In 2005, the contractor for a highway construction project on I-90 in Albany, N.Y., requested permission from the New York State Department of Transportation (NYSDOT) to try a novel technique for illuminating the 3-mile nighttime work zone: semipermanent, high-mast lighting to be installed at the start of the project and then taken down after the project’s completion.

Typically, nighttime work-zone lighting is provided by portable light towers containing high-intensity discharge lamps and floodlight luminaires. NYSDOT granted permission following a safety review, and then contracted with the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute to evaluate the lighting system’s performance in order to determine if this approach might be suitable for other construction projects.

The LRC’s evaluation consisted of three parts:

- Conducting photometric measurements to document, and model, the light levels provided by the system;
- Analyzing the visual performance of construction workers; and
- Comparing the cost, energy use and environmental impact to conventional work-zone lighting.

Based on the results of the evaluation, the LRC developed some pre-
Preliminary recommendations to NYSDOT regarding if and when this approach could be considered viable for other nighttime construction projects.

**POLE POSITIONING**

The high-mast installation consisted of just over 100 70-ft poles, each containing four 1,500-watt metal halide floodlights. Poles were spaced about 150 ft apart in a staggered formation. About two-thirds of these poles were located within the 30-ft-wide clear zone for this highway. The floodlight reflectors were custom-tailored for this construction project by the luminaire manufacturer, who rented the luminaires to the contractor for the duration of the project.

The entire lighting system was powered by five 250-kilowatt diesel generators. These generators had similar noise ratings as the generators used to power each portable light tower, but were located outside the clear zone, resulting in a much quieter work zone than is typically found.

Field measurements of light levels on the site revealed that the installation, as hoped, exceeded the minimum recommendations from the “National Cooperative Highway Research Program (NCHRP) Report 498, Illumination Guidelines for Nighttime Highway Work,” for the type of construction work being performed (10 foot-candles). The lighting also was exceptionally uniform (1.5 to 1 average to minimum illuminance).

Using the measurements made in the field, a simulation model of the lighting installation was developed using photometrically accurate lighting software, making some practical assumptions about the distributions of the customized floodlight luminaires. These assumptions were deemed valid because the light levels measured in the field and those predicted by the model were in close agreement, within 10% of each other. A similar model was developed using photometric data for the portable tower luminaires. These models permitted the project team to assess the performance of the lighting without obstructing or delaying the construction work at the actual site.

**OUT FROM THE SHADOWS**

The uniform illumination on the pavement from the high-mast lighting system suggested that construction workers in the site would have improved visibility under this system, in part because of reduced shadows. This expectation was borne out by calculations of the visibility of objects such as tools located on the ground on each side of a maintenance vehicle parked in the construction site, and of the visibility of controls such as key-operated switches on construction equipment. These calculations used the Relative Visual Performance model developed by the LRC Director Mark Rea and described in the Illuminating Engineering Society of North America’s Lighting Handbook, which uses the size, luminance and contrast of an object to determine how quickly and accurately it can be seen.

Under conventional illumination from portable light towers, when the objects were located in the shadowed side of a vehicle or equipment, they were invisible. Under the high-mast system, the increase uniformity meant that light levels on all sides of vehicles and equipment were sufficient to maintain good visibility by workers.

NCHRP Report 498 cites glare as an important issue to consider when using portable light towers for nighttime construction. Their reduced height relative to typical roadway lighting makes them difficult to align to avoid glare from all of the many possible locations from which they might be seen. The high mounting heights of the installation on I-90 helped reduce glare by keeping the luminaires away from worker and driver lines of sight. This was borne out by calculations using the “International Illumination Commission’s Report 112, Glare Evaluation System for Use Within Outdoor Sports and Area Lighting.”

Overall, the lighting system was quite successful at supporting visual performance of both construction workers and drivers in the work zone, while reducing glare considerably.

**LIGHT OFFERING**

The high-mast lighting system was not inexpensive. Installation costs, rental charges and equipment costs totaled nearly $1.2 million for this project. Operating costs to run the system were just over $1,000 per night; over the duration of the project (about 235 days), operating costs totaled more than $240,000. Overall, the total operational cost of the high-mast lighting for the entire project was about $1.4 million.

In comparison, setting up and taking down the portable light towers, requiring three hours each night, would cost about $1,200 nightly. Assuming a contractor would use 120 portable light towers, owning 100 and renting 20, operation and rental costs would be almost $3,300 per night. Since setting up and removing the light towers takes time that would otherwise be used performing the construction work, the project was estimated to have required 275 days rather than the 235 days. The resulting total operating cost for conventional light towers for the project is estimated at

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just over $1.2 million, about 15% less than for the high-mast system. Despite this higher cost, both NYSDOT and the contractor felt that the higher cost of the high-mast system was justified by the improved visual performance, reduced glare and reduced noise from this type of lighting.

Of note, even though the high-mast installation used a similar number of floodlight luminaires, with similar wattages as a corresponding portable light tower installation for a similar construction project, the nightly operating cost for the high-mast lighting system was 2 1/2 times less than that estimated for the portable light towers, even though the portable towers would have been operated for fewer hours per night. This is primarily because in comparison to individual generators for each portable tower, the larger generators used in the high-mast installation have greater efficiency, requiring significantly less diesel fuel to operate a similar load. Given the state of diesel fuel prices in 2008 compared with 2005, when the economic analysis was performed, the differences in overall cost would likely be smaller than the 15% originally calculated.

In addition to the obvious environmental implications of greatly reduced diesel fuel consumption, the light pollution impact of the high-mast installation was evaluated by placing a virtual “shoebox” over the construction site in the simulation model and calculating the amount of light leaving the construction site under each type of installation. The total amount of light leaving the site was similar from each installation, but the density of light leaving the site was greater from the portable light towers, because these would tend to be located in a more concentrated part of the overall work zone on any given night. The local newspapers and publications from local environmental organizations were reviewed to see if any concerns about light pollution were raised. No such concerns were found, but there is not enough evidence from this single installation to suggest that the high-mast lighting installation had no negative impacts on local flora or fauna relative to conventional lighting.

**AIM FOR THE HIGH**

Overall, the use of semipermanent, high-mast lighting for this construction project was successful. While it is relatively expensive, for long-term projects it appears to be beneficial in terms of increasing overall efficiency, while creating a visual environment that probably contributes positively to the safety of workers and drivers. The location of many of the poles within the clear zone is a definite concern; while the present project was on a freeway with guide rails and other channelization present to direct traffic flow and hopefully minimize run-off-the-road incidents, for projects without such highway features it is more critical to maintain the clear zone.

Taking these factors into account, a possible approach for considering whether high-mast lighting should be considered can be outlined. For projects with a score of 4 or higher, semipermanent, high-mast lighting might be a feasible approach. Those with a negative score probably are not good candidates. No doubt, there are other factors that will be important in deciding whether this relatively new lighting technique is potentially beneficial. Agencies that have used high-mast work-zone lighting are encouraged to publicize their experiences, good and bad, so that others can determine if it might be a suitable addition to the work-zone safety toolbox.

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The Outdoor Site-Lighting Performance system was developed by the LRC in order to provide quantifiable metrics for characterizing a lighting installation’s light pollution impacts in terms of sky glow, light trespass and discomfort glare. These metrics all use illuminance quantities calculated at the boundaries of a property (in the case of roadway lighting and the right-of-way), conceived in the form of a “shoebox” over the property. Using illuminance quantities on the surfaces of the virtual shoebox permits the incorporation of these metrics into commercially available calculation software used by engineers in the specification of lighting equipment and layouts. Sky glow is characterized by the overall light leaving a property, light trespass by the maximum light level crossing a property boundary and discomfort glare by the ratio of the light from a luminaire to that from the surfaces surrounding the luminaire. For more information, see the October 2007 issue of the *Institution of Lighting Engineers’ Lighting Journal* (www.lrc.rpi.edu/researchareas/pdf/insidethebox.pdf).