Highway Worker Safety: Technologies

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 an ongoing effort to improve safety, Caltrans is investigating innovative practices and technologies to protect construction and maintenance workers on California's highways. The recently formed Safety Innovation Working Group will provide leadership and commitment to improving roadway safety across California through proven and ready-to-be-deployed innovations and technology, with a focus on three areas:

- Education and outreach (internal and external).
- Policy and legal options.
- Equipment such as warning devices and barriers to keep workers safe on the roadway.

This investigation focuses on the availability and current use of technologies in work zones and during highway/roadside maintenance activities to:

- Physically protect workers while they are on highway sites.
- Warn workers of approaching vehicles or other hazards.
- Reduce worker exposure to hazards, such as by shortening the time needed for them to be on the roadway.

Caltrans is interested in obtaining design specifications used by other states and/or recommended by national and industry groups related to these technologies, including information on portable barriers, warning lights, electrical cabinets, changeable message signs (CMSs), pothole patchers, i-cones and automated flagger assistance devices.

Key questions to address include:

- What technologies are available today?
- What promising technologies are in development?
- How are the safety benefits and costs being quantified by organizations using these technologies?

Summary of Findings

We present our findings in seven topic areas, summarized below.

National Guidance

- The Federal Highway Administration (FHWA) and other national organizations offer a great deal of guidance on work zone safety procedures and equipment, particularly in the area of intelligent transportation systems (ITS). ITS constitutes a considerable area of ongoing research at universities and transportation agencies, and though its primary application in work zones is to reduce congestion, it can also be used to more directly improve worker safety.
- FHWA's *Work Zone Best Practices Guidebook* includes descriptions of traffic management technologies by topic and state, including specifications for barriers, autoflaggers, lighting, rumble strips and other tools for several states.
- NCHRP has published three reports related to this inquiry, providing some specifications for work zone devices and strict regulations as to their crashworthiness, a factor relevant to worker safety.

Current Caltrans Practices

We have provided some information on current Caltrans standards for work zone devices, including the California Manual on Uniform Traffic Control Devices (CA MUTCD) barrier specifications and 2008 California Strategic Highway Safety Implementation Plan's Safety Needs Action Plan to address work zone safety relevant to this inquiry.

Other State Practices

We have provided specifications for particular areas of work zone safety where available, including barrier and other specifications from Illinois and Iowa, ITS guidelines from North Carolina and Washington, and a variety of specifications from Minnesota. Additional state-specific specifications are provided under the entry for FHWA's *Work Zone Best Practices Guidebook* (see the National Guidance section), and more state information should be available in the final version of this document, which will include the results of a survey of state DOTs.

California Initiatives and Partnerships

California and regional research organizations such as the University of California, Davis (UC Davis) Advanced Highway Maintenance and Construction Technology Research Center are addressing highway worker safety technology issues on an ongoing basis. We have reported here on their work testing barriers and intrusion alarms.

Other Recent Research

Recent studies include the development of iCones for traffic information gathering, speed display trailers and improvements on other elements of a work zone ITS strategy.

Research in Progress

We have included references to ongoing studies on mobile barrier systems, ITS, speed trailers, CMSs and other tools.

Industry Resources and Other Organizations

Lastly, we have provided information on a few industry groups and work zone technology vendors, which along with the AASHTO and TRB committees listed provide touchstones for further contacts with experts in the area of current and cutting-edge highway worker safety technology solutions.

National Guidance

FHWA Work Zone Mobility and Safety Program, Federal Highway Administration.
http://www.ops.fhwa.dot.gov/wz/
This page includes information on work zone safety best practices, design and construction strategies, performance measurement, and ITS and technology. Some specific resources found through this page and elsewhere on the FHWA site include the following:

Innovative Technology Workshops
http://www.ops.fhwa.dot.gov/wz/workshops/sheet3.htm
This page provides several abstracts and presentations (with presenter contact information) for specific topics related to work zone safety, including these related to technology:

- "Intrusion Devices—New and Emerging Technology in Worker Safety," which alerts workers of a vehicle that has penetrated the work zone. Three systems discussed in detail are the Safety Line SL-D12 Work-Zone Intrusion Alarm, the SonoBlaster! "Dual Alert" Work Zone Intrusion Alarm and Logic Systems' Wireless Warning Shield.
  http://www.ops.fhwa.dot.gov/wz/workshops/originals/Ken_Kochevar_ID.ppt

- "Safer Work Zones Through ITS," which describes safety measures deployed by Florida DOT during an eight-year highway construction project, including safety goals and evaluation techniques for each component of the management system.
  http://www.ops.fhwa.dot.gov/wz/workshops/originals/Tahira_Faquir.ppt

- "The Major Rehabilitation of the Eastbound McClugage Bridge," which provides a case study on an Illinois bridge rehabilitation, including the safety technologies used: a moveable barrier system, an automated real-time traffic control system and video surveillance.
  http://www.ops.fhwa.dot.gov/wz/workshops/originals/George%20Ryan%20McClugage.ppt

- "Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center." (See "California Initiatives and Partnerships" on page 9 of this report.) This presentation provides an overview of techniques to reduce worker exposure, such as automated cone placement via the AHMCT Cone Shooter, automated crack sealing and a debris vacuum to enable trash removal without a worker outside a vehicle. Solutions presented that are in development include worker assistance tools to automate lifting and landscaping as well as truck-mounted falling-weight deflectometers and embedded/fly-by/thrown sensors for bridge inspection. There is some mention of additional services such as work zone warning systems (intrusion alarms, radio interrupt systems and improved backup alarms) and keep-in-vehicle technologies (pavement sign painters, shoving blades and grapplers for existing vehicles).
  http://www.ops.fhwa.dot.gov/wz/workshops/originals/bosler.ppt

ITS Resources
http://www.ops.fhwa.dot.gov/wz/its/index.htm.
This page includes links to several reports and case studies, for example, on portable CMSs, automated work zone information systems and dynamic lane merge systems.

FHWA ITS In Work Zones Fact Sheet, Federal Highway Administration, 2003.
http://cms.transportation.org/sites/ssom/docs/ITS%20Fact%20Sheet.pdf
This two-page document provides examples of how ITS technologies are being used to anticipate and mitigate congestion caused by highway work zones, which in turn improves safety. Examples include the following:

- Dynamic lane merge systems facilitate safe traffic merging on approaches to work zones.
- Speed advisory detection and display systems encourage vehicles to slow down.
- Variable speed limit systems detect traffic and weather data to calculate and display condition-responsive speed limits on signs and can provide information to CMSs and other driver resources (such as web sites and radio alerts).

The document describes case studies from North Carolina, Illinois and Michigan, and provides links to additional resources.

Work Zone Best Practices Guidebook, Federal Highway Administration, 2007.
http://ops.fhwa.dot.gov/wz/practices/best/bestpractices.htm
This document indexes by topic and state short descriptions of traffic management technologies (http://ops.fhwa.dot.gov/wz/practices/best/topindex.asp?ID=110), equipment (http://ops.fhwa.dot.gov/wz/practices/best/topindex.asp?ID=97) and worker safety (http://ops.fhwa.dot.gov/wz/practices/best/topindex.asp?ID=124). For each item, contacts are listed at a state agency for more information about the particular technology. Potentially relevant entries are:

- Illinois and Indiana uses of Quick Change Movable Barriers.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=288&from=topindex&Category_ID=97

- Michigan's use of halogen slow/stop paddles to illuminate work zones and warn motorists, especially during daytime hours.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=301&from=topindex&Category_ID=97

- Minnesota's use of a remotely operated autoflagger to remove flaggers from the traffic lane, increasing worker safety.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=140&from=topindex&Category_ID=97

- North Carolina's use of water-filled barriers in place of temporary precast concrete barriers or nonmetallic drums; the primary benefit here is increased safety for travelers in the event of a crash, not for workers.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=303&from=topindex&Category_ID=97

- Ohio's use of 42-inch flexible cones ("Grabber-Cones," pictured at http://www.roadtech.com/cones_grabber.html), which are designed for quick installation, reducing worker exposure during short-term, nighttime projects including maintenance.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=204&from=topindex&Category_ID=97

- Ohio's use of rumble strips at the beginning of work zones.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=206&from=topindex&Category_ID=110

- Missouri's improved warning lights on vehicles to increase the visibility of vehicles, for example, in work zones.
  http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=273&from=topindex&Category_ID=124

- Minnesota's Portable Traffic Management System — Smart Work Zone, which uses traffic detection cameras and CMSs in and around the work zone area. http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=159&from=topindex&Category_ID=110

- FHWA and several states are also listed with similar systems to Minnesota's. Their primary goal is reducing congestion, which indirectly improves safety but is not the focus of this Investigation.

Also listed are some uses of technology by Caltrans, which we are including to help determine whether action should be taken to internally review or increase their use:

- Automated Cone Machine for placement and retrieval, which reduces worker exposure when placing cones. http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=16&from=topindex&Category_ID=97

- Portable concrete barrier (K−rail) connection, which improves the barrier between traffic and workers and reduces worker exposure from maintenance/replacement of damaged sand barrels. http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=21&from=topindex&Category_ID=97

FHWA Crashworthy Work Zone Traffic Control Devices, Federal Highway Administration. This page provides guidance on crash-testing work zone traffic control devices, referring often to the NCHRP reports listed below.
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/wzd/

Recommended Procedures for the Safety Performance Evaluation of Highway Features, *NCHRP Report 350*, 1993.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_350-a.pdf
This report evaluates the safety performance of various highway safety features, including the crashworthiness of traffic control devices. Among the safety features addressed are barriers, crash cushions, trailer-mounted devices, barricades, sign stands, cones and barrels.
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/nchrp_350/catg3.cfm.

The policies of many individual states regarding NCHRP 350 compliance are linked from http://www.workzonesafety.org/safety_products/nchrp_350_approval/state_policies.

A Guide for Reducing Work Zone Collisions, *NCHRP Report 500*, Vol. 17, 2005.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v17.pdf
This report provides a comprehensive strategy for reducing the risk of work zones. Relevant to this inquiry, it includes:

- A discussion of the use of ITS for traffic control to improve safety (pages V-41 to V-48). Its focus is effective implementation of a strategy, not detailed accounts of new technologies.
- Methods to reduce flaggers' exposure to traffic, including the use of automated flagger assistance devices (pages V-61 to V-66).
- Measures to reduce work space intrusions, including physical separation measures such as portable concrete barriers, shadow vehicles and vehicle arrestor barriers; intrusion alarms; and channeling devices such as drums (pages V-70 to V-75). There is not a great deal of detail on any of these items.
- Other somewhat relevant sections of the report are those on improving the visibility of personnel, vehicles and traffic control devices, and on work zone design guidance.

Crashworthy Work-Zone Traffic Control Devices, *NCHRP Report 553*, 2006.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_553.pdf
This report supplements Report 350 with more recent research on barricades (fiber-reinforced plastic) and traffic control devices (portable sign supports, plastic drums, two-piece traffic cones and vertical panels). The report provides general information on design considerations in selecting a work zone traffic control device and specific design alternatives for particular devices. The emphasis seems to be not primarily on worker safety, but on the safety of drivers crashing into the devices, though having well-designed equipment in work zones should indirectly affect worker safety by reducing the severity of crashes in the area.

Intelligent Transportation Systems Joint Program Office, U.S. DOT Research and Innovation Technology Administration.
http://www.its.dot.gov/index.htm
This site includes analyses of a number of aspects of work zone management, including intrusion detection, lane control and other topics.
http://www.itsoverview.its.dot.gov/ROM.asp

- **Benefits of Using Intelligent Transportation Systems in Work Zones—A Summary Report**, April 2008.
  http://ntl.bts.gov/lib/31000/31000/31075/14494.htm
  This study evaluated ITS systems at sites in North Carolina, Arkansas, Michigan, Texas, and the District of Columbia to quantify the mobility and safety benefits of using ITS applications for work zone management.

- **Intelligent Transportation Systems for Work Zones**, January 2007.
  http://ntl.bts.gov/lib/jpodocs/brochure/14320.htm
  This brief report provides some case studies for the use of ITS in work zones, provides lessons learned and explains the federal Work Zone Safety and Mobility Rule. This report does not directly address worker safety.

- **Comparative Analysis Report: The Benefits of Using Intelligent Transportation Systems in Work Zones**, October 2008.
  http://ops.fhwa.dot.gov/wz/its/wz_comp_analysis/comp_anl_rpt_08.pdf
  This report evaluated 10 work zones for safety, mobility and delay impacts of ITS use.

Work Zone Positive Protection Toolbox, American Traffic Safety Services Association, 2009.
http://www.atssa.com/galleries/default-file/WZ%20Positive%20Protection%20Toolbox%20LL%20-%20FINAL.pdf
This booklet describes devices that are currently available to prevent the intrusion of motorized traffic into the work zone. It includes portable concrete barriers, ballast-filled barriers and moveable concrete barriers as well as shadow vehicles with truck-mounted attenuators and vehicle arresting systems that prevent road users from entering a closed section of roadway.

Smart Work Zone Deployment Initiative, Iowa State University Institute for Transportation, TPF-5(081), updated Nov. 22, 2010.
http://www.intrans.iastate.edu/smartwz/
http://www.pooledfund.org/projectdetails.asp?id=303&status=6
This pooled fund facilitates a number of projects on increasing safety and smoothing traffic flow through work zones. Some specific projects relevant to work zone safety technologies include:

- **Synthesis of Traffic Calming Techniques in Work Zones**, Eric Fitzsimmons, Nicole Oneyear, Shauna Hallmark, Neal Hawkins, Tom Maze, January 2009.
  http://www.intrans.iastate.edu/smartwz/reports/2009-hallmark-calming.pdf
  This report identifies technologies in work zone traffic calming, including in-lane treatments such as temporary rumble strips, pavement markings, automated work zone information systems, dynamic lane mergers, automated flagger assistance devices, and dynamic signing and radar units. In Section 9, Recent Vendor Technologies" (page 32 of the report), researchers identify newer options such as the use of traffic microwave sensors; a single-piece curb system to provide safe channelization (the FG3000 Interstate-grade Curb System by Davidson Traffic Control Products); and Sequential Work Zone Lamp (SynchroGUIDE by Dorman VariText), which involves a set of high-intensity superbright single-LED devices that are placed along barricades. These devices have intelligent wireless technology that can provide directional guidance via lighting along a barricade as a driver travels past.

- **Assessment of Channelizing Device Effectiveness on High Speed/High Volume Roadways**, Reginald Souleyrette, Thomas McDonald and Dennis Kroeger, July 2007.
  http://www.intrans.iastate.edu/smartwz/reports/2007-souleyrette-channeling-device.pdf
  This study collected current practices and observed driver reactions to different types of cones to help DOTs select effective channeling devices.

- **Smart Work Zone Deployment Initiative Projects**, updated June 28, 2011.
  http://www.intrans.iastate.edu/smartwz/projects.cfm
  This page lists numerous devices tested through the pooled fund. Most apparently relevant to this Preliminary Investigation are categorized under "Static Device Evaluations" and "Other." They include several types of temporary rumble strips, barricades, portable lighting towers, autoflaggers and other elements promoting work zone safety.

TRB Committee on Work Zone Traffic Control (AHB55).
http://sites.google.com/site/trbcommitteeahb55
This group shares information on aspects of work zone safety through its annual meetings. Some presentation papers from these meetings relevant to the use of technologies follow:

- **"The Concept of a Smart Drum Speed Warning System,"** John Sullivan, Chris Winkler, Michael Hagan, Barry Kantowit, University of Michigan Transportation Research Institute, 2007.
  https://sites.google.com/site/trbcommitteeahb55/Welcome/discussions-threads/2007annualmeeting/WorkZoneSafetyITSSmartDrumSullivan.pdf
  This presentation describes a system developed by the Michigan Transportation Research Institute to warn drivers approaching the end of a queue running up to a work zone. The automated system detects the queue length and displays a warning on barrels at an appropriate distance from the queue so that drivers will slow down. While this does not directly address worker safety, it addresses accidents around work areas that could then affect workers.

- **"Moveable Portable Concrete Barriers and Others,"** notes from the 2006 Summer Meeting.
  http://tinyurl.com/3fb5thy
  This two-page document lists elements to consider in determining when positive barrier protection is required and how to configure the barrier.

AASHTO Subcommittee on Systems Operations and Management, undated.
http://ssom.transportation.org/Pages/default.aspx
This group tracks ongoing developments in the use of ITS in work zones. Some resources on this page include:

- **General Work Zone ITS Deployment Resources.**
  http://ssom.transportation.org/Pages/GeneralWorkZoneITSDeploymentResources.aspx
  This page provides standards and specifications elements in work zone ITS deployments in Minnesota and North Carolina.

- **Traffic Management.**
  http://ssom.transportation.org/Pages/TrafficManagement.aspx
  This page includes specifications, evaluations and case studies from several states related to facilitating traffic flow in and around work zones, which supports worker safety.

Note: OSHA had some resources on work zone safety, but not evidently related to technologies.

Current Caltrans Practices

Work Zone Traffic Control Tools, Caltrans, 2007.
http://www.dot.ca.gov/hq/traffops/signtech/signdel/workzones.htm
This site includes current policies, including links to specific parts of the CA MUTCD related to work zone traffic controls and traffic safety systems.

> **Traffic Safety Systems**, Chapter 7, CA MUTCD.
> http://www.dot.ca.gov/hq/traffops/saferesr/Chapter-7-Traffic-Manual-9-2008.pdf
> This chapter includes a section on moveable concrete barriers (page 7-25) but does not discuss the use of newer technologies or other details of design configurations that would enhance worker safety.

Safety Needs Action Plan (SNAP) for Challenge Area 14: Enhance Work Zone Safety, California Strategic Highway Safety Implementation Plan, August 27, 2008.
http://www.workzones.ucdavis.edu/items/CA14_SNAP_080925.pdf
Originally presented to a Caltrans steering committee in July 2007, this document includes detailed action plans, with steps to reduce worker exposure and improve worker visibility (page 8), and advanced technology to improve work zone safety (pages 9-10), including the use of Safety Edge in pavement construction projects, maintenance vehicles that support rolling work zones, Vehicle Infrastructure Integration systems to enable real-time communications between users and the roadway, and improved procedures and tools to support quicker adoption of new, promising technologies.

Signs & Work Zones Branch, Caltrans, 2007.
http://www.dot.ca.gov/hq/traffops/signtech/signdel/index.htm
http://www.dot.ca.gov/hq/traffops/signtech/signdel/workzones.htm
These sites include additional links and information concerning current Caltrans policies in this area, including relevant sections of the MUTCD; work zone standard plans; and a qualified products list (http://www.dot.ca.gov/hq/esc/approved_products_list/pdf/highway_safety_features.pdf) that includes safety features such as crash cushions, guardrail/end treatments, barriers, truck-mounted attenuators and call boxes.

Other State Practices

Illinois

Standard Specifications for Traffic Control and Barricades, American Traffic Safety and Services Association, 2011.
http://www.atssa.com/MemberCenter/Chapters/IllinoisStandardSpecificationsforTrafficContr.aspx
This page provides links to several specification documents and a list of materials suppliers. Section 701 (http://dot.state.il.us/desenv/spec2007/div700.pdf) specifies as required (page 574 of the specification) type I, II and III barricades; vertical barricades; vertical panels; truck-mounted attenuators; portable CMSs; temporary rumble strips; and other measures.

Iowa

Work Zone Safety Committee, Iowa Department of Transportation, undated.
http://www.iowadot.gov/traffic/sections/itsauwz/wzpolicy.htm
Iowa Department of Transportation offers detailed design sheets (in .dgn format) (http://www.iowadot.gov/design/stdrdpln.htm) that include specifications for temporary barrier rails (steel and precast concrete), temporary sand barrel crash cushions, electrical cabinets and traffic control devices for lane and road closures. Iowa's design manual (http://www.iowadot.gov/design/dmanual/manual.html?reload) also includes short whitepapers on the use of traffic control devices (Chapter 9) such as CMSs, temporary barrier rails, road closure barricades, channelizing devices, warning lights and floodlights. Chapter 8 also describes the design of temporary side obstacle treatment in work zones.

Minnesota

Work Zone Safety Resources, Minnesota Department of Transportation, undated.
http://www.dot.state.mn.us/trafficeng/workzone/index.html
Minnesota Department of Transportation provides a variety of specifications and policy sheets regarding work zone safety, including technical memoranda (http://www.dot.state.mn.us/trafficeng/publ/techmemo.html) on temporary portable precast barriers, tubular markers and weighted channelizers, pilot cars, crashworthy requirements for work zone devices, CMSs, rumble strips and other tools for improving work zone and roadside safety for highway workers. MnDOT's list of work zone manuals and guidelines (http://www.dot.state.mn.us/trafficeng/workzone/wzmanual.html) includes links to relevant portions of the MnMUTCD and the MnDOT Roadside Design Manual.

> **Intelligent Work Zone Toolbox**, Minnesota Department of Transportation, 2008.
> http://ssom.transportation.org/Documents/MN-IWZToolbox.pdf
> This document provides guidelines for intelligent work zone (IWZ) system selection. The IWZ concept includes ITS elements such as CMSs, video cameras and vehicle sensors, but it seems primarily aimed at driver safety (for example, displaying a warning to a speeding driver). This would indirectly benefit worker safety.

New Hampshire

DOT Positive Protection Guidance for Work Zones, New Hampshire Department of Transportation, February 2010.
http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents/FINAL_positive_protection_workzone_guidance_02221.pdf
This document briefly specifies design factors for positive protection: how to design a work zone, including spacing for warning signs and channelization devices, when to use a truck- or trailer-mounted attenuation, sand barrel arrays, temporary impact attenuation devices and lateral protection devices (temporary barriers and guardrails).

North Carolina

"SmartZone" System, AASHTO, January 2006.
http://ssom.transportation.org/Documents/Smartzone_spec.pdf
This document, apparently composed for a specific construction project, specifies the elements of a SmartZone system, including portable CMSs, traffic sensors and a wireless base station. It also broadly specifies contractor responsibilities and other elements for implementing such a system. Though the primary goal appears to be maintaining traffic flow through the zone, the document provides a model of a work zone management system that could be part of an effective worker protection strategy. North Carolina appears to be a leader in the use of SmartZones; projects from this state are described in "Safety Effects of a Work Zone Intelligent Transportation System" (page 11 of this report) and in FHWA's two-page "ITS Technologies in Work Zones" (http://cms.transportation.org/sites/ssom/docs/ITS%20Fact%20Sheet.pdf).

Washington

Work Zone Intelligent Transportation Systems, Washington State Department of Transportation, 2011.
http://www.wsdot.wa.gov/Safety/WorkZones/its.htm
This site provides information about the historical use of work zone ITS in Washington; the techniques employed (such as dynamic lane merging, variable speed limits and work zone photo enforcement); and the "Work Zone Safety and Mobility" chapter of the WSDOT Design Manual (http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1010.pdf), which includes guidance on elements such as protective devices (concrete, steel and water-filled barriers); impact attenuators; truck-mounted attenuators; screening to block motorists' views of distracting construction activity; illumination; warning lights; CMSs; and automated flagger assistance devices (pages 1010-27 through 1010-35).

Please see also FHWA entry "Work Zone Best Practices Guidebook" under **National Guidance**.

California Initiatives and Partnerships

Advanced Highway Maintenance and Construction Technology Research Center (AHMCT)
http://www.ahmct.ucdavis.edu/index.php?title=Main_Page
AHMCT, based at UC Davis, works with Caltrans to evaluate new technologies. Research reports and ongoing projects are organized by category; those concerning worker safety are listed at http://www.ahmct.ucdavis.edu/index.php?title=ReportsEmployeeSafety. The most relevant listings there are:

- **"A Risk Assessment and Cost Benefit Analysis for the Balsi Beam Mobile Work Zone Crash Protection System,"** Mary C. Arico, Bahram Ravani, 2009.
  Abstract at http://www.ahmct.ucdavis.edu/index.php?title=ReportsEmployeeSafety
  This project analyzed the risks and potential safety benefits of a rapid-deployment guardrail-type device. The report is available from AHMCT upon request. A short Caltrans presentation on the Balsi Beam can be found at http://www.workzonesafety.org/files/documents/database_documents/balsi_beam.pdf, which includes a list of potential construction and maintenance applications.

- **"Development of New Kinds of Mobile Safety Barriers,"** George Burkett, Vue Her, Steven A. Velinsky, 2009.
  http://www.ahmct.ucdavis.edu/images/UCD_ARR_09_02_28_01.pdf
  This project discusses the status of intrusion alarms for work zones. Investigators performed test simulations on low-profile barriers to determine the optimal geometry.

- **"Temporary Barrier Usage in Work Zones,"** Cristopher Lohse, Duane A. Bennett, Steven A. Velinsky, 2007.
  http://www.ahmct.ucdavis.edu/images/FinalReportTempBarriers_080821.pdf
  This project reports on the creation of a toolbox of safety barriers to help Caltrans more easily design configurations for specific work zones.

- Other reports that may be of interest listed on this site concern cone placement and a device that helps workers lift heavy loads; both of these could reduce worker injury by lessening their time on the work site.

- Additional reports not in the Employee Security category may be of interest in helping to make maintenance activities more efficient, again resulting in workers spending less time on highways (for example, Labor Intensive Tasks in Roadside Vegetation Maintenance, 2008, and Vegetation Cutting Tool, 2005).

Safety & Operations Program, Western Transportation Institute (Montana State University), 2008.
http://www.westerntransportationinstitute.org/research/safety/default.aspx
This program is an ongoing effort to develop innovations in ITS use, traffic monitoring, safety in work zones and during traffic-related incidents, and other areas. One current study appeared to be relevant to this investigation:

- **Explore ITS Technologies for Work Zones and Impact Areas** (in progress, ending Dec. 31, 2011).
  http://www.westerntransportationinstitute.org/research/4W2833.aspx
  This study focuses primarily on reducing work zone congestion and delays, but includes in its survey the use of excessive speed warning systems. It will include a survey of transportation agencies that might be of use to Caltrans.

Work Zone Safety Training, Berkeley Institute of Transportation Studies, UC Berkeley, 2011.
http://www.techtransfer.berkeley.edu/workzones/
http://www.techtransfer.berkeley.edu/tse/ts_resources.php#WorkZones
These sites do not include information on new technologies but offer work zone safety training, including understanding safety equipment and traffic controls, and other resources.

Other Recent Research

Use of Innovative Traffic Control Devices to Improve Safety at Short-Term Rural Work Zones, Texas Department of Transportation, 2000.
http://www.itsbenefits.its.dot.gov/its/benecost.nsf/0/F61943DF4661F59E85257260007508B4.
This study showed that speed display trailers can reduce average vehicle speeds by 5 mph and decrease the number of vehicles traveling at excessive speeds in rural work zones.

Monitoring Traffic in Work Zones: The iCone System, SRF Consulting Group for the Minnesota Department of Transportation, November 2010.
http://www.dot.state.mn.us/guidestar/2006_2010/Monitoring_Traffic_in_Work_Zones.html.
Final report: http://www.dot.state.mn.us/guidestar/2006_2010/icone/icone_final_report.pdf.
This project tested the iCone System, whose core function is to detect traffic speeds and relay the data to a central server using equipment stored inside a typical traffic barrel. These were used in the study to monitor speeds near and farther away from construction zones, and then to determine whether existing static signage near work zones was sufficient to notify drivers of the zones. This technology could be used to test the effectiveness of Caltrans' work zone notification measures.

Deployment and Evaluation of ITS Technology in Work Zones, Rob Bushman, Curtis Berthelot, Rod Klashinsky, University of Saskatchewan, 2003.
http://ssom.transportation.org/Documents/ITSTechnologyinWorkzones.pdf
This report evaluated the impacts of work zone safety technologies deployed at multiple high-speed rural work zones in Texas, particularly dynamic lane merger systems and variable speed limit systems.

Safety Effects of a Work Zone Intelligent Transportation System, Rob Bushman, Curtis Berthelot, Joseph Chan, Rod Klashinsky, University of Saskatchewan, 2004.
http://ssom.transportation.org/Documents/SafetyEffectsofWorkZoneITS.pdf
This report describes a Smart Work Zone deployment in 2003 in North Carolina and analyzes the safety impact of the system. Due to the limited number of crash occurrences and the variability of time between crashes, no conclusive results could be drawn.

Research in Progress

Use, Test & Evaluation of a Mobile Work Zone Barrier System, Oregon Department of Transportation.
http://trid.trb.org/view.aspx?id=1104269
The study will evaluate mobile barrier systems: the efficiency in deploying and removing the system, its impacts on the work operations, the impacts on worker safety and productivity compared to traditional protective measures, and the types of projects for which it is most suitable.

Development of Sensing Methodology for Intelligent and Reliable Work Zone Hazard Awareness, Transportation Research Board.
http://trid.trb.org/view.aspx?id=976596
This project will develop a methodology based on vision-based object recognition algorithms and integrated global positioning systems and vision technologies to recognize and warn against intruding vehicles as well as hazards inside work zones.

Improved Positive Protection Guidance for Work Zones, Texas Department of Transportation.
http://trid.trb.org/view.aspx?id=974595
Researchers are conducting a variety of different analyses to assess the safety, cost and other qualitative trade-offs of a variety of technologies and strategies for providing positive protection in work zones, including barriers and CMSs.

Industry Resources and Other Organizations

National Work Zone Safety Information Clearinghouse—Safety Products.
http://www.workzonesafety.org/safety_products/
This site includes resources by safety product type. A subsection entitled Manuals, Policies, Guidelines and Handbooks includes links to numerous state, academic and industry guides, most of which, however, are not specific to work zone safety, do not focus on technologies, and are a decade or more old.
http://www.workzonesafety.org/standards_practices/manuals_guidelines_forms/manuals_guidelines_handbooks

ITS America Safety Forum.
http://safety.itsa.wikispaces.net/
This group promotes ITS solutions and is primarily concerned with driver safety. Its charter from 2009 can be found at http://www.itsa.org/files/pdf/SafetyForumCharter0509.pdf.

American Traffic Safety Services Association (ATSSA).
http://www.atssa.com
This international trade organization offers training courses to DOT and other staff on work zone safety management (using grants from FHWA). An ITS Safety and Mobility Solutions brochure provides an overview of commonly used ITS applications in work zones, including work space intrusion systems (http://www.atssa.com/galleries/default-file/2008July21_ITS_Safety_and_Mobility.pdf).

Traffic Tech Group: Traffic Safety Equipment & Work Zone Safety Products.
http://www.traffic-tech.com/traffic_safety_equipment_work_zone_safety_products.php
This is a vendor offering message signs, crash cushions, portable camera systems, breakaway posts, work zone crash barriers and truck-mounted attenuators.

Energy Absorption Systems: Work Zone Products.
http://www.energyabsorption.com/products_workzone.asp

This vendor offers a similar array of products.