U.S. Department of Transportation
Federal Highway Administration

TRAFFIC CONTROL HANDBOOK FOR MOBILE OPERATIONS AT NIGHT

Guidelines for Construction, Maintenance and Utility Operations

US Department of Transportation
Federal Highway Administration

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16. Abstract

This report is a synthesis of current practices for performing mobile highway operations at night. The information presented in this report is based on a review of work zone manuals from a selection of state and local highway agencies, discussions with highway officials, and field observations of a select number of nighttime highway mobile work zone operations.

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NOTE: Users of this Handbook should be aware that changes to the provisions in this Handbook may occur as a result of the Final Rule on Proposed Revision 2 of the Manual on Uniform Traffic Control Devices (MUTCD). The Final Rule on Proposed Revision 2 is expected to be published late in 2003.

This Handbook is intended for use by a wide range of highway practitioners. It emphasizes that adequate advance planning and time to set up and remove good temporary traffic control is essential to ensure the safety of workers and road users.

Field Staff responsible for traffic control on moving construction and maintenance operations can use this Handbook as a field guide during night mobile operations. It provides examples of traffic control setups and discusses safety practices suggested for these operations.

Highway Agency Staff will find this Handbook helpful in assessing mobile night operations. This information will be helpful in establishing procedures and standards for mobile night operations covering a wide range of conditions.

Managers of construction and utility companies will find this Handbook useful to select equipment and traffic control devices for use in mobile traffic control operations at night. It provides information that can be used to establish safety practices to protect employees.

Staff of FHWA Resource Centers, State LTAP Centers, and other safety professionals involved in safety training and technology transfer activities will find this Handbook a concise source of current information on traffic control and safety practices for mobile operations conducted at night.

Acknowledgements

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INTRODUCTION

Highway construction and maintenance activities are typically performed on roadways while they continue to operate at or near their normal traffic volumes. In addition, traffic flow must be maintained during highway incidents such as accidents, material spills, and special events. It is essential that temporary traffic control provided during construction and maintenance activities, and during highway incidents, ensures adequate **mobility** for the traveling public, along with a high level of **safety** for travelers and workers. At the same time, adequate **roadway access** must be provided to allow the activity to proceed effectively and efficiently.

Part 6 of the MUTCD, which addresses Temporary Traffic Control, defines ***Mobile Operations*** as ***"work that moves intermittently or continuously."*** In simple terms, mobile operations move along the highway at speeds well below the normal traffic speed. Mobile operations may stop occasionally or at regular intervals, for periods of up to several minutes. The work may be done directly from the moving vehicle or equipment, or it may involve workers on foot.

An important consideration for mobile operations is that traffic control devices and safety features must be moved to keep pace with the operation. Devices used for these operations must either be easily transportable such that they can be moved with each relocation, or mounted on the work vehicles and equipment.

Increasingly, high traffic volumes on many highways make it difficult to perform work operations in or near travel lanes during much of the day because of the disruption in traffic flow and the risk this introduces for workers and the traveling public. As a result of these concerns, all kinds of highway work are increasingly scheduled for off-peak periods, particularly at night, to alleviate the problems associated with working in heavy traffic.

This photograph shows a busy 4-lane suburban arterial highway. A steady stream of vehicles occupies all lanes. A lane closure to permit construction or maintenance activities during these conditions will obviously result in more congestion and significantly increased delays.

This Handbook provides guidance for mobile highway work operations scheduled to take place during darkness. While lower traffic volumes at night reduce traffic conflicts, other risk factors are introduced by reduced visibility, higher speeds, and changes in behavior and expectancies of both drivers and workers. This guidance addresses issues of when and where mobile night operations may be suitable, as well as the traffic control devices and safety devices that should be used to ensure a high level of safety.

Mobile night work typically involves operations performed from moving vehicles and equipment. *This includes; applying pavement markings and pavement sweeping,* operations involving workers on foot, *debris and trash removal, pothole patching, and repairs to small signs and delineators.*

Work operations that occupy a location for more than a few minutes are not considered to be mobile work. Work zone traffic controls for these longer durations are not covered in this Handbook, and should be addressed according to the guidelines of the MUTCD Part 6 for Short Duration Work or other categories of work duration as appropriate. National Cooperative Highway Research Program (NCHRP) Report 476, "Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction" provides extensive information for longer duration operations conducted at night.

DECIDING WHEN TO USE MOBILE NIGHT OPERATIONS

The decision to conduct mobile work operations at night actually involves two options – using **mobile rather than fixed** traffic control operations, and evaluating the relative risks and merits between **night and day work** for the activity.

Mobile vs. Fixed- The first option is addressed in detail in Chapter 6G of the MUTCD. Highway work may be protected either by mobile traffic control operations, with the traffic control setup moving with the work, or by fixed setups, with the traffic control remaining stationary for some period of time.

Mobile traffic controls rely upon devices that move with the operation, either mounted on the vehicles and equipment, or portable devices that are easily moved to keep pace with the operation. **Fixed lane and shoulder closures are rarely feasible for mobile operations because they require too much time to place and remove.**

Fixed traffic controls, by comparison, typically involve the use of temporary signs and channelizing devices, supplemented by various other devices, to establish lane or shoulder closures that remain in place for some period of time.

The primary advantage of mobile operations is that they minimize interference with traffic because they occupy only the minimum space and time needed to complete the work and provide traffic control. Fixed operations, on the other hand, require more time and space, thus increasing exposure for traffic and workers while the lane or shoulder closure is in place. However, a tradeoff is involved, because fixed traffic control setups usually provide more advance warning to drivers and better separation between the traffic space and work space.

The decision to employ a mobile operation should be based on careful consideration of the nature of the work to be performed, and the characteristics of the roadway and traffic conditions where the work is to occur. As a minimum, the following points should be considered:

1. Operations that will require stationary occupation of a section of roadway for more than a few minutes should normally employ fixed traffic control setups meeting the requirements of ***Short Duration*** or ***Short-term Stationary*** operations as defined in Chapter 6G of the MUTCD.
2. Work that moves continuously along the highway, even at very slow speeds, is a good candidate for ***Mobile Work*** if traffic volumes are light to moderate and roadway conditions are such that adequate advance warning to drivers can be provided.
3. Operations that require workers to be on foot should normally be protected by fixed lane/shoulder closures unless traffic volumes are low, roadway conditions are favorable, and the duration of the activity is very brief.
4. Work operations should normally be protected by fixed lane/shoulder closures where sight distance is restricted and/or traffic patterns are complex, unless traffic volumes are low and adequate advance warning can be provided as part of the mobile operation.
5. Using mobile traffic controls for operations that require workers to be on foot for brief periods reduces exposure for traffic and workers associated with setting up and removing fixed traffic controls, and may present the safest choice when traffic volumes are low, and roadway and traffic conditions are favorable.

For the purposes of this discussion, low traffic volumes are defined as conditions under which vehicles can maneuver and change lanes freely and no congestion or backups occur when a lane or shoulder is occupied by work operations.

Night vs. Day-While night work often results in reduced traffic impacts because volumes are lower, it adds risks associated with reduced visibility, higher speeds, behavior and expectancy issues for drivers and workers alike, and a number of other issues. The decision to work at night, whether for mobile operations or traditional fixed operations, should be based on a careful comparison of the pros and cons associated with each option. A detailed procedure to assess the feasibility of performing highway work at night is provided in **NCHRP Report 475, "A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance."** It is recommended that persons considering the use of night work review that Procedure for more detailed guidance. Similar to our decision of whether to use mobile vs. fixed operations, the decision of whether to work at night should be based on careful consideration of the nature of the work to be performed and the characteristics of the roadway and traffic conditions where the work is to occur. As a minimum, the following points should be considered.

Points to Consider for Mobile Night Operations-

1. Certain operations must be conducted immediately to restore safe roadway operation. Examples include repairing traffic signals, replacing STOP signs and other critical signs, removing debris from travel lanes, repairing serious pavement defects, and establishing traffic controls to respond to incidents such as crashes, spills, or natural disasters. When these situations occur at night, night operations are necessary to restore safe traffic operations.
2. The primary indicator for night work is reduced traffic volumes such that work operations can be completed without undesirable traffic congestion. For highways carrying high traffic volumes during normal daylight work periods, night work often provides a substantial advantage in terms of reduced traffic impact.
3. To allow normal traffic flow during daylight, traffic controls for night operations must be placed and removed nightly. Because mobile operations require the placement of very few fixed devices, they are especially suitable for night work.
4. The safe completion of mobile night operations requires the availability of adequate traffic control devices and safety features such as specially designed work vehicles, good vehicle-mounted work lights and warning lights, mobile impact attenuators, and other safety devices described in this Handbook. **Mobile night operations should NOT be considered, even on an emergency basis, unless an adequate supply of traffic control and safety devices is available to address the specific conditions to be encountered.** Refer to MUTCD Section 6G.04 and this Handbook for information on suitable devices.
5. The availability of adequate staffing for night operations is essential. When night shifts are already in place in an agency, night operations may provide an efficient use of that staff when they are not needed for other operations such as incident management or snow removal operations.
6. Many agencies have guidelines in place dictating when lanes may be closed on certain freeways and other major highways. Such guidelines may require scheduling operations at night when lane closures are necessary, even for very brief periods such as those that can be completed by mobile operations.
7. Impacts on residential and business communities associated with night work, such as glare from work lights and equipment noise, need to be considered in making the decision to work at night. Because mobile work minimizes the duration of these impacts at any one location, these impacts are often not a

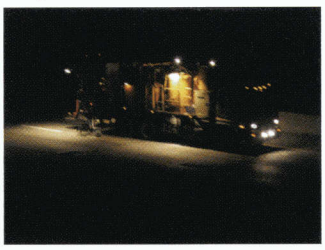
drawback for mobile night operations.

8. Where parked vehicles and other daytime conditions restrict access to the roadway for sweeping and other pavement operations, working at night may provide the needed roadway access without major disruption to daytime traffic patterns.
9. On highways with narrow median shoulders, safe daytime access to the median to remove debris and repair or replace traffic control devices often requires a full lane closure resulting in major traffic congestion. These operations can often be conducted as a mobile operation at night when traffic volumes are low, with minimal impact on traffic flow.

Typical Mobile Night Operations- These operations are carried out routinely in some highway agencies, while other agencies restrict mobile night operations, or all night operations, to emergency responses, or to major construction projects. Highway work often carried out as mobile night operations include the following:

- **Pavement marking installation** - new markings and restriping. Longitudinal markings are most common, but intersection and special markings are also done at night.
- **Pavement marking removal** - to revise traffic patterns or prepare pavement for new markings.
- **Raised pavement markers -** new installations and lens replacement.
- **Shoulder rumble strips** - installation.
- **Pavement sweeping -** where parked vehicles or traffic limits daytime access.
- **Pavement sampling -** coring, pavement soundings, skid tests, etc.
- **Pavement repairs -** limited in scope, such as pothole patching and other small repairs.
- **Debris cleanup -** both routine cleanup and removal of debris, and emergency removal of storm debris and spilled material.
- **Vegetation control -** application of herbicides adjacent to shoulders.
- **Traffic signal repairs -** routine lamp replacement and emergency repairs.
- **Post mounted delineators** - repair, replacement, installation.
- **Small roadside signs -** repair, replacement, installation.
- **Cleaning drainage facilities -** catch basins, drop inlets, etc.
- **Emergency repairs** - miscellaneous operation necessary to restore safe highway operation that can be completed within a few minutes. Operations requiring longer exposure of work crews should use stationary traffic control setups.
- **Incident management –** Unplanned incidents may require the setup of detours, road closures, diversions, etc. to control traffic through or around the incident area. While the established traffic controls may need to remain in place for an extended period, the operation to set them up may be handled as a mobile operation during night hours. Likewise, planned incidents such as movement of oversize loads may occur at night, and fall into the category of mobile operations.

This photograph shows a pavement marking applicator working at night. This work vehicle is equipped with warning lights, work lights, and signs.



Many of these operations can be carried out from moving work vehicles. While some operations require workers to be on foot, they can generally be carried out at each location within a few minutes. **Work operations requiring longer than a few minutes at a specific location should not be categorized as mobile.**

Refer to the MUTCD Part 6 and to NCHRP Report 476 for information on work zone traffic control for longer operations.

WORK ZONE TRAFFIC CONTROL FUNDAMENTALS

Part 6 of the MUTCD provides basic guidance concerning the design and operation of work zone traffic control. This section provides a brief overview of that guidance, which is found in Chapters 6A, 6B, and 6C of the MUTCD. Persons responsible for traffic control on mobile night operations should be knowledgeable concerning the material covered in those chapters.

Objectives of Work Zone Traffic Control – The three following objectives must all be satisfied by work zone traffic control:

- Provide a high level of safety for workers and the public.
- Maintain mobility and minimize congestion and community impact by maintaining acceptable levels of service.
- Provide adequate access to the highway to complete the work efficiently while meeting quality requirements for the completed product.

These objectives frequently compete against each other. Satisfactory work zone traffic control often requires tradeoffs such that each of these objectives can be met to the greatest extent possible.

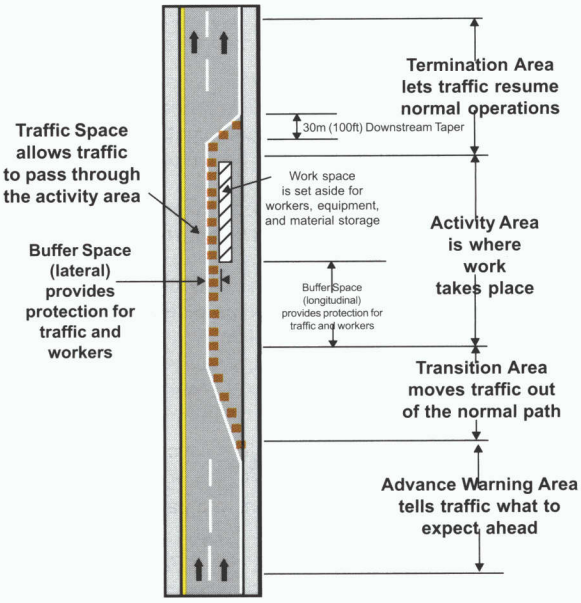
Fundamental Principles – The following fundamental principles should be addressed in mobile night operations, the same as any other highway work:

1. The control of vehicular and pedestrian traffic through the work zone must be an integral part of highway construction, maintenance, and utility operations, fully addressing the objectives stated above. A temporary traffic control plan in detail appropriate to the project should be prepared before the work begins.
2. Vehicular and pedestrian movements should be inhibited as little as possible, consistent with safety and efficient completion of the work.
3. Highway users must be provided with clear, positive guidance while approaching and traversing the work zone. This includes adequate warning, delineation, and path guidance.
4. Routine inspections of the work zone must be completed by qualified individuals to ensure that the temporary traffic controls function as intended at all times.
5. Attention should be given to maintaining roadside safety as the work progresses. As a minimum, work vehicles, equipment, and materials should not be parked or stored where they may present a hazard to vehicles that leave the travel lanes.
6. Each person whose actions affect work zone safety should receive training appropriate for the job decisions he or she is required to make.
7. Good public relations are essential to keep the public informed about the work, how they will be impacted, and the actions needed to ensure smooth, safe traffic flow.
8. Temporary traffic control devices not appropriate to the actual situation on the highway must be covered or removed as soon as practical when they are no longer needed, even when the work is suspended for short periods of time.

All traffic controls on highways open to travel by the public must be authorized by the official body having jurisdiction over that highway. This applies to temporary traffic controls for work operations, the same as for permanent traffic controls. **Work zone traffic controls used in mobile night operations must be authorized by, and meet the requirements of, the highway agency having jurisdiction over the highway where the work takes place.**

Component Parts of a Work Zone – In addition to work zone traffic control objectives and fundamental principles, it is also essential to understand the basic components that make up a work zone. These components are defined in the figure below. The four basic areas of a work zone are as follows:

- **Advance warning area –** approaching traffic is told what to expect ahead.
- **Transition area –** traffic is moved out of its normal path.
- **Activity area –** this is where the work takes place. It is comprised of the work space, traffic space, and buffer space to provide physical separation between traffic and the work activity.
- **Termination area** – normal traffic operations are resumed.



This figure illustrates a two-lane, one-way roadway, with the component parts of the Temporary Traffic Control Zone (TTCZ) listed. Starting at the upstream end of the TTCZ and proceeding downstream, these parts include the advance warning area, the transition area, the activity area, and the termination area. The activity area is further divided into longitudinal buffer space in advance of the work space and lateral buffer space adjacent to the work space.

Although mobile operations frequently do not utilize traffic signs placed on the ground and channelizing devices to mark the intended travel path, it is still essential that the functions of the component parts of the work zone be addressed.

- **Advance warning** is provided by traffic signs, arrow panels, and warning lights on the work vehicles and equipment, and may be supplemented by signs placed on the ground or by portable changeable message signs.
- **A transition area** is created by the work vehicles and the traffic control devices they carry, causing vehicles to move to the

intended path as they approach the activity area. Channelizing devices such as traffic cones or drums are frequently not used in mobile operations. Instead, the travel path is defined by work vehicles on the shoulder approaching the activity area, and in the travel lanes in advance of and through the activity area.

- **The activity area** is defined by the work vehicles, which are typically equipped with warning lights, signs, and other devices to make them noticeable to drivers and to convey to drivers the appropriate travel path through the activity area.
- **The termination area** is generally not specifically defined or marked for mobile operations, and drivers simply resume normal operation once they pass the work.

Maintaining good sight distance to the work operation is considered especially important at night. This can be accomplished by ensuring that an adequate number of advance warning and shadow vehicles are used, and that they are positioned far enough behind the work operation. When sight distance on a highway is restricted in some locations, the position of the advance warning vehicles can be varied as necessary to provide good approach sight distance.

TRAFFIC CONTROL DEVICES AND SAFETY FEATURES FOR MOBILE NIGHT OPERATIONS

Because mobile operations are continuously moving, or move frequently with only brief stops as the work progresses, traffic control devices and safety features used to alert traffic and to protect road users and workers must move with the operation. While some fixed devices may be used with mobile operations, most of the devices are mounted on the work vehicles and equipment, or are portable devices that can be set up and moved quickly.

Traffic control devices used for work zone traffic control include ***signs, signals, markings, channelizing devices, and other devices*** (including arrow panels, changeable message signs, and warning lights). In addition, other safety devices such as traffic barriers, crash cushions, and vehicle arresting systems are used to protect workers and road users. Although these devices do function to "regulate, warn, or guide" traffic, and they are not "traffic control devices" in the traditional sense, they play an essential role in providing a safe work and travel environment.

Traffic control devices and safety features used in mobile operations, especially at night, must be adapted to provide advance warning to approaching traffic as the operation moves along the roadway. Adequate visibility must be ensured during darkness, both for drivers and for workers to perform the work task safely and efficiently. Physical measures to protect road users and workers from conflicts between traffic and work operations are very important because mobile operations occupy open travel lanes without benefit of stationary lane closures and other measures typically employed in longer-term traffic control setups.

Devices used at night can be grouped into the eight categories discussed in the following sections. The information that follows is intended to describe the range of traffic control devices and other safety devices that are commonly used in mobile night operations, and to provide selection criteria that can be helpful in selecting the devices most appropriate for a given set of highway, traffic, and operational characteristics. **Regardless of the information presented here, it is essential that the actual selection of traffic control devices and safety features for any operation meets the MUTCD and the specifications and other requirements of the highway agency having jurisdiction over the highway where the work occurs.**

1. Signs – Signs are an essential part of mobile night operations to warn drivers of conditions ahead and to convey to drivers information needed to safely travel through the activity area. Warning signs are most frequently needed, but regulatory signs are also needed on occasion.

Sign messages – Content of ***warning sign*** messages should inform drivers of the situation ahead, and provide information needed to traverse the work zone. Typical warning signs include "Road Work Ahead" and "Right or Left Lane Closed" or "Shoulder Closed." Warning signs may be supplemented by ***regulatory signs*** such as "Do Not Pass." Other examples of sign messages suitable for mobile operations are shown in the ***Typical Application Diagrams*** at the end of the Handbook. ***Guide signs*** are not frequently used for mobile night operations, although guidance may be provided on fixed signs or Changeable Message Signs in advance of work locations to encourage drivers to seek alternate routes.

Sign location – Signs for mobile operations are frequently mounted on the work vehicles. This becomes essential when the work operation moves continuously over an extended area. For operations that stop frequently, or that are confined to a relatively short section of highway, signs placed on the ground may be used to supplement vehicle-mounted signs. Because they can provide warning further in advance of the activity area, fixed signs are desirable when it is feasible to move them to stay in proximity to the work location.

Signs mounted on equipment should be placed as high as possible to improve visibility – TA-17 in Part 6 of the MUTCD requires a minimum height of 4 feet above the pavement to the bottom of the sign. **Attachment of signs to work vehicles should not interfere with the work function. It is also essential that signs mounted on work vehicles do not obstruct visibility of the vehicle's warning lights or arrow panel. A well-designed mounting system is important to provide secure attachment of the sign, while providing for easy changeover when a different sign is needed.**

Lightweight portable sign supports should be used for ground-mounted signs to facilitate setup and movement. Sign support/sign combinations should address impact safety considerations.

Other sign characteristics – Because signs used in mobile operations are often on the work vehicles rather than placed in advance of them, it becomes important to use the largest practical ***sign sizes*** that can be accommodated. This helps to provide improved advanced warning to approaching traffic, and helps to compensate for the absence of warning signs upstream of the work vehicles.

Adequate **retro*reflectivity*** is essential for signs used in night operations. Although the MUTCD does not currently require specific levels of retroreflectivity for signs used in work zones, consideration for use of high-performance retroreflective sheeting, especially materials with good angularity properties, can help to ensure that signs are visible and legible to approaching drivers under conditions of darkness and a wide range of viewing conditions. The use of ***fluorescent sheeting*** may also improve visibility for warning signs when operations start at dusk or extend into dawn.

The standard ***diamond warning sign shape*** is generally required by the MUTCD for signs placed on the ground and used on service vehicles. However, ***rectangular shapes*** for warning signs on vehicles may be used to facilitate mounting, and they may permit the use of larger legend sizes. Regardless of sign shape, it is essential that all warning signs use the standard ***black legend and border on an orange background.***

Sign illumination – Signs mounted on the rear of work vehicles, even when incorporating highly retroreflectorized sheeting, may not provide adequate visibility and legibility under some conditions. These signs are often positioned high on the vehicle. Combined with varying approach angles for traffic from the rear, the sign is often not within low-beam headlight patterns, resulting in inadequate sign visibility and legibility until the approaching vehicle is very close to the work vehicle. Focusing a vehicle-mounted floodlight on the rear of the work vehicle to illuminate the sign provides a simple solution for this problem. Good results can be obtained by mounting the floodlight below the sign, aimed upward, such that it provides good illumination without creating glare for approaching drivers. If the work vehicle is equipped with a Truck-Mounted Attenuator (TMA), the TMA provides a convenient location for the floodlight. Depending on the mounting position of the lights and sign and the size of the sign, one or two automotive-type floodlights, 75 to 100 watts, is adequate to provide an acceptable level of illumination.

This photograph shows the rear of a work vehicle at night. It is equipped with warning lights, two orange signs reading "LANE CLOSED" and "WET PAINT", a Truck-Mounted Attenuator and an arrow panel displaying a Right Arrow symbol. A floodlight mounted on the attenuator illuminates the orange signs.

2. Channelizing Devices – These devices are used less frequently for mobile operations because it is impractical to place and retrieve the devices as the work progresses along the roadway. Except as noted below, ***the use of channelizing devices*** to close lanes and shoulders is rarely necessary or practical for mobile operations. However, suitable devices can be used to ***define small work spaces occupied by workers on foot*** when an operation stops briefly. Typical examples include installing pavement markings in an intersection or cleaning drainage facilities. For these situations, channelizing devices serve the dual function of guiding traffic around the work space, and providing a positive outline for workers to remind them of the limits of the work space and keep them from wandering into the traffic space.

Use of closely spaced channelizing devices to define these work spaces improves visibility for drivers and provides more positive definition of the work space for workers. A maximum of 40 feet is recommended, with closer spacing desirable. For small work spaces, the total number of cones needed is not large, and a close cone spacing such a 10 to 20 feet can be provided without the need to place a large number of cones. The small additional effort to set and remove these cones is thought to be more than offset by the improved safety of the operation.

Channelizing devices also may be used in mobile night operations to ***mark freshly installed pavement markings*** to discourage drivers from crossing them until they are adequately dry to avoid tracking.

Suitable channelizing devices for mobile night operations must be easy to place and retrieve quickly and safely. Equally important, they must provide good visibility for drivers, and they must have good stability so they are not displaced by traffic or during mobile placement from work vehicles.

Devices that tip over during placement, or while in place, create a serious concern in that the operation must stop to adjust or retrieve the device. Not only does this slow down the operation, it creates a substantial risk by placing workers on foot in traffic.

Traffic cones are the best choice for mobile night operations. They can be stacked, permitting a large number to be transported on the

work vehicle. They can be easily set and retrieved, either by workers on foot, or from a moving work vehicle. Cones with broad bases are more stable, and are less prone to displacement by traffic or tipping over during placement from a moving work vehicle. Although taller cones may be somewhat more visible, 28-inch cones are frequently chosen for mobile night work because they are thought to be more stable than taller cones. For delineating new traffic markings, and outlining small activity areas where traffic speeds are not high, the improved stability and ease of handling of the 28-inch cones probably outweighs any visibility advantage of the taller cones.

All channelizing devices used at night must incorporate retroreflective materials, according to the requirements of Sections 6F.55 through 6F.61 of the MUTCD.

Spacing of channelizing devices used in tangent sections is addressed in Section 6F-55 of the MUTCD. The recommended spacing is based on the speed limit of the highway, and is given as 0.4 times the speed limit in km/h, or 2 times the speed limit in mph. ***Spacing of cones used to delineate newly placed pavement markings*** should be based on multiples of the broken line spacing to facilitate placement. For a standard broken line spacing of 12 m (40 ft), a spacing of every other broken line for speeds of 70 km/h (40 mph) or less, and every third broken line for higher speeds, is considered adequate for most conditions. This spacing is reasonably consistent with Section 6F-55 guidelines, and facilitates placement from moving work vehicles. For more complex situations, such as heavier traffic or areas with frequent lane changes, it may become desirable to reduce the cone spacing to every broken line to discourage traffic from crossing the fresh markings. When broken line spacing differs significantly from the standard 12 m (40 ft), cone spacing should be adjusted to maintain a similar spacing, while matching the actual broken line spacing.

This photograph shows a three-lane, one-way roadway at night. Traffic cones are placed on the lane line closing the left lane. The cones are marked with two retroreflective white bands. A work vehicle with an Arrow Panel and Truck Mounted Attenuator is positioned in the closed lane.

3. Warning Lights and Markings on Work Vehicles – The MUTCD requires the use of warning lights on work vehicles for certain mobile operations and recommends them for others. For mobile operations at night, it is essential that all work vehicles and equipment are highly visible when operated or parked on or near the travel lanes. It is therefore essential that all work vehicles and equipment used in these operations are equipped with highly visible warning lights.

A wide range of ***warning lights for work vehicles*** is available. However, there are no generally accepted guidelines to dictate the optimum choice of warning lights for a given situation. The choice of lights to be used on a work vehicle should be based on consideration of the work operations and traffic conditions where the operation will take place. The following points should also be considered:

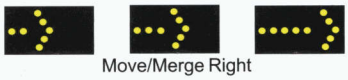
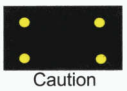
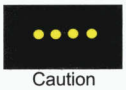
- The standard color for vehicle warning lights is yellow. Other colors such as red or blue are restricted to use by emergency vehicles in most jurisdictions. **Warning light colors other than yellow should be used only when permitted by the jurisdiction where the work will occur, and only when there is a specific need or reason for the alternate color.**
- Both strobe lights and flashing/rotating incandescent lights are widely used and are capable of providing good visibility.

- Strobe lights are highly visible–i.e., drivers from considerable distances can detect them, and they have good conspicuity in complex visual situations. However, white strobe lights may appear blue at night.
- Strobe lights are relatively low cost to purchase, require low maintenance, and present a low current draw compared to incandescent lights.
- Flashing/rotating incandescent lights are believed superior to strobe lights in terms of driver depth perception and closing rates. In other words, drivers can more easily determine the distance to the flashing/rotating light, and which way and how fast it is moving.
- Regardless of the type of warning light used, it is recommended that the light is clearly visible from a distance of 3,000 ft. under normal operating conditions at night.
- For large trucks and equipment, a minimum of two warning lights should be mounted high on the equipment to ensure 360° visibility.
- Attaching warning lights so that two lights are visible to approaching drivers, i.e., one light at each corner of the vehicle improves visibility and improves driver comprehension of distance and closing rates.
- For large or complex work vehicles or equipment, such as pavement stripers, careful design of the warning light layout is essential to ensure that the lights are visible to drivers from all approach angles and distances.
- For pickups and passenger cars, a single warning light mounted near the center of the roof typically provides good visibility.
- A wide range of light bars is available. These devices provide good visibility, and are suitable for mounting on the roofs of pickups, passenger cars, and other smaller work vehicles. However, it may be difficult to place them to provide good 360-degree visibility on large trucks and equipment.
- Warning lights on pavement stripers and other equipment or work vehicles should be mounted such that it does not create a glare problem for operators and workers.
- The capability of the vehicle's electrical system should be considered when selecting warning lights. This may be especially critical when the vehicle is parked with the engine off, or operating at idle.
- Four-way emergency flashers on work vehicles may be used to supplement warning lights, but they cannot substitute for warning lights. There is evidence that 4-way flashers are effective in alerting drivers to slow moving or stopped vehicles.

In addition to warning lights, the use of retroreflective marking is recommended for work vehicles and equipment used in night operation. Retroreflective markings supplement the warning lights, and are essential if the vehicle warning lights fail or are otherwise not in operations. This is especially important for vehicles parked near the roadway. Another advantage of retroreflective markings is that they are effective in defining the size and shape of the vehicle. To be most effective, retroreflective markings should be visible on all sides of the vehicle, and should generally outline the total perimeter.

4. Arrow Panels–Requirements for arrow panels are given in Section 6F-53 of the MUTCD. They are strongly recommended for use on shadow vehicles and other vehicles for mobile operations on multilane roads because they are very effective in alerting drivers that a lane is closed. When used to warn drivers that a lane is closed, the arrow panel should be operated in one of the arrow or chevron modes. These modes are defined in Figure 6F-3 of the MUTCD as shown below. **Arrow panels may also be used on two-lane, two-way roadways, but in this case, they must be operated in the caution mode so they do not mislead drivers into oncoming traffic. The caution mode should also be used when the arrow panel is used for a shoulder closure, or parked on a shoulder and no lane closure is intended.**

Figure 6F-3. Advance Warning Arrow Display Specifications

Operating Mode	Panel Display (Type C panel Illustrated)
At least one of the three following modes shall be provided:	(Right arrow is shown: Left arrow is similar)
Flashing Arrow	Move/Merge Right
Sequential Arrow	 Move/Merge Right
Sequential Chevron	Move/Merge Right
The following mode shall be provided: Flashing Double Arrow	Move/Merge Right or Left
The following mode shall be provided: Flashing Caution	 Caution or  Caution

Panel Type	Minimum Size	Minimum Legibility Distance	Minuim Number of Elements
A	1,200 x 600mm (48 x 24 in)	0.8 km (1/2 ml)	12
B	1,500 x 750mm (60 x 30 in)	1.2 km (3/4 ml)	13
C	2,400 x 1,200mm (96 x 48 in)	1.8 km (1 ml)	15
D	None•	0.8 km (1/2 ml)	12

• Length of arrow equals 1,200mm (48in.), width of arrowhead equals 800mm (24in.)

This figure illustrates panel displays that are acceptable for use on arrow panels. Displays shown include a flashing right arrow, a sequential right arrow, a sequential right chevron, a flashing double arrow (each head is lighted), and two caution modes consisting of bulbs lighted in all four corners and a horizontal bar.

Arrow panels should be mounted as high as possible on work vehicles to improve visibility-the MUTCD recommends a minimum of 7 ft. from the roadway to the bottom of the panel. To facilitate high ***mounting heights***, arrow panels on work vehicles should be equipped with a system to raise them into position when in operation, and to lower them into the travel position when not needed. Automated systems such as hydraulic lifts are especially efficient when large panels are frequently raised and lowered. They make it quicker and easier to position the panel, and reduce the risk of worker injuries from climbing on work vehicles at night.
Mechanical systems such as hinged panels or pulley systems may also be satisfactory if the arrow panel is readily accessible to the operator.

Use of the largest possible arrow panel size improves visibility and increases the distance at which drivers can detect and understand the message. While smaller panel sizes are permitted by the MUTCD, the 8' x 4' panels are strongly recommended for mobile night operations, especially for higher speeds and volumes. Use of this size on all highways optimizes visibility and advance driver warnings, and helps to compensate for the absence of other advance warning devices typical with mobile operations.

To avoid adverse affects of glare that can create difficulty for drivers approaching and passing the arrow panel, it is essential that the ***panel be dimmed at night*** to no more than 50 percent of its full intensity. The brightness of the panel should be checked under actual night conditions to ensure that it does not create a glare problem. Additional dimming may be necessary depending on the panel used and its position on the work vehicle.

For stationary lane closures, the MUTCD recommends the use of one arrow panel for each lane closed, positioned on the shoulder at the beginning of the closure taper. For moving lane closures, however, it is acceptable to use arrow panels on multiple work vehicles to reinforce that the lane is closed.

For moving lane closures on multi-lane facilities, it is recommended that each vehicle in the moving train be equipped with an arrow panel operated in the arrow or chevron mode. This includes the first advance warning vehicle (which normally operates on the shoulder), all subsequent shadow vehicles partially or fully in the closed lane and all work vehicles. If not all vehicles are equipped with arrow panels, it is essential to provide arrow panels on the advance warning vehicle fully on the shoulder, any shadow vehicle partially in the closed lane and the first shadow vehicle fully in the closed lane.

5. Changeable Message Signs (CMSs)–These devices are very effective in alerting drivers to mobile operations ahead, and conveying specific information that drivers can use either to avoid the work area, or to travel through it safely. CMSs may consist of permanently mounted signs, portable trailer mounted signs, or truck-mounted signs. When available, permanent signs can be used effectively to inform drivers that mobile operations are present ahead, to inform drivers of what to expect in terms of delays and lane closures, and to suggest alternate routes to avoid the work. Trailer-mounted CMSs positioned on the roadside in advance of the work zone can fulfill the same function, and offer the added advantage that they can be relocated as needed to remain close to the area where the work is occurring. For work operations that cover a substantial distance in a single night, the trailer-mounted CMSs can be easily repositioned as the work progresses. CMSs can also be mounted on work vehicles to travel with the work operation. They are especially effective when used to provide advance warning upstream of the work operation when positioned on a vehicle traveling on the shoulder. A similar role can be performed by a trailer-mounted CMS towed by a pickup or similar vehicle to keep pace with the moving operation. However, mounting the CMS on a work vehicle instead of a separate advance warning vehicle provides the advantage of eliminating one vehicle from the operation that may otherwise be unneeded.

Requirements and guidance for CMS use is provided in Section 6F-52 of the MUTCD. When used for mobile operations at night, it is essential to limit messages to two phases that can be read and understood by drivers at prevailing speeds. CMSs are most effective when used to convey specific, real-time messages to drivers. An example of an effective two-part message for mobile night operations would be "PAVEMENT STRIPING AHEAD – LEFT LANE CLOSED." General messages and cautionary reminders such as "ROAD WORK AHEAD – PLEASE SLOW DOWN" are much less effective and should be avoided.

Note: Trailers used to support arrow boards and Changeable Message Signs should be appropriately delineated with retroreflective material so that they are readily visible at night when they are not in use and left on the roadway.

This photograph shows a trailer-mounted Changeable Message Sign at night. The message reads "Merge Left" with an arrow pointing left.

6. Service vehicles—service vehicles play a major role in mobile operations, because the work either is performed directly from the vehicles, or they are used to transport workers, equipment, and materials from site to site. These vehicles perform three distinct roles in the traffic control and work operations:

- ***Work vehicles*** are used to perform the actual work, carry materials, and provide a mobile work platform for workers. Examples include pavement stripers, cone-setting vehicles, dump trucks used to transport patching materials, and similar vehicles. Included in this group is mobile equipment such as sweepers and pavement grinders.
- ***Shadow vehicles*** are used to block closed lanes or shoulders, and provide physical separation between traffic and the work operation. Shadow vehicles are typically not directly involved in a work function, but are included to provide traffic control.
- ***Advance warning vehicles*** follow the work operation to provide advance warning to approaching traffic. These vehicles are typically placed on the shoulder or in a traffic lane well in advance of the operation. The distance of the advance warning vehicle upstream from the operation should vary as needed at curves and hillcrests to provide good sight distance for approaching traffic.

All three types of vehicles and equipment play an important role in providing safe, effective traffic control. It is essential that all vehicles used in the operation are equipped with the appropriate warning lights and markings, signs, arrow panels, CMSs, and other safety features. Especially important for shadow vehicles and other service vehicles are Truck-Mounted Attenuators (TMAs) that are discussed at length in a subsequent section. Service vehicles in mobile operations also require coordination to maintain the traffic control plan, especially when visual contact between vehicles is not possible. **Communication between all service vehicles should be provided by radio or cellular telephone.**

In addition to traffic control devices and safety equipment, service vehicles also need to be equipped with equipment specific to the tasks it must perform. Specialized equipment may included the following:

- ***Occupant Safety Features***–Drivers and passengers in these vehicles are at risk from crashes during mobile work operations, especially from rear end impacts by vehicles that intrude into the work space. It is therefore essential that occupant safety features are incorporated into service vehicles and that their use is rigidly enforced. Seat belts and shoulder harnesses must be provided and in use at all times. Belts and harnesses and their attachments must be maintained in good condition, be readily accessible to occupants, and be replaced if they become worn, frayed, or otherwise damaged. The use

  of head restraints or high-back seats is another important safety feature, especially for shadow vehicles. These fea-

tures help to protect occupants from whiplash and similar injuries from rear end impacts. Consideration should also be given to providing padding to vehicle interiors, and eliminating sharp edges and projections, to the extent possible, that may cause injuries during crashes, or that may pose a risk as workers enter and exit vehicles during work operations.

Finally, features should be provided to assist workers in safely entering and exiting vehicles and otherwise accessing workstations and equipment during the work operations. All steps, stairs, and workstations should include nonskid surfaces. Handgrips and safety rails are essential wherever operators and workers must climb onto or into vehicles and equipment, or must work above ground level or on a moving vehicle.

- ***Work platforms***–When service vehicles are used as a mobile work platform, features must be incorporated into them to provide workers with safe access to perform the intended task. Three primary considerations must be addressed: Workers must be protected from falling from the vehicle or into equipment on the vehicle; workers should be protected from traffic that strikes the service vehicle; and, adequate access must be provided to complete the work efficiently.

  Mobile operations frequently involve placement and removal of traffic cones to protect fresh traffic markings and other purposes. Worker platforms installed in the side of vehicles are frequently used for this purpose. Placed close to ground level, they provide good access for workers to place and retrieve cones without the need to dismount frequently to adjust or retrieve misplaced cones. It is essential that these platforms include railings to protect workers from falling from the vehicle, while maintaining good access to place and retrieve cones. Locating the platform in the side of the vehicle provides better worker protection in the event of rear impacts.

  For operations such as installing pavement markers or replacing their lenses, side platforms do not provide adequate work access, particularly when the worker must mount and dismount frequently. For such operations, a rear-mounted work platform may be more efficient. However, it is still essential to provide an effective fall-protection system to protect workers from falls when they are on the platform, especially when the vehicle is moving between work locations. Workers on rear-mounted platforms are more exposed to rear-end impacts. It is thus essential to protect these workers by placement of a shadow vehicle closely behind the work platform. Placement of shadow vehicles is discussed in detail on the next page.

  For some operations, restraint systems may be useful to prevent workers from falling from the platform. If used, these systems must keep the worker on the platform and minimize the risk of the worker falling to the pavement and being dragged or run over by the vehicle.

- ***Automated Cone Setters***–Equipment is commercially available that places and retrieves cones mechanically. Although the equipment requires a worker on the truck bed to load the machine and retrieve cones, the need to place a worker on the platform is eliminated. This equipment may offer cost savings and reduce worker risks.

The photograph on the left shows a daytime view of a truck used to place cones during a moving operation. It is a dual-axle truck with a flatbed rack-type body. A small platform is built into the side of the body near the front. This platform is situated approximately one foot above the pavement, and is equipped with a safety rail along the outside edge. During cone placement and retrieval, a worker stands on the platform to place or retrieve cones from the pavement. The photo on the right shows a worker placing cones from a similar moving work vehicle at night. The truck displays warning lights and work lights.

- ***Electrical capacity***–Another key concern for vehicles used in mobile night operations is adequate generating capacity to power warning lights, arrow panels, CMSs, and work lights. Depending on the type of equipment mounted on the truck, adequate capacity may be provided by the vehicle's electrical system. When work lights are used on the vehicle, it is often necessary to add auxiliary generating capacity. Small engine powered generators can be mounted on the work vehicle, typically mounted to the frame below the work body. If hydraulics are available on the truck, hydraulically powered generators offer advantages in that they are smaller and more compact and do not require engine maintenance and refueling.

Proper placement of all three types of vehicles is essential both during moving operations and during intermittent stops. Placement needs to consider both traffic control needs, and safe, efficient completion of the work.

- ***Work vehicles*** are typically placed in the lane or on the shoulder where the work occurs during moving operations. For intermittent stops, the work vehicle should be as close as possible to the actual work operation to provide easy access to tools and material, to provide physical protection for workers, and to minimize the need for workers to move away from the protected work space. In moving operations, the work vehicle is typically the first vehicle in the operation on one way and divided highways, and frequently on undivided multilane highways. On two-way highways and on undivided multilane highways where there is a concern for opposing traffic conflicts, placement of an advance warning vehicle in front of the work vehicle may be desirable, depending on traffic volume, roadway conditions, and the nature of the operation.

- ***Shadow vehicles*** typically follow closely behind the work vehicle to provide protection against rear end impacts from vehicles entering the closed lane or shoulder. The position behind the work operation is a tradeoff between the shadow vehicle being pushed ahead into the work operation if impacted by a large vehicle, and the risk of a vehicle intruding into the work space ahead of the shadow vehicle. Ideal placement must consider the speed of both traffic and the work operation, the weight of the shadow vehicle, and the presence of heavy trucks in the traffic stream. The range of distances behind the work operations may be as close as 22.5 m (75 ft) to as great as 67.5 m (225 ft). **The decision of where to position the shadow vehicle relative to the work space should be based on careful consideration of actual**

conditions, using the guidance provided in Chapter 9 of the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide*. That reference provides suggested priorities for the consideration for use of shadow vehicles and TMAs. The following table from that reference provides examples of distances for positioning shadow vehicles behind work operations.

Distances shown are measured in feet from the front of the shadow vehicle to the rear of the work vehicle. These distances are suitable for work vehicle speeds of 15 mph or less.

Examples of Shadow Vehicle Position Behind Work Vehicle

Traffic Speed	SV wt. 22,000 lbs. or more		SV wt. less than 22,000 lbs.	
	Stationary	Moving	Stationary	Moving
>55 mph	150	175	175	225
45-55 mph	100	150	125	175
<45 mph	75	100	100	100

Mobile night operations pose an increased risk to road users and workers because it is rarely feasible to use standard lane closures, visibility is reduced at night, and driver performance is often reduced compared to daytime. For these reasons, a high priority should be given to include shadow vehicles with TMAs in all mobile night operations on moderate and high-speed highways.

7. Truck-Mounted Attenuators (TMAs) – TMAs are portable crash cushions mounted on the rear of shadow vehicles and other service vehicles. They reduce the risk of injuries in rear end crashes into shadow vehicles by absorbing part of the impact energy. Extensive experience with TMAs confirms that they are highly effective in reducing injury severity for road users and workers in work zone crashes. It is therefore highly desirable to include TMAs on as many vehicles as possible to compensate for the added risks associated with mobile night operations, and the lack of protection afforded by stationary lane closures.

Except where speeds are very low, TMAs should be provided on all advance warning and shadow vehicles that partially or fully occupy a travel lane. The addition of TMAs to work vehicles and to advance warning vehicles fully on the shoulder is highly desirable whenever sufficient TMAs are available.

A variety of TMAs are commercially available, and the selection of the one to be used should be based on careful consideration of device characteristics, as well as the operations and highway situations where they are to be used.

This photograph shows a truck-mounted attenuator attached to the rear of a large truck used in mobile work operations. This photograph was taken in daytime to show details of the truck and attenuator, but it is suitable for night operations.

- ***Level of Crash Protection*** – TMAs are available to meet two levels of crash protection. Those rated as meeting Test Level (TL) II are intended for differential impact speeds up to 70 km/h (45 mph), while TL III devices are intended to accommodate differential speeds up to 100 km/h (60 mph). TL II devices are lighter and more compact, and may offer some operational advantages compared to the larger TL III devices. They offer good protection where speed differentials between traffic and the work operation rarely exceed 45 mph. How-

ever, TL III devices can safely accommodate higher impact speeds, making them more desirable for higher speed roadways. **Routinely equipping service vehicles with TL III devices provides added safety for all work zones, and ensures that they are present when needed, even when most operations occur on lower speed roadways.** In addition to TL II and TL III performance levels, some TMAs are qualified for angle impacts as well as head-on impacts. These TMAs may provide a safety advantage for mobile work where angle impacts are a concern.

- ***Vehicle weight***–TMAs are available for use with a wide range of vehicle weights, and can be used with trailers as well as with trucks. **The weight and type of vehicle used to transport the TMA must be consistent with the manufacturer's instructions, and with the requirements of the highway agency where it is to be used.** Vehicles weights as low as 4500 kg (10,000 lbs.) may be suitable with some TMAs under certain conditions. Lighter vehicles may offer operational advantages and may reduce impact severity for occupants of passenger vehicles involved in crashes with the TMA. However, increased weight offers improved protection for occupants of the shadow vehicle and reduced risk of the shadow vehicle being pushed into the work space, especially if impacted by a large truck at a high speed. **For these reasons, vehicles used to transport TMAs should be as heavy as possible, except where traffic speeds are very low.**

- ***Trailer-mounted TMAs***– Acceptable performance is also possible with TMAs mounted on the rear of trailers. Trailer-mounted TMAs offer an advantage for fixed operations in that a truck and driver are not tied up for long periods. For mobile operations, this advantage is lost because the TMA must move frequently or continuously. However, mounting TMAs on trailers is acceptable provided it meets the requirements of the TMA manufacturer and the highway agency.

- ***Warning lights and markings***–TMAs protrude some distance behind the vehicle to which they are attached. It is therefore essential that they are adequately marked with warning lights and retroreflective materials that they are highly visible to approaching vehicles at night, especially to those that may approach from the side rather than the rear.

- ***TMA Maintenance and Repair***–These devices are subject to occasional damage from minor crashes and from incidental contact during transport and work operations. To perform as intended in severe crashes, it is essential that TMAs be maintained in good condition. To minimize crash risks, lights and markings should be maintained in good condition. An adequate supply of spare parts is essential to facilitate timely repairs. **In the event of a crash that results in other than superficial damage, full reconditioning of the device according to the manufacturer's instructions is essential before the device is returned to service.**

8. Work Lights–Adequate illumination is essential during night work to allow efficient completion of the work task and to enhance worker safety. Lighting devices attach to the work vehicles and equipment, and may occasionally be supplied by portable trailer-mounted luminaires typically provides illumination for night operations. Regardless of the lighting devices used, it is essential that they provide adequate illumination, and that they do not result in glare that interferes with the driving or work tasks. Guidance on recommended levels of illumination and procedures to control glare is discussed at length in NCHRP Research Results Digest 216 and NCHRP Report 476.

- ***Illumination levels***–The recommended minimum level of horizontal illumination is 59 lux (5 footcandles) in the area where the work is performed. More complex tasks may require higher

illumination levels of 108 or 215 lux (10 or 20 footcandles), depending upon the nature of the task. Although most tasks require that illumination be maintained on the horizontal work surface, some tasks such as work on overhead signs and sign structures require that illumination be maintained on the vertical work surface.

- ***Glare control*** – Primarily positioning and aiming light sources such that they are not aimed directly at drivers and workers achieve glare control. Generally, the more vertical the aim, the less concern with glare. Likewise, aiming light sources such that they do not intersect the normal line of vision at a flat angle reduces the glare effect.

- ***Luminaire position***–For portable trailer-mounted luminaires, or for fixed luminaires, elevating the light source as high as possible, and aiming it downward, reduces glare and improves illumination of the work surface. For light sources attached to work vehicles, especially for mobile operations, it is difficult to position the lights very high.

  For lights used to illuminate the roadway surface, positioning low on the vehicle, only a few feet above the pavement, helps to eliminate glare concerns, and increases the level of illumination on the pavement. Lighting for pavement marking applications fall into this category-floodlights are typically positioned to illuminate the spray guns and the pavement in the vicinity of the application. Auxiliary floodlights mounted on the front of the vehicle, and directed onto the pavment markings, often supplement conventional headlamps. These lights are very effective in helping the operator to maintain position during marking application. Additional work lights may need to be positioned higher on the truck to provide good visibility for workers to operate the equipment, and to place and retrieve traffic cones from the vehicle.

  It is essential to position all vehicle-mounted lights so that they do not substantially increase the overhead clearance requirements of the vehicle. Overhead visibility for the operator is extremely limited at night, and contact with overhead structures and overhead utilities presents a severe risk to workers and the public. Lighting devices should not be mounted above the normal height of the vehicle unless it is absolutely essential, and adequate precautions are in place to prevent contact with overhead structures and utilities.

- ***Types of work lights*** – work lights mounted on vehicles typically include halogen and other types of incandescent floodlights. ***Automotive-type floodlights*** in the range of 75 to 100 watts operate on 12-volt vehicle electrical systems, and can be conveniently mounted where needed to provide illumination for work tasks on the vehicle. Floodlights of this type can also be positioned to illuminate signs mounted on the rear of the work vehicle. Locating these floodlights low on the vehicle, aimed upward toward the sign, provides good illumination without creating glare for approaching drivers. However, these lamps may not provide adequate illumination for larger work tasks where large work spaces need to be illuminated.

  500-watt ***halogen floodlights*** are compact in size, and can be conveniently mounted on work vehicles. They provide sufficient light to illuminate a larger area of pavement around the work vehicles. Typical uses for these lights include pavement marking applications and cone setting/retrieval. They can also be mounted above vehicle work stations, such as the operator's station on a pavement striper, to provide uniform lighting of a large area with minimal glare. While these lamps provide superior illumination to automotive-type lamps, they require a 120-volt power source.

These photographs show typical work lights and warning lights mounted on work vehicles. The photo on the left shows two 500-watt halogen floodlights attached near the top of the material tank on a truck-mounted pavement striper. These lights are aimed front and rear, and angled downward 45 degrees. The photo on the right shows a work vehicle with two flashing yellow warning lights mounted on the roof.

Work lights mounted low on pavement marking stripers are prone to buildup of paint over-spray, and require frequent cleaning to remove material buildup and maintain light output. Use of glass lenses on these lights is important so paint buildup can be removed without damaging the lens. Plastic and other lens materials are subject to scratching and abrasion that eventually reduces light output and distorts the intended beam pattern.

Trailer-mounted luminaires–light plants–are very effective for lighting large work areas where high levels of illumination are needed. However, these devices are of limited use for mobile night operations because of the effort involved in moving and adjusting the lights as the work operation moves. In some cases, light plants may be towed along with the operation. However, this is problematic because the luminaires need to be positioned as high as possible to minimize glare and improve the uniformity of illumination. Raising and lowering the tower at each work location is very time-consuming. Moreover, moving the light plant with the tower raised is extremely dangerous because of the risk of contact with overhead structures and utilities, and the inherent instability of the device. **Moving light plants at night with the tower in the raised position should be avoided because of the risks involved.**

Other types of lighting devices may also be adapted to mobile operations, especially where substantial areas must be illuminated for operations that require brief stops at intermittent locations. ***Balloon-type luminaires*** attached to the work vehicle may be rigged such that they can be quickly raised into position at each work location, and lowered for travel between sites. These lights can provide uniform, glare-free illumination over a sizeable area. They are capable of lighting a larger area than vehicle-mounted flood lamps, and are easier to raise and lower than tower-mounted luminaries.

Trailer-mounted light plants positioned on truck beds allow easy transport between intermittent work sites. While these plants provide a high level of light output, it may be difficult to position the luminaires such that they can uniformly light the work area without creating glare problems or exceeding overhead clearance limits. Positioning the tower in a vertical position and raising it only a few feet above the truck bed may achieve adequate illumination near the vehicle without creating a concern for overhead clearance as the truck moves from site to site. However, aiming the luminaires in a nearly

horizontal direction to provide light ahead of or on one side of the vehicle is generally ineffective because of the glare problems created.

If a light plant is transported on a truck, it is essential that it be securely attached such that it cannot move during transport. Adequate clearance around the light plant is necessary to allow worker access, and side racks or other forms of railings should be provided on the truck body to protect workers from falls.

Crashworthiness Requirements–Part 6 of the MUTCD includes crashworthiness standards and guidance for various work zone traffic control devices and safety features. The basic goal is that all such devices should perform in a predictable manner when impacted, and should not present an undue hazard to road users and workers. Refer to Chapter 9 of the AASHTO *Roadside Design Guide* for detailed information.

FHWA policy requires that all roadside appurtenances, including work zone hardware, used on the National Highway System meet the performance criteria contained in the National Cooperative Highway Research Program (NCHRP) Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. The FHWA policy lists specific requirements to demonstrate that traffic control devices and safety features used in work zones comply with NCHRP 350. Compliance with these requirements is being phased in over an extended period, and most devices must now comply.

Detailed information on these requirements is available on a FHWA Web site, safety.fhwa.dot.gov/programs/roadside_hardware.htm. This Web site can also be accessed from the FHWA web site, www.fhwa.dot.gov by clicking on FHWA Web Sites and then on *Roadside Hardware – NCHRP 350*. This Web site identifies hardware in compliance with NCHRP 350 and includes copies of FHWA acceptance letters for each of them. In the case of proprietary items, links are provided to manufacturers' Web sites as a source of detailed information on specific devices. The site also contains an "Ask the Experts" section where questions on roadside design issues can be addressed. In addition, some highway agencies maintain an approved list of traffic control and safety devices to use on their projects.

Although the FHWA requirement for NCHRP 350 compliance applies only to projects on the National Highway System, the use of NCHRP compliant devices is considered a desirable practice at all locations to ensure that the traffic control devices and safety features used perform in a safe and predictable manner if impacted. A wide range of devices in compliance with NCHRP 350 are commercially available, as well as a number of generic designs that can be adapted for use by highway agencies and contractors. Most suppliers of work zone hardware certify that their devices are in compliance, making it relatively easy to ensure that devices purchased are in compliance.

The FHWA policy provides for the continued use of some devices already in inventory that were not certified in compliance with NCHRP 350. While continued use of such devices through the end of their normal service life may be acceptable, it is important to understand the crashworthiness requirements for all work zone devices. Crashes involving highway safety features may impose a substantial risk to road users and workers, and it is important that they perform in a safe, predictable manner when impacted. Using devices that comply with NCHRP 350 is the best way to address this important safety concern.

Speed Control For Mobile Night Operations-Traffic speed is a concern for highway work operations, including mobile night operations. While it is important to maintain reasonable and

safe speeds through work zones, the MUTCD cautions that "drivers will only reduce their speeds if they clearly perceive a need to do so." Section 6C.01 further points out that "Reduced speed limits should be used only when required by restrictive features in the temporary traffic control zone." When a speed reduction is needed, it should be limited to no more than 10 mph if at all possible.

For mobile operations, the length of the work zone is usually quite short, and it is often not practical to post and enforce reduced speed limits. However, when drivers exceeding the normally posted speed limit in the vicinity of the work operation create concern, police enforcement should be requested to enforce speed limits along the section of highway where the work occurs. Police enforcement to curb other aggressive driving behavior near the work operation may also enhance safety.

This photograph shows a police patrol vehicle stationed near a night work site. The rooftop warning lights are in operation, and the police markings on the rear of the vehicle are visible.

While active police enforcement is regarded as the most effective measure for controlling speeds in work zones, a number of other techniques may provide some benefits. ***Increasing driver awareness*** of work activities ahead is often effective in reducing average speeds. This can be accomplished through use of ***changeable message signs***, either fixed or portable. ***Speed trailers*** that display the speed of approaching vehicles may also be helpful, especially when traffic volumes are not high, and the nature of the work is such that the trailer can be maintained fairly close behind the work operation.

Some evidence indicates that ***maintaining good sight distance*** to the work operation may also be helpful in encouraging drivers to slow down as they approach a work operation This can be accomplished by ensuring that an adequate number of advance warning and shadow vehicles are used, and that they are positioned far enough behind the work operation. When sight distance on a highway is restricted in some locations, the position of the advance warning vehicle can be varied as necessary to provide good approach sight distance.

NCHRP Report 476 provides more extensive information on the use of police enforcement and other techniques for controlling speeds in nighttime work zones.

Flagger Operations–Flaggers are used in work zone traffic control operations to control alternating one-way traffic, to stop traffic for brief periods, and to control traffic in other situations where normal devices such as traffic signals and stop and yield signs cannot be used. However, use of flaggers is frequently neither desirable nor applicable for mobile night operations for a number of reasons. First, because many mobile operations are moving constantly, it is impossible for flaggers to keep pace with these operations. The normal procedure for these moving operations is to direct traffic to pass the moving operation when it occupies one lane or shoulder of a multi-lane roadway. For mobile operations on two-lane, two-way highways, the normal procedure is to prohibit passing entirely, or to allow passing only when traffic and highway conditions permit

safe passing. For all of these situations, flaggers are not needed to control alternating one-way traffic. Another concern for flagging in mobile night operations is the poor visibility associated with night work, and the lack of large-scale work lights on most mobile operations.

Flagging may occasionally be used in operations that stop intermittently for tasks such as pothole patching or applying pavement markings at intersections. In these situations, flagging may be used to protect workers by alerting traffic and guiding them around the work space.

To avoid the risks inherent in night flagging, the use of flaggers should be avoided in mobile night operations unless adequate traffic control and worker safety cannot be provided by other methods such as the use of advance warning and shadow vehicles.

When it becomes necessary to use flagging operations at night, it is essential to adequately light the flagger station to make the flagger visible to approaching traffic. Positioning the flagger near existing roadway illumination normally does not provide adequate lighting. Rather, it is necessary to provide temporary lighting for the flagger station. This can be accomplished by vehicle mounted work lights, or by a trailer mounted light plant located near the flagger. If vehicle-mounted lights are used, they must be mounted high enough to light the flagger from above so they do not create glare for approaching drivers or the flagger, or create shadows such that the flagger is not positively illuminated. **The use of vehicle headlights to illuminate a flagger is unacceptable because it creates a dangerous glare situation. Of equal concern, the flagger is often placed in a backlighted situation, making it extremely difficult for the driver to observe the flagger's instructions. Flaggers should be lighted from the front to avoid this concern.**

This photograph shows a flagger during a night work operation. The flagger is standing near a work truck equipped with a balloon-type luminaire positioned above the truck. The flagger is wearing high-visibility apparel and is holding a stop-slow paddle.

In addition to good lighting for the flagger station, it is also important to provide high-visibility apparel for the flagger. This issue is discussed in detail in the section below on worker apparel.

To ensure good visibility for night flagging operations, a retroreflectorized stop/slow paddle should be used. A retroreflectorized flag may be substituted for the paddle in emergencies. White flashing lights may be used on the paddle to enhance conspicuity. In some jurisdictions, a lighted wand may be used, or may be required, to supplement the paddle or flag at night.

The use of adequately trained and supervised flaggers, adhering to the guidelines of Chapter 6E of the MUTCD, is always critical to ensure safe, effective flagging operations. Strict adherence to these principles is especially important at night, considering the added risks involved in night work. Additional guidance on night flagging operations, including lighting, is provided in NCHRP Report 476.

A good alternative when flagging is considered necessary for mobile night operations is the use of uniformed police officers to direct traffic. Combined with the presence of a lighted police cruiser positioned nearby, the officer often commands a higher degree of respect and compliance than does a flagger. However, availability of police officers for work zone traffic control is often problematic, especially when needed on short notice. When engaged in flagging operations, police officers should wear high-visibility apparel.

WORKER SAFETY CONCERNS

Highway work is a high-risk occupation under the best of circumstances. Considering the added risks associated with mobile night operations, it is imperative that safety issues are identified and addressed to minimize risks to workers. Common safety risks inherent in mobile night operations include reduced visibility of workers, vehicle intrusions into the work space, workers on foot in or adjacent to travel lanes, falls from work vehicles, workers struck by work vehicles and equipment, and contact with overhead utilities. Techniques that are effective in controlling these risks are discussed in the following sections.

High-Visibility Apparel–To reduce the risk of being struck by vehicles traveling through the work zone, or by work vehicles and equipment, all workers should wear good quality high-visibility apparel at all times. Section 6E.02 of the MUTCD provides minimum standards for high-visibility clothing that must be provided for all workers, including flaggers, that may be exposed to traffic or work vehicles and equipment. This clothing must be orange, yellow, yellow-green, or fluorescent versions of these colors, and must include retroreflective materials for night use. As a minimum, the garment must be visible for a distance of 1,000 ft., and must clearly identify the wearer as a person. OSHA regulations also require high visibility apparel for workers exposed to traffic-see Regulation CFR 1926.651(d). However, the Occupation Safety and Health Association (OSHA) requirement is even less specific than the MUTCD.

American National Standards Institute/ International Safety Equipment Association (ANSI/ISEA) 107-1999, American National Standard for High-Visibility Safety Apparel, provides a consensus standard for worker apparel. Although neither the MUTCD nor OSHA mandate this standard, it provides more specific guidance on high-visibility apparel that may be suitable for various workplace situations. For night highway operations, either Class 2 or Class 3 garments should be considered.

Good high-visibility apparel may take several forms. As a minimum, vests that cover the entire upper torso should be required. Shirts or jackets of the approved colors, and incorporating retroreflective striping, may be substituted for vests. Either pants and shirts, or coverall-type garments, provide a greater area of high-visibility material, and delineate the worker's entire body. These full-body garments thus provide greater visibility than vests, shirts, or jackets.

The selection of high-visibility apparel to be worn by workers should be made by a knowledgeable person, with adequate consideration of the work environment and level of exposure of the workers to traffic and work vehicles. In addition to satisfying basic visibility requirements, the following issues should also be addressed:

- To promote acceptance and use by workers, high-visibility garments must be comfortable to wear. They must fit well, and they must be adequately ventilated and promote evaporation of perspiration in warm weather.
- Loose fitting garments and long sleeves should be avoided for workers working on mechanical equipment to avoid the risk of entanglement and snagging.
- These garments must be maintained clean and in good condition. Soiled or damaged garments must be cleaned or replaced promptly.
- Garments must fit properly to provide, as a minimum, full coverage of the upper torso.
- Requirements for high-visibility apparel must be enforced for all workers exposed to traffic or work vehicles, including truck drivers, upper-level supervisors, and project visitors. While

these garments are not needed when the worker is inside a vehicle, they must be used whenever the worker is outside the vehicle, even briefly. **Ensuring that high-visibility apparel is always worn when needed can best be accomplished by adopting safety policies that require all workers to wear the apparel at all times.**

This photograph shows a worker wearing high-visibility apparel at a night work operation.

Lighting for Work Tasks–Providing adequate lighting to safely perform work tasks is critical to promoting worker safety during night operations; and, is applicable to mobile operations the same as for conventional fixed operations. The previous section on **Work Lights** provided information on where illumination is needed, and types of lighting that can be used. **It is essential that workers on foot are visible to approaching traffic and work vehicles and equipment involved in the operation. It is equally essential that adequate illumination be provided to permit workers to perform their assigned tasks with minimum risks from trips and falls, from contacts with sharp or otherwise dangerous objects present on equipment or in the work operation, and from other mishaps involving tools and materials.**

Fall Protection–Work operations performed from moving vehicles, or requiring workers to climb on and off work vehicles and equipment, expose workers to the risk of fall accidents. This risk is increased in mobile night operations because of reduced visibility and unstable moving vehicle. If a slip or fall occurs, the worker may land on the pavement, where the moving work vehicle and traffic pose an extreme risk of serious injury.

It is therefore essential that effective measures to prevent falls be installed at all locations on vehicles where workers must perform work tasks or where occasional access is necessary to adjust or operate equipment.

These measures may consist of railings, grab rails and handholds, ladders and stairs, and restraint systems such as body harnesses and lanyards. These measures are discussed at more length in the preceding section on work platforms. In addition to incorporating fall prevention and protection features into work vehicles, it is essential that they are maintained in good condition, and that workers are trained in their proper use. Equally important, workers and supervisors must be held accountable for using these safety features when required. A railing cannot prevent a fall if it is not properly adjusted and positioned on the work vehicle when workers are present and the operation is underway.

Protecting Workers from Traffic – Previous sections discussed traffic control devices and other safety features and practices that can be used to protect workers from vehicles that enter the work space or impact work vehicles. The risk of vehicles entering the work space is significant, and must be addressed. However, **workers that enter travel lanes on foot without protection are at even greater risk, and it is equally essential that this risk be controlled.**

Work operations should be planned in a manner that minimizes the

need for workers on foot in or near traffic lanes during mobile night operations. Procedures to accomplish this goal include performing work tasks directly from work vehicles, and placing and retrieving channelizing devices from specially designed and equipped vehicles. When it becomes necessary for workers on foot to perform tasks near traffic, it is essential that the work space is clearly defined by closely spaced channelizing devices if possible, and by appropriately placed work vehicles. In addition, flaggers or spotters may be used to watch for approaching traffic.

It is equally important that workers are trained and supervised to minimize the presence of workers outside the defined work space. Work rules should be enacted and enforced such that workers are discouraged from wandering out of the defined work space unless absolutely necessary. Further, workers should be trained to position themselves defensively to the greatest extent possible. This includes entering and exiting vehicles on the side away from traffic whenever possible, standing as far away from traffic as possible, and performing tasks from a position that provides the best possible view of oncoming traffic.

Protecting Workers From Work Vehicles–Workers struck and backed over by work vehicles and equipment is a serious risk in highway work, and the restricted visibility and moving vehicles associated with mobile night operations makes this risk even greater. Specific procedures need to be in place to control this risk. The following steps should be considered as part of an overall safety plan:

- All drivers and workers should be trained about the risks of workers being struck or backed over by vehicles and equipment. Reinforcement of this training should be provided on a regular basis through jobsite safety meetings.
- Work plans should be developed and implemented to minimize the presence of workers on foot in areas where moving work vehicles and equipment must operate, and especially where backing is necessary.
- All vehicles and equipment should be equipped with good illumination to the front and rear so operators can see workers and other potential hazards in the vicinity of the vehicle. They should also be equipped with backup warning alarms in compliance with OSHA regulations.
- A "no blind backing" policy should be strictly enforced for all vehicles and equipment with restricted rear visibility. These vehicles should be permitted to back only when controlled by spotters who maintain positive visual contact with the operator.
- Workers should not dismount from the rear of work vehicles unless positive communication is established alerting the operator that a worker is now on foot behind the vehicle.

Work Safety Rules and Procedures–The risks inherent in mobile night operations make it imperative to establish safety rules that are to be enforced on the project. In addition to basic safety rules, work procedures used in these operations should be developed to support the goal of minimizing risk for road users and workers. These rules and procedures should be established by a safety professional with adequate knowledge of the operations and working conditions involved. The material in this Handbook can be helpful in identifying some of the rules that may be necessary to minimize common risks and hazards associated with mobile night operations. Safety rules and procedures should be reviewed periodically and revised as necessary to address changing conditions and actual experience with the work operations to which they apply.

Basic safety rules commonly required for these operations include the following:

- Use of seat belts/shoulder harnesses for vehicle occupants.
- Mandatory wearing of high-visibility apparel.

- Mandatory hard-hat use by all workers.
- Restrictions on vehicle backing where workers are present.
- Restrictions on worker movement or presence outside the designated work space.
- Use of railing systems and other restraints to prevent falls from moving work vehicles.
- Restricting workers from riding or working from the unprotected beds of pickup trucks or other vehicles.

Work procedures can enhance safety by eliminating or controlling specific risks to which road users and workers would otherwise be exposed. Typical examples include:

- Use of specifically designed and equipped work vehicles to place and retrieve channelizing devices.
- Designated spotters to direct backing vehicles where workers or pedestrians are present.
- Use of spotters to monitor clearance near overhead utilities.
- Provision of specially designed work platforms with railings, lighting, and nonskid surfaces for operations where workers must work on moving vehicles and equipment.
- Loading work vehicles during daylight hours or in lighted work yards to eliminate the risks encountered when these operations are conducted on the roadside during darkness.
- Vehicle and equipment inspection and maintenance procedures to ensure that all lights and other safety equipment are in place and operating properly at the start of each shift.
- Periodic inspection of the mobile traffic control operations.

Traffic Control and Safety Training–A basic principle stated in Part 6 of the MUTCD is that all workers involved in work zone traffic control should be adequately trained and knowledgeable in the work that they must perform. This applies equally to individual workers, flaggers, jobsite supervisors, traffic control designers, and upper level management. OSHA also imposes worker safety training requirements in various sections of 29 CFR Part 1926, "Occupational Safety and Health Standards for Construction".

Based on these requirements, and on common sense, **it is essential that all workers are trained and competent to safely complete the traffic control and other tasks they are assigned to perform.**

This goal can best be achieved by providing adequate training to all workers prior to assignment of the task, and then by reinforcing job skills and knowledge through regular jobsite training programs. Components essential for effective worker safety training programs include the following:

- New employee orientation to familiarize new workers with basic safety rules, worksite procedures, and company policies concerning safety. This orientation should be completed before a worker is assigned to a work operation.
- Detailed technical training appropriate for the responsibilities assigned. As a minimum, one or more persons with technical training in work zone traffic control should be involved in the planning and supervision of mobile night operations. Training is widely available from a number of sources at a wide range of locations.
- Jobsite refresher training is essential to maintain skills, and especially to maintain a high degree of safety awareness. Typically known as "toolbox safety meetings" or "tailgate meetings," these training sessions should be held on a regular interval at the reporting location or work site. Topics and training materials appropriate for the work operations and job conditions should be prepared in advance.

- Training and safety meetings should also be held as needed to address jobsite occurrences and incidents related to safety,

and changes in the work operation or safety rules and procedures.

- All levels of training should emphasize the principles that safety is an integral part of the work operation, and that workers are expected to know and adhere to safety rules and procedures. Further, anyone that fails to adhere to these requirements will be held accountable.

WORK ZONE TRAFFIC CONTROL REFERENCES

Numerous references are available to provide general information on work zone traffic control. Some of this information is applicable to mobile night operations as well. A few of the key references are listed below and Web site addresses are provided. Some of these references can be viewed or printed from the Web sites, and ordering information is provided for the remaining documents.

1. Manual of Uniform Traffic Control Devices - Part 6 – Temporary Traffic Control – http://mutcd.fhwa.dot.gov.
2. NCHRP Report 475 – A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance - www.trb.org.
3. NCHRP Report 476 – Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction – www.trb.org.
4. NCHRP Research Result Digest 216 – Illumination Guidelines for Nighttime Highway Work – www.trb.org.
5. American Traffic Safety Services Association – A Guide to Temporary Traffic Control in Work Zones – www.atssa.com.
6. National Work Zone Safety Information Clearinghouse - Texas A&M University, Texas Transportation Institute – http://wzsafety.tamu.edu.
7. Federal Highway Administration – Web site – Roadside Hardware – NCHRP 350 - http://safety.fhwa.dot.gov/programs_hardware.htm. This website can also be accessed from the FHWA Web site, www.fhwa.dot.gov.
8. AASHTO Roadside Design Guide – 2001. www.transportation.org.
9. NCHRP Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features – www.trb.org.
10. Standard Highway Signs Book - http://mutcd.fhwa.dot.gov.
11. American National Standard for High-Visibility Safety Apparel– http://www.safetycentral.org/isea

TYPICAL APPLICATION DIAGRAMS

The design and selection of the appropriate traffic control plan and safety features for a specific night mobile operation should be made by knowledgeable, qualified individuals based on consideration of the highway and traffic characteristics where the work is to occur, and the nature of the work to be performed. Traffic control devices and other safety devices should be consistent with Part 6 of the MUTCD and other documents referenced in this Handbook. Many highway agencies have developed standard traffic control plans and other safety practices and requirements that are consistent with the MUTCD, but may exceed its minimum requirements or require the use of one of the specific options allowed by the MUTCD. **It is therefore essential to be familiar with the requirements of the highway agency where the work is to take place, and to ensure that all applicable requirements are met.**

The total number of highway situations and mobile night work combinations is almost limitless, and a variety of traffic control plans may be suitable for any particular combination. While it is impractical to provide suggested traffic control plans for a very large

number of situations, it is considered potentially helpful to present a limited number of examples to illustrate the principles and guidance presented in this Handbook.

Following are ten Typical Application Diagrams (TADs) that illustrate examples of traffic control plans and safety features that may be appropriate for use in mobile night work. These examples include both two-lane and multilane highways, and both simple and more complex highway and traffic situations. Some of the examples illustrate pavement-marking applications, which is one of the most common mobile night work operations. Others illustrate generic operations that may be suitable for a number of specific work tasks. Some examples are suitable for operations that move constantly, while others are suitable for operations that stop intermittently, with workers deployed on foot for brief periods.

Pavement-marking applications are categorized in these TADs as slow-dry and rapid-dry. The difference between the two relates to the length of line that must be protected while the marking material dries. Rapid-dry materials are those that can be protected with a moving vehicle train. Slow-dry materials are those for which cones are used for protection. Drying time, D, is given by the expression: $D = 1.47\ vt$, where "v" is the striping speed in mph and "t" is the track-free time of the material in seconds. As the drying time becomes longer, it becomes impractical to protect the line without coning.

While these examples are intended to illustrate the principles and guidance provided in this Handbook and the MUTCD, they should not be directly applied for any operation without careful consideration of the actual characteristics of the highway, traffic, and work operation. Appropriate revisions to the TAD should be made by adding or changing traffic control devices and other safety features as appropriate for the actual conditions.

The following Typical Application Diagrams are provided:

NMTA-1 Night Mobile Operation on Shoulder of Two-Lane Two-Way Roadway

NMTA-2 Night Mobile Operation on Shoulder of High Speed Multi-Lane Highway

NMTA-3A Night Striping Operation on Two-Lane Two-Way Roadway – Slow-Dry Material

NMTA-3B Night Striping Operation on Two-Lane Two-Way Roadway – Rapid-Dry Material

NMTA-4 Night Mobile Operation in Turn-Lane of Multi-Lane Highway

NMTA-5A Night Striping Operation on Multi-Lane Highway – Coning Required – Striping Operation

NMTA-5B Night Striping Operation on Multi-Lane Highway – Coning Required – Cone Retrieval

NMTA-6 Night Striping Operation on Multi-Lane Highway – Coning Not Required

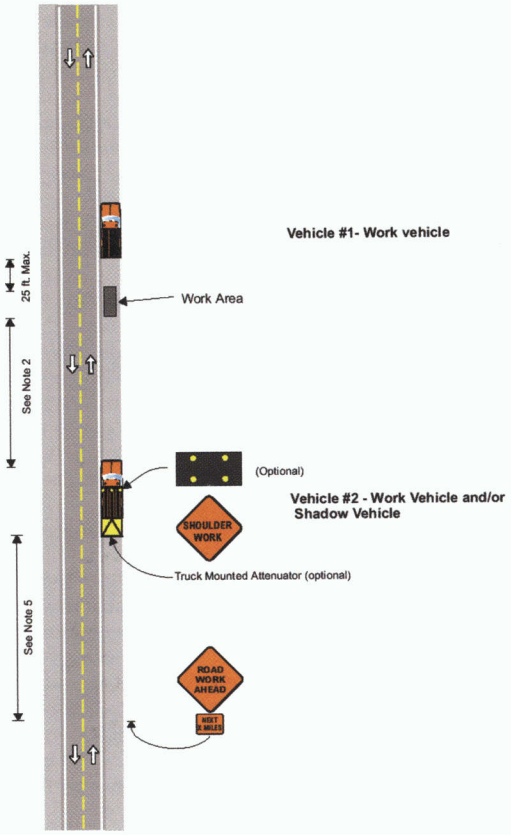
NMTA-7 Night Striping Operation on Multi-Lane Highway - Narrow Shoulders and Restricted Sight Distance

NMTA-8 Night Mobile Operation on Interior Lane of Multi-Lane Highway

NMTA-1 Night Mobile Operation on Shoulder of Two-Lane Two-Way Roadway

1. This plan is appropriate for intermittent moving operations positioned on the shoulder, completely free of or with only minimal intrusion into the travel lane. Such operations stop briefly, typically for 15 minutes or less, at various locations along a highway.
2. The distance between the work vehicle and the shadow vehicle should be based on traffic conditions. Refer to page 20 of this handbook for guidance .
3. Vehicle #1 may be omitted when the size of the work crew does not require two vehicles. If only one vehicle is used, the workspace should be positioned immediately in front of the vehicle.
4. Work lights should be provided on Vehicles 1, 2, or both, depending upon the nature of the work operation. Both vehicles should be equipped with warning lights with 360° visibility.
5. When multiple work locations within a limited distance make it practical to place stationary signs, the ROAD WORK AHEAD sign may be placed on the shoulder. The distance from the sign to the work should be kept as short as possible, not to exceed 2 miles.
6. Where sight distance is good and traffic speed and volume are not high, this plan may be adapted to continuously moving operations such as sweeping. Vehicle 1 performs the work and Vehicle 2 serves as the shadow vehicle and advance warning vehicle. Except for work on very short highway segments, it is not normally practical to use stationary signs for continuously moving operations.
7. When shoulder width does not permit both vehicles to be positioned completely beyond the travel lane, refer to NMTA-3A, 3B, and 7 for guidance.
8. Refer to TA-4 of Part 6, MUTCD for additional guidance.

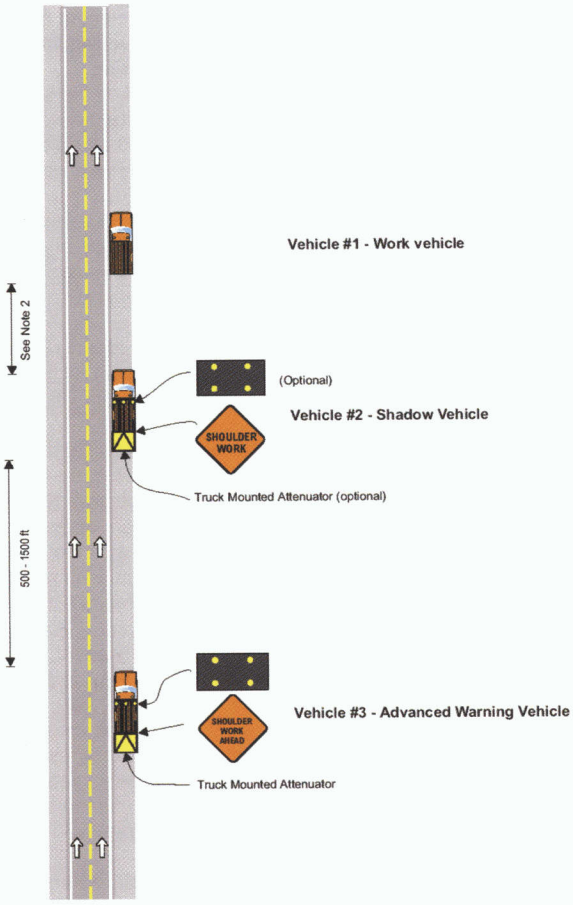
NMTA -1 Night Mobile Operation on Shoulder of Two-Lane Two-Way Roadway



NMTA-2 Night Mobile Operation on Shoulder of High Speed Multi-Lane Highway

1. This plan is appropriate for continuously moving operations such as sweeping or herbicide application, especially where sight distance is not good or higher traffic speed and volume may be encountered.
2. The distance between the work vehicle and the shadow vehicle should be based on traffic conditions. Refer to page 20 of this hanbook for guidance.
3. Where the operation must stop briefly at intermittent locations, a stationary ROAD WORK AHEAD sign may be placed on the shoulder. It should be kept as close as possible to the operation, not to exceed 2 miles.
4. For continuously moving operations, all work is performed from Vehicle 1, with no workers on foot. When intermittent stops require workers to be on the pavement, the work space should be located immediately behind or ahead of Vehicle 1.
5. Work lights should be provided on Vehicle 1 to light the work operation, and may be provided on Vehicles 2 and 3 as needed, depending upon the nature of the operation. All vehicles should be equipped with warning lights with 360° visibility.
6. When shoulder width does not permit all vehicles to be positioned completely beyond the travel lane, refer to NMTA-5 and 6 for guidance.
7. The position of Vehicle 3 should vary based on sight distance, ramps, intersections, shoulder obstructions, etc. A minimum of 500 ft. in advance of Vehicle 2 is desirable, with a maximum of 1,500 ft. Shorter distances may be used for low-speeds.
8. Vehicle 3 may be deleted where speeds are less than 55 mph and sight distance is adequate to provide at least 1,500 ft visibility to Vehicle 2 (1,000 ft. visibility for speeds of 40 mph or less).
9. Refer to TA-4 of Part 6, MUTCD for additional guidance.

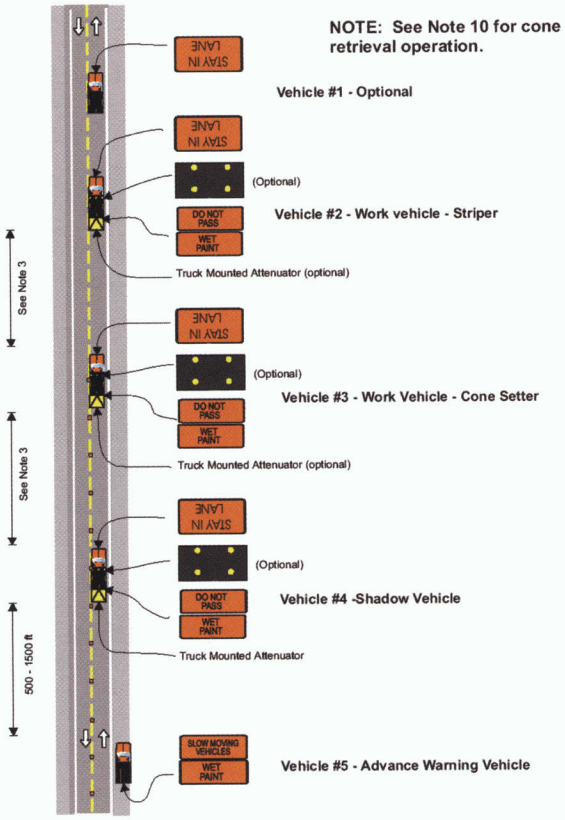
NMTA-2 Night Mobile Operation on Shoulder of High-Speed Multi-lane Highway



NMTA-3A Night Striping Operation on Two-Lane Two-Way Roadway – Slow-Dry Material

1. This plan is appropriate for placement of pavement marking materials that require coning to protect the fresh line from tracking.
2. Work lights should be provided on the striper and cone-setting vehicle to illuminate the work operation, and may be provided on other vehicles. All vehicles should be equipped with warning lights with 360 visibility.
3. The distances between the shadow vehicle and the cone placement/retrieval vehicle and between the cone placement vehicle and striper should be based on traffic conditions. Refer to page 20 of this handbook for guidance.
4. Arrow panels in the caution mode may be used on all vehicles. If used, they shall not be operated in a directional mode on highways carrying traffic in both directions.
5. Vehicle 1 may be deleted where sight distance is good and traffic speed and volume are not high.
6. Vehicle 4 may be deleted where sight distance is good and traffic speed is 55 mph. or less.
7. The position of Vehicle 5 should be varied, based on available sight distance. A minimum of 500 ft. in advance of Vehicle 4 is desirable, with a maximum of 1,500 ft.
8. Vehicle 5 should be deleted if it cannot be located completely on the shoulder. If Vehicle 5 is deleted, Vehicle 4 should be retained.
9. The entire operation should pull off the roadway periodically to permit the traffic queue to pass.
10. For cone retrieval, a separate three vehicle train consisting of Vehicles 3, 4, and 5 may be used, with the "STAY IN LANE" sign removed from the front of Vehicle 4.
11. Refer to TA-17 of Part 6, MUTCD for additional guidance.

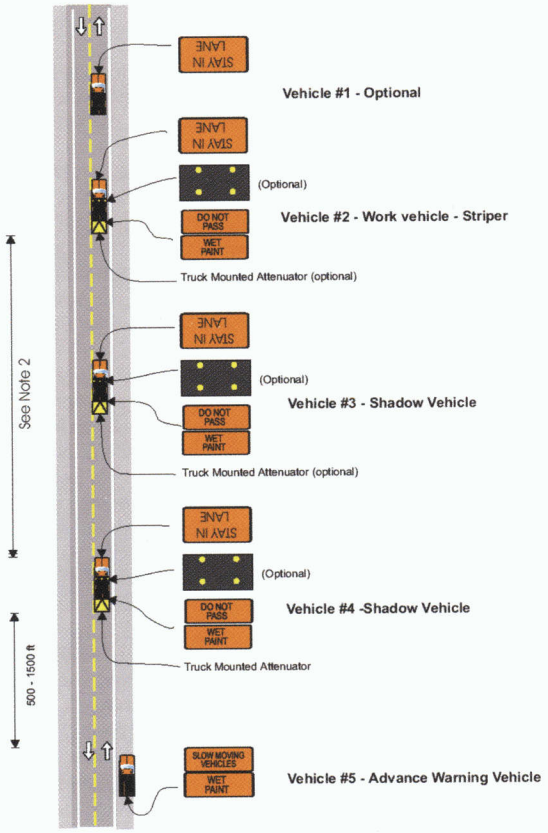
NMTA - 3A Night Striping Operation On Two-Lane Two-Way Roadway - Slow-Dry Material



NMTA-3B Night Striping Operation on Two-Lane Two-Way Roadway – Rapid-Dry Material

1. This plan is appropriate for placement of rapid-drying pavement marking materials that do not require coning to protect the fresh line from tracking.
2. The required number and spacing of protection vehicles is based on the track-free time of the pavement marking material and the speed of the operation. For a track-free time of 30 seconds and a striping speed of 10 mph, approximately 450 ft. of line must be protected. This can be accomplished by placing protection vehicles 225 and 450 ft. behind the striper.
3. Work lights should be provided on the striper to illuminate the work operation, and may be provided on other vehicles. All vehicles should be equipped with warning lights with 360° visibility.
4. Arrow panels in the caution mode may be used on all vehicles. If used, they shall not be operated in a directional mode on highways carrying traffic in both directions.
5. Vehicle 1 may be deleted where sight distance is good and traffic speed and volume are not high.
6. The position of Vehicle 5 should be varied, based on available sight distance. A minimum of 500 ft. in advance of Vehicle 4 is desirable, with a maximum of 1,500 ft. Shorter distances may be used for low speeds.
7. Vehicle 5 should be deleted if it cannot be located completely on the shoulder.
8. Refer to TA-17 of Part 6, MUTCD for additional guidance.

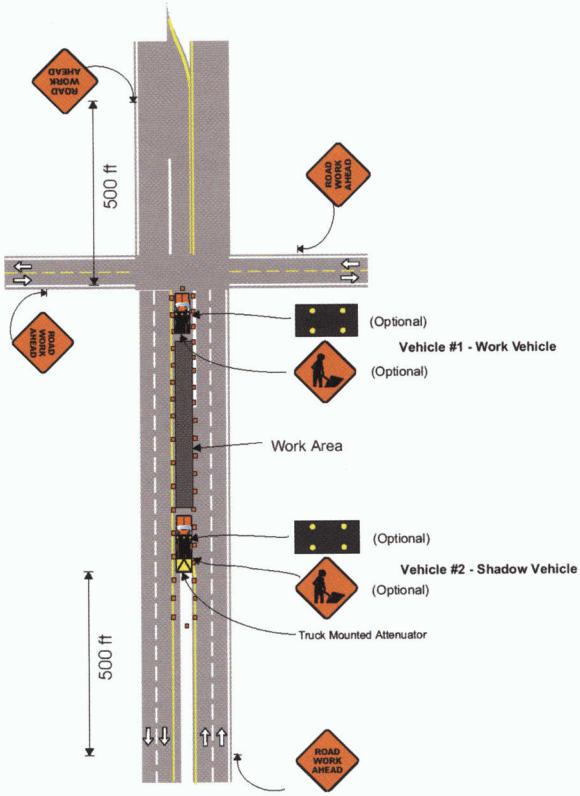
NMTA - 3B Night Striping Operation On Two-Lane Two-Way Roadway - Rapid-Dry Material



NMTA-4 Night Mobile Operation in Turn-Lane of Multi-Lane Highway

1. This plan is appropriate for applying pavement marking symbols, pothole patching, or other operations that require occupation of the work space for a few minutes. This plan is intended for operations that do not occupy a travel lane.
2. Work lights should be provided on both vehicles to illuminate the work operation. Both vehicles should also be equipped with warning lights with 360° visibility.
3. Arrow panels in the caution mode may be used on all vehicles. If used, they shall not be operated in a directional mode on highways carrying traffic in both directions.
4. The location of the ROAD WORK AHEAD sign should be based on site characteristics, including traffic speed and volume and approach sight distance. Longer distances, up to 1,500 ft. or more, are appropriate for rural high-speed highways. Shorter distances are appropriate in urban areas with slower speeds and closely spaced intersections.
5. Where shoulder widths are adequate, advance warning vehicles equipped with appropriate signs and warning lights may be substituted for the ROAD WORK AHEAD signs. Use of advance warning vehicles in place of signs is especially effective for operations that move frequently.
6. Closely spaced cones are placed along both sides of the work space between the work vehicles to reduce the risk of intrusions, and to define the work space for workers. A spacing of 20 ft. is recommended.
7. Traffic spotters/flaggers may be used to monitor worker movement and location and watch for approaching traffic when necessary.
8. The position of Vehicle 1 should be adjusted as necessary to provide adequate access to perform the work task. If necessary, work may be performed in front of Vehicle 1 which is very close to the intersection. However, a spotter should be used to warn workers of approaching traffic.
9. The ROAD WORK AHEAD signs and cones may be omitted for operations that occupy the site only momentarily, such as pothole patching. If the signs are omitted, appropriate vehicle-mounted signs should be used.
10. Additional traffic control may be needed for traffic turning left at the intersection.

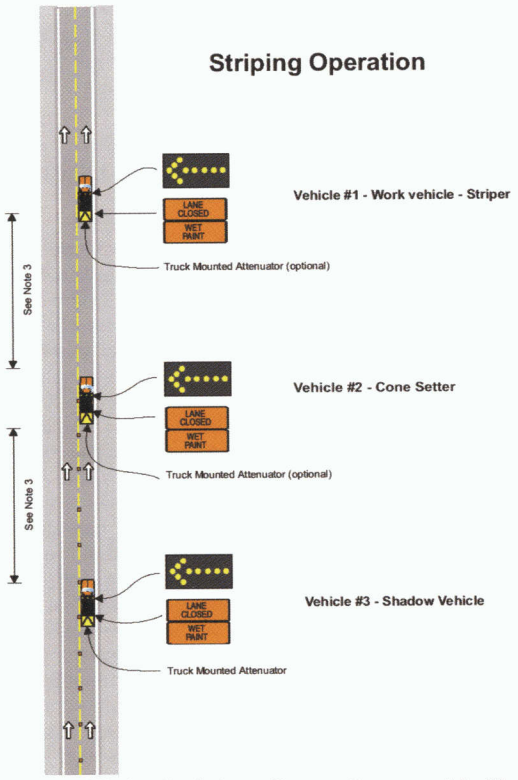
NMTA - 4 Night Mobile Operation in Turn-Lane of Multi-Lane Highway



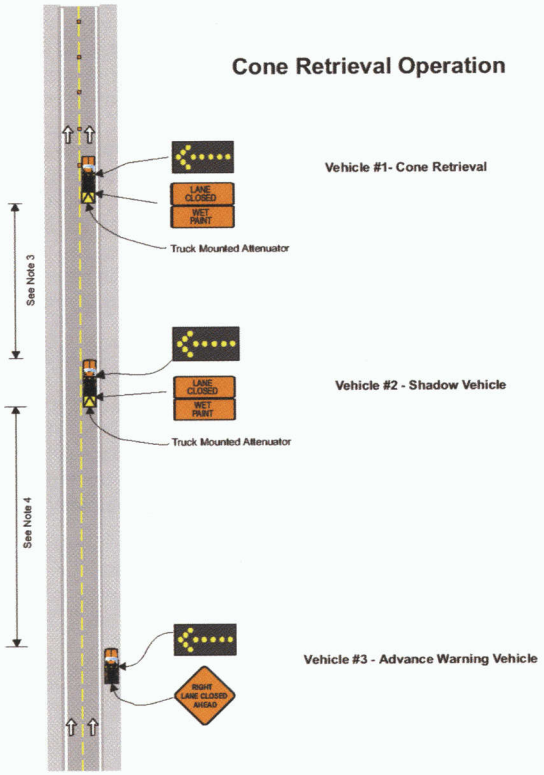
NMTA-5A
Night Striping Operation on Multi-Lane Highway – Coning Required – Striping Operation
NMTA-5B Night Striping Operation on Multi-Lane Highway – Coning Required – Cone Retrieval

1. These plans are appropriate for placement of pavement marking materials on exterior lanes of multi-lane highways, where coning is required to protect the fresh line from tracking.
2. Work lights should be provided on the striper and cone-setting and retrieval vehicles to illuminate the work operation, and may be provided on other vehicles. All vehicles should be equipped with warning lights with 360° visibility.
3. The distances between the shadow vehicle and the cone placement/retrieval vehicle and between the cone placement vehicle and striper should be based on traffic conditions. Refer to page 20 of this handbook for guidance.
4. The position of Vehicle 3 in the cone-retrieval operation should be varied as the operation proceeds to provide good sight distance for approaching traffic. It may range from a minimum of 500 ft. to a maximum of ˚ mile. Where obstructions create a narrowed shoulder for short distances, Vehicle 3 should quickly bypass the obstruction when gaps in traffic permit, and then resume its position on the shoulder beyond the obstruction.
5. Where narrow shoulders do not permit Vehicle 3 in the retrieval operation to be positioned completely outside the travel lane, it may straddle the edge line. If it cannot be completely outside the travel lane, it should be equipped with a truck-mounted attenuator, and the sign legend should be the same as for Vehicle 2.
6. Vehicle 3 may be deleted from both operations when sight distance is good, traffic speed is less than 50 mph, and traffic volumes are low.
7. Cones should be placed at every-other lane marking. Closer spacing may be used if needed to discourage traffic from crossing the fresh markings.
8. Refer to TA-35 of Part 6, MUTCD for additional guidance.

NMTA-5A Night Striping Operation on Multi-Lane Highway-Coning Required



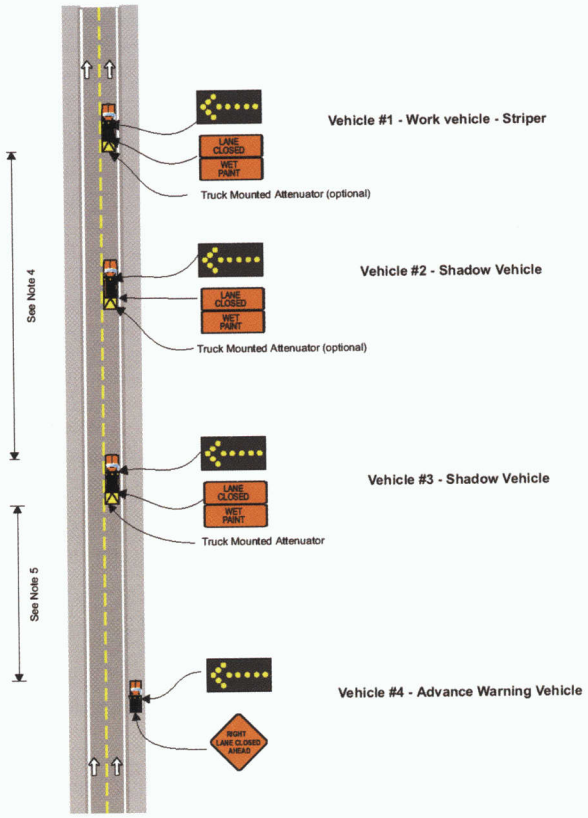
NMTA-5B Night Striping Operation on Multi-Lane Highway-Coning Required



NMTA-6 Night Striping Operation on Multi-Lane Highway– Coning Not Required

1. This plan is appropriate for placement of rapid-drying pavement marking materials on exterior lanes of multi-lane highways, where coning is not required to protect the fresh line from tracking.
2. This plan is intended for highways where full-width shoulders permit the advance-warning vehicle to be positioned on the shoulder completely beyond the travel lane. Where narrow shoulders do not permit the placement of Vehicle 4 completely outside the travel lane, refer to NMTA-7.
3. Work lights should be provided on the striper as needed to illuminate the work operation, and may be provided on other vehicles. All vehicles should be equipped with warning lights with 360° visibility.
4. The required number and spacing of protection vehicles is based on the track-free time of the pavement marking material and the speed of the operation. For a track-free time of 30 seconds and a striping speed of 10 mph, approximately 450 ft. of line must be protected. This can be accomplished by placing protection vehicles 225 and 450 ft. behind the striper. Maximum spacing should be adequate to discourage traffic from entering the closed lane between work vehicles. A range of 200 ft. to 500 ft. is generally effective.
5. The position of Vehicle 4 should be varied as the operation proceeds to provide good sight distance for approaching traffic. It may range from a minimum of 500 ft. to a maximum of ˚ mile behind Vehicle 3.
6. Where obstructions create a narrowed shoulder for short distances, Vehicle 4 should quickly bypass the obstruction when gaps in traffic permit, and then resume its position on the shoulder beyond the obstruction.
7. Vehicle 4 may be deleted when sight distance is good, traffic speed is less than 50 mph, and traffic volumes are low.
8. This plan may be adapted for striping in the left lane where full median shoulders or a flush median permit Vehicle 4 to be positioned completely outside the travel lane. If positioned in a flush median, appropriate signs or an arrow panel in caution mode should be added to the front of the vehicle to alert on-coming traffic.

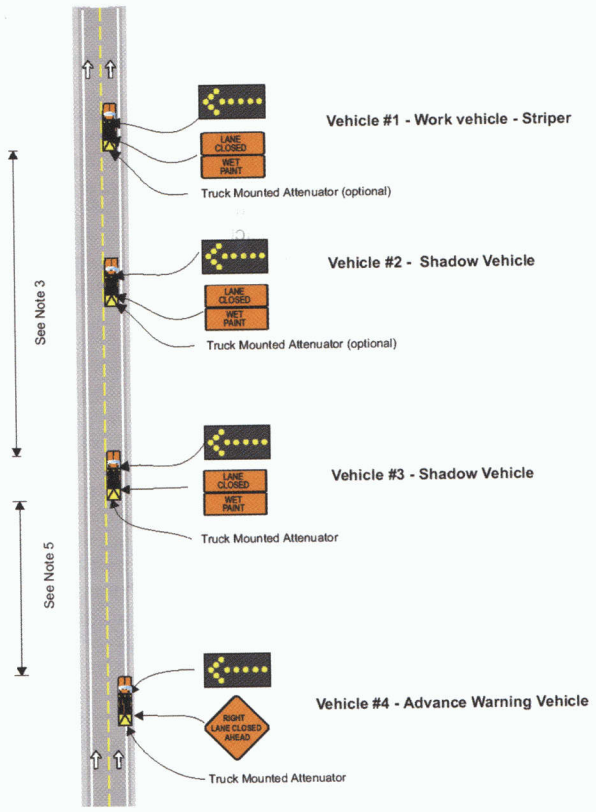
NMTA-6 Night Striping Operation on Multi-Law Highway-Coning Not Required



NMTA-7 Night Striping Operation on Multi-Lane Highway– Narrow Shoulders and Restricted Sight Distance

1. This plan is appropriate for placement of rapid-drying pavement marking materials on exterior lanes of multi-lane highways, where coning is not required to protect the fresh line from tracking, and narrow shoulder require the advance-warning vehicle to be placed partly in the travel lane.
2. Work lights should be provided on the striper as needed to illuminate the work operation, and may be provided on other vehicles. All vehicles should be equipped with warning lights with 360° visibility.
3. The required number and spacing of protection vehicles is based on the track-free time of the pavement marking material and the speed of the operation. For a track-free time of 30 seconds and a striping speed of 10 mph, approximately 450 ft. of line must be protected. This can be accomplished by placing protection vehicles 225 and 450 ft. behind the striper. Maximum spacing should be adequate to discourage traffic from entering the closed lane between work vehicles. A range of 200 ft. to 500 ft. is generally effective.
4. Where sight distance is restricted by severe highway alignment, additional protection vehicles may be needed to reduce spacing as necessary to discourage traffic from entering the closed lane between vehicles.
5. Vehicle 4 should maintain a distance of 500 ft. to ° mile behind Vehicle 3, depending on traffic speed and sight distance. Its actual position should vary within this range to maintain its position where sight distance for approaching traffic is adequate.
6. When sight distance restrictions are encountered, Vehicle 4 should quickly bypass the restriction when traffic gaps permit, and then resume its normal speed further ahead where adequate sight distance is available.
7. When a total absence of shoulders forces the placement of Vehicle 4 completely within the travel lane, it should be deleted.
8. This plan may be adapted for striping in the left lane where Vehicle 4 can be positioned partially in the travel lane. If positioned partially in a flush median, appropriate signs or an arrow panel in caution mode should be added to the front of the vehicle to alert on-coming traffic.

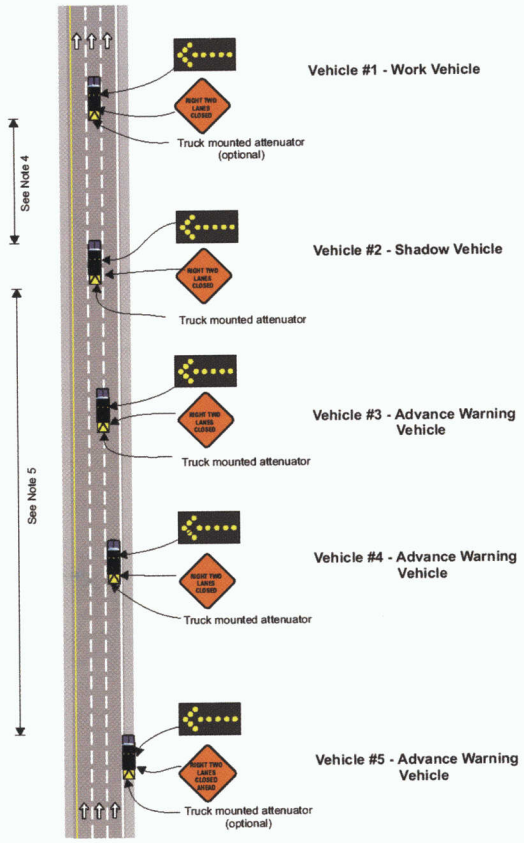
NMTA - 7 Night Striping Operation on Multi-Lane Highway - Narrow Shoulders and Restricted Sight Distance



NMTA-8 Night Mobile Operation on Interior Lane of Multi-Lane Highway

1. This plan is appropriate for mobile operations in the interior lane of a multi-lane highway. It may be used for continuously moving operations or for operations that stop briefly, such as pothole patching.
2. For pavement marking operations, additional vehicles may be needed to place and retrieve cones or to protect the fresh line from tracking – refer to NMTA 5, 6, and 7.
3. Work lights should be provided on the work vehicle as needed to illuminate the work operation, and may be provided on other vehicles. All vehicles should be equipped with warning lights with 360° visibility.
4. The distances between the shadow vehicle and the work vehicle should be based on traffic conditions. Refer to page 20 of this handbook for guidance.
5. The length of the taper formed by the moving vehicles should be based on guidance in Table 6C-2, Part 6 of the MUTCD. For speeds of 45 mph or greater, the distance in feet is the product of the lane width in feet and the speed in mph (L = WxS).
6. Where traffic speed and volume are not high and sight distance is good, Vehicle 3 may be deleted.
7. When traffic speed and volumes are high, added vehicles may be necessary to provide extra distance between the two merge tapers.
8. Where narrow shoulders or brief obstructions do not permit Vehicle 5 to be positioned fully on the shoulder, refer to NMTA-5, 6 and 7 for additional guidance. Under all circumstances, a minimum of four vehicles should be included in this plan.
9. Work access to the center lane may also be provided by closing the left and center lanes. The decision of whether to close the right or left lane should be based on the available shoulder widths and sight distances, and the frequency of on/off ramps requiring traffic to cross the right lane.

NMTA-8 Night Mobile Operation on Interior Lane of Multi-Lane Highway



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