

Warrants for the Installation and Use of Technology Devices to Assist Transportation Operations, Traffic Management, and Information Dissemination (Warrants for ITS Devices)

PHASE 1 and 2

Final Report

Warrants include:

- Closed Circuit Television
- Dynamic Message Signs
- Highway Advisory Radio
- Road Weather Information Systems
- Variable Speed Limit Devices
- Dynamic Speed Display Signs
- Ramp Meters
- Curve Warning Systems
- Intelligent Work Zones

Prepared for the



ENTERPRISE Pooled Fund Study

Prepared by



Athey Creek Consultants

May 14, 2010

Project Website

<http://enterprise.prog.org/itswarrants/>

Table of Contents

1. Executive Summary	1
2. Introduction	3
2.1 Background	3
2.2 Defining the Concept	3
2.3 Current Status	4
3. Devices Selected for Warrant Development	5
4. The Warrant Development Process	7
5. How to Use the Warrants.....	10
5.1 Warrant Process.....	10
5.2 Warrant Guidelines	11
5.3 Technology Device Warrants Website.....	11
6. Results of Phase 2 Warrants Testing and Use.....	12
6.1 Multi-state Warrant Testing Results.....	12
6.2 Actual Use of the Warrants.....	14
7. The Future - Ongoing Warrant Development and Use	15
7.1 The Future of the ITS Warrants.....	16
7.2 Ongoing Development Budget Estimate.....	17
7.3 Conclusions	18
8. ITS Technology Device Warrant Text	19
8.1 CCTV Warrants	20
8.2 DMS Warrants.....	27
8.3 HAR Warrants	39
8.4 RWIS Warrants	44
8.5 Variable Speed Limit Warrants	49
8.6 Dynamic Speed Display Signs Warrants.....	54
8.7 Ramp Meter Warrants	58
8.8 Curve Warning System Warrants.....	63
8.9 Intelligent Work Zone Warrants	67
References.....	74

1. Executive Summary

The ENTERPRISE Pooled Fund Study in 2009 developed initial warrants for the following Intelligent Transportation System (ITS) devices to assist agencies in the decision process of deploying technology devices as well as to validate the location of deployed devices.

- Closed Circuit Television (CCTV);
- Dynamic Message Signs (DMS);
- Highway Advisory Radio (HAR); and
- Road Weather Information Systems (RWIS).

This second phase of the project focuses on developing warrants for the following technology devices:

- Variable Speed Limit (VSL) Signs;
- Dynamic Speed Display Signs (DSDS);
- Curve Warning Systems;
- Ramp Meters; and
- Intelligent Work Zones.

Transportation professionals at the state/province, county, and city levels face challenges on how to handle increasing requests for the deployment of technology devices. The overall approach to the ITS warrants is modeled after the Manual on Uniform Traffic Control Devices (MUTCD) warrants for traffic signal installations. Based on this model, the ITS warrants identify guidelines to assist deployment decisions of technology devices.

During Phase 1 more than 20 transportation professionals participated in testing the warrants and some agency's are actively using the warrants as part of the decision making process for selecting device locations. Phase 2 is continuing to support the success of Phase 1 by providing additional device warrants for transportation professionals to use.

In addition to documenting warrants for these devices, this project is continuing to test and refine the warrants as well as exploring the industry acceptance for this concept. Ideally, the ENTERPRISE Program hopes that a National or International agency will embrace the concept of technology device warrants and carry the concept forward in order to support traffic engineers for years to come.

Warrant Website

An operational outcome of the first phase of the project was a project website. Visitors to the project website may execute the warrants by 'pointing and clicking' to answer the warrant questions. Website users will immediately receive the results of the warrant questions (either informed that the deployment in question is 'warranted', is 'not warranted', or is 'partially warranted'). Users may request to view the criteria and decision factors that led to the warrant conclusions.

More than anything, the warrants website is an effective tool for monitoring the testing of the warrants. Each time a visitor to the site executes a warrant (either for testing or for actual deployment analysis) the results are logged. Therefore, the project team working on the warrants can poll the database and view the number of times each warrant has been executed, the results of each execution, and any feedback documented.

The intent of the on-line tool was to serve as an effective mechanism for continued warrant development, testing, refinement and use by the industry. The warrant devices for phase 2 are included on the website and follow the same format as phase 1. For more information about the warrants visit the project website at: <http://enterprise.prog.org/itswarrants/>

While the ENTERPRISE ITS warrants project is now complete, the ITS warrants website will remain in operation for at least 12 months, and possibly longer if there is interest from the community. Athey Creek Consultants will continue to operate the site, responding to feedback and questions.

2. Introduction

2.1 Background

The ENTERPRISE Pooled Fund Study (<http://enterprise.prog.org>) is a collaboration of nine U.S. states, one Canadian province, the Federal Highway Administration, Transport Canada, and the Dutch DOT. Together, these 13 transportation agencies fund and perform projects that address specific needs in the members' agencies, that are related to advanced technologies in transportation, and that are most suited to collaborative group efforts. Each year, the ENTERPRISE group develops an annual work plan defining projects to be performed during the coming year.

In 2006, many ENTERPRISE member agencies were facing the challenge of increasing requests for the deployment of technology devices (commonly referred to as Intelligent Transportation Systems (ITS) devices). The group believed that a process of assessing whether individual devices are warranted at specific locations could help them in prioritizing device deployments. The group funded a first phase of the warrant development process that was completed in 2009 and then based on the results began developing a second phase of warrants for additional technology devices that is summarized in this report.

2.2 Defining the Concept

In the fall of 2006, The ENTERPRISE group began to develop a limited set of warrants for technology devices, modeled after the successful use of warrants by the Manual of Uniform Traffic Control Devices (MUTCD). In Phase 1 and Phase 2 the intent of the ENTERPRISE group's effort was to develop a similar set of warrants for selected technology devices in order to assess the feasibility and viability of technology device warrants.

The ENTERPRISE ITS warrants project was managed jointly by representatives from the Minnesota Department of Transportation (Mn/DOT) and the Washington State Department of Transportation (WSDOT). Both states contributed management to the project.

In addition to the project managers, ENTERPRISE representatives and personnel from with each member's agency contributed experiences, technical input and expertise from related to the warrants. The specific goals of the ENTERPRISE Warrants Project are summarized as follows:

- To identify a small number of technology devices that would be the focus of the initial warrants and then based on the results and feedback expand the focus of the initial warrants;
- To develop warrants for the installation of these devices to demonstrate the concept;
- To perform outreach to the transportation community and encourage testing and use of the warrants;

- Based on the feedback of the warrants testing, to assess the feasibility of wide scale technology device warrant use; and
- To seek industry input on the most appropriate agency to ‘house’ the device warrants in the future.

2.3 Current Status

The project activities have developed a set of technology device warrants for Phase 1 and Phase 2 of the ENTERPRISE warrants projects.

While the ITS warrants were developed by the ENTERPRISE member agencies, together with the project contractor (Athey Creek Consultants), a much larger group of industry representation was involved in the process, summarized as follows:

- A workshop was conducted as part of the 2009 ITS Canada Annual meeting in which over 50 members of ITS Canada gave feedback, input, and direction to the project;
- The ITS warrants were presented at numerous forums including the ITE mid-year meeting, the ITS World Congress in 2008, the National Rural ITS Conference, and to local ITS meetings and workshops; and
- Additional representatives from (non-ENTERPRISE) transportation agencies tested and trialed the warrants on the warrants website, offering input and feedback that was considered by the development team.

This document represents the project Final Report that identifies the efforts performed to develop the device warrants. Section 8 of this report contains the text of each device warrant. In addition to this printed report, the project has a project website that houses the latest versions of the warrants, as well as an interactive tool to execute the warrants on-line. Readers are encouraged to visit the project website in order to view the current project status at any time: <http://enterprise.prog.org/itswarrants/>.

3. Devices Selected for Warrant Development

The ENTERPRISE project participants selected four devices to be the focus of Phase 1 and five devices to be the focus of Phase 2 of the warrant development process.

The set of devices for which warrants have been developed, and the associated definition of each device (as defined by this project) are summarized as follows:

Phase 1 Devices

- **Closed Circuit Television (CCTV)**
CCTV are defined as a video or still picture camera system used to collect images, communicate images to end users, and project images onto a video monitor, television screen, Internet display, or other monitoring equipment.
- **Dynamic Message Signs (DMS)**
DMS are defined as either fixed or portable signs capable of displaying any text message entered by an operator (either locally or remotely).
- **Highway Advisory Radio (HAR)**
HAR is defined as low power AM or FM radio transmissions where localized information is broadcast and can be heard on standard AM or FM radios. Most often, travelers are alerted to the presence of the broadcast using static or dynamic signs displaying the frequency of the transmission. 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.
- **Road Weather Information Systems (RWIS)**
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.

Phase 2 Devices

- **Variable Speed Limit Devices (VSL)**
VSL devices are defined as a signs capable of displaying different speed limits to travelers (in which the speed limit is either a recommended or mandatory limit) that are either manually activated or controlled by a combination of detectors and algorithms to select appropriate speeds.
- **Dynamic Speed Display Signs (DSDS)**
DSDS are defined as 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'.

- **Ramp Meters**

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.

- **Curve Warning Systems**

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, weather) and/or roadway conditions (snow, ice, and rain) at approaches to sharp curves.

- **Intelligent Work Zones (IWZ)**

Intelligent Work Zones are defined as a collection of devices that collectively warn travelers of various hazards associated with work zones.

4. The Warrant Development Process

The technology device warrant development process was a structured 4 step process. This process is summarized as follows:

Step 1: Definition of Purposes

The technology devices described by the warrants are used by transportation professionals and/or the traveling public for a variety of purposes. In order to respect the fact that devices are considered for different purposes, multiple warrants have been developed for each device and each warrant focuses on a specific purpose for the device. As an example, for the VSL device, there are a total of four warrants (four purposes).

The definition of the purposes for each device (and therefore the warrants) was developed by the ENTERPRISE group, working together with the consultant team. It is recognized that there may be additional purposes for which warrants should be developed for each device, however the group reached consensus on the initial set of purposes and warrants for development. Table 1 summarizes the purposes addressed by each warrant.

Table 1 – Summary of Purposes Addressed by the Device Warrants

Device	Warrant ID	Warrant Name
Phase 1 Devices		
CCTV	CCTV Warrant #1	Traffic Observation (for signal control changes)
	CCTV Warrant #2	Traffic Incident or Event Verification
	CCTV Warrant #3	Weather Verification
	CCTV Warrant #4	Traveler Information
	CCTV Warrant #5	Field Device Verification
	CCTV Warrant #6	Intelligent Work Zone
DMS	DMS Warrant #1	To Inform Travelers of Weather Conditions
	DMS Warrant #2	To Inform Travelers of Traffic Conditions
	DMS Warrant #3	Changing Traffic Control & Conditions
	DMS Warrant #4	Special Events
	DMS Warrant #5	Parking Availability
	DMS Warrant #6	Transit Park-&Ride Availability
	DMS Warrant #7	Evacuation Routes
	DMS Warrant #8	Jurisdictional Boundaries
HAR	HAR Warrant #1	Weather & Driving Conditions
	HAR Warrant #2	Venue Parking
	HAR Warrant #3	Changing Traffic Control & Conditions
	HAR Warrant #4	Special Events

Device	Warrant ID	Warrant Name
R/WIS	R/WIS Warrant #1	Support Maintenance and Operations at Key Locations
	R/WIS Warrant #2	Support Regional, Statewide or Provincial Weather Monitoring or Modeling
	R/WIS Warrant #3	Support Traveler Information
Phase 2 Devices		
VSL	VSL Warrant #1	Maximize Capacity
	VSL Warrant #2	Safe Stopping Distances
	VSL Warrant #3	Safe Travel Speeds for Conditions
	VSL Warrant #4	Work Zones
DSDS	DSDS Warrant #1	Transition Zones
	DSDS Warrant #2	Posted Speed Adherence
	DSDS Warrant #3	Intelligent Work Zones
Ramp Meters	Ramp Meter Warrant #1	Corridor-wide Ramp Meter Deployment
	Ramp Meter Warrant #2	Isolated Ramp Meter Deployment
	Ramp Meter Warrant #3	Ramp Metering During Work Zone Activity
Curve Warning System	Curve Warning System Warrant #1	Rural Two-Lane Highway Curves
	Curve Warning System Warrant #2	High Risk Locations
	Curve Warning System Warrant #3	Truck Rollovers on Ramps
Intelligent Work Zones	DMS Warrant #3(PHASE 1 WARRANT)	Changing Traffic Condition
	CCTV Warrant #6	Intelligent Work Zone
	HAR Warrant #3 (PHASE 1 WARRANT)	Changing Traffic Conditions
	VSL Warrant #4 (PHASE 2 WARRANT)	Work Zones
	DSDS Warrant #3 (PHASE 2 WARRANT)	Intelligent Work Zones
	Ramp Meter Warrant #3 (PHASE 2 WARRANT)	Ramp Metering During Work Zone Activity

Step 2: Identification of Critical Factors for Each Warrant

With the purposes defined for each warrant, the next step in the warrant development process was to identify the critical factors associated with whether or not a device is warranted at a specific location. These critical factors were defined to be the factors most important in determining whether or not a device is both needed and able to serve the purpose in question at the specific location.

For example, Table 2 illustrates the factors defined by the group as most critical in determining if a DSDS is warranted for the purpose of ‘Promoting speed adherence in location so speed limit reduction zones’.

Table 2 – A Sample Definition of Critical Factors for DMS Device

Device	Purpose	Critical Factors
DSDS	To promote speed limit adherence in locations of speed limit reduction zones.	1. Average speed (85 th percentile speed) compared to posted speed
		2. Speed transition difference (in mph)
		3. Proximity to other DSDS

Step 3: Warrant Development

Once the factors were defined for each warrant (each purpose), the next step was to draft the text of each warrant. Using the example above, even with the definition of critical factors, there were still many decisions to be made about the parameters, cut-off thresholds, and decision points to be included in the warrants.

The Pooled Fund structure of the ENTERPRISE group was very conducive to this portion of the warrants development process. Within Step 3, the warrants were developed for each purpose and the draft warrants were shared with the Pooled Fund members. Collectively, the members came to agree on an initial version of the warrants. The initial version of the warrants was then used in Step 4 – Testing and Adjustments.

Step 4: Preliminary Testing and Warrant Adjustment

During Step 4, each of the ENTERPRISE members was asked to test the warrants against technology device deployments that were either:

- Being considered;
- Under development; or
- Already developed in recent years.

By testing the warrants against all three types of deployments, it provided a much larger pool of test cases, and also offered various levels of feedback. For example, agencies that tested the warrants against devices they had already deployed were able to receive feedback from the warrants process and compare that to their own decision about whether they feel the device is needed where it is currently deployed.

5. How to Use the Warrants

The warrants are arranged by the functions or purposes for each device, and were developed to be a series of simple yes or no questions that can be answered quickly, avoiding the complexity of collecting a lot of data before using the warrants. In general, the intent is that the warrants would require a minimal amount of data collection or information gathering and would enable a user to complete the warrant process in less than 30 minutes.

5.1 Warrant Process

The users of the device warrants are encouraged to follow three successive actions in order to determine if the device in question is justified at the specific location being considered.

Action 1: Purpose Selection

Identify and select the most appropriate purpose(s) (function) that the device is being considered to perform at the candidate location. If the device will be used for multiple purposes, run the warrant analysis for each purpose.

Action 2: Consideration of Warrant

For each purpose, there is a series of yes/no questions asked by the warrants. Once users complete the questions, they will have either discovered that the use of the Warrant has concluded either:

- A) The device is warranted;
- B) The device is partially warranted (in which case users are informed that if one or more additional purposes are partially met, the device shall be considered warranted); or
- C) The device is not warranted at this location.

Action 3: Next Steps

For each device that the warrants process identifies as 'Warranted', it is recommended that additional engineering and planning studies (as appropriate) be conducted for the device at the candidate location. These will include such considerations as:

- Whether there is power supply;
- Whether there is appropriate access for maintenance and operations; and
- Whether it is safe to deploy this device at this location.

Please note that the Warrants do not address these engineering and planning decisions, but rather the warrants simply look at whether the specific device is warranted at the location, given the need, the conditions at the location, and the potential benefits delivered by the device.

5.2 Warrant Guidelines

Many of the warrants examine whether lower cost or less technology oriented solutions would be more appropriate. Whenever possible, notes are included in the warrants that may suggest alternative approaches with the intention of saving the users money and complexity.

5.3 Technology Device Warrants Website

As part of the ENTERPRISE Warrants Phase 1 Project, a project website was created. The technology device warrants website plays several roles:

- Houses the latest versions of each Phase 1 and Phase 2 warrant;
- Allows website visitors to click boxes to answer yes/no questions about the site in question and receive a notice of whether the device is warranted at the location (as well as any feedback, notes, or qualifiers);
- Tracks the number of times each warrant was executed by website visitors and the results of each warrant use (i.e. tracks the number of times a warrant was used on-line and the number of times the device was reported as *'warranted'*, *'not warranted'*, or *'partially warranted'*;
- Allows visitors to enter contact information or a description of the site they performed the warrant on (entry of contact information is optional); and
- Provides project background information as well as warrant criteria information.

The interactive nature of the warrants website and the ability of the site to log the number of warrant trials and the outcomes of each trial provide an effective tool for future development of device warrants. Warrants can be loaded on the website and tested over the Internet by transportation professionals (note: the warrants website and testing is available to anyone and does not require any registration or the disclosure of any personal information). Testers can enter feedback as they test each device and the system will log whether the tester agrees with the outcome of the warrant. The website is hosted at <http://enterprise.prog.org/itswarrants/>

6. Results of Phase 2 Warrants Testing and Use

The structure of the ENTERPRISE Pooled Fund Study allowed for numerous agencies and individuals to test the warrants. The testing involved state/provincial governments, county governments, and local city governments.

The intent of the warrant testing was twofold:

- To test the value of the warrants in helping agencies determine if devices should be deployed and therefore testing the concept of ITS warrants; and
- To test the draft versions of the warrants to determine if the threshold values and specific questions are appropriate or need to be refined.

Testing the Value of Warrants and the Concept

The value of the warrants was tested by agencies considering deployment of ITS devices, and by agencies that have recently deployed ITS devices. The online testing website allows agencies to quickly answer questions about each candidate deployment location and receive an answer to whether or not the device is determined to be 'Warranted' for the location. The results of each warrant test are tracked for review and analysis. Verbal feedback from the test locations then verified whether the warrants produced results that agree with local opinions.

Testing to Refine and Verify the Draft Warrants

The second intent of testing the warrants is actually a part of the overall warrant development process. The 'qualitative' nature of the device warrants is such that the initial drafting of warrants is a best 'first shot' at defining the parameters, thresholds and decision points to be used to determine if a device is justified. However, real-world practical use of the warrants is needed to either verify these values or refine them. From another perspective, ideally the warrants would be supported by actual mathematical calculations to justify each calculation in the warrants. However, these calculations are simply not known, nor are there any physical supporting evidence of such calculations. Therefore, the warrant development has started with initial draft warrants, and then the transportation industry (and the testing and feedback of over 20 transportation agencies) has helped refine the warrants. The on-line website and ongoing feedback loop will ultimately allow any agency that chooses to contribute to the warrant process.

6.1 Multi-state Warrant Testing Results

The first state agency to formally test the warrants was the Michigan Department of Transportation (MDOT). MDOT had recently completed a strategic plan for ITS deployments throughout the state, including numerous locations where ITS devices are being considered. This provided a challenging test-bed to trial the warrants against actual deployment sites. In total, the warrants were trialed for five devices in five different locations throughout Michigan, resulting in four devices being identified as 'warranted' and one device identified as 'not warranted'. In each case of warrant testing, the tests allowed further development and refinement of the warrants based on actual feedback and comments from traffic engineers familiar with the local situations.

A second set of warrants tests were conducted in Southeastern Minnesota. CCTV cameras are being considered for deployment along I-35 at the interchange of Trunk Highway 19 (near Northfield, Minnesota), and at the interchange with I-90 (near Albert Lea). In addition, the CCTV warrant was tested at a site in the city of Rochester, Minnesota that is prone to a high number of merges and traffic congestion. These tests offered a perspective from rural areas and small urban areas.

The ENTERPRISE Group has involved over 20 transportation agencies to assist in testing the warrants and expects the number of test participating agencies to continue to grow. These include rural areas such as I-35 in southern Minnesota, to small urban areas such as the city of Rochester, to major metropolitan areas such as Minneapolis, Minnesota and Seattle, Washington. Typically, each time a Warrant is tested, the feedback has resulted in slight changes to the warrant (either the context of the Warrant or the text describing the Warrant). As a result, the warrants have improved and now better represent the agencies that have contributed towards them.

Expressions of Support and Concerns

The testing also resulted in considerable positive feedback about the concept of ITS device warrants. The concept has been presented to state traffic engineering, local traffic engineers, planners, and operations and maintenance personnel. There has been overwhelming support for the concept and the benefit it offers to decision makers. The only concerns expressed are best summarized as follows:

- *Concern that the warrants are too restrictive and local experts may understand a need for a device in locations where the warrants do not support it.* This concern is a good example of the need to continue to allow open feedback from the community to adjust warrants when needed. Finally, it is important to consider that there will always be locations where devices are needed due to unique and specific situations. For this reason, the ITS Warrants should be one tool that engineers and planners use.
- *Concern that in locations where development is occurring and devices are being considered based on anticipated travel patterns that will exist when the new development is completed.* The concern is that devices may not meet the warrants, however it would be prudent to install the devices during the construction phase. For this concern, local transportation professional should perform local engineering and analysis to determine if device installations are appropriate.

6.2 Actual Use of the Warrants

The section presents some examples of real-world uses of the ITS warrants.

Virginia Department of Transportation

The Virginia Department of Transportation (VDOT) operates approximately 41 Road Weather Information System (R/WIS) devices throughout the state to monitor weather and road conditions in real-time. Each device communicates data back to VDOT offices and the weather and road condition reports are used to support VDOT maintenance activities and traveler information dissemination systems. VDOT continues to add R/WIS devices as needs are understood and funding allows. Future deployment plans for RWIS are determined through coordination with District Maintenance Offices and Regional Operations Partners.

After preliminary testing of the R/WIS device warrants, VDOT now uses the device warrants as one consideration when developing deployment plans for R/WIS devices. The structure of the warrants has allowed maintenance engineers to answer the warrant questions quickly. When device deployments are proposed or requested, VDOT engineers now sit down and execute the warrants for the locations being considered.

North Dakota Department of Transportation

North Dakota DOT is not a member of the ENTERPRISE Pooled fund. However, North Dakota DOT became aware of the ITS warrants project, and used the ITS warrants website to assist in selecting technology deployments for rural safety initiatives. The ITS warrants were used to examine concepts for deployment, and the result of the warrants use was recommendations of simpler technology deployments. North Dakota DOT contacted the ENTERPRISE Pooled Fund to relay their experience with the ITS warrants and commented that it was beneficial to them in prioritizing their deployment plans.

Kansas Department of Transportation (KDOT)

In preparation for rural safety deployments, KDOT used the ITS warrants to prioritize deployments and included an explanation of the warrants use when submitting their rural safety deployment plan. Like other uses, the ITS warrants was just a tool to assist the decision-making process, however feedback was very positive regarding the value and effectiveness of the warrants.

7. The Future - Ongoing Warrant Development and Use

The warrants developed for the nine devices described in this report represent just a portion of the number of ITS devices in the industry. The concept of this project was to assess the value and potential for ITS warrants. It was always recognized that if the ITS warrants were agreed to be valuable (and if a group adopted the ITS warrants idea) that additional warrants would be developed. Therefore, the nine devices is not meant as an all-inclusive set of devices or warrants, but rather was chosen by the group as a set of devices and related purposes to be used to test the concept of warrants for technology devices.

In addition, the development/testing/refinement process followed during this project has identified a recommended 'iterative' process for continued warrants development. This iterative process is based on the fact that the on-line interactive website allows transportation professionals to test the warrants in real-time. Each time they execute a warrant, the results (as well as any feedback offered) may be viewed instantly by the warrant development team. In order to avoid too many changes to the warrants, and to maintain consistency in the warrants, the project has created a 'Warrant Review Board' to review suggested changes, examine and analyze feedback and testing results, and ultimately determine if warrant changes are needed. Currently, the Warrant Review Board consists of representatives from WSDOT and Mn/DOT, however additional state/provincial, county, and city transportation professionals are welcome to join the review board and may express interest in participation on the project website. Figure 1, below, illustrates the four step iterative process for testing and refining the warrants.

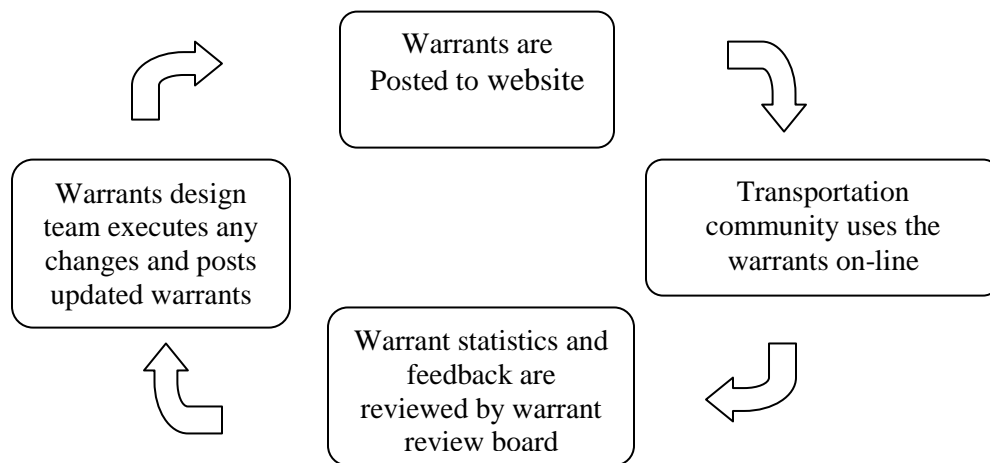


Figure 1 – Warrant Testing and Revision Process

7.1 The Future of the ITS Warrants

Beyond the ENTERPRISE ITS warrants project the future of ITS warrants is likely to involve a combination of three approaches:

1. Continued use of the ITS warrants using ENTERPRISE tools;
2. Continued use of the ITS warrants as they are integrated into existing local decision making processes; and
3. A formal continuation of the warrants development process by a new host agency (*note: the ENTERPRISE group never had intentions of hosting the ITS warrants long term. Rather the intent was to demonstrate the feasibility in hopes that a public agency would adopt the warrants.*)

Each of these options is presented in the following sub-sections.

Continued Use of the ITS Warrants using ENTERPRISE Tools

The ITS warrants are currently being used by a number of transportation agencies to assist their decision making process regarding the deployment of ITS devices. These agencies may access the warrants as follows:

- By accessing the ITS warrants website where all the ITS warrants are posted and available through the on-line tool; or
- By accessing the published Final Report document from the ENTERPRISE website or other distributions.

The continued operation of the ITS warrants website for at least 12 months from the close of the project will allow this ongoing use of the warrants, and the website will track the use of the warrants and any feedback offered. Agencies may also use the published report (which includes all warrant text).

Integration of ITS Warrants into Existing Local Decision Making Processes

The ITS warrants are included in the Mn/DOT ITS Design Manual (currently in the final stages of development), as guidelines for ITS device deployments. This is one example of how the warrants, as developed in this project, can be adopted into local manuals or guidelines.

Another possibility would be for the ITS warrants to be submitted to ITE as best practices.

A Formal Continuation of the Warrants Development Process

The third option for ongoing use of the ITS warrants would be for a public agency to formally adopt the concept of the ITS warrants. This would involve a commitment to developing additional warrants (as needed), and to support the warrants by accepting feedback and input from the entire community.

For any agency considering adopting and supporting the ITS warrants, the key activities expected to be performed would include:

- ***Continued open forum for ITS warrant input and development.*** The current ITS warrants website was the ENTERPRISE Program’s concept for the most efficient way to gather input from the transportation community. In the future, this same website or a modified website could be used to continue to gather input and feedback on the warrants. Similarly, a new host agency could employ a different strategy to gather input and feedback from the community (e.g. committees, meetings, webinars, surveys).
- ***Warrant updates and modifications.*** Over the four year project timeline of the ENTERPRISE project, the initial warrants have gradually become increasingly stable and now require little updates or modifications. However, if a public forum is used to solicit ongoing feedback, there will be times when (either through testing or general consensus) it is agreed that the warrants must be modified. Technically, this is a simple task, however the supporting agency might decide to vet such changes, or conduct public outreach.
- ***Development of additional warrants.*** The development of additional warrants can be as large or as small a task as the host agency wishes it to be. However, there are two critical criteria for the development of ITS warrants:
 - ***#1:*** That the development involve public agencies with sufficient experience in the devices for which warrants are being developed (in order to offer insight and input); and
 - ***#2:*** That the development involve public agencies who have either recently deployed the ITS devices or who have plans to deploy them (to assist in testing).

7.2 Ongoing Development Budget Estimate

The entire four year budget for the ENTERPRISE ITS warrants development, testing, outreach, and support was less than \$100,000. The group has refined a process that uses a combination of the Internet, local presentations at workshops, training seminars, and conferences, as well as email and phone communication to solicit feedback and input to the warrant development process.

Based upon these experiences, ongoing development of additional warrants and maintenance of existing warrants (including continued outreach, updating, and refinement) would not exceed an estimated annual budget of \$50,000 per year.

7.3 Conclusions

The ITS warrants have been well accepted by the transportation community. Several examples of money and time savings from agencies using the ITS warrants have been documented (both ENTERPRISE and Non-ENTERPRISE member agencies). The ITS warrants are an attempt to fill a need in the transportation industry for support in the decision process for deploying ITS devices. Based upon the feedback from those who have been exposed to the warrants, it appears that they help address this need.

The ITS warrants are intended to play a role in the overall ITS deployment decision making process. The ENTERPRISE members believe they have demonstrated not only the potential for ITS warrants, but an effective method of public development, testing, refinement and support of the warrants. Ongoing hosting development and refinement of ITS warrants could be performed by a host agency for approximately \$50,000 per year. It is the recommendation of the group that a public agency perform this role and formally continue the ITS warrant development and operation.

8. ITS Technology Device Warrant Text

The following pages contain the ITS technology device warrant questionnaires for CCTV, DMS, HAR, R/WIS, VSL signs, DSDS, Ramp Meters, Curve Warning Systems, and Intelligent Work Zones at the time this Final Report is being published. As noted earlier, the most up to date warrants will continue to be maintained on the project website. The project website is: <http://enterprise.prog.org/itswarrants/>

ITS Device Warrants offer a tool to support local transportation professionals in selecting locations for ITS device deployments. Local design standards and guidelines should be the ultimate determining factor in final selection of the locations.

8.1 CCTV Warrants

CCTV shall mean 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) warrants have been identified to capture the most common uses of Closed Circuit Television (CCTV). While there are other purposes and uses for CCTV, the warrants developed to date have focused on the following five.

CCTV Warrant - 1: Traffic Observation for Signal Control Changes

Purpose: To visually observe traffic conditions in order to determine if alternate signal timings are appropriate before implementing alternate traffic signal timing plans remotely.

CCTV Warrant - 2: Traffic Incident or Event Verification

Purpose: To allow traffic operations personnel or emergency response teams to visually verify traffic flow and/or incidents (e.g. crashes, debris in roadway) in order to activate or dispatch appropriate response and post message to traveler information systems.

CCTV Warrant - 3: Weather Verification

Purpose: To allow maintenance dispatchers and traffic control personnel to verify weather conditions on the roadway, either to guide traveler information dissemination or to dispatch snow removal and treatment operations.

CCTV Warrant - 4: Traveler Information

Purpose: To allow travelers to understand traffic delay and road weather conditions by viewing images of the roadway from the Internet prior to departing.

CCTV Warrant - 5: Field Device Verification

Purpose: To allow traffic or maintenance operations personnel to verify operational functionality of in-field devices (such as Dynamic Message Signs, road/lane closure gates, and other devices).

CCTV Warrant - 6: Intelligent Work Zone

Purpose: To allow travelers or transportation professionals to understand construction or maintenance traffic delay by viewing images of the roadway remotely.

CCTV Warrant #1: Traffic Observation for Signal Control Changes

Purpose:	To visually observe traffic conditions in order to determine if alternate signal timings are appropriate before implementing alternate traffic signal timing plans remotely.
Device is warranted if:	<ol style="list-style-type: none">1. There are typically periods of time at least twice per week of 'loaded' cycles (i.e. where the vehicles in the queue do not all dissipate in one green cycle) that last 15 minutes or longer. AND2. The signalized intersection has sufficient cross street traffic such that visual observation is needed determining if alternate signal timings are appropriate to benefit the primary direction of flow (i.e. in order to verify that the secondary street is not backing up). AND3. The operations personnel have the ability to activate special event timing plans remotely. <p><i>Partial Warrant Criteria:</i> If either #1 or #3 above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

CCTV Warrant #2: Traffic Incident or Event Verification

Purpose:	To allow traffic operations personnel or emergency response teams to visually verify traffic flow and/or incidents (e.g. crashes, debris in roadway) in order to activate or dispatch appropriate response and post message to traveler information systems.
Device is warranted if:	<ol style="list-style-type: none">1. The candidate location encounters incidents as frequently as twice per month for arterial streets or once per month for freeways. AND2. The incidents and events that occur on freeways typically cause delay to travelers of at least 15 minutes while the incident is active and has not been cleared. OR The incidents and events that occur on arterials typically cause impact travel such that the signal progression is no longer occurring and vehicles are not clearing green cycles. AND3. The location encounters:<ul style="list-style-type: none">• At least 2 hours per day of peak period travel where traffic flow exceeds 1,100 veh/hr/lane; or• Conditions considered Level of Service C; or• Average annual daily traffic (AADT) of 16,800 for a 2 lane road; 33,600 for a 4 lane road; 50,400 for a 6 lane road; 67,200 for an 8 lane road.

CCTV Warrant #3: Weather Verification

Purpose:	To allow maintenance dispatchers and traffic control personnel to verify weather conditions on the roadway, either to guide traveler information dissemination or to dispatch snow removal and treatment operations.
Device is warranted if:	<ol style="list-style-type: none">1. The location typically encounters at least 10 winter weather events each season. <p>AND</p> <ol style="list-style-type: none">2. Winter weather events have a significant impact to travelers at this location (due to such circumstances as either: local terrain, lack of alternate routes, winding or steep routes), and it is a location that travelers are frequently concerned about. <p>AND</p> <ol style="list-style-type: none">3. If there are<ul style="list-style-type: none">• No nearby weather sensors reporting real-time conditions; or• No regular manual observations and reports of visibility, precipitation, or pavement temperatures, or• Nearby weather sensors would be enhanced through the capability of visual observation. <p><i>Partial Warrant Criteria:</i> If #1 And #3 above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

CCTV Warrant #4: Traveler Information

Purpose:	To allow travelers to understand traffic delay and road weather conditions by viewing images of the roadway from the Internet prior to departing.
Device is warranted if:	<p>1a. The location visible by the camera image has a history of congestion on a regular basis (i.e. each commuter day is a candidate for congestion).</p> <p>OR</p> <p>1b. The location is prone to weather situations that travelers would not otherwise be forewarned about (e.g. spots where fog regularly forms, bridges that ice early, mountain passes with weather that differs from approaches).</p> <p>OR</p> <p>1c. The location is in a remote area that receives considerable traffic volume due to commercial vehicle traffic or recreational traffic.</p> <p>AND</p> <p>2. The majority of travelers to the area have Internet access in proximity to the area where camera images are of value to travelers prior to departure.</p> <p><i>Partial Warrant Criteria:</i> If either #1a, #1b, or #1c above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

CCTV Warrant #5: Field Device Verification

Purpose:	To allow traffic or maintenance operations personnel to verify operational functionality of in-field devices (such as Dynamic Message Signs, road/lane closure gates, and other devices).
Device is warranted if:	<ol style="list-style-type: none">1. The proper operations of the device can be remotely monitored by a camera. <p>AND</p> <ol style="list-style-type: none">2. The failure of the device presents a safety hazard. <p>OR</p> <ol style="list-style-type: none">3. The camera operation would avoid unnecessary trips to verify functionality of the field device. <p><i>Warrant Criteria:</i> If #1 And #2 above are met, Or if #3 above is met, the warrant is considered 'Warranted'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'</p>

CCTV Warrant #6: Intelligent Work Zone

Purpose:	To allow travelers or transportation professionals to understand construction or maintenance traffic delay by viewing images of the roadway remotely.
Device is warranted if:	<ol style="list-style-type: none">1. The alignment or traffic control that is visible by a camera image is expected to change periodically during the construction period. OR The construction zone encounters periods of queues or delays for at least 30 minutes each day. AND2. The construction zone is in a location where there is not a convenient alternate route for the majority of traffic to deviate from the typical route.

8.2 DMS Warrants

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) warrants have been identified to capture the most common uses of Dynamic Message Signs (DMS). While there are other purposes and uses for DMS, the warrants developed to date have focused on the following eight purposes.

The warrants do not distinguish between types of DMS (portable, overhead, roadside). Rather the intent of the warrants is to contribute to the understanding of the need for some type of DMS. Detailed design would contribute to the selection of the specific DMS type.

- | | |
|-------------------------|---|
| DMS Warrant - 1: | To Inform Travelers of Weather Conditions
Purpose: To provide road weather information to drivers so that the drivers can choose whether to continue travel on the route or whether to adjust their speed, route of travel, or divert from the trip in anticipation of an upcoming weather hazard. |
| DMS Warrant - 2: | To Inform Travelers of Traffic Conditions
Purpose: To provide current traffic status information (incidents, congestion, travel time, road work) to drivers so that drivers can choose to divert to avoid the situation, to reduce driver anxiety, and to reduce crashes involving drivers encountering unexpected stopped traffic. |
| DMS Warrant - 3: | Changing Traffic Control or Conditions
Purpose: To notify drivers in advance of special changing traffic conditions and roadway configuration changes associated with road construction or maintenance in order to reduce driver confusion that could result in a crash. |
| DMS Warrant - 4: | Special Events
Purpose: To provide parking or alternate route information about special events or major venues to drivers in order to reduce congestion and delays due to unnecessary "circling the block" or non-participating drivers being caught in traffic. |
| DMS Warrant - 5: | Parking Availability
Purpose: To provide real time parking availability information to drivers to avoid unnecessary "circling the block" looking for parking spots. |
| DMS Warrant - 6: | Transit Park and Ride Lot Availability
Purpose: To provide real time parking availability information to drivers regarding transit park and ride lots. |
| DMS Warrant - 7: | Evacuation Routes
Purpose: To provide evacuation route information to drivers during disaster or homeland security events. |

DMS Warrant - 8:

Jurisdictional Information

Purpose: To provide jurisdictional specific information to drivers at or near borders between two jurisdictions.

DMS Warrant #1: To Inform Travelers of Weather Conditions

Purpose:	To provide road weather information to drivers so that the drivers can choose whether to continue travel on the route or whether to adjust their speed, route of travel, or divert from the trip in anticipation of an upcoming weather hazard.
Device is warranted if:	<ol style="list-style-type: none">1. If the location is prone to weather situations that travelers would not otherwise be forewarned about (e.g. spots where fog regularly forms, bridges that ice early, mountain passes with weather that differs from approaches).AND2. If there is available road weather information for the area downstream of the candidate DMS location.AND3. If there is the capability (either manually by staff members or automated through a condition reporting system) to create event specific descriptions of weather conditions to be displayed on the DMS.AND(either 4-A, 4-B, 4-C)4A. If there is a need to disseminate event specific descriptions (rather than a lower technology approach such as activating a flashing warning sign that says "Weather Alert When Flashing").OR4B. If there are options for either alternate routes or services, that might be described on the DMS, where travelers may wait out conditions.OR4C. If flashing beacon signs have been tried and not proven to generate responses from travelers.AND

	<p>5. If weather events contribute to a significant number of crashes or road closures such that there are major impacts to travelers (this may include 1 or more annual closures or crashes on a freeway or 10 or more crashes or closures on arterials).</p> <p><i>Warrant Advice:</i> If the only warrant being met for a DMS is the weather information warrant, then it is recommended that the lesser technologies are considered before deploying full DMS capabilities.</p> <p><i>Partial Warrant Criteria:</i> If either #1 or #5 above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>
--	---

DMS Warrant #2: To Inform Travelers of Traffic Conditions

Purpose:	To provide current traffic status information (incidents, congestion, travel time, road work) to drivers so that drivers can choose to divert to avoid the situation, to reduce driver anxiety, and to reduce crashes involving drivers encountering unexpected stopped traffic.
Device is warranted if:	<ol style="list-style-type: none"> 1. If the target area is monitored by CCTV cameras, traffic detectors, or another method of monitoring the conditions, or are travel times for the downstream stretch of road AND 2. Events occurring in the area unexpectedly impact or impede traffic (e.g. close a lane, encounter slow traffic in one or more lanes, or events on the shoulder) an average of at least two times per month AND 3a. If there are acceptable alternate routes with adequate capacity to accept vehicles that may deviate based upon the information OR 3b. If the location is a stretch of road where no alternate route are possible and travelers would benefit from information describing the cause and/or extent of delays in order to relieve driver anxiety or confusion OR 3c. If there are horizontal or vertical curves that create safety issues when traffic is stopped unexpectedly AND 4. The route being considered for the DMS has on average <ul style="list-style-type: none"> At least 2 hours of peak period travel where traffic flow exceeds 1,100 veh/hour/lane; or Experiences conditions considered Level of Service C; or Experiences average annual daily traffic (AADT) of 16,800 for a 2 lane road; 33,600 for a 4 lane road; 50,400 for a 6 lane road; 67,200 for an 8 lane road.

	<p><i>Partial Warrant Criteria:</i></p> <p>If #2 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>
--	--

DMS Warrant #3: Changing Traffic Control or Conditions

Purpose:	To notify drivers in advance of special changing traffic conditions and roadway configuration changes associated with road construction or maintenance in order to reduce driver confusion that could result in a crash.
Device is warranted if:	<ol style="list-style-type: none"> 1. The candidate location is upstream of an area with construction or maintenance activities that are expected to cause at least 15 minutes of delay to the mainline traffic AND 2. If the candidate location is upstream of traffic control or construction/maintenance activities that are expected to change more frequently than once every 60 days AND 3. If the speed limit is greater than 45 MPH <p><i>Notes:</i></p> <p><i>A. If question #2 is not met (activities do not change frequently), lower cost static signage is recommended.</i></p> <p><i>B. Portable DMS vs. permanent DMS should be considered based on the expected duration of events impacting the area.</i></p> <p><i>Partial Warrant Criteria:</i></p> <p>If #2 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

DMS Warrant #4: Special Events

Purpose:	To provide parking or alternate route information about special events or major venues to drivers in order to reduce congestion and delays due to unnecessary "circling the block" or non-participating drivers being caught in traffic.
Device is warranted if:	<p>1. If the location contains a venue that houses ticketed events (typically with rapid and tight arrival patterns for a specified start time)</p> <p>AND</p> <p>2a. If the event venue typically houses at least two weekday (M-F) ticketed event per week (including seasonal sporting events that only occur during the season)</p> <p>OR</p> <p>2b. If the event venue typically houses at least 10 events per year attracting 30,000 visitors or more.</p> <p>AND</p> <p>3. If the setting of the venue is such that mainline traffic (not attending the event) is impacted by the conditions at least once per week.</p> <p>AND</p> <p>4. If there are alternate parking or traffic options that could be displayed on signs to direct visitors to more preferred options.</p> <p><i>Warrant Advice:</i> Placement of DMS signs should consider the intent of each sign. For example, further upstream signs are more effective at helping non-visitors to the venue avoid traffic congestion while signs closer to the venue are effective for directing drivers to open capacity.</p> <p><i>Partial Warrant Criteria:</i> If either #1, and either #2a or #2b above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

DMS Warrant #5: Parking Availability

Purpose:	To provide real time parking availability information to drivers to avoid unnecessary "circling the block" looking for parking spots.
Device is warranted if:	<ol style="list-style-type: none">1. If the area contains ample parking to handle the regular visitors, either during commuter periods or special events <p>AND</p> <ol style="list-style-type: none">2. If the area contains a set of similar parking garages (similar parking costs) each with generally comparable ingress and egress and access to events (i.e. parking facilities are all generally equal options to select from). <p>AND</p> <ol style="list-style-type: none">3. If visitors regularly are unable to find parking, and 'circling the block' occurs for more than 15 minutes during the AM commuter period or prior to special events, as visitors seek out parking spaces.

DMS Warrant #6: Transit Park and Ride Lot Availability

Purpose:	To provide real time parking availability information to drivers regarding transit park and ride lots.
Device is warranted if:	<ol style="list-style-type: none">1. If the area contains park-and-ride lots that fill to capacity on either a regular basis or during regularly occurring events (e.g. inclement weather, sporting events). <p>AND</p> <ol style="list-style-type: none">2. If alternate park-and-ride lots are available (either upstream or downstream) that do not typically fill to capacity. <p>AND</p> <ol style="list-style-type: none">3. If there is the capability (or willingness) to monitor park-and-ride facilities for available spaces.

DMS Warrant #7: Evacuation Routes

Purpose:	To provide evacuation route information to drivers during disaster or homeland security events.
Device is warranted if:	<ol style="list-style-type: none">1. If the area is a major metropolitan area or has nearby icons that increase the likelihood of requiring an evacuation (e.g. nuclear reactor, major attraction). <p>AND</p> <ol style="list-style-type: none">2. If the area evacuation procedures allow for traffic movements and/or the use of roads that otherwise are not available to the public (e.g. contra-flow lanes). <p><i>Partial Warrant Criteria:</i> If #2 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

DMS Warrant #8: Jurisdictional Information

Purpose:	To provide jurisdictional specific information to drivers at or near borders between two jurisdictions.
Device is warranted if:	<p>1. If there are differing rules or regulations between adjacent jurisdictions</p> <p>AND</p> <p>2a. If display of differing rules or regulations on static signs would either not attract enough attention</p> <p>OR</p> <p>2b. If the rules or regulations change frequently (e.g. load restrictions)</p> <p><i>Partial Warrant Criteria:</i> If #1 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

8.3 HAR Warrants

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) warrants have been identified to capture the most common uses of Highway Advisory Radios (HAR). While there are other purposes and uses for HAR, the warrants developed to date have focused on the following four.

HAR Warrant - 1: Weather and Driving Conditions

Purpose: To provide road weather information and/or regulatory restriction information (e.g. chain requirements) to drivers in rural areas to alert them to impending conditions.

HAR Warrant - 2: Venue Parking

Purpose: To provide parking or route guidance information around major venues where unfamiliar travelers can benefit from verbal explanations (e.g. airports, National Parks, tourist attractions)

HAR Warrant - 3: Changing Traffic Conditions

Purpose: To notify drivers in advance of special changing traffic conditions and roadway configurations associated with road construction or maintenance.

HAR Warrant - 4: Special Events

Purpose: To notify travelers about special events (either prior to the event start date or during the event), alerting travelers to the impacts of these events on traffic, and to guide event attendees to the event.

HAR Warrant #1: Weather and Driving Conditions

Purpose:	To provide road weather information and/or regulatory restriction information (e.g. chain requirements) to drivers in rural areas to alert them to impending conditions.
Device is warranted if:	<ol style="list-style-type: none"> 1. If the location is upstream and within 4 hours driving proximity to locations that are prone to weather situations that travelers would not otherwise be forewarned about (e.g. spots where fog regularly forms, bridges that ice early, mountain passes with weather that differs from approaches). <p>AND</p> <ol style="list-style-type: none"> 2. If there is available road weather monitoring devices or manual observations for the area downstream of the candidate HAR location. <p>AND</p> <ol style="list-style-type: none"> 3. If there is a need to disseminate a detailed report (such as those possible using HAR recordings) as opposed to flashing beacons or DMS. <p>OR</p> <ol style="list-style-type: none"> 4. If weather events contribute to a significant number of crashes or road closures such that there are major impacts to travelers (this may include 1 or more annual closures or crashes on an Interstate highway or 10 or more crashes or closures annually on arterials). <p><i>Partial Warrant Criteria:</i> If #1 And #3 above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

HAR Warrant #2: Venue Parking

Purpose:	To provide parking or route guidance information around major venues where unfamiliar travelers can benefit from verbal explanations (e.g. airports, National Parks, tourist attractions).
Device is warranted if:	<p>1. The venue is visited by at least 10,000 visitors per day (either year-round or seasonally)</p> <p>AND</p> <p>Either 2a, 2b, or 2c</p> <p>2a. If there are parking and drop-off/pick-up options that are not inherently simple enough to disseminate using static or DMS sign displays</p> <p>OR</p> <p>2b. If there are parking options and real-time parking availability information available for dissemination</p> <p>OR</p> <p>2c. If there are more than one primary access routes to the venue covered by the range of the HAR device (i.e. one HAR device would support all approaches vs. multiple signs being needed)</p> <p><i>Partial Warrant Criteria:</i></p> <p>If #2a, #2b, or #2c above are met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

HAR Warrant #3: Changing Traffic Conditions

Purpose:	To notify drivers in advance of special changing traffic conditions and roadway configurations associated with road construction or maintenance.
Device is warranted if:	<ol style="list-style-type: none">1. The candidate location is upstream of an area with traffic control changes (e.g. lane closure, crossover, contra flow) where travelers would benefit from a verbal explanation <p>AND</p> <ol style="list-style-type: none">2. If the candidate location is expected to encounter either long term construction or maintenance activities or changing traffic control situations for longer than 2 months <p><i>Partial Warrant Criteria:</i> If #1 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

HAR Warrant #4: Special Events

Purpose:	To notify travelers about special events (either prior to the event start date or during the event), alerting travelers to the impacts of these events on traffic, and to guide event attendees to the event.
Device is warranted if:	<ol style="list-style-type: none">1. The temporary event is expected to attract more than 600 vehicles in any one hour period.ANDEither 2a. or 2b.2a. There is a route of travel for event attendees that creates considerably less impact on traffic than other approaches (i.e. if event attendees can be directed to this route it will minimize impacts).OR2b. There is an optional route for non-event traffic to avoid the impacts of this event.AND3. The message(s) that need to be relayed to the travelers are too complex to convey in a portable sign (better relayed through spoken reports).

8.4 RWIS Warrants

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) warrants have been identified to capture the most common uses of Road Weather Information Systems (RWIS). While there are other purposes and uses for RWIS, the warrants developed to date have focused on the following three.

R/WIS Warrant #1: Support Maintenance Activities at Key Locations

Purpose: To provide site specific atmospheric and road surface condition reports to the agencies responsible for responding to weather events in order to promote safe travel and maintain travelers' mobility.

R/WIS Warrant #2: Support Regional ,Statewide, or Provincial Weather Monitoring

Purpose: To monitor weather and road surface conditions on a regional, statewide, or provincial grid in order to support wide area weather monitoring and/or modeling and weather prediction.

R/WIS Warrant #3: Support Traveler Information Systems Through R/WIS at Key Locations

Purpose: To gather real-time data describing atmospheric weather and road surface conditions in order inform travelers of the conditions, either through pre-trip traveler information systems or through en-route information dissemination systems.

RWIS Warrant #1: Support Maintenance Activities at Key Locations

Purpose:	To provide site specific atmospheric and road surface condition reports to the agencies responsible for responding to weather events in order to promote safe travel and maintain travelers' mobility.
Device is warranted if:	<p>Either 1a, 1b, or 1c</p> <p>1a. The location surrounding the candidate site typically experiences 3 or more crashes related to weather events each year</p> <p>OR</p> <p>1b. The location surrounding the candidate site has experienced 1 or more fatalities per year in crashes related to weather events</p> <p>OR</p> <p>1c. The location surrounding the candidate site is prone to weather events frequently causing difficult driving conditions (e.g. treacherous roads in winter storms, seasonal or storm related flooding, pockets of fog)</p> <p>AND</p> <p>Either 2a or 2b</p> <p>2a. The number of weather events that would be measured and reported at the location is typically more than 10 per year</p> <p>OR</p> <p>2b. The area surrounding the site experiences rare weather events that cause serious operational problems that often last multiple days (e.g. one major ice storm)</p> <p>AND</p> <p>3. There is not another weather and road surface monitoring station that provides access to the data within 10 miles of the candidate site</p>

	<p><i>Note:</i></p> <p>In using the warrants, it is recommended that the agency research whether any other agencies (National Park System, Department of Natural Resources, Department of Aviation) has weather and/or road condition monitoring stations and make the data publicly available.</p>
--	---

RWIS Warrant #2: Support Regional ,Statewide, or Provincial Weather Monitoring

Purpose:	To monitor weather and road surface conditions on a regional, statewide, or provincial grid in order to support wide area weather monitoring and/or modeling and weather prediction.
Device is warranted if:	<p>1. The candidate region, state, or province typically encounters 10 or more inclement weather events each year</p> <p>AND</p> <p>2a. The transportation agency responsible for maintenance in the region, state, or province has (or is planning) the ability to utilize grid weather reports (either manually or with the help of a decision support system) to influence their treatment of conditions</p> <p>OR</p> <p>2b. The transportation agency responsible for traveler information in the region, state, or province operates (or is planning to operate) a region-wide traveler information system including weather reports throughout the area</p> <p>AND</p> <p>3. The transportation agency responsible for maintenance and the agency responsible for traveler information in the region has examined and/or tested current perpetual data sources (e.g. NWS) and determined that these sources do not fully meet the needs for the region.</p>

RWIS Warrant #3: Support Traveler Information Systems Through R/WIS at Key Locations

Purpose:	To gather real-time data describing atmospheric weather and road surface conditions in order inform travelers of the conditions, either through pre-trip traveler information systems or through en-route information dissemination systems.
Device is warranted if:	<p>1. The number of crashes related to weather events in the area surrounding the RWIS site (roughly 20 mile radius) is more than 5 per year</p> <p>AND</p> <p>2. If there are unique geography conditions at the site that prohibit the prediction of accurate weather from such systems as NWS forecasts</p> <p>AND</p> <p>Either 3a, 3b, or 3c</p> <p>3a. The area in consideration is prone to fog or other local (non regional) visibility restrictions (defined as 10 or more events per year where fog presents dangerous driving conditions)</p> <p>OR</p> <p>3b. The area in consideration is near an attraction or other draw (winter recreation area, college, resort area) that attracts visitors traveling at least 1 hour to reach the destination</p> <p>OR</p> <p>3c. The area is along a regular commuter path.</p>

8.5 Variable Speed Limit Warrants

For purposes of the warranting ITS process, Variable Speed Limit (VSL) devices are defined as a signs capable of displaying different speed limits to travelers (in which the speed limit is either a recommended or mandatory limit) that are either manually activated or controlled by a combination of detectors and algorithms to select appropriate speeds.

Four (4) warrants have been identified to capture the most common uses of Variable Speed Limit devices. While there are other purposes and uses for VSL, the warrants developed to date have focused on the following four.

VSL Warrant #1: Maximize Capacity

Purpose: To maximize capacity by maintaining uniform travel speeds that are optimal for the current volume of traffic, and prevent the system from becoming 'unstable' and reaching congested conditions.

VSL Warrant #2: Safe Stopping Distances

Purpose: To encourage travel at speeds that are conducive to stopping safely for stopped vehicles (e.g. crashes, stalls, other incidents).

VSL Warrant #3: Safe Travel Speeds for Conditions

Purpose: To maintain safe travel speeds during periods when road and/or driving conditions may be impacted.

VSL Warrant #4: Work Zones

Purpose: To post varying speed limits for construction zones in order to only slow traffic when necessary, or to maintain consistent speeds to promote safety.

VSL Warrant #1: Maximize Capacity

Purpose:	To maximize capacity by maintaining uniform travel speeds that are optimal for the current volume of traffic, and prevent the system from becoming 'unstable' and reaching congested conditions.
Device is warranted if:	<ol style="list-style-type: none">1. The typical peak hour volume of the corridor exceeds 1,100 vphpl. AND2. The route segment has a history of reduced speeds of 40 mph or less for a least one hour on typical days (55 mph posted speed). AND3. There is a regularly occurring speed differential of at least 10 mph (<i>The 2009 MUTCD identifies roadway signs for all speed differentials in which the speed limit is reduced by 10 mph or more, therefore this value is used for the Warrants threshold</i>) between the upstream and downstream locations of the segment (e.g. a downstream bottleneck location has typical speeds that are slower than an upstream location). (1)

VSL Warrant #2: Safe Stopping Distances

Purpose:	To encourage travel at speeds that are conducive to stopping safely for stopped vehicles (e.g. crashes, stalls, other incidents).
Device is warranted if:	<ol style="list-style-type: none">1. The peak hour volume exceeds 1100 vphpl. AND2. The rear-end crash rate for the segment is higher than expected for the local area, based upon the judgment of local engineers. AND3. It has been observed that there is a significantly higher rate of secondary crashes on the candidate segment than other segments in the metropolitan area. AND4. There is a regularly occurring significant speed differential of at least 10 mph (<i>The 2009 MUTCD identifies roadway signs for all speed differentials in which the speed limit is reduced by 10 mph or more, therefore this value is used for the Warrants threshold</i>) between the upstream and downstream locations of the segment (e.g. a downstream bottleneck location has typical speeds that are slower than an upstream location). (1)

VSL Warrant #3: Safe Travel Speeds for Conditions

Purpose:	To maintain safe travel speeds during periods when road and/or driving conditions may be impacted.
Device is warranted if:	<ol style="list-style-type: none"> 1. The area in consideration is a stretch of road (typically a minimum of 2 miles or longer) and not an isolated spot location (such as a bridge or a vertical curve) where other technologies may be more appropriate. <p>AND</p> <ol style="list-style-type: none"> 2. The area regularly experiences adverse conditions (e.g. snow, water on the road, fog, wind, blowing snow, animal migrations) that result in traffic problems, slow downs, low visibility or safety hazards for travelers. <p>OR</p> <p>The area experiences rare conditions that result in traffic problems, but the resulting traffic problems are known to impact large numbers of vehicles (e.g. locations with crashes that occur every 1-2 years but cause very large traffic pileups, impacting numerous vehicles).</p> <p>OR</p> <p>The geography or geometry of the area pose a known risk for traffic problems when traveled by vehicles at varying speeds.</p> <p>AND</p> <ol style="list-style-type: none"> 3. The crash rate for the segment or corridor is higher than expected for similar segments within the state, based upon the judgment of local engineers. For example: is the stretch of road a known location for high crash rates. <p>AND</p> <ol style="list-style-type: none"> 4. The area experiences regular speed differentials of at least 10 mph (<i>The 2009 MUTCD identifies roadway signs for all speed differentials in which the speed limit is reduced by 10 mph or more, therefore this value is used for the Warrants threshold</i>) between drivers that are believed to contribute to crashes. (Speed differentials may be due to vehicles traveling slow for various reasons (e.g. commercial vehicles with chains limiting speed, cautious or unfamiliar drivers traveling considerably slower than other drivers), weather conditions that may not be obvious to all travelers (black ice, freezing conditions, water on the roadway, fog, heavy winds, blowing dust), or other factors). (1)

VSL Warrant #4: Work Zones

Purpose:	To post varying speed limits for construction zones in order to only slow traffic when necessary, or to maintain consistent speeds to promote safety.
Device is warranted if:	<p>1. The schedule of the construction activities being performed AND the design of the work zone are such that the vehicles are not required to be slowed to the same speed 24 hours per day. For example, if vehicles are slowed to a speed during the day when workers are present, but when work is not occurring the absence of workers and layout of the construction zone (lane width, geometries, structure) would allow higher speeds.</p> <p>OR</p> <p>The planned construction activities and design of the work zone will create varying conditions for travelers during the period of construction (e.g. periods when the safe speed will change, periods when travel lanes will change, anticipated geometry changes).</p> <p>OR</p> <p>The construction zone already exists and there is a noticeable differential in the speed of vehicles as they progress through the work zone (where travelers would benefit from slowing earlier).</p> <p><i>Note: Many locations include additional fines for speeding in work zones, and the design of any variable speed limit system must consider this aspect before determining if variable speed systems are appropriate for work zones.</i></p>

8.6 Dynamic Speed Display Signs Warrants

For the purposes of the warranting process, Dynamic Speed Display Signs (DSDS) are defined as 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) warrants have been identified to capture the most common uses of Dynamic Speed Display Signs (DSDS) devices. While there are other purposes and uses for DSDS, the warrants developed to date have focused on the following three.

- | | |
|-------------------------|---|
| DSDS Warrant #1: | Transition Zones
Purpose: To promote speed limit adherence in locations of speed limit reduction zones. |
| DSDS Warrant #2: | Posted Speed Adherence
Purpose: To promote speed limit adherence in locations prone to vehicles exceeding the speed limit. |
| DSDS Warrant #3: | Intelligent Work Zones
Purpose: To promote speed adherence in locations where posted speeds have temporarily been reduced for construction, maintenance or other traffic control. |

DSDS Warrant #1: Transition Zones

Purpose:	To promote speed limit adherence in locations of speed limit reduction zones.
Device is warranted if:	<ol style="list-style-type: none">1. The 85th percentile speed (as determined by a speed study) at a location within the lower speed limit area exceeds the posted speed limit by at least 5 mph. (2) AND2. The zone experiences a posted speed limit reduction of at least 10 mph. AND3. There are no other Dynamic Speed Display Signs along the route encountering the speed transition, within 5 miles in either direction (excluding DSDS within school zones). (3) <p><i>Note: Signs tend to be most effective where there are two lanes or less in one direction of travel.</i></p>

DSDS Warrant #2: Posted Speed Adherence

Purpose:	To promote speed limit adherence in locations prone to vehicles exceeding the speed limit.
Device is warranted if:	<ol style="list-style-type: none">1. The 85% speed (as determined by a speed study) exceeds the posted speed limit by at least 5 mph, or by at least 3 mph in a school zone. (4) (2) AND2. The area is within 500 yards of a major pedestrian generator (e.g. school, park, library, senior center, office building). (5) OR The area is primarily a residential area or a heavily traveled pedestrian area. (5) AND3. The posted speed limit is 35 mph or less. (4) AND4. There are no other Dynamic Speed Display Signs along the route within a 5 mile in either direction of the proposed sign (excluding DSDS within school zones). (3) <p><i>Note: Signs tend to be most effective where there are two lanes or less in one direction of travel.</i></p>

DSDS Warrant #3: Intelligent Work Zones

Purpose:	To promote speed adherence in locations where posted speeds have temporarily been reduced for construction, maintenance or other traffic control.
Device is warranted if:	<p>1. The work zone is currently in operation and observations suggest that the 85th percentile speed at a location within the work zone exceeds the posted speed limit by at least 5 mph.</p> <p>OR</p> <p>Workers will be located adjacent to the open traffic lane.</p> <p>OR</p> <p>Hazardous roadway conditions, such as a temporary unusually tight curve, or a rough road surface, requiring extra driving precaution.</p> <p><i>Note: Signs tend to be most effective where there are two lanes or less in one direction of travel.</i></p>

8.7 Ramp Meter Warrants

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) warrants have been identified to capture the most common uses of Ramp Meters. While there are other purposes and uses for Ramp Meters, the warrants developed to date have focused on the following three.

- | | |
|-------------------------------|--|
| Ramp Meter Warrant #1: | Corridor-wide Ramp Meter Deployment
Purpose: This Warrant addresses the need for a 'zone' of Ramp Meters along a stretch of freeway (typically considered in 3-6 mile segments). |
| Ramp Meter Warrant #2: | Isolated Ramp Meter Deployment
Purpose: This Warrant addresses the need for an isolated Ramp Meter deployment, that is not part of an overall corridor ramp metering approach. |
| Ramp Meter Warrant #3: | Ramp Metering During Work Zone Activity
Purpose: To meter on-ramp traffic during road work activities to improve safety and/or consistent traffic flow. |

Ramp Meter Warrant #1: Corridor-wide Ramp Meter Deployment

Purpose:	This Warrant addresses the need for a 'zone' of Ramp Meters along a stretch of freeway (typically considered in 3-6 mile segments).
Device is warranted if:	<p>1. <i>Control Factors.</i> During the AM or PM Peak Period, the Zone in consideration has at least 30 minutes per commute day (measured in 5 minute increments) where the demand is equal to or exceeds 95% of the downstream capacity, according to the following equation?</p> $MV + OR > (ER + MC) * .95$ <p>Where:</p> <p>MV = Upstream Mainline Volume (in veh/5 min.)</p> <p>OR = The sum of On-Ramp volumes of ramps within the zone (in veh/5 min.)</p> <p>ER = The sum of Exit Ramp Volumes within the zone (in veh/5 min.)</p> <p>MC = Downstream Mainline Capacity (in veh/5 min.)</p> <p>OR</p> <p>Platoons from signalized intersections are recognized to adversely impact <i>ALL</i> on-ramps feeding the freeway segment under consideration. For example if hourly volume, based on maximum 30 second volume readings projected to hourly volumes, exceed 1100 vph. (regardless of overall hourly volume).</p> <p><i>Note: Overall hourly volume entering from arterials may be relatively low (e.g. 700 vph. However, during periods when platoons arrive, if 30 second readings of volumes represent 1100 vph or greater, this factor is considered met.</i></p> <p>AND</p> <p>2. <i>Safety Factors.</i> There is one or multiple area(s) within the zone where crashes are understood to exceed the typical crash rate (at the ramp gore point or within 500 feet in either direction of the gore point) for the metropolitan area. (6)</p> <p>AND</p> <p>3. <i>Functionality Factors.</i> Volumes at ramps being considered for meters, within the zone, fall within the range of 240 – 900 vphpl during peak periods. (7)</p>

Ramp Meter Warrant #2: Isolated Ramp Meter Deployment¹

Purpose:	This Warrant addresses the need for an isolated Ramp Meter deployment, that is not part of an overall corridor ramp metering approach.
Device is warranted if:	<p>1. The freeway operates at speeds less than 50 mph for a duration of at least 30 minutes for 200 or more calendar days per year. (6)</p> <p>OR</p> <p>There is a high frequency of crashes (collision rate along the freeway exceeds mean collision rate in the subject metropolitan area) near the freeway entrances because of inadequate merge area or congestion? (6)</p> <p>OR</p> <p>The ramp meter will contribute to maintaining a specific level of service (LOS) identified in local transportation plans and policies. (6)</p> <p>OR</p> <p>The ramp meter will contribute to maintaining a higher level vehicle occupancy through the use of HOV preferential treatments as identified in the region's transportation system management (TSM) plan. (6)</p> <p>OR</p> <p>The ramp meter will contribute to balancing demand and capacity at a system of adjacent ramps entering the same freeway facility. (6)</p> <p>OR</p> <p>The ramp meter will mitigate predictable sporadic congestion on isolated sections of freeway because of short peak period loads from special events or from severe peak loads of recreational traffic. (6)</p> <p>AND</p> <p>2. The Total Mainline-Ramp Design Hour Volume (mainline volume plus ramp volume) exceeds the following: (8)</p> <ul style="list-style-type: none"> • Two mainline lanes in one direction – 2,650 (vph); • Three mainline lanes in one direction – 4,250 vph;

¹ The majority of the isolated intersection ramp meter warrant was originally developed by ITS Engineering and Constructors, Inc. on behalf of Arizona Department of Transportation, published as 'Ramp Meter Design, Operations, and Maintenance Guidelines'.

	<ul style="list-style-type: none"> • Four mainline lanes in one direction – 5,850 vph; • Five mainline lanes in one direction – 7,450 vph; • Six mainline lanes in one direction – 9,050 vph. <p>OR</p> <p>The total volume of the sum of traffic in the right most lane and the ramp exceed 2100 vph during the design hour. (8)</p> <p>OR</p> <p>Platoons from signalized intersections are recognized to adversely impact the ramp in consideration. If hourly volume, based on maximum 30 second volume readings projected to hourly values, exceed 1100 vph. (regardless of overall hourly volume). (9)</p> <p><i>Note: Overall hourly volume entering from arterials may be relatively low (e.g. 700 vph). However, during periods when platoons arrive, if 30 second readings of volumes represent 1100 vph or greater, this factor is considered met.</i></p> <p>AND</p> <p>3. <i>Functionality Factors.</i> Volumes at ramps being considered for meters, within the zone, fall within the range of 240 – 900 vphpl during peak periods. (7)</p> <p><i>Note: The length and geometry of the ramp is a factor in the final decision of whether to deploy a ramp meter. The current warrant for ramp meters does not address this factor, as it is believed the analysis of the ramp will be a part of the preliminary and final design. The focus of the warrant is on whether or not a ramp meter is needed (warranted), not on whether a ramp meter can be designed at the location, as that would be determined during the design process.</i></p>
--	--

Ramp Meter Warrant #3: Ramp Metering During Work Zone Activity

Purpose:	To meter on-ramp traffic during road work activities to improve safety and/or consistent traffic flow.
Device is warranted if:	<p>1. <i>Capacity Factors.</i> There is a temporary reduction in capacity of through lanes due to either a reduction in the number of lanes, or a reduction in the width of lanes of traffic, causing a backup of traffic during peak periods.</p> <p>OR</p> <p><i>Geometric Factors.</i> There is a temporary change in the geometry or length of the acceleration lane that will potentially have a negative impact on ramp traffic merging with the mainline traffic.</p> <p>OR</p> <p><i>Behavior Factors.</i> There is a desire to discourage the use of the ramp during the period of road work.</p>

8.8 Curve Warning System Warrants

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, weather) and/or roadway conditions (snow, ice, and rain) at approaches to sharp curves.

Three (3) warrants have been identified to capture the most common uses of Curve Warning System Devices. While there are other purposes and uses for Curve Warning Systems, the warrants developed to date have focused on the following three.

- | | |
|---|---|
| Curve Warning System Warrant #1: | Rural Two-Lane Highway Curves
Purpose: To provide additional warnings beyond static advisory curve warning signs to warn drivers of actions required to reduce risks associated with rural two lane curves. |
| Curve Warning System Warrant #2: | High Risk Locations
Purpose: To influence driver behavior in horizontal curves where an excessive level of crashes are occurring. |
| Curve Warning System Warrant #3: | Truck Rollovers on Ramps
Purpose: To influence the behavior of commercial vehicle operators driving on ramps. |

Curve Warning System Warrant #1: Rural Two-Lane Highway Curves

Purpose:	To provide additional warnings beyond static advisory curve warning signs to warn drivers of actions required to reduce risks associated with rural two lane curves.
Device is warranted if:	<p>1. The Radius of Curvature is less than 1,000 ft. <i>Research conducted by Texas Transportation Institute found the risk of crashes on curves increases significantly when the radius of curvature is less than 1,000ft.</i> (10)</p> <p>AND</p> <p>2. The horizontal curve is considered part of a visual trap (i.e. the beginning of the horizontal curve immediately follows a vertical curve and is hidden from the line of sight, or where the main road curves but a minor road (and sometimes utility lines) continue on the tangent). (11)</p> <p>OR</p> <p>There is an observed pattern of vehicles entering the curve at speeds that are faster than safe speeds. For example, the 85th percentile speed exceeds the recommended or posted speed limit.</p> <p>OR</p> <p>There are typically 2 or crashes on the curve each year. (12)</p> <p><i>Note: if there has been at least one crash in the last year on the horizontal curve, a lower technology solution may be appropriate. Freeborn County (Minnesota) Safety Study identified high risk curves to have a combination of a visual trap, a low radius of curvature and at least one previous crash. (11)</i></p> <p>AND</p> <p>3. The highway is a 2-lane highway (1 lane each direction). (11)</p> <p>AND</p> <p>4. The Speed Limit on the Highway is 55 MPH or greater. (11)</p> <p>OR</p> <p>The Speed Differential (difference between the regulatory speed limit and the advisory speed limit) is 25 MPH or greater. (10)</p>

Curve Warning System Warrant #2: High Risk Locations

Purpose:	To influence driver behavior in horizontal curves where an excessive level of crashes are occurring.
Device is warranted if:	<p>1. <i>Crash Rate Factor.</i> The Crash Rate (crashes per million vehicle miles traveled) within the vicinity of the curve exceeds 1 crash per million vehicle miles traveled, when computed over a 3 year period.</p> <p>Calculation: $CR = (\# \text{ of crashes} * 10^6) / (\text{Length} * \text{ADT} * 365 \text{ Days} * 3 \text{ years})$. (13)</p> <p>OR</p> <p>The Curve has been identified as a location with a high probability for crashes, using the locally accepted crash analysis (e.g. one of the top 10 locations in the state most prone to curve related accidents, or on a list of areas most prone to crashes).</p> <p>AND</p> <p>2. <i>Speed Factor.</i> The number of vehicles that has been observed to enter the curve at speeds that are considered unsafe is more than expected, based on the judgment of local engineers. (e.g., high profile vehicles entering rural curves at speeds believed to be unsafe).</p> <p>OR</p> <p>There is evidence of near misses and/or rapid deceleration either within the curve or in the approach to the curve. (e.g. pavement skid marks, scrapes along guard rails)</p>

Curve Warning System Warrant #3: Truck Rollovers on Ramps

Purpose:	To influence the behavior of commercial vehicle operators driving on ramps.
Device is warranted if:	<p>1. <i>Crash Rate Factor.</i> The Curve has a history of at least one truck rollover crash every 5 years. (12)</p> <p>AND</p> <p>2. <i>Speed Factor.</i> Vehicles have been observed to enter the curve at speeds that are unsafe. (e.g. trucks entering ramps at unsafe speeds).</p> <p>OR</p> <p>There is evidence of near misses and/or rapid deceleration either within the curve or in the approach to the curve. (e.g. pavement skid marks, scrapes along guard rails)</p>

8.9 Intelligent Work Zone Warrants

Intelligent Work Zones are defined as a collection of devices that collectively warn travelers of various hazards associated with work zones.

Six (6) warrants have been identified to capture the most common uses of Intelligent Work Zone Devices. While there are other purposes and uses for Intelligent Work Zones as well as existing system components to consider, the warrants developed to date have focused on the following six.

DMS Warrant #3:	Changing Traffic Condition (WARRANT FROM PHASE 1) Purpose: To notify drivers in advance of special changing traffic conditions and roadway configuration changes associated with road construction or maintenance in order to reduce driver confusion that could result in a crash.
CCTV Warrant #6:	Intelligent Work Zone Purpose: To allow travelers or transportation professionals to understand construction or maintenance traffic delay by viewing images of the roadway remotely.
HAR Warrant #3:	Changing Traffic Conditions (WARRANT FROM PHASE 1) Purpose: To notify drivers in advance of special changing traffic conditions and roadway configurations associated with road construction or maintenance.
VSL Warrant #4:	Work Zones (WARRANT FROM PHASE 2) Purpose: To post varying speed limits for construction zones in order to only slow traffic when necessary, or to maintain consistent speeds to promote safety.
DSDS Warrant #3:	Intelligent Work Zones (WARRANT FROM PHASE 2) Purpose: To promote speed adherence in locations where posted speeds have temporarily been reduced for construction, maintenance or other traffic control.
Ramp Meter Warrant #3:	Ramp Metering During Work Zone Activity (WARRANT FROM PHASE 2) Purpose: To meter on-ramp traffic during road work activities to improve safety and/or consistent traffic flow.

DMS Warrant #3: Changing Traffic Condition (WARRANT FROM PHASE 1)

Purpose:	To notify drivers in advance of special changing traffic conditions and roadway configuration changes associated with road construction or maintenance in order to reduce driver confusion that could result in a crash.
Device is warranted if:	<ol style="list-style-type: none">1. The candidate location is upstream of an area with construction or maintenance activities that are expected to cause at least 15 minutes of delay to the mainline traffic; <p>AND</p> <ol style="list-style-type: none">2. If the candidate location is upstream of traffic control or construction/maintenance activities that are expected to change more frequently than once every 60 days; <p>AND</p> <ol style="list-style-type: none">3. If the speed limit is greater than 45 MPH. <p><i>Notes:</i></p> <ol style="list-style-type: none">A. <i>If question #2 is not met (activities do not change frequently), lower cost static signage is recommended.</i>B. <i>Portable DMS vs. permanent DMS should be considered based on the expected duration of events impacting the area.</i> <p><i>Partial Warrant Criteria:</i></p> <p>If #2 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

CCTV Warrant #6: Intelligent Work Zone

Purpose:	To allow travelers or transportation professionals to understand construction or maintenance traffic delay by viewing images of the roadway remotely.
Device is warranted if:	<ol style="list-style-type: none">1. The alignment or traffic control that is visible by a camera image is expected to change periodically during the construction period. OR The construction zone encounters periods of queues or delays for at least 30 minutes each day. AND2. The construction zone is in a location where there is not a convenient alternate route for the majority of traffic to deviate from the typical route.

HAR Warrant #3: Changing Traffic Conditions (WARRANT FROM PHASE 1)

Purpose:	To notify drivers in advance of special changing traffic conditions and roadway configurations associated with road construction or maintenance.
Device is warranted if:	<ol style="list-style-type: none">1. The candidate location is upstream of an area with traffic control changes (e.g. lane closure, crossover, contra flow) where travelers would benefit from a verbal explanation; AND2. If the candidate location is expected to encounter either long term construction or maintenance activities or changing traffic control situations for longer than 2 months; <p><i>Partial Warrant Criteria:</i> If #1 above is met, the warrant is considered 'Partially Met'. If one or more additional purposes are partially met at this location for this device, the device shall be considered 'Warranted'.</p>

VSL Warrant #4: Work Zones (WARRANT FROM PHASE 2)

Purpose:	To post varying speed limits for construction zones in order to only slow traffic when necessary, or to maintain consistent speeds to promote safety.
Device is warranted if:	<ol style="list-style-type: none">1. The schedule of the construction activities being performed AND the design of the work zone are such that the vehicles are not required to be slowed to the same speed 24 hours per day. For example, if vehicles are slowed to a speed during the day when workers are present, but when work is not occurring the absence of workers and layout of the construction zone (lane width, geometries, structure) would allow higher speeds. OR2. The planned construction activities and design of the work zone will create varying conditions for travelers during the period of construction (e.g. periods when the safe speed will change, periods when travel lanes will change, anticipated geometry changes). OR3. The construction zone already exists and there is a noticeable differential in the speed of vehicles as they progress through the work zone (where travelers would benefit from slowing earlier). <p><i>Note: Many locations include additional fines for speeding in work zones, and the design of any variable speed limit system must consider this aspect before determining if variable speed systems are appropriate for work zones.</i></p>

DSDS Warrant #3: Intelligent Work Zones (WARRANT FROM PHASE 2)

Purpose:	To promote speed adherence in locations where posted speeds have temporarily been reduced for construction, maintenance or other traffic control.
Device is warranted if:	<p>1. The work zone is currently in operation and observations suggest that the 85th percentile speed at a location within the work zone exceeds the posted speed limit by at least 5 mph.</p> <p>OR</p> <p>Workers will be located adjacent to the open traffic lane.</p> <p>OR</p> <p>Hazardous roadway conditions, such as a temporary unusually tight curve, or a rough road surface, requiring extra driving precaution.</p> <p><i>Note: Signs tend to be most effective where there are two lanes or less in one direction of travel.</i></p>

Ramp Meter Warrant #3: Ramp Metering During Work Zone Activity (WARRANT FROM PHASE 2)

Purpose:	To meter on-ramp traffic during road work activities to improve safety and/or consistent traffic flow.
Device is warranted if:	<ol style="list-style-type: none"> 1. Capacity Factors. There is a temporary reduction in capacity of through lanes due to either a reduction in the number of lanes, or a reduction in the width of lanes of traffic, causing a backup of traffic during peak periods. OR 2. Geometric Factors. There is a temporary change in the geometry or length of the acceleration lane that will potentially have a negative impact on ramp traffic merging with the mainline traffic. OR 3. Behavior Factors. There is a desire to discourage the use of the ramp during the period of road work.

References

1. **MUTCD.** 2009.
2. **City of St. Paul Minnesota, Department of Public Works, Traffic Engineering.** *Dynamic Speed Display Signs* . 2004.
3. **Mn/DOT.** *Dynamic Speed Display Sign Memo.*
<http://dot.state.mn.us/trafficeng/committees/minutes/jul/Attachment%202.pdf>.
4. **THE STATE OF VERMONT, Agency of Transportation.** *Guidelines for the Use of Radar Speed Feedback Signs on.* 2009. website:
http://www.aot.state.vt.us/documents/3014_Guidelines_on_the_Use_of_Radar_Speed_Feedback_Signs.pdf.
5. **City of Bellevue (Washington), Transportation Department.** *Stationary Radar Sign Program 2009 Report.* 2009.
6. **Federal Highway Administration.** *2003 Edition, Manual on Uniform Traffic Control Devices.* 2003.
7. **Caltrans, Traffic Operations Program.** *Ramp Meter Design Manual.* 2000.
8. **Kimley Horn & Associates.** *Arizona Department of Transportation, Freeway Management System, Design Guidelines.* 2002.
9. **Mn/DOT.** Discussions re: Ramp Meter Warrants Development Process. 2009.
10. **Bonneson, J., M. Pratt, J. Miles, and P. Carlson.** *Development of Guidelines for Establishing Effective Curve Advisory.* FHWA/TX-07/0-5439-1. Texas Department of Transportation, Austin, Texas. 2007.
11. **CH2M Hill.** *Freeborn County Road Safety Audit Review.* 2008.
12. **Preston, Howard and Schoenecker, Ted.** *Potential Safety Effects of Dynamic Signing at Rural Horizontal Curves.* Local Road Research Board, Minnesota Department of Transportation. 1999.
13. **Oregon Department of Transportation.** *Myrtle Creek Curve Crash Analysis.* 2008.
14. **ITS Engineers and Constructors.** *Ramp Meter Design, Operations, and Maintenance Guidelines.* Transportation Technology Group, Arizona Department of Transportation. 2003.
15. **Mn/DOT.** *Stratified Zone Metering - The Minnesota Algorithm.* 2003.
16. **Wayne Sandberg, Ted Schoenecker, Kristi Sebastian, and Dan Soler.** *Long-Term Effectiveness of Dynamic Speed Monitoring Displays (DSMD) for Speed Management at Speed Limit Transitions.*