Traffic Management Systems (TMSs) Managing the Use of Variable Speed Limits (VSLs) During Adverse Weather Conditions

Transportation Management Center (TMC) Pooled-Fund Study[(1)]

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Issues Faced by Transportation Agencies Managing Traffic During Adverse Weather

- TMSs face challenges managing and controlling traffic during adverse weather conditions for the following reasons:
  - Roadway and weather conditions change rapidly.
  - Drivers may drive too fast for prevailing conditions.
  - Increased travel speeds increase crash risk.
- Operational strategies and the information to be shared are influenced by changing weather and roadway conditions.
- VSLs is a strategy to consider during adverse weather.
- VSL use requires careful planning to integrate into TMSs.

How Are VSLs Used During Adverse Weather?

- Agencies can use VSLs to actively manage traffic in the following situations:
  - During adverse weather.
  - To improve safety and reliability.
- Agencies alert drivers and encourage reduced speeds before they encounter adverse conditions by implementing the following:
  - Posting lower speed limits on VSL signs.
  - Displaying messages about travel conditions on changeable message signs (CMSs).
- Agencies share information through push button notifications, traveler information websites, or social media platforms.
- Agencies inform State patrol, maintenance teams, and emergency responders of upcoming or prevailing conditions.

VSL Benefits

- Improve safety.
- Reduce number of crashes.
- Reduce crash-related road closures.
- Reduce travel speeds based on roadway conditions.
- Increase driver awareness on why travel speeds are being adjusted.
- Achieve positive results from before and after studies as follows:
  - Ohio Department of Transportation (DOT): Reduced crashes during snow events by 35 percent.(2)
  - Ohio DOT: Decreased injuries and fatalities from 20 to 9 crashes per year.(2)
  - Wisconsin DOT: Reduced average vehicle speed by 13 percent.(3)
  - Utah DOT (UDOT): Improved speed limit compliance and significantly reduced crashes.(4)

Desired Outcomes of Using VSLs

- Improve safety.
- Improve travel time reliability.
- Reduce vehicle speeds and speed variations during adverse weather.
- Improve driver awareness of and compliance with adjusted speed limit by providing information (e.g., lane or roadway closures) in advance of slowdowns.
- Manage the use of VSL based on changing circumstances.
- Share information and coordinate with emergency responders and service providers.

Key Considerations

- Enforcement: Regulatory versus advisory speed limits.
- Effective VSL sign locations.
- Operational strategies.
- VSL benefits may vary from site to site for multiple uncontrolled factors, including the following:
  - Motorist awareness of events that result in VSL use.
  - Speed limit compliance rate.
  - Driver behavior.
  - Road geometry.

Challenges With Implementing VSLs

- VSL benefits may vary from site to site because of the following:
  - Driver awareness of reasons to slow down.
  - Speed limit compliance rate.
  - Driver behavior.
  - Road geometry.
- VSL compliance is typically low if speed limits are not enforceable.
- VSL use across the State or region may benefit from:
  - Knowing when to use and how to change speeds.
  - Conveying the relevant information to travelers on why VSLs are being used.
  - Applying policies and procedures consistently.

Support for Using and Managing VSLs

- TMSs need the capabilities and resources to support actively managing and operating VSLs.
- TMSs need to perform the following functions:
  - Collect and process data.
  - Disseminate information to travelers, emergency responders, and service providers.
  - Monitor how weather may be impacting traffic.

Issues to Consider When Incorporating VSL Into TMSs

- VSL operational requirements are similar to those of other TMS operational strategies.
- Agencies may establish formal operating procedures for VSLs.
- TMSs may need to automate the operation of VSLs to achieve desired speed reductions.
- TMC operator's involvement may be needed to operate VSLs.
- TMS's capability to communicate with emergency responders and other agencies is important.

VSLs and Display of Messages on CMS for Motorists

- Many agencies use VSLs concurrently with CMS.
- CMSs are used for traffic control purposes.
- Messages displayed need to be easy to understand and contain relevant information to be effective.
- The following documents include specific information about how to effectively use CMSs and the messages they display:
  - Chapter 1A-02 of the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD).[5]
  - Chapters 2A and 2L of MUTCD.[5]
  - "Uses of and Nonstandard Syntax on Changeable Message Signs" (FHWA Official Ruling No. 2(09)-174 (I)).[6]
  - *Guidelines for Disseminating Road Weather Messages* (Publication No. FHWA-JPO-13-005).[7]
  - *Changeable Message Sign Operation and Messaging Handbook* (Publication No. FHWA-OP-03-070).[8]

Examples of CMS Messages Used With VSLs[5][6][7]

- “Speed Limit.”
- “Ice in Places.”
- “Carry Chains or Traction Tires.”
- “Snow Zone.”
- “Slippery When Wet.”

Considerations When Planning for VSLs

- Evaluate staffing resources.
- Identify training needs.
- Integrate VSLs into TMSs.
- Consider statewide regional implementation.
- Review policies and processes to operate VSLs.
- Evaluate the availability of supporting devices to provide travel condition information to travelers.

VSLs and CMSs—Scenario for Changing Speeds Based on Changing Conditions

- The Road Weather Management System sends data to TMS on timing of expected snow.
- The TMS operator decides to change the speed limit and posts messages on CMS about the reason for a speed limit reduction.
- The snow begins to fall.
- The visibility declines.
- The grip factor declines.
- Based on the changing conditions, the TMS operator performs the following actions:
  - Adjusts the speed limit.
  - Shares information and coordinates with emergency responders and roadway maintenance.
  - Posts updates on the website and social media.

Considering TMSs in Planning for VSL Operations

- TMC staffing and training needs—Ohio DOT:
  - Add a traffic management specialist on every shift.
  - Focus on CMS, VSL, and smart lanes.
  - May focus on VSLs for weather during the winter months.
  - Shift to other TMC duties during warmer months.
- Integration into the TMS—Oregon DOT:
  - Speed data and closed-circuit television (CCTV) camera images help operator pinpoint problems areas.
  - TMS operator controls VSLs and CMSs.
- Statewide versus regional deployments:
  - State DOTs deployed VSLs along routes with history of crashes.
  - Pennsylvania DOT's (PennDOT's) regional TMCs manage VSLs.
  - PennDOT Central Office approves using speed limits below a minimum threshold.

Examples of Agencies Using VSLs During Adverse Weather

- Ohio DOT.[2]
- Oregon DOT.[9]
- PennDOT.[10]
- UDOT.[4]
- Washington State DOT (WSDOT).[11]

Ohio DOT VSL Example[2]

- Located on I–90 along Lake Erie.
- Data inputs to TMS are used to set speeds:
  - National Weather Service alerts.
  - Road Weather Information System (RWIS).
  - Local agency field observations.
  - CCTV camera observations.
  - Traffic speeds.
- System is managed by statewide TMC.
- CMS and VSL are integrated into TMS.
- Speed limits are recommended by TMS.
- Speed limits are enforceable.
- Extensive stakeholder and public outreach.

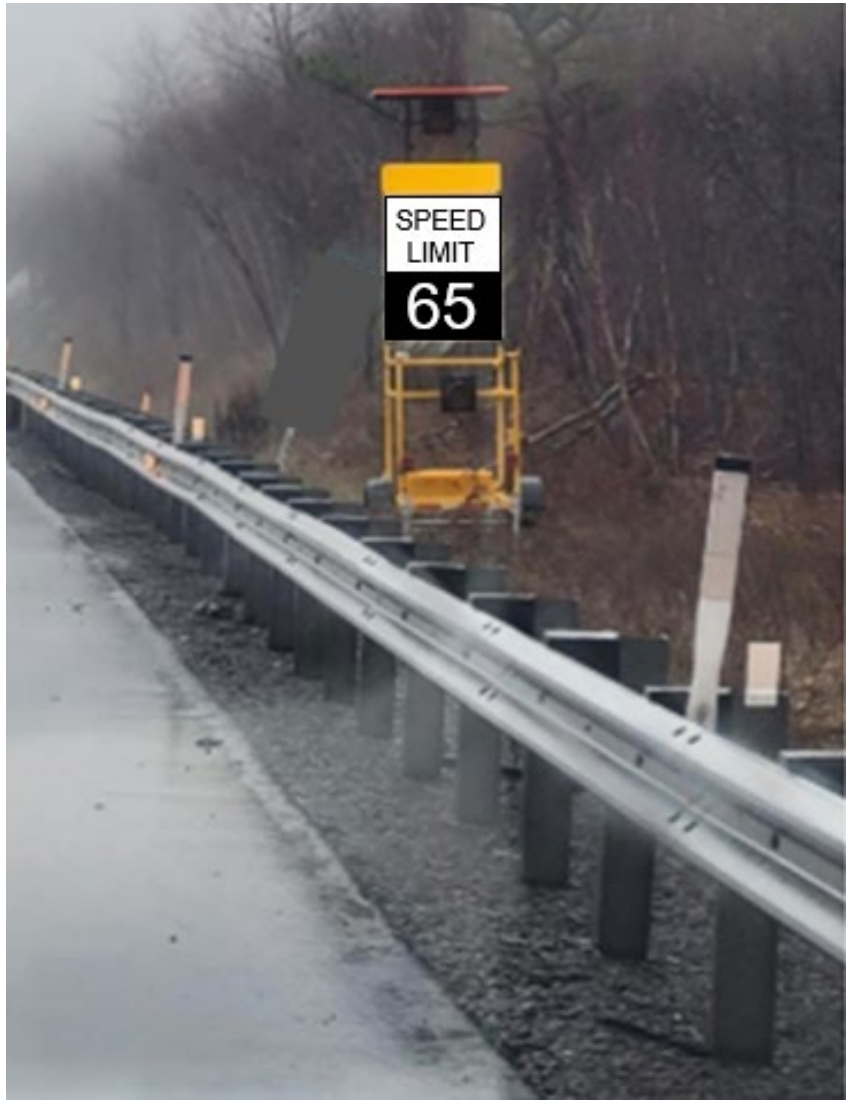
Oregon DOT VSL Example[9]

- Locations on US–97, I–5, and I–84.
- Data inputs are used to set speeds:
  - RWIS (air temperature, relative humidity, speed, and pavement friction).
  - CCTV cameras.
- Two independent systems share data and calculate speed limit.
- Higher priority speed is posted on signs.
- Process is mostly automated.
- Minimum allowable speed limit is 30 mph.
- Speed limits are enforceable.
- Coordination with law enforcement.

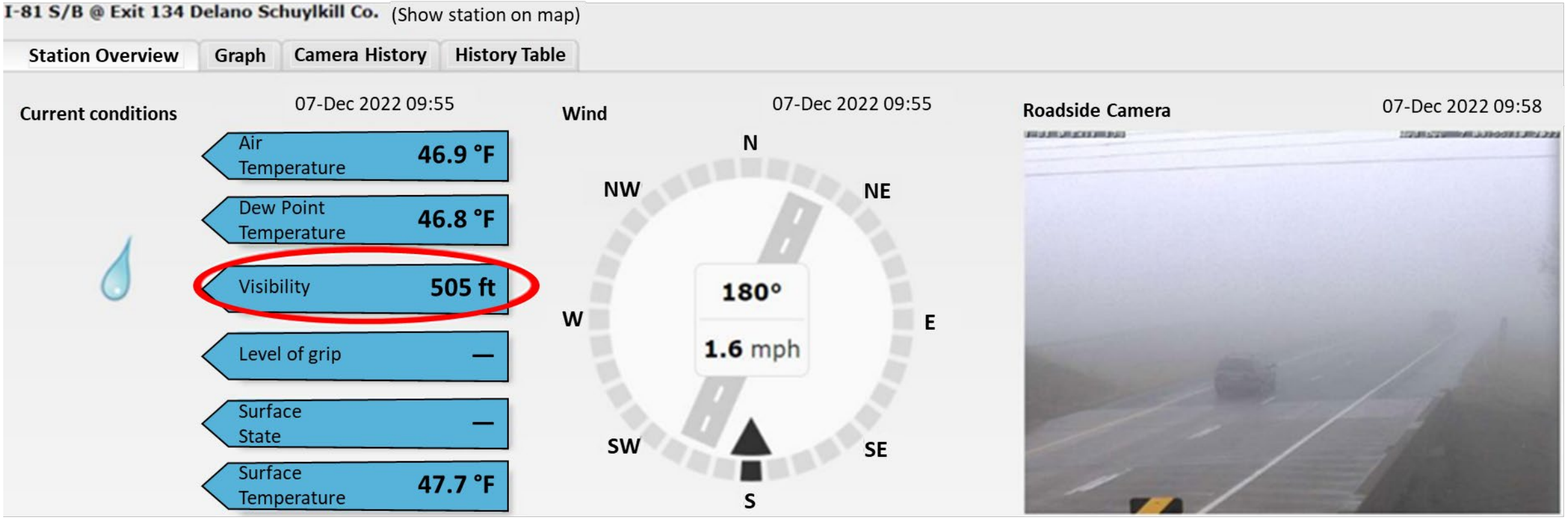
Oregon DOT—Combined VSL and CMS Example

PennDOT VSL Example[10]

- Pilot programs along I–80 and I–81 across multiple PennDOT Districts.
- Data inputs are used to set speeds:
  - RWIS (air temperature, relative humidity, wind, pavement friction).
  - Field reports.
  - CCTV cameras.
- VSL signs are placed:
  - After each on-ramp.
  - At other locations based on weather and crash data.
- Manual process follows procedures.
- Portable VSL sign units are used for pilot program.
- Flashers activate during speed limit reduction.[12]



PennDOT RWIS Dashboard—Key Input Into VSLs[10]



UDOT VSL Example[4]

- Location is I–80 in Parley's Canyon (approximately 13 mi).
- Data inputs to TMS are used to set speeds:
  - Radar detection.
  - RWIS.
- Automatic TMS process are based on real time prevailing traveling speeds.
- Close coordination is conducted across multiple groups:
  - TMC operators control VSLs through TMSs.
  - UDOT weather group monitors RWIS and notifies TMC of adverse conditions.
  - TMC operators work closely with snowplow operators.
- Speed limits are enforceable.
- Research found that amber light-emitting diodes (LEDs) have better visibility during snow events.

WSDOT VSL Example[11]

- Location is I–90 over Snoqualmie Pass (approximately 25 mi).
- Data inputs are used to set speeds:
  - Radar detection.
  - RWIS (air temperature, relative humidity, speed, wind, pavement friction).
  - CCTV cameras.
  - Field observations.
- Speed limits are enforceable.
- CMSs and VSLs are integrated into regional TMS.
- Speed limit reductions are tied closely with chain requirements.

WSDOT VSL Operational Guidelines[1]

Traction Requirements	Speed Limit	Pavement Conditions	Visibility	Weather	Blocking Incidents
None	70/65	Dry or bare and wet	Good: clear >0.5 mi	Fair to moderate rain	Incident on shoulder
Traction tires advised (no oversize loads)	55	Light snow, slush, or ice in places	Moderate: fog <0.2 mi	Hard rain	Incident
Traction tires required (chains required on trucks).	45	Snow and ice, deep slush, shallow water	Poor: blowing snow <0.1 mi	Heavy rain or snowfall	Lanes blocked traffic moving
Chains required (for all vehicles)	35	Severe freezing rain, deep snow, slush or standing water	Poor: blowing snow <0.1 mi	Heavy rain or snowfall	Lanes blocked traffic stopped ahead

[1] WSDOT. 2024. *VSL Operational Guidelines*. Unpublished internal document.

Lessons Learned in Incorporating VSLs in TMS

- Integrating VSLs into TMS allows operators to effectively manage VSLs:
  - All relevant information is accessible in a single location (TMS).
  - Messages are remotely posted to CMSs and VSL signs through TMS.
- Implementation of VSLs does not always require new positions or additional training for staff.
- VSL operator requirements are similar to other TMS operational strategies.
- VSLs are most effective when used in conjunction with CMSs:
  - CMSs provide motorists credible reasons for speed limit changes.
  - CMSs improve compliance with the speed limit.
- Close coordination with maintenance crews and law enforcement is important to provide firsthand knowledge of road conditions.

Future Direction in Incorporating VSLs in TMS

- Many agencies are collecting data to determine the quantitative benefits of VSLs.
- Many agencies are moving toward integrating VSLs into TMS.
- Many agencies are moving toward using a TMS that provides automated VSL management:
  - TMS automatically reduces speed limits based on data inputs.
  - TMC operators can use TMS to manually override.
- Observed benefits will lead to the increased use of VSLs in other corridors.

Available Resources

- FHWA. 2014. "Chapter 6. Weather-Related Variable Speed Limit Case Studies" (web page). https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12022/chap_6.cfm, last accessed April 1, 2024.
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- NOCoE. 2020. "Lake 90 Variable Speed Limit Corridor" (web page). https://transportationops.org/case-studies/lake-90-variable-speed-limit-corridor, last accessed April 1, 2024.
- PennDOT. 2024. "VSL Pilot Program Reducing Speeds, Crashes in District 2." PennDOT Way (blog). PennDOT. September 7, 2022. https://www.penndot.pa.gov/PennDOTWay/pages/Article.aspx?post=570, last accessed April 1, 2024.

Additional Information on Other TMS Practices

- National Operations Center of Excellence (NOCoE). n.d. “Traffic Management Systems and Centers portal (web page). https://transportationops.org/traffic-management-systems-and-centers, last accessed June 2, 2023.
- FHWA. 2023. “TMC Pooled-Fund Study” (web page). https://tmcpfs.ops.fhwa.dot.gov/, last accessed April 1, 2024.
- FHWA. 2024. “Road Weather Management Program” (web page). http://ops.fhwa.dot.gov/weather/, last accessed June 2, 2023.

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5. FHWA. 2022. *Manual on Uniform Traffic Control Devices for St*reets and Highways, 2009 Edition. Washington, DC: FHWA. https://mutcd.fhwa.dot.gov/pdfs/2009r1r2r3/mutcd2009r1r2r3edition.pdf, last accessed April 1, 2024.
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8. Dudek, C.L. 2004. *Changeable Message Sign Operation and Messaging Handbook.* Report No. FHWA-OP-070. Washington, DC: FHWA. https://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/CMS%20Operation%20and%20Messaging%20Handbook-Final%20Draft.pdf, last accessed June 1, 2024.
9. Oregon DOT. 2012. "Evaluation of a Variable Speed Limit System for Wet and Extreme Weather Conditions: Phase 1 Report. https://rosap.ntl.bts.gov/view/dot/24673, last accessed July 9, 2024.
10. PennDOT. 2022. "Variable Speed Limit Pilot on I–81" (web page). https://www.tesc.psu.edu/assets/Session%20PDFS/TESC%20Session%20Presentations/Speeds-May-Vary-A-Closer-Look-at-Variable-Speen-Limits-PennDOTs-Winter-Weather-VSL-Corridors.pdf, last accessed April 1, 2024.
11. Washington DOT. 2022. "Variable Speed Limits" (web page). https://tsmowa.org/category/intelligent-transportation-systems/variable-speed-limits, last accessed April 1, 2024.

Speaker's Notes (1/31)

None.

Speaker's Notes (2/31)

None.

Speaker's Notes (3/31)

This presentation is organized as follows:

1. Using VSLs During Adverse Weather – discuss the background for the implementation of VSLs, the potential benefits, how they are being used and the desired outcomes
2. Challenges and Considerations – discuss some challenges that an agency may face and some considerations
3. Agency Practices and Examples – discuss a handful of agencies who have implemented VSLs along their roadways and what they are doing
4. Summary of Benefits and Lessons Learned – summarize the benefits and lessons learned that agencies have shared
5. Resources

Speaker's Notes (4/31)

Drivers typically adjust their speeds based on prevailing roadway conditions such as heavy traffic congestion. However, there are instances where roadway conditions are not immediately apparent to drivers, and this can present a safety hazard. For example, when an incident occurs on a roadway that severely slows down or even stops traffic. It is important for state departments of transportation (DOTs) to consider alerting drivers and encourage a reduction in operating speeds before the slowdown. This is typically done by posting variable speed limits (VSL) or displaying roadway or travel condition information messages on blank out signs or changeable message signs (CMS) upstream of slowdowns.

Traffic management systems (TMSs) operated by state DOTs are faced with challenges in collecting reliable road condition and weather information to support how they manage and control traffic. Changing weather and roadway conditions may influence which operational strategies a TMS may use and what information may be shared with the public or with motorists along a particular roadway. The use of variable speed limits, or speed harmonization, is an example of one operational strategy agencies may use to improve safety and reliability of travel when roadway conditions may be adversely impacted by weather events.

Implementation issues related to consistency in setting speed limits appropriate for conditions can be a challenge as supporting data may not provide for clear recommendations, and other factors such as traffic may affect appropriateness of selected speed limits and effectiveness of influencing driver behavior. Operational practices vary by agency in the use of automated, manual, or hybrid methods to make speed limit decisions. Furthermore, enforcement is an issue to be considered if VSLs are regulatory and not advisory.

Speaker's Notes (5/31)

Posted speed limits on a roadway are important in maintaining a safe and efficient transportation network. However, inclement weather can change roadway conditions in a short amount of time. This abrupt change may not allow drivers to adapt their travel speeds or driving behaviors in time. The use of VSL when roadway conditions and adverse weather provide the opportunities for agencies to actively manage and operate traffic based on changing circumstances to improve safety and mobility. Benefits may include reduced crash frequency and severity, reduced time to clear incidents, and more reliable travel times.

VSLs have been applied on roadways in multiple states to adjust regulatory or advisory speed limits based on traffic and road conditions such as adverse weather with limited visibility, reduced road friction, and/or high winds. By reducing speed limits according to defined criteria in a weather-responsive management strategy, traveling vehicles' speeds can be reduced to safer travel speeds and better harmonized to allow for lower variations in speed. The potential for crashes can be lowered, due to the improved ability for drivers to react to slowing traffic or changing road conditions and maintain vehicle control in adverse weather conditions.

Speaker's Notes (6/31)

The consensus among state DOTs is that VSL implementation can help improve road safety during inclement weather along corridors by reducing crashes and increasing driver awareness. Many state DOTs are currently in the process of conducting before-and-after comparison studies to quantitatively measure the effectiveness of VSL implementation. PennDOT is currently in the final stages of their analysis and preliminary numbers are indicating that drivers are slowing down. UDOT has received positive feedback from their highway patrol who have observed improved driver compliance during inclement weather along VSL corridors.

Ohio DOT completed a comparison study that found that VSL reduced crashes during snow events by 58%, reduced secondary crashes by 63%, and reduced incident clearance times by 31 minutes.

UDOT conducted a study that compared the driver compliance rate before and after VSL with an amber legend implementation. The study collected bi-weekly data every year between 2018 to 2020 and results were compared to data from when the corridor had VSL with a white legend. The study found that driver compliance rates improved by 9% on average with an amber legend during the wintertime. The study also found that there was a 50% decrease in crash numbers after installing the new VSL signs.

Speaker's Notes (7/31)

Agencies that have implemented VSLs based on weather conditions have identified many resulting benefits including lower travel speeds, reduced crashes during adverse weather events, reduced secondary crashes, and fewer crash-related road closures. The full benefits of VSLs are realized when agencies can relay current and credible information to motorists as to why there are changes in the speed limit. When drivers trust the information being presented and understand the need for a speed limit reduction, they are more likely to comply.

The use of VSLs relies on prevailing information on the roadway such as traffic speeds, volumes, weather, visibility, and road surface conditions to determine appropriate speed limits and display them to drivers. This strategy improves safety performance and traffic flow by reducing travel speeds and speed variance. VSLs coupled with CMSs may also improve driver awareness by providing information in advance of slowdowns such as potential lane closures, which could reduce the probability for secondary crashes. VSLs can slow faster-moving traffic as it approaches a queue or bottleneck thus improving safety on corridors that are susceptible to sudden changes in weather conditions.

Speaker's Notes (8 /31)

It is important for state departments of transportation (DOTs) to consider alerting drivers and encourage a reduction in operating speeds before the slowdown. This is typically done by posting variable speed limits (VSL) or displaying roadway or travel condition information messages on blank out signs or changeable message signs (CMS) upstream of slowdowns.

VSLs have been applied on roadways in multiple states to adjust regulatory or advisory speed limits based on traffic and road conditions such as adverse weather with limited visibility, reduced road friction, and/or high winds. It is important for agencies who are considering implementing VSLs as an option, to decide if the speed limits shown on VSLs will be enforceable or advisory. Regulatory speed limits will require changes in legislation and coordination with law enforcement.

Implementation issues related to consistency in setting speed limits appropriate for conditions can be a challenge as supporting data may not provide for clear recommendations, and other factors such as traffic may affect appropriateness of selected speed limits and effectiveness of influencing driver behavior. Operational practices vary by agency in the use of automated, manual, or hybrid methods to make speed limit decisions. Furthermore, enforcement is an issue to be considered if VSLs are regulatory and not advisory.

Speaker's Notes (9/31)

TMSs need data collection tools such as RWIS, speed sensors and CCTV.

TMSs need dissemination tools such CMSs and VSL signs and the software to update them from the TMC.

TMC staff need awareness of how weather impacts traffic.

Compliance with VSLs are typically low when speed limits are not enforceable. So, several agencies have worked with their state legislatures to revise legislation to make speed limits along VSL corridors enforceable.

Speaker's Notes (10/31)

TMSs need more than just software and system hardware to effectively manage VSL. They need other resources and capabilities, such as:

- A mechanism to collect data and the data that is collected.
- Mechanisms to inform travelers, emergency responders, and service providers with information about the reduced speeds displayed, including why speeds are reduced.
- TMC staff who understand the impacts of weather on traffic conditions.

Speaker's Notes (11/31)

When an agency implements VSL and integrates control of VSL in their TMS, there are a number of issues they can consider, including:

- VSL operational requirements are similar to those of other TMS operational strategies.
- Agencies may establish formal internal operating procedures for VSLs.
- Level of automation for speed reduction.
- TMC operator involvement.
- TMS capability to communicate with emergency responders and other agencies.

Speaker's Notes (12/31)

Agencies that use CMSs with VSLs are encouraged to adhere to the basic principles of the MUTCD. Many of the criteria specific to CMSs are stated in Chapter 2L of the MUTCD, and other criteria, such as background and legend color are stated in Chapter 2A and apply to CMSs.

Consistent with the principles articulated in the MUTCD, CMSs are not intended for promotional purposes or messages that are unrelated to traffic control. Limiting the uses of CMS to messages primarily related to traffic control is expected to help transportation agencies preserve the effectiveness of the sign and its primary function as traffic control devices whose messages adhere to established criteria. In the case of providing weather-related information, agencies should focus on providing information on expected adverse road conditions rather than basic weather information or advisories.

The "Guidelines for Disseminating Road Weather Messages" (Publication Number FHWA-JPO-12-046) provides effective and specific guidelines for agencies to communicate weather information in a way that is consistent with what travelers need, want, and will use when making travel decisions. The report states that if a CMS is difficult to understand, read, or hear, then travelers will be less likely to use that information to make good decisions. To effectively use CMSs, the message should contain the following three key elements:

1. Information that contains the relevant weather event
2. Information that provides the change needed due to said weather event
3. Message content that is easily understood and displayed in a clear manner

Speaker's Notes (13/31)

There are several messages that could be displayed on a CMS to support reduced speeds displayed through the VSL subsystem. These include:

- The reduced speed limit.
- Messages that explain why the speed limit is reduced, such as "Ice in Places.", "Slippery When Wet", or "Snow Zone"
- Information on precautions that drivers should take, such as "Carry chains of traction tires."

Speaker's Notes (14/31)

There are several things that agencies can consider when planning for VSLs:

- What are the impacts on staffing resources? Will more operators be needed?
- Do operators need new training to operate the VSL effectively?
- Can VSL be integrated into the existing TMS? If not, how can the existing TMS be upgraded or replace?
- Will VSL be implemented on a single corridor, statewide, or regionally?
- Are new or revised policies or processes needed to operate VSL effectively?
- Do we have the needed supporting devices to provide travel condition information?

Speaker's Notes (15/31)

An illustrative example of the steps operators might take to manage the VSL and supporting CMS when a snow event is anticipates consists of:

- Road Weather Management System sends data to TMS on timing of expected snow.
- TMS operator decides to change speed limit and posts messages on CMS on reason for speed limit reduction.
- Snow begins to fall.
- Visibility declines.
- Grip factor declines.
- Based on changing conditions TMS operator:
  - Adjusts speed limit.
  - Shares information and coordinated with emergency responders and roadway maintenance.
  - Posts updates on website and social media.

Speaker's Notes (16/31)

Many agencies have successfully operated VSLs with existing TMC staff since VSL operational requirements are similar to those of other TMS operational strategies.

Speaker's Notes (17/31)

Five State DOT's that use VSL during adverse weather conditions will be presented on the following slides, That are:

- Ohio DOT
- Oregon DOT
- Pennsylvania (DOT)
- Utah (UDOT)
- Washington State DOT (WSDOT)

Speaker's Notes (18/31)

In December 2016, massive snow squalls on I-90 caused a major pileup that resulted in a 14-hour road closure. The Ohio DOT took swift action to reduce the frequency and severity of crashes throughout this corridor. Speed data collected from the major pileup showed that relative speeds did not decrease, even after weather conditions began to worsen, and drivers continued to travel more than 70 mph. After enabling legislation was passed in the summer of 2017, Ohio DOT began designing a permanent VSL corridor. Ohio DOT implemented their first VSL during the 2018-2019 snow and ice season.

Ohio DOT held multiple stakeholder meetings, relied heavily on social media campaigns, and met with local media to explain the new corridor operations. Furthermore, a VSL layer was created on Ohio DOT's traveler information system, OHGO, to visually display corridor signs as well as push alerts to subscribers every time there is a speed limit change.

The VSL is managed out of the statewide traffic management center (TMC). State operators coordinate closely with local agencies located along this stretch of I-90 to verify field conditions in areas that are outside of state surveillance. The VSL is integrated into Ohio DOT's Advanced Traffic Management System (ATMS) where TMC operators can post messages to dynamic message signs (CMS) and VSL signs in the field. The system has several inputs that include the National Weather Service (NWS) alerts, local agency field observations, CCTV cameras observations, and speed data from INRIX that detects slowdowns. Static warning signs are placed approximately ¼ to ½ mile in advance of the first VSL sign entering the VSL corridor in each direction.

Speaker's Notes (19/31)

Oregon DOT's VSL includes two main systems that work independently but share data. The ATM Suite receives various data inputs such as INRIX probe data and RWIS data and can output ATM messages such as VSL and weather warnings. The Response Plan System can automate messages from regional Traffic Operation Centers (TOCs) based on incident data. Message outputs from both systems then get sent to the Message Queue Manager (MQM) which chooses the higher priority before sending to the Vanguard system, which sends the messages to the signs. All systems are mostly automated but can be manually overridden by an operator when needed.

To improve communication between Oregon DOT and law enforcement, Oregon DOT developed a Variable Speed Reporter website that allows law enforcement to access data logs and speed change history. The website requires a secure network connection and is updated every time a speed change event occurs. Law enforcement can see what speed limits are active on each VSL and the location of each VSL site.

Speaker's Notes (20/31)

This is a VSL and VMS Cantilever Structure on I-5 Siskiyou Pass. There are typically two VSL signs located at each VSL site in Oregon. VSL signs can only display graphics and are combined with a larger variable message sign (VMS). One VSL will display the standard speed and the other VSL will display the truck speed. During a speed reduction event, the standard speed limit sign will reflect the reduced speed and the truck speed sign will display a weather warning message.

Speaker's Notes (21/31)

PennDOT installed portable VSL units that include an LED display that changes based on the prevailing speed limit. During normal circumstances, these units display the corridor's normal speed limit. The units are equipped with flashers above and below the LED display that are activated in the event of a speed limit reduction. Speed reduction to the VSL unit is currently a manual process and follows business rules rather than a defined algorithm. Regional TMC operators have the authority to lower the speed limit from 65 mph to 55 mph. Regional TMCs then need state permission to lower the speed limit further until the statewide minimum of 45 mph.

Speaker's Notes (22/31)

The TMC receives weather station data and field reports and the TMC operator makes the decision to reduce the speed limit. RWIS are equipped with pavement sensors, air temperature/relative humidity sensors, surface temporary sensors, wind, and a CCTV camera to measure visibility and provide surveillance.

The VSL is currently a separate module within the TMC's ATMS that is used in conjunction with the Advanced Queue Warning System and CMSs.

Speaker's Notes (23/31)

Due to exposure to frequent inclement weather on a section of I-80 in Parley's Canyon, UDOT implemented a VSL zone using regulatory CMS. However, UDOT found that the visibility of white digits was greatly reduced during inclement weather, especially snowstorms. Hence, UDOT conducted extensive research to compare the visibility of white digits versus amber/yellow digits in both direct sunlight conditions and snowstorms. Studies found that the new amber legend VSLs had much improved visibility in the summer and were not significantly affected by inclement weather in the winter. Another critical finding was the sight distance with an amber legend increased, providing drivers more time to respond to the speed limit.

UDOT's current system automatically lowers the speed limit based on real-time prevailing traveling speeds. The system includes a series of radar detectors, weather stations and VSL signs along the corridor. The system is broken down into zones where each VSL sign location is considered a zone. UDOT has a weather group that monitors the weather 24/7 that works closely with snowplow deployment and the VSL. TMC operators will check current speeds through their on-line based Performance Management System (PeMS) and coordinate with the weather group to determine if a speed reduction due to weather conditions is necessary.

Speaker's Notes (24/31)

In response to the high crash rate due to inclement weather conditions during both the summer and winter seasons, WSDOT implemented a VSL on a 25-mile stretch of I-90 over the Snoqualmie Pass in 1997. The current system, which is operated by the Northwest region's TMC, consists of radar detection, weather stations, and 13 full matrix walk-in overhead VMSs. The VMSs are located on the mainline downstream of each on-ramp, and the signs display an enforceable reduced speed limit when warranted by weather conditions.

The VSL and CMS systems in the Northwest region are integrated into the regional TMC's ATMS. Through the ATMS, speed data from INRIX and CCTV camera footage can be seen to pinpoint problems areas. The ATMS is also used to control content on the VSLs and the CMSs. Prevailing traffic speed and weather conditions data are evaluated in the field and transmitted by state patrol or field maintenance staff to the TMC. Based on these requests from the field, WSDOT staff determine if a speed reduction is needed and make the change manually. WSDOT keeps a detailed log of when speed limits are changed and why. WSDOT then sends out monthly reports to local courthouses with the activity logs to inform decision making speeding ticket cases and verify the prevailing speed limit at a certain time.

Speaker's Notes (25/31)

Speed limits are changed in 10 mph increments and are tied closely to traction tire requirements. WSDOT found that the main reason for full roadway closures along this stretch of I-90 was attributed to trucks without tire chains that spin out. When traction tires were advised, the speed limit was reduced to 55 mph; if traction tires were required, the speed limit was reduced to 45 mph; and if chains were required, the speed limit was reduced to 35 mph. Based on this finding, WSDOT also worked with state patrol to focus efforts on chain up areas to enforce traction tire chains.

Speaker's Notes (26/31)

There are major benefits in integrating VSLs into an agency's TMS. It allows TMC operators to access and review all the relevant information in a single location and can provide a holistic picture of roadway and traffic conditions. Also, having the VSL integrated into the TMS allows TMC operators to post messages automatically to CMS and VSL signs in the field.

The implementation of VSL does not necessarily require that a state DOT needs to revise organizational structure or open multiple new positions. Many agencies have been able to successfully operate VSLs with existing staff or minimal staff. Also, the addition of VSLs to a TMS or TMC does not require additional training for staff because the operational requirements for VSLs are like those of typical TMSs. The one additional skill that is needed is a good understanding of how road conditions impact safe driving speeds. VSL operators should have experience managing traffic during inclement weather.

To ensure efficiency and effectiveness of VSLs, it is important for state DOTs to work together with maintenance staff, enforcement agencies, and other municipalities.

Speaker's Notes (27/31)

Most VSLs receive multiple different sources of data from their TMS including weather, speed, and roadway sensor information with varying levels of reliability and accuracy. Currently, the process for speed limit reduction is still a manual process for many agencies. This process requires a TMC operator to make the change following a set of guidelines, an SOP or engineering judgement. Some agencies are looking to automate their systems so that speed limits will be reduced automatically based on RWIS, pavement sensors and other data.

Several agencies are in the process of expanding the VSLs by installing more VSL corridors. A few states have conducted studies have that show the benefits of VSLs, but more studies are needed to help guide new VSL deployments. Typical benefits of VSLs include reduced speeds, fewer crashes and road closures and increased driver awareness during inclement weather. It would be helpful to have additional studies that define clear performance measures for agencies to analyze the tangible benefits of VSL.

Speaker's Notes (28/31)

None.

Speaker's Notes (29/31)

None.

Speaker's Notes (30/31)

None.

Speaker's Notes (31/31)

None.