Mobile Barrier Trailer

Analysis of an emerging work zone protection system

By Matthew R. Hallowell, J. Brent Protzman and Keith R. Molenaar

THE CONSTRUCTION INDUSTRY accounts for a disproportionate injury rate. According to Bureau of Labor Statistics (BLS), the construction industry consistently employs approximately 5% of the American workforce but accounts for approximately 12% of all occupational fatalities. These occupational injuries have a significant impact on the economy. In 2004, the industry was responsible for 460,000 disabling injuries resulting in a total estimated cost of $15.64 billion (NSC, 2006).

Within the construction industry, the highway sector accounts for the highest injury and illness rate (BLS, 2007). When compared to workers on all other types of construction sites, workers on road construction sites were found more likely to be killed by vehicles and heavy equipment (BLS, 2007; CPWR, 2008). The estimated direct costs of highway construction zone accidents were as high as $6.2 billion per year between 1995 and 1997 with an average cost of $3,687 per accident (Mohan & Gautam, 2002).

As highway agencies continue to repair America's progressively failing transportation infrastructure, roadways must be renewed quickly with minimum disruption to the community. Such work requires the use of specific strategies such as nighttime work, continuous work, extended shifts, modularization and others aimed to compress schedules. Based on the observations made by previous researchers, these emerging construction trends are likely to result in an increase in injuries and illnesses.

Highway agencies and private contractors use many methods to protect highway work zones, including cones, signage, semipermanent concrete barriers and vehicular barriers created by enclosing the work zone with idle equipment (i.e., ring of steel). This study investigates the benefits and limitations of a new method of protecting highway work zones: mobile barrier systems. Specifically, this article presents the findings from an in-depth analysis of the MBT-1, a mobile barrier system with unique features targeted at injury prevention, and provides a comparison of this system with existing strategies. The study pays specific attention to lighting schemes associated with the MBT-1 as the lighting-related benefits are the most ambiguous.

Causes of Highway Work Zone Injuries

Several studies have focused on the causes of highway construction and maintenance injuries. According to NIOSH (2001), nighttime work, contact with heavy equipment and being struck by passing vehicles are the leading root causes of fatalities. Other literature reports that highway workers are also at risk of injury or death from contact with overhead power lines, falls from machinery or structures, gas line explosions, or being struck by falling objects or materials (Bryden & Andrew 1999).

Nighttime Work

Highway construction and maintenance is often performed throughout the night to minimize traffic delays during high-volume times. Nighttime highway construction has been established as more hazardous for both passing drivers and construction personnel. The factors that contribute to nighttime work zone fatalities are summarized in Table 1 (p. 32).

Specific risk events increase substantially during nighttime work. For example, Transportation Re-

Abstract: *Within the construction industry, the highway sector is particularly dangerous. Despite the fact that highway work zone safety has received signficant attention from the research community, injury rates continue to climb due to increasing nighttime work under traffic. This article describes a study of the attributes and potential impacts of a mobile barrier trailer, an innovative technology designed for use in highway work zones.*

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Table 1

Factors Contributing to Nighttime Work Zone Fatalities

Contributing factor	% fatalities attributed[a]
Fatigue or impairment of vehicle operators	64%
Poor lighting conditions	43%
Workers not wearing safety garments	14%
Unfavorable weather	8%
Poor performance of safety garments	7%
Other	32%

Note. *Data from "Worker Safety Issues in Nighttime Highway Construction," by D. Arditi, M. Ayrancioglu and J. Shi, 2005,* Engineering Construction and Architectural Management, *12(5), pp. 487-501.*

[a]*Some fatalities were attributed to multiple factors.*

Highway construction and maintenance is often performed throughout the night to minimize traffic delays during high-volume times. Nighttime highway construction has been established to be more hazardous for both passing drivers and construction personnel.

search Board (2008) found that the rate of private vehicles entering a work zone at high speed (i.e., incursions) triples after dark while the frequency of injuries resulting from debris and a projectile entering a work zone doubles.

Heavy Mobile Equipment

Most fatal injuries incurred by road construction workers are attributable to vehicle- and mobile heavy-equipment-related incidents. When compared to workers on all other types of construction sites, workers of many differing occupations on road construction sites were found more likely to be killed by vehicles and heavy equipment. In fact, Bryden and Andrew (1999) found that heavy mobile equipment contributed to 22% of highway construction worker injuries and 43% of deaths in New York between 1993 and 1997.

Poor Signage

According to Maze, Kamyab and Schrock (2000), many accidents result from poor signage. Maze, et al., found that among all the techniques used (e.g., police, radar detectors, automatic signs, and flagging devices), flagging and the use of police enforcement strategies had the most positive impact. Additionally, Benekohal and Shu (1992) found that programmable signage is much more effective than standard signage or cones because of the visibility and size.

Incursions

Incursions could likely become a larger problem as more highway construction work is performed on active roadways. Incursions range from cars hitting cones to actual interaction with workers; they are usually the result of drivers under the influence, fatigue, poor visibility or poor signage. These incidents are commonly caused by driver distraction, which has been cited as the leading cause of vehicular crashes (Lohse, Bennett & Velinsky, 2007). Driver distractions can be caused by many factors including adjacent construction, cell phones and electronic systems such as music players and GPS units. Such distractions are exceptionally prevalent among young drivers.

Improving Highway Work Zone Safety

To respond to the relatively high incident rate, several studies have been conducted to determine measures to improve site safety on highway construction and maintenance projects. For example, NIOSH conducted a study that involved the aggregation of relevant literature and a 3-day workshop that brought together 60 stakeholders from government agencies, labor unions and private employers to discuss measures to reduce highway construction site worker injuries from vehicles and equipment. It includes preventive measures to help protect highway workers from hazards posed by construction and traffic vehicles and is considered the most definitive guide to highway work zone safety (NIOSH, 2001).

The NIOSH document outlines the roles and responsibilities of the contracting agency (e.g., highway agency), the contractor and policy makers at the federal, state and local levels. NIOSH suggests the following strategies:

- Assign a traffic control supervisor who is knowledgeable in traffic control principles and who will assume overall responsibility for the safety of the work zone setup.
- Set up temporary traffic control devices, such as signage, warning devices, paddles and concrete barriers in a consistent manner throughout the work zone to provide passing motorists with advanced warning of upcoming work zones.
- Educate flaggers in topics such as traffic flow, work zone setup and proper placement of channelizing devices.
- Require all workers on foot to wear high-visibility safety apparel.

Despite these efforts, highway construction zone safety remains unsatisfactory. Additional innovative strategies and tools that are specifically designed for highway construction and maintenance are needed. Recently, contractors and state highway agencies have begun to use physical barrier systems and lighting schemes to reduce safety risks in work zones. The remainder of this article discusses the salient aspects of physical barrier systems and lighting schemes.

Highway Work Zone Barrier Systems

Mobile barrier systems are emerging as a method for protecting work zones by providing a moveable, rigid barrier between the work zone and passing traffic. Traditional systems provide varying degrees of protection ranging from negligible protection to crash-tested protection systems (Mobile Barriers LLC, 2009). While this article decribes recent advances in mobile barrier systems, the concept of a mobile barrier is not new. In fact, according to the Texas Transportation Institue (2004), iterations of these systems have been produced since the 1950s. Photos 1 and 2 depict some first-generation mobile barriers.

Lohse, et al. (2007), describe various barrier systems implemented in the construction industry. The sidebar on p. 33 lists each major system and its advantages and disadvantages.

Overview of the MBT-1 System

The mobile barrier trailer (MBT-1, Photo 3, p. 34) is a rigid-wall trailer that serves as a structural and visual barrier between a highway construction worksite and active roadways. The trailer is specifically designed to provide fore, aft and side protection from passing traffic. The rigid trailer is towed into place by a standard semitractor at the front and includes an integrated crash attenuator at the rear. The attenuator and tractor trailer provide approximately 40 ft of protection. The MBT-1 also includes three removable 20-ft panels, which allows users to select 60, 80 or 100 ft of protection based on the area and accessibility of the worksite and the comfort and competence of the driver.

Each structural panel is 5 ft in height and includes an additional 4 ft of visual (nonstructural) barrier. In its maximum height configuration, the barrier includes 5 ft of structural protection and a total of 9 ft of visual barrier between workers and passing traffic. In addition to providing a physical and visual barrier, the MBT-1 includes other unique features that mitigate risks within the enclosed work zone, such as an integrated three-line message board, vertical lift, usable power, portable air, welder, storage and supply areas, radar, safety lighting and work lighting.

Perhaps the most notable aspect of the MBT-1 is the fact that it is the only barrier system that has been crash-tested and approved for use on the national highway system by Federal Highway Administration (FHWA) under the National Cooperative Highway Research Program 350 and (Test 311) MASH-08 Guidelines (Mobile Barriers LLC, 2009). The test utilized a 5,135 lb 2002 Dodge Ram 1500 Quad Cab pickup truck at a speed of 100 km/hr at an angle of 25º. No structural damage occurred and a maximum dynamic deflection of 2 ft was observed (Gomez-Leon, 2008).

Photos 1 and 2 depict some early attempts at mobile barriers for highway work zones.

Advantages & Disadvantages of Existing Mobile Barrier Systems

Safeguard Link System. This system is a towable steel barrier system. The barrier is constructed with wheels at the base and can be towed longitudinally with a pneumatic attachment or a hand crank. The barrier can be installed at a rate of 200 to 300 ft every 30 minutes. This system results in relatively large deflections when struck by a vehicle and is not appropriate for high-speed work zones.

BarrierGuard 800. This system is a semimobile steel barrier that is typically used as a replacement for concrete barriers. It is more mobile than concrete barriers because of its relatively low weight. The most useful feature of the system is that 1,000 ft of barrier can be set up in about 1 hour and curved sections can be added to accommodate curvature within the perimeter of the work zone. A disadvantage is that the system must be anchored when used, making it difficult to move in a short time.

VulcanBarrier. This system is a portable steel barrier with steel sections in effective lengths of 4, 8 and 12 m. The system meets NCHRP 350 TL-3 test requirements and uses an interlocking steel pivot that allows each module to follow curves of up to 6º. Disadvantages of this system are that it must be anchored, it is difficult to move in a short time, and it requires separate equipment to move the sections.

Concrete Reaction Tension System (CRTS). This concrete barrier system relies on a barrier transfer machine that can move barriers up to two lanes at a speed of 10 mph. The CRTS system can move across lanes allowing for versatility of lane closures. However, the system is relatively expensive as special equipment is required to move the barriers.

Steel Reactive Tension System (SRTS). Like the CRTS, the SRTS requires a barrier transfer machine. In fact, the applications of the SRTS are the same with the CRTS. While the steel system offers less protection to workers, it is lighter and smaller allowing the system to be moved more quickly and used in situations with minimal lane width.

K Rail. This system is a concrete barrier that provides low deflection and very high containment. This system allows for pin connections (1.1 m deflection) and bolted connections (1 m deflection). The weight of this system makes it difficult to move, as heavy equipment is required. Further, the K Rail is limited in its applications due to cost, and it is most suited for bridge work.

Balsi Beam. This is a steel barrier system that provides 30 ft of protected work space. The system is composed of two hydraulically controlled box beams attached to the sides of a flatbed trailer. The system is towed by a semitractor making it highly mobile. While the system is light and agile, it has yet to pass the most rigorous FHWA crash test standards.

Note. *Adapted from "Temporary Barrier Usage in Work Zones," by C. Lohse, D. Bennett and S. Velinsky, 2007, Sacramento, CA: California Department of Transportation.*

Photo 3: The mobile barrier trailer (MBT-1) is a rigid-wall trailer that serves as a structural and visual barrier between a highway construction worksite and active roadways.

While the effects of most of the noted features are obvious, the potential safety associated with work zone lighting warranted additional investigation. To measure the quality of this lighting, various scenarios were modeled using illuminance, glare and shadowing relationships. This analysis was performed to help future users of MBT-1 select appropriate lighting schemes for highway construction and maintenance work tasks.

Before presenting the results of the analysis, an overview of lighting metrics and relationships is provided. It should be noted that the fully extended MBT-1 system includes three 1,000 W halogen light sources (one for each barrier section), which each provide 32,000 lumens. Each light pole can be adjusted between 9 and 12 ft in mounting height.

Overview of Properties of Lighting Schemes

Lighting of a work zone can have a considerable effect on motorists and worker safety, quality of work, productivity and worker morale (Finley & Ullman, 2007). Although lighting requirements for nighttime construction have been established, many variables affect the quality of work zone lighting. The intensity, orientation, direction and location of lighting sources affect lighting quality, specifically illumination, glare and shadowing. If visibility is poor, workers are more likely to be struck by heavy equipment, passing motorists or materials.

The following discussion covers the three salient aspects of lighting that affect safety on highway work zones: 1) illuminance; 2) glare; and 3) shadowing. To provide context, these terms are defined as follows.

- **Illuminance** is the amount of light arriving at a surface measured in lux (1 lux = 1 lumen/m^2 = 0.093 foot-candle).
- **Glare** is uncomfortable or disabling light in the field of view caused by excess luminance and luminance contrast.
- **Shadowing** is a part of a surface that appears dark and unperceivable when a physical object blocks light.

Illuminance

Ellis, Amos and Kumar (2003) discuss different lighting layouts, including light plant and machine-mounted lighting methods, and provide illumination guidelines for different construction tasks. These guidelines are based on human, environmental, task-related and lighting factors. The result of this study showed that Illuminating Society of North America and OSHA have recommended minimum light levels for three categories of construction (Table 2).

Table 2

Recommended Minimum Illuminance Levels & Categories for Nighttime Highway Construction/Maintenance

Category	Minimum illuminance level lx (fc)	Area of illumination	Type of activity	Example of areas and activities to be illuminated
I	54 (5)	General illumination throughout spaces	Performance of visual task of large size; medium contrast; low desired accuracy; or for general safety requirements	•Excavation •Sweeping and cleanup •Movement area in the work zone •Movement between two tasks
II	108 (10)	General illumination of tasks and around equipment	Performance of visual task of medium sizes; low to medium contrast; medium desired accuracy; or for safety on and around	•Paving •Milling •Contcrete work •Around paver, miller and other construction equipment
III	216 (20)	Illuminance on task	Performance of visual task of small sizes; low contrast; or desired high accuracy and fine finish	•Crack fililng •Pot filling •Signalization or similar work requiring extreme caution and attention

Note. *Adapted from* Illumination Guidelines for Nighttime Highway Work, *by R. Ellis, S. Amos and A. Kumar, 2003, Washington, DC: Transportation Research Board, National Research Council.*

Glare

According to Ellis, et al. (2003), the three major sources of glare on construction worksites are passing vehicles, temporary work area lighting and lighting on construction equipment. In addition to limiting construction workers' vision, glare can cause discomfort and pain when severe. Bullough, Brons, Qi, et al. (2008), describe glare on the comparative de Boer scale that includes descriptors of glare which range from just noticeable (1) to just permissible (5) to unbearable (9).

They model discomfort glare (DG) as a function of the light from the source, the light from the immediate surroundings of the source and the overall ambient light, then use the de Boer scale to evaluate the potential for glare.

Shadowing

The third visual performance metric, shadowing, is measured using the vector-scalar ratio (VSR). This ratio is intended to classify the directionality of light, which quantifies the potential for shadowing and object recognition capabilities of a given lighting setup.

While little has been published on this topic, Cuttle (1971) developed a guideline for calculating and analyzing the VSR using the six Cartesian directions. In this relationship, the illumination vector is defined as the directional component of light (i.e., where the light comes from relative to a specific reference point) while the scalar illuminance is the degree to which the light diffuses over a target area. The vector quantity divided by the scalar quantity provides the VSR and has a maximum value of 4.0 (no diffusion) and a minimum value of 0 (complete diffusion).

Once VSR is calculated, the values can be compared against Table 3 to determine the directionality of the light.

Findings From Light Modeling

The evaluation metrics for the MBT-1 lighting follow standard design guidelines in the measurement of the VSR and the de Boer glare metric. The guidelines presented by Report 498 were used to evaluate the extent to which the MBT-1 lighting is adequate based on the quantitative measure of illuminance and the qualitative measure of glare. In addition, the VSR was used to evaluate the intensity of shadows in the workzone and the de Boer glare metric was used to quantitatively evaluate glare.

Computations required measurement of quantitative metrics and creation of a computer model that simulates the exterior lighting condition based on the MBT-1's one-, two- and three-pole configurations. The program used for this was AGI32, which takes 3-D model inputs and the light source intensity distribution file and computes the illuminance at specified calculation points in the 3-D environment.

The calculation point boundary was defined as a rectangular grid that is the complete length of the MBT-1 setup (two or three sections and 9- or 12-ft mounting by 40 ft) perpendicular to the barrier. Only two and three sections of the MBT-1 were analyzed as the single light pole no longer has any advantage over a standard generator light cart. The large calculation grid allows an evaluation of the usable work space at night based on lighting conditions alone. Within this boundary, a 5 x 5 ft spacing between points was used to get a reasonable understanding of the lighting quality across the work area.

Quantity of Light

The evaluation of quantity of light is based on the horizontal illuminance at the ground plane computed in the model. This is a critical aspect that determines the general visibility of the unobstructed workplane. This is a verification of the task visibility ignoring issues relating to shadows on the specific task and glare in the field of view. Without adequate light levels, workers are likely to underperform, but more critically, are more likely to be involved in incidents that were initiated inside the work zone.

In general, the MBT-1 has adequate illuminance for all task categories as long as they are performed within 20 ft of the barrier with all configurations. In terms of illuminance alone, there appears to be little difference in usable area by changing from a 9-ft mounting

Shadowing is measured using the vector-scalar ratio. This ratio helps classify the directionality of light, which quantifies the potential for shadowing and object recognition capabilities of a given lighting setup.

Table 3

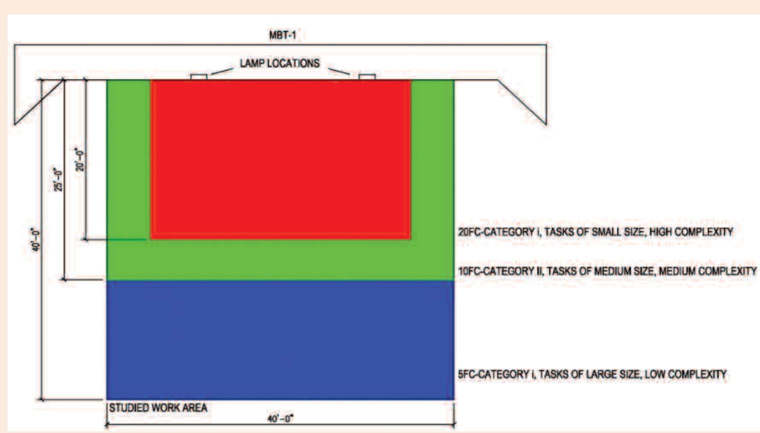
VSR Interpretation

VSR	Strength of the flow of light	Typical appraisal
3	Very strong	Strong contrasts: Detail in shadow is not discernible.
2.5	Strong	Noticeably strong directional effect: Suitable for display but generally too harsh for human features.
2	Moderately strong	Pleasant appearance of human features for formal or distant communication.
1.5	Moderately weak	Pleasant appearance of human features for informal or close communication.
1	Weak	Soft lighting effect for subdued contrasts.
0.5	Very weak	Flat shadow-free lighting: Directional effect is not discernible.

Note. *Adapted from* The Flow of Light in Lighting Design, *by C. Cuttle, 1971, St. Helens, England: Environmental Advisory Service, Merseyside.*

Figure 1

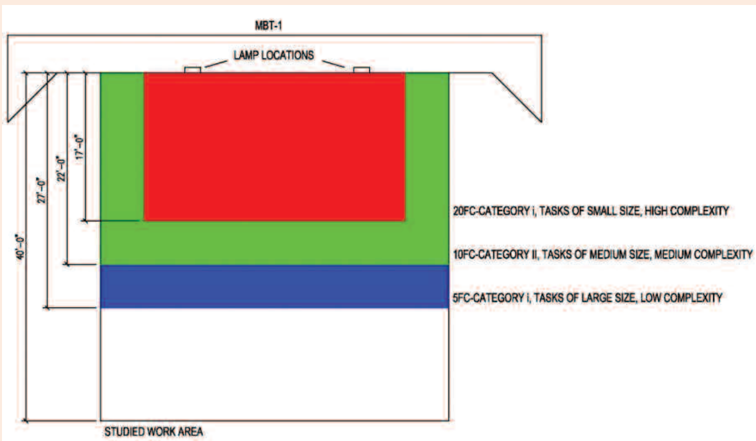
Illuminance Categories & Task Capabilities: Two Sections, 12 ft



Note. *Illuminance categories and corresponding task capabilities for studied work area for two sections of MBT-1 at 12-ft mounting height.*

Figure 2

Illuminance Categories & Task Capabilities: Two Sections, 9 ft



Note. *Illuminance categories and corresponding task capabilities for studied work area for two sections of MBT-1 at 9-ft mounting height.*

Figures 1-4 indicate the recommended work zones by task type and MBT-1 setup. These figures highlight the areas of the work zone where specific task categories (1-3) are most appropriate given the quantity and quality of light.

to a 12-ft mounting, although the 9-ft mounting has a much lower uniformity. Therefore, based on illuminance alone, it appears that the 12-ft mounting has a slight advantage over the 9-ft mounting, unless a specific activity requires greater illuminance than Category III according to Ellis, et al. (2007).

Figures 1-4 (pp. 35-38) indicate the recommended work zones by task type and MBT-1 setup. These figures highlight the areas of the work zone where specific task categories (1-3) are most appropriate given the quantity and quality of light. As shown, all of the lighting schemes for the MBT-1 provide a large illuminated area for each task type. Just as important is the increased level of uniformity that a multiple source system, such as the MBT-1, creates as opposed to a single source.

Shadowing

The evaluation of shadow strength is based on the VSR also computed at the ground plane. As AGI32 does not compute VSR directly, six separate calculation planes (one for each positive and negative Cartesian direction) were created. VSR was computed at each location on this grid. If VSR is too high and an object or piece of equipment is introduced in the work zone, objects or tasks within the shadowed area will be hard to see and potentially avoidable incidents can occur.

Even with the multiple lamp scheme, there remains a strong directionality of light and potential for dangerous shadows. This can be seen in the best case-scenario of VSR (which uses three separate sources at a mounting height of 12 ft) shown in the contour plot of Figure 5 (p. 38). The regions with the highest values (3.5 to 4) have the highest shadowing and the regions with the lowest values (0 to 0.5) have the least shadowing.

Therefore, tasks that require extensive detail or complex tasks should be performed as close to the barrier system as possible or during the day. Again, it is important to note that, theoretically, the shadows caused by a single source system are completely debilitating; this requires repositioning to be able to see objects or obstacles within the shadowed region. While shadowing is still high with the MBT-1 lighting system, the addition of multiple light sources decreases shadowing, which allows for an increase in visibility within shadowed regions.

Glare

Ellis, et al. (2007), provide a guideline to avoid glare. The light source should be aimed no higher than 60°. MBT-1's lighting complies with this guideline under all lighting schemes. In some locations, workers will be subject to bright light sources that cause significant glare. The glare produced by MBT-1's lights was examined using the relationships and strategies discussed in the literature review of this article.

According to Figure 6 (p. 38), which shows the least de Boer rating, created from the results of the glare metric calculations, the MBT-1 fixtures will create uncomfortable glare regardless of where in the construction area the lamps are viewed from. Glare will be strongest 20 to 30 ft from the system. According to the de Boer scale, the glare in this region is disturbing, while less than 20 ft from the MBT-1 the glare is just permissible. The fixture will have the highest intensity values in this area and the lamp will be in full view of workers.

Therefore, head-up tasks, those that do not require one to look primarily at the ground plan, should be completed as close to the MBT-1 as possible and preferably less than 20 ft away. As much as glare is a problem with the MBT-1 lighting configuration, a much brighter single light source, as found in the traditional roadway construction lighting setup, would likely be much greater.

Perceived Benefits of the Mobile Barrier

The MBT-1 system provides an innovative solution to the increasing safety issues related to construction and maintenance on highway work zones. As noted, the major causes of highway work zone injuries include poor illumination, poor signage, incursions and workers on foot being struck by heavy mobile equipment.

The MBT-1 addresses all of these causal factors by providing up to 100 ft of crash-tested barrier with adjustable lighting, a customizable three-line message board and a visual barrier between workers and active roadways. The system also provides a less-cluttered work zone due to a decrease in the collateral vehicles associated with the ring of steel (Mobile Barriers LLC, 2009).

Based on research conducted by Hinze (2006), worksites with visual barriers to prevent distractions increase both safety and productivity. No other barrier system currently provides such a visual barrier that is also crash-tested to prevent injuries associated with incursions. The visual barrier improves safety by reducing the frequency of rubbernecking from the traveling public and distractions to workers from passing traffic. According to Hinze, reducing distractions from outside the work zone increases productivity and safety because attention can be redirected on hazards within the work zone and task achievement.

The primary lighting benefits of the MBT-1 versus traditional roadway construction lighting are due to the multiple source layout, therefore is really only an improvement when multiple sections are used. Using multiple light sources has multiple potential benefits. First, a distributed lighting scheme creates more uniform brightness across the work zone. The optics from a single source can only do so much to spread the light across the work zone.

Also, multiple source locations reduce shadowing. The overlap of the light from each source allows light to strike the work plane even when one source is being blocked by an object or worker.

In addition, to achieve the same brightness on the work zone from only one source, the source must be much brighter, which creates additional glare and potential effectiveness and safety issues.

Conclusions & Recommendations

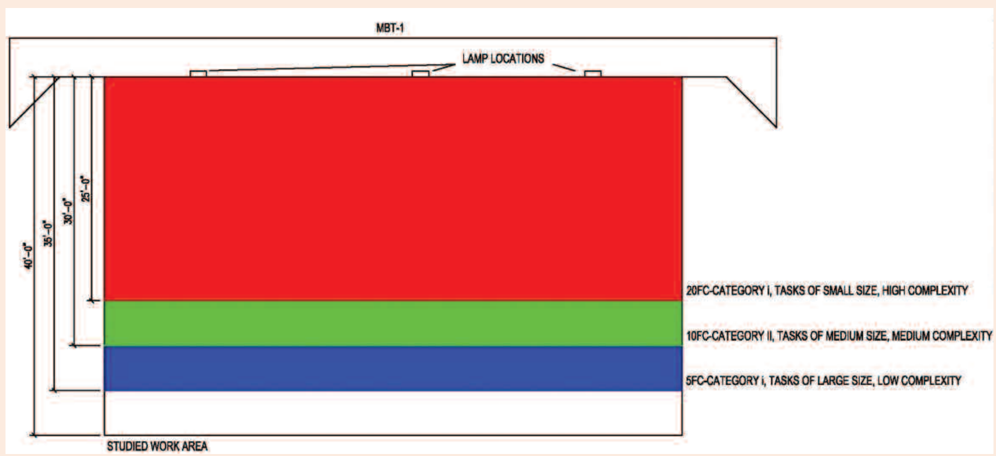
The MBT-1 could have a significant impact on the safety of highway construction and maintenance work zones. Unlike other systems, it offers a completely mobile barrier that requires minimal equipment to operate and includes high-quality lighting schemes that are preferred to traditional work zone lighting methods, a programmable message board and an attenuator. The system is also crash-tested to the most rigorous FHWA standards. This research shows that when used properly, this system offers excellent work zone lighting in addition to the mobile steel barrier.

One chief benefit of the system is that it provides a highly mobile, high-strength physical barrier from adjacent traffic. Daniel, Dixon and Jared (2000) found that straight, level work zone roadways are much more accident prone than ones with horizontal or vertical curves. This is because drivers are much more comfortable on straight, level roads as opposed to curved ones and so less rubbernecking occurs on more dangerous roadways (Harb, 2008).

All of the lighting schemes for the MBT-1 provide a large illuminated area for each task type. Also important is the increased level of uniformity that a multiple source system creates.

Figure 3

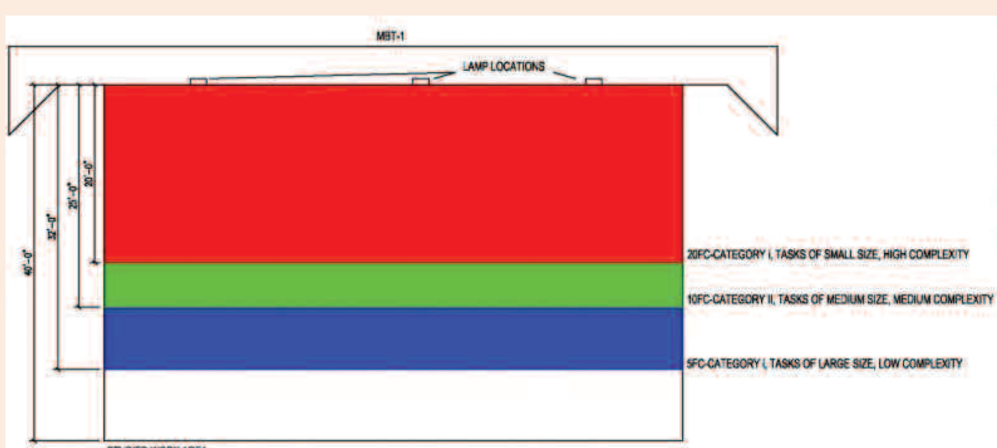
Illuminance Categories & Task Capabilities: Three Sections, 12 ft



Note. *Illuminance categories and corresponding task capabilities for studied work area for three sections of MBT-1 at 12-ft mounting height.*

Figure 4

Illuminance Categories & Task Capabilities: Three Sections, 9 ft



Note. *Illuminance categories and corresponding task capabilities for studied work area for three sections of MBT-1 at 9-ft mounting height.*

Figure 5

VSR Over Construction Area

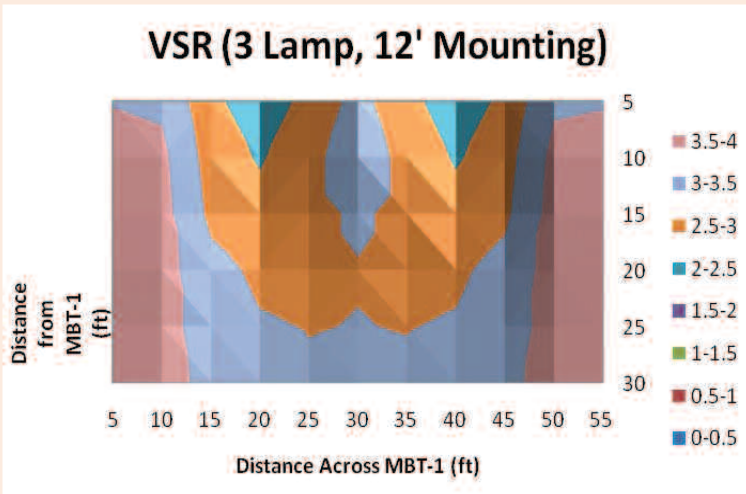
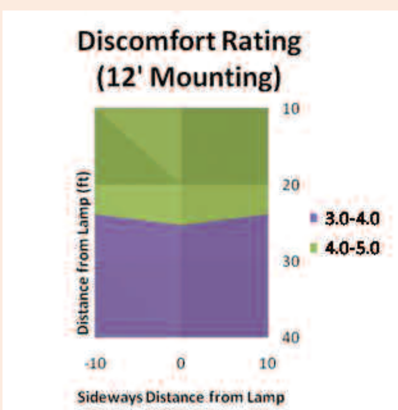


Figure 6

de Boer Glare Ratings



Note. *de Boer glare ratings for 12-ft mounting from a single source.*

The MBT-1 provides a solid barrier that prevents vehicles from entering into the construction work zone despite potential distractions.

Additionally, the system offers increased lighting uniformity, decreased shadowing in the work zone and decreased glare when performing heads-up tasks. Those agencies or private contractors that consider using the system can consider the following recommendations for optimizing the lighting system:

• Use the maximum number of light poles available for the specific MBT-1 setup.

• The most difficult tasks should be performed as close to the barrier system as possible to take advantage of the maximum brightness and minimum glare.

• Always use the 12-ft poles in lieu of the 9-ft poles to achieve the greatest shadow reduction and least possible glare.

Finally, the authors recommend future research on the following topics: 1) the life cycle safety impact of various work zone protection systems; 2) cost-benefit analysis of the MBT-1 and other barrier systems; 3) comparison of lighting models with actual measurements; 4) a longitudinal study that investigates the impact of mobile barriers over time; and 5) a study that investigates the most applicable construction and maintenance tasks for MBT-1 deployment. ■

Tasks that require extensive detail or complex tasks should be performed as close to the barrier system as possible or during the day, as should head-up tasks, which do not require one to look primarily at the ground plan.

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