Preliminary Investigation (PI-0296)

Caltrans Division of Research, Innovation and System Information

Work Zone Safety: Synthesis of Literature and Industry Survey

Requested by
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Executive Summary

Background

California Department of Transportation (Caltrans) and highway contractors are concerned about vehicle intrusion crashes in work zones, which more commonly occur on state highways because of higher speed limits than local roads. Almost three-quarters of intrusion crashes happen during daytime operations, and when they occur, they typically involve work vehicles, equipment and materials.

To ensure the most innovative commercially available products are used to reduce the frequency of intrusion crashes and to improve work zone safety on California highways and roads, Caltrans sought information about recently developed safety innovations that alert workers and drivers in work zones. An online survey gathered information from manufacturers and vendors that provide work zone-related safety products and systems. Results of a literature search about recently developed safety innovations for use in work zones supplemented the survey findings. (*Note*: Some of the product descriptions in this Preliminary Investigation refer to the Manual for Assessing Safety Hardware (MASH), which is published by the American Association of State Highway and Transportation Officials (AASHTO) and presents uniform guidelines for crash-testing permanent and temporary highway safety features and recommends evaluation criteria to assess test results.)

Summary of Findings

Survey of Practice

An online survey was distributed to approximately 400 members of the American Traffic Safety Services Association (ATSSA), which represents the roadway safety infrastructure industry through effective legislative advocacy, traffic control safety training and member partnerships. The survey gave ATSSA members the opportunity to provide publicly available information about new, innovative work zone safety products and about existing work zone safety products that have been enhanced to offer innovation in work zone safety.

Twelve representatives responded to the survey. Three companies offer new work zone safety products only; two companies offer both new and enhanced products. Respondents from the following five companies reported that their organizations offer new products, however, representatives did not provide information about these products: 3M; Hill & Smith, Inc.; Lindsay; PPP; and Shur-Tite Products.

Below are survey results from the companies that offer new and enhanced work zone safety products. Additional new product descriptions from ATSSA are also included.

New Work Zone Safety Products

New products are summarized below in the following categories:

- Portable intelligent traffic management systems.
- Portable speed monitoring display.
- Portable traffic signal.

- Traffic safety devices.
- Truck-mounted attenuator (TMA).

More information about product features and benefits is available in the **Detailed Findings** section of this report.

Portable Intelligent Traffic Management Systems

ConnectedTech by iCone
Road-Tech Safety Services, Inc.

Add-on smart devices can be attached to arrow boards, warning lights, TMA trucks and flagger paddles to create a network of connected traffic control equipment. The platform tells automated vehicles and anyone using digital maps the precise location of the work zone and when workers are in the work zone. The arrow board device tells drivers if they need to merge right or left. These add-ons:

- Improve driver and worker safety.
- Improve travel times.
- Will aid drivers in making real-time decisions as they approach active work areas.

Driveway Assistance Device
Horizon Signal Technologies, Inc.

The Driveway Assistance Device controls traffic from residential driveways that fall within a one-lane bidirectional work zone. The device is more efficient and cost-effective than using flaggers or temporary traffic signals, which require mainline traffic to be stopped at each driveway in the work zone. The devices:

- Maximize work zone traffic flow by servicing all driveways during each cycle.
- Improve safety by reducing the likelihood of wrong-way driving.
- Improve efficiency.

Level 3 Technology Package
Royal Innovative Solutions

The Level 3 Technology Package integrates three technological systems: high-definition cameras; a black box DVR recording system; and a truck-mounted, full matrix changeable message sign (CMS). This integration enhances work zone safety by allowing workers to efficiently communicate traffic conditions to motorists through custom messages. This product:

- Displays custom messages on the fly that can be created from an in-cab controller.
- Allows contractors to use mounted cameras that capture footage of work zone activity that is saved on the in-cab solid-state hard drive.
- Reduces potential liability disputes if a crash occurs by accurately capturing events that led to the incident on the saved footage.

Portable Speed Monitoring Display

Work Zone Speed Control System
Horizon Signal Technologies, Inc.

The Work Zone Speed Control System is used in work zones that involve a lane closure to help stop unsafe speeding vehicles before they enter the work zone. This system comprises a radar

speed display placed ahead of the work zone, Horizon's Portable Traffic Signal System and a wireless communication platform. The system:

- Helps to increase work zone safety.
- Detects speeds from 5 mph to 105 mph.
- Allows programmable thresholds for signal actuation and custom messages.

Portable Traffic Signal

Clearance Time Extender
Horizon Signal Technologies, Inc.

The Clearance Time Extender is a portable traffic signal used in applications involving lane closures. Previously, red clearance intervals were fixed and calculated by factoring the distance between each portable traffic signal and the anticipated speed of the vehicles traveling through the work zone. Project designers had to account for the slowest moving vehicle traveling through the work zone, which often meant overcompensating the red clearance intervals to ensure all vehicles had exited the work zone. This practice increased overall cycle lengths and wait times for drivers. With the Clearance Time Extender, red clearance intervals can be adjusted to help ensure slow-moving vehicles clear the work zone before allowing opposing green indications. These signals:

- Increase signal timing efficiency.
- Increase work zone safety.

Traffic Safety Devices

HighwayGuard Barrier
Trinity Highway Products

Meeting MASH test level requirements, these temporary steel barriers provide positive protection in work zones. In addition to reducing transportation costs when deployed on project sites, the barriers:

- Help reduce work zone congestion in high-traffic areas.
- Can be used in work zone applications with other compatible end treatments.

City Post Family of Channelizers
Pexco, LLC

City Post traffic channelizers (permanent tubular markers) are intended for extremely high-risk areas or high-impact zones, such as high occupancy vehicle/high occupancy toll (HOV/HOT) lanes, bike lanes and centerline applications with narrow footprints. The products are 3.25 inches in diameter and can be installed in concrete and asphalt. They are made from the strongest polymers available and fused at the factory, eliminating the need for pins, fasteners and components. Three channelizers were described:

City Post SM (Surface Mount)

- Is a traditional bolt-down post.
- Offers a safe, impact-friendly design.
- Requires low maintenance.

City Post EAC (Embedded Anchor Cup)

- Offers an easy “spin-in” installation to minimize worker exposure.
- Is designed for superior durability and quick replacement.
- Can be removed and stored in winter.
- Has removable plug covers for the anchor cup until a post is replaced.

City Post GD (Glue Down)

- Optimizes adhesion through its unique pinwheel base design.
- Remains flexible and continues to fully rebound after more than 100 hits at 70 mph.

X Marker
PPP

The X Marker is a temporary traffic control device that is used to clearly identify a lane as closed for construction or events. Placed in intervals along the center of the closed lane, the X Marker combines the effectiveness of runway devices with sign enhancement innovation and standard temporary traffic control applications to produce an innovative, economical approach to work zone safety. The lightweight, durable device:

- Clearly identifies a closed lane to prevent motorists from entering a work zone, especially extended work zones or those with limited site distance due to changes in vertical or horizontal design such as hills or curves.
- Enhances safety for workers and motorists.

U-Flex
Shur-Tite Products

The U-Flex 3-inch post is designed to withstand bumper and tire impacts in HOV and bike lanes. A quick-release design allows workers to easily remove and replace a post from its base. The post also features a weep hole that allows for proper rainwater drainage, avoiding premature failures. This product:

- Offers low-cost, fast maintenance.
- Reduces time in traffic for workers.

REACT M
Trinity Highway Products

This severe-duty crash cushion (MASH 2016 Test Level 3) protects roadside and median hazards. It consists of six high density polyethylene (HDPE) cylinders attached to a steel backup and basetrack assembly. Various cylinder wall thicknesses help the device withstand impacts from light cars or heavier, high-center-of-gravity vehicles. The system’s self-restoring features:

- Offer residual capacity.
- Require low maintenance.

Truck-Mounted Attenuator

SS180M (MASH) Truck-Mounted Attenuator
Trinity Highway Products

This MASH-tested truck-mounted impact attenuator protects workers, vehicle operators and drivers in mobile and stationary work zones. It contains two lightweight aluminum cartridges in a potentially reusable steel support frame. The TMA:

- Helps to absorb rear-end impacts at speeds up to 62 mph when impacted within MASH crash test standards.
- Is designed to help minimize damage from low-speed nuisance hits up to 6 mph.

Enhanced Work Zone Safety Products

Enhanced products from two companies are presented below in the following categories:

- Intelligent transportation system solutions.
- Web-based tools.

Intelligent Transportation System Solutions

Transnomis
Road-Tech Safety Services, Inc.

This automated work zone information system uses portable sensors and message signs that network with iCone devices to automatically tell drivers when a lane is closed and to merge right or left.

Web-Based Tools

ConeIQ
ConeIQtrack LLC

This maintenance of traffic solution creates digital work zone layouts that can be customized for each site. It contains two modules:

- Design layout, which designs work zone layout according to federal or state requirements.
- Inspection and compliance, which uses GPS readings and images to determine if the layout is set up according to requirements.

The product:

- Improves safety and compliance.
- Increases operational efficiency.
- Can be accessed on a subscription basis and does not require downloads.

Related Research and Resources

A literature search of recent publicly available domestic resources identified a representative sampling of publications and products that are organized into the following topic areas:

- National research and guidance.
- State research and guidance.
- Related resources.
- Innovations by equipment type.

Tables summarizing these resources are presented by topic area beginning on page 8. Each table provides the publication or project title; the year of publication if research is completed; the source; a brief description of the resource; and the page number of the complete citation in the **Detailed Findings** section of this report, where significantly more detail can be found about the resource.

Gaps in Findings

Despite distributing the survey to ATSSA's extensive member list, response to the call for new and enhanced product information was low. As a result, information was gathered for only a small number of work zone products. Caltrans could benefit from additional inquiries to vendors and manufacturers of these products to possibly identify additional devices and solutions.

Next Steps

Moving forward, Caltrans could consider:

- Examining the information provided by survey respondents about products that Caltrans does not currently use for possible application in agency work zones.
- Reaching out to the following vendor representatives who reported that their companies offer new, innovative work zone safety products for information about these products:
    - 3M.
    - Hill & Smith, Inc.
    - Lindsay.
    - PPP.
    - Shur-Tite Products.
- Contacting nonresponding vendors and manufacturers that may offer work zone safety innovations.
- Examining the extensive resources presented in this report regarding work zone safety equipment and software solutions.

National Research and Guidance

Publication or Project (Date)	Page	Source	Excerpt From Abstract or Description of Resource
Use of Smart Work Zone Technologies for Improving Work Zone Safety (research in progress)	25	National Cooperative Highway Research Program	Seeks to document the use and effectiveness of smart work zone technologies used by state departments of transportation (DOTs) to improve the safety of workers and drivers affected by work zone activity.
Synthesis of Research Related to the Use and Implementation of Advanced Technology to Improve Work Zone Management (August 2020)	26	Federal Highway Administration	Identifies and summarizes efforts underway related to connected vehicles, autonomous vehicles and other advanced technologies for improving work zone safety and mobility.

State Research and Guidance

Publication or Project (Date)	Page	State	Excerpt From Abstract or Description of Resource
Smart Work Zone Deployment Initiative (FY2020-FY2024) (research in progress)	26	Multiple states	Seeks to evaluate new products and conduct related research focused on the enhancement of safety and mobility in highway work zones.
Review of Equipment and Accessories for Truck-Mounted Attenuator (TMA) Trucks (research in progress)	27	California	Seeks to examine specific equipment and accessories available for TMA trucks such as radar speed feedback signs, camera systems that record multiple views, communication systems and panic/warning lights.
Florida ATMA Pilot Demonstration and Evaluation (research in progress)	27	Florida	Seeks to evaluate the performance of an autonomous truck-mounted attenuator (ATMA) system to better understand its feasibility or applicability to enhance operational or safety benefit on work zones in Florida.
UFTI-T2 Center Receives Grant to Evaluate New Technology: Autonomous Truck-Mounted Attenuator (June 2020)	27	Florida	Identifies the strengths and limitations of an ATMA and conducts a cost–benefit analysis to evaluate its usefulness for improving worker safety on Florida highways.
Synthesis of Intelligent Work Zone Practices (June 2014)	28	Multiple states	Documents the resources, uses and benefits of the following intelligent work zone technologies: queue warning systems, dynamic merge systems, alternate routes and variable speed limits in work zones.
Active Work Zone Safety Using Emerging Technologies 2017 (July 2017)	28	Alabama	Conducts conceptual analysis and experimental evaluation of intrusion sensing technologies for work zone safety.
Iowa DOT Using Audible Attenuators to Increase Short-Term Work Zone Awareness (April 2021)	28	Iowa	Examines Iowa DOT's use of various safety practices, including operator-activated audible alarms attenuators, on short-term, stationary or slow-moving maintenance operations.

Publication or Project (Date)	Page	State	Excerpt From Abstract or Description of Resource
Evaluation of the Smart Work Zone Speed Notification System (June 2019)	29	Minnesota	Examines the ability of the Smart Work Zone Speed Notification system to alleviate congestion, queuing and rear end crashes in work zones by using portable changeable message signs (PCMS) to inform drivers of the speed of the downstream segment.
Looking Deep Into the Eyes: Green Light on TMAs Could Be Another Option for DOTs (September 2018)	29	Missouri	Explores the use of green lights on TMAs to improve mobile work-zone safety.
Evaluation of Automated Flagger Assistance Devices (February 2018)	29	Missouri	Assesses the use of automated flagger assistance devices in place of flaggers to improve the safety of work zones for both workers and the traveling public.
Using IoT Technology to Create Smart Work Zones (July 2020)	30	North Carolina	Explores the feasibility of improving road work zone safety by using state-of-the-art Internet of Things (IoT), artificial intelligence and computer vision technologies.
Work Zone Intrusion Alert Technologies: Assessment and Practical Guidance (June 2017)	30	Oregon	Assesses the effectiveness of available work zone intrusion alert technologies and provides recommendations for using the technologies in future Oregon DOT construction and maintenance work zones.
Smart Work Zone Guidelines: Design Guidelines for Deployment of Work Zone Intelligent Transportation Systems (ITS) (October 2018)	31	Texas	Introduces six smart systems, including decision tools, for use in work zones.
Closed Course Performance Testing of AWARE Intrusion Alarm System (April 2017)	31	Texas	Describes AWARE (Advance Warning And Risk Evasion) and system's use of a target threat detection and tracking methodology to logically assess approaching vehicle speed, location and possible trajectory.

Related Resources

Publication or Project (Date)	Page	Source	Excerpt From Abstract or Description of Resource
Improving Construction Work Zone Safety Using Technology: A Systematic Review of Applicable Technologies (February 2020)	32	Journal of Traffic and Transportation Engineering	Applies a three-step approach to identify and review literature pertinent to the safety of highway construction work zones.
Active Work Zone Safety: Preventing Accidents Using Intrusion Sensing Technologies (March 2019)	32	Frontiers in Built Environment	Conducts a conceptual analysis and experimental evaluation of intrusion sensing technologies for work zone safety.

Innovations by Equipment Type

Publication or Project (Date)	Page	Source	Excerpt From Abstract or Description of Resource
2017 DH1000 PCMS (2017)	33	Addco	Combines a connected sign and a cloud-based system to manage PCMS.
TraffiCloud Web-Based Traffic Device and Data Management System (undated)	33	All Traffic Solutions, Inc.	Presents a secure, web-based traffic management ecosystem that allows users to access, monitor and manage all traffic devices, dynamic messaging and data from any internet-connected device.
Get the Message Across [Message Boards] (undated)	34	K&K Systems, Inc.	Displays messages using energy-efficient LED and efficient solar panels.
Changeable Message Signs (undated)	34	Renaissance Technologies Inc.	Describes PCMS that are controlled by TrafAlert software, which integrates with products from all major manufacturers.
Camera Option for Message Board (undated)	34	Solar Technology, Inc.	Describes message boards outfitted with a camera that monitors traffic to allow users to customize messages in real time.
GEWI and iCone Products Partner to Improve Safety With Real-Time Work Zone Information (undated)	35	GEWI	Provides real-time travel information that can be delivered to navigation devices through apps and in-car navigation systems.
Internet of RoadWork (IoR) (undated)	35	iCone Products, LLC	Provides internet-addressable, GPS-enabled technology devices that interface with existing traffic control equipment.
JamLogic—Smart Work Zone Solutions (undated)	35	Ver-Mac	Provides transparent client server access to all devices and data.
Smart Arrowboard (undated)	35	Ver-Mac	Turns existing arrow boards into a connected work zone by providing real-time key lane closure information to motorists, government agencies and operations.
Traffic Cameras and Sensors (undated)	35	Ver-Mac	Combines portable cameras, sensors and JamLogic software to deliver messages to roadside message signs in work zones.
SP-3248-DSL (Speed Wizard) (undated)	36	Ver-Mac	Describes a work zone digital speed limit and speed awareness system that automatically sends a work zone speed notification to Waze, DOTs and potentially automated vehicles.
RoadQuake 2F Temporary Portable Rumble Strip (undated)	36	PSS Innovations	Alerts distracted drivers in work zones and other changing road conditions.
Rumble Mat Layer Chassis Mounted Single (undated)	36	Verdegro	Describes a vehicle that can apply or remove a single rumble mat.
Rumble Mat Layer/Rumble Mat Layer Chassis Mounted (undated)	37	Verdegro	Describes two variants of automatic Rumble Mat Layers: Rumble Mat Layer and Rumble Mat Layer Chassis Mounted.

Publication or Project (Date)	Page	Source	Excerpt From Abstract or Description of Resource
TMA Puller, 2021 Virtual Tool and Equipment Showcase (2021)	37	Missouri DOT	Describes a vehicle that quickly and safely removes and resets TMAs to dump trucks.
Two New Products Improve Safety in Highway Construction Work Zones (February 2020)	37	Engineering News-Record	Features two MASH-tested products from Trinity Highway Products: SMT and SS180 M.
DVR and Camera System (undated)	37	J-Tech	Describes a system that provides an accurate, locked-down recording of events in and around work vehicles to protect agencies from liability claims and to provide a means to analyze incidents and apply lessons learned to new safety procedures.
Truck Mounted Smart Generator (undated)	38	Royal Innovative Solutions	Addresses problems of truck engine idle and diesel particulate filters (DPF) in the work zone for Class 6 trucks with high idle time.
ATMA (Autonomous TMA) (undated)	38	Royal Truck and Equipment, Inc.	Describes a leader/follower system that uses a human-driven leader vehicle to transmit its GPS position data to the unmanned follower vehicle, which uses the data to follow the exact path and speed of the leader vehicle.
Hazard Warning Signs (undated)	38	SWARCO	Describes an electronic hazard warning system that gives dynamic warning messages to drivers to mitigate road hazards.
Smart VMS Trailer (undated)	39	SWARCO	Presents an intelligent, IoT-enabled variable message sign (VMS) trailer that provides driver information via VMS, travel time estimation, speed reduction detection, traffic monitoring and vehicle communication.
Work Zone Safety: Eco Synchro4D (August 2020)	39	Unipart Dorman	Describes the Eco Synchro4D, which combines the latest in LED lamp and unidirectional, self-colored polycarbonate lens technology with intelligent synchronization wireless communications technology to improve nighttime driver recognition of merging tapers.
Work Zone Safety: ConeLITE Synchro (October 2018)	39	Unipart Dorman	Describes the ConeLITE Synchro lamp, which uses intelligent wireless sequential operation of warning lights to form a clear directional path for traffic during lane closures.
Impact Detection System (undated)	39	pi-lit (Pi Variables, Inc.)	Supports a local area radio mesh network that allows many sensors to report data through a single cellular or fiber cable gateway.

Detailed Findings

Background

A five-year moving average shows that work zone-related crashes are increasing. These crashes are more common on state highways, which typically have higher speed limits than local roads. Both California Department of Transportation (Caltrans) and highway contractors are concerned about vehicle intrusion crashes. According to a 2010 Caltrans report, vehicle intrusion crashes account for 7.5% of all work zone-related crashes occurring during daytime operations and 12.4% of all work zone-related crashes occurring during nighttime operations.[1] Almost three-quarters of intrusion crashes happen during daytime operations, and when they occur, they typically involve work vehicles, equipment and materials rather than a highway worker.

To ensure the most innovative commercially available products are used to reduce the frequency of intrusion crashes and to improve work zone safety on state highways and roads, Caltrans sought information about recently developed safety innovations that alert workers and drivers in work zones. An online survey gathered information from manufacturers and vendors that provide work zone-related safety products and systems. Supplementing the survey findings are the results of a literature search about recently developed safety innovations for use in work zones. (*Note*: Some of the product descriptions in this Preliminary Investigation refer to the Manual for Assessing Safety Hardware (MASH), which is published by the American Association of State Highway and Transportation Officials (AASHTO) and presents uniform guidelines for crash-testing permanent and temporary highway safety features and recommends evaluation criteria to assess test results.)

Survey of Practice

An online survey (Appendix A) was distributed to approximately 400 members of the American Traffic Safety Services Association (ATSSA), which represents the roadway safety infrastructure industry through legislative advocacy, traffic control safety training and member partnerships. Members were asked to provide publicly available information about new, innovative work zone safety products and existing work zone safety products that have been enhanced to offer innovation in work zone safety. Survey responses are presented in a supplement to this report.

Summary of Survey Results

Twelve representatives responded to the survey. Three companies offer new work zone safety products only:

- Horizon Signal Technologies, Inc.
- Pexco LLC.
- Trinity Highway Products LLC.

Two companies offer both new and enhanced products:

- ConeIQtrack LLC (two responses describe the same product).
- Road-Tech Safety Services, Inc. (two responses, both reporting new products and one reporting enhanced products).

[1] Work Zone Intrusion Countermeasure Identification, Assessment and Implementation Guidelines, California Department of Transportation, May 2010. https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/f0016954-final-report-task-1102.pdf

Five companies reportedly offer new products, however, representatives did not provide information about these products:

- 3M.
- Hill & Smith, Inc.
- Lindsay.
- PPP.
- Shur-Tite Products.

Below are survey results from the companies that offer new work zone safety products. Additional new product descriptions from ATSSA are also included. Information about enhanced work zone safety products begins on page 23. Documentation provided by respondents or sourced through a limited literature search are included with the product descriptions as supplemental resources.

New Work Zone Safety Products

New products are described below in the following categories:

- Portable intelligent traffic management systems.
- Portable speed monitoring display.
- Portable traffic signal.
- Traffic safety devices.
- Truck-mounted attenuator.

Information gathered from the survey responses is supplemented with additional details about product features and benefits sourced from the product information.

Portable Intelligent Traffic Management Systems

ConnectedTech by iCone
Road-Tech Safety Services, Inc.

Product Type	iCone add-on smart devices can be attached to existing traffic control equipment to create a network of connected equipment. Add-ons available for arrow boards, warning lights, truck-mounted attenuator (TMA) trucks and flagger paddle.
Product Use	• Attaches easily to existing arrow boards or warning lights. • Automatically sends location and start and end time data to digital maps.
Features	• Allows interrelated products to report work zone data directly to navigation systems and in-dash devices of connected cars. • Improves driver and worker safety and travel times. • Will aid real-time decisions of vehicles as they approach active work areas.
Description of Innovation	The platform tells automated vehicles and anyone using digital maps the precise location of the work zone and when workers are in the work zone. Arrow board device tells drivers if they need to merge right or left.

Benefits	• Improves safety for drivers and workers. • Improves travel times. • Eventually will aid real-time decisions of vehicles as they approach active work zones.

Supplemental Resource

iCone Products, Road-Tech Safety Services, Inc., undated.
https://www.iconeproducts.com/
From the web page:

> ConnectedTech proprietary technologies by iCone monitor fixed assets, deliver immediate notification via live stream or XML screen, and provide historical metrics on all products, result[ing] in labor reduction and rapid repair capabilities. ConnectedTech integrates with all iCone smart devices to interface with existing traffic control equipment[,] providing improved safety.

Users can access live traffic data from this web page.

Driveway Assistance Device
Horizon Signal Technologies, Inc.

Product Type	Work zone traffic control.
Product Use	Controls traffic from residential driveways that fall within a one-lane bidirectional work zone.
Features	• Alerts drivers entering the work zone from a driveway to the direction of traffic. • Uses a flashing arrow to indicate the direction traffic is flowing through the work zone. Drivers enter the queue in the direction of the flashing arrow. • Has full conflict monitoring capabilities and can be activated and deactivated sequentially to maximize safety within the signal setup. • Links multiple devices wirelessly to create a network.
Description of Innovation	Previously, flaggers or three-color temporary traffic signals were used in driveway scenarios. This practice was less efficient and not cost-effective because it required mainline traffic be stopped to serve one driveway at a time. The Driveway Assistance Device allows all driveways to be served simultaneously without holding mainline traffic.
Benefits	• Maximizes work zone traffic flow by servicing all driveways during each cycle. • Improves safety by reducing the likelihood of wrong-way driving. • Improves efficiency.

Supplemental Resource

Driveway Assistance Device, Horizon Signal Technologies, Inc., undated.
https://horizonsignal.com/driveway-assistance-device/
Access to information about the device's benefits and specifications supplement general product information. Also available on this web page is access to the product brochure and a

case study of New Jersey Department of Transportation's use of the devices at 31 driveways during work zone repair following Hurricane Sandy.

Level 3 Technology Package
Royal Innovative Solutions

Note: This product description was provided by ATSSA.

Product Type	Integration of three technological systems in one package: several high-definition cameras; a black box DVR recording system; and a truck-mounted, full matrix changeable message sign (CMS).
Product Use	Improves safety by allowing workers to efficiently communicate custom messages to travelers.
Features	• Allows contractors to use mounted cameras that capture footage of work zone activity that is saved on the in-cab solid-state hard drive. Product can be used on stationary, moving shadow or support vehicles. • Displays custom messages on the fly and serves as a radar board that overlays the speed of traffic on captured footage.
Description of Innovation	Integration of these separate systems to enhance work zone safety.
Benefits	• Alerts motorists to changing traffic conditions quickly, enhancing safety for the work crew and drivers. • If a crash occurs, reduces potential liability disputes by accurately capturing events that led to the incident on the saved footage.
Additional Information	• Can customize CMS messages from an in-cab controller.

Supplemental Resources

Full Matrix Changeable Message Sign (CMS), Royal Innovative Solutions, undated.
https://royalinnovativesolutions.com/radar-message-cms-boards
From the web page: The truck-mounted full matrix changeable message sign (CMS) allows you to customize warning messages in real time on the fly, whether you're on the road or in the work zone. Unlike other boards, the CMS gives you the ability to create, change and display custom messages and graphics from inside the cab using a mounted controller. The enhanced radar detection system of the CMS allows you to display either the speed of the fastest passing vehicle or the nearest vehicle. When the CMS is paired with our DVR and camera system, it's capable of recording and overlaying radar speed on playback to capture valuable documentation of incidents when they happen.

Cameras and DVR System, Royal Innovative Solutions, undated.
https://royalinnovativesolutions.com/mobile-dvr-radar-board/
From the web page: Our mobile DVR system captures all activity in and around your crash truck. It can be configured with 4 [to] 8 cameras that record with event triggering such as engine start, TMA deployment, vehicle movement, and even [G]-force impact.

Multiple camera views, including rear-mounted, increase awareness in your work zone and lower the risk of accidents. Fleet tracking allows you to increase company safety and decrease liability.

Portable Speed Monitoring Display

Work Zone Speed Reduction System
Horizon Signal Technologies, Inc.

Product Type	Work zone safety device.
Product Use	Used in work zones that involve a lane closure. Stops unsafe speeding vehicles before they enter the work zone.
Features	• Detects vehicles that are traveling at a predetermined unsafe speed. • Displays a preprogrammed message to motorists. • Simultaneously sends a wireless alert to the portable traffic signal controller, which pre-empts the running signal program and displays a red indication in the direction of the approaching vehicle.
Description of Innovation	The speed reduction system combines a radar speed display placed in advance of the work zone with Horizon's Portable Traffic Signal System and a wireless communication platform.
Benefits	• Helps protect workers and motorists while increasing overall work zone safety. • Detects speeds from 5 mph to 105 mph. • Allows programmable thresholds for signal actuation and custom messages.
Additional Information	Winner of a 2021 ATSSA Innovation Award.

Supplemental Resource

Work Zone Speed Control System, Horizon Signal Technologies, Inc., undated.
https://horizonsignal.com/speed-control-system/
Details of this speed reduction system are provided along with product benefits and specifications, and access to the product brochure.

Portable Traffic Signal

Clearance Time Extender
Horizon Signal Technologies, Inc.

Product Type	Portable traffic signals.
Product Use	Used in portable traffic signal applications involving lane closures. Adjusts red clearance intervals to help ensure slow-moving vehicles clear the work zone before allowing opposing green indications.
Features	• Automatically adjusts red clearance interval in real time. • Gives slow-moving vehicles extra time to clear the zone. • Holds all opposing green indications until vehicles clear. • Establishes detection zones using noninvasive sensors to detect slow-moving vehicles and adjust red clearance times. The quantity and length of detection zones can be adjusted based on application requirements. • Is compatible with all Horizon signal systems.
Description of Innovation	Previously, red clearance intervals were fixed and calculated by factoring the distance between each portable traffic signal and the anticipated speed of

	the vehicles traveling through the work zone. Project designers had to account for the slowest moving vehicle traveling through the work zone, which often meant overcompensating the red clearance intervals to ensure all vehicles had exited the work zone. This practice increased overall cycle lengths and wait times for drivers. The Clearance Time Extender allows portable traffic signal systems to identify any vehicles that have not yet cleared the zone and adjusts the red time to increase safety and signal timing efficiency.
Additional Information	The system can also be configured with: • Pedestrian crosswalk signal indicators (Manual on Uniform Traffic Control Devices (MUTCD) compliant). • Driveway Assistance Device for use on residential driveways. The system also offers: • Advanced remote monitoring, sending text and/or email alerts about signal operation and battery voltage levels. • Flagger/pilot car module, allowing a flagger or pilot car driver to control signal status with built-in safeguards.

Supplemental Resource

Clearance Time Extender, Horizon Signal Technologies, Inc., undated.
https://horizonsignal.com/red-clearance-time/
Information on this web page explains system operation. Access to the product brochure is also provided.

Traffic Safety Devices

Below are descriptions of:

- HighwayGuard Barrier.
- City Post channelizers:
  - City Post SM.
  - City Post EAC.
  - City Post GD.
- X-Marker.
- U-Flex post.
- REACT M safety cushion.

HighwayGuard Barrier

Trinity Highway Products

Product Type	MASH-tested steel barrier for work zones.
Product Use	Provides positive protection in work zones with portable temporary barrier.
Features	• Offers portable, longitudinal redirecting steel barrier made of lightweight, galvanized steel segments. Deployable in either single 20-foot segments or dual 40-foot segments. • Designed to help reduce work zone congestion in high traffic areas by creating temporary lane shifts and work zone closures during off-peak or weekend hours.

Description of Innovation	Steel barriers provide lower transportation costs to deploy on projects.
Benefits	Can be used in work zone applications with other compatible end treatments.
Additional Information	• MASH 2016 Test Level 3 and Test Level 4 compliant. • Product has been submitted to Caltrans. • The vendor is available to present more information about this product.

Supplemental Resource

HighwayGuard Barrier, Trinity Highway Products, undated.
https://trinityhighway.com/product/highwayguard/
Product information brief: https://trinityhighway.com/wp-content/uploads/2021/06/HighwayGuard-Barrier-3-1-21.pdf
Access to product specifications, assembly and maintenance information, and other documentation is available from this web page.

City Post
Pexco, LLC

City Post channelizers (permanent tubular markers) have been used nationally and internationally since 2012. These devices are intended for extremely high-risk areas or high-impact zones, primarily for high occupancy vehicle/high occupancy toll (HOV/HOT) lanes, bike lanes and centerline applications with narrow footprints. In curb island marking applications, the respondent noted that "most K and Q markers will only take a couple [of] impacts before they are lost as [an] island marker. [W]e have City Post[s] that have been taking hits for years." He added that this performance minimizes maintenance and increases safety.

The survey respondent provided information for three products:

- City Post SM (Surface Mount) (bolted down to the road surface).
- City Post EAC (Embedded Anchor Cup) (cored in to the road surface).
- City Post GD (Glue Down) (epoxied to the road surface).

(*Note*: Information about each product is summarized beginning on page 19.)

Texas Transportation Institute has tested all three models at speeds of 70 mph and up to 200 impacts on concrete and asphalt surfaces. The respondent noted two design features:

- The products are made from the strongest polymers available and fused at the factory, eliminating the need for pins, fasteners and components. The respondent added that minimizing the focus point of energy in the product by eliminating these points increases product longevity.
- With a diameter of 3.25 inches, the City Post is the largest diameter post on the market.

City Post products have been used by Florida Department of Transportation (DOT) (see *Supplemental Resources* below) and in several California projects, including bike lanes in San Diego and Metro Express lanes in Los Angeles County. In addition, the posts are expected to be implemented in a San Francisco Safe Streets project (anticipated installation: June 2021).

Supplemental Resources

City Post High Performance Channelization Solutions, Pexco LLC, Davidson Traffic Control Products, August 2019.
https://www.pexco.com/assets/files/Comprehensive_City_Post_Brochure_II.pdf
This product brochure includes applications, features and benefits, and installation information for the City Post channelizers. Key installations are also highlighted.

Executive Summary—Impact Testing of Managed Lane Channelizer Posts, Pexco LLC, July 2016.
https://www.pexco.com/pdfs/traffic-products/channelizer-posts/City%20Post%20GD/city-post-tti-testing-for-fdot-executive-summary-july-1-2016.pdf
This two-page summary describes testing conducted on two of Pexco's City Post products in March 2016 by Texas Transportation Institute and sponsored by Florida DOT. The project sought to identify a minimum level of performance to ensure that the highest performing products will be used on managed lanes in Florida. Researchers tested seven products, including City Post GD and City Post SM, which outperformed the other five posts. Testing results were used to establish minimum performance levels of delineators to withstand the impacts of bumpers and tires (wheel-over) at high speeds.

City Post SM (Surface Mount)

Product Type	Traffic channelizer.
Product Use	Intended for extremely high-risk areas or high-impact zones, primarily HOV/HOT lanes, bike lanes, curb island markings and centerline applications with narrow footprints.
Features	• Offers a traditional bolt-down post. • Installs in concrete and asphalt.
Description of Innovation	• 3.25-inch round channelizer. • Thermoplastic polyurethane composition for high-impact resistance. • One-piece construction with no springs or mechanical fasteners to fail.
Benefits	• Safe, impact-friendly design. • Low maintenance.
Additional Information	• Impact-tested. • Compliant with MUTCD, National Cooperative Highway Research Program (NCHRP) 350 and MASH 2016. • The vendor is available to present additional features of this product.

Supplemental Resource

City Post SM—Surface Mount, Pexco, LLC, undated.
https://www.pexco.com/traffic/products/bollards-and-channelizer-posts/city-post-surface-mount/
Access to additional information, CAD drawings, specifications and other documents related to the City Post SM is available from this web page.

City Post EAC (Embedded Anchor Cup)

Product Type	Traffic channelizer.
Product Use	Intended for extremely high-risk areas or high-impact zones, primarily HOV/HOT lanes, bike lanes, curb island markings and centerline applications with narrow footprints.

Features	• Installs in concrete and asphalt. • Offers an easy “spin-in” installation to minimize worker exposure. • Can be removed and stored in winter. • Has removable plug covers for the anchor cup until a post is replaced.
Description of Innovation	• 3.25-inch round channelizer. • Thermoplastic polyurethane composition for high-impact resistance. • One-piece construction with no springs or mechanical fasteners to fail.
Benefits	• Designed for superior durability and quick replacement.
Additional Information	• MUTCD, NCHRP 350 and MASH 2016 compliant. • The vendor is available to present additional features of this product.

Supplemental Resource

City Post Model EAC (with Embedded Anchor Cup), Pexco, LLC, undated.
https://www.pexco.com/traffic/products/bollards-and-channelizer-posts/city-post/
Access to additional information, CAD drawings, specifications and other documents related to the City Post Model EAC is available from this web page.

City Post GD (Glue Down)

Product Type	Traffic channelizer.
Product Use	Intended for extremely high-risk areas or high-impact zones, primarily HOV/HOT lanes, bike lanes, curb island markings and centerline applications with narrow footprints.
Features	• Installs in concrete and asphalt • Optimizes adhesion through its unique pinwheel base design.
Description of Innovation	• 3.25-inch round channelizer. • Thermoplastic polyurethane composition for high-impact resistance. • One-piece construction with no springs or mechanical fasteners to fail.
Benefits	• Remains flexible and continues to fully rebound after more than 100 hits at 70 mph.
Additional Information	• MUTCD, NCHRP 350 and MASH 2016 compliant. • Model has been used on Florida HOV/HOT lanes for years. • The vendor is available to present additional features of this product.

Supplemental Resources

City Post GD—Glue Down, Pexco, LLC, undated.
https://www.pexco.com/traffic/products/bollards-and-channelizer-posts/city-post-gd-glue-down/
Access to additional information, CAD drawings, specifications and other documents related to the City Post Model GD is available from this web page.

X Marker
PPP

Note: This product description was provided by ATSSA.

Product Type	Temporary traffic control device.
Product Use	Use to clearly identify a lane as closed for construction or events. Placed in intervals along the center of the closed lane.
Features	• Clearly and concisely identifies the protected lane, reducing the likelihood that motorists will unintentionally enter work zones. • Offers C-channel construction of lightweight, durable high density polyethylene (HDPE) is wind-resistant with more than 280 degree reflective viewing angles. • Easily attached and removed from most common sign stands, and fold for safe transport.
Description of Innovation	The stand-mounted, highly visible device integrates features from the airfield, sign and temporary traffic control industries. The proven effectiveness of similar runway devices is combined with sign enhancement innovation and standard temporary traffic control applications to produce an innovative, economical approach to work zone safety.
Benefits	• Clearly identifies a closed lane to prevent motorists from entering a work zone, especially extended work zones or those with limited site distance due to changes in vertical or horizontal design such as hills or curves. • Enhances safety for workers and motorists.

U-Flex
Shur-Tite Products

Note: This product description was provided by ATSSA.

Product Type	Temporary traffic control device.
Product Use	Designed for HOV and bike lanes.
Features	• Is a flexible, 3-inch post that withstands bumper and tire impacts. • Allows workers to replace the post independent of the base. • Features a weep hole designed to eliminate rainwater retention. • Increases visibility of reflective sheeting.
Description of Innovation	This design allows for quick post replacement in high traffic areas. The integrated weep hole allows for proper drainage, avoiding premature failures.
Benefits	• Offers low-cost, fast maintenance. • Reduces time in traffic for workers.
Additional Information	According to AASHTO's National Transportation Product Evaluation Program data, this product provides the best performance of a 3-inch post.

REACT M
Trinity Highway Products

Product Type	Severe-duty crash cushion (MASH 2016 Test Level 3).
Product Use	Protects roadside and median hazards.

Features	• Consists of six HDPE cylinders attached to a steel backup and basetrack assembly.
	• Offers various cylinder wall thicknesses designed to help withstand impact by light cars or heavier, high-center-of-gravity vehicles.
	• Includes a self-contained backup structure designed to:
	  ○ Resist movement during head-on and side impacts.
	  ○ Protect hazards up to 30 inches wide.
	• Has shown self-restoring characteristics when impacted within MASH 2016 crash test standards.

Description of Innovation	The REACT M system's low-maintenance, self-restoring features offer residual capacity.
Benefits	• Residual capacity. • Low maintenance.
Additional Information	The vendor is available to present more information about this product.

Supplemental Resource

REACT M, Trinity Highway Products, undated.
https://trinityhighway.com/product/react-m/
Product information brief: https://trinityhighway.com/wp-content/uploads/2021/02/REACT-M-2-21-21.pdf
Access to product specifications, assembly and maintenance information, and other documentation is available from this web page.

Truck-Mounted Attenuator

SS180M (MASH) Truck-Mounted Attenuator

Trinity Highway Products

Product Type	MASH truck-mounted impact attenuator
Product Use	Protects workers, vehicle operators and motorists in mobile and stationary work zones.
Features	• Use on stationary, moving shadow or support vehicles. • Contains two lightweight aluminum cartridges in a potentially reusable steel support frame; a 180-degree tilt feature folds at the center to stack the cartridge sections. • Offers short height while in storage mode, which is ideal for garage storage and low overpasses.
Description of Innovation	TMA that meets MASH requirements.
Benefits	• Helps to absorb rear-end impacts at speeds up to 62 mph when impacted within MASH crash test standards. • Is designed to help minimize damage from low-speed nuisance hits up to 6 mph.
Additional Information	• Product has been submitted to Caltrans. • The vendor is available to present more information about this product.

Supplemental Resource

SS180M, Trinity Highway Products, undated.
https://trinityhighway.com/product/ss180m/
Product information brief: https://trinityhighway.com/wp-content/uploads/2019/10/SS180-M-9-23-19-.pdf
Access to product specifications, assembly and maintenance information, and other documentation is available from this web page.

Enhanced Work Zone Safety Products

Enhanced products from two companies are described below in the following categories:

- Intelligent transportation system solutions.
- Web-based tools.

Intelligent Transportation System Solutions

Transnomis
Road-Tech Safety Services, Inc.

Product Type	Automated work zone information system.
Product Use	Uses portable sensors and message signs that network with iCone devices to automatically tell drivers when a lane is closed and to merge right or left.
Description of Innovation	• Links Transnomis software to iCone devices. • Displays messages automatically on arrow boards and message signs.
Additional Information	The system may have been demonstrated for Caltrans Headquarters.

Supplemental Resource

Road Information Management and Communications, Transnomis Solutions, undated.
https://www.transnomis.com/
From the web site: Transnomis Solutions specializes in road information management and communications solutions for agencies with road information and all that need it. Our service offerings range from low-cost hosted web services to comprehensive, fully integrated, custom intelligent transportation systems (ITS). We serve municipal and provincial governments, associations and corporations in Canada, the USA and overseas.

Web-Based Tools

ConeIQ
ConeIQtrack LLC

Product Type	Software as a service.
Product Use	• *Module 1: Design layout.* Allows work zone layout design according to federal or state requirements (similar to MUTCD). • *Module 2: Inspection and compliance.* Once a work zone has been implemented, captures GPS readings and images to determine if the layout is set up according to the agency's requirements.
Features	• Creates work zones on an online map in seconds. • Can be used on laptops, tablets or cellphones.

Description of Innovation	Maintenance of traffic solution used by contractors (and potentially departments of transportation) to create digital work zone layouts that can be customized for each site.
Benefits	• Improves safety and compliance. • Increases operational efficiency and simplifies training. • Can be accessed on a subscription basis. • Does not require downloads.
Additional Information	• Currently used in California. • Can support all states and MUTCD products. • The vendor can provide a demo account to Caltrans for testing.

Supplemental Resource

ConeIQ, ConeIQtrack LLC, undated.
Product information: www.coneiqtrack.com
Video demonstration: https://youtu.be/rR7BbWTzbJ0
The ConeIQ web page allows users to explore the design layout and inspection and compliance modules. Blog posts update users about the technology's features.

Related Research and Resources

Caltrans is particularly interested in identifying recent domestic publications and other resources that describe innovations in work zone safety products such as:

- Portable changeable message signs (PCMS).
- Portable speed monitoring displays.
- Vehicle-activated signs.
- Single-use removable temporary rumble strips.
- Reusable temporary rumble strips.
- TMAs.
- Highway advisory radio.
- Work zone intrusion alarms.
- Work zone sequential flashing warning lights.
- Mobile work zone barriers.
- Portable intelligent traffic management systems.

A literature search of recent publicly available domestic resources identified publications that are organized into the following topic areas:

- National research and guidance.
- State research and guidance.
- Related resources.
- Innovations by equipment type.

National Research and Guidance

Research in Progress

NCHRP Synthesis 20-05/Topic 52-11: Use of Smart Work Zone Technologies for Improving Work Zone Safety, start date: September 2020; expected completion date: unknown.
Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4987
From the final scope: The objective of this synthesis is to document the use and effectiveness of smart work zone technologies used by state DOTs for the purpose of improving the safety of workers and drivers affected by work zone activity. Information to be gathered includes (but is not limited to) use of:

- Dynamic warning systems to provide accurate notifications to drivers and workers (e.g., queue warning, travel time through the work zone, dynamic lane merge, work zone intrusion alarm, truck entering systems).
- Variable speed limit systems to reduce vehicular speed differential in advance of and within a work zone (e.g., radar speed feedback signs).
- Smart technologies integrated with crowdsourcing systems to provide data for dynamic warning systems.
- Work zone location technologies.
- Performance measures used to determine the effectiveness of work zone technologies (e.g., metrics, crash reduction, delay reduction).
- Measures of return on work zone technology investment used by DOTs.
- Data transmission issues regarding availability of cellular service and bandwidth for deploying smart work zone technologies.

Completed Research and Guidance

Synthesis of Research Related to the Use and Implementation of Advanced Technology to Improve Work Zone Management, Federal Highway Administration, August 2020.
https://www.workzonesafety.org/files/documents/training/fhwa_wz_grant/tti-artba_synthesis_advanced_technology_wz_management.pdf
From the introduction: Efforts are currently underway to develop and test ways to support CV [connected vehicle] and AV [automated vehicle] operations approaching and passing through work zones. Efforts are also underway to explore how wireless communications and other advanced technologies can improve work zone safety and mobility for human drivers and workers as well. This synthesis has been developed to identify and summarize the various efforts underway regarding CVs, AVs and other advanced technologies for improving work zone safety and mobility. The synthesis covers the following categories:

- Efforts to define and collect digital work zone event data.
- Non-CV efforts to disseminate work zone event data to human drivers.
- CV pilot tests and demonstrations that include work zone components.
- Efforts to support ADS [automated driving system] accommodation of work zones.
- Efforts to utilize advanced technologies to improve worker safety in work zones.
- Other initiatives.

The synthesis provides an effort-by-effort synopsis of the following:

- Title of the activity.
- Entities involved.
- Overall description of the effort.
- Specific work zone involvement in the effort.
- Key work zone-related findings or lessons learned to date.
- Contact(s) for more information.

State Research and Guidance

Research in Progress

Multiple States

Smart Work Zone Deployment Initiative (FY2020-FY2024), Smart Work Zone Deployment Initiative, Transportation Pooled Fund Program, start date: January 2020; expected completion date: December 2025.
Pooled fund description at https://trid.trb.org/view/1644217
From the description: This program represents an ongoing effort among cooperating states' DOTs, the FHWA [Federal Highway Administration], universities and industry to evaluate new products and conduct related research focused on the enhancement of safety and mobility in highway work zones. Over 100 studies and evaluations have been completed since the inception of the SWZDI [Smart Work Zone Deployment Initiative] and final reports are posted in the Smart Work Zone Deployment Initiative web site at https://swzdi.intrans.iastate.edu/.

California

Review of Equipment and Accessories for Truck-Mounted Attenuator (TMA) Trucks, California Department of Transportation, start date: November 2019; expected completion date: April 2022.
Project description at https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/research-notes/task3685-rns-03-21-a11y.pdf
From the project summary: The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center proposes to evaluate specific equipment and accessories available for TMA trucks. This research would include radar speed feedback signs, camera systems able to record multiple views, communication systems and panic/warning lights.

Florida

Florida ATMA Pilot Demonstration and Evaluation, Florida Department of Transportation, start date: June 2020; expected completion date: March 2021.
Project description at https://rip.trb.org/view/1710225
From the project description: The main objective of the research project is to evaluate the performance of an autonomous truck-mounted attenuator (ATMA) system based on: a. Ongoing or completed projects by other agencies that adopted ATMA; b. Actual testing of the equipment during a demonstration pilot in Gainesville, FL. The goal of this project is to produce a critical analysis report to better understand the feasibility or applicability of the autonomous system to enhance operational or safety benefit on work zones in Florida.

Related Resource:

> **"UFTI-T2 Center Receives Grant to Evaluate New Technology: Autonomous Truck-Mounted Attenuator,"** Newsletters, University of Florida Transportation Institute, June 2020.
> https://techtransfer.ce.ufl.edu/2020/06/30/ufti-t2-center-collaborates-with-fdot-to-evaluate-new-technology-autonomous-truck-mounted-attenuator/
> *From the newsletter article*: Deployment of the autonomous truck-mounted attenuator (ATMA) in Florida has the potential to significantly increase worker safety and save taxpayer costs during highway maintenance and construction. The evaluation will identify strengths and limitations and conduct a cost–benefit analysis of the ATMA to evaluate its usefulness for improving worker safety of Florida highways. Before introducing the ATMA technology to Florida roadways, the research team will use a controlled testing environment with no traffic to assess safety features. UF researchers will also examine use of the ATMA technology in real work zones on different roadway types, including high speed urban and rural roadways and low speed urban roadways. The ATMA will follow and protect a work vehicle[,] which will be equipped with a falling weight deflectometer (FWD), a device [that] evaluates the strength of pavement.

Completed Research and Guidance

Multiple States

Synthesis of Intelligent Work Zone Practices, Tina Roelofs and Chris Brookes, ENTERPRISE Pooled Fund Study, June 2014.
https://enterprise.prog.org/Projects/2010_Present/iwz/ENT_SynthesisofIWZPractices_FINALReport_June2014.pdf
From the abstract: The ENTERPRISE Pooled Fund Program initiated a project to document the resources available as well as uses and benefits regarding the following Intelligent Work Zone (IWZ) technologies: queue warning systems, dynamic merge systems, alternate routes and variable speed limits in work zones. A detailed literature search was conducted to summarize work zone materials available related to the four work zone technologies. In addition, intelligent work zone representatives from transportation agencies were contacted to provide details on recent related deployments and provide input to the project.

The purpose of this report is to understand the current status of work on IWZ activities by combining the resources gathered through a literature search with the information collected from the transportation agencies on recent deployments. Also included is a summary of the four IWZ technologies including examples of successes, any guidance possible when technologies are most effective, and the configurations that demonstrated the best results.

Alabama

Active Work Zone Safety Using Emerging Technologies 2017, Eric Marks, Stephanie Vereen and Ibukun Awolusi, Alabama Department of Transportation, July 2017.
http://utca.eng.ua.edu/files/2019/08/15412-Final-Report.pdf
From the abstract: The main objective of this study was to conduct both conceptual analysis and experimental evaluation of intrusion sensing technologies for work zone safety. To achieve the objectives of this research, a comprehensive review of the applicable technologies was conducted to identify the intrusion technologies that can be implemented for work zone safety. An objective assessment of each technology was provided based on selected weighing metrics to elicit their capabilities. Candidate commercially available technologies were selected and evaluated using field experiments in simulated work zones. The findings of the study indicate that a limited number of the applicable technologies exist and the selected commercially available technologies evaluated have the capabilities to effectively provide alerts to highway work zone personnel when a hazardous situation is present.

Iowa

"Iowa DOT Using Audible Attenuators to Increase Short-Term Work Zone Awareness," *Roads and Bridges*, April 30, 2021.
https://www.roadsbridges.com/iowa-dot-using-audible-attenuators-increase-short-term-work-zone-awareness
From the article: The Iowa Department of Transportation is employing a number of safety practices including the use of audible attenuators on short-term, stationary or slow-moving maintenance operations. The attenuators are designed to warn drivers of crews ahead and take the impact of a crash if a driver does not slow down or move over for the crew. An attenuator is a trailer that is pulled behind a truck equipped with flashing lights and signage signaling the presence of crews. If a driver does not appear to slow down or move over for the crew, the attenuator operator has the ability to turn on additional flashing lights that shine at a higher frequency. If a driver is still not responding to the extra lighting, the attenuator operator can then activate an audible sound [alarm] in a final attempt to get the attention of the driver.

Minnesota

Evaluation of the Smart Work Zone Speed Notification System, John Hourdos, Gordon Parikh, Peter Dirks, Derek Lehrke and Pavel Lukashin, Minnesota Department of Transportation, June 2019.
http://www.dot.state.mn.us/research/reports/2019/201921.pdf
From the abstract: The Smart Work Zone Speed Notification (SWZSN) system aims to alleviate congestion, queuing and rear end crashes in work zones by informing drivers of the speed of the downstream segment using a type of portable [i]ntelligent [l]ane [c]ontrol [s]ystem (ILCS), [p]ortable [c]hangeable [m]essage [s]igns (PCMS). The hypothesis was that drivers, knowing the speed up to [1] mile downstream, will slow down early or at least be alert and perform smoother decelerations. Video of the SWZSN was analyzed over two years of operation by the Minnesota Traffic Observatory. Overall, the system resulted in beneficial reductions of selected decelerations by the drivers. In situations where the messages communicated to the drivers were consistent and accurate, reductions of more than 30% in the selected deceleration rates were observed. Unfortunately, there were several cases where counterproductive or misleading messages were communicated to the drivers, prompting relative increases to the selected deceleration rates. The most important observation, stemming from both positive and negative influences, was that the speed notification system was noticed by drivers and resulted in a statistically significant influence on driving behavior, unlike other driver alert systems.

Missouri

"Looking Deep Into the Eyes: Green Light on TMAs Could Be Another Option for DOTs," Siyang Zhang, Zhu Qing, Henry Brown, Calros Sun and Praveen Edara, *Roads and Bridges*, September 4, 2018.
https://www.roadsbridges.com/looking-deep-eyes
From the article: In order to reduce the number of vehicle collisions with TMAs, innovative solutions are needed. MoDOT [Missouri Department of Transportation] sought to explore the use of green lights on TMAs as a possible countermeasure to improve mobile work-zone safety. The objective of this project was to assess the effectiveness of green lights on TMAs for MoDOT. To achieve this objective, both a simulator test and field test were used to obtain quantitative measures for different TMA light configurations. For the simulator study, four light configurations were examined as shown in Figure 1: amber/white, green only, green/amber and green/white. The field study included an investigation of only the amber/white and green-only configurations.

Evaluation of Automated Flagger Assistance Devices, Henry Brown, Carlos Sun, Siyang Zhang and Zhu Qing, Missouri Department of Transportation, February 2018.
https://spexternal.modot.mo.gov/sites/cm/CORDT/cmr18-004.pdf
From the abstract: Automated flagger assistance devices (AFADs) are designed to improve worker safety by replacing flaggers who are typically located near traffic approaching a work zone. In this study, a new AFAD developed by the Missouri Department of Transportation (MoDOT) was evaluated via a combined driving simulator and field study. The MoDOT AFAD configuration conformed to the Manual on Uniform Traffic Control Devices and involved STOP/SLOW paddles, red/yellow lights and a changeable message sign (CMS). This AFAD was incorporated onto a truck-mounted attenuator for operator protection. Driver behavior measures, including approach speed, initial braking location, full stop distance, reaction time and intervention rate, were used to measure the effectiveness of AFAD as compared to a human flagger. In the field study, the AFAD induced slower vehicle approach speeds (4.20 mph less), stopped vehicles farther back (11.4 feet), and released traffic quicker (1.3 seconds less) than flaggers. In the driving simulator study, the AFAD and its alternative designs significantly

reduced average approach speeds (7.7 to 8.9 mph) and increased the distance at which the approaching vehicles came to a complete stop (24 to 48 feet). Both the field and the simulator study were followed by surveys that captured driver preferences and understanding. The results from both surveys showed that drivers understood AFADs well and preferred AFADs over human flaggers, especially for the MoDOT AFAD configuration. Overall, the AFAD has potential to improve the safety of work zones for both workers and the traveling public.

North Carolina

Using IoT Technology to Create Smart Work Zones, Erol Ozan, Yuanyuan Fu and Brian Dunn, North Carolina Department of Transportation, July 2020.
https://connect.ncdot.gov/projects/research/RNAProjDocs/Final%20Report%202019-24.pdf
From the abstract: This study explores the feasibility of improving road work zone safety by using state-of-the-art Internet of Things (IoT), artificial intelligence (AI) and computer vision technologies. This project included in-depth analysis of the key technologies and systems that have the potential to improve work zone safety. In order to gain an understanding of the major triggers of the most harmful crashes in work zones, the project team analyzed the crash data in North Carolina. Driven by insights gained through an extensive literature review and the analysis of North Carolina work zone crash data, this project developed two proof-of-concept systems using IoT, AI and computer vision technologies for work zone safety. The developed systems provide capabilities for two functions: (1) work zone intrusion warning and (2) vehicle queue detection. The proof-of-concept intrusion alert system comprised a mobile device attached on a tripod to monitor a restricted area and a system to alert the workers when an intrusion occurs. The workers receive alerts instantly through alarm sounds and vibrations generated by their mobile devices. The systems were tested using a simulated test environment and the findings of the tests indicated their potential to provide a robust technical approach. A proof-of-concept queue warning system was also developed and tested. The results indicated its potential to be used in smart work zones as a low-cost and easy-to-deploy system. Both systems were implemented with the capability to run on Android smartphones. However, the software is extremely portable, and therefore, the technical design can be embedded in any type of hardware. This report also identifies three commercially available devices that have good potential to be used in the field as part of a smart work zone to improve the work zone safety.

Oregon

Work Zone Intrusion Alert Technologies: Assessment and Practical Guidance, John Gambatese, Hyun Woo Lee and Chukwuma Aham Nnaji, Oregon Department of Transportation, June 2017.
https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR790_IntrusionAlertTech.pdf
From the abstract: A work zone intrusion alert technology is a type of safety system that is used in a roadway work zone to alert field workers and secure time for them to escape when errant vehicles intrude into the work zone. Although such technologies have potential to significantly improve the overall safety of construction work zones, previous studies reported mixed findings, resulting in limited application of intrusion alert technologies. In response, the primary goal of this research study is to scientifically assess the effectiveness of currently available work zone intrusion alert technologies, and to provide recommendations for use of the technologies in future ODOT [Oregon DOT] construction and maintenance work zones. To fulfill this goal, the research gathered information about work zone intrusion alert technologies, gained experiential input and advice from ODOT staff and industry practitioners, and tested technologies under controlled conditions and in active work zones. While sample sizes were limited, the findings from the study indicate that aspects of intrusion alarms via visual, audio and haptic means can

be effective warning mechanisms in a work zone. To improve the potential impacts of these technologies, this report identifies recommended minimum standards for each of the aforementioned means of alert. Implementation of the research results is expected to assist ODOT with enhancing the safety of motorists and workers in construction work zones on high-speed roadways.

Texas

Smart Work Zone Guidelines: Design Guidelines for Deployment of Work Zone Intelligent Transportation Systems (ITS), Texas Department of Transportation, October 2018.
https://ftp.dot.state.tx.us/pub/txdot-info/trf/smart-work-zone-guidelines.pdf
From the introduction: This guide provides an introduction to six [s]mart [w]ork [z]one (SWZ) systems that have been identified by TxDOT [Texas DOT] for use in work zones. It includes [s]ystem [s]election [d]ecision [t]ools, which use project specific criteria for [g]o/[n]o-[g]o decisions for each of these systems and [f]unction [s]election [d]ecision [t]ools to meet specific project needs. These tools are intended to streamline the design process and produce a uniform SWZ delivery across the [s]tate. The six SWZ systems include the following:

- Temporary queue detection.
- Temporary speed monitoring.
- Temporary construction equipment alerts.
- Temporary travel time display.
- Temporary incident detection and surveillance.
- Temporary over-height vehicle warning.

Closed Course Performance Testing of the AWARE Intrusion Alarm System, LuAnn Theiss, Gerald Ullman and Tomas Lindheimer, Texas A&M Transportation Institute, April 2017.
https://static.tti.tamu.edu/tti.tamu.edu/documents/TTI-2017-2.pdf
From the executive summary: Oldcastle Materials and ARTIS, LLC have joined forces to develop an innovative work zone intrusion detection and alarm system. This system has been named AWARE, for Advance Warning And Risk Evasion. Unlike previous intrusion alarm systems that rely on the detection of vehicles crossing a predetermined perimeter (typically identified with pneumatic tubes or infrared beams), this new system utilizes a target threat detection and tracking methodology to logically assess approaching vehicle speed, location and possible trajectory.

This study was conducted to assess performance of the AWARE intrusion alarm system in a closed course environment. This testing was intended to verify that the alarm system does produce the proper alert when conditions warrant (i.e., lights activate and do so when the approaching vehicle is at the appropriate distance based on the threat detection and SSD [stopping sight distance] algorithms). In addition, the testing was also intended to verify that alerts were not activated when conditions did not warrant (i.e., that the system does not produce a false alarm). The performance of the Worktrax devices designed to be worn by field personnel and activated when an intrusion threat is detected was also evaluated. These devices were positioned at the AWARE system vehicle and at locations upstream of the vehicle to assess the ability of the system to correctly determine the location of the devices and their position relative to the intrusion threat.

Related Resources

"Improving Construction Work Zone Safety Using Technology: A Systematic Review of Applicable Technologies," Chukwuma Nnaji, John Gambatese, Hyun Woo Lee and Fan Zhang, *Journal of Traffic and Transportation Engineering,* Vol. 7, Issue 1, pages 61-75, February 2020.
https://www.sciencedirect.com/science/article/pii/S2095756419301837?via%3Dihub
From the abstract: Once considered conventional, the construction industry is gradually increasing its reliance on innovations such as the application of technologies in safety management. Given the growing literature on technology applications in safety management and the varying opinions on the utility of applied technologies, a systematic review that streamlines findings from past studies is indispensable to construction stakeholders. Although a number of review studies are available in the building construction sector, the level of fragmentation and uniqueness within the construction industry necessitates a review study specifically targeting the heavy civil sector. In response, the present study applies a three-step approach to identify and review articles pertinent to the safety of highway construction work zones. The factors considered include the number of publications per year, publication locations and technology types. In addition, the present study proposes to broadly group work zone safety technologies (WZSTs) into three categories based on their primary purpose: speed reduction systems, intrusion prevention and warning systems, and human-machine-interaction detection systems. Key findings include WZST research trends, application of smart work zone systems, and the potential relationship between WZSTs and fatalities. The paper ends with the identification of six additional research areas aimed at deepening the understanding of technology's role in highway safety management. The trend analysis and an in-depth discussion of each technology category alongside the identified research gaps will provide a substantial informative body of knowledge that both benefits current practitioners and directs researchers towards potential future studies.

"Active Work Zone Safety: Preventing Accidents Using Intrusion Sensing Technologies," Ibukun Awolusi and Eric Marks, *Frontiers in Built Environment*, Vol. 5, Article 21, March 2019. Publication available at
https://www.researchgate.net/publication/331499591_Active_Work_Zone_Safety_Preventing_Accidents_Using_Intrusion_Sensing_Technologies
From the abstract: Highway construction work zones are hazardous environments characterized by a dynamic and limited workspace. A host of interactions between workers, passing commuter vehicles, and moving construction equipment occurs in highway work zones, fostering dangerous situations that can result in injury or death. Active strategies, such as the deployment of intrusion sensing and alert technologies in highway work zones and in transportation infrastructure construction and maintenance, can be effective at mitigating these unforeseen conditions. The main objective of this study was to conduct both conceptual analysis and experimental evaluation of intrusion sensing technologies for work zone safety. To achieve the objectives of this research, an exploratory review of the applicable technologies was conducted to identify the intrusion technologies that can be implemented for work zone safety. An objective assessment of each technology was provided based on selected evaluation metrics to elicit their capabilities. Candidate commercially available technologies were selected and evaluated using field experiments in simulated work zones. The findings of the study indicate that the commercially available technologies have the potential to enhance [the] safety of work zone workers by providing warning alerts when hazardous situations exist. This research contributes to the body of knowledge by providing strategies for selecting and implementing intrusion sensing technologies for active work zone safety.

Innovations by Equipment Type

Identified below are vendor and other descriptions of innovative work zone safety products in the following equipment categories:

- PCMS.
- Portable intelligent traffic management system.
- Portable speed monitoring display.
- Reusable temporary rumble strips.
- TMAs.
- Vehicle-activated signs.
- Work zone sequential flashing warning lights.
- Product for multiple equipment types.

The literature search did not identify vendor or related descriptions of innovations in these work zone safety equipment categories:

- Highway advisory radio.
- Mobile work zone barriers.
- Single-use removable temporary rumble strips.
- Work zone intrusion alarms. (Oregon DOT has conducted research on work zone intrusion alert technologies; see page 30 for more information.)

Portable Changeable Message Signs

2017 DH1000 PCMS, Addco, 2017.
http://www.addco.com/Product/DH1000
From the web page: When we combine a connected sign and a cloud-based system to manage your signs, we take information from everywhere and use that to make the sign better. Introducing Auto-Deployment, where [the] sign automatically raises and rotates to the optimal position for any given roadway. Unhook the hitch, drop the jacks and get back in your vehicle. Tap the Deploy button and you're done.

TraffiCloud Web-Based Traffic Device and Data Management System, All Traffic Solutions, Inc., undated.
https://www.alltrafficsolutions.com/solutions/trafficloud/
From the web page: TraffiCloud is the secure, web-based traffic management ecosystem that makes it quick and easy to access, monitor and manage all your traffic devices, dynamic messaging and data from any [i]nternet-connected device.

- View dashboards and reports of all collected data, or just one traffic device.
- Make more insightful traffic management decisions based on real-time data analytics from all your traffic program components.
- Run six ready-made reports in seconds right out of the box!
- Remotely manage all connected devices and dynamic messages—regardless of manufacturer—from one central location.
- Improve workflows, optimize resources and cut down on workforce hours.

The TraffiCloud Traffic Suite includes all the features you need for effective and efficient traffic program management. Traffic Suite features can also be purchased individually.

Get the Message Across [Message Boards], K&K Systems, Inc., undated.
https://www.k-ksystems.com/message-signs.html
From the web page: K&K Systems message boards utilize energy-efficient LED and the latest and most efficient solar panels to display your message brightly during the day, night, rain, snow and sleet continuously.

Changeable Message Signs, Renaissance Technologies Inc., undated.
http://www.rtiwz.com/home/road-side-field-devices/changeable-message-signs
From the web page: RTI's portable changeable message signs are controlled by TrafAlert, our software package, which integrates all major manufacturers, including ADDCO, AMSIG, Precision Solar, Solar Tech, Ver-Mac and Wanco.

All portable changeable message signs are heavy duty and meet the following minimum specifications:

- [Three]-line/[eight]-character or full matrix display.
- Visible from at least 1,000 feet.
- Solar recharged with deep cycle battery power.
- NTCIP [National Transportation Communications for ITS Protocol] compatible communications.
- Wireless-enabled communications and trailer mounts for portability.
- Minimum of [four] corner-mount outrigger jacks for stability.
- GPS-enabled location control and monitoring.
- Remote voltage and current monitoring from onboard power sensing electronics.

Camera Option for Message Board, Solar Technology, Inc. (SolarTech), undated.
https://solartechnology.com/wp-content/uploads/CameraOption-1.pdf
From the web page: Full-sized message boards can be outfitted with a camera that can extend above the board to monitor traffic. This option is useful in smart work zones. By using real-time traffic information supplied by the camera, transportation officials can customize messages to warn motorists about what is actually happening ahead. The camera option allows the camera to be raised to nearly 20 feet above the ground.

All SolarTech portable changeable message boards already include free remote access**—**GPS, modem and cellular service—to locate the board and change its message remotely. (Camera image transmission requires a separate modem and cell service.) These message boards with cameras also include a tilt and rotate solar array for optimal solar power collection.

Portable Intelligent Traffic Management Systems

GEWI and iCone Products Partner to Improve Safety With Real-Time Work Zone Information, GEWI, undated.
https://gewi.com/2020/09/gewi-and-icone-products-partner-to-improve-safety-with-real-time-work-zone-information/
From the web page: GEWI and iCone Products are partnering to help travelers avoid and safely navigate roadwork projects by providing accurate and real-time travel information, which can be delivered directly to navigation devices through apps and in-car navigation systems.

Using the cloud-based, real-time data from iCone's ConnectedTech devices, GEWI's TIC Software further enables road agencies and their work zone contractors to manage information about the location and status of work zone assets. This data can in turn be used to create traffic and travel events which can be distributed to in-vehicle navigation systems, connected apps and the web.

Internet of RoadWork (IoR), iCone Products, LLC, undated.
https://www.iconeproducts.com/why-icone
From the web page: ConnectedTech is a suite of [internet-addressable, GPS-enabled] technology devices that interface with existing traffic control equipment. Once deployed, our interrelated products intelligently report work zone data directly to navigation systems and in-dash of connected cars. The platform improves safety for drivers and workers, travel times and eventually will aid real-time decisions of vehicles as they approach active work areas.

JamLogic—Smart Work Zone Solutions, Ver-Mac, undated.
https://www.ver-mac.com/en/jamlogic-software/smart-work-zones
From the web page: … JamLogic software provides transparent client server access to all devices and data. The software analyzes traffic data and provides real-time information to the motoring public, project managers, agencies, traffic management centers (TMC) and public web sites.

Smart Arrowboard, Ver-Mac, undated.
https://ver-mac.com/en/products/series/serie/arrowboards/product/smart-arrowboard/99
From the web page: The Smart ArrowBoard is a solution that turns any existing arrowboard into a connected work zone by providing real-time key lane closure information to motorists, government agencies and operations. Short-term lane closures are set up on highways every day impacting traffic and motorists' commute. The Smart ArrowBoard will allow operations and government agencies to be proactive instead of reactive to unexpected lane closures.

This solution allows motorists to be alert in advance of the presence of a work zone via their navigation systems. Therefore, you will have less traffic near your operations and it will allow motorists to safely drive through active work zones.

Traffic Cameras and Sensors, Ver-Mac, undated.
https://www.ver-mac.com/en/products/series/serie/traffic-cameras-sensors/4
From the web page: Our portable cameras and sensors are the perfect equipment to be integrated into smart work zone projects. Our sensors gather speed data and combined with our JamLogic software, messages can be automated on message signs along the road. Our camera trailers are mainly used to monitor work zones, construction sites or special events. Most of our products in this line are powered by solar panels and batteries and are made of high-quality construction to provide long-lasting equipment.

Portable Speed Monitoring Display

SP-3248-DSL (Speed Wizard), Ver-Mac, undated.
https://www.ver-mac.com/en/products/series/serie/speed-signs/product/speed-wizard/102
From the web page: Ver-Mac's Speed Wizard is the industry-first combination [w]ork [z]one [d]igital [s]peed [l]imit (WZDSL) and [s]peed [a]wareness [s]ystem. The two-digit, 18-inch white LED displays the work zone speed limit while the two-digit 18-inch amber LED displays the speed of [the] oncoming motorist. The [s]peed [a]wareness display automatically adjusts to the WZDSL speed and has three levels of warning to the motorist. The Speed Wizard will automatically send a work zone speed notification in real time to Waze and through WZDx to DOTs and potentially automated vehicles.

Reusable Temporary Rumble Strips

RoadQuake 2F Temporary Portable Rumble Strip, PSS Innovations, undated.
https://pss-innovations.com/safety-products/rumble-strip-systems/roadquake%C2%AE-2f-temporary-portable-rumble-strip
From the web page: Designed to reduce accidents and save lives, RoadQuake 2F Temporary Portable Rumble Strip (TPRS) alerts distracted drivers in work zones and other changing road conditions. Ideal for work zones where daily installation and removal [are] required.

Features and Benefits:

- Temporary—No nails or glue are needed for installation and use.
- Quick installation and removal, and no cleanup.
- Portable—No installation equipment needed. A crew of two can install an array in minutes.
- Durable—[Three- to five-year] life under normal conditions.
- Suitable for use in rain and temperatures of 0 degrees to 180 degrees F and in speeds up to 80 mph.
- Generates the same level of sound and vibration as milled strips.
- 13" W x 3/4" H x 132" L when unfolded; covers an entire lane.
- Folds to a compact 66" length; weighs 110 [pounds].
- Prominent red stripe on the underside of the strip takes the guesswork out of installation.
- Section 6F.87 of the MUTCD, 2009 Edition[,] allows for colors of white, black and orange. PSS manufactures RoadQuake TPRS in yellow for international customers.

Rumble Mat Layer Chassis Mounted Single, Verdegro, undated.
https://www.verdegro.com/newsmessage/16/verdegro-rumble-mat-layer-chassis-mounted-single
From the web page: Verdegro introduces the RML-CMS [Rumble Mat Layer Chassis Mounted Single]. This new model Rumble Mat Layer can pick [up]/place one rumble mat (identical version as for the RML and RML-CM) and is the cheapest model available in the line of Rumble Mat Layers. It is very easy to use and can be installed underneath a van or truck.

Rumble Mat Layer/Rumble Mat Layer Chassis Mounted, Verdegro, undated.
https://www.verdegro.com/newsmessage/14/introduction-rumble-mat-layer
From the web page: Andreas strips must be applied and removed under the most risky circumstances. For that reason, [it is] from September 1, 2020, mandatory to [apply] the andreas strips mechanically on [D]utch highways. Verdegro has two variants of automatic Rumble Mat Layers, namely: Rumble Mat Layer and Rumble Mat Layer Chassis Mounted (mounting under the truck or between the TMA and the truck).

Truck-Mounted Attenuators

TMA Puller, 2021 Virtual Tool and Equipment Showcase, Missouri Department of Transportation, 2021.
https://www.modot.org/58-tma-puller
From the description: The TMA Puller was created as a quick, safer way to remove and reset TMAs to their respective dump trucks throughout snow season when trucks are constantly called out and returned after storms. The Puller was built using scrap steel around the yard, which saved money. Work is simplified by using a fork[lift] truck or loader to do the work, instead of having several employees shake and pull the TMA unit off by hand. Improves safety by having the TMA fully supported through the entire process of installation and removal, protecting employees removing the pins, electric and hydraulic lines.

"Two New Products Improve Safety in Highway Construction Work Zones," *Engineering News-Record*, February 2020.
http://digital.bnpmedia.com/publication/?i=648584&article_id=3593215&view=articleBrowser&ver=html5
This article features two MASH-tested products from Trinity Highway Products: SMT and SS180 M*. From the article*:

> SMT is a trailer-mounted attenuator for efficient deployment. Its system [comprises] two lightweight aluminum cartridges contained in a steel support frame. It has LED lights, replaceable energy-absorbing cartridges and a potentially reusable steel frame after an impact within MASH crash test standards.
>
> The SS180 M is a truck-mounted attenuator consisting of two lightweight aluminum cartridges contained in a potentially reusable steel support frame. It is designed to help minimize damage from low-speed nuisance hits up to 6 mph. A 180-degree tilt feature folds at the center to stack the two cartridge sections on top of each other. Its short height while in storage mode makes it convenient for garage storage and low overpasses.

DVR and Camera System, J-Tech, undated.
https://jtechusa.com/dvr-camera-system
From the web page: J-Tech's DVR (Digital Video Recorder) System is controlled by a solid-state base unit featuring constant recording with a configurable incident trigger. The dash mounted 7-inch monitor has a touch screen which can be used to select single or multiple camera views. When the reverse gear is engaged, the monitor automatically switches to rear view to ensure safe backing. A high-view camera is mounted on the arrow board facing forward into the bed of the truck. Up to four additional cameras are available for even greater 360-degree visibility.

J-Tech's DVR System provides you with an accurate, locked-down recording of events in and around your work vehicles. Indisputable recordings protect you from liability claims and provide a means to analyze incidents and apply those lessons learned to new safety procedures.

Truck Mounted Smart Generator, Royal Innovative Solutions, undated.
https://royalinnovativesolutions.com/truck-mounted-generator/
From the web page: The RigMaster Generator addresses the problems of truck engine idle and DPF in the work zone for Class 6 trucks with high idle time. Work trucks, like TMA (truck-mounted attenuator) trucks require electrical power to run lighting and computerized equipment. This is especially true of TMA trucks that have many safety lights, advanced warning arrow boards, DVR systems and of course the attenuator, that all operate on electricity. The truck-mounted generator saves you money on fuel consumption and wear-and-tear on the engine and is currently available for Class 6 trucks.

ATMA (Autonomous TMA), Royal Truck and Equipment, Inc., undated.
https://royaltruckandequipment.com/autonomous/
From the web page: The ATMA (Autonomous TMA) truck is a self-driving TMA truck that operates completely unmanned in a follower mode when paired with a lead vehicle. This innovative technology was first developed for use by the U.S. military and has since been adapted for the roadway construction industry through our partnership with Kratos Defense.

The leader/follower system includes a human-driven leader vehicle that transmits its GPS position data [called “eCrumbs”] back to the unmanned follower vehicle. The follower vehicle then uses the data to follow the exact path and speed of the leader vehicle at each point along the route.

Vehicle-Activated Signs

Hazard Warning Signs, SWARCO, undated.
https://www.swarco.com/products/electronic-signs/vehicle-activated-safety-signs/hazard-warning-signs
From the web page: Improve safety on the roads by guiding the travelers on their journey using SWARCO’s Hazard Warning Solution Signs. A hazard warning system is an electronic traffic warning sign that is used to give dynamic warning messages to drivers to mitigate hazards on the road. Our expert design capabilities provide the solution for any situation. The signs display LED messages [that] can be used for junction warnings, flood warnings and even cyclist detection.

Recent major implementations include

- Queue warning.
- Overheight vehicle.
- Turning traffic.
- Pedestrian in road.
- Hazardous bend.
- Adverse camber.
- Flooding.
- High winds.
- Ice/snow.
- Schools.

Activation can be via vehicle detection, weather monitor or direct from a local authority control [center], providing a fully bespoke solution to suit your needs. Using our over 30 years-worth of experience in this area, we are happy to offer advice on schemes and best practice solutions for accident-reduction. Features of our products include live information from your sign including the number of activations and a status report on power, communication and fault detection to ensure safety critical signs are always in optimum condition, all of which can be accessed remotely using SWARCO’s Zephyr software.

Smart VMS Trailer, SWARCO, undated.
https://www.swarco.com/solutions/connected-driving/road-works-warning
From the web page: SWARCO's smart warning trailer is an intelligent, IoT-enabled VMS trailer that is used for driver information via variable message signs (VMS), travel time estimation, speed reduction detection, traffic monitoring and vehicle communication. This is especially useful at road works.

Work Zone Sequential Flashing Warning Lights

Work Zone Safety: Eco Synchro4D, Unipart Dorman, August 2020.
https://www.unipartdorman.com/assets/ecosynchro_4d3.pdf
From the brochure: The Eco Synchro4D was designed to offer clients a dusk till dawn D cell battery powered, lower cost version to complement the highly successful 24/7 SynchroGUIDE. The Eco Synchro4D is triggered by a photocell for automatic nighttime operation requiring no intervention after being initially switched on and will offer continual duration operating lifetimes of circa [six] months. The Eco Synchro4D combines the latest in LED lamp and lens technology with intelligent synchronization wireless communications technology to improve nighttime driver recognition of the merging taper and help meet the challenge of reducing work zone fatalities and secondary effects. Unlike arrow boards and static lights, the delineation is not spot based but is continual for the entire taper length, a critically important feature during hours of darkness and poor weather conditions where visibility is reduced. [*Note*: The LED lamp technology referred to above is Type C, low-intensity, continuous LED backlighting overlaid with a sequential Type B, high-intensity LED pulse. The lens technology employs a unidirectional, self-colored polycarbonate lens.]

Work Zone Safety: ConeLITE Synchro, Unipart Dorman, October 2018.
https://www.unipartdorman.com/assets/conelite_synchro.pdf
From the brochure: Independently proven to significantly improve driver lane discipline approaching high speed lane closures, the ConeLITE Synchro lamp kits are available in blue, red or amber and are always ready for simple quick deployment. What sets the ConeLITE Synchro series apart from other types of flashing warning lights is the unique intelligent wireless sequential operation of the lights in forming a clear directional path for traffic during lane closures. Each lamp automatically recognizes where it sits in the deployed chain with no master slave relationship. Proven to improve driver recognition of the merging taper the ConeLITE Synchro helps meet a commitment to the well-being and safety of all traffic participants.

Product for Multiple Equipment Types

Impact Detection System, pi-lit (Pi Variables, Inc.), undated.
https://pi-lit.com/products/impact-detection-system
From the web page: pi-lit's radio mesh network allows many sensors to report through a single cellular or fiber-cable gateway.

Critical Safety Devices to Monitor:

- Crash cushions and end treatments.
- Guardrails and cable barriers.
- Signs (gore, stop, yield, chevron, etc.).
- Railroad crossing gates.
- Work zone delineators (barrels, cones, message boards).

Contacts

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Appendix A: Survey Questions

The following survey was distributed to members of the American Traffic Safety Services Association (ATSSA).

Survey on Innovations in Work Zone Safety Products

Note: The response to the question below determined how a respondent was directed through the survey.

(Required) Does your company offer new, innovative work zone safety products?

Response Options:

- No. (Directed the respondent to the **Enhanced Existing Work Zone Safety Products** section of the survey.)
- Yes. (Directed the respondent to the **New, Innovative Work Zone Safety Products** section of the survey.)

New, Innovative Work Zone Safety Products

Please describe up to three **new, innovative work zone safety products** your company offers.

Note: You'll be asked to provide links to publicly available product information. If you have files to share that are not available online, please send them to carol.rolland@ctcandassociates.com.

Innovative Product 1
Product Type:
Product Name, Model Number and Vendor:
How the Product is Used:
Description of the Innovation:
Link(s) to Product Information:
Other Comments:

Innovative Product 2
Product Type:
Product Name, Model Number and Vendor:
How the Product is Used:
Description of the Innovation:
Link(s) to Product Information:
Other Comments:

Innovative Product 3
Product Type:
Product Name, Model Number and Vendor:
How the Product is Used:

Description of the Innovation:
Link(s) to Product Information:
Other Comments:

(Required) Does your company offer **existing work zone safety products that have been enhanced to offer innovation** in work zone safety?

- No. (Directed the respondent to the **Wrap-Up** section of the survey.)
- Yes. (Directed the respondent to the **Enhanced Existing Work Zone Safety Products** section of the survey.)

Enhanced Existing Work Zone Safety Products

Please describe up to three existing products your company offers that have been enhanced to offer innovation in work zone safety.

Note: You'll be asked to provide links to publicly available product information. If you have files to share that are not available online, please send them to carol.rolland@ctcandassociates.com.

Enhanced Existing Product 1
Product Type:
Product Name, Model Number and Vendor:
How the Product is Used:
Description of the Enhancement:
Link(s) to Product Information:
Other Comments:

Enhanced Existing Product 2
Product Type:
Product Name, Model Number and Vendor:
How the Product is Used:
Description of the Enhancement:
Link(s) to Product Information:
Other Comments:

Enhanced Existing Product 3
Product Type:
Product Name, Model Number and Vendor:
How the Product is Used:
Description of the Enhancement:
Link(s) to Product Information:
Other Comments:

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.