

December 2025

RESEARCH PROJECT TITLE

The Effect of Nighttime Lighting Systems on Workers' Visibility and Safety

SPONSORS

Smart Work Zone Deployment Initiative
(Part of TPF-5(438))
Federal Highway Administration
(InTrans Project 20-733)

PRINCIPAL INVESTIGATOR

Chun-Hsing Ho, Associate Professor
Durham School of Architectural
Engineering and Construction
University of Nebraska–Lincoln
chunhsing.ho@unl.edu / 425-233-1016

CO-PRINCIPAL INVESTIGATOR

Kyungki Kim, Assistant Professor
Durham School of Architectural
Engineering and Construction
University of Nebraska–Lincoln

MORE INFORMATION

intrans.iastate.edu

SWZDI

Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

The Smart Work Zone Deployment Initiative (SWZDI) is a transportation pooled fund that supports research investigations into better ways to improve the safety and efficiency of traffic operations and highway work in work zones. The primary objective is to promote and support research and outreach activities that focus on innovative policies, processes, tools, and products that enhance the implementation, safety, and mobility impacts of work zones. The fund is administered by Iowa State University's Institute for Transportation, and the lead agency is the Iowa Department of Transportation.

The sponsors of this research are not responsible for the accuracy of the information presented herein. The conclusions expressed in this publication are not necessarily those of the sponsors.

The Effect of Nighttime Lighting Systems on Workers' Visibility and Safety

tech transfer summary

This study provides recommendations for optimal nighttime lighting configurations in work zones, offering agencies practical guidance to improve safety and visibility.

Objectives and Goal

This objectives of this project were as follows:

- Investigate how the characteristics of lighting—specifically glare, luminance, and visibility—affect the visual performance of construction workers.
- Examine the influence of lighting arrangements (i.e., the orientation and positioning of light towers) on the perceptions of both construction workers and motorists.
- Identify hazardous situations that arise from poor lighting setups in nighttime work zones.

The goal was to ensure that the lighting strategies implemented not only facilitate construction activities but also improve the visibility and promote the safety and well-being of workers and motorists in nighttime work zones.

Background

Nighttime work zones present unique safety challenges for both roadway workers and motorists. The inherent risks of driving are amplified after dark; the nighttime fatality rate on US roadways is three times higher than the daytime rate. Visibility has been the top priority for all lighting system designs in nighttime work zones. However, to ensure worker visibility, many work zones are paradoxically over-illuminated, which can create harmful levels of glare.

This glare is a critical safety hazard, defined by the Illuminating Engineering Society (IES) in terms of its effects. Disability glare impairs the ability to see detail by scattering light within the eye, creating a visual haze that reduces contrast. Discomfort glare causes annoyance or pain, which can lead to fatigue and distraction. The most extreme form, blinding glare, is so intense that for a period after the source is removed, no visual perception is possible.

All forms of glare can negatively affect the visual performance of workers on foot and motorists traveling through construction areas, ultimately impacting overall work zone safety.

Problem Statement

Existing lighting design guidelines and technical reports, such as those from the IES, provide general recommendations but lack supplemental information to address specific safety concerns.

Current practices do not sufficiently evaluate the comparative impacts of different lighting sources, orientations, and configurations on visibility and glare. More critical than the overall amount of light is its direction; research has consistently shown that the aiming of portable light towers is a decisive factor in generating glare.

A systematic assessment of these factors is essential to improve safety outcomes in nighttime work zones

Research Description

This research included the following components:

1. A comprehensive survey of practitioners regarding current nighttime work zone lighting arrangement practices
2. Experimental field testing that evaluated visibility and glare conditions from both drivers' and workers' perspectives in controlled test environments
3. An assessment of nighttime work zone illuminance levels, including both quantitative and qualitative experiments

Survey Design and Implementation

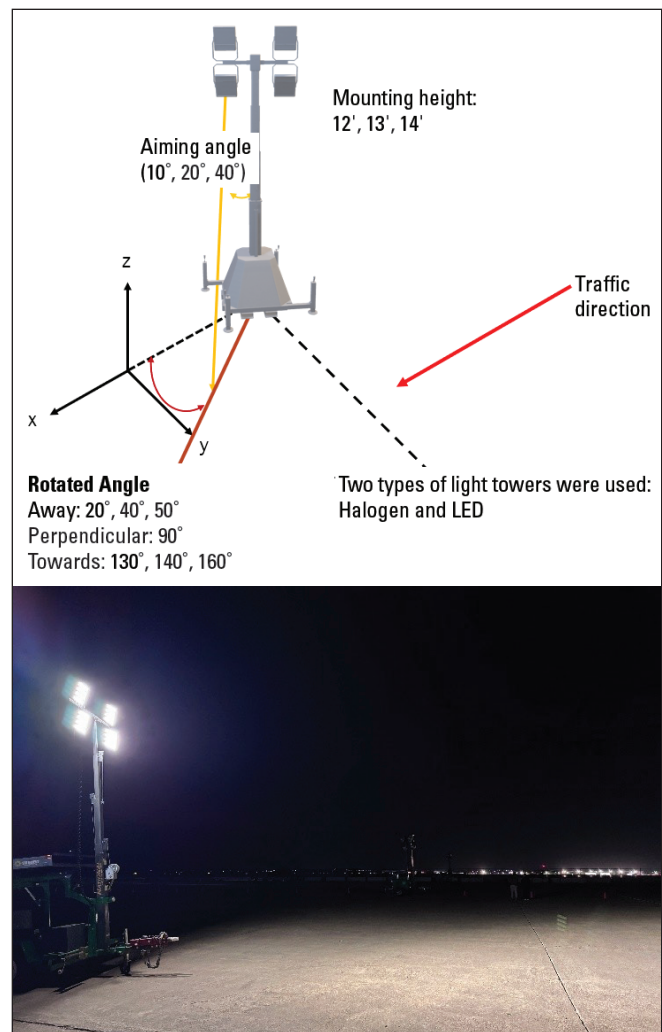
The survey was designed to gather feedback from industry professionals regarding their experiences with nighttime work zone lighting systems. The target population included contractors, state department of transportation (DOT) inspectors, and maintenance crews, representing diverse perspectives from operational implementation to regulatory compliance and hands-on experience.

Field Illumination Test

A field test was conducted at the University of Nebraska–Lincoln's Midwest Roadside Safety Facility (MwRSF) at a controlled experimental site that replicated nighttime work zone environments. This study rented two types of portable light towers with different light sources, LED modules and metal halide, representing the mainstream lighting technologies currently used in nighttime construction.

The research team set up a single lane at MwRSF. For each light tower configuration, measurements were taken at 7 points marked by safety cones, with cones placed at 15 ft (4.6 m) intervals. Field experiments measured photometric parameters and evaluated lighting performance from the perspectives of both drivers and workers.

Data collection followed standardized procedures for measuring illuminance, luminance, and glare intensity at multiple grid points within the test site. Results were compared against established standards and guidelines to identify effective lighting practices that maximize visibility while minimizing harmful glare.



Light tower configuration options (top) and field test (bottom)

Assessment of Nighttime Work Zone Illuminance Levels

Three key parameters were measured: horizontal illuminance for assessing worker task performance, and pavement luminance and vertical illuminance at the driver's eye level for glare analysis. For the driver's perspective, the research team calculated a glare index by measuring pavement luminance and vertical illuminance. For the worker's perspective, ground horizontal illuminance was used to assess brightness in a nighttime work zone.

In addition to the quantitative photometric evaluation, the research team conducted a qualitative analysis to assess the practical use of the lighting configurations in actual construction activities. This assessment focused on the visual clarity and measurement precision needed for common tasks in nighttime construction, including construction layout reading and tape measure reading.

Key Findings

- The survey revealed that while 68% of respondents were generally satisfied with current lighting systems, significant issues remain. These include insufficient coverage affecting worker visibility (53%) and glare affecting drivers (36%). Respondents primarily attributed these problems to improper geometric configurations—specifically aiming and rotation angles—rather than inadequate lamp output.
- According to the field experiments, optimal configurations that met both driver and worker visibility criteria typically featured rotation angles of 40° to 50°, mounting heights of 12 to 13 ft, and aiming angles of 20° to 40°.
- Under these conditions, workers could read the smallest text at 145 ft from the light source (halogen) and perform precise tape measurements at 300 ft from the light source (LED), all while maintaining acceptable glare levels.
- Certain lighting configurations were found to be unsafe. For example, a perpendicular orientation (90° rotation angle) often resulted in excessive illuminance, exceeding the Federal Highway Administration's maximum thresholds, while a rotation angle of 160° (toward traffic) often resulted in insufficient lighting.
- High rotation angles (130° to 160°) combined with low aiming angles (10°) produced unacceptable glare (i.e., a veiling luminance ratio [VLR] greater than 0.4) across the entire work zone. Two representative configurations illustrate this risk:
 - Halogen lighting setup featuring a 12 ft mounting height, a 10° aiming angle, and a 130° rotation angle), yielding a VLR of 1.136
 - LED lighting setup featuring a 14 ft mounting height, 40° aiming angle, and 130° rotation angle), yielding a VLR of 3.996
- When LED light towers were configured with appropriate rotation angles (40° to 50°), lighting performance improved significantly. Measurement points with insufficient illuminance readings dropped from 48.2% to 25.6% (≈47% reduction), and average VLR decreased from 0.385 to 0.308 (≈20% reduction).
- Qualitative tests showed that both halogen and LED lighting sources provided a horizontal illuminance (E_h) of at least 40 lux within a 105 ft range. Under these proper lighting coverage areas, workers achieved the highest precision on both the layout reading and tape measure reading tasks.
- The finding that 34.3% of all measurements produced unacceptable glare underscores that three configurations—rotation angle, aiming angle, and mounting height—are more influential than the choice of lighting source. Prioritizing optimal lighting configurations would enable agencies to provide safer construction environments for workers in the vicinity of nighttime work zones.

Implementation Readiness and Benefits

Adequate nighttime lighting configurations can improve the perception of construction workers and motorists in nighttime work zones. Contractors and state DOT engineers rely on relevant lighting design guidelines and informed knowledge about proper construction lighting setups to improve visibility.

The results from this project provide supplemental information and recommendations regarding the nighttime construction practices of state DOTs as well as updates for relevant lighting system standards that can benefit contractors and state DOT staff, including construction workers, inspectors, operators, and others, in nighttime work zones.

The recommended lighting configurations could help increase work zone safety and reduce risks to construction workers and motorists in nighttime construction sites, particularly for the disadvantaged community.