7
5-3.00 SYSTEMS ENGINEERING PROCESS	5-9
5-3.01 Regional ITS Architecture	5-9
5-3.02 Concept of Operations	5-11
5-3.03 System Requirements	5-11
5-3.04 Detailed Design Documents	5-11
5-3.05 Test and Acceptance Plans	5-11
5-3.06 Operations and Maintenance Plan	5-11
5-4.00 ITS PLANNING GUIDANCE	5-11
5-4.01 Closed Circuit Television (CCTV)	5-12
5-4.02 Dynamic Message Signs (DMS)	5-12
5-4.03 Highway Advisory Radio (HAR)	5-13
5-4.04 Road Weather Information Systems (RWIS)	5-13
5-4.05 Variable Speed Limits (VSL)	5-13
5-4.06 Dynamic Speed Display Signs (DSDS)	5-13
5-4.07 Ramp Meters	5-14
5-4.08 Curve Warning Systems	5-14
5-4.09 Intelligent Work Zones (IWZ)	5-14
5-4.10 Intersection Conflict Warning Systems (ICWS)	5-15
5-5.00 ITS SYSTEMS	5-15
5-5.01 Archived Data Management (AD)	5-18
5-5.02 Advanced Traveler Information Systems (ATIS)	5-18
5-5.03 Advanced Traffic Management Systems (ATMS)	5-19
5-5.04 Advanced Public Transportation Systems (APTS)	5-37
5-5.05 Commercial Vehicle Operations (CVO)	5-38
5-5.06 Emergency Management (EM)	5-39
5-5.07 Maintenance and Construction Management (MCM)	5-39
5-5.08 Advanced Vehicle Safety Systems (AVSS)	5-45
5-6.00 POWER, COMMUNICATIONS, AND CONTROL	5-46
5-6.01 Source of Power	5-46
5-6.02 Electronic Communications	5-46
5-6.03 System Control Software	5-47
5-7.00 ITS DEVELOPMENT	5-47
5-7.01 Role of the Office of Traffic, Safety, and Technology (OTST)	5-47
5-7.02 ITS Office and District Project Solicitation	5-48
5-8.00 INTERAGENCY AGREEMENTS	5-49
5-9.00 REFERENCES	5-49

List of Figures

Figure 5-1	Highway Advisory Radio (HAR) Sign (Iowa DOT)	5-19
Figure 5-2	CCTV Camera	5-20
Figure 5-3	Example Dynamic Message Sign	5-23
Figure 5-4	Dynamic Speed Display Sign	5-24
Figure 5-5	Intelligent Lane Control Signals	5-26
Figure 5-6	Intelligent Lane Control Sign Options	5-26
Figure 5-7	Ramp Meter	5-27
Figure 5-8	Variable Speed Limit (VSL) Signs	5-31
Figure 5-9	Curve Warning Systems	5-32
Figure 5-10	Loop Based Wrong Way Detection	5-36
Figure 5-11	WIM System	5-38
Figure 5-12	RWIS System	5-43
Figure 5-13	RICWS Minor Road Warning	5-45
Figure 5-14	RICWS Major Road Warning	5-45
Figure 5-15	IRIS DMS Display	5-47

List of Tables

Table 5-1	MN ITS Development Objectives	5-16
-----------	-------------------------------------	------

5-1.00 INTRODUCTION

5-1.01 Purpose

This chapter is intended to document currently available Intelligent Transportation System (ITS) technologies and their applications. This chapter will present uniform guidelines, procedures, and preferred practices used in the planning, design, construction, and maintenance of ITS systems.

5-1.02 Scope

ITS is the application of advanced technology to solve transportation problems, and supports the movement of people, goods, and services. ITS improves transportation safety and mobility and enhances productivity through the use of advanced information and communications technologies. ITS encompass a broad range of wireless and wire line communications-based information and electronics technologies. When integrated into the transportation system's infrastructure, and in vehicles themselves, these technologies relieve congestion, improve safety, and enhance American productivity

This chapter is intended as an overview of guidelines and procedures for the process of ITS design and operation in Minnesota. Please refer to the ["MnDOT ITS Design Manual"](#) (ITS Design Manual) for detailed information about designing ITS systems.

ITS system applications cover a wide range of uses, including freeway management, traffic signals, and work zone management. This results in some overlap between this chapter and other chapters of this manual, depending on the ITS system being discussed.

References to other applicable documents can be found in Section 5-9.0 of this chapter, the ITS Design Manual, and the Office of Traffic, Safety, and Technology ([OTST](#)) website.

5-1.03 Chapter Organization

This chapter is organized into the following sections:

- Section 1 - Introduction
- Section 2 - Glossary
- Section 3 - Systems Engineering Process
- Section 4 - ITS Planning Guidance
- Section 5 - ITS Systems
- Section 6 - Power, Communications, and Control
- Section 7 - ITS Development
- Section 8 - Interagency Agreements
- Section 9 - References

5-2.00 GLOSSARY

5-2.01 Definitions

Architecture

The organizational structure of a system identifying its components, their interfaces, and a concept of execution among them.

Automatic Vehicle Identification (AVI)

A technology system using transponders on vehicles and outside sensors to determine if vehicles on toll lanes are carrying a valid transponder and what the vehicle's classification is (truck vs. passenger car, SOV vs. HOV). The system also processes the appropriate toll transaction based on the information.

Blank-Out Sign (BOS)

A type of Dynamic Message Sign that has the capability to show a blank message or one fixed message.

Changeable Message Sign (CMS)

A sign that is capable of displaying one of two or more predefined messages, or a blank message. This manual uses the term Dynamic Message Sign for Changeable Message Signs.

Closed Circuit Television (CCTV)

A video monitoring and security system used to provide continuous traffic monitoring by the facility operator along the length of the facility and particularly at points of entry and tolling locations.

Components

Components are the named "pieces" of design and/or actual entities (sub-systems, hardware units, software units) of the system/sub-system. In system/sub-system architectures, components consist of sub-systems (or other variations), hardware units, software units, and manual operations.

Design

Those characteristics of a system or components that are selected by the developer in response to the requirements.

Detector Loops (Loop Detector Amplifiers)

A loop of electrical wires embedded in the pavement and used to detect and classify the type of vehicles passing over them. The loops are linked to the lane controller and can be used individually to count traffic, detect vehicles at a traffic signal, or in tandem to measure vehicle speeds.

Dynamic Message Sign (DMS)

A sign that is capable of displaying one or more predefined messages automatically without user intervention. This manual uses the term DMS more broadly to include any sign system that can change the message presented to the viewer such as Variable Message Sign, Changeable Message Sign, Portable Changeable Message Sign, and Blank-Out Sign (BOS).

Dynamic Pricing

Tolls that vary in real time in response to changing congestion levels, as opposed to variable pricing that follows a fixed schedule.

Express Lanes

A lane or set of lanes physically separated from the general-purpose capacity provided within major roadway corridors. Express lane access is managed by limiting the number of entrance and exit points to the facility. Express lanes may be operated as reversible flow facilities or bi-directional facilities.

Firmware

The combination of a hardware device and computer instructions and/or computer data that resides as read-only software on the hardware device.

Gap Analysis

A technique to assess how far current (legacy) capabilities are from meeting the identified needs, to be

used to prioritize development activities. This is based both on how far the current capabilities are from meeting the needs (because of insufficient functionality, capabilities, performance or capacity) and whether the need is met in some places and not others.

Hardware

Articles made of material, such as signal controller, load switches, fiber optics, radar detectors, fittings, and their components (mechanical, electrical, electronic, hydraulic, and pneumatic). Computer software and technical documentation are excluded.

High-Occupancy Toll Lanes (HOT lanes)

Managed, limited-access, and normally barrier-separated highway lanes that provide free or reduced cost access to HOVs, and also make excess capacity available to other vehicles not meeting occupancy requirements at a market price.

High-Occupancy Vehicle (HOV)

A passenger vehicle carrying more than a specified minimum number of passengers, such as an automobile carrying more than one person. HOVs include carpools, vanpools, and buses.

HOV Lane

An exclusive traffic lane or facility limited to carrying HOVs and certain other qualified vehicles.

Incident Management

Managing forms of non-recurring congestion, such as spills, collisions, immobile vehicles, or any other impediment to smooth, continuous flow of traffic on freeways.

Intelligent Transportation Systems (ITS)

Intelligent Transportation Systems (ITS) are electronics, communications, or information processing systems or services used to improve the efficiency and safety of the surface transportation system.

Interface

The functional and physical characteristics required to exist at a common boundary - in development, a relationship among two or more entities (such as software-software, hardware-hardware, hardware-software, hardware-user, or software-user).

Lane Controller

A microprocessor ETC component that coordinates the activities of all equipment in a single lane and generates the transactions assigned to individual customers using that lane.

Lane Management Tools

Access – Limiting or metering vehicle ingress to the lane or spacing access so that demand cannot overwhelm HOT lane capacity. See also Limited Access.

Eligibility – Limiting lane use to specific types of users, such as HOVs, motorcycles, low emission vehicles, or trucks. For most typical HOT lane settings, eligibility requirements would be used during selected hours or at specific access ramps.

Pricing – Imposing a user fee on a lane that helps regulate demand by time-of-day or day-of-week. The fee increases during periods of highest demand.

Legacy System

The existing system to which the upgrade or change will be applied.

Level-of-Service (LOS)

Also known as "Traffic Service," LOS is a qualitative measure describing operational conditions within a traffic stream. LOS assesses conditions in terms of speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety. Six levels of service are defined by letter designations from A to F, with LOS A representing the best operating conditions, and LOS F the worst.

Market Packages

Potential products or sub-systems that address specific services (as used in an ITS architecture).

Metropolitan Planning Organization (MPO)

Federally mandated regional organizations responsible for comprehensive transportation planning and programming in urbanized areas. Work products include the Transportation Plan, the Transportation Improvement Program, and the Unified Planning Work Program.

National ITS Architecture

A general framework for planning, defining, and integrating ITS. It was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments across the country. The National ITS Architecture is available as a resource for any region and is maintained by the US DOT independently of any specific system design or region in the nation.

Quality Assurance

A planned and systematic pattern of all actions necessary to provide adequate confidence that management, technical planning, and controls are adequate to establish correct technical requirements for design and manufacturing, and to manage design activity standards, drawings, specifications, or other documents referenced on drawings, lists or technical documents.

Queue Jump

Elevated ramps or at-grade lanes that can be used by motorists stopped in traffic to bypass congestion.

Regional ITS Architecture

A specific regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects in a particular region.

Specification

A document that describes the essential technical requirements for items, materials, or services including the procedures for determining whether or not the requirements have been met.

Stakeholders

The people for whom the system is being built, as well as anyone who will manage, develop, operate, maintain, use, benefit from, or otherwise be affected by the system.

System

An integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective.

System Element

A system element is a balanced solution to a functional requirement or a set of functional requirements that must satisfy the performance requirements of the associated item. A system element is part of the system (hardware, software, facilities, personnel, data, material, services, and techniques) that, individually or in combination, satisfies a function (task) the system must perform.

System Specification

A top level set of requirements for a system. A system specification may be a system/sub-system specification, Prime Item Development Specification, or a Critical Item Development Specification.

Systems Engineering

An inter-disciplinary approach and a means to enable the realization of successful systems. Systems engineering requires broad knowledge and a mindset that looks at the big picture. Systems engineers act as facilitators and skilled conductors of teams.

Transportation Demand Management (TDM)

Actions that improve transportation system efficiency by altering transportation system demand using such strategies and facilities as pricing, ridesharing, park-and-ride facilities, transit friendly development/zoning, and employer-based programs such as staggered work hours and telecommuting. TDM programs improve the efficiency of existing facilities by changing demand patterns rather than embarking on capital improvements.

Transportation System Management (TSM)

Integrated protocols and computerized ITS systems used to manage roadway and transit facilities. TSM techniques improve system capacity without physical expansion or behavioral changes. Typical TSM measures involve continuous management and operation of traffic systems and utilization of integrated traffic control systems, incident management programs, and traffic control centers.

Variable Message Signs

A type of DMS, which allows a user to create and download the message to be displayed into the temporary memory area of the sign controller. This manual uses the term Dynamic Message Sign for Variable Message Sign.

Video Surveillance

The use of pan-tilt-zoom, steerable moving picture cameras to survey a toll plaza, ETC collection area, or a segment of roadway to monitor for incidents.

5-2.02 Acronyms

<u>Acronym</u>	<u>Definition</u>
AD	Archived Data Management
ADA	Americans with Disabilities Act
AMBER	America's Missing: Broadcast Emergency Response
APTS	Advanced Public Transportation System
ATIP	Annual Transportation Improvement Plan
ATIS	Advanced Traveler Information System
ATMS	Advanced Traffic Management System
ATR	Automated Traffic Recorder
AVL	Automatic Vehicle Location
AVSS	Advanced Vehicle Safety System
AWOS	Automated Weather Observation System
CAD	Computer Aided Dispatch
CARS	Condition Acquisition and Reporting System
CCTV	Closed Circuit Television
CICAS	Cooperative Intersection Collision Avoidance System
CVIEW	Commercial Vehicle Information Exchange Window
CVISN	Commercial Vehicle Information Systems and Networks
CVO	Commercial Vehicle Operations
DDS	Data Distribution Server
DMS	Dynamic Message Sign
DTN	Data Transmission Network
DVR	Digital Video Recording
EAS	Emergency Alert System
EM	Emergency Management
EMS	Emergency Medical Services
EOC	Emergency Operations Center
EVP	Emergency Vehicle Preemption
FAA	Federal Aviation Administration
FAST	Free and Secure Trade
FHWA	Federal Highway Administration

FIRST	Freeway Incident Response Safety Team
FMCSA	Federal Motor Carrier Safety Administration
GIS	Geographic Information System
GPS	Global Positioning System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
HRI	Highway-Rail intersection
ICM	Integrated Corridor Management
IEEE	Institute of Electrical and Electronics Engineers
IFTA	International Fuel Tax Agreement
IRP	International Registration Plan
ISP	Information Service Provider
ITS	Intelligent Transportation Systems
IVR	Interactive Voice Response
IWZ	Intelligent Work Zone
LED	Light Emitting Diode
LPFM	Low Power FM Radio
MCM	Maintenance and Construction Management
MCMIS	Motor Carrier Management Information System
MDSS	Maintenance Decision Support System
MDT	Mobile Data Terminal
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MSP	Minnesota State Patrol
MUTCD	Manual on Uniform Traffic Control Devices
NOAA	National Oceanic and Atmospheric Administration
OS/OW	Oversize/Overweight
OTST	Office of Traffic, Safety, and Technology (MnDOT)
PDA	Personal Digital Assistant
PRISM	Performance and Registration information Systems Management
PSAP	Public Safety Answering Point
RASAWI	Rest Area Sponsorship, Advertising, and Wireless Internet
RCA	Resource Consumption Application
RDS	Radio Data Service
RFID	Radio-Frequency Identification
RTMC	Regional Transportation Management Center
RWIS	Road Weather Information System
SAFER	Safety and Fitness Electronic Records
SEOC	State Emergency Operations Center
SOV	Single Occupancy Vehicle
STIP	State Transportation Improvement Plan
TMC	Transportation/Traffic Management Center

TOCC	Transportation Operation and Communications Center
TSP	Transit Signal Priority
UPA	Urban Partnership Agreement
VSL	Variable Speed Limit
VWS	Virtual Weigh Station
WAN	Wide Area Network
WIM	Weigh-in-Motion
XML	Extensible Markup Language

5-3.00 SYSTEMS ENGINEERING PROCESS

The International Council of Systems Engineers uses the following definition for “systems engineering”:

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem:

1. Operations
2. Cost & Schedule
3. Performance
4. Training & Support
5. Test
6. Manufacturing
7. Disposal

Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

ITS projects shall conform to the National ITS Architecture and Standards and development of the regional ITS architecture should be consistent with the transportation planning process. ITS projects funded with highway trust funds shall be based on a systems engineering analysis. Which should result in the final design of all ITS projects funded with highway trust funds shall be consistent with the regional ITS architecture.

Detailed information can be found in the FHWA document “Systems Engineering for Intelligent Transportation Systems – An Introduction for Transportation Professionals”. The information can be found at: <http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf>.

The following sections provide a brief summary of the steps required in the Systems Engineering Process.

5-3.01 Regional ITS Architecture

The [Minnesota Statewide Regional ITS Architecture, Version 2014 - Overview Volume](#) states:

The Minnesota Statewide Regional Intelligent Transportation Systems (ITS) Architecture Version 2014 is an update of the previous version that was developed in 2009. The purpose of this update is to: 1) foster integration of the deployment of regional ITS systems; 2) facilitate stakeholder coordination in ITS planning, deployment and operations; 3) reflect the current state of ITS planning and deployment; 4) provide a high-level planning for enhancing the state transportation systems using current and future ITS technologies; and 5) conform with the National ITS Architecture and the Federal Highway Administration (FHWA) Final Rule 940 and Federal Transit Administration (FTA) Final Policy on ITS Architecture and Standards.

The Final Rule and the Final Policy provide policies and procedures for implementing [Section 5206\(e\)](#)

[of the Transportation Equity Act for the 21st Century \(TEA–21\)](#), pertaining to conformance with the National ITS Architecture and Standards. The Final Rule and the Final Policy ensure that ITS projects carried out using funds from the Highway Trust Fund including the Mass Transit Account conform to the National ITS Architecture and applicable ITS standards.

Regional ITS architectures help guide the planning, implementation, and integration of ITS components and systems. The National ITS Architecture is a tool to guide the development of regional ITS architectures. It is a common framework that guides agencies in establishing ITS interoperability and helps them choose the most appropriate strategies for processing transportation information, implementing and integrating ITS components and systems, and improving operations. The Minnesota Statewide Regional ITS Architecture is a specific application of the framework specified in the National ITS Architecture, tailored to the needs of the transportation stakeholders in Minnesota.

The Minnesota Statewide Regional ITS Architecture geographically covers the entire state of Minnesota, encompassing local, regional, and state transportation agencies and transportation stakeholders. It represents a shared vision of how each agency's systems work together by sharing information and resources to enhance transportation safety, efficiency, capacity, mobility, reliability, and security. During the development of the Minnesota Statewide Regional ITS Architecture, agencies that own and operate transportation systems collaboratively consider current and future needs to ensure that the current systems, projects and processes are compatible with future ITS projects in Minnesota. The collaboration and information sharing among transportation stakeholders helps illustrate integration options and gain consensus on systematic and cost-effective implementation of ITS technologies and systems.

The Minnesota Statewide Regional ITS Architecture is a living document and will evolve as needs, technology, stakeholders, and funding streams change.

The "[Minnesota Statewide Regional ITS Architecture, Version 2014 – Volume 9: ITS Initiatives and Project Concepts for Implementation](#)" states:

FHWA Rule 940 (http://ops.fhwa.dot.gov/its_arch_imp/docs/20010108.pdf) provides policies and procedures for implementing Section 5206(e) of the Transportation Equity Act for the 21st Century (TEA–21), Public Law 105–178, 112 Stat. 457, pertaining to conformance with the National ITS Architecture and Standards. The rule states, in part, that the final design of all ITS projects funded with Highway Trust Funds must accommodate the interface requirements and information exchanges as specified in the regional ITS architecture. The Minnesota Statewide Regional ITS Architecture is a specific application of the framework specified in the National ITS Architecture, tailored to the needs of the transportation stakeholders statewide.

After funding has been programmed for a specified ITS project, or a transportation project incorporating ITS elements, the focus is on having the ITS project follow a sound systems engineering process. The following are activities after funding has been programmed into the State Transportation Improvement Program (STIP):

1. **Refine Scope/STIP Authorization:** The MnDOT Project Manager, or if a local project, the local Project Manager will work with partners to develop agreements, refine scopes, etc.
2. **ATIP/STIP Authorization:** If the project is federally funded projects must be entered on the ATIP/STIP before authorization can be obtained.
3. **Identification of Projects to Demonstrate Rule 940 Conformity:** For federally funded ITS projects, several steps need to be followed as part of the systems engineering analysis and Rule 940 requirements. Rule 940 states that the systems engineering analysis shall include, at a minimum:
 - Identification of portions of the regional ITS architecture being implemented.
 - Identification of participating agencies roles and responsibilities.
 - Requirements definitions.
 - Analysis of alternative system configurations and technology options to meet requirements.

- Procurement options.
- Identification of applicable ITS standards and testing procedures.
- Procedures and resources necessary for operations and management of the system.

The rule requirements are applicable for all ITS projects funded through the Highway Trust Fund account. Conformity with the Rule 940 requirements is required for both routine and non-routine projects. However, with routine projects, the effort and the scope of systems engineering analysis should be minimal. For non-routine projects, the scale of the systems engineering analysis depends on the scope of the project.

While the use of the architecture and the systems engineering approach is mandatory for federally funded projects, project developers are encouraged to use this approach for any ITS project using state or local funds, especially for projects that integrate with other systems in the region.

More information can be found at the Minnesota Planning and Regional Architecture webpage: http://www.dot.state.mn.us/guidestar/2006_2010/mnitsarchitecture.html.

5-3.02 Concept of Operations

The Concept of Operations documents the total environment and use of the system to be developed in a non-technical and easy-to-understand manner. The Concept of Operations presents this information from multiple viewpoints, and provides a bridge from the problem space and stakeholder needs to the system level requirements.

5-3.03 System Requirements

Requirements are the foundation for building Intelligent Transportation Systems (ITS). They determine what the system must do and drive the system development. Requirements are used to determine (verify) if the project team built the system correctly. The requirements development process identifies the activities needed to produce a set of complete and verifiable requirements.

5-3.04 Detailed Design Documents

Detailed design documents are developed based on the Concept of Operations and the System Requirements. See the [ITS Design Manual](#) for guidance on the development of detailed design documents.

5-3.05 Test and Acceptance Plans

The software and hardware components are individually verified and then integrated to produce higher-level assemblies or subsystems. These assemblies are also individually verified before being integrated with others to produce yet larger assemblies, until the complete system has been integrated and verified.

5-3.06 Operations and Maintenance Plan

Once the customer has accepted the ITS system, the system operates in its typical steady state. System maintenance is routinely performed and performance measures are monitored. As issues, suggested improvements, and technology upgrades are identified, they are documented, considered for addition to the system baseline, and incorporated as funds become available. An abbreviated version of the systems engineering process is used to evaluate and implement each change. This occurs for each change or upgrade until the ITS system reaches the end of its operational life.

5-4.00 ITS PLANNING GUIDANCE

The purpose of this section is to assist in the decision making process of determining if an ITS device should be considered or to validate existing device deployments. As part of the [ENTERPRISE Pooled Fund research project](#), planning guidance was developed for:

- Closed Circuit Television

- Dynamic Message Signs
- Highway Advisory Radio
- Road Weather Information Systems
- Variable Speed Limit
- Dynamic Speed Display Signs
- Ramp Meters
- Curve Warning Systems
- Intelligent Work Zones
- Intersection Conflict Warning Systems

Note: “ITS Warrants” changed to “ITS Planning Guidance” in 2014 to eliminate the statutory/legal implications associated with the publication of official warrants.

The following sections summarize the planning guidance for ITS devices that are available as of the date of this publication. The link below directs you to the ENTERPRISE Pooled Fund Study webpage that includes a link to the current ITS Planning Guidance, which includes detailed information regarding each guideline. See <http://enterprise.prog.org/itswarrants/>.

5-4.01 Closed Circuit Television (CCTV)

For purposes of the ITS planning guidance process, CCTV refers to a video or still picture camera system used to collect images and relay images to a central monitoring location, and project images onto a video monitor, television screen, Internet display, or other monitoring equipment. Six (6) planning guidelines have been identified to capture the most common purposes and uses of CCTV. While there are other purposes and uses for CCTV, the planning guidelines developed to date have focused on the following six.

- CCTV Planning Guideline 1 – Traffic Observation for Signal Control Changes
- CCTV Planning Guideline 2 – Traffic Incident or Event Verification
- CCTV Planning Guideline 3 – Weather Verification
- CCTV Planning Guideline 4 – Traveler Information
- CCTV Planning Guideline 5 – Field Device Verification
- CCTV Planning Guideline 6 – Intelligent Work Zone

A detailed description of the CCTV planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/cctv.html>

5-4.02 Dynamic Message Signs (DMS)

For purposes of the ITS planning guidance process, DMS are defined as either fixed or portable signs capable of displaying any text message entered by an operator (either locally or through remote access). Eight (8) planning guidelines have been identified to capture the most common purposes and uses of DMS. While there are other purposes and uses for DMS, the following eight DMS planning guidelines developed to date have an ITS focus.

- DMS Planning Guideline 1 – To Inform Travelers of Weather Conditions
- DMS Planning Guideline 2 – To Inform Travelers of Traffic Conditions
- DMS Planning Guideline 3 – Changing Traffic Control or Conditions
- DMS Planning Guideline 4 – Special Events
- DMS Planning Guideline 5 – Parking Availability
- DMS Planning Guideline 6 – Transit Park and Ride Lot Availability
- DMS Planning Guideline 7 – Evacuation Routes
- DMS Planning Guideline 8 – Jurisdictional Information

A detailed description of the DMS planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/dms.html>. A detailed description and guide regarding changeable message signs (CMS) can be found at <http://www.dot.state.mn.us/trafficeng/workzone/wzmanual.html>.

5-4.03 Highway Advisory Radio (HAR)

For purposes of the ITS planning guidance process, Highway Advisory Radio (HAR) refers to low power AM or FM radio transmissions where localized information is broadcast and travelers are alerted to the presence of the broadcast using static or dynamic signs. The localized transmissions may cover areas that range from 5 miles to 30 miles depending upon the terrain and technologies used. The radio transmissions may be either at fixed permanent locations or mobile devices that may be temporarily located and moved as needed. Four (4) planning guidelines have been identified to capture the most common purposes and uses of HAR. While there are other purposes and uses for HAR, the planning guidelines developed to date have focused on the following four.

HAR Planning Guideline 1 – Weather and Driving Conditions

HAR Planning Guideline 2 – Venue Parking/Route Guidance

HAR Planning Guideline 3 – Changing Traffic Conditions

HAR Planning Guideline 4 – Special Events

A detailed description of the HAR planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/har.html>

5-4.04 Road Weather Information Systems (RWIS)

For purposes of the ITS planning guidance process, RWIS refer to in-field atmospheric and/or road weather monitoring devices that are capable of measuring conditions and reporting conditions back to a central server or a roadside device. Three (3) planning guidelines have been identified to capture the most common purposes and uses of RWIS. While there are other purposes and uses for RWIS, the planning guidelines developed to date have focused on the following three.

RWIS Planning Guideline 1 – Support Traveler Safety and Mobility

RWIS Planning Guideline 2 – Support Regional, Statewide, or Provincial Weather Monitoring

RWIS Planning Guideline 3 – Support Traveler Information Systems through RWIS at Key Locations

A detailed description of the RWIS planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/rwis.html>

5-4.05 Variable Speed Limits (VSL)

For purposes of the ITS planning guidance process, VSL refers to a sign capable of displaying different speed limits to travelers (in which the speed limit is either an advisory (recommended) or statutory (mandatory) limit) that are either manually activated or controlled by a combination of detectors and algorithms to select appropriate speeds. Four (4) planning guidelines have been identified to capture the most common purposes and uses of VSL. While there are other purposes and uses for VSL, the planning guidelines developed to date have focused on the following four.

VSL Planning Guideline 1 – Maximize Capacity

VSL Planning Guideline 2 – Safe Stopping Distance

VSL Planning Guideline 3 – Safe Travel Speeds for Conditions

VSL Planning Guideline– Work Zones

A detailed description of the VSL planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/vsl.html>

5-4.06 Dynamic Speed Display Signs (DSDS)

For purposes of the ITS planning guidance process, DSDS refers to permanent or temporary signs that detect and display a vehicle's current speed to the driver. Often the speed display flashes if the vehicle is exceeding the speed limit. Dynamic Speed Display Signs are also commonly referred to as "Your speed is" signs, or "Driver Feedback" signs. Three (3) planning guidelines have been identified to capture the most common purposes and uses of DSDS. While there are other purposes and uses for DSDS, the planning guidelines developed to date have focused on the following three.

DSDS Planning Guideline 1 – Transition Zones

DSDS Planning Guideline 2 – Posted Speed Adherence

DSDS Planning Guideline 3 – Intelligent Work Zones

A detailed description of the DSDS planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/dsds.html>. See also [MnDOT Technical Memorandum 13-01-T-01](#): Dynamic Speed Display Signs.

5-4.07 Ramp Meters

For purposes of the ITS planning guidance process, Ramp Meters are defined by the Manual on Uniform Traffic Control Devices as traffic control signals that control the flow of traffic entering a freeway facility. Three (3) planning guidelines have been identified to capture the most common purposes and uses of Ramp Meters. While there are other purposes and uses for Ramp Meters, the planning guidelines developed to date have focused on the following three.

Ramp Meter Planning Guideline 1 – Corridor-wide Freeway Traffic Management

Ramp Meter Planning Guideline 2 – Localized Freeway Traffic Issues

Ramp Meter Planning Guideline 3 – Work Zone Activity

A detailed description of the Ramp Meter planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/rampmeters.html>

5-4.08 Curve Warning Systems

For purposes of the ITS planning guidance process, Curve Warning Systems are defined as a collection of devices deployed with the goal of reducing vehicle crashes and roadway departures within horizontal curves. Technology devices may include real-time warning signs triggered by vehicle factors (e.g. speed, height, weight, etc.) and/or roadway conditions (snow, ice, and rain) at approaches to curves. Three (3) planning guidelines have been identified to capture the most common purposes and uses of Curve Warning Systems. While there are other purposes and uses for Curve Warning Systems, the planning guidelines developed to date have focused on the following three.

Curve Warning Planning Guideline 1 – Rural Two-Lane Highway Curves

Curve Warning Planning Guideline 2 – High Risk Locations

Curve Warning Planning Guideline 3 – Truck Rollovers on Ramps/Curves

A detailed description of the Curve Warning planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/curvewarning.html>

5-4.09 Intelligent Work Zones (IWZ)

For purposes of the ITS planning guidance process, Intelligent Work Zones are defined as a collection of devices that collectively warn travelers of various hazards associated with work zones. The following Intelligent Work Zone Systems are addressed with the planning guidelines. Note that there are additional devices to consider when deploying an IWZ as well as existing system components to consider.

DMS Planning Guideline 3 – Changing Traffic Control or Conditions

CCTV Planning Guideline 6 – Intelligent Work Zone

HAR Planning Guideline 3 – Changing Traffic Conditions

VSL Planning Guideline 4 – Work Zones

DSDS Planning Guideline 3 – Intelligent Work Zone

Ramp Meter Planning Guideline 3 – Work Zone Activity

A detailed description of the IWZ guidelines can be found at: <http://enterprise.prog.org/itswarrants/workzone.html>. Also see the Minnesota IWZ Toolbox Guide found at <http://www.dot.state.mn.us/trafficeng/workzone/wzmanual.html>.

5-4.10 Intersection Conflict Warning Systems (ICWS)

For purposes of the ITS planning guidance process, Intersection Conflict Warning Systems are defined as a traffic control device placed on major, minor, or both roads of an intersection to provide drivers with a real-time, dynamic warning of vehicles approaching or waiting to enter the intersection. ICWS are typically installed to address crash factors associated with limited sight distance and poor gap selection at stop-controlled intersections.

ICWS Planning Guideline 1 – Intersections with High Crash Frequencies or Rates (Reactive Approach)

ICWS Planning Guideline 2 – Intersection Characteristics (Proactive Approach)

A detailed description of the ICWS planning guidelines can be found at: <http://enterprise.prog.org/itswarrants/icws.html>. Information regarding rural intersection conflict warning systems (RICWS) can be found at: <http://www.dot.state.mn.us/trafficeng/signals/conflictwarning.html>.

5-5.00 ITS SYSTEMS

MnDOT has deployed numerous ITS systems over the years in support of the goals and objectives presented in the Minnesota Statewide architecture. This section presents an overview of many of the typical ITS systems that have been deployed in order to provide an idea of the tools that are available to address specific needs using technology. The summaries include:

- Definition
- Purpose and Usage
- Components Used

The systems listed here are not all inclusive. The types of systems being deployed in Minnesota and across the country increase every day. Table 5.1 on the following 2 pages is organized by market package group from the [Minnesota Statewide Regional ITS Architecture](#). The Statewide Architecture has established eight ITS development objectives, listed as headings across the top of the table. The table illustrates how each of the ITS Service Packages relates to each of the objectives.

Table 5-1 MN ITS Development Objectives

Section	ITS Service Package by Group	MN ITS Development Objectives							
		Improve Safety	Increase Operational Efficiency and Reliability	Enhance User Mobility, Convenience, and Comfort	Improve Security	Support Economic Productivity & Development	Preserve the System	Enhance Integration and Connectivity	Reduce Environmental Impacts
5-5.01 Archived Data Management (AD or ADMS)									
5-5.01.01	Future Placeholder								
5-5.02 Advanced Traveler Information Systems (ATIS)									
5-5.02.01	511 Traveler Information			X					
5-5.02.02	Dynamic Way-finding Systems		X	X		X			
5-5.02.03	Highway Advisory Radio (HAR)	X	X						
5-5.03 Advanced Traffic Management Systems (ATMS)									
5-5.03.01	Closed Circuit Television (CCTV)	X	X	X	X				
5-5.03.02	Detection Systems		X						
5-5.03.03	Dynamic Message Signs (DMS)	X		X					
5-5.03.04	Dynamic Speed Display Signs (DSDS)	X		X					
5-5.03.05	Electronically Operated Gates	X	X		X				
5-5.03.06	Enforcement - HOV/HOT Facilities	X	X						
5-5.03.07	Enforcement - Speed Limit	X	X		X				
5-5.03.08	Enforcement - Traffic Signal (Red Light)	X	X		X				
5-5.03.09	Intelligent Lane Control Signals (ILCS)		X				X		
5-5.03.10	Intersection Conflict Warning System (ICWS)	X	X	X					
5-5.03.11	MnPASS HOT Lanes		X	X			X		X
5-5.03.12	Ramp Metering		X	X			X		X
5-5.03.13	Reversible Lanes		X	X			X		X
5-5.03.14	Roadside Lighting System Control	X			X				X
5-5.03.15	Speed Monitoring	X	X						
5-5.03.16	Traffic Signal Control		X			X	X		X
5-5.03.17	Travel Times			X					
5-5.03.18	Truck Priority		X	X		X			
5-5.03.19	Variable Speed Limit (VSL)	X	X						
5-5.03.20	Warning System – Bridge Height	X		X					
5-5.03.21	Warning System - Curve Advisory	X		X					

Table 5-1 MN ITS Development Objectives, cont.

Section	ITS Service Package by Group	MN ITS Development Objectives, cont.							
		Improve Safety	Increase Operational Efficiency and Reliability	Enhance User Mobility, Convenience, and Comfort	Improve Security	Support Economic Productivity & Development	Preserve the System	Enhance Integration and Connectivity	Reduce Environmental Impacts
5-5.03.22	Warning System - Foggy Conditions	X		X					
5-5.03.23	Warning System - Highway-Rail Grade Crossing	X		X					
5-5.03.24	Warning System - Icy Pavement Conditions	X		X					
5-5.03.25	Warning System - Ramp/Curve Truck Rollover	X		X					
5-5.03.26	Warning System - Stopped or Slow Traffic Ahead	X		X					
5-5.03.27	Warning System - Water on Road	X		X					
5-5.03.28	Warning System - Wildlife	X		X					
5-5.03.29	Wrong Way Movements	X		X					
5-5.04 Advanced Public Transportation Systems (APTS)									
5-5.04.01	Transit Signal Priority		X	X			X		
5-5.04.02	Real-Time Arrival System		X	X			X		
5-5.04.03	Transit Customer Information System		X	X			X		
5-5.05 Commercial Vehicle Operations (CVO)									
5-5.05.01	Weigh-in Motion			X		X	X		
5-5.06 Emergency Management (EM)									
5-5.06.01	Future Placeholder	X							
5-5.07 Maintenance and Construction Management (MCM)									
5-5.07.01	Intelligent Work Zones	X	x	X					
5-5.07.02	Road and Weather Information Systems (RWIS)	X		X					
5-5.07.03	Work Zone Accident Reduction Deployment (WZARD)	X		X					
5-5.07.04	CAD / AVL	x	x		x				
5-5.08 Advanced Vehicle Safety Systems (AVSS)									
5-5.08.01	Future Placeholder	X							

5-5.01 Archived Data Management (AD)

See the [MN Regional ITS Architecture for a complete listing of AD Service Packages](#).

5-5.01.01 Future Placeholder

5-5.02 Advanced Traveler Information Systems (ATIS)

See the [MN Regional ITS Architecture for a complete listing of ATIS Service Packages](#). The following sections highlight several more common applications.

5-5.02.01 511 Traveler Information

Definition

The Minnesota Department of Transportation's 511 Traveler Information System provides real-time, accurate traffic information about current road conditions, including:

- Weather related road conditions
- Traffic crashes and incidents
- Construction and maintenance locations and information
- Traffic speeds
- Traffic camera views
- Oversize/overweight truck restrictions.

Purpose and Usage

The [Minnesota Department of Transportation's 511 Traveler Information](#) websites, 511 App and phone provides the traveling public with up-to-date road reports 24 hours a day, seven days a week. The program allows travelers to sign up for a 'Personalize Your 511' account that features specific routes tailored to travelers' needs. The 511 program offers the traveling public a wide range of options in planning their travels.

Components Used

Typical components used for MnDOT's 511 Traveler Information System include the items listed below. See the [ITS Design Manual](#) for further discussion of the components and design considerations.

- Communications
- IRIS

5-5.02.02 Dynamic Way-Finding Systems

Definition

This system provides guidance to specific destinations based on real-time traffic conditions.

Purpose and Usage

These systems are used to guide the motoring public. Based on real-time traffic conditions, messages would be displayed on field devices and on websites providing recommendations for the best route to the destination. These messages could be generated by traffic management center operators, or through the use of control software that would automatically select the route based on current conditions. In Minnesota, dynamic way-finding systems have been deployed for parking availability in downtown St. Paul, and in Bloomington on the regional system around the Mall of America.

Components Used

Typical components used for a Dynamic Way-Finding System include the items listed below. See the [ITS Design Manual](#) for further discussion of the components and design considerations.

- DMS or Hybrid Signing
- Communications
- Power
- Surveillance and/or Detection
- Manual Control or control software to select route

5-5.02.03 Highway Advisory Radio (HAR)

Definition

Highway Advisory Radio (HAR) refers to low power AM or FM radio transmissions where localized information is broadcast and travelers are alerted to the presence of the broadcast using static or dynamic signs. The localized transmissions may cover areas that range from 5 miles to 30 miles depending upon the terrain and technologies used. The radio transmissions may be either at fixed permanent locations or mobile devices that may be temporarily located and moved as needed.



Figure 5-1 Highway Advisory Radio (HAR) Sign (Iowa DOT)

Purpose and Usage

HAR provides motorist information similar to DMS but can provide more detailed information. The information broadcast can include:

- Congestion reports
- Hazardous conditions
- Travel times
- Alternate routes
- Special event information
- Parking locations
- Weather and road conditions
- Construction information

HAR systems can be permanent or portable. FCC licensing is required, and each HAR site is limited to a maximum of 10-watts of power. HAR can broadcast either AM or FM radio signals, and the typical message length is up to two minutes. MnDOT does not currently operate HAR.

Components Used

Typical components used for a HAR project include the items listed below. See the [ITS Design Manual](#) for further discussion of the components and design considerations.

- HAR Field System
- Communications

5-5.03 Advanced Traffic Management Systems (ATMS)

See the [MN Regional ITS Architecture for a complete listing of ATMS Service Packages](#). The following sections highlight several more common applications.

5-5.03.01 Closed Circuit Television (CCTV)

Definition

Closed circuit television (CCTV) cameras are a key part of traffic management systems. The primary benefit of CCTV is the ability to provide visual information required to make informed decisions. CCTV cameras are used for roadway traffic monitoring, verification of incidents detected by other means (e.g., cellular calls, speed detectors, etc.), and for assistance in determining appropriate responses to an unplanned event or incident. Beyond these tasks, cameras can be utilized for:

- Monitoring traffic movements on the mainline and ramps
- Dynamic Message Sign verification
- Verification of stranded motorists and incidents
- Observing localized weather and other hazardous conditions
- Dispatching of safety personnel



Figure 5-2 CCTV Camera

Purpose and Usage

CCTV cameras are one of the primary methods of monitoring traffic conditions and detecting incidents. CCTV cameras allow an operator at the Regional Transportation Management Center (RTMC) to monitor traffic on both freeways and surface streets to determine the location of congestion and incidents. If an incident or heavy congestion occurs on a freeway, traffic can be diverted to a parallel surface street, and the timing of the signals on the surface street can be modified to provide more green time in the direction parallel to the freeway.

- **Detecting Incidents and Advising Motorists**
One of the primary purposes of CCTV is to assist with incident detection. CCTV cameras can be located on both freeways and surface streets. Cameras are especially useful at an interchange where a camera has a view of both the freeway and the surface streets. If an incident is detected on either a freeway or surface street, changeable message signs (CMS) may be used to alert drivers and to possibly divert traffic elsewhere.
- **Advising Motorists of Traffic Problems in the Area**
CCTV cameras can be used to find a major traffic problem and dynamic message signs (DMS) can alert drivers to the problem.
- **Monitoring Traffic Conditions Resulting from Special Events and Advising Motorists**

CCTV cameras and DMS(s) are useful during special events, both planned (such as a concert or a football game), as well as unplanned emergencies (such as a terrorist attack or a storm). Special events create traffic patterns that are quite different from normal. Many drivers going to a special event may not normally drive through the corridor in question, and are not familiar with alternate routes. Roadway and lane configurations may be different; for example, a normally two-way road may be converted to one-way in the peak direction, or a road may be closed for security reasons or to provide access for emergency vehicles.

- **Assisting with Parking Information**

CCTV cameras, as well as other technologies, can monitor a large parking lot to determine which lots or sections are full, and CMS(s) (or other methods of information dissemination) can notify drivers as to which parking lots are full or closed, and to direct drivers to parking lots that have available capacity.

Components Used

Typical components used for a CCTV project include the items listed below. See the [ITS Design Manual](#) for further discussion of the components and design considerations.

- Camera System
- CCTV Mounting
- Management System Control Software
- Control Cabinet
- Power
- Communications

5-5.03.02 Detection Systems

Definition

The different types of vehicle detectors available include, but are not limited to, the following types.

1. Intrusive Detection (in-roadway)
 - Inductive loop detects a change in resonant frequency by the introduction of a metal in the magnetic field of the detection zone.
 - Magnetic/Magnetometer detects moving ferrous metal objects – pulse.
 - Microloop detects a change by moving metal in the earth's magnetic field – pulse. Small inductive loop placed on top of a magnetometer.
2. Non-Intrusive Detection (above roadway or sidefire)
 - Photo electric/Infrared/laser detects a break in a beam of light – presence or pulse.
 - Radar/Microwave detects moving objects by sending and receiving electronic pulses – pulse.
 - Ultrasonic detects sound with a microphone – presence or pulse.
 - Video detects a change in a video pixel range – presence or pulse.
 - Combination systems, i.e. combining video and radar.

Normal loop or magnetic detectors will operate in either the pulse mode or presence mode. The magnetic detector produces a short output pulse when detection occurs, no matter how long the vehicle remains in the detection area. The normal loop is intended to produce a detector output for as long as a vehicle is in the field of detection.

Non-intrusive detector technologies include active and passive infrared, microwave radar, ultrasonic, passive acoustic, laser, and video image processing. Active infrared, microwave radar, and ultrasonic are active detectors that transmit wave energy toward a target and measure the reflected wave. Passive infrared, passive acoustic, and video image processing are passive detectors that measure the energy emitted by a target or the image of the detection zone.

Traffic detection systems play important roles not only in traditional transportation management but also in advanced transportation management systems. Traffic detection systems provide data to meet different needs in transportation fields.

Purpose and Usage

The control of traffic relates to the movement of vehicles and pedestrians. Since the volume of these movements generally varies at different times of the day, it is desirable to be able to detect approaching movements by placing one or more devices in the path of approaching vehicles or at a convenient location for the use of pedestrians.

Most advanced management systems and technologies in the ITS field rely on real-time traffic data, which reflects current conditions of traffic network. Traffic detection is a critical part in many advanced traffic systems, such as responsive ramp metering control and freeway incident detection.

Ramp metering control is the most common technology for reducing freeway congestion. The system measures freeway mainline capacity and traffic flow, and controls the rate at which vehicles enter the freeway mainline. Many studies show that ramp metering increases freeway efficiency, and reduces accidents and recurring congestion.

In freeway incident management systems, detectors generally are used to detect two types of congestion: recurring and nonrecurring. Recurring congestion is predictable at specific locations and times. Nonrecurring congestion is caused by random, temporary incidents, such as accidents and other unpredictable events.

Traffic detector technologies are continuously incorporated into new ITS application fields. For example, a portable intelligent transportation system provides traveler information in specific sites to improve safety and operation in work zones. A computerized control system integrates detector (speed sensor) and traveler information dissemination technologies. The control system automatically determines appropriate responses according to current traffic conditions.

Another type of detection is the “speed analysis system”. This system is a hardware assembly composed of two loop detectors and auxiliary logic. The two loops are installed in the same lane a precise distance apart. A vehicle passing over the loops produces two actuations. The time interval between the first and the second actuation is measured to determine vehicle speed.

Newer inductive-loop detector electronics units and loop configurations are capable of vehicle classification. The electronics module uses artificial neural network software to classify the traffic stream into the 23 categories

Components Used

Typical components used for a CCTV project include the items listed below. See the [ITS Design Manual](#) for further discussion of the components and design considerations.

- Detection System (intrusive or non-intrusive)
- Control Cabinet
- Power
- Communications

5-5.03.03 Dynamic Message Signs (DMS)

Definition

Any sign system that can change the message presented to the viewer such as Variable Message Sign (VMS), Changeable Message Sign (CMS), and Blank-Out Sign (BOS).



Figure 5-3 Example Dynamic Message Sign

Purpose and Usage

A dynamic message sign is an electronic traffic sign often used on roadways to give travelers information about special events. Such signs warn of traffic congestion, accidents, incidents, roadwork zones, or speed limits on a specific highway segment. In urban areas, DMS are used within parking guidance and information systems to guide drivers to available car parking spaces. They may also ask vehicles to take alternative routes, limit travel speed, warn of duration and location of the incidents or just inform of the traffic conditions.

A complete message on a panel generally includes a problem statement indicating incident, roadwork, stalled vehicle etc.; a location statement indicating where the incident is located; an effect statement indicating lane closure, delay, etc. and an action statement giving suggestion what to do traffic conditions ahead. These signs are also used for AMBER Alert messages.

Components Used

Typical components used for a DMS project include the items listed below. See [ITS Design Manual](#) for further discussion of the components and design considerations.

- Dynamic Message Sign
- Management System Control Software
- Control Cabinet
- Power
- Communications

5-5.03.04 Dynamic Speed Display Signs (DSDS)

Definition

A dynamic speed display sign is a device that detects and display a vehicle's current speed back to the driver.



Figure 5-4 Dynamic Speed Display Sign

Purpose and Usage

DSDS have been shown to have a significant speed-reducing effect in temporary applications such as work zones or neighborhood speed watch programs.

Components Used

Typical components used for a DSDS project include the items listed below. See the [ITS Design Manual](#) for further discussion of system components and design considerations.

- Sign(s)
- Speed Detector
- Power

See also [MnDOT Technical Memorandum No. 13-01-T-01](#): Dynamic Speed Display Signs.

5-5.03.05 Electronically Operated Gates

Definition

These are electronically operated gates that are used to close a roadway for unplanned events (incidents, weather, etc.), or planned events (sporting events, reversible lanes, etc.).

Purpose and Usage

The purpose of using electronically operated gates at freeway on-ramps is to minimize the utilization of law enforcement vehicles and personnel as temporary roadway barriers. Traffic Gates allow for easy closure of freeway entrance ramps during planned incidents such as sporting events and unplanned incidents such as freeway emergencies.

Examples of electronically operated gates include:

- Interstate and non-interstate snow and ice closure gates
- Interstate 394 gate for reversible HOV
- Gates at transit stations to control transit flow
- Battery backup may be used for electronically operated gates.

Components Used

Typical components used for an electronically operated gate project include the items listed below. See the [ITS Design Manual](#) for further discussion of system components and design considerations.

- Foundation
- Gate Pole and Arm with electronic mechanism
- Management System Control Software
- Control Cabinet
- Power
- Communications

5-5.03.06 Enforcement - HOV/HOT Facilities

Definition

These systems provide police officers additional information to enforce compliance with HOV/HOT Lane facility requirements.

Purpose and Usage

This is a current Innovative Idea project.

Components Used

This section is reserved for future manual updates.

5-5.03.07 Enforcement - Speed Limit

Definition

These systems provide photo enforcement for speeding at locations where there is a history of crashes with excessive speed as a contributing factor or in work zones.

Purpose and Usage

This section is reserved for future manual updates.

Components Used

This section is reserved for future manual updates.

5-5.03.08 Enforcement – Traffic Signal Red Light Enforcement Enhancement

Definition

These are systems that will provide police officers with photo evidence or other data to verify red light running violations.

Purpose and Usage

This system represents portable or permanent photo/surveillance systems located at intersections with high crash rates. The purpose is to inform and educate the traveling public of the dangers of running red lights. The system is planned for MnDOT District 6 and evaluated in District 3.

In District 3, the project provided on-site officers with photo and video evidence that could be used at the time of the infraction to verify the violation.

Components Used

This section is reserved for future manual updates.

5-5.08.09 Intelligent Lane Control Signals (ILCS)

Definition

ILCS are devices mounted above each lane that provide guidance to motorists. The messages change based on current traffic conditions.

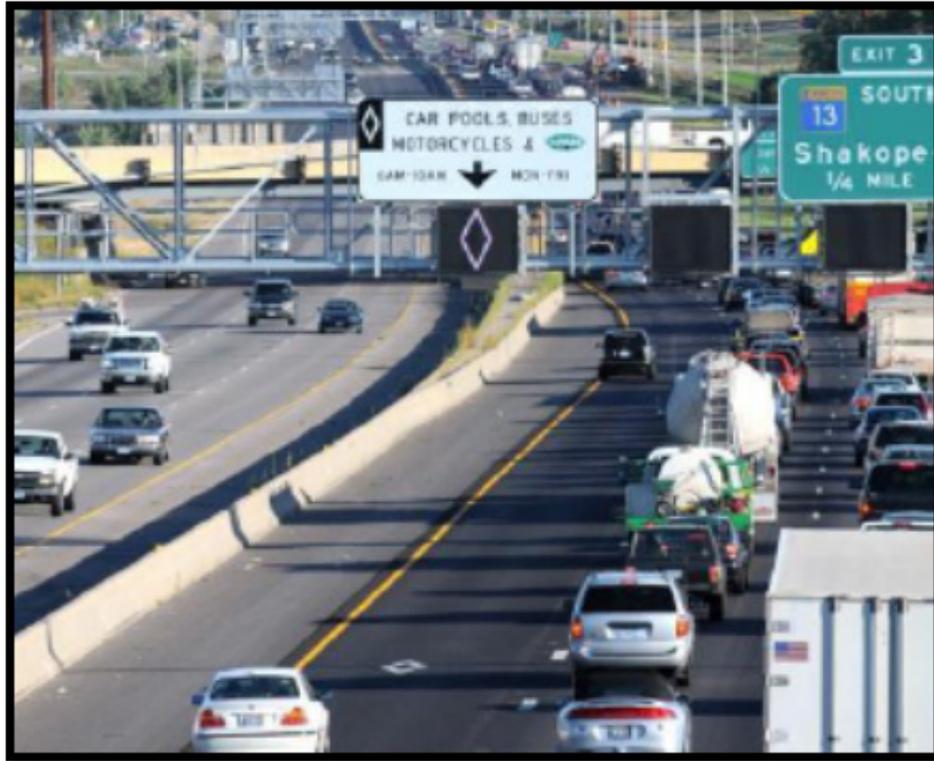


Figure 5-5 Intelligent Lane Control Signals

Purpose and Usage

Intelligent Lane Control Signals (ILCS) are dynamic lane signals used for incident management, speed harmonization, and priced dynamic shoulder lane. Figure 5.6 shows the available message options for ILCS.

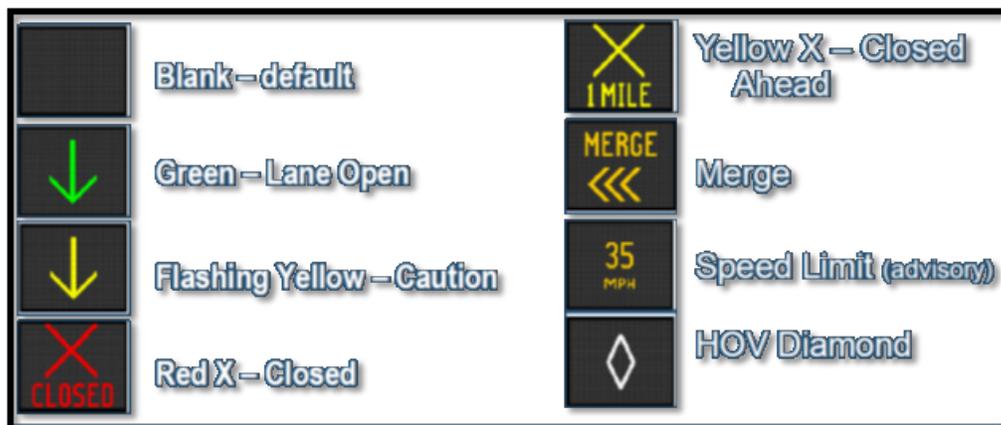


Figure 5-6 Intelligent Lane Control Sign Options

Components Used

This section is reserved for future updates.

5-5.03.10 Ramp Meter

Definition

Ramp Meters are traffic signals on highway entrance ramps, and they are designed to reduce crashes, reduce congestion and provide more reliable travel times.



Figure 5-7 Ramp Meter

Purpose and Usage

Ramp metering is a system element for addressing recurring freeway congestion. They control the rate at which vehicles enter the mainline such that the downstream capacity is not exceeded, thereby allowing the freeway to carry the maximum volume at a uniform speed.

Another benefit of ramp metering is its ability to break up platoons of vehicles that have been released from a nearby-signalized intersection. The mainline, even when operating near capacity, can accommodate merging vehicles one or two at a time. However, when platoons (i.e., groups) of vehicles attempt to force their way into freeway traffic, turbulence and shockwaves are created, causing the mainline flow to breakdown. Reducing the turbulence in merge zones can also lead to a reduction in the sideswipe and rear-end type accidents that are associated with stop-and-go, erratic traffic flow.

Components Used

Typical components used for a Ramp Meter project include the items listed below. See Section 3.0 Freeway Management of this manual, and the [ITS Design Manual](#) for further discussion of the system components and design considerations.

- Ramp Meter Signals and Mounting
- Management System Control Software
- Control Cabinet
- Power
- Communications

5-5.03.11 *Reversible Lanes*

Definition

A reversible lane is a lane in which traffic may travel in either direction depending on traffic flow patterns.

Purpose and Usage

The reversible lanes on I-394 are separated from the general purpose lanes and are controlled by signs and automated gates. The flow is reversed for the morning and afternoon peak periods.

Components Used

Components include:

- Automated gates
- DMS
- Communications
- Power

5-5.03.12 *Roadside Lighting System Control*

Definition

These systems manage electrical systems by monitoring operation conditions and using the lighting controls to carry the amount of light provided along the roadside. These systems allow a center to control lights based on traffic conditions, time of day, and the occurrence of incidents.

Purpose and Usage

These systems can increase the safety of a roadway segment by increasing lighting and conserve energy at times when conditions warrant a reduction in the amount of lighting.

Components Used

The roadway lighting system will be able to be controlled through the RTMC's fiber optic system. Lighting levels and intensities can be controlled remotely.

5-5.03.13 *Speed Monitoring*

Definition

A system used to monitor traffic speeds on the roadways.

Purpose and Usage

Every Federal Fiscal Year (October through September), quarterly and annual speed monitoring reports are prepared by MnDOT's Office of Traffic, Safety, and Technology (OTST) and submitted to the Federal Highway Administration (FHWA) Division Administrator. The results of this program are used to determine speed trends throughout the United States. Additional reports are sent to the Commissioner, all MnDOT Districts, the MnDOT Library, the Department of Public Safety, and the Legislative Reference Library.

Various methods are currently being used for the collection of data. Radar transmission devices, although useful in certain situations, are not used in the speed monitoring program due to manpower requirements. Below is a list of speed data collection devices.

Weigh-In-Motion (WIM) Stations

- These devices are located throughout the State and collect a variety of data including the weight and speed of vehicles. The information is collected automatically.

Automatic Traffic Recorders (ATR) Sites

- ATRs automatically collect information by means of in-pavement loop detectors. ATRs are located throughout the State and are typically used to determine vehicle counts. A small number of them have been installed to allow the collection of speed data.

Portable data collection machines with road tubes, in-pavement loop detectors, or portable magnetic sensing devices.

- This method of data collection requires the placement of a sensing device on the road surface which connects to the data collection machine located off the road. This method is undesirable due to manpower requirements.

Components Used

Speed monitoring system components include a device to measure speed, such as radar, loop detectors, video detection, and portable data collection devices such as pneumatic tubes. The system also typically requires a power source, communications, and a cabinet with control device/software. See the [ITS Design Manual](#) for further discussion of system components and design considerations.

*5-5.03.14 Tolling - MnPASS HOT Lanes***Definition**

I-394, on the west side of the Twin Cities, and I-35W, south of Minneapolis, operates a High Occupancy Toll (HOT) lane. Carpoolers may use the lane for free and single occupant vehicles may opt to pay a toll to use the lane. The toll charged to single occupant vehicles varies according to conditions. The ongoing operations allows for toll collection to be entirely automated (no manual fare collection).

Purpose and Usage

The purpose of this type of project is to improve travel times and reduce congestion for users along the highway, and to provide an uncongested express lane for high occupancy vehicles and single-occupancy vehicles paying an electronic toll. Drivers that use the MnPASS Express Lane will experience improved traffic flow, reduced congestion, and better commute times along the route.

Components Used

This section is reserved for future manual updates.

*5-5.03.15 Traffic Signal Control***Definition**

See Traffic Signals, Chapter 9 of this manual.

Purpose and Usage

See Traffic Signals, Chapter 9 of this manual.

Components Used

See Traffic Signals, Chapter 9 of this manual.

*5-5.03.16 Travel Times***Definition**

Systems that calculate and disseminate travel times between two points on freeways and non-freeways in a real-time format.

Purpose and Usage

In the Metro area, the Minnesota Department of Transportation (MnDOT) calculates and disseminates freeway travel times based upon freeway loop detector data. Currently there is not an operational approach toward monitoring or disseminating arterial travel times throughout the Twin Cities. Several recent initiatives now underway, including the performance based measures required by MAP-21, identify the need for travel time reporting on arterial routes. A key element to Integrated Corridor Management (ICM) is to present travelers with travel time comparisons for freeways, arterials, and transit. MnDOT has explored several options for cost effective arterial travel time monitoring and estimation.

Components Used

Freeway Travel Times in the metro area use frequently spaced loop detectors, control cabinets, and a fiber optic cable backbone to collect data. An algorithm within the IRIS software calculates the travel time data, and displays messages on DMS as desired.

Non-freeway travel time systems that have been tested by MnDOT include:

- SMART-Signal (signalized arterials)
- SENSYS Systems
- Bluetooth Data
- INRIX
- Commercial Probe Data
- Cell Phone Traffic Data
- MATT (signalized arterials)
- Rural Travel Times During Construction (rural highways)

5-5.03.17 Truck Priority

Definition

Truck Priority is a system to grant trucks priority treatment at specified signalized intersections, typically two-lane highways. Currently there is a truck priority system in use in Sherburne County at Trunk Highway 24 and CSAH 8.

Purpose and Usage

Truck Priority is a means to improve the operation of heavy trucks passing through traffic signal controlled intersections on rural high-speed highways by detecting the presence of trucks and extending the green time sufficiently for the truck to pass through the intersection.

Components Used

The truck priority system components include two loop detectors spaced 30 feet apart (or other detection that can distinguish heavy commercial vehicles) connected to the traffic signal cabinet. Truck Priority requires additional logic programmed into the traffic signal controller.

5-5.03.18 Variable Speed Limit (VSL)

Definition

VSL is a sign capable of displaying different speed limits to travelers (in which the speed limit is either an advisory (recommended) or statutory (mandatory) limit) that are either manually activated or controlled by a combination of detectors and algorithms to select appropriate speeds.



Figure 5-8 Variable Speed Limit (VSL) Signs

Purpose and Usage

Variable Speed Limit (VSL) signs are used across the country to lower posted speed limits in certain areas. They allow for operators to adjust the speed limit (either regulatory or advisory) without changing the sign. They are used in conjunction with Intelligent Transportation Systems to lower speed limits for several reasons including congestion, construction, accidents, fog, snow, and ice. VSL signs have been successfully tested by several state departments of transportation.

The [MN MUTCD](#) Table 2A-5 provides color standards for the illuminated speed limit and background of VSL Signs under Changeable Message Signs.

Components Used

Typical components used for a VSL project include the items listed below. See the [ITS Design Manual](#) for further discussion of system components and design considerations.

- Sign(s)
- Management System Control Software
- Control Cabinet
- Power
- Communications

5-5.03.19 Warning System – Bridge Height

Definition

This type of system detects over height vehicles moving toward obstacles such as bridges, tunnels and other overhead structures and individually warns drivers. A sign is activated when an over height vehicle is detected by the system.

Purpose and Usage

The purpose of this system is to detect over-height vehicles and warn the drivers of the impending problem. This will enable them to exit the freeway and avoid the possibility of contact with the bridge.

Components Used

Components include:

- Laser detection
- Communications
- Controller
- Power
- DMS.

5-5.03.20 Warning System – Curve Advisory

Definition

The Curve Warning System provides a programmable active warning based on the speed of the vehicle as it approaches the curve and provides a warning message to the driver to reduce speed if it is excessive.



Figure 5-9 Curve Warning Systems

Purpose and Usage

A dynamic curve warning sign (DCWS) is a technology that may help drivers select an appropriate speed when approaching a horizontal curve. A DCWS generally consists of a warning sign combined with a speed measuring device (e.g., radar) that activates a variable message (e.g., SLOW DOWN) when vehicles are traveling above a set threshold. The technologies used to create a DCWS are currently available and the devices have been implemented at various locations.

Currently there are two warning systems being used in Meeker County, one on southbound CSAH 25 and another on eastbound CSAH 3. These are county-only systems.

Components Used

Typical components used for a DCWS project include the items listed below. See the [ITS Design Manual](#) for further discussion of system components and design considerations.

- Warning Sign
- Detection to Determine Speed
- Management System Control Software
- Control Cabinet
- Power
- Communications

5-5.03.21 Warning System – Foggy Conditions

Definition

This type of system is a highway visibility sensor that measures the density of roadway fog and is linked to traveler information systems.

Purpose and Usage

The need for a highway fog warning system has long been internationally recognized. With such a system, motorists can avoid tragic pile-up accidents caused by dense or patchy fog, which are often fatal.

MnDOT does not currently use this system.

Components Used

This section is reserved for future manual updates.

MnDOT does not currently ha

5-5.03.22 Warning System – Highway Rail Grade Crossing

Definition

This element represents roadside equipment that alerts motorists of railroad crossings at at-grade intersections. Gates are activated and deactivated as trains are detected approaching and clearing the intersection.

Purpose and Usage

This section is reserved for future manual updates.

Components Used

This section is reserved for future manual updates.

5-5.03.23 Warning System – Icy Conditions

Definition

This system detects conditions where ice may be forming on the pavement, and provides notification to drivers of this condition.

Purpose and Usage

Warning systems for icy conditions are generally installed in locations where experience has shown that icy conditions are re-occurring, and that the potential for crashes is high. The system uses ground sensors installed in the road surface. The sensors measure (among other parameters) the surface temperature, the freezing point temperature, and the pavement surface condition (dry, damp, wet, slippery because of ice, black-ice, hoarfrost, or snow).

When icy conditions are identified, notification is given to the public via DMS, static signs with flashing beacons, and/or maintenance crews are notified of the condition.

MnDOT currently operates a static warning sign system with flashing beacons on I-35 in Burnsville next to the Buck Hill Ski Area. This system is activated by the Regional Transportation Management Center (RTMC) based on communication from Buck Hill staff when snow making operations are being employed.

There is also a static sign warning system in Wright County on Trunk Highway 12 between the cities of Dassel and Cokato.

Components Used

Components include:

- Pavement sensors capable of detecting icy conditions
- Power
- Control software
- DMS
- Communications back to a maintenance facility
- Static signs with flashing beacons

5-5.03.24 Warning System - Ramp/Curve Truck Rollover**Definition**

Ramp/Curve Truck Rollover Warning Systems provide warning to commercial vehicles as they enter a curve or ramp at a speed that is likely to cause a rollover.

Purpose and Usage

The purpose of these systems is to reduce truck rollovers in locations that have a history of this type of incident. MnDOT's Metro District has installed a system in Washington County at an interchange ramp located at the junction of I-694/I-94/I-494 and will be installing a system on I-94 at the Lowry Hill Tunnel in Minneapolis.

Components Used

Typical components used for a Ramp/Curve Truck Rollover Warning System include the items listed below.

- Non-intrusive detection
- Weigh-in-motion (WIM) sensors
- Loops
- Blank out signs with warning beacons or dynamic message signs with warning beacons
- Communication systems
- Power

One particular type of warning system gathers information on heavy commercial vehicles using WIM technology. This system collects and instantaneously analyses data to determine if a vehicle is traveling too fast for the roadway geometry. If so, the operator is warned via a dynamic message sign.

Another system gathers information based on vehicle height and speed. If a vehicle determined to be above a defined height travels at a speed greater than a predetermined speed, the vehicle operator will be warned via a dynamic message sign.

5-5.03.25 Warning System - Stopped or Slow Traffic Ahead**Definition**

This system provides warning to motorists about stopped or slow traffic ahead, typically in a work zone situation.

Purpose and Usage

Stopped traffic on freeways poses safety and operational concerns to drivers, transportation agencies, construction and maintenance contractors, and enforcement and emergency service personnel. Safety issues relate to driver ability to make gradual transitions from freeway speeds to stopped conditions without erratic maneuvers or crashes. Operational concerns relate to the reliability and predictability of the freeway network. The primary type of multi-vehicle crash on a freeway facility is the rear-end collision, comprising over 50 percent of freeway crashes by some research findings, caused generally due to normal speed traffic encountering stopped traffic on the main lanes or ramps. Drivers frequently have minimal or no warning about downstream queuing, and information given on static signs is difficult to keep current with rapidly fluctuating queues in congested areas.

Components Used

Typical components used for a Stopped or Slow Traffic Ahead Warning System include the items listed below.

- Non-intrusive detection
- Warning signs with flashers or portable DMS
- Communication systems
- Power

See [ITS Design Manual](#) and the [IWZ Toolbox](#) for further discussion of system components and design considerations.

5-5.03.26 Warning System – Water on Road**Definition**

A highway sensor that measures the presence of water on the roadway and is linked to traveler information systems.

Purpose and Usage

This system will detect the presence of water on a roadway. Once a predetermined level has been reached, the system will automatically activate a sign warning drivers and advising them not to pass. The system may also send a message to the agency notifying them of the condition.

MnDOT does not currently use this system.

Components Used

Typical components used for a Water on Road Warning System include the items listed below.

- Device to detect water levels
- Communications
- Power
- Control equipment,
- Warning signs with flashers

5-5.03.27 Warning System – Wildlife**Definition**

The Wildlife Warning System detects the presence of large wildlife (deer, elk, moose, etc.) on the side of the road and activates signs warning the motoring public of the presence.

Purpose and Usage

The purpose of the Wildlife Warning System is to reduce the number of large wildlife vehicle crashes on instrumented roadway sections by detecting large wildlife and activating a flashing beacon on a standard deer sign, warning motorists of the presence of deer.

The Wildlife Warning System consists of two subsystems: detector stations and signs. The detector stations are placed along the roadside at distances of approximately 150 to 400 feet, depending on terrain conditions. Pairs of passive infrared beams are emitted by the detectors and both must be broken for a detection “event” to occur. Video detection has also been used to detect wildlife. When an animal is detected, a communications device connected to the detector receiver broadcasts a unique identifier over a radio network.

The duration of beacon flash and the list of associated detectors for each sign is user-programmable through a software application.

MnDOT does not currently use this system.

Components Used

Typical components used for a Wildlife Warning System project include the items listed below. See the [ITS Design Manual](#) for further discussion of system components and design considerations.

- Detection

- Warning signs with flashers
- Management System Control software
- Power
- Communications

5-5.03.28 Wrong Way Detection

Definition

This includes a system used to detect vehicle traveling in the wrong direction on a traveled way.

Purpose and Usage

An important area of concern relative to highway safety is the occurrence of drivers going the wrong way on one-way streets, highway mainline lanes, or highway entry or exit ramps. Along with significant signing, various monitoring approaches have been tried and implemented to provide immediate detection of vehicles going the “Wrong Way”. To date, systems using magnetic induction loops represent the most common solution for “Wrong Way” detection. With magnetic induction loop systems, two or more loops are placed in the roadway as shown in Figure 5.10. Relative to the correct direction of travel, loop #1 is the upstream vehicle detection sensor and loop #2 is the downstream vehicle detection sensor. In the presence of traffic, vehicle detection at loop #1 followed by detection at loop #2 indicates the correct direction of travel by the detected vehicle. Vehicle detection at loop #2 followed by detection at loop #1 indicates the incorrect direction of travel by the detected vehicle. When properly installed and maintained, the loop-based system performance should be reasonable.

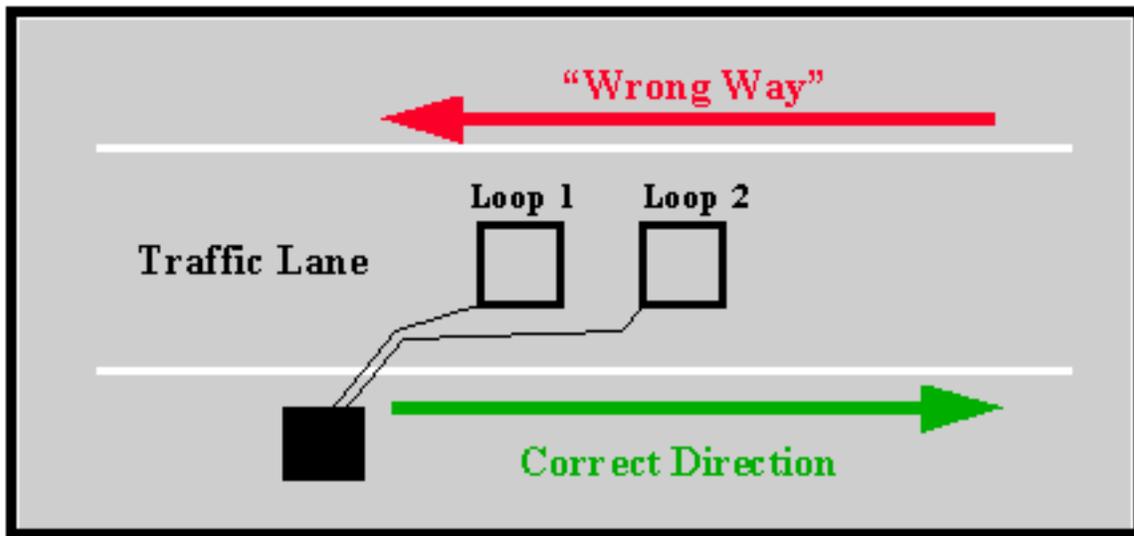


Figure 5-10 Loop Based Wrong Way Detection

The Detection Zone (Area of Detection, Detection Area, Zone of Detection, Effective Loop Area, Field of Influence, Field of View, Sensing Zone, Footprint) is the area of the roadway within which a vehicle is detected by a sensor system.

Components Used

The wrong-way detection system utilizes:

- Loop detectors
- Control equipment
- Communications
- Power

5-5.04 Advanced Public Transportation Systems (APTS)

5-5.04.01 Real-Time Bus Arrival Signs

Definition

These systems provide real-time arrival/departure information to travelers at a bus stop.

Purpose and Usage

Real-time information for bus and light rail arrival/departure times will be displayed to passengers via electronic message signs at bus stops and light rail stations in the Twin Cities metro area. Signs will also be installed at key decision points for drivers along arterial roads and freeways prior to entrances to park-and-ride facilities. Commuter rail arrival/departure times could also be displayed to travelers in the future.

Components Used

System components include:

- DMS
- Communications
- Power
- Link to Metro Transit's NexTrip Real-time bus arrival database

5-5.05.02 Transit Signal Priority (TSP)

Definition

These systems provide advantages for transit vehicles at signalized intersections by modifying the signal timing to give priority to transit vehicles.

Purpose and Usage

TSP Systems are implemented to improve schedule adherence, customer satisfaction, transit reliability, and travel speed. In Minnesota, TSP systems are currently operational in St. Cloud and the Minneapolis Metro Area.

St. Cloud's system utilizes existing EVP detectors and emitters to provide communication between buses and intersections. The traffic signal controller has a TSP module that is programmable.

As part of the Urban Partnership Agreement (UPA) in 2009, Metro Transit deployed TSP at over 30 intersections (MnDOT, City of Minneapolis, and Ramsey County) and on approximately 800 Metro Transit buses. The system became operational in the Fall of 2010. The system will expand to the BRT Red Line that began service in 2013.

The system deployed in the Metro area, which uses real-time vehicle position data and a wireless communication network, was deployed within each signal cabinet and on the Metro Transit bus fleet. A priority request to provide a green light is automatically placed at an intersection equipped with TSP if the bus is determined to be behind schedule. The system is configured to log TSP requests and TSP activations to both Metro Transit and the operating agency to support intersection monitoring and system fine-tuning.

Components Used

- TSP components include:
 - TSP traffic signal controller module
 - Priority detectors mounted at the intersections
 - GPS mounted on the buses
 - Connection on the bus to the TransitMaster system to determine schedule adherence
 - Central control software
 - Power
 - Communications

5-5.04.03 Transit Customer Information Systems

Definition

These systems provide information regarding park-and-ride availability and trip time comparisons to key destinations between transit and passenger vehicles.

Purpose and Usage

Real-time information on availability of parking spaces at transit park-and-ride facilities will be displayed to drivers via electronic message signs at selected park-and-ride locations in the Twin Cities metro area.

Components Used

System components for parking availability include:

- Detection at the ramps
- Communications
- Power
- DMS displaying parking availability.

Trip time comparison systems components include:

- DMS
- Communications
- Power
- Link to Metro Transit's travel time database

5-5.05 Commercial Vehicle Operations (CVO)

5-5.05.01 Weigh-in-Motion

Definition

Weigh-in-motion (WIM) devices collect volume, classification, speed axle loadings, vehicle and axle configuration, and truck volume characteristics.

Purpose and Usage

MnDOT currently uses WIM system data in [Daily Weight Enforcement Reports](#) for a number of sites. Note that WIM system data is not enforceable.

When a vehicle passes over a WIM site, a sensor emits an analog signal whose strength is directly proportional to the axle weight of the vehicle, and the approximate weight is recorded.



Figure 5-11 WIM System

After the volume, class, speed, and weight data from all WIM sites is processed and analyzed, the [WIM Monthly Station Reports](#) are posted online and data is submitted to the FHWA. Analysis of annual trends in the data can lead to a better understanding of changing truck fleet characteristics and truck weights.

Gross vehicle and axle weight monitoring is useful for a wide range of reasons, including:

- Pavement design, monitoring, and research
- Bridge design, monitoring, and research
- Size and weight enforcement
- Legislation and regulation
- Administration and planning

Components Used

Each weigh in motion system will consist of the following components. These components will vary with the type of system you require.

- Weight sensors - the hardware that weighs the vehicle. The type of sensor depends on your system requirements - portable or permanent installation.
- Cabling - connects the weight sensors to the computer.
- Computer Interface - data acquisition electronics that convert the scale readings to real weight.
- PC Software - does calculations on the weight readings and stores the data.

5-5.06 Emergency Management (EM)

5-5.06.01 Future Placeholder

5-5.07 Maintenance and Construction Management (MCM)

5-5.07.01 Intelligent Work Zones

Definition

Intelligent Work Zones (IWZ) are a system of devices that provides motorists, and/or workers, “real-time” information for improved mobility and safety through a work zone. MnDOT has prepared in [“Intelligent Work Zone Toolbox”](#) which can be used as a guideline to select the appropriate IWZ for a specific work zone traffic issue. The IWZ System descriptions contained in this toolbox are intended as brainstorming material and should lead to practical solutions to a project’s unique problems. The examples are purposely left void of many dimensions, except where particular distances are highly recommended, and engineering judgment is required to customize the system to a project.

The IWZ Toolbox can be found at: <http://www.dot.state.mn.us/trafficeng/workzone/iwz/MN-IWZToolbox.pdf>

Purpose and Usage

IWZ Systems may be sorted into 3 category types based upon detectable stimuli: (1) Traffic, (2) Vehicle, and (3) Environmental. The 3 categories are shown below with their typically associated systems: The real-time data collected for any of these systems may be combined, averaged, analyzed for trends, and utilized for several informational uses. For example, data collected for ‘Stopped Traffic Warnings’ may be to control a ‘Dynamic Merge’ system or to calculate “Travel Time’ through a corridor.

1. Traffic Responsive Systems collect and respond to average traffic characteristics such as speed and volume of a group of vehicles and the systems react to trends of increasing/decreasing values. The combination of these basic systems form the basis for Route Management Systems (or Traveler Information Systems) by analyzing and reporting information in various ways. These applications may include:
 - Travel Time Information (Trip Time or Estimated Delay)

- Speed Advisory Information
 - Congestion Advisory
 - Stopped Traffic Advisory
 - Dynamic Merge (Late or Early)
 - Traffic Responsive Temporary Signals
 - Temporary Ramp Metering
2. Vehicle Responsive Systems collect and respond to individual vehicle characteristics such as speed, dimensions, and location. When adverse conditions are detected by these systems, motorists need immediate warnings for quick response. These applications may include:
 - Excessive Speed Warning (including Dynamic Speed Display Signs)
 - Over Dimension Warning
 - Work Space / Haul Road Intrusion Warning
 - Construction Vehicle Warnings
 3. Environmentally Responsive Systems collect and respond to changing non-traffic conditions of weather, roadway or working characteristics such as visibility conditions or roadway surface conditions and hazards. These applications may include:
 - Hazardous Condition Warnings (Flooding, Ice, Fog, Smoke, Dust, etc.)

Temporary Traffic Control Devices may be equipped with advanced communication and/or remote control capabilities that do not react “intelligently” to detectable field data, but the devices provide safer working conditions or improve incident response. Although these devices may not be “Intelligent”, they have been included in the IWZ Toolbox as additional safety tools for consideration when an IWZ System is being deployed. These applications may include:

- Changeable Work Zone Signage (WZ Speed Limit Signs)
- Traffic Surveillance Cameras (removed from Toolbox)

Components Used

Each IWZ System in the Toolbox is a collection of standard system components which have been combined to produce a useful real-time system. The individual component functions include the collection of data, verifying the accuracy of the data, transmitting the data, storing and managing the data, analyzing the data, and/or providing the data to the motorist.

Detection Components

The detectors may include:

- Radar
- Pneumatic Road Tubes
- Light Beams
- Acoustical
- Ultrasonic
- Magnetic
- Piezo-Electric
- Video
- RFID
- Probe Injection Technologies, etc.

System Monitoring Components

Typical redundancies should be built into most systems (based upon risk assessment for the system failure) and the various types of quality control testing or system mode, monitoring may be utilized.

System Communication Components

The typical forms of transmitting data, some of these may include:

- Cellular Modems
- Internet - Wireless Access Points
- Radio
- Hard wired
- Optical, etc.

System Analysis Components

Analysis algorithms are designed or modified for each application of an IWZ System to fit the conditions of the project. Algorithms can be designed with apparent limitations and strengths, and field testing is necessary to ensure the quality of the data analysis.

Data Management Components

The storage of data and analysis of the data for various trends, events, etc. may utilize many different database systems.

Dynamic Informational Components

Dynamic components provide information to the motorists and may include:

- 511 Systems (internet & phone/cell phone),
- Dynamic Message Signs (DMS) in dynamic mode
- Static signs with dynamic features,
- Remotely activated traffic control devices,
- Audible or visual alarms,
- Real-time highway advisory radio (HAR),
- Public media announcements,
- CB Radio, etc.

Supplementing Existing System Components:

MnDOT, through its Regional Transportation Management Center (RTMC) and out-state Transportation Operation and Communications Centers (TOCC's), has the capability to provide a variety of IWZ Systems for MnDOT construction and maintenance projects. However, MnDOT's detection devices, communications networks or traveler information systems may not be adequate for a proposed IWZ System. Discrepancies may be due to construction interrupting permanent installations, or that the existing system components do not extend to the project area.

IWZ System components provided by a contractor would supplement the services of the RTMC or TOCC's, when various devices/services are not currently available and may include any of the component types listed above.

5-5.07.02 Road and Weather Information Systems (RWIS)

Definition

A road weather information system (RWIS) is a combination of technologies that collects, transmits, and disseminates weather and road condition information. The component of an RWIS that collects weather data is the environmental sensor station (ESS). An ESS is a fixed roadway location with one or more sensors measuring atmospheric, surface (i.e., pavement and soil), and/or hydrologic (i.e., water level) conditions including:

- Atmospheric sensors – air temperature, barometric pressure, relative humidity, wind speed and direction, precipitation type and rate, visibility distance
- Surface sensors – pavement temperature and condition (dry, wet, ice, freeze point, chemical concentration), subsurface temperature, subsurface freeze/thaw cycles)
- Hydrologic sensors (stream, river and tide levels)

Data collected from environmental sensors in the field are stored on site in a Remote Processing Unit (RPU) located in a cabinet. In addition to the RPU, cabinets typically house power supply and battery back-up devices. The RPU transmits environmental data to a central location via a communication system. Central RWIS hardware and software collect field data from numerous ESS, process data to support various operational applications, and display or disseminate road weather data in a format that can be easily interpreted by a user. Environmental data may be integrated into automated motorist warning systems, and transmitted to TMCs, emergency operations centers and maintenance facilities for decision support. This information may also be used to enhance forecasts and supplement mesoscale environmental monitoring networks (i.e., mesonets).

Weather service providers (who are often RWIS/ESS vendors) also use the data to develop tailored weather services and products, including:

- pavement temperature/bridge icing forecasts,
- ice and snow prediction,
- optimization of treatment routes and resource allocation and
- thermal mapping.

Thermal mapping is a process to quantify the variation in nighttime road surface temperatures across the roadway network. This variation can be 10°F or greater (depending on exposure, altitude, traffic, and road materials), which can impact which areas may become icy before others.

Types of Road Weather Management Strategies

Transportation managers utilize environmental data to implement three types of road weather management strategies: advisory, control and treatment.

Advisory

Advisory strategies provide information on prevailing and predicted conditions to both transportation managers and motorists.

Control

Control strategies alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity.

Treatment

Treatment strategies supply resources to roadways to minimize or eliminate weather impacts. Many treatment strategies involve coordination of traffic, maintenance, and emergency management agencies.

Winter maintenance managers utilize road weather information to assess the nature and magnitude of threats, make staffing decisions, plan treatment strategies, minimize costs (i.e., labor, equipment, materials), and assess the effectiveness of treatment activities (by agency staff or subcontractors). Traffic managers may alter ramp metering rates, modify incident detection algorithms, vary speed limits, restrict access to designated routes, lanes, or vehicle types (e.g., tractor-trailers) and disseminate road weather information to motorists in order to influence their travel decisions. Some Traffic Management Centers integrate weather data with traffic monitoring and control software.

Emergency managers may employ decision support systems that integrate weather observations and forecasts with population data, topographic data, as well as road network and traffic data. When faced with flooding, tornadoes, hurricanes, or wild fires; emergency managers may use this data to evacuate vulnerable residents, close threatened roadways and bridges, and disseminate information to the public.

Note: RWIS uses a different key than other cabinets.

Minnesota's RWIS is a system that automatically collects, processes, and distributes current and forecasted weather and road surface information.

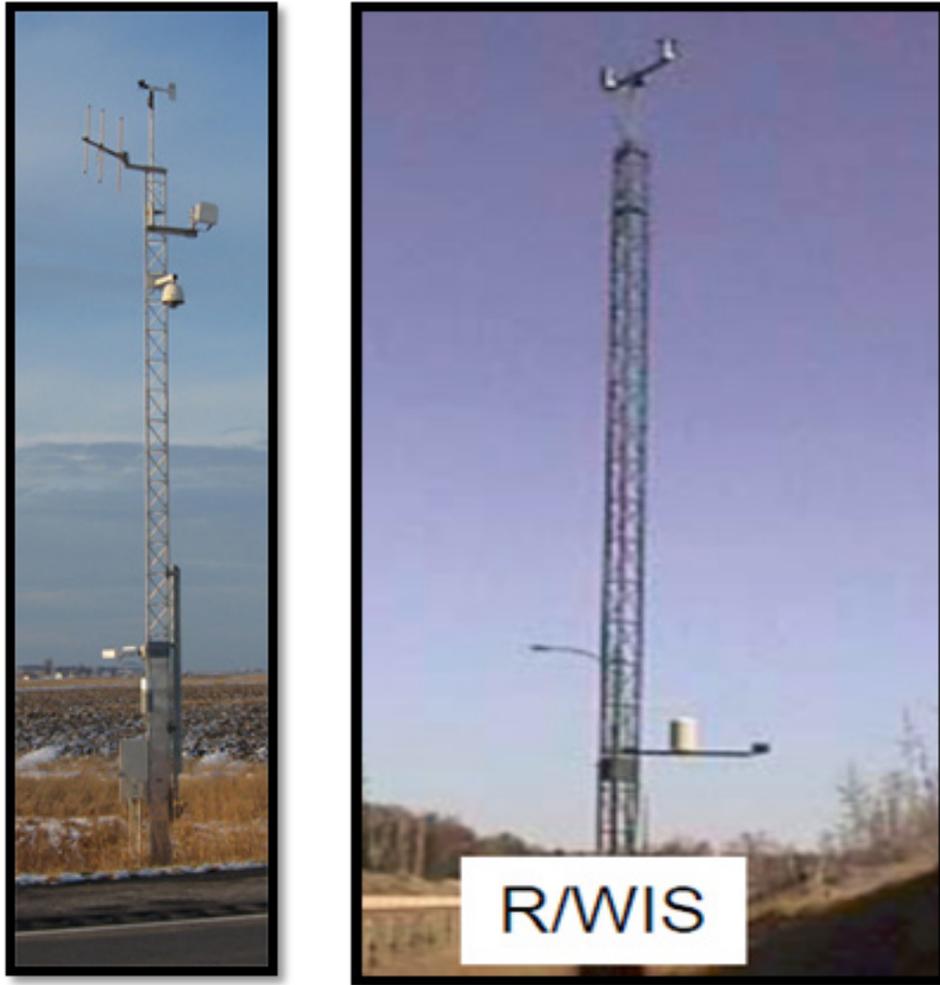


Figure 5-12 RWIS System

Purpose and Usage

Minnesota's RWIS includes in-field detectors, communications to relay data to a central processing center, and display mechanisms to display data and resulting information to maintenance and traveler information providers, as well as the traveling public.

Data gathered from a series of in-pavement sensors, sub-surface probes and meteorological equipment were combined with a weather forecast to predict pavement surface conditions up to 12 hours in advance. Advanced traveler information systems provided drivers and fleet operators with RWIS data including up-to-the-minute warnings about changing conditions. Highway operations managers use RWIS for timely and cost-effective snow plowing and deicing.

Components Used

Typical components used for a RWIS project include the items listed below. See the [ITS Design Manual](#) for further discussion of the system components and design considerations.

- RWIS
- Management System Control Software
- Power
- Communications

5-5.07.03 *Work Zone Accident Reduction Deployment (WZARD)*

Definition

A WZARD system provides unaware drivers with advance notification of the presence of maintenance, work zone, incident management and law enforcement vehicles in order to reduce crashes and improve safety along a project corridor.

Purpose and Usage

One of the primary goals of this WZARD is to put into place the infrastructure necessary to improve safety for snow/ice and other work zone operations. Other goals and objectives include reducing incidents by providing the traveling public with real-time information about corridor traffic operations between Rogers and St. Cloud, Minnesota. The goals and objectives for the WZARD project can be grouped into three main areas:

Traffic Incident Management

- Improve corridor safety during work zone operations
- Improve safety for traffic incidents and/or traffic enforcement activities
- Reduce the occurrence of snow plow/vehicle crashes
- Reduce the occurrence of secondary incidents

Transportation System Efficiency

- Improve traffic safety and mobility
- Improve travel times along the I-94 corridor
- Reduce corridor congestion
- Manage recurrent peak period congestion, including weekend seasonal traffic
- Reduce vehicle emissions

Public Communications/Traveler Information

- Provide real-time traveler information along the corridor
- Provide travelers with advance warning of maintenance operations upstream
- Provide CCTV images to RTMC, District 3 Operations and State Patrol

Components Used

Typical components used for a WZARD project include DMS and IRIS, in conjunction with AVL and Geofencing.

5-5.07.04 *Computer Aided Dispatch (CAD)/Automated Vehicle Location (AVL)*

Definition

This section is reserved for future manual updates.

Purpose and Usage

This section is reserved for future manual updates.

Components Used

This section is reserved for future manual updates.

5-5.07.05 *Maintenance Decision Support System (MDSS)*

Definition

This section is reserved for future manual updates.

Purpose and Usage

This section is reserved for future manual updates.

Components Used

This section is reserved for future manual updates.

5-5.08 Advanced Vehicle Safety Systems (AVSS)

5-5.08.01 Rural Intersection Conflict Warning System

Definition

Rural Intersection Conflict Warning System (RICWS) detects vehicles on the major and/or minor roads, and then provides an applicable warning to vehicles on the other roadway to alert them of potential conflict.



Figure 5-13 RICWS Minor Road Warning



Figure 5-14 RICWS Major Road Warning

Purpose and Usage

These systems address crashes at stop-controlled intersections by providing drivers with a dynamic warning of other vehicles approaching the intersection. Crash reduction/modification factors can be found at the Crash Modification Factors Clearinghouse (http://www.cmfclearinghouse.org/study_detail.cfm?stid=315).

Crash reduction is heavily impacted by driver confidence in the system. Driver confidence can be influenced by system reliability both in detecting and activating for approaching/entering vehicles, system malfunction/ down time, and duration of warning as it relates to acceptable gap selection on the minor road.

Typical applications will include both a major road warning and minor road warning.

When major road ADT reaches high volumes (approximately 12,000 veh/day), the minor road warning will be active nearly continuously and may no longer be effective. For these situations, a major road warning only should be used.

Components Used

Typical components used for an ICWS project include the items listed below. Typical ICWS layouts are shown in Figures 5.7-5.9. See the ITS Design Manual for further discussion of system components and design considerations.

- Static and/or BOS signs
- Detection
- Control Cabinet
- Power
- Communications

In addition, see MnDOT's RICWS page at: <http://www.dot.state.mn.us/trafficeng/signals/conflictwarning.html> and the ENTERPRISE Pooled Fund website at: <http://enterprise.prog.org/>.

For the RICWS concept layout, please refer to the MnDOT [ITS Design Manual](#).

5-6.00 POWER, COMMUNICATIONS, AND CONTROL

5-6.01 Source of Power

Most ITS systems currently operate on 120 Volts AC with a power drop from the local utility company. Some systems operate using a low voltage DC power source, facilitating battery, solar power, or wind power options.

ITS systems usually include sensitive electronics located in an outdoor environment and mounted on metal poles. A lightning storm can cause the equipment to fail if it is not properly protected. Every control cabinet should have a quality properly rated solid state surge suppression device located where the power conductors terminate in the cabinet. In addition to the grounding required by the National Electrical Code at the service cabinet, the control cabinet should also have a grounding conductor going from its ground bus to a ground rod. The ground rod may be the one used by the service cabinet or a different one if the cabinets are not co-located. If the system includes tall mounting poles and is not connected by metal conduit, the pole installation should also include a ground rod. As per the National Electrical Code, it is essential that all metal cabinets, poles, housings, conduits, etc. all be connected together into a properly bonded and grounded system. All communications and video field cables should have surge suppression at both ends where they enter an enclosure or cabinet. Much unfortunate experience has shown that systems that are not properly grounded or protected from surges will not last long in the outdoor roadside environment.

Part of the design of an ITS system should be consideration of failure modes. Any source of power is subject to failure. Some ITS systems are not safety critical and can tolerate the occasional power outage. For safety critical systems, battery backup is an option. Battery backup can keep the system operational for a certain period of time when utility power is out. The size of the battery backup system can be calculated based on the load drawn by the system and the length of time it must run on battery power. One consideration of battery backup is that the batteries will need to be replaced periodically, maybe every five to seven years, to ensure that they can still hold a charge. Battery backup should also be checked every six months to ensure that the systems are ready to work when called upon.

In remote rural areas, obtaining a utility power drop can be very expensive if there are no electrical utilities in the area. For some low-power ITS applications, solar and/or wind power is an option. These options are also environmentally friendly. Resources are available to aid in designing the solar power. Factors include the amount of power the system needs, the percent of the time the system is operating (such as flashers that only flash upon certain infrequent events), the amount of time the system must operate in the absence of any sunlight, and the geographic location which affects the amount of sunlight received.

It is a good idea to over design the solar power system with large safety margins. Experience has seen several solar powered systems whose operation was disrupted due to inadequate solar power configurations. In Minnesota in mid-winter, hours of sunlight are limited and the cold causes the batteries to be inefficient, which makes it a challenge for solar powered systems. Wind power provides a nice complement to solar power. Cloudy times having less sunlight are often accompanied by higher winds. Wind turbines work better the higher they are mounted, and so mounting height could become a cost issue.

Similar to solar power, resources are available to aid in designing wind powered systems. Off the shelf systems for solar and wind, including controllers, are available from multiple sources. Underground battery boxes for solar powered systems may fill with water and be ruined. Battery boxes located on sign structures require that the sign post be breakaway (u-channel post mounting is not appropriate).

5-6.02 Electronic Communications

Data communications between the central server and field microprocessors are achieved in a variety of ways. Traditionally, copper cables have been used with standard modems on each end, but newer devices use a network of fiber-optic communication lines. See the [ITS Design Manual](#) for guidance in fiber optic design. The RTMC had some issues with ice crush causing problems with fiber cables.

Solicit information from the RTMC when installing fiber cables. They can provide valuable information regarding the best installation method.

Wireless communications is another option. With wireless communications you have to do a site survey to

examine line of site. If the site survey is done in the winter, it may change in the spring when foliage returns to trees. Watch out for things that are likely to change in the future, like growth of trees or places where new buildings may be built in the line of site.

Other options may include Ethernet or Leased Telephone Lines.

5-6.03 System Control Software

IRIS (Intelligent Roadway Information System) is MnDOT's Freeway Management System control software. IRIS is an open-source Advanced Traffic Management System (ATMS) software project developed by MnDOT. IRIS uses a General Public License (GPL). Figure 5.13 illustrates a screen from IRIS (DMS Control).

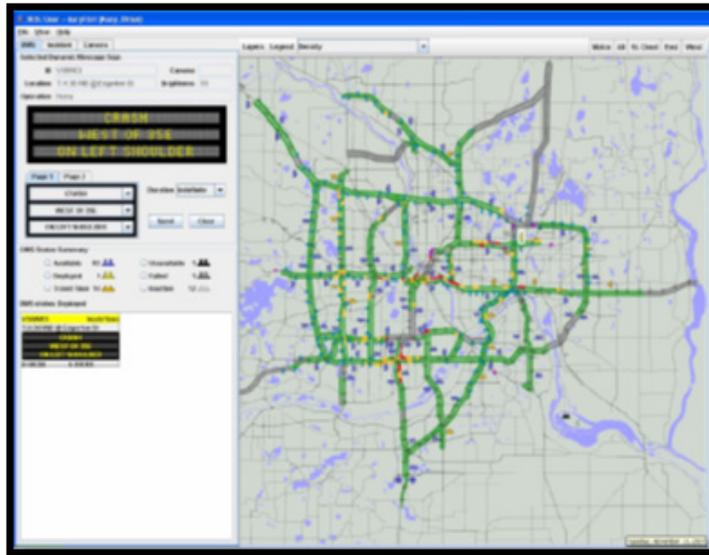


Figure 5-15 IRIS DMS Display

As an alternative to IRIS, commercial software is available that can do many of these functions. If you only have to manage one or two types of devices, such as cameras and DMS, then often the device manufacturers have software that comes with the device that enables you to control just that type of device.

5-7.00 ITS DEVELOPMENT

5-7.01 Role of the Office of Traffic, Safety, and Technology (OTST)

MnDOT's OTST establishes guidelines and procedures, striving for uniformity in traffic engineering, throughout the state of Minnesota, and builds relationships between state, county, and city engineering staff to resolve questions about engineering and roadway safety.

The ITS Section of OTST provides the following services:

- Makes recommendations for ITS deployment projects
- Conducts pilot and demonstration projects
- Serves as technical advisors to districts and other agencies
- Manages ITS projects considered experimental
- Manages Guidestar ITS projects
- Manages and maintains the Minnesota Statewide Regional ITS Architecture
- Participates in National Pooled Fund Studies with other states

The MnDOT Office of Traffic, Safety, and Technology website includes a wide variety of traffic engineering information, including ITS: www.dot.state.mn.us/trafficeng/index.html.

5-7.02 ITS Office and District Project Solicitation

MnDOT's Office of Traffic, Safety, and Technology's ITS Section solicits MnDOT Districts and Offices for ITS projects in Minnesota with up to \$1 million per year in funding over four years. This funding program is intended to encourage ITS deployment by providing dedicated funds that do not compete with other construction priorities.

Projects can be stand-alone ITS projects or ITS components of other construction projects. Projects can be for any dollar amount up to the entire dollar amount available per year. To be considered an ITS project, the project must fit the description of one or more of the ITS "Service Packages" that make up the National ITS Architecture. A description of the service packages can be found at: <http://local.iteris.com/itsarch>.

Funding for the program will be District C Federal STP funds in the State Road Construction (SRC) appropriation, with the following intended purpose as stated in state law:

"This appropriation is for the actual construction, reconstruction, and improvement of trunk highways, including design-build contracts and consultant usage to support these activities. This includes the cost of actual payment to landowners for lands acquired for highway rights-of-way, payment to lessees, interest subsidies, and relocation expenses."

THESE FEDERAL FUNDS WILL REQUIRE A 20 PERCENT NON-FEDERAL MATCH FROM THE DISTRICT.

The district will be responsible for including selected projects in the STIP and obtaining appropriate state and federal project numbers. This program will not fund operations and maintenance of the ITS project, technology and/or equipment. The OTST ITS section will provide funding numbers for the federal funds.

According to Federal Final Rule 940, ITS projects using federal funds must fit within a regional ITS architecture and must follow a systems engineering process. Minnesota has a "Minnesota Statewide Regional ITS Architecture (Version 2014)" meeting the requirements of this rule. (http://www.dot.state.mn.us/guidestar/2006_2010/mnitsarchitecture.html). Depending upon the scope of the proposed project, the project may require development of a Concept of Operations document and a Functional Requirements document. The ITS section can provide assistance in determining what is needed and how to best meet the requirements of Final Rule 940 and will work with the districts whose projects are selected.

ITS projects should address identified needs. Section 4 of this Chapter explains some draft ITS warrants that may help justify the project, and Section 5 provide a list of projects that have been successfully implemented elsewhere in the state. The OTST ITS Section anticipates issuing this solicitation annually for any unused funds from the previous solicitation plus new funds for the year subsequent to the previous solicitation time frame.

PROCESS FOR SUBMITTING APPLICATIONS:

1. Obtain an application from OTST
2. Fill out the Office/District ITS Solicitation Application Form in Microsoft Word format (.doc or .docx).
3. Submit the application electronically to Susan Sheehan at susan.sheehan@state.mn.us.
4. Applications are typically due in April.

EVALUATION AND SELECTION OF APPLICATIONS

An evaluation committee consisting of OTST ITS Section staff, OTST management and possibly District Staff and a representative from the Office of Capitol Programs and Performance Measures will evaluate and select proposals. Criteria to be considered in selecting projects include the following:

- Project identifies a documented need
- Project meets an ITS warrant
- Project fits into a larger ITS plan or complements other construction projects
- Project utilizes proven technologies
- Office/District has identified a plan for operating and maintaining the system

- Office/District has identified a plan for delivering the project
- Office/District has identified a source of state match

For more information, contact:

Susan Sheehan, OTST – ITS
651-234-7061
susan.sheehan@state.mn.us

5-8.00 INTERAGENCY AGREEMENTS

ITS projects can require permits, agreements, or partnerships with other agencies. Typical items to be discussed in an interagency agreement could include but are not limited to:

- Permits for acquiring power and/or communications
- Cost-sharing (infrastructure and ongoing)
- Maintenance
- Communications Sharing (fiber-optic cable)
- Sharing of video and/or data
- Shared operations of devices

Please contact OTST or the Permits office for more information and sample agreements.

5-9.00 REFERENCES

The pages contained within the manual are current at the time of publishing. Please keep in mind that the reference material is periodically updated, so the user is cautioned against using the reference materials included in the manual indefinitely, without checking the original sources for updates.

The following is a list of the reference material used for this manual.

1. Systems Engineering for Intelligent Transportation Systems – An Introduction for Transportation Professionals, FHWA. <http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf>
2. Definition of ITS Application Areas, USDOT-RITA. <http://www.itsoverview.its.dot.gov/faq.asp>
3. USDOT A Guide for HOT Lane Development, Glossary. http://ntl.bts.gov/lib/jpodocs/repts_te/13668_files/images/13668.pdf
4. FHWA Systems Engineering Guidebook for ITS. www.fhwa.dot.gov/cadiv/segb/index.htm
5. Minnesota Statewide Regional ITS Architecture Update 1. www.dot.state.mn.us/guidestar/2006_2010/mnitsarchitecture.html
6. Enterprise - Warrants for the Installation and Use of Technology Devices for Transportation Operations and Maintenance. <http://enterprise.prog.org/itswarrants/>
7. FHWA Traffic Detector Handbook: Third Edition—Volume I. <http://www.fhwa.dot.gov/publications/research/operations/its/06108/>
8. FHWA Office of Operations - Traffic Control Systems Handbook. <http://ops.fhwa.dot.gov/publications/fhwahop06006/index.htm>
9. FHWA Work Zone ITS Implementation Guide (Jan 2014). <http://www.ops.fhwa.dot.gov/publications/fhwahop14008/>
10. MnDOT Evaluation of Non-Intrusive Technologies for Traffic Detection. http://www.dot.state.mn.us/guidestar/2006_2010/nit_phaseIII/FINAL%20REPORT.pdf