Improved Chain Control Operations

Requested by
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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

In California, field maintenance personnel use turntable signs to advise motorists of chain control conditions on rural highways and freeways. To do this an operator has to park, exit the vehicle, turn the sign on the shoulder and then walk across the freeway to turn the matching sign on the median. This is repeated multiple times for chain control as well as for signs indicating icy or snowy conditions. Walking across highways this frequently and in these conditions can be hazardous to maintenance personnel.

Caltrans staff requested a Preliminary Investigation to identify safer and more efficient state practices and tools being used to alert travelers to winter weather conditions. We reviewed recent research, national guidance and related efforts of other state DOTs to determine:

- Tools for notifying travelers of chain control requirements and weather conditions.
- Usage and operation of changeable, dynamic and variable message signs for winter weather notifications.
- Operation of non-electronic signs.

Summary of Findings

To better understand the tools that states are using for conveying winter weather and chain control information to travelers, we surveyed states informally and followed up with phone interviews. Our research also included a scan of national and state research efforts to identify additional guidance and tools that Caltrans can use to improve its chain control operations. We focused on two categories of research: changeable message signs (CMS), and the remote operations of these signs and integration into intelligent transportation systems (ITS).

We have organized our findings in the following sections: **State Practice, Related National Guidance, Related Research,** and **Online Tools and Resources**. Key highlights of our research include:

State Practice

- **Tools:** All states surveyed use a combination of the following tools to notify drivers of chain control requirements or other winter weather conditions:
  - 511 phone system.
  - A web-based traveler information system.
  - Highway advisory radio system.
  - Both static and changeable/dynamic/variable message signs—permanent or portable.

- **Operations:**
  - **Changeable Message Signs and Intelligent Transportation Systems:** Each state operates its permanent CMSs remotely from centralized operations centers using a variety of software solutions (or software developed in-house). In some cases these solutions are integrated with traveler information systems that provide information over the web (as in Colorado, where users have real-time access to messages currently displayed on any CMS in the state). Colorado DOT (CDOT) is enhancing its system with an Active Traffic Management System that will eventually adjust speed limits automatically based on information it receives from weather stations concerning visibility and other conditions.
  - **Portable Changeable Message Signs:** Portable CMSs must be programmed on-site.
  - **Non-Electronic Signs:** In most cases, these signs must be changed manually by maintenance personnel who leave their vehicles. Nevada DOT (NDOT) has upgraded these signs to a regulatory sign with yellow flashers and a yellow "When Flashing" banner. These signs can be toggled on and off via radio so that personnel don't have to leave their vehicles and their safety is improved. NDOT is in a second phase of integrating these signs into its centralized operations software so that signs can be controlled remotely. As an added safely measure, CDOT uses manual speed limit signs to slow traffic near chain-up stations.
- **Enforceability:** CMSs relevant to chain control are sometimes enforceable in Nevada, Colorado and Oregon, depending on whether they are considered regulatory or advisory. In Oregon, chains can be legally required on vehicles over a certain gross weight, and signs can legally require either chains or traction tires on smaller vehicles. (See Oregon legal regulations on chain requirements and the content of signs to display them, Appendix B.) CMSs in North Dakota are not enforceable. (These are not used for chain control.)

Related National Guidance

- The Federal Highway Administration (FHWA) provides various resources for implementing CMSs, including relevant provisions in the Manual of Uniform Traffic Control Devices (MUTCD), a handbook on portable CMSs, and guidance on the effects of various kinds of CMS on drivers.
- Both the FHWA and the National Cooperative Highway Research Program (NCHRP) have resources on ITSs in both the United States and Europe—including CMS management, integration with weather forecasting, 511 implementation and other tools.

Related Research

- Several states have carried out research and implementation related to CMSs and ITSs for winter weather traffic management.

Online Tools and Resources—Chain Control Laws

- We found several useful web sites providing information about chain control laws nationwide.

Gaps in Findings

The development of ITSs, their use to control CMSs and integration into weather notifications are very active areas of research nationwide. Ongoing developments should provide numerous other tools in the near future for improving chain control operations in California.

Next Steps

Caltrans might consider the following related to chain control operations in California:

- The use of permanent CMSs, where possible, for chain control and winter weather notifications.
- Where permanent CMSs are not possible, the use of portable CMSs that can be operated remotely via radio, allowing maintenance personnel to remain in their vehicles.
- Where the use of portable CMSs is not possible, the use of radio-operated flashing static signs (as in Nevada), to be heeded by travelers only when actively flashing.
- When possible, the integration of all of the above solutions into ITSs, including especially systems that integrate with weather stations and automatically adjust signs based on this information (as in Colorado).
- An upgrade to its web-based traveler information systems that integrates the status of signs (as in Colorado).

Contacts

During the course of this Preliminary Investigation, we talked with the following individuals by phone or email:

State Agencies

Colorado DOT
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North Dakota DOT
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Oregon DOT
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State Practice

To understand how states use signage and other technologies for chain control and other winter weather alerts, we surveyed state agencies via the AASHTO Snow and Ice Listserv (http://www.transportation.org/?siteid=88&pageid=2174) and followed up by phone with respondents who had signage practices that might be of interest to Caltrans. Questions included:

1. What tools (such as signage, television, Internet, phone and radio) does your state use to notify motorists that tire chains are required and of other hazardous weather conditions?
2. If your state uses changeable, dynamic or variable message signs:
    a. How are the signs managed and operated? How are they integrated into an overall traffic management system? Are they integrated into advanced road safety and weather warning systems?
    b. Are the signs automated or operable remotely?
    c. What is the content of sign notifications, and how is this content displayed?
    d. Are the electronic signs legally enforceable?
3. If your state uses non-electronic signs:
    a. How general or specific is the signage language?
    b. How often do signs have to be changed to match weather conditions? How are these changes managed? Do workers have to leave their vehicles to change the signs? If so, how does your state address the safety issues involved in entering the roadway?
    c. Are the signs changeable remotely or without having to leave the vehicle?
4. Are you aware of other innovative non-signage technologies that are particularly suited to winter and hazardous weather notifications? Please describe and provide vendor information, if available.
5. Please provide a name and phone number/e-mail for contacting your state for additional information on this topic.

Survey and Interview Results

Our informal survey and interviews involved four states: Colorado, Nevada, North Dakota and Oregon.

Colorado DOT

Ali Imansepahi, Resident Engineer, CDOT ITS Branch, ali.imansepahi@dot.state.co.us, (303) 512-5858;
Phillip Anderle, Highway Maintenance Supervisor, CDOT, phillip.anderle@dot.state.co.us, (970) 350-2119.

1. **Tools:** Telephone (both traditional and 511) and radio (530 AM). Colorado also uses a Travel Information System, which delivers information via the web (http://www.cotrip.org/), including interactive maps of road conditions, speeds, roadwork and devices. By clicking on "Devices" (http://www.cotrip.org/device.htm) and then "Signs," users are provided with a map of CMSs and their current messages, including chain control requirements.
2. **Changeable Message Signs:** CDOT uses dynamic message signs. Its primary dynamic message sign (DMS) vendor has been Skyline Products (www.skylineproducts.com). CDOT uses the old character matrix and newer line matrix signs on both overhead and ground mounts. It is currently working on full matrix specifications to use in its next DMS installations. CDOT also has a large number of Precision Solar Controls smaller ground-mount DMSs in the remote and mountainous areas of the state. (See http://www.precisionsolarcontrols.com/.) It has had numerous maintenance issues with these signs and plans to replace them as funding becomes available. In the past, CDOT also used Dambach and Display Solutions DMSs, but these are no longer in operation because of maintenance costs. See the following article for more information about maintenance: http://www.enroutetraffic.com/pdfs/ITS%20AmericaMaintenance%20Costs%20of%20Dynamic%20Message%20Signs%20_1_.pdf
    a. **Operations:** Signs are managed and operated by one of three Operations Centers (there is redundancy between centers), including the Colorado Transportation Management Center (CTMC) and two Tunnel Operations centers at Eisenhower Tunnel and Hanging Lakes Tunnel as well as one City center located in Colorado Springs. All four centers use CTMS software that has specifically been developed to operate and maintain DMSs and all other aspects of real-time or near real-time traveler information. This software was custom developed by CDOT using Java, and runs on LINUX (Redhat.) It operates everything but the closed circuit televisions. The CTMC is the primary clearinghouse for traveler information and posts various types of messages that affects otherwise normal traffic patterns on DMSs, including inclement weather, chain law, road

closures, road construction and trip travel times. CTMC also posts Amber Alerts or DMSs. **CDOT is currently using manual variable speed limit signs to slow traffic at or near truck chain-up stations.** In addition, CDOT is currently working on an **Active Traffic Management** (ATM) system, which will introduce the first automatic variable speed limits on two segments of I-70 near the Eisenhower Tunnel. This system is supposed to come online in 2011. In the first phase of this project, speed limits will be changed manually based on the pavement condition and visibility by CDOT's maintenance forces; however, future enhancements will include a **fully automated system that adjusts the speed limits based on the information it receives from the weather stations**. It will always have a manual override option.

i. CDOT variable message sign usage policy: http://www.cotrip.org/its/whitepapers/VMSPolicy-Final.pdf

b. **Remote Management:** Signs can be operated automatically (programmed to come on and go off). The signs are generally operated remotely via CTMS from one of the operations centers—some automation is present as CDOT posts estimated travel times on certain corridors.

c. **Format and Language:** Depends on the application and the size of the DMS. In general, CTMC staff tries to disseminate the information through postings on a single panel. However, in some cases such as road constructions or Amber Alerts, a second plan may be used.

d. **Enforceability:** At the present time, the only "regulatory" or legally enforceable DMSs are the ones on I-25 HOV (high occupancy vehicle) lanes in Denver and chain law information.

3. **Non-Electronic Signs:** CDOT uses non-electronic signs where DMSs or blank-out signs are not available.
   a. **Language:** In general they are 48"X48" fold-up signs used for road closures in conjunction with gates on on-ramps, detours, rock falls and "turn on headlights" around tunnels.
   b. **Operations:** Depending on the weather, the maintenance crew makes the call on when the signs are deployed. They also decide on when the signs are folded back up. The workers leave their vehicles to deploy signs. They follow various CDOT mandated safety procedures. The following links partially address this topic:
   http://www.dot.state.co.us/WorkplaceSafetyManual/sogscodealpha4.cfm
   (scroll down to 03132.02 Traffic Variable Message Sign, Permanent -- Maintenance and Repair)
   c. http://www.dot.state.co.us/WorkplaceSafetyManual/sogscodenumerical2.cfm
   (scroll down to 1903.00 Variable Message Board, Portable)
   d. http://www.dot.state.co.us/Traffic_Manuals_Guidelines/Work_Zones/Work_Zone_Materials.asp
   e. **Remote Management:** No.
4. **Other Technologies:** Significant, federally funded ITS-based efforts (Vehicle Infrastructure Integration) are under way to disseminate crucial roadway alerts to the motorists in their vehicles. Please refer to FHWA's web site for more information:
   http://search.fhwa.dot.gov/search?q=vehicle+infrastructure+integration&ie=&site=fhwa_web&output=xml_no_dtd&client=fhwa_web&lr=&proxystylesheet=fhwa_web&oe=

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1. **Tools:** NDOT uses regulatory signs alongside the road as the primary notification for chain requirements. Once chain controls are in place on the roads, maintenance personnel advise operations center staff who then input information into a 511 traveler information system, which goes out to the public via a web site (http://www.nevadadot.com/traveler/roads/) and phone line. Where there are appropriate DMSs in place, a corresponding message is posted (for example, "Chains required XX miles ahead"). NDOT also uses a highway advisory radio (HAR) system in place on certain routes, and the appropriate 511 information (which includes chain controls) is automatically sent out to the HAR sites.
2. **Changeable Message Signs:**
   a. **Operations:** DMSs in Nevada are primarily operated from operations centers. NDOT has purchased the KITS software developed by Kimley Horn & Associates and used by a number of regions for freeway and arterial management. (See http://www.kimley-horn.com/kha/disciplines.asp?menuID=209 and http://www.kimley-horn.com/kha/PDFs/KITS%20tech%20doc.pdf.) NDOT refers to the software as the Central System Software and uses it to control field devices. Chain control information is posted when appropriate. On Highway I-80, NDOT works with Caltrans, and Caltrans can post information on

three westbound DMSs in the Reno area to warn drivers of driving conditions over Donner Pass in California. Messages are coordinated betweens Caltrans and NDOT operations centers.

   b. **Remote Management:** The permanently mounted signs are controlled at the operations centers but can be programmed on-site, if needed. Portable signs (used more in emergency situations) are programmed on-site.
   c. **Format and Language:** Generally "Chains or Snow Tires Required XX Miles Ahead."
   d. **Enforceability:** Signs are considered advisory and auxiliary messages, and the regulatory signs are enforceable. Nevada chain requirements are available at http://www.nevadadot.com/traveler/pdfs/tractionControl.pdf

3. **Non-Electronic Signs:** Historically these signs were turnstiles that had to be unlocked and turned manually by maintenance personnel when chain controls were needed. **NDOT has upgraded most installations to a regulatory sign with yellow flashers and a yellow "when flashing" banner as an improved safety measure for its personnel.** The signs were designed to communicate via an 800-MHz radio system, and the plow drivers and other maintenance personnel use DTMF tones on the radio (in all maintenance vehicles or via a handheld radio) to toggle the signs on and off. NDOT is in the second phase of this upgrade involving **integrating these signs into its Central System Software**, which controls all field devices (DMS, ramp meters, CCTV, etc.). This effort will allow control of the signs from operation centers. NDOT has also improved roadside safety by adding chain-up areas just after chain control points in many areas.
   a. **Language:** See Nevada Chain Control Signs documentation, Appendix A, of this investigation.
   b. **Operations:** Signs are changed when crews determine it is appropriate. During a weather event, employees are out patrolling and dealing with ice and snow removal and make changes as needed.
   c. **Remote Management:** If old-style signs are still in place, then no. NDOT is replacing these signs with flashing signs to improve safety.
4. **Other Technologies:** I-80 at the California border poses difficulties for drivers during winter events. Caltrans tries to mitigate some of the problems by restricting trucks to non-peak times. (For example, many Californians drive to Lake Tahoe, NV, on Friday evenings for skiing and return on Sunday.) Because cars and trucks don't mix well, trucks are held back during the highest volume periods. Caltrans will hold truck traffic (on both the Nevada and California sides) during these times as well as when road conditions are not conducive to trucks. Crews also perform a truck chain check in advance of the pass (making sure trucks are carrying adequate chains) when chains may be necessary because of the weather. Because there is inadequate truck parking in the Reno area, NDOT works to provide as much advance notice of closure or truck holds along I-80 in Nevada, as well as Utah and Wyoming, to prevent trucks from backing up at the state line.

North Dakota DOT
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1. **Tools:** North Dakota does not have chain requirements. It provides a web-based road condition map (http://www.dot.nd.gov/travel-info/) and a telephone 511 service for the public. During events NDDOT has several means of informing the public: Highway patrol and local sheriffs can contact radio stations; media will ask DOT and highway patrol for TV and radio interviews about conditions; and DOT roadside message boards are used for emergency conditions. NDDOT services are provided by Meridian Environmental Technologies in North Dakota (http://www.meridian-enviro.com/).
2. **Changeable Message Signs**
   a. **Operations:** DMSs in North Dakota are managed and operated either from a central location for statewide events or from district offices for local events. DMSs (permanent and portable) are all controlled from a single software system (Intelligent Control). This system works well for the variety of sign manufacturers used by NDDOT. The signs are not integrated into any other systems.
   b. **Remote Management:** Signs are operated remotely.
   c. **Format and Language:** The content of the signs consists of travel information. NDDOT tries to get the information in one phase if possible, but some content requires multiple phases (no more than two), especially on the portable DMSs.

d. **Enforceability:** DMS messages are not enforceable. NDDOT's law on tire chains/studs is:

39-21-40. Restrictions as to tire equipment.

1. Every solid rubber tire on a vehicle must have rubber on its entire traction surface at least one inch [2.54 centimeters] thick above the edge of the flange of the entire periphery.

2. No person may operate or move on any highway any motor vehicle, trailer, or semitrailer having any metal tire in contact with the roadway.

3. No tire on a vehicle moved on a highway may have on its periphery any block, stud, flange, cleat, or spike or any other protuberance of any material other than rubber which projects beyond the tread of the traction surface of the tire, except that it is permissible to use farm machinery with tires having protuberances which will not injure the highway, and except also that it is permissible to use tire chains of reasonable proportions. It is also permissible to use, from October fifteenth to April fifteenth, pneumatic tires which have metal studs which do not project more than one-sixteenth of an inch [1.59 millimeters] beyond the tread of the traction surface of the tire, except that it is permissible to use such tires on school buses at any time during the year.

3. **Non-Electronic Signs**
   a. **Language:** NDDOT has static signs with flashing beacons at bridges to warn of possible icing conditions and use for flooding conditions. Text is typically "Watch for ice on bridge" or "Watch for water on road." It also has permanent signs informing the public of its 511 system.
   b. **Operations:** Static signs are usually up for long periods and don't require much attention. These signs are managed by the districts. Personnel do have to leave their vehicles to flip or swing signs.
   c. **Remote Management:** No.
4. **Other Technologies:** Cell phone text alerts and similar notifications.

Oregon DOT

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1. **Tools:** ODOT uses a variety of signage, including PVMSs, VMSs and static signs. It also posts chain requirement information on its traveler information web site (http://tripcheck.com), and on its 511 phone system.
2. **Changeable Message Signs**
   a. **Operations:** The determination to activate a chain condition is determined by the district manager. If there is a VMS sign at the location, the district manager's office contacts the regional traffic operation center and requests that the appropriate chain condition message be placed on the sign. If the district uses a portable VMS sign, it may post the predetermined chain condition messages in the field or have the operation center post it. ODOT also has static signs that can be manually rotated to the appropriate condition. The local maintenance workers must change the sign manually.
   b. **Remote Management:** The signs are not automated. VMS, PVMS and CMS signs are remotely controlled from the regional traffic operation center.
   c. **Format and Language:** See Appendix B for static sign and VMS sign information.
      i. For PVMSs, the messages are:
         1. SNOW ZONE CHAINS REQUIRED ALL VEHICLES
         2. SNOW ZONE CHAINS REQUIRED UND 10K TRACTION TIRES OK
         3. SNOW ZONE CHAINS REQUIRED OR TRACTION TIRES
   d. **Enforceability:** The VMS signs that display the message as shown in Appendix B of this investigation are enforceable. Messages on PVMS are not.
3. **Non-Electronic Signs**
   a. **Language:** See Appendix B.
   b. **Operations:** Varies. Workers have to leave their vehicle to rotate manually changeable signs. Field workers have to park and leave their vehicles as part of their normal job duties.

c. **Remote Management:** ODOT also has a few remotely controlled drum signs that are capable of displaying the chain conditions. These signs are controlled from the regional traffic operation center.

4. **Other Technologies:** ODOT has built a rotating drum sign in-house. Skyline Products has also built ODOT drum signs. A consultant designed and a local panel shop fabricated several drum signs in the past for ODOT. Most states just use their VMSs. Some, like Caltrans, have film module signs that could be used for chain control notifications. Skyline Products makes the film module products, which are usually used for the gas station industry.

Related National Guidance

We highlight below reports recently issued by FHWA, NCHRP and TRB with regard to CMSs and ITS/Advanced Traveler Information Systems (ATISs).

Changeable Message Signs

Manual on Uniform Traffic Control Devices, Section 2A.07—Changeable Message Signs
FHWA, 2009.
http://mutcd.fhwa.dot.gov/htm/2003r1r2/part2/part2a.htm
Highway and transportation organizations are encouraged to develop and experiment with changeable message signs and to carefully evaluate such installations so that experience is gained toward adoption of future standards.

Impacts of Using Dynamic Features to Display Messages on Changeable Message Signs
FHWA Report No. FHWA-HOP-05-069, August 2005.
http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Final%20Research%20Report%20091905.pdf
This study compares the effects on motorists of static, flashing and dual-phase CMSs, and recommends changes to the MUTCD based on its results. Results show that while flashing messages took no longer to read than static messages, drivers unfamiliar with the signs may not comprehend them as well. Dual-phase messages took significantly longer to read, and drivers did not comprehend them as well.

Portable Changeable Message Signs Handbook
FHWA Report No. FHWA-RD-03-066, 2003.
http://www.tfhrc.gov/pavement/ltpp/reports/03066/index.htm
This handbook presents basic guidelines for the use of portable CMSs, including when to use them, screen characteristics, message design, portable CMS placement and other operational issues.

Uniform Traffic Control and Warning Messages for Portable Changeable Message Signs
FHWA Report No. FHWA-RD-95-173, March 1996.
http://www.fhwa.dot.gov/tfhrc/safety/pubs/95173/95173.PDF
This document recommends CMS message content for various situations.

Intelligent Transportation Systems/Advanced Traveler Information Systems

Traveler Information Systems in Europe
FHWA Report No. FHWA-PL-03-005, August 2003.
http://international.fhwa.dot.gov/travelinfo/
This study is a scan of eight cities in Spain, Germany, Sweden, Scotland and England that have established traveler information products and services for all transportation modes. The study of European practices will help U.S agencies develop traveler information services and other systems to help travelers make informed decisions about their schedules, modes and routes of travel. These include traveler information products that are coupled with weather, location, event and emergency information. The scan team evaluated information content, customer needs, business/cost recovery models, technology applications, consistency and standards, and legal and policy issues, and made specific recommendations for applications in the United States.

Real-Time Traveler Information Systems
NCHRP Synthesis Report No. 399, February 2009.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_399.pdf
Real-time traveler information systems have proven to be effective at informing travelers about the circumstances affecting their trips, including weather and road conditions. A variety of traveler information systems exist, including telephone support phone numbers, Internet dissemination sites, in-vehicle or handheld devices able to receive notices and alerts, and field devices informing travelers while en route. Operations of these traveler information dissemination systems may be performed by either public or private agencies. The purpose of this synthesis was to gather and report on the state of the practice for real-time traveler information delivery. The study conducted within this synthesis project involved four key data collection processes:

- An online survey of agencies currently operating traveler information systems.
- Observations and testing of existing traveler information systems.
- A literature review of documented surveys, evaluations and benefit-cost analyses of traveler information systems.
- Interviews and discussions with industry experts from public and private agencies.

Covered information sources included:

- Public-operated 511 phone systems are available free of charge to callers; 42 public-operated 511 phone systems in 33 states offer coverage to 128 million Americans (47 percent of the population). Public 511 phone systems are available to anyone with access to a telephone.
- Public-operated traveler information web sites are available free of charge to users. Each of the 50 states offers some form of traveler information web site.
- Field devices such as DMSs—visible to drivers through the windshield and dashboard (which can be considered to include the line of sight visible out the front windshield) at no cost to drivers and without any need for devices. Highway advisory radio is another example of a field device that allows travelers to hear reports from standard AM or FM radios.
- Private sector traveler information providers offer web, phone or special devices (for example, navigation system or handheld devices) primarily in metropolitan areas; some products are now expanded to include rural areas.
- Private-operated news and media outlets disseminate traffic, weather and event information over radio and television broadcasts with the majority of traffic and event information describing metropolitan areas.

Related Research

The following reports, papers and articles document recent research on and state implementation of CMSs and ITS/Advanced Traveler Information Systems.

Changeable Message Signs

The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable Message Signs—Phase II, **Minnesota Department of Transportation**, Report No. MN/RC 2008-27, August 2008.
http://www.lrrb.org/pdf/200827.pdf
Researchers evaluated how lowering the complexity and ambiguity of CMS messages would affect driver behavior and traffic flow. Researchers used a driving simulator to evaluate:

- The validity of simulator speed-reduction data in comparison to real-world data.
- Driver attitudes toward the utility of CMSs.
- The efficiency of Mn/DOT's Regional Transportation Management Center management of CMS deployments.

Results showed that clarifying message content could lead to significant improvements in their safety and effectiveness—with significantly more drivers taking the advice they provide.

VMS—Variable Message Signs: A Literature Review, Danish Road Directorate, Report No. 570A, 2007.
http://www.vti.se/EPiBrowser/Publikationer/R570ASwe.pdf
This literature review is primarily aimed at describing studies that deal with the interactions between driver behavior and VMSs. References consist of studies published between 2000 and 2005—in Europe or about European conditions. Topics include VMS effects on driver behavior, driver attitudes, VMS design, driver understanding and recall of VMS, related accidents and regulations concerning VMS. The literature review is supplemented by a behavioral background and recommendations from a behavioral science perspective.

Amber Alert, Disaster Response and Evacuation, Planned Special Events, Adverse Weather and Environmental Conditions, and Other Messages for Display on Dynamic Message Signs, Texas Transportation Institute, Report No. FHWA/TX-06/0-4023-4, October 2005.
http://tti.tamu.edu/documents/0-4023-4.pdf
This study evaluates the best DMS designs for communicating Broadcast Emergency Response (AMBER) alerts; disaster response and evacuation (flooding, hurricane evacuation and terrorist attacks); planned special events; and adverse weather and environmental conditions. Researchers conducted four focus group studies in six cities in Texas to discuss driver information needs, and used focus group results as the basis for more extensive human factors laboratory studies subsequently conducted in six cities in Texas. Laboratory study methodologies included laptop computer programs, maps, card selection process and a driving environment simulator. This report contains specific findings and recommendations concerning message design issues for DMSs for each of the topic areas identified.

Driver Acceptance of Weather-Controlled Road Signs and Displays, P. Rama, J. Luoma, *Transportation Research Record,* No. 1573, 1997, pages 72-75.
Abstract: http://pubsindex.trb.org/view.aspx?id=577375
This study was designed to investigate driver acceptance of the weather-controlled road signs and displays on Finland's southern coast, where road condition changes are particularly frequent and rapid. Researchers studied 36 variable speed limit signs and five variable message displays that warned drivers of hazardous conditions on a 14-km-long experimental road section. Local weather and road surface conditions were monitored automatically from road weather stations and used to automatically calculate and display appropriate speed limit and slippery road signs, as well as temperature displays. Results showed that most drivers recalled the variable signs very well, considered them useful and considered posted speed limits to be appropriate. However, only a relatively small proportion of drivers said that the slippery road sign or temperature displays influenced their behavior.

Motorist Information Needs and Changeable Message Signs for Adverse Winter Travel, S. G. Pouliot, E. M. Wilson, *Transportation Research Record,* No. 1403, 1993: pages 45-48.
Abstract: http://pubsindex.trb.org/view.aspx?id=383942
The purpose of this study was to evaluate motorist information needs during adverse winter travel conditions and apply this information to changeable message signs. Researchers studied local commuters and interstate truck traffic along Interstate 80 in southeast Wyoming via field surveys and laboratory studies, and used results to recommend changeable sign messages for display during adverse weather travel conditions. This study includes a chronological history of changeable message signs and guidelines for their use from the early 1950s on.

Winter Weather Operations

Concepts for Managing Freeway Operations during Weather Events, Texas Transportation Institute, Report No. FHWA/TX-07/0-5278-1, February 2007.
http://tti.tamu.edu/documents/0-5278-1.pdf
ftp://ftp.dot.state.tx.us/pub/txdot-info/rti/psr/5278.pdf
The goal of this research was to help the Texas Department of Transportation (TxDOT) develop a structured, systematic approach for managing traffic during common weather events that affect traffic operations, such as fog, high winds, heavy rains, and snow and ice storms. Researchers conducted a survey of selected TxDOT districts to determine what information traffic management center (TMC) operators needed to manage traffic operations during weather events. They also conducted a literature review to assess systems and technologies that other states have deployed to manage traffic during weather-related events, as well as the current state of weather-related detection and monitoring technologies. Finally, they used historical traffic detector and weather information to assess the impact of different weather events on traffic operations. Researchers then analyzed this data to develop a concept of operations for how TMC operators should respond to different types of weather-related events, including limited visibility conditions, ponding and flash flooding, high winds, severe thunderstorms, tornados and winter storms. The

report includes a catalog of advisory, control and treatment strategies (or ACTS); criteria for implementing different types of responses; and proposed messages for use on DMSs. Researchers also provided a framework that TxDOT can use to integrate weather information from the National Weather Service and other private weather providers into its TMC operations software.

Advanced Traveler Information Systems and Intelligent Transportation Systems

Maine Statewide Deployment and Integration of Advanced Traveler Information Systems, Nathan P. Belz, Per Erik Garder, Transportation Research Board 88th Annual Meeting, 2009.
http://pubsindex.trb.org/view.aspx?id=881243
Researchers evaluated components of Advanced Traveler Information Systems (ATIS) for their effects on motorists in Maine, including Dynamic Message Signs, Variable Speed Limit Signs (VSLS) and Overheight Vehicle Detection (OHVD) systems. They collected speed data to determine the effects of VSLSs on traveler speed during storms of varying intensity, evaluated an OHVD system in Bangor, and identified institutional issues and barriers associated with Intelligent Transportation System (ITS) deployment. Results show that drivers will not slow down to posted speeds unless they feel conditions are appropriate, possibly because VSLSs are not enforced and that the OHVD system is an effective deterrent. Institutional issues included long-term funding commitments for ATIS, acceptable messaging, integration of information databases, inter-agency coordination, enforcement and education of the public.

Information Flow System for Winter Service, Richard J. Nelson, *Routes/Roads*, Vol. 342, 2009, pages 80-89.
Abtract: http://ntlsearch.bts.gov/tris/record/tris/01145240.html
This article describes how technological advances such as remote sensing devices have allowed near-real-time data on local weather and road conditions, allowing the forecasting of future road conditions and the development of decision-making support systems and other tools for winter service provision optimization.

Nebraska Department of Roads: An Example of Statewide Incident and Transportation Management, Daniel A. Lukasik, Jon Ogden, Jim Schmailzl, Steven Worley, Steven McDonald, 15th World Congress on Intelligent Transport Systems and ITS America's 2008 Annual Meeting, 2008.
Abstract: http://ntlsearch.bts.gov/tris/record/tris/01144583.html
This study describes the deployment of an affordable Advanced Transportation Management System (ATMS) in Nebraska. The system introduces a web-based software application that allows any NDOR staff person to monitor roadway situations, weather conditions, travel speeds, incidents, planned construction activities and roadway assets while simultaneously being able to operate roadway message signs, surveillance cameras and in the future automated roadway/ramp gate closure systems. The deployment of the system did not interfere with the operation of independent districts and state functional units, and is a model for the implementation of a system that utilizes technologies and an architecture that enables common statewide incident and traffic management, without breaking the bank for the deployment of elaborate communication, computer and software technologies.

Advanced Traveler Information System in Santa Clarita, CA, Sri Chakravarthy, Andrew Yi, Cesar Romo, Jean Fares, Connie Li, 15th World Congress on Intelligent Transport Systems and ITS America's 2008 Annual Meeting, 2008.
Abstract: http://ntlsearch.bts.gov/tris/record/tris/01137181.html

This paper describes the City of Santa Clarita's identification and evaluation of technologies for implementing an Advanced Traveler Information System locally to provide travelers with detailed information about traffic incidents, the weather, construction and special events. This study outlines a step-by-step Phase II of this project involving the installation of detection devices, Closed Circuit Televisions (CCTVs), portable CMS, Fiber Optic Interconnect Gap Closure and a Traveler Information web site to disseminate information about the city streets and the adjacent freeways to traveler in the city. The web service and radio will provide real-time traffic information to travelers concerning travel time, weather, incidents and construction. In the future, this system could be linked with other ATIS through California Department of Transportation, Los Angeles County, and other local agencies.

Online Tools and Resources—Chain Control Laws

The following **Online Tools** provide information about chain control laws nationwide:

- **Pennsylvania Motor Trucking Association, "State Chain Laws"**
  http://www.pmta.org/documents/ChainLaws-November2009.pdf

  This useful summary of U.S. and Canadian chain law requirements is organized by state/province in a single document, current as of November 2009.

- **TireChainsRequired.com**
  http://www.tirechainsrequired.com/laws.html

  This web site includes an interactive map for finding the precise chain requirement legal code for every state, as well as supplemental links to FAQs, manuals and other information.

- **TireChains.com**
  http://www.tirechain.com/

  This web site includes links to both chain requirements and real-time information on state road conditions; it also alerts users when state chain laws change.

- **The Trucker's Report**
  http://www.thetruckersreport.com/chain-law-information/

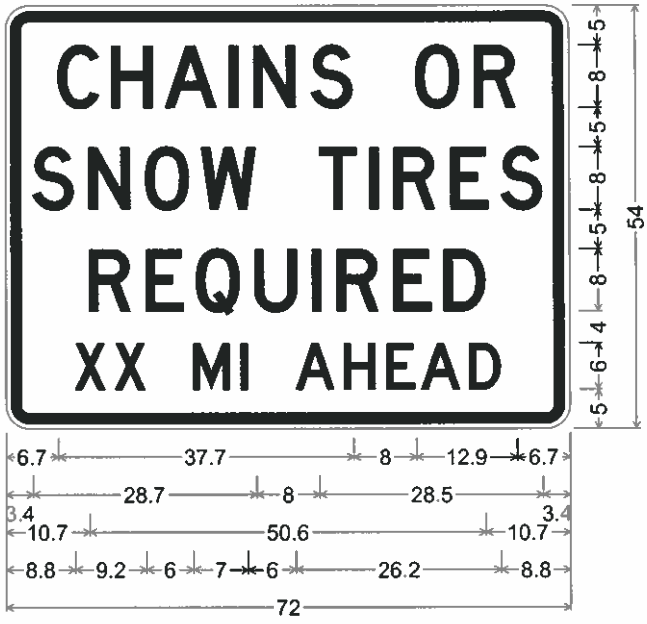
  This site summarizes chain requirements for trucks, identifies difficult passes and provides trucking association web site links for each state.

- **The American Driver**
  http://www.theamericandriver.com/files/info/chain_up_info.html

  This summary lists truck chain requirements for each state on a single page, and uses a diagram to show which tires on an eighteen-wheeler must be chained for a given state. It also includes an FAQ.

RNV7-1_72x48;
3.0" Radius, 1.3" Border, 0.8" Indent, Black on White;
"CHAINS OR" D; "SNOW TIRES" D; "REQUIRED" D;

NEVADA DOT	STATE OF NEVADA DEPARTMENT OF TRANSPORTATION STANDARD SIGN SUPPLEMENT 2006	CHAINS OR SNOW TIRES REQUIRED SCALE: 1/2" = 1'-0"	SIGN NUMBER RNV7-1



RNV7-2_72x54;
3.0" Radius, 1.3" Border, 0.8" Indent, Black on White;
"CHAINS OR" D; "SNOW TIRES" D; "REQUIRED" D;
"XX MI AHEAD" D;

NEVADA DOT	STATE OF NEVADA DEPARTMENT OF TRANSPORTATION STANDARD SIGN SUPPLEMENT 2006	CHAINS OR SNOW TIRES REQUIRED XX MILES AHEAD SCALE: 1/2" = 1'-0"	SIGN NUMBER RNV7-2

1.8" Inner border Black, 6.0" Radius, 1.5" Outer border, White on Yellow;
[WHEN FLASHING] Black D 50% spacing;
RNV7-3_84x72;
6.0" Radius, 1.8" Border, 1.5" Indent, Black on White;
[CHAINS OR] D; [SNOW TIRES] D; [REQUIRED] D;

NEVADA DOT	STATE OF NEVADA DEPARTMENT OF TRANSPORTATION STANDARD SIGN SUPPLEMENT 2006	WHEN FLASHING CHAINS OR SNOW TIRES REQUIRED SCALE: 1/2" = 1'-0"	SIGN NUMBER RNV7-3

RNV7-4R_60x48; 3.0" Radius, 1.3" Border, 0.8" Indent, Black on White;
"CHAIN" C; "INSTALLATION" C; "AREA ONLY" C; Standard Arrow Custom 18.0" X 6.0" 0°;

NEVADA DOT	STATE OF NEVADA DEPARTMENT OF TRANSPORTATION STANDARD SIGN SUPPLEMENT 2006	CHAIN INSTALLATION AREA ONLY SCALE: 1" = 1'-0"	SIGN NUMBER RNV7-4 R,(L)

APPENDIX B
OREGON SIGN REGULATIONS

734-017-0015
Use of Chains or Traction Tires

A Department of Transportation District Manager or persons authorized by a District Manager shall authorize the posting of appropriate signs and determine when weather conditions require the following:

(1) Chains or traction tires must be carried but are not required to be used;

(2) Chains to be used on vehicles with a rated gross vehicle weight (GVW) of 10,000 pounds or less that are towing and single drive axle vehicles with a rated gross vehicle (GVW) over 10,000 pounds.

[*(2)*]**(3)** Chains must be used on vehicles towing or with a rated gross vehicle weight (GVW) over 10,000 pounds;

[*(3)*]**(4)** Chains or traction tires must be used on all vehicles except those vehicles exempt in ORS 815.145 and Division 17 rules;

Stat. Auth.: ORS 184.616, ORS 184.619, and ORS 815.045
Stats. Implemented: ORS 815.045 and ORS 815.140

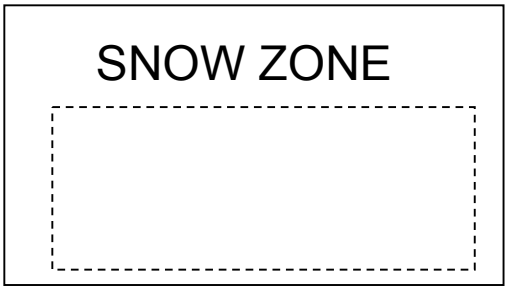
734-017-0025
Signs

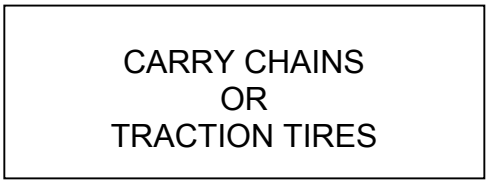
Signs to be used to post areas requiring "chains" or "chains or traction tires" are shown in detail in [*Exhibit 2, Signing*] **Exhibit 2-A, Signing for Post Mounted Signs and Exhibit 2-B, Signing for Variable Message Signs**.

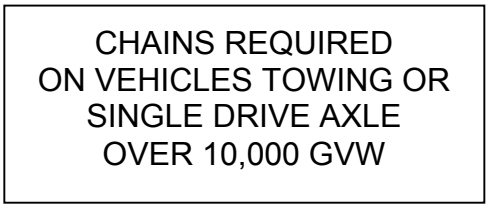
Stat. Auth.: ORS 184.616, ORS 184.619, and ORS 815.045
Stats. Implemented: ORS 815.045

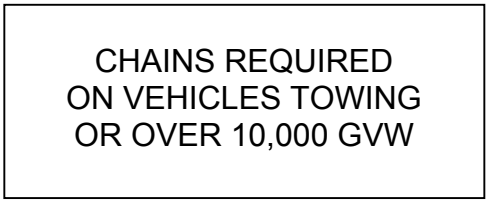
EXHIBIT 2-A
(734-017-0025)

Signing for Post Mounted Signs









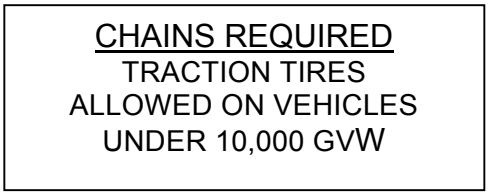


EXHIBIT 2-B
(734-017-0025)

Signing for Variable Message Signs

Panel 1	SNOW ZONE
Panel 2	Carry Chains Or Traction Tires

Panel 1	SNOW ZONE Chains Reqd When
Panel 2	Towing Or Single Drive Over 10000

Panel 1	SNOW ZONE Chains Required On
Panel 2	Vehicles Towing or Over 10000

Panel 1	SNOW ZONE Chains Required
Panel 2	Tract Tires Allowed Under 10000