


Nighttime Lighting Guidelines for Work Zones

A guide for developing a lighting plan for nighttime work zones

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American Traffic Safety Services Association

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Federal Highway Administration

Table of Contents

INTRODUCTION

Many State Departments of Transportation (DOT) use some form of nighttime work zone to conduct construction and maintenance activities on or near the travel portion of the road system. Roadway lighting eases the task of driving at night by illuminating the pavement to help drivers see the general direction of the roadway, aiding them in seeing structures alongside the roadway more clearly, and enabling them to see areas of the roadway where headlights do not provide adequate light. There is a similar need to provide adequate lighting in nighttime work zones. However, limited guidance is currently available to address lighting needs relative to the many different tasks that are conducted in a work zone. *The Manual on Uniform Traffic Control Devices* (MUTCD) and other existing guidance documents provide minimum specifications for certain general categories of work zone tasks, but they do not provide information regarding the appropriate type, quantity, or configuration of lighting systems to use for specific work zone activities.

This document provides a procedure for designing a nighttime lighting system in work zones where no formal lighting plan exists. Engineers, designers, and contractor personnel can use this process without the need to be an expert in illumination. These guidelines may also help in developing specifications and standards for work zone lighting for use by owner-agency as well as contractor personnel to ensure consistency, effectiveness, and safety. The document also presents examples of existing specifications that are intended to provide uniformity and consistency for agencies across the country.

The information contained in this document will help practitioners in selecting the most appropriate type, quantity, and configuration of lighting for nighttime work zones while not only meeting minimum industry-accepted lighting requirements for construction and maintenance work activities but also taking into account the need to minimize the negative impacts of glare on drivers. Practitioners can use this information to create a basic lighting scheme accomplishing the following objectives:

- To provide the appropriate level of lighting that allows construction work to be completed safely and effectively;
- To reinforce both the intent of the traffic control plan as well as provide better guidance for drivers traveling through the work zone; and, most importantly
- To improve the overall safety of the workers and traveling public.

Any lighting scheme provided for nighttime work zones needs to meet all standards found in the MUTCD, including guidelines related to personal protective equipment, signing, barricades, or other traffic control measures.

NIGHTTIME WORK ZONE ILLUMINATION LEVELS

The National Cooperative Highway Research Program (NCHRP) *Report 498: Illumination Guidelines for Nighttime Highway Work* developed a set of illumination guidelines that were based on work zone task illumination requirements. Three categories were recommended based on considerations such as minimum lighting levels recommended by the Illuminating Engineering Society (IES), Federal and State lighting requirements and guidelines, research, and expert opinions. Researchers found these categories to adequately account for a majority of highway-

and bridge-related construction and maintenance activities. Examples of work zone tasks and their associated recommended illumination levels are summarized in the Table 1.

Table 1. Recommended Illumination Levels by Task, Source: NCHRP 498

Examples of Tasks	Illumination Level	Average Minimum Maintained Illuminance
All work operations areas; setup of lane or road closures, lane closure tapers, and flagging stations	Level I	54 lux (5 foot-candles*)
Areas on or around construction equipment; asphalt paving, milling, and concrete placement/removal	Level II	108 lux (10 foot-candles)
Pavement or structural crack/pothole filling; joint repair, pavement patching/ repairs; installation of signal/electrical/mechanical equipment	Level III	215 lux (20 foot-candles)
*A foot candle (fc) is defined as unit of illumination that is equal to one lumen per square foot, or 10.764 lux.		

Level I illuminance is important in areas where the work crew is in motion, moving from spot to spot. This level of illuminance is appropriate for tasks requiring low accuracy, involving slow-moving equipment, and where there are large objects to be seen.

Level II illuminance is recommended for areas on or around construction equipment to provide a safer environment for the workers operating the equipment, allowing them to perform tasks that require a moderate level of accuracy, as described in Table 1 above.

Finally, Level III illuminance is appropriate for those tasks that require a greater level of visual acuity or for tasks with a higher level of difficulty.

TYPES OF LIGHTING FOR WORK ZONES

There are limited types of temporary lighting available for use for nighttime roadway construction, although new technology and innovations may provide better options in the future. The most commonly used temporary lighting systems include:

- **Portable Light Plant Towers** – This lighting consists of numerous luminaires mounted to a mast arm that is capable of holding the luminaires at various mounting heights. The mast arm is attached to a trailer with a generator that can be towed by a vehicle. To prevent glare these lighting systems should not be aimed toward traffic and should be aimed downward at the work and rotated outward no greater than 30 degrees from straight down unless the light has been designed specifically to prevent glare. (See Figure 1).
- **Balloon Lighting** - This type of lighting consists of a large balloon type luminaire that provides a fairly large area of evenly distributed light and is relatively glare-free. Balloon lights can be mounted on slow-moving equipment or portable light towers.

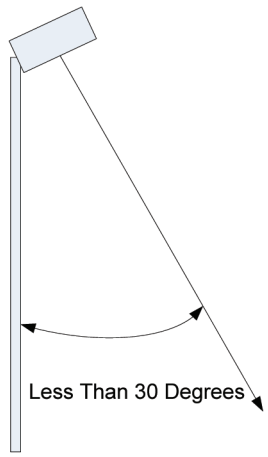


Figure 1-Lighting System Orientation

- **Roadway Luminaires Mounted on Temporary Poles** – This would consist of any permanent roadway lighting fixture mounted on temporary poles and hard wired to an electrical system. This type of system would normally be prepared by a lighting design professional.
- **Factory-Installed Lights on Equipment** – Headlights installed on most equipment do not normally provide adequate lighting for most work operations and as a large component of glare should not be used when facing any oncoming traffic.

The following factors should be considered when selecting the types of lighting that are best suited for the work zone.

- **Mobile work zones, such as a paving operation** – If the work zone is mobile, the length of the work activity for one night may dictate either that the lighting plan be continuous for the length of the work zone or that a mobile system be used so that the lighting moves with the various work activities.
- **Stationary work zones** – Work duration would determine the type of lighting in this situation. A long-duration work zone could use roadway luminaires mounted on temporary poles, while shorter duration work zones could use trailer-mounted light towers or balloon lighting at fixed locations.
- **Glare** – Glare from the lighting systems should be minimized for both the workers and any adjacent motorist. Glare should be considered from each direction and on all approaching roadways and opposing lanes of traffic, even those separated by grass medians.
- **Light Trespass** – Trespass occurs when light spills onto private property. This could be a problem in a residential area—depending on how long the lighting system is in place—and could require shielding as a preventative measure.
- **Cost** – The rental cost for portable light plant towers ranges from $500 to $900 per month and the purchase cost ranges from $9,000 to $15,000 per unit. These costs vary depending on location, type, size, height, etc. Based on a similar range of factors, the cost for balloon lighting normally ranges from $2,000 to $3,800 per unit.

Figure 2 - Example of Portable Tower Lighting

Figure 3 - Example of Balloon Lighting

SUGGESTED STEPS FOR DEVELOPING A LIGHTING PLAN

1. Determine Work Activities and Lighting Levels

At this step, identify the work activities to be performed. This step requires a good understanding and knowledge of the planned work process, whether it is construction or maintenance. Based on the work activities, the lighting levels needed for the work should be noted (See Table 1 for examples).

Unless otherwise stated by State DOT standards or policy, use an initial luminance level of 5 fc throughout any area where workers and slow moving equipment are in close proximity. Flagging stations should be designed with this as a minimum level of luminance. As a rule of thumb, practitioners should ensure that drivers can see the flagging station at a minimum distance of 1,000 feet at night.

Next, identify where an illumination level of 10 fc is needed. These are the locations in the work area that require closer interaction between workers and equipment. The speed of the equipment or the complexity of the work may necessitate an increase in illumination (see Table 1 for examples). To increase the illumination to 10 fc, additional fixtures may be added directly to equipment. Adding **balloon lighting** to the equipment, as shown in Figure 4, provides even illumination in a circular area around equipment with minimal glare. This is a noteworthy treatment for equipment located adjacent to traffic lanes.

Workers performing tasks requiring the highest level of attention to detail and care fall in the last category. Examples of tasks requiring 20 fc would be work at signalized intersections, installing lighting, and pouring/filling pavement cracks.

Figure 4 - Balloon Lighting in a Nighttime Work Zone

Source: Illinois Center for Transportation, *Nighttime Construction: Evaluation of Lighting Glare for Highway Construction in Illinois*, Research Report FHWA-ICT-08-014, December 2007.

2. Determine the Work Zone Area to be Illuminated

The general steps in determining the lighting area of a work zone are as follows:

- Use a scale layout of the roadway (a scale plan sheet from the construction plans if available) to determine the area of need.
- Draw the project area on the layout. This should show types of work, with location of workers and equipment. This may need to be done to match the construction stages of the work and should include any other incidental work and workers such as material testing inspectors (pavement coring after the paving operation), installation of lighting or signing structures attached to a bridge, or any other work after the major work has been completed.

- Sketch locations of key items from the traffic control plan and other site characteristics on the layout such as lane drop details, on-site obstructions, existing street lighting, and lane shifts.
- Locate any flagger or spotter stations on the layout and provide for lighting their station.

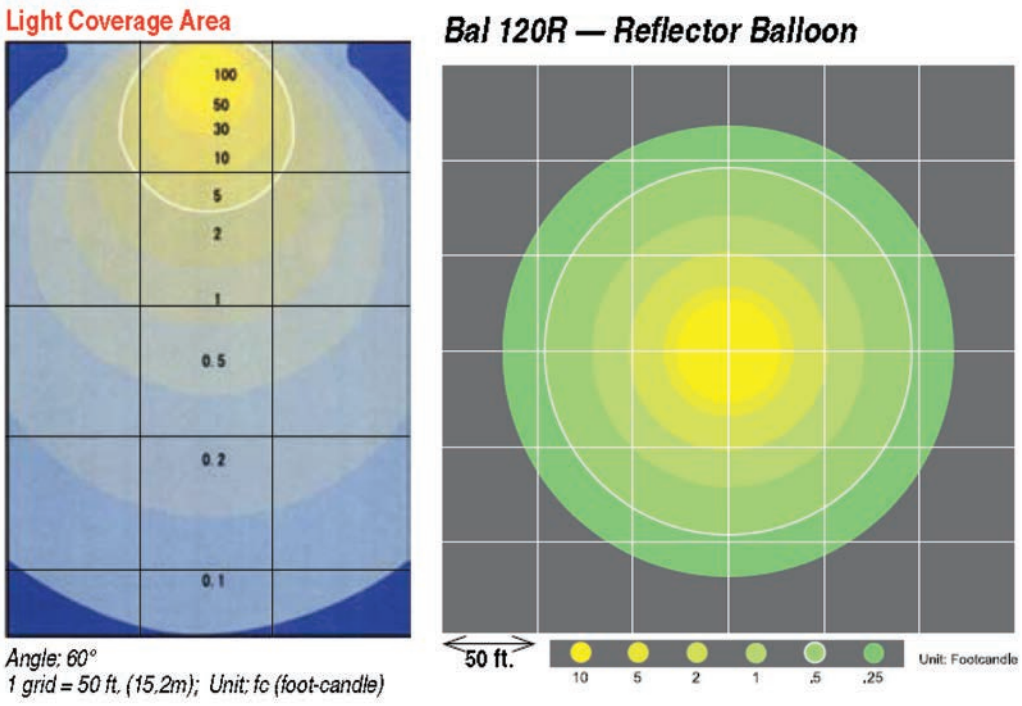
3. Select Type of Lighting System and Source

Once the work activities have been identified, it is necessary to determine the type of lighting source to use. Based on the planned work activities and whether the work is mobile, stationary, or long duration, a lighting source using balloon luminaires, portable light plant towers, or roadway luminaires should be chosen. See "Types of Lighting for Work Zones" above.

4. Select Fixture Locations

Examples of Iso-footcandle Charts[1] provided by lighting vendors are shown in Figure 5. Based on the type of fixtures selected, these kinds of diagrams can be overlaid on the layout of the work zone to determine where the lighting levels fall on the roadway. If the diagrams overlap on the roadway, the foot-candles can be added at a specific location. Much of this information is contained in most roadway lighting software and can be a more practical method to determine the lighting scheme for large work areas.

When placing lighting sources on the design the location needs to be one that is accessible and adequate for transporting and placing the light source.



Source: GloBug Light Coverage for Flood Lighting

Figure 5 - Examples of Iso-footcandle Charts

[1] Iso-footcandle charts are a tool for evaluating and comparing the light pattern a luminaire produces.

5. Check Design for Adequacy

Field Check the Design

Once the lighting plan is installed and activated, field observations of the work zone lighting should be performed by driving and walking through the work zone. The field check should be conducted from the vantage point of the motorist and workers to ensure that glare is controlled and the lighting is adequate for the work being done. Agencies may indicate that field observations are adequate to ensure the lighting plan is appropriate. Some State DOTs may require that a photometer, used to measure illumination, be furnished on the work site so measurements can be taken to verify that the necessary lighting levels in the work area are met.

Finalize the Lighting Layout

Once the field check is complete and the work area has been reviewed, any necessary modifications or adjustments should be implemented and the work zone plan or inspection report should show that deficiencies were identified and remediated. As with any modification or adjustment to a plan that puts the work zone in greater compliance with standards and policies, complete and thorough records must be kept.

STATE OF THE PRACTICE

A number of States have created lighting specifications for nighttime work zones. The following table summarizes the specifications used by seven agencies:

Table 2. Comparison of Seven State DOT Agency Nighttime Work Zone Lighting Specifications

Agency	Activity or Task	Equipment	Specifications
Caltrans	All Nighttime Operations		10 fc
Florida DOT (Vecellio, 2006)	Proper workmanship and inspections		5 fc
Georgia DOT (Vecellio, 2006)	All Nighttime Operations Average maintained horizontal illuminance		20 fc over the work area for tower lights Minimum 50,000 lumens for a tower light 460,000 lumens combined outputs of all fixtures on each tower light Machine lights shall have light outputs between 22,000 and 50,000 lumens
Illinois DOT	All nighttime operations	Tower Lighting and/or Balloon Lighting	Provide a minimum of 5 fc throughout the work area Provide a minimum of 10 fc for flaggers
Missouri DOT	Construction equipment and labor are active		5 fc
	Flaggers and other specified locations in lighting plan		0.6 fc

Agency	Activity or Task	Equipment	Specifications
New Jersey DOT (Vecellio, 2006)	Tasks on and around Equipment		100 lux uniformity ratio of 5:1 or less
	Specific tasks such as crack filling, saw-cutting, and joint sealing		200 lux uniformity ratio of 5:1 or less
North Carolina DOT (Vecellio, 2006)		Tower Lights	50,000 – 460,000 Lumens 20 fc
		Machine Lights	22,000 – 50,000 lumens output to provide 10 fc 13' mounting height
Nova Scotia DOT and Public Works (Vecellio, 2006)	All Areas Where Workers and Inspection Staff Work		60 lux average; 30 lux point
Rhode Island DOT (Vecellio, 2006)		Rollers, pavers, and pick-up trucks	Use 250 watt Metal Halide type lights
Note: See "Other Information and Guidance Resources" below for source information for these standards. *A foot candle (fc) is defined as unit of illumination that is equal to one lumen per square foot or 10.764 lux.			

In addition, the following specifications were adopted by the Illinois DOT[2] after the 2007 ILDOT study, *Nighttime Construction: Evaluation of Lighting Glare for Highway Construction in Illinois*.

SECTION 702. NIGHTTIME WORK ZONE LIGHTING

702.01 Description. This work shall consist of furnishing, installing, maintaining, moving, and removing lighting for nighttime work zones. Nighttime shall be defined as occurring shortly before sunset until after sunrise.

702.02 Materials. The lighting shall consist of mobile and/or stationary lighting systems as required herein for the specific type of construction. Mobile lighting systems shall consist of luminaires attached to construction equipment or moveable carts. Stationary lighting systems shall consist of roadway luminaires mounted on temporary poles or trailer mounted light towers at fixed locations. Some lighting systems, such as balloon lights, may be adapted to both mobile and stationary applications.

702.03 Equipment. The Contractor shall furnish an illuminance meter for use by the Engineer. The meter shall have a digital display calibrated to NIST standards, shall be cosine and color corrected, and shall have an accuracy of ± five percent. The sensor shall have a level indicator to ensure measurements are taken in a horizontal plane.

702.04 General. At the preconstruction conference, the Contractor shall submit the type(s) of lighting system to be used and the locations of all devices. Before nighttime construction may begin, the lighting system shall be demonstrated as being operational.

[2] Federal Highway Administration, *Nighttime Construction: Evaluation of Lighting Glare for Highway Construction in Illinois*, by K. El-Rayes et al. (FHWA-ICT-08-014). Available at: http://ict.illinois.edu/publications/report%20files/FHWA-ICT-08-014.pdf

702.05 Nighttime Flagging. The requirements for nighttime flagging shall be according to Article 701.13 and the glare control requirements contained herein.

702.06 Lighting System Design. The lighting system shall be designed to meet the following.

(a) Lighting Levels. The lighting system shall provide a minimum of 5 foot candles (54 lux) throughout the work area. For mobile operations, the work area shall be defined as 25 ft. (9 m) in front of and behind moving equipment.

For stationary operations, the work area shall be defined as the entire area where work is being performed.

Lighting levels will be measured with an illuminance meter. Readings will be taken in a horizontal plane 3 ft. (1 m) above the pavement or ground surface.

(b) Glare Control. The lighting system shall be designed and operated so as to avoid glare that interferes with traffic, workers, or inspection personnel.

Lighting systems with flood, spot, or stadium type luminaires shall be aimed downward at the work and rotated outward no greater than 30 degrees from nadir (straight down). Balloon lights shall be positioned at least 12 ft. (3.6 m) above the roadway.

As a large component of glare, the headlights of construction vehicles and equipment shall not be operated within the work zone except as allowed for specific construction operations. Headlights shall never be used when facing oncoming traffic.

(c) Light Trespass. The lighting system shall be designed to effectively light the work area without spilling over to adjoining property. When, in the opinion of the Engineer, the lighting is disturbing adjoining property, the Contractor shall modify the lighting arrangement or add hardware to shield the light trespass.

702.07 Construction Operations. The lighting design required above shall be provided at any location where construction equipment is operating or workers are present on foot. When multiple operations are being carried out simultaneously, lighting shall be provided at each separate work area.

The lighting requirements for specific construction operations shall be as follows.

(a) Installation or Removal of Work Zone Traffic Control. The required lighting level shall be provided at each truck and piece of equipment used during the installation or removal of work zone traffic control. Headlights may be operated in the work zone.

(b) Milling and Paving. The required lighting level shall be provided by mounting a minimum of one balloon light to each piece of mobile construction equipment used in the work zone. This would include milling machines, mechanical sweepers, material transfer devices, spreading and finishing machines, and rollers; but not include trucks used to transport materials and personnel or other vehicles that are continuously moving in and out of the work zone. The headlights of construction equipment shall not be operated within the work zone.

(c) Patching. The required lighting level shall be provided at each patching location where work is being performed.

(d) Pavement Marking and Raised Reflective Pavement Marker Removal/Installation. The striping truck and the attenuator/arrow board trucks may by operated by headlights alone; however, additional lighting may be necessary for the operator of the striping truck to perform the work. For raised reflective pavement marker removal and installation and other pavement marking operations where workers are on foot, the required lighting level shall be provided at each truck and piece of equipment.

(e) Layout, Testing, and Inspection. The required lighting level shall be provided for each active area of construction layout, material testing, and inspection. The work area shall be defined as 15 ft. (7.6 m) in front and back of the individual(s) performing the tasks.

701.13 Flaggers.[3]
…For nighttime flagging, flaggers shall be illuminated by an overhead light source providing a minimum vertical illuminance of 10 fc (108 lux) measured 1 ft. (300 mm) out from the flagger's chest. The bottom of any luminaire shall be a minimum of 10 ft. (3 m) above the pavement. Luminaire(s) shall be shielded to minimize glare to approaching traffic and trespass light to adjoining properties.

Illinois, of course, is not the only State with nighttime lighting standards and specifications. Below is an excerpt from the New York State Department of Transportation's Standard Specifications.

NEW YORK STATE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS of May 1, 2008

619-1.19 Nighttime Operations. Work shall consist of developing a Nighttime Operations and Lighting Plan, and furnishing, installing, operating, maintaining, moving and removing lighting equipment for nighttime construction operations as shown in the contract documents or as directed by the Engineer.

619-3.19 Nighttime Operations. Work occurring after sunset and before sunrise will be considered nighttime operations. All workers involved in nighttime operations shall wear protective helmets and nighttime apparel in accordance with §107-05A. High Visibility Apparel at all times. Vehicles operating on the pavement of a closed roadway or travel lane shall display four-way flashers or rotating amber beacons at all times. Vehicles using headlights, except for rollers and vehicles retrieving channelizing devices, shall travel facing in the same direction as adjacent traffic in order to avoid glare and confusion to drivers.

The Contractor shall meet the following additional requirements for work zone traffic control during nighttime operations.

A. Nighttime Operations and Lighting Plan. Thirty days prior to the start of nighttime operations, the Contractor shall submit a written Nighttime Operations and Lighting Plan to the Engineer for approval. The plan shall detail all aspects of the traffic control setup, the functions, responsibilities and identities of the traffic control supervisor and other details as necessary. It shall include a contingency plan identifying foreseeable problems and emergencies that may arise, and the approach that will be used to address them. This plan shall be revised and updated by

[3] Illinois Department of Transportation, Division 700. *Work Zone Traffic Control and Protection, Signing, and Pavement Marking*, http://dot.state.il.us/desenv/spec2012/Div700.pdf, January 1, 2012. Page 589.

the Contractor as necessary during the progress of the work to accommodate conditions on the contract. The Contractor shall submit a Nighttime Operations and Lighting Plan to the Engineer, at a scale and printed size similar to the contract plans and appropriate to adequately describe the work, including the following:

- Layout showing location of light towers, including typical spacing, lateral placement and mounting height, and clearly show the location of all lights necessary for all work to be done at night.
- Description of light towers to be used and electrical power source.
- Specific technical details on all lighting equipment, including brand names, model numbers, power rating and photometric data.
- Details of any hoods, louvers, shields or other means to be used to control glare.
- Attachment and mounting details for lights to be attached to equipment.
- Lighting calculations confirming that the illumination requirements will be met by the layout.

The Contractor shall maintain a supply of emergency flares for use in the event of unanticipated situations such as traffic accidents, equipment breakdowns, failure of lighting equipment, etc.

B. Lighting for Nighttime Operations. Prior to the first night of nighttime operations, the Contractor shall set up and operate the lighting equipment at night as a trial run to demonstrate its ability to establish a safe, properly illuminated, nighttime operation. The Contractor shall furnish the Engineer with a photometer, capable of measuring the level of illumination, for use as necessary to check the adequacy of illumination throughout nighttime operations.

1. Equipment. The Contractor shall supply all lighting equipment required to provide a work zone safe for the workers and traffic. Material and/or equipment shall be in good operating condition and in compliance with applicable safety and design codes.

a. Light Towers. Light towers shall be provided as a primary means of illumination, and shall provide Level I illumination throughout the work space. They may be supplemented to the extent necessary by lighting fixtures mounted on construction equipment to provide Level II or Level III illumination where required for paving, milling and similar moving operations. Light towers shall be sturdy and free-standing without the aid of guy wires or bracing, and shall be capable of being moved as necessary to keep pace with construction operations. Light towers shall be positioned to minimize the risk of being impacted by traffic on the roadway or by construction traffic or equipment.

b. Light Towers on Paving, Milling, and Finishing Machines. If needed to supplement portable and/or trailer-mounted light towers, towers shall be affixed to paving, milling, and finishing machines to provide the required level of illumination for the specified distance in front of and behind the machine. No portion of machine-mounted light towers shall exceed a height of 13 feet above ground. Luminaires shall be aimed and adjusted to provide uniform illumination with a maximum uniformity ratio of 5:1. The hopper, auger, and screed areas of pavers and the operator's controls on all machines shall be uniformly illuminated.

c. Construction Equipment Lights. All construction equipment, including rollers, backhoes, loaders, and other equipment operating in areas not illuminated to a minimum of Level I Illumination, shall be equipped with a minimum of two 500 watt flood lights facing in each direction to provide a minimum of 1 foot-candles of horizontal illumination measured 60 feet in front of and behind the equipment. In areas illuminated to a minimum of Level I, construction equipment may move unescorted. In non-illuminated areas, construction equipment shall be equipped with conventional vehicle headlights, shall be illuminated with flood lights on the vehicle, or shall be escorted to permit safe movement. Headlights shall not be permitted as the sole means of illumination while working.

d. Equipment Mounting. The Contractor shall provide suitable brackets and hardware to mount lighting fixtures and generators on machines and equipment. Mountings shall be designed so that light fixtures can be aimed and positioned as necessary to reduce glare and to provide the required illumination. Mounting brackets and fixtures shall not interfere with the equipment operator or any overhead structures, and shall provide for secure connection of the fixtures with minimum vibration.

e. Portable Generators. The Contractor shall provide portable generators to furnish adequate power to operate all required lighting equipment. Fuel tank capacity and availability of fuel on site shall be sufficient to permit uninterrupted operation throughout the planned shift. Adequate switches shall be provided to control the various lights. All wiring shall be weatherproof and installed in accordance with 29 CFR 1926 Subpart K requirements. All power sources shall be equipped with a Ground-Fault Circuit Interrupter.

2. Illumination Requirements. Tower-mounted luminaires, whether fixed, portable, trailer-mounted, or equipment-mounted, shall be of sufficient wattage and/or quantity to provide the required level of illumination and uniformity over the area of operation. The uniformity of illumination, defined as the ratio of the average illumination to the minimum illumination over an area requiring an indicated illumination level, shall not exceed 5:1. Illumination levels on approach roadways should be increased sequentially to prevent motorists from becoming disoriented by rapid changes from full dark to very bright conditions. Existing street and highway lighting shall not eliminate the need for the Contractor to provide lighting. Consideration will be given to the amount of illumination provided by existing lights in determining the wattage and/or quantity of lights to be provided. Such consideration shall be presented in the Contractor=s Nighttime Operations and Lighting Plan. In the event of any failure of the lighting system, nighttime operation(s) shall be discontinued until the required level of illumination is restored.

a. Level I (5 foot-candles). Level I illumination shall be provided for all areas of general construction operations to include all work operations by Contractors= personnel, including work zone traffic control set-up and operations, staging, excavation, cleaning and sweeping, spoil disposal, landscaping, planting and seeding, layout and measurements ahead of the actual work, borrow areas, spoil areas, and truck cleanout areas. Level I illumination shall be provided at the area of lane and/or road closure tapers continuously, including the setup and removal of the closure tapers. Level I illumination shall be provided a minimum of 400 feet ahead and 800 feet behind a paving or milling machine, or for the entire area of concrete placement or pavement work if less than 1500 feet. This area shall be extended as necessary to incorporate all vehicle and equipment operations associated with the paving operation. The only exception to the requirement for Level I illumination throughout the area of construction operations is that finish rollers can work beyond the area of Level I illumination using floodlights mounted on the roller.

b. Level II (10 foot-candles). Level II illumination shall be provided for flagging stations, asphalt paving, milling, and concrete placement and/or removal operations, including bridge decks, 50 feet ahead and 100 feet behind a paving or milling machine.

c. Level III (20 foot-candles). Level III illumination shall be provided for pavement or structural crack filling, joint repair, pavement patching and repairs, installation of signal equipment or other electrical/mechanical equipment, and other tasks involving fine details or intricate parts and equipment.

3. Glare Control. All lighting shall be designed, installed, and operated to avoid glare that affects traffic on the roadway or that causes annoyance or discomfort for residences adjoining the roadway. The Contractor shall locate and aim lighting fixtures to provide the required level of illumination and uniformity in the work zone without the creation of objectionable glare. The Engineer will determine when glare exceeds acceptable levels, either for traffic or for adjoining residences.

The Contractor shall provide shields, visors or louvers on luminaires as necessary to reduce objectionable levels of glare. As a minimum, the following requirements shall be met to avoid objectionable glare on roadways open to traffic in either direction:

- Tower-mounted luminaires shall be aimed either generally parallel or perpendicular to the roadway.
- Luminaires shall be aimed such that the angle between the center of the beam axis and the vertical mounting pole is no greater than 45E.
- No luminaires shall be permitted that provide a luminous intensity greater than 20,000 candelas at an angle of 72E above the vertical.
- Except where prevented by overhead utilities or structures, towers shall be extended to their full working height when in use to reduce glare and provide uniform illumination.

These two specifications were chosen to show the differences in how a specification could be developed that would provide lighting for a work zone. The New York specification, as with several other state specifications, requires a lighting plan:

- Be developed and submitted for approval 30 days prior to the start of construction,
- To provide details on equipment and basically assumes portable light towers would be the lighting source.
- To provide lighting level computations be submitted to show the lighting levels will be provided by the layout, which would require a lighting professional.

The Illinois specification requires the contractor to provide certain lighting levels for specified construction operations and activities. It is basically up to the contractor to provide the lighting with no prior plan approval.

CONCLUSIONS AND RECOMMENDATIONS

State DOTs and local agencies should consider the information contained in this guide to be a tool to help them improve the safety of both workers and the traveling public in work zones at night. Those agencies that do not have lighting specifications for work zones may want to use this guideline as a first step in developing a specification for contractors to use. It is also advisable for all agencies that perform road work at night to train their key personnel in minimum lighting requirements, needs, and best practices by project and work activity.

In the end, the key steps practitioners should follow in developing a light plan are to:

1. Determine work activities and lighting levels
2. Determine the work zone area to be illuminated
3. Select type of lighting source
4. Select fixture locations
5. Check design for adequacy

This guide may be used to facilitate such training sessions, discussions, and improvements in practice for both public and private sector stakeholders. Doing so will ensure that lighting schemes in nighttime work zones accomplish the following vital objectives:

- Provide the appropriate level of lighting that allows construction work to be completed safely and effectively;
- Reinforce the intent of the traffic control plan and provide better guidance for drivers traveling through the work zone; and most importantly,
- Improve the overall safety of workers and the traveling public.

OTHER INFORMATION AND GUIDANCE RESOURCES

MUTCD

Federal Highway Administration (2009). *Manual on Uniform Traffic Control Devices*. Washington, DC.

Research

Jennifer S. Shane, A. K. (2012). *NCHRP Report 726: A Guidebook for Nighttime Construction: Impacts on Safety, Quality, and Productivity*. Washington, D.C.: Transportation Research Board of the National Academies.

Ralph D. Ellis, Jr., Scott Amos, Ashish Kumar (2003). *NCHRP Report 498 Illumination Guidelines for Nighttime Work*. Transportation Research Board of the National Academies, Washington, D.C.

Bryden, J. E., and D. J. Mace (2002). NCHRP Report 476 *Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction*. Transportation Research Board of the National Academies, Washington, D.C.

Marwa M. Hassan, Ibrahim Odeh, and Khaled El-Rayes, "Glare and Light Characteristics of Conventional and Balloon Lighting Systems." Transportation Research Board 89th Annual Meeting held in Washington, D.C. on January 11-15, 2010.

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Standards, Policies, Specifications

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Developed by:

The American Traffic Safety Services Association

15 Riverside Parkway Suite 100

Fredericksburg, VA 22406-1022

800-272-8772

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