Alternatives to Flares for Use in Managing Traffic During Moving Lane Closures

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Executive Summary

Background

The California Department of Transportation (Caltrans) Division of Maintenance uses moving lane closures to conduct periodic roadway maintenance such as sweeping and striping. On freeways and multilane highways, Caltrans uses flares in advance of these moving lane closures to help alert motorists of a lane closed ahead. The flares are activated and placed by the driver of the shadow truck (typically, the last vehicle in a moving lane closure) using a flare launcher attached to the truck. Although effective at getting motorists' attention, flares pose a potential fire risk if one is hit by a vehicle and rolls into roadside brush. There are also health and environmental concerns associated with the smoke emitted from the flare and the perchlorate contained within it.

Caltrans is seeking information about methodologies used by other state departments of transportation (DOTs) to effectively alert motorists to upcoming moving lane closures, including the use of traditional incendiary flares and alternative traffic control strategies.

To assist Caltrans in this information-gathering effort, CTC & Associates summarized the results of an online survey of state DOTs that examined current practices for alerting motorists to a moving lane closure. A literature search was also conducted to identify publicly available sources of guidance and current practices.

Summary of Findings

Survey of Practice

An online survey distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance and the No Boundaries Roadway Maintenance Pooled Fund sought information about the practices used on freeways and multilane highways in advance of moving lane closures to help alert motorists to a lane closed ahead.

The 27 representatives from 25 state DOTs who responded to the survey provided limited information about the use of traditional incendiary flares in moving lane closures and the nonincendiary flare alternatives that might replace them. Respondents provided more details about the other traffic control strategies used by their agencies to alert motorists to moving lane closures ahead.

Survey results are summarized below in the following topic areas:

- Use of traditional flares.
- Use of flare alternatives.
- Other traffic control strategies.
- Effective traffic control strategies.

Use of Traditional Flares

Only two respondents described their agencies' use of incendiary flares to control traffic during moving lane closures:

- In Michigan, traditional flares are deployed from what the respondent described as the "trailing truck." The agency only uses traditional flares on roadways with long paved shoulders and in sections that are fully outfitted with curb and gutter. This would appear to preclude their use in the freeway and multilane highway applications of interest to Caltrans.
- Washington State DOT uses both hand-deployed flares and flares deployed from inside vehicles via a deployment chute or tube. Flare use is limited to "proper weather conditions and in ideal locations." The respondent noted that the agency does not generally deploy traditional flares in dry or hot weather with "dry, flashy fuels" near the roadway. Although the respondent indicated that the agency follows all environmental and hazardous materials policies, he did not describe how the agency met those requirements when using traditional flares.

Several respondents described other uses of traditional flares, including their use by law enforcement and emergency response teams (Illinois, Kansas and New York State DOTs) and incident management teams (New Jersey and New York State DOTs). Illinois emergency responders use "pucks" that simulate a flare without the flame.

Use of Flare Alternatives

Three respondents described the current or potential use of electric flares with LED lights to warn motorists of moving lane closures:

- Too few electric flares have been supplied for Michigan DOT to assess their effectiveness, with the respondent indicating that "one supervisor has a bag of three of them." The respondent noted that widespread use would be "too costly and not practical for moving operations," and that the flares have to be picked up in person and are "dangerous to have to retrieve."
- New Jersey DOT does not currently use electric flares but is investigating the use of LED lights or a similar flare alternative.
- Washington State DOT uses puck-style LED lights that are secured to a bracket and placed on cones intermittently throughout a traffic control setup. The respondent was not able to provide product details, though noted that the crews using LED lights report positive results. A downside is their limited runtime, and batteries can be depleted during a shift. The flares are picked up by maintenance crews as they are demobilizing the work zone. The agency has also used a retractable tower stand of LED lights for purposes other than traffic control.

Other Traffic Control Strategies

Respondents reported on their agencies' use of four traffic control strategies that might be employed to advise motorists of a moving lane closure ahead:

- Advance warning vehicle outfitted with an arrow sign.
- Additional shadow vehicle or truck-mounted attenuator vehicle.
- Highway patrol vehicle.
- Roadside or dynamic message sign.

More than half of respondents make use of all four strategies. Respondents are least likely to employ highway patrol vehicles to control traffic in a moving lane closure.

Effective Traffic Control Strategies

When asked to identify the traffic control strategies most effective in alerting drivers in advance of a moving lane closure, many respondents discussed in more detail the four strategies identified above. Respondents were most likely to report on a combination of strategies that produced effective results, with advance warning vehicles most often used in combination with other strategies. Highlighted below are some specific agency practices:

- *Advance warning vehicles*. Advance signage is used in conjunction with advance warning vehicles by Florida and Maryland DOTs; Oklahoma DOT uses an advance warning vehicle with arrow board and a shadow vehicle with an attenuator.
- *Arrow boards*. Utah DOT equips its incident management trucks and maintenance vehicles with arrow boards. The LED arrow boards and strobe lights used by Connecticut DOT are highly effective, though the respondent noted that they are sometimes too bright for use in urban areas. Maintenance crews pick up the arrow boards and strobe lights after the moving lane closure is complete.
- *Law enforcement*. Highway patrol or other law enforcement presence was deemed the most effective traffic control strategy by the respondents from Alabama, Florida, Kentucky, Nevada and South Carolina transportation agencies. In South Carolina, the DOT and Department of Public Safety have partnered to establish Safety Improvement Teams in each district that "efficiently mobilize highway patrol resources to work zones when needed."

  Respondents from Maryland, New Jersey and Texas DOTs also reported on the effective use of law enforcement coupled with truck-mounted attenuators.
- *Shadow vehicles*. Missouri and South Dakota DOTs reported the effective use of shadow vehicles. In South Dakota, additional shadow vehicles on the shoulder prior to the advance warning vehicle are beneficial in higher traffic areas. In Kansas, message boards are used in combination with extra shadow vehicles.
- *Signage*. The Oklahoma DOT respondent noted that use of dynamic message boards in metro areas is "very effective." In Rhode Island, advance message boards, static signs and arrows on truck-mounted attenuators are complemented by red lights added to field crew vehicles.

Related Research and Resources

The literature search uncovered no guidance for the use of traditional flares to control traffic during moving lane closures. A sampling of national and state general guidance for traffic control during moving lane closures was identified. These resources are supplemented by national and state guidance for the use of specific traffic control strategies.

General Guidance: National

A National Cooperative Highway Research Program (NCHRP) project that was expected to begin May 2020 anticipates documenting the use of smart work zone technologies by DOTs to improve the safety of workers and drivers affected by work zone activity. Among the topics expected to be addressed is the use of dynamic warning systems to provide accurate notifications to drivers. A 2019 NCHRP synthesis highlighted existing guidelines in the Manual on Uniform Traffic Control Devices for temporary traffic control associated with short duration and mobile operations, including the placement of an additional work vehicle downstream from workers and the use of truck-mounted changeable message signs.

<u>General Guidance: State</u>

Among the state-related guidance cited in this section of the report are manuals prepared by the Illinois State Toll Highway Authority and transportation agencies in California, Florida, Kentucky, Minnesota, New York, Oregon, South Carolina, Virginia and Washington that describe agency practices for traffic control during mobile operations. Some publications include plan sheets and typical traffic control layouts. An August 2010 Illinois DOT report includes recommendations to improve the safety of moving lane closures and describes the equipment and personnel needed for four base lane closure cases. An August 2017 Ohio DOT report evaluated equipment-related safety enhancements to improve safety practices for short duration work zones.

<u>Specific Traffic Control Strategies</u>

Flares

Two federal agency publications that address the use of flares focus on their use by law enforcement and emergency responders in connection with traffic incident management. While not specific to moving lane closures, a March 2012 Federal Emergency Management Agency publication briefly examines three types of flare devices used in temporary traffic control zones: incendiary flares, chemical light sticks and LED flares. A June 2008 U.S. Department of Justice publication presents a more detailed evaluation of chemical and electric flares and examines specific alternative products.

Law Enforcement

Florida DOT examined the effectiveness of deploying stationary police vehicles with blue lights in dynamic freeway work zones in a March 2018 report.

Signage

An October 2010 Texas DOT report developed guidance to assist the agency in making better use of truck-mounted changeable message signs during scheduled and unscheduled operations. Researchers used a human factors laboratory study and field evaluation to identify recommended symbols and phrases.

Truck-Mounted Attenuators and Shadow Vehicles

National guidance includes two U.S. DOT research efforts in progress that are examining the automation of truck-mounted attenuators and shadow vehicles used in work zones. A research effort expected to conclude in December 2020 will examine what's needed to effectively deploy an autonomous truck-mounted attenuator. A second research effort that is expected to conclude in August 2020 is seeking to develop an automated control system for truck-mounted attenuator vehicles using a short following distance that will remove the driver from the at-risk vehicle. A 2008 field guide from American Traffic Safety Services Association and Federal Highway Administration provides guidelines for the use of shadow vehicles and truck-mounted attenuators in work zones.

State guidance includes a November 2014 Texas DOT conference paper that examines the use of a fully autonomous vehicle located at the rear of a work zone that is capable of communicating with other vehicles in the work crew. A May 2013 report recommended that Texas DOT continue using heavier support vehicles, regardless of attenuator type, to provide greater protection for workers in the support vehicle and workers on foot. Research in progress in Virginia that is expected to conclude in 2022 seeks to identify the most promising methods that could reduce the occurrence and severity of truck-mounted attenuator crashes for both stationary and mobile work zone operations; an October 2015 Virginia DOT study on the same topic offered recommendations to reduce the incidence of truck-mounted attenuator crashes in Virginia work zones. Finally, a Wisconsin DOT manual provides the agency's policy on the use of truck-mounted attenuators.

Other Traffic Control Devices and Systems

The efficacy of two mobile work zone alarms for use in mobile work zones is evaluated in a June 2015 Missouri DOT report. Researchers noted that such alarms have the potential to be an effective tool in improving safety, and modifications to the alarm sound and warning message could improve system effectiveness.

Gaps in Findings

While state DOT response to the survey was fairly robust, very few respondents reported on experience with incendiary and nonincendiary flares. Respondents identified other traffic control strategies used in connection with moving lane closures but provided few details of those practices. The literature search also failed to uncover significant, current research on the use of incendiary and nonincendiary flares to alert motorists to a moving lane closure. However, research in progress, expected to conclude in 2020 and later, could provide results that will be of interest to Caltrans.

A follow-up, in-depth examination of the other traffic control strategies briefly addressed in this Preliminary Investigation (advance warning vehicles outfitted with an arrow sign, additional shadow vehicles or truck-mounted attenuator vehicles, highway patrol vehicles, and roadside or dynamic message signs) could provide useful information for Caltrans.

Next Steps

Moving forward, Caltrans could consider:

- Consulting with Washington State DOT to learn more about the agency's use of traditional hand-deployed flares and flares deployed from inside vehicles via a deployment chute or tube.
- Engaging with selected respondents to inquire about the current or potential use of alternatives to traditional flares, specifically:
  - Illinois DOT's reporting of Illinois emergency responders' use of pucks that simulate a flare without the flame.
  - New Jersey DOT's investigation of the use of LED lights or a similar flare alternative.
  - Washington State DOT's use of puck-style LED lights that are secured to a bracket and placed on cones.
- Reviewing the effective traffic control strategies reported by respondents to consider how Caltrans might use them.

Detailed Findings

Background

The California Department of Transportation (Caltrans) Division of Maintenance uses moving lane closures to conduct periodic roadway maintenance such as sweeping and striping. On freeways and multilane highways, Caltrans uses flares in advance of these moving lane closures to help alert motorists of a lane closed ahead. The flares are activated and placed by the driver of the shadow truck (typically, the last vehicle in a moving lane closure) using a flare launcher attached to the truck. Although effective at getting motorists' attention, flares pose a potential fire risk if one is hit by a vehicle and rolls into roadside brush. There are also health and environmental concerns associated with the smoke emitted from the flare and the perchlorate contained within it.

Alternatives to traditional incendiary flares exist, such as chemical light sticks, glow sticks and electric flares that contain LED lights. Since these devices need to be retrieved after use, Caltrans could only deploy them in static lane closures where employees could safely and easily collect them. Employees in Caltrans District 8 devised an approach to retrieve glow sticks by attaching baling wire and washers to the glow sticks and using a large magnet mounted to the rear of a portable changeable message sign truck to retrieve the devices.

Caltrans would like to learn more about how other state departments of transportation (DOTs) effectively alert motorists to upcoming moving lane closures, including alternatives to traditional incendiary flares. If traditional flares are used, Caltrans is interested in learning how other states manage fire risk and environmental concerns.

To assist Caltrans in this information-gathering effort, CTC & Associates summarized the results of an online survey of state DOTs. The survey examined current practices for alerting motorists to a moving lane closure. A literature search was also conducted to identify publicly available sources of current practices. Findings from these efforts are presented in this Preliminary Investigation in two areas:

- Survey of practice.
- Related research and resources.

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance and the No Boundaries Roadway Maintenance Pooled Fund. The survey sought information about the practices used on freeways and multilane highways in advance of moving lane closures to alert motorists to a lane closed ahead.

Survey questions are provided in Appendix A. The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Twenty-seven representatives from 25 state DOTs responded to the survey:

- Alabama.
- Connecticut.
- Florida.
- Illinois.
- Iowa.
- Kansas.
- Kentucky.
- Maine.
- Maryland (two responses).
- Michigan.
- Minnesota.
- Mississippi.
- Missouri.
- Nevada.
- New Jersey.
- New Mexico.
- New York (two responses).
- North Dakota.
- Oklahoma.
- Rhode Island.
- South Carolina.
- South Dakota.
- Texas.
- Utah.
- Washington.

Only two agencies use traditional incendiary flares in moving lane closures. These respondents noted that conditions and locations are selected carefully to avoid the potential for fire. Three agencies have used LED flares or glow sticks, or are looking into using them. None provided detail on how these flares are retrieved when the moving lane closure is complete. All agencies reported using other traffic control strategies, or a combination of strategies, to alert motorists to moving lane closures ahead.

Survey results are summarized below in the following topic areas:

- Use of traditional flares.
- Use of flare alternatives.
- Other traffic control strategies.
- Effective traffic control strategies.

Resources describing research in progress, guidelines and procedures associated with traffic control for moving lane closures are included in the **Related Research and Resources** section of this report that begins on page 13.

Use of Traditional Flares

While respondents reported limited use of traditional flares by the DOT to manage moving lane closures, this type of flare is used by DOT-related groups and other state agencies for other purposes.

State DOT Use for Moving Lane Closures

Only the Michigan and Washington State DOT respondents reported on their agencies' use of incendiary flares to manage moving lane closures:

- In Michigan, traditional flares are deployed from what the respondent described as the "trailing truck." The agency only uses traditional flares on roadways with long paved shoulders and in sections that are fully outfitted with curb and gutter. This would appear to preclude their use in the freeway and multilane highway applications of interest to Caltrans.
- Washington State DOT uses both hand-deployed flares and flares deployed from inside vehicles via a deployment chute or tube. Flare use is limited to "proper weather

conditions and in ideal locations." The respondent noted that the agency does not generally deploy traditional flares in dry or hot weather with "dry, flashy fuels" near the roadway. Although the respondent indicated that the agency follows all environmental and hazardous materials policies, he did not describe how the agency met those requirements when using traditional flares.

Other Flare Uses

Several respondents described the use of traditional flares for other applications:

- *Illinois*. Although the state DOT does not use traditional flares, the respondent noted that police, fire and emergency medical service units in the state use them, as well as "pucks" that simulate a flare without the flame.
- *Kansas*. The state's highway patrol may still use traditional flares when responding to accidents.
- *New Jersey*. While New Jersey DOT operations crews do not use incendiary or nonincendiary flares in connection with moving lane closures (the respondent offered pothole repair or animal removal as examples), two other DOT-related groups maintain incendiary and LED flares in their inventories:
    - The DOT's Safety Service Patrol uses these flares when assisting motorists stopped in a lane or on a shoulder on certain state highways when the situation requires additional visibility.
    - The Incident Management Response Team, which is part of the collaborative Statewide Traffic Incident Management Program supported by New Jersey DOT and New Jersey State Police, may use traditional flares for short- or long-term incident response.
- *New York 1*. Traditional flares are only used for emergency response by law enforcement when arriving on the scene.

Use of Flare Alternatives

Three respondents—Michigan, New Jersey and Washington State DOTs—described the sometimes limited or potential use of nonincendiary flares for moving lane closures:

Electric Flares With LED Lights

- Too few electric flares have been supplied for Michigan DOT to assess their effectiveness, with the respondent indicating that "one supervisor has a bag of three of them." The respondent noted that widespread use would be "too costly and not practical for moving operations," and that the flares have to be picked up in person and are "dangerous to have to retrieve."
- New Jersey DOT does not currently use electric flares but is investigating the use of LED lights or a similar flare alternative.
- Washington State DOT uses puck-style LED lights that are secured to a bracket and placed on cones intermittently throughout a traffic control setup. The respondent was not able to provide product details, though noted that the crews using LED lights report positive results. A downside is their limited runtime, and batteries can be depleted during a shift. The flares are picked up by maintenance crews as they are demobilizing the work zone. The agency has also used a retractable tower stand of LED lights for purposes other than traffic control.

Other Traffic Control Strategies

Respondents reported on their agencies' use of four traffic control strategies that might be employed to advise motorists of a moving lane closure:

- Advance warning vehicle outfitted with an arrow sign.
- Additional shadow vehicle or truck-mounted attenuator vehicle.
- Highway patrol vehicle.
- Roadside or dynamic message sign.

More than half of respondents make use of all four strategies. Respondents are least likely to employ highway patrol vehicles to control traffic in a moving lane closure.

Table 1 summarizes survey responses.

Table 1. Traffic Control Strategies Used to Alert Motorists to Moving Lane Closures

State	Advance Warning Vehicle (With Arrow Sign)	Additional Shadow Vehicle/Truck Mounted Attenuator Vehicle	Highway Patrol Vehicle	Roadside or Dynamic Message Sign
Alabama	X	X	X	X
Connecticut	X	X	X	X
Florida	X	X	X	X
Illinois	X	X	X	X
Iowa	X	X		X
Kansas	X	X		X[1]
Kentucky	X	X	X	X
Maine	X	X	X	X
Maryland 1	X	X	X	X
Maryland 2[2]	X	X	X	X
Michigan		X		X
Minnesota	X	X		X
Mississippi	X	X		X
Missouri	X[3]	X	X	
Nevada	X	X	X	X
New Jersey	X	X	X	X
New York 1	X	X		X
New York 2	X	X		X
Oklahoma	X	X	X	X
Rhode Island[4]	X	X		X
South Carolina	X	X	X	X
South Dakota	X	X		X
Texas	X	X	X	X

State	Advance Warning Vehicle (With Arrow Sign)	Additional Shadow Vehicle/Truck Mounted Attenuator Vehicle	Highway Patrol Vehicle	Roadside or Dynamic Message Sign
Utah[5]	X	X		
Washington	X	X	X	X
TOTAL	**24**	**25**	**15**	**23**

1 The agency uses trucks with message boards.

2 Reflective striping on cones and barrels is also used.

3 An arrow board is deployed on a protection vehicle.

4 Overhead dynamic message signs are used whenever available in the area, as are advance static signs warning of road work ahead.

5 Incident management vehicles are used in urban settings.

Effective Traffic Control Strategies

When asked to identify the traffic control strategies most effective in alerting drivers in advance of a moving lane closure, most respondents discussed in more detail the four strategies identified in Table 1. Respondents were most likely to report on a combination of strategies that produced effective results, with advance warning vehicles most often used in combination with other strategies. Table 2 presents survey responses organized by the traffic control strategy cited by the respondent.

Table 2. Effective Traffic Control Strategies to Alert Motorists to Moving Lane Closures

Traffic Control Strategy	State	Description
Arrow Boards	Utah	The agency equips its incident management trucks and maintenance vehicles with arrow boards. The respondent noted that “motorists are moving over sooner and actually slowing through our work zones. We get better adherence overall and we [feel] it provides improved protection for our employees in the field.”
Arrow Boards and Strobe Lights	Connecticut	The LED arrow boards and strobe lights used by the agency are highly effective, though the respondent noted that they are sometimes too bright for use in urban areas. The arrow boards and strobe lights are picked up by maintenance crews after the moving lane closure is complete.
Law Enforcement	Alabama, Florida, Kentucky, Nevada, South Carolina	*Alabama*. Law enforcement presence appears to yield the best result in the effort to inform drivers and effect a reduction in operating speed. *Florida.* Highway patrol can be used but is not required for all situations. *Kentucky*. Law enforcement officers are the most effective option when they are available. *Nevada*. Highway patrol presence is most effective. *South Carolina*. Highway patrol presence (the respondent highlighted the patrol vehicles’ blue lights) has proven to be the most effective method to slow down traffic in South Carolina. The state’s DOT and Department of Public Safety have

Traffic Control Strategy	State	Description
		partnered to establish Safety Improvement Teams in each district that "efficiently mobilize highway patrol resources to work zones when needed."
Shadow Vehicle	Missouri, South Dakota	*South Dakota*. Additional shadow vehicles on the shoulder before the advance warning vehicle are beneficial in higher traffic areas.
Combination of Strategies: Advance Warning Vehicle	Florida, Iowa, Maryland 2, New York 1 and 2, Oklahoma	*Florida.* The agency uses a combination of advance warning vehicles, shadow vehicle, law enforcement and signage. *Iowa.* Advance warning vehicles are used with dynamic message signs. *Maryland 2.* While no measures have been unilaterally successful, the agency has found advance signage and an advance warning vehicle with an arrow panel to be the most effective measures. *New York 1 and 2*. Advance warning vehicles, vehicles with attenuators and dynamic message signs have proven to be effective. *Oklahoma*. The agency uses an advance warning vehicle with arrow board and a shadow vehicle with an attenuator. In metro areas, use of dynamic message boards is "very effective."
Combination of Strategies: Law Enforcement	Maryland 1, New Jersey, Texas	*Maryland 1*. Law enforcement vehicles are used with truck-mounted attenuators. *New Jersey*. New Jersey State Police slowdowns are used with truck-mounted attenuators. *Texas*. Law enforcement is used with a truck-mounted attenuator with arrow board.
Combination of Strategies: Shadow Vehicle	Kansas, Mississippi	*Kansas*. Message boards are used in combination with extra shadow vehicles. *Mississippi*. The agency applies Manual on Uniform Traffic Control Devices guidance for mobile operations and uses an arrow board on a shadow vehicle in caution mode. Truck- or trailer-mounted attenuators are provided if available.
Combination of Strategies: Signage	Connecticut, Rhode Island	*Connecticut*. The agency employs variable message sign boards, advance warning signs and lighted truck-mounted signs. *Rhode Island*. Advance message boards, static signs and arrows on truck-mounted attenuators are complemented by red lights added to field crew vehicles.

Related Research and Resources

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

- General guidance.
- Specific traffic control strategies:
  - Flares.
  - Law enforcement.
  - Signage.
  - Truck-mounted attenuators and shadow vehicles.
  - Other traffic control devices and systems.

Citations may be further organized by national and state resources.

General Guidance

National

Research in Progress: NCHRP Synthesis 20-05/Topic 52-11: Use of Smart Work Zone Technologies for Improving the Safety of Workers and Drivers Affected by Work Zone Activity, estimated start date: May 2020; expected completion date: unknown.
Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4987
From the preliminary scope: The objective of this synthesis is to document the use of smart work zone technologies used by 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.
- Automated work zone management systems to direct traffic movement upstream of work zone activity.
- Dynamic lane merging systems for merging of traffic in a reduced lane configuration.
- Variable speed limit systems to reduce vehicular speed in advance of work zone activity and within a work zone.
- Dynamic notification of slow moving vehicles entering and exiting the work zone activity area.
- Smart alert technologies integrated with crowdsourcing systems to provide accurate alert notifications to upstream drivers.

NCHRP Synthesis 533: Very Short Duration Work Zone Safety for Maintenance and Other Activities, LuAnn Theiss and Gerald L. Ullman, 2019.
Publication available at http://www.trb.org/Publications/Blurbs/179364.aspx
This publication highlights existing guidelines in the Manual on Uniform Traffic Control Devices for temporary traffic control associated with short duration and mobile operations (see page 5 of the report; page 14 of the PDF). Included in this discussion are practices to improve worker safety, including optimizing the spacing between shadow vehicles in transition areas, placing an additional work vehicle 50 to 100 feet downstream of the workers to discourage vehicles from

cutting back into the closed lane too soon, and using truck-mounted, changeable message signs.

State

California

Work Zone Intrusion Countermeasure Identification, Assessment and Implementation Guidelines, Gerald L. Ullman, Melisa D. Finley and LuAnn Theiss, 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
Discussion of potential countermeasures for intrusions into mobile operations begins on page 48 of the report (page 62 of the PDF).

Florida

General Information for Traffic Control Through Work Zones, Florida Department of Transportation, January 2020.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/design/standardplans/2021/idx/ir102-600.pdf?sfvrsn=6919ab15_2
These standard plan sheets provide information for traffic control through work zones. The plan sheet on page 7 of the PDF describes the use of an advance warning arrow board for moving lane closures on multilane roadways.

Illinois

Roadway Traffic Control and Communications Manual, Illinois State Toll Highway Authority, March 2018.
https://www.illinoistollway.com/documents/20184/473059/Rdwy+TrafficCntrlCommManual_Mar2019.pdf/ea8b412c-7641-4152-af32-c89648d5aae0?version=1.3
Mobile operation plates (plates 8-10L) appear in Section 15, Maintenance of Traffic Plates and Notes, beginning on page 117 of the report (page 126 of the PDF).

Improving the Safety of Moving Lane Closures—Phase II, Douglas Steele and William Vavrik, Illinois Department of Transportation, August 2010.
https://www.ideals.illinois.edu/bitstream/handle/2142/45847/FHWA-ICT-10-072.pdf?sequence=2
This report recommends revisions to existing traffic control standards and describes the equipment and personnel required for each scenario, the configuration and spacing of traffic control vehicles, buffer and work space lengths, and appropriate messages for each of four base cases:

- Right lane closure.
- Left lane closure.
- Center lane closure (three or more traffic lanes per direction).
- Two lane closures (one center and one outer lane).

Researchers propose the use of six optional components when resources are available and conditions merit:

- Additional traffic control vehicles in the transition area.
- A lead truck downstream of the work space.

- A blocker truck to prevent shoulder passing.
- An additional warning truck in the advance warning area.
- A buffer truck to increase spacing between the shadow vehicle and workers.
- A spotter within the work space to alert workers of upstream traffic conditions.

Researchers also provide recommendations for three special cases:

- Working at or near horizontal and vertical curves.
- Working near ramps.
- Continuously moving operations.

Kentucky

Guidelines for Traffic Control in Short Duration/Mobile Work Zones, Kentucky Transportation Center, University of Kentucky, March 2008.
https://www.kyt2.com/sites/default/files/08shortdurationmobile_final.pdf
This publication summarizes guidelines listed in the Manual on Uniform Traffic Control Devices with particular emphasis on short duration and mobile activities. Included are basic principles, a description of standard traffic control devices used in work areas, and guidelines for the application of the devices and application diagrams. Selected excerpts follow:

- In mobile operations a shadow vehicle (equipped with an arrow panel or sign) should follow the work vehicle.
- Where feasible, in mobile operations, warning signs should be placed along the roadway and moved periodically as work progresses.
- The distance between warning signs and the work should not exceed 2 miles.
- Appropriately marked vehicles with high-intensity lights may be used in place of signs and channelizing devices. The high intensity lights may be rotating, flashing, oscillating or strobe lights (typically LED).
- For mobile operations, a sign may be mounted on a work vehicle, a shadow vehicle or a trailer stationed in advance of the temporary traffic control zone or moving along with it.
- The work vehicle, the shadow vehicle or the trailer may or may not have an impact attenuator.
- For mobile and constantly moving operations, such as pothole patching and striping operations, a shadow vehicle, equipped with appropriate lights and warning signs, may be used to protect the workers from impacts by errant vehicles. The shadow vehicle may be equipped with a rear-mounted impact attenuator.

Minnesota

Minnesota Temporary Traffic Control Field Manual, Office of Traffic Engineering, Minnesota Department of Transportation, January 2018.
http://www.dot.state.mn.us/trafficeng/publ/fieldmanual/fieldmanual.pdf
This manual illustrates “typical traffic control layouts that all state, county and city roadway operations staff should use.” Page 110 of the PDF provides a list of layouts for multilane divided roads organized by the duration of the operation. Mobile operations are classified as 15 minutes or less; short duration operations are one hour or less.

Note: The survey respondent called particular attention to the following layouts:

- Review layouts 11 to 13, 36, 41 and 49 to 54 and select from among them based on volume, type of road and duration.
- For moving flagging operations, follow layouts 16 and 17.
- For striping operations, follow layouts 76 to 79.

New York

Part II: Typical Application Index, Work Zone Traffic Control, New York State Department of Transportation, undated.
https://webapps.dot.ny.gov/part-ii-typical-application-index?f%5B0%5D=filter_term%3A31
This web page provides documents illustrating traffic control techniques used for various lane and shoulder closures for mobile operations on freeways or expressways.

Ohio

Evaluation of Safety Practices for Short Duration Work Zones, Melisa D. Finley, LuAnn Theiss, Gerald L. Ullman, Adam Pickens, Mark Benden and Jacqueline Jenkins, Office of Statewide Planning and Research, Ohio Department of Transportation, August 2017.
https://ohiomemory.org/digital/collection/p267401ccp2/id/15346
From the abstract: In Phase 1, researchers evaluated the safety and efficiency of current O[hio] DOT procedures for single work shift maintenance operations. Based on these findings, researchers identified potential safety enhancements (procedures and equipment).

In Phase 2, researchers evaluated the following equipment-related safety enhancements:

- addition of a basket to existing temporary traffic control (TTC) setup and removal equipment,
- use of a specially designed vehicle for TTC setup and removal,
- use of equipment-mounted task lighting on specific equipment,
- use of personal lighting,
- use of Performance Class 3 apparel, and
- use of a mobile barrier.

Oregon

Oregon Temporary Traffic Control Handbook: For Operations of Three Days or Less, Oregon Department of Transportation, September 2016.
http://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/OTTCH-v2011.pdf
Section 5.7, Freeway Work, beginning on page 125 of the publication (page 132 of the PDF), provides guidance on different types of operations conducted on freeways. Portions of this section that will be of particular interest follow:

- Freeway mobile operations are described on page 126 of the publication (page 133 of the PDF).
- Diagram 700, Freeway Mobile Operations (page 127 of the publication, page 134 of the PDF), covers mobile operations occupying one lane or the shoulder of a freeway.
- Diagram 720 (page 130 of the publication, page 137 of the PDF), covers lane closures on a freeway.

Section 5.7 also addresses work on an exit ramp and ramp closures.

South Carolina

Work Zone Traffic Control Procedures and Guidelines for SCDOT Maintenance Activities, South Carolina Department of Transportation, February 2019.
https://www.scdot.org/inside/pdfs/WZTCM/Work_Zone_Traffic_Control_Manual.pdf
This guidance document includes sections specific to mobile operations:

- *Intermittent Mobile Operations*. A general discussion of this type of operation begins on page 29 of the document (page 53 of the PDF). Further details and Drawing Nos. 535-01-A and 535-01-B are provided beginning on page 184 of PDF.
- *Continuous Mobile Operations*. A general discussion of several types of operations that fall into this category begins on page 32 of the document (page 56 of the PDF). Other relevant details include:
    - *Mobile Operations: Continuous Interstate Routes; Right Travel Lane/Left Travel Lane*. Further details and Drawing Nos. 540-03-A and 540-03-B begin on page 213 of the PDF.
    - *Mobile Operations: Continuous Dual Lane Closures; Interior Travel Lane Operations; Interstate Routes; Right Travel Lanes/Left Travel Lanes*. Further details and Drawing Nos. 540-04-A and 540-04-B begin on page 216 of the PDF.

Virginia

Work Zone Safety: Guidelines for Temporary Traffic Control, Virginia Department of Transportation, September 2019.
http://www.virginiadot.org/business/resources/traffic_engineering/workzone/2019_WZPG_Aug2019.pdf
From the introduction: The purpose of this handbook is to present basic guidelines for work zone traffic control and to supplement the *2011 Virginia Work Area Protection Manual* with Revision 1. This handbook presents the requirements of Part VI of the Manual on Uniform Traffic Control Devices (MUTCD) with particular emphasis on short term work sites on roads and streets in rural and urban areas. These requirements apply to temporary traffic control zones, as found in construction, maintenance and utility work areas. This handbook presents information and gives examples of typical traffic control applications for two-lane and multilane work zones.

Washington

Work Zone Traffic Control Guidelines for Maintenance Operations, Washington State Department of Transportation, June 2018.
https://www.wsdot.wa.gov/publications/manuals/fulltext/M54-44/Workzone.pdf
A discussion of mobile operations appears in Section 4, Mobile Operations, beginning on page 4-1 of the report (page 57 of the PDF).

Specific Traffic Control Strategies

Flares

Traffic Incident Management Systems, U.S. Fire Administration, Federal Emergency Management Agency, March 2012.
https://www.usfa.fema.gov/downloads/pdf/publications/fa_330.pdf
This publication focused on traffic incident management for firefighters addresses three types of flare devices used in temporary traffic control zones: incendiary flares, chemical light sticks and LED flares (see page 30 of the document; page 40 of the PDF).

Evaluation of Chemical and Electric Flares, Charlie Mesloh, Mark Henych, Ross Wolf, Komaal Collie, Brandon Wargo and Chris Berry, National Institute of Justice, Office of Justice Programs, U.S. Department of Justice, June 2008.
https://www.ncjrs.gov/pdffiles1/nij/grants/224277.pdf
From the executive summary:

> Traditional magnesium highway flares create substantial risks to both the officer and the surrounding area. In addition to these immediate risks, long-term environmental impacts on soil and water have been identified in previous research studies. As a result, this study identified and examined alternative highway flare systems utilizing chemical or electric sources of energy to determine their suitability and visibility.
>
> A methodology utilizing a standardized visibility measure was designed to compare the different flares and related traffic control devices. The flares and related traffic control devices were tested in scenarios across a range of distance intervals up to and including one mile. Scenarios were developed and established based upon driver reaction and stopping distance times.
>
> The findings suggest that the traditional highway flare, despite its inherent risks, was found to be highly visible and scored well during testing in all scenarios. The chemical and electric flares tested were less visible than the highway flare when deployed at ground level. In some cases, minor depressions in the road surface were found to completely obscure the flare's visibility. However, when the same chemical and electric flares were elevated to a 36-inch height above the ground, their visibility scores increased dramatically and they were all visible at a distance of one mile.

While not specific to the technology appropriate for use with moving lane closures, this somewhat dated publication examined products that might be of interest to Caltrans:

- PowerFlare (puck-shaped light device with a 360-degree arrangement of LED lights around the circumference).
- Cyalume light sticks (chemical luminescent tubes).
- TurboFlare (puck-shaped, 360-degree LED battery-operated light device).
- Tektite ELZ (battery-operated xenon strobe system that runs on two C-cell alkaline batteries).
- ProFlare (disk-shaped, battery-operated light with three settings: rotary, steady on and flashing).

- FlareAlert Beacon Pro (waterproof light with a hard plastic housing and red lens).
- PDK Technologies, Inc. LiteFlare (palm-sized LED low-profile flare system housed in a hard polymer shell).

Given the date of this publication, some of these products may no longer be available.

Law Enforcement

Effectiveness of Stationary Police Vehicles With Blue Lights in Freeway Work Zones, Albert Gan, Wanyang Wu, Wallied Orabi and Priyanka Alluri, Florida Department of Transportation, March 2018.
https://rosap.ntl.bts.gov/view/dot/37253
From the abstract: For the dynamic work zone on I-75 which included both 2-lane and 2.5-lane closures (out of three), it was found that the average speed within the work zone with 2-lane closure was reduced by 3.8 mph following the deployment of police vehicle, and by 2.7 mph following the removal of police vehicle. The deployment of police vehicle was also found to reduce vehicle speeding within the work zone by about 16%. In the case with 2.5-lane closure, the average speed within the work zone was reduced by 2.8 mph following the deployment of police vehicle, and by 3.1 mph following the removal of police vehicle. The latter result was not considered reliable as it was derived based on very limited data. The deployment of police vehicle with 2.5-lane closure was found to reduce vehicle speeding by 10%.

Signage

Assessment of Need and Feasibility of Truck-Mounted Changeable Message Signs (CMS) for Scheduled and Unscheduled Operations: Technical Report, Dazhi Sun, Pranay Ravoola, M.A. Faruqi, Brooke Ullman and Nada Trout, Texas Department of Transportation, October 2010.
http://tti.tamu.edu/documents/0-6167-1.pdf
From the abstract: The goal of this project was to develop implementation guidance that the Texas Department of Transportation (TxDOT) can use to make better decisions regarding the use of truck mounted changeable message signs (TMCMS) during scheduled and unscheduled operations.
….

This project identified the types of messages/information that could be displayed on TMCMS for different situations, and also developed specific guidance for TxDOT on the use of TMCMS during scheduled and unscheduled operations.

Related Resource:

> **"Driver Comprehension of Messages on Truck-Mounted Changeable Message Signs During Mobile Maintenance Operations,"** Brooke R. Ullman, Gerald L. Ullman and Nada D. Trout, *Transportation Research Record 2258*, pages 49-56, 2011.
> Citation at https://doi.org/10.3141/2258-06
> *From the abstract:* Use of truck-mounted changeable message signs (TMCMSs) during mobile maintenance operations is desirable to provide drivers with information to better prepare them for unexpected conditions. Traditionally, temporary traffic control devices used during mobile operations have been limited to arrow boards and sometimes static warning messages mounted on a work vehicle. The use of warning signs in advance of an operation

typically is not practical because of the constant movement and stop-and-go nature of the work. TMCMSs can fill an information gap for these mobile operations and provide drivers with better information about them, including actions to be expected. This paper describes the use of findings from a human factors laboratory study and basic message design principles to create a sampling of recommended messages for use on TMCMSs during mobile maintenance operations. These messages were defined by the type of work, road type and the identified concerns to be addressed.

Truck-Mounted Attenuators and Shadow Vehicles

National Guidance

Research in Progress: Development of ATMA/AIPV Deployment Guidelines Considering Traffic and Safety Impacts, Mid-America Transportation Center, University Transportation Centers Program, start date: December 2019; expected completion date: December 2020. Project description at https://trid.trb.org/view/1685038
From the project description: Autonomous Truck Mounted Attenuator/Impact Protection Vehicle (ATMA/AIPV) is a quickly emerging technology and is expected to bring considerable potentials *(sic)* in transportation infrastructure maintenance by removing drivers from the risk. The system includes a lead truck (LT), a follow truck (FT), a truck mounted attenuator (TMA) installed on the FT, and a leader-follower system that enables the FT to drive autonomously and follow the LT. While exciting technology is being developed and shows promising benefits in roadway maintenance, what's not well studied [are] the impacts of such autonomous system to traffic operation and roadway safety, and subsequently how should DOT develop deployment strategies with those aspects taken into consideration. To bridge this important gap, this project aims to study the associated critical research questions, and in the end develop a practical software tool that takes in DOT inputs such as roadway network GIS shapefile, traffic counts and ATMA/AIPV system characteristics, and outputs a set of recommended deployment strategies, including the roadway maintenance sequence, staffing plan and needed resource, potential impacts to the traffic network and any suggested traffic management plan to ensure a smooth and safe traffic flow while effectively maintaining the roadway facilities.

Research in Progress: Automated Truck Mounted Attenuator, U.S. Department of Transportation, start date: February 2019; expected completion date: August 2020. Project description at https://trid.trb.org/view/1591977
From the project description: Truck-Mounted Attenuators (TMAs) are energy-absorbing devices added to heavy shadow vehicles to provide a mobile barrier that protects work crews from errant vehicles entering active work zones. In mobile and short-duration operations, drivers manually operate the TMA—keeping pace with the work zone as needed to function as a mobile barrier protecting work crews. While the TMA is designed to absorb and/or redirect the energy from a colliding vehicle, there is still significant risk of injury to the TMA driver when struck. TMA crashes are a serious problem in Virginia where they have increased each year from 2011 (17 crashes) to 2014 (45 crashes), despite a decrease in the number of active construction sites between 2013 and 2014. Although various efforts have been made to improve TMA driver crashworthiness (e.g., by adding interior padding, harnesses, and supplemental head restraints), the most effective way to protect TMA drivers may be to remove them from the vehicle altogether. Recent advances in automated vehicle technologies—including advanced sensing, high-precision differential global positioning system (GPS), inertial sensing, advanced control algorithms, and machine [learning]—have enabled the development of automated systems capable of controlling TMA vehicles. Furthermore, the relatively low operating speeds and platoon-like operating movements of leader-follower TMA systems make an automated

control concept feasible for a variety of mobile and short-duration TMA use cases. This project seeks to develop an automated control system for TMA vehicles using a short following distance, leader-follower control concept which will remove the driver from the at-risk TMA vehicle.

Field Guide for the Use and Placement of Shadow Vehicles in Work Zones, American Traffic Safety Services Association and Federal Highway Administration, 2008.
https://www.workzonesafety.org/files/documents/training/fhwa_wz_grant/shad_veh_final.pdf
From the introduction: This field guide provides guidelines on the use of shadow vehicles and Truck Mounted Attenuators (TMAs) in highway work zones. It summarizes information from various sources into a compact format for use as a field reference when considering the use of shadow vehicles in advance of workers or other equipment or work vehicles.

State Guidance

Texas

"Enhanced Work Zone Safety Through Cooperative Autonomous Vehicle Systems," Michael Brown, Paul Avery and Purser Sturgeon, *2014 International Conference on Connected Vehicles and Expo (ICCVE)*, November 2014.
Citation at https://ieeexplore.ieee.org/document/7297701
From the abstract: Despite improvements in work zone safety, injuries and fatalities remain a significant problem for work zone personnel. Crew and vehicles are often protected with the use of a vehicle located at the rear of the work zone, which is fitted with a mechanism to attenuate the impact energy of a vehicle. This vehicle, called an impact attenuation, or crash cushion, vehicle, is designed and placed to be struck by any errant vehicles; however, this vehicle is an active part of the work crew and is often manned by a member of the work crew, and this person can still be injured or killed when the vehicle is struck. This paper will present recent work by SwRI [Southwest Research Institute] in conjunction with the Texas Department of Transportation (TxDOT) to replace this manned vehicle with a fully-autonomous vehicle, capable of communicating with other vehicles in the work crew, traffic management systems, and, using visual recognition techniques, follow other vehicles in the crew or even respond to arm gestures by a member of the work crew.

Worker Safety During Operations With Mobile Attenuators, LuAnn Theiss and Roger P. Bligh, Texas Department of Transportation, May 2013.
http://tti.tamu.edu/documents/0-6707-1.pdf
From the report's recommendations on page 53 of the report (page 63 of the PDF):

> The researchers also recommend that TxDOT continue to require 20,000 ±1000 lb support vehicles for attenuators used on TxDOT projects, regardless of attenuator type. The research indicates that the use of heavier support vehicles reduces roll-ahead distance during a collision. The heavier support vehicles also reduce occupant impact velocity and ridedown acceleration for workers in the support vehicle. Heavier support vehicles provide greater protection for workers located in the support vehicle as well as workers on foot located ahead of the support vehicle. In addition, minimum distances between the support vehicle and the location of workers should be maintained at all times during work operations.
>
> Finally, based on the impact testing results, the researchers found no evidence that trailer-mounted attenuators performed worse than truck-mounted attenuators during angled impacts, such as the worst case of Test 3-53 impacts. The researchers recommend that future research include an in-depth examination of actual field impacts to attenuators in

order to determine if the devices perform consistently with the limited amount of FHWA impact testing data.

Virginia

Research in Progress: Strategies to Reduce Truck Mounted Attenuator Crashes, Virginia Transportation Research Council, start date: September 2019; expected completion date: February 2022.
Project description at https://trid.trb.org/view/1646753
From the project description: The objective of this project is to identify the most promising methods that could reduce the occurrence and severity of truck mounted attenuator (TMA) crashes in construction and maintenance work zones, including both stationary and mobile operations. The research team will investigate methods to improve safety such as increasing the conspicuity of TMAs, including changes in markings, colors or lighting; changes in traffic control devices; changes in the location, staging or setup of TMAs for different work zone configurations; improvements in operator training; methods to improve the safety of the TMA operator in the event a collision does occur; and connected vehicle applications that provide vehicle-to-vehicle warnings and pre-collision alarms or advance notice of the TMA's location for oncoming drivers.

Investigation of Truck Mounted Attenuator (TMA) Crashes in Work Zones in Virginia, Benjamin H. Cottrell, Jr., Virginia Department of Transportation, October 2015.
http://www.virginiadot.org/vtrc/main/online_reports/pdf/16-r7.pdf
From the abstract: Truck mounted attenuators (TMAs) are deployed on shadow vehicles in work zones to mitigate the effects of errant vehicles that strike the shadow vehicle, either by smoothly decelerating the vehicle to a stop when hit head-on or by redirecting the errant vehicle. The purpose of this study was to investigate crashes involving TMAs in work zones in Virginia. The objectives of the study were (1) to review trends over the last 3 to 5 years in crashes involving TMAs including a measure of traffic exposure such as the frequency of work zones using TMAs; and (2) to identify the causal factors of crashes in work zones where TMAs are involved.
….

The study offers a number of recommendations to reduce the incidence of TMA-involved crashes. First, VDOT [Virginia DOT] should require TMA operator training. Second, VDOT's Traffic Engineering Division should share the information with regard to TMA crash experience with the VDOT regions, with particular emphasis on the regions with the highest number of crashes. In addition, VDOT's Traffic Engineering Division should review the benefits of having the first TMA vehicle in a travel lane straddling the lane, as opposed to being fully in the lane, and the spacing of TMA vehicles near ramps during mobile operations. Finally, VDOT should consider working with the Virginia Department of Motor Vehicles and/or others on media and outreach campaigns for distracted driving and include mobile work zones for safer work zones.

Wisconsin

Subject 43: Truck Mounted Attenuators, Chapter 5, Section 1, Highway Maintenance Manual, Bureau of Highway Operations, Wisconsin Department of Transportation, June 2020.
https://wisconsindot.gov/Documents/doing-bus/local-gov/hwy-mnt/mntc-manual/chapter05/05-01-43.pdf
This manual section provides the general policy on truck-mounted attenuators, as well as details on how they should be used.

Other Traffic Control Devices and Systems

Evaluation of Mobile Work Zone Alarm Systems, Henry Brown, Carlos Sun and Tim Cope, Missouri Department of Transportation, June 2015.
https://spexternal.modot.mo.gov/sites/cm/CORDT/cmr15-011.pdf
From the abstract: Maintenance of highways often involves mobile work zones for various types of low speed moving operations such as striping and sweeping. The speed differential between the moving operation and traffic, and the increasing problem of distracted driving can lead to potential collisions between approaching vehicles and the truck-mounted attenuator (TMA) protecting the mobile work zone. One potential solution to this problem involves the use of a mobile work zone alarm system. This report describes the field evaluation of two types of mobile work zone alarm devices: an Alarm Device and a Directional Audio System (DAS). Three modes of operation were tested: continuous, manual and actuated. The components of the evaluation included sound level testing, analysis of merging distances and speeds, and observations of driving behavior. The sound level results indicated that the sound levels from both systems fall within national noise standards. All of the tested configurations increased the merging distance of vehicles except for the Alarm Actuated setup. The DAS Continuous setup also reduced vehicle merging speeds and the standard deviation of merging distance. In some instances, undesirable driving behaviors were observed for some of these configurations, but it is unclear whether these driving behaviors were due to the presence of the mobile work zone alarm device. Analysis of alarm activations indicated that factors such as horizontal curves and movement of the TMA vehicle created false alarms and false negatives. The research demonstrated that mobile work zone alarms have the potential to be an effective tool in improving safety by providing audible warnings. Further refinements to the systems, such as modifications to the alarm sound and warning message, could improve system effectiveness.

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Appendix A: Survey Questions

The following survey was distributed to the member lists of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance and the No Boundaries Roadway Maintenance Pooled Fund. Potential respondents were expected to have knowledge of or experience with the practices used on freeways and multilane highways in advance of moving lane closures to help alert motorists to a lane closed ahead.

Alternatives to Flares for Use in Traffic Management

(Required) In moving lane closures (sweeping, striping, etc.) on freeways and multilane highways, does your agency use traditional incendiary flares to alert motorists of a lane closed ahead?

- Yes (skips respondent to **Use of Traditional Incendiary Flares**; after completing these questions, respondent continues to **Use of Flare Alternatives**)
- No (skips respondent to **Use of Flare Alternatives**)

Use of Traditional Incendiary Flares

1. How does your agency deploy traditional flares in moving lane closures?
2. How has your agency addressed the potential for accidental fire (for example, a flare being pushed off the road by a vehicle and starting a brush fire)?
3. How has your agency addressed the environmental impacts (for example, environmental and/or hazmat policies)?

Use of Flare Alternatives

Before You Begin

- If your agency **has used** alternative (nonincendiary) flares, please respond to all questions below.
- If your agency **has not used** alternative (nonincendiary) flares, please skip to **Question 5**.

1. Please describe the types of alternative (nonincendiary) flares your agency has used in moving lane closures. Include in your description the product, product materials and brand name of the flare.
    - Electric flares (LED lights or similar)
    - Chemical-based flares/light sticks
    - Glow sticks
    - Other (please describe)
2. Please describe the effectiveness of the nonincendiary flares your agency has used in moving lane closures.
    - Electric flares (LED lights or similar)
    - Chemical-based flares/light sticks
    - Glow sticks
    - Other (please describe)

3. Please describe any challenges your agency has encountered using nonincendiary flares in moving lane closures.
    - Electric flares (LED lights or similar)
    - Chemical-based flares/light sticks
    - Glow sticks
    - Other (please describe)
4. How do you retrieve nonincendiary flares from the roadway after the moving lane closure is complete?
5. Besides flares, what other methods does your agency use to alert motorists of a moving lane closure ahead? Select all that apply.
    - Advance warning vehicle (with arrow sign)
    - Additional shadow vehicles/truck-mounted attenuator vehicles
    - Highway patrol vehicles
    - Roadside signs or dynamic message signs
    - Other (please describe)
6. Which method or combination of methods has your agency found to be the most effective at alerting drivers and slowing down traffic in advance of a moving lane closure?

Wrap-Up

1. Please use this space to provide any comments or additional information about your previous responses.
2. If available, please provide links to documentation related to your agency's use of flares or other warning methods in moving lane closures. Please send any files not publicly available online to andrea.thomas@ctcandassociates.com.