Synthesis of Best Practice for Increasing Protection and Visibility of Highway Maintenance Vehicles

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ABSTRACT

This paper presents current practices in enhancing visibility and protection of highway maintenance vehicles involved in moving operations such as snow removal, crack sealing, pothole patching, and shoulder operations. The most recent information for current moving operation practices throughout the country and the state of Iowa is discussed, better enabling transportation agencies to adequately assess the applicability and impact of each strategy to their best use and budgetary limitations.

A review of relevant literature, including the *Manual on Uniform Traffic Control Devices*, suggests that there are few concise current guidelines for moving work zones, resulting in a good deal of variability in states' practices. Furthermore, a sparsity of investigative studies of equipment and techniques used to enhance the safety of public and workers in moving maintenance activities is evident. This is in contrast to stationary work zone operations where researchers have significantly contributed to the field of knowledge throughout the years. A compilation of current moving work zone practices is believed to be beneficial in supplementing current literature resources and for identifying future research needs.

A national survey found that most states use amber warning lights on orange colored maintenance vehicles and almost all apply a form of retro-reflective material to enhance nighttime visibility. In general, snow removal vehicles use more warning lights and devices than standard maintenance equipment. All responding states indicated using shadow vehicles and/or truck mounted crash attenuators with routine maintenance moving operations. A supplemental Iowa county survey found that similar traffic control and warning devices are used on snow removal and standard maintenance vehicles. Mounted warning signs and rotating or strobe warning lights are common for routine operations while snow removal equipment utilizes retro-reflective tape, warning flags, rotating and strobe lights, and auxiliary headlamps.

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Key words: maintenance—*Manual on Uniform Traffic Control Devices*—moving operations——warning devices

INTRODUCTION

Despite the development and availability of many new accouterments such as crash attenuators, specialized warning lights, and retro-reflective materials, a large number of crashes are still attributed to inadequate visibility of maintenance vehicles and personnel in moving work zone operations. While conspicuity and subsequent safety have been greatly improved in recent years, still no precise summary of products and practices is available as reference for supervisors and workers in moving operations.

Current literature and available references provide few substantive guidelines for effective traffic control in moving work zones such as pavement marking application, snow removal activities, surface patching, crack filling, and shoulder operations. Consequently, considerable variability in practice exists among states. This paper will describe an effort to compile and summarize current practice for temporary traffic control measures used throughout the country to improve visibility and protection of maintenance workers and equipment in moving operations.

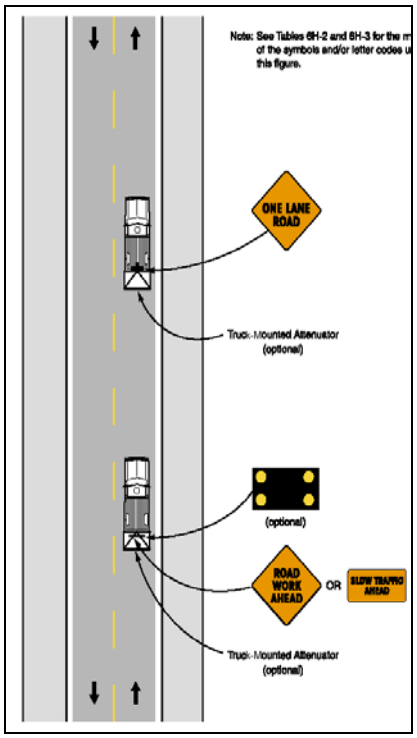
In addition to a review of current literature, both a national and Iowa county survey were conducted to determine current states' practices in improving visibility and safety in moving work zones. A review of current references, existing literature and responses to the surveys are described.

GUIDANCE FOR MOVING OPERATIONS (LITERATURE REVIEW)

Part 6 (Temporary Traffic Control) of the *Manual on Uniform Traffic Control Devices* (MUTCD) (*1*) presents several recommendations and standards of practice for moving operations. Specifically, Section 6G.02 includes guidance in the use of appropriate traffic control devices, shadow vehicles, and warning lights. Typical applications in Chapter 6H illustrate these applications for mobile work on shoulders (TA-4), two lane roads (TA-17), and multilane facilities (TA-35). These applications require or strongly recommend that work vehicles be equipped with rotating or strobe warning lights. Arrow panels and shadow vehicles are also recommended when work occupies a traffic lane. Truck mounted attenuators are presented as an option for additional protection. Refer to Figures 1 and 2.

In addition to the MUTCD, several studies and states' practices describe application of certain devices to better delineate work vehicles and activities in mobile operations.

Although the MUTCD does recommend the use of warning lights on moving vehicles, neither color nor configuration is detailed. Several states have adopted specific colors such as blue. (Alaska, Colorado, Minnesota, Texas, and others). The blue color is opined to signify a particularly hazardous exposure, demanding a higher level of driver alertness. (*2*, *3*). A study by the Texas Transportation Institute (TTI) found that a combination of colors and configurations was effective in alerting drivers and reducing speeds (*3*). Other studies have also considered various warning light designs, configurations, and applications including light bars, rotating beacons, strobes, and flashers. Two rotating lights supplemented with a flashing light were found most effective in some studies (*4*, *5*). The state of Missouri found that strobes were more effective than standard rotating lights and now use these in many maintenance operations (*6*).



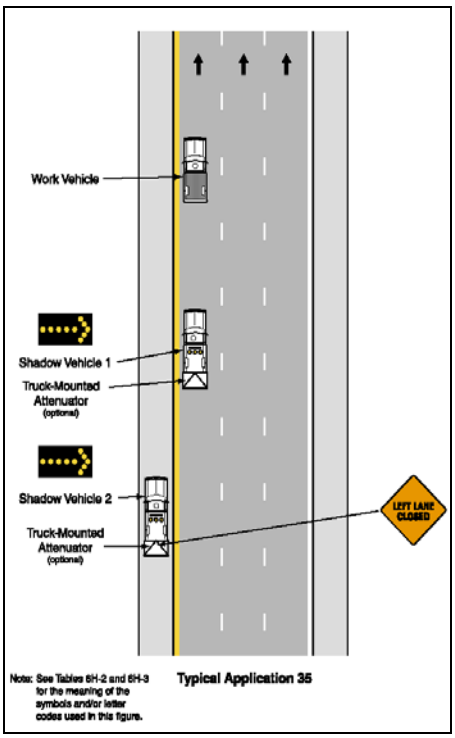


FIGURE 1. MUTCD TA-17 **FIGURE 2. MUTCD TA-35**

Shadow vehicles and truck-mounted attenuators (TMAs) can provide an extra level of protection for both workers and road users. While no known standards fully describing the use of these devices have been identified, some practices have been adopted in various states. Humphreys and Sullivan (*7*) developed guidelines for the use of shadow vehicles and TMAs in various mobile and short-term applications, and these are shown in Tables 1 and 2.

TABLE 1. Recommendations for the Assignment of Shadow Vehicles

Closure/Exposure Condition	Freeway	Non-Freeway with Speed Limit		
		>=50 mph	40–45 mph	<=35 mph
Shadow vehicle for no formal lane closure for operation involving exposed personnel	Very highly recommended	Very highly recommended	Very highly recommended	Very highly recommended
Shadow vehicle for no formal lane closure for operation **NOT** involving exposed personnel	May be justified*	May be justified*	May be justified*	May be justified*
Shadow vehicle for no formal shoulder closure for operation involving exposed personnel	Highly recommended	Highly recommended	Recommended	Recommended
Shadow vehicle for no formal shoulder closure for operation **NOT** involving exposed personnel	May be justified*	May be justified*	May be justified*	May be justified*

***** May be justified on basis of special conditions encountered on an individual project.

TABLE 2. Recommendations for the Application of Truck-Mounted Attenuators

Closure/Exposure Condition	Freeway	Non-Freeway with Speed Limit		
		>=50 mph	40–45 mph	<=35 mph
Shadow vehicle for no formal lane closure for operation involving exposed personnel	Very highly recommended	Highly recommended	Recommended	Desirable
Shadow vehicle for no formal lane closure for operation **NOT** involving exposed personnel	Highly recommended	Highly recommended	Recommended	Desirable
Shadow vehicle for no formal shoulder closure for operation involving exposed personnel	Highly recommended	Recommended	Recommended	Recommended
Shadow vehicle for no formal shoulder closure for operation **NOT** involving exposed personnel	May be justified*	Recommended	Desirable	May be justified*

* May be justified on the basis of special conditions encountered on an individual project.

Retro-reflective markings are very effective in enhancing visibility of work equipment at night and in low light conditions. The National Highway Traffic Safety Administration (NHTSA) requires large commercial trailers to be treated with these materials and a resultant reduction in nighttime impacts have been noted (*8*). Several states also utilize retro-reflective tape to improve conspicuity of maintenance vehicles. New Jersey applied this highly visible material to maintenance vehicles in 1996 and followed with similar use on snowplows and emergency vehicles (*9*). Minnesota, Iowa, and several other states make effective use of these retro-reflective markings. A study by TTI found that retro-reflective magnetic strips applied to flagger vehicles were effective in improving night visibility and recommended further use (*10*).

Advanced vehicle control systems (AVCS) have been developed to improve safety for both workers and road users, particularly in higher speed and traffic volume exposures. Shadow vehicles and snow removal equipment pose special hazards for operators and ASCS applications have been employed to address these concerns. Two applications, a remote driven vehicle (RDV) and a fully autonomous shadow vehicle are designed to actually remove the operator from hazardous exposure by allowing remote operation (*11*, *12*) These systems have been tested in Minnesota under the Strategic Highway Research Program (SHRP) and may be fully available in the future. AVCS devices can also provide needed guidance assistance to snowplow operators during periods of severely reduce visibility. Using a magnetic marking system in the roadway, operators are provided edge of road and forward collision data to assist in steering. Improved safety and efficiency are expected through use of this innovation.

Visibility of snowplowing equipment is a particular concern in many states, considering the adverse effects of blowing snow, headlight glare, and obscured windows. A National Cooperative Highway Research Program (NCHRP) study investigated methods for improving conspicuity of snowplows and vision of operators (*13*). The study concluded that steady burning light bars mounted on the rear of the plows can be effective in increasing on-coming drivers' recognition of reduced vehicle speed and location. In addition the study concluded that side vanes mounted on the rear of trucks and deflectors on the front can reduce accumulation of snow on the vehicle thus improving performance of warning lights and overall vehicle visibility for road users. The Iowa Department of Transportation (Iowa DOT) in 1995 studied crashes involving snow removal equipment, concluding that reduced visibility was a major contributor to rear end collisions (*14*). The study recommended use of rear deflectors to reduce snow accumulation with improved lights and retro-reflective markings for better road user visibility. A follow up study in 1999 found the deflectors to be quite effective and recommended extended use as well as

utilization of a new design, "scoop" deflector (*15*, *16*) In addition, the Iowa DOT examined the use of "Teflon" spray and taillight air blasters to avoid snow build-up on rear lights (*15*). Experiments with use of a section of snow fence augmented with retro-reflective tape affixed to the rear of snowplow trucks have been conducted by the Iowa DOT and future evaluations for the use of rear view cameras and dual speed displays have been recommended (*17*).

Although the MUTCD does address temporary traffic control measures for moving work operations, the recommendations and guidelines are not significantly definitive. For example, use of warning lights is required for some applications, but color is not specified. Consequently considerable variability in traffic control procedures and practices among the states is observed. Interest and concern is evident in this area among transportation agencies therefore additional guidance for safe and efficient temporary traffic control in mobile operations, particularly for night work, is needed.

SURVEYS

To assess common practice among the states in addressing traffic control needs for moving operations, a national survey was conducted. Forty-eight state departments of transportation were contacted either by email or telephone. Thirty-four state departments of transportation and three Wisconsin counties responded to the survey, an approximate 71 percent rate. In addition, to learn about maintenance work zone visibility practices in rural local agencies in Iowa, a survey was conducted in all 99 counties. This survey was sent to county engineers requesting information pertaining to temporary traffic control measures for maintenance vehicles during routine granular road maintenance and snow removal operations. Sixty-one counties, approximately 62 percent, provided information in response.

All responding state agencies use amber colored warning lights, either exclusively or with other colors. Alabama and Rhode Island use a mixture of white, amber, and red, while Alaska, Colorado, and Mississippi prefer amber and blue. Other states use different combinations but only Louisiana uses amber and red together. Strobe warning lights are preferred over rotating beacons in most responding states due to the perceived improved conspicuity. Several states are experimenting with light emitting diodes (LEDs) in various applications.

Retro-reflective marking material is applied to large trucks in most responding agencies, although the color varies. Over half use red and white tape, but California for example utilizes a six inch wide orange marking on both sides of large vehicle cabs. Idaho uses a retro-reflective yellow stripe on all vehicles and Massachusetts applies a blue and green combination. Small vehicles are also marked with retro-reflective materials in many agencies.

Vehicle color is important in providing recognition and distinction to maintenance vehicles. Orange and yellow appear to be the most popular colors although white is also specified in some agencies. Eau Claire County in Wisconsin has selected yellow-green as the color of choice, opining that this color provides more visibility under a wider range of lighting conditions.

Almost all responding states use shadow vehicles, arrow panels, and/truck mounted attenuators in at least some moving operations. Use and number of these devices varies among states. Georgia, Massachusetts, and New Hampshire report effective use of changeable message signs on some moving equipment. Kansas uses a mobile radio transmitter to advise approaching drivers of mobile painting operations.

Visibility of snow removal equipment is a major concern in many states and a variety of methods and materials were identified from survey responses. Generally more warning lights are employed on snowplowing vehicles than for standard maintenance equipment. Additional lights are added to both front

and rear of vehicles and some states place warning lights on plow blades. Some agencies use different colored lights for snow removal than standard maintenance activities. Blue and white colors supplementing amber are displayed in some states. LED lights are also used by a few agencies. Retro-reflective markings are also increased on snow removal vehicles to improve visibility and supplemental flags are mounted on this equipment in some states such as Kentucky and Nevada. Deflectors and air foils are used to reduce air borne snow and subsequent accumulation in several agencies.

A unique survey of Iowa counties was undertaken to learn of common traffic control practices used by local agencies for routine mobile maintenance and snow removal operations. Of particular interest were measures employed during granular road maintenance using motor patrols. Survey responses indicate that most Iowa counties use amber rotating or strobe warning lights and vehicle mounted warning signs on motor patrols, however only eleven counties reported using ground mounted warning signs for these activities. Flags attached to the vehicles is a strategy in some counties and a few local agencies use strobe lights to good effect. For snow removal operations, 75 percent of responding counties reported using retro-reflective markings on vehicles, many applied directly to plow blades. A high percentage of counties also mount warning flags on snow removal equipment. Auxiliary headlamps and strobe lights exhibit common usage and about 39 percent of responding counties use snowplow deflectors.

CONCLUSIONS AND RECOMMENDATIONS

The surveys revealed a high interest in safety for workers and road users in moving operations among the states and Iowa counties, evidenced by increased use of warning lights and other devices. Some procedures are quite common, but a great deal of variation in practice was determined. Experimentation with new methods and materials for enhancing visibility of mobile equipment reinforces a common concern for the potential risks posed by a constantly moving work area.

A need for more definitive guidelines and recommendations on a national level is evident. As new materials are developed and improved methods discovered, focused studies should be undertaken to identify and present reliable guidance in effective traffic control measures for use by transportation agencies in these particularly hazardous exposures for both workers and road users.

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REFERENCES

1. Federal Highway Administration (FHWA). *Manual on Uniform Traffic Control Devices.* Millennium edition. FHWA, U.S. Department of Transportation, Washington, D.C., December 2000.

2. Cameron, R. Emergency Warning Light Technology. *Transportation Research Circular 475: 11th Equipment Management Workshop.* Transportation Research Board, National Research Council, Washington, D.C., July 1997, pp. 52–58.

3. Ullman, G.L. Special Flashing Warning Lights for Construction, Maintenance, and Service Vehicles: Are Amber Beacons Always Enough? *Transportation Research Record*, No. 1715, 2000, pp. 43–50.

4. Hanscom, F.N., and R.F Pain. *Warning Lights on Service Vehicles in Work Zones.* VTI Rapport 351A. National Swedish Road and Traffic Research Institute, Linkoeping, Sweden, 1990, pp. 57–69.

5. Hanscom, F.N., and R.F. Pain. *Service Vehicle Lighting and Traffic Control Systems for Short-Term and Moving Operations*. NCHRP Report 337. Transportation Research Board, National Research Council, Washington, D.C., December 1990.

6. Missouri Department of Transportation. Flash! New Warning Lights Grab Motorists' Attention. April 30, 2002.http://www.modot.state.mo.us/news/2002_htm/newsrelease/ may/4-30-02.htm. Accessed May 3, 2002.

7. Humphreys, J.B., and T.D. Sullivan. Guidelines for the Use of Truck-Mounted Attenuators in Work Zones. *Transportation Research Record*, No. 1304, 1991, pp. 292–302.

8. Morgan, C. *The Effectiveness of Retroreflective Tape on Heavy Trailers.* Report DOT HS 809 222. National Highway Traffic Safety Administration, U.S. Department of Transportation, March 2001.

9. 3M. New DOT Safety Standard for Maintenance Vehicles Set to Protect Workers During Nighttime Operations. http://www.3m.com/us/safety/tcm/solutions/pia_dotstd.jhtml. Accessed May 13, 2002.

10. Fontaine, M.D., P.J. Carlson, and H.G. Hawkins, Jr. *Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones: Second Year Activities and Final Recommendations.* FHWA Report FHWA/TX-01/1879-2. Texas Transportation Institute, College Station, Texas, October 2000.

11. Federal Highway Administration. Moving Barrier Protects Work Crews. http://www.fhwa.dot.gov////winter/roadsvr/CS080.htm. Accessed March 12, 2002.

12. Raytheon E-Systems. *Advanced Vehicle Control Systems for Maintenance Vehicle Applications.* Raytheon E-Systems, Falls Church, Virginia, December 20, 1996.

13. National Cooperative Highway Research Program. Improved Visibility for Snowplowing Operations. *NCHRP Research Results Digest 250.* Transportation Research Board, National Research Council, Washington, D.C., November 2000.

14. Iowa Department of Transportation. *Continuous Quality Improvement Snow Plow Accident Study Report*. Iowa Department of Transportation, Ames, Iowa, June 1996.

15. Iowa Department of Transportation. *Snowplow Study Team Recommendations*. Iowa Department of Transportation, Ames, Iowa, November 1999.

16. SPI Industries, Inc. The Scoop. March 26, 2002. http://www.spiplastics.com/thescoop.htm. Accessed May 21, 2002.

17. Stalker Radar. The Stalker Speedboard. http://www.stalkerradar.com/law_speedboard.html. Accessed May 21, 2002.