

# **Mn/DOT Emergency Lighting Field Evaluation**

## **Summary and Recommendations**

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### **Introduction**

The purpose of this paper is to summarize the observations and recommendations made at the Mn/DOT Emergency Lighting Evaluation conducted on June 19<sup>th</sup>, 2006 at the MN State Fair grounds Midway area. The evaluation itself was a comparison of emergency light styles used by a variety of agencies that respond to highway incidents. The study concentrated on rear facing lighting only, side and front lights were not looked at. The pool of evaluators was made up of Mn/DOT lighting staff, Dr. Mike Hanen-Smith (doctor of optometry), and representatives from the emergency services present. The evaluation had several goals, including; allowing the Mn/DOT personnel responsible for Mn/DOT truck lighting standards to see current styles of lighting used by emergency services and to allow those responders to see how their lights compare with others in different ambient light situations. A second goal was to get the professional opinion of a vision specialist on the physiological affects of emergency lighting on different classes of drivers. A third goal was to gather lighting recommendations for a Mn/DOT-sponsored highway responder safety training program.

**It is important to note that while proper emergency lighting can play a role in protecting responders from secondary incidents it is by no means a guaranty of safety. Responders should park defensively, allow for advanced warning and proper decision sight distance, and try to shield themselves from passing traffic as much as practical. Drunk, drowsy and distracted drivers are a severe threat to responders parked along the roadways. Mn/DOT early warning trucks equipped with 8 foot wide by 4 foot high flashing arrow boards are struck several times a year by driver's who claimed "they never saw them". Vehicles may lose control on icy or wet pavement and slide into the scene or responders can be struck by flying debris, all completely independent of emergency lighting displayed.**

A total of fifteen vehicles were evaluated; 2 ambulances, 3 police squads, 4 fire trucks, 4 DOT plow trucks, 1 DOT freeway service patrol pickup and 1 DOT utility pickup. Vehicles were viewed in 3 groups of 5 from two distances, 1000 feet and 150 feet. The 1000 foot distance simulated a 13 second decision sight distance at 50 mph, the 150 foot distance simulated a 2 second distance at 50 mph. All vehicles were observed in three ambient light conditions, bright sun (1pm-2pm), twilight (7:30pm-8:45pm) and darkness (9pm-10pm). The evaluation was conducted in the vacant State Fair Midway lot. This lot is flat, paved and is 1200 feet long, 200 feet wide, and has no visual obstructions and no lighting. The long portion of the lot is oriented east / west, which allowed a fairly strong sun glare for the twilight portion. For the evaluation, vehicles were spaced 30 feet apart, with all rear-facing lighting activated typical for a highway response. The observers stood behind each vehicle group being evaluated, starting first at the 1000 foot distance, then moving to 150 feet, scoring each vehicle on a 1 to 5 scale of relative "noticeability", pain or discomfort from the light's brightness, and opinion on overall lighting. Observers were also encouraged to write down their own comments on each specific vehicle's lighting array.

### **Recommendations and Observations**

#### **Responder Awareness and Training**

Responders are frequently unaware of what their own vehicle looks like from the perspective of the driving public. Agencies should require all responders to observe their own emergency lighting schemes at a variety of distances (near and far), during different ambient light (bright sun, dusk, and dark) and weather conditions (clear, rain, snow, fog) so that they better understand the limitations and impact of the lights utilized.

## **Field Comparisons of Similar Light Packages Prior to Purchase**

Great variance was found between similar styles of lighting in output strength, color visibility, and overall effectiveness. For example, two comparable LED light packages were tested on Mn/DOT plow trucks; evaluators found one package very bright and effective, the other less so. Those responsible for purchasing emergency lighting should compare competing light packages, side by side, in a variety of ambient light, and if possible, weather conditions before making equipment installation choices. It is also recommended to include a variety of observers, spanning as much of the legal driving age as possible, including both men and women. Even with the limited pool of evaluators during the Mn/DOT field test, a wide range of opinion on the effectiveness, visibility, and distraction factors was noted.

## **Brightness and Intensity versus Ambient Light**

Bright, sunny conditions are the most challenging time for emergency lights. All of the emergency lights evaluated in the field study performed reasonably well during dark conditions, but several failed during bright sun. Conversely, many of the light packages that rated well during bright sun were described as overly bright, distracting, and produced strong glare reactions during dark conditions. Any evaluation of light packages should include observation during the brightest and darkest ambient light conditions.

## **Vertical Height**

Vertical height is the single most important element in the visibility of emergency vehicle lighting. Lighting should be placed as high as possible to be visible over other vehicles and slight changes in terrain.

## **Vertical Separation**

Vehicle lighting placement must account for the visual angle of oncoming traffic. Rear facing emergency lighting should outline the vehicle vertically as well as horizontally to help establish size and scale recognition for approaching traffic. A lack of separation between horizontal rows of lights, such as light bars, causes those lights to blend together when viewed from a distance. All vehicles benefit from illuminating all four rear corners. Larger vehicles such as fire trucks, ambulances and DOT plow trucks should also consider a middle row of lighting to prevent a confusing dark center. Smaller vehicles, like police squads, should consider balancing roof mounted light bars with bumper mounted strobes.

## **Flash Patterns**

Optimizing the sequence of flashing lights must balance between outlining the shape of the vehicle and attracting attention, without becoming confusing. Sequences that produce an “all lights off” time should be avoided; this includes sequences that switch between illuminating all-left and all-right. Typical vehicle lighting, such as brake and tail lights are oriented on a horizontal planes, therefore it is recommended that flashers be tied to operate diagonally to attract more attention. The recommended pattern should produce a sequence of top right/bottom left and top left/bottom right.

Lights that flash quicker tend to produce stronger glare reactions than slower patterns. More research is needed on exact specifications for on/off time, however it is recommended that the ON time be longer than the OFF time. When programming flash times, a suggested range is 60% to 75% on and 25% to 40% off.

## **Size of Strobes/LED's**

When comparing placement of single-array flashing lights; evaluators generally preferred large, bright, single-color lights over a mixture of smaller, high intensity LED's or strobes. Larger sized lights were more visible and better to able communicate vehicle size, especially in bright sun.

## **Light colors**

Colors available to various responding agencies are regulated through State law. However, within those restrictions, differences were noted in the relative visibility of the same color displayed by different vendors. Therefore it is recommended that competing light packages be compared side by side between different vendors to choose the optimum color display.

Evaluators generally noted that red lights were more visible in daytime than blue. At night, blue lights tended to be more visible than red. This finding matches other studies and generally is due to differences in color sensitivity of the human eye during bright and dark ambient light conditions. Amber colored lights were visible in all ambient light conditions. Multiple colors, especially on light bars, had a tendency to morph together into a blob of whitish colored light from a distance. Light-bar mounted traffic director arrow sticks had a tendency to overpower the colored light bar at long distances, but were not recognizable as giving instruction, instead having an overall appearance as a amber flasher. A strong, focused display of a single color, i.e.: red strobes on fire trucks were preferred over a less defined mix of light styles and colors. However, most evaluators recommended adding a second strong color such as blue to add contrast.

## **Arrow Sticks / Traffic Directors**

Six of the vehicles evaluated (3 fire, 2 police, and one Mn/DOT) were equipped with narrow amber light strips, commonly known as “traffic directors” or “arrow sticks”. One of the police vehicles and the Mn/DOT FIRST truck had the traffic director mounted as part of the light bar assembly, the other vehicles had them mounted separately. None of the six were visible distinctly enough from 1000 feet as providing direction; at best they became an amber flasher. The light bar mounted traffic directors tended to mix with the rotators and generally was not distinctly recognizable even at close range. The arrow sticks mounted separately from other lights became visible from 150 feet, especially during the lower light periods. However, the relatively small size (1 to 3 inches high), lack of clear message, inconsistent use, and combination with other flashing lights makes the effectiveness of the instructional message questionable.

## **Down-lighting**

Downward facing lighting, mounted on the vehicle’s undercarriage, can be used to illuminate and delineate vehicle space to nearby and passing traffic during low light periods. This type of lighting could also be helpful in illuminating responders wearing retroreflective gear operating near the emergency vehicle without causing glare reactions for oncoming traffic.

## **Training the Public: Standardized Response, Lighting, and Operational Usage**

The most significant element in emergency lighting is the driving public’s behavior as they approach emergency vehicles. Many individual responders assume their lighting provides adequate information, however to the general public emergency lights present little actual direction; instead they simply illuminate the vehicle. In some cases the variety and intensity of the lights overwhelms other critical visual items, such as a responder on foot directing traffic. Attempts to provide direction, in the form of small arrow sticks, are too small and indistinguishable to truly be effective. As much as practical, standardized response placement makes emergency scenes more recognizable to the public. Standardized levels of lighting intensity also communicate valuable information to oncoming traffic while still keeping within the decision sight distance. For example, use of high intensity rear flashing lights only when marking an imminent hazard, such as blocking a lane of traffic, while using less distracting, lower powered “marker” lights while parked on the shoulder. Key messages that need to be articulated to oncoming traffic include: “Keep going, but use caution”, “move over here”, or “stop”.

## **Lighting that Changes Intensity Based on Ambient Light Conditions**

Vehicles marked consistently as being “most noticeable” during bright sun period also tended to be rated as being painfully bright during dark periods. Overly bright lights run the risk of blinding drivers at night creating additional safety risks. Having the ability to either manually or automatically reduce the power of the lights would be a logical solution, however individual responders felt this would be a liability hazard in the event their vehicle is struck while in a “reduced light” condition. This issue needs to be investigated further. On a departmental level, having clear policies and procedures for lighting use could be a means to protect individual responders from litigation.

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## Evaluation Questions

### Far (1000 feet)

1. How "noticeable" are the lights in comparison to the other vehicles? (1 = Less 3=Average 5=More)
2. To what extent does the lighting convey or outline the shape and size of the vehicle? (1 = Not at all to 5 = Completely)
3. If applicable, how effective is the arrowstick or arrowboard in telling you where to go? (1 = Not Effective to 5 = Very Effective)
4. What light color is MOST visible? <sup>1</sup>
5. What light color is LEAST visible?
6. Overall from this distance is the vehicle under lit, just right, or over lit?

### Near (150 feet)

1. How "noticeable" are the lights in comparison to the other vehicles? (1 = Less, 3=Average, 5=More)
2. To what extent does the lighting convey or outline the shape and size of the vehicle?
3. If applicable, how effective is the arrowstick or arrowboard in telling you where to go? <sup>2</sup> (1 = Not Effective to 5 = Very Effective, N/A if no device) <sup>3</sup>
4. To what extent does the brightness or intensity of the lights cause discomfort making it difficult to look at the vehicle? (1 = No discomfort, 3 = Average, 5 = Great Discomfort)
5. To what extent do the emergency lights block out the "pedestrian"? (1 = Does NOT obscure, barrel IS visible to 5 = Completely obscures, barrel NOT visible)
6. Overall from this distance is the vehicle under lit, just right, or over lit?

### Rating Scale



Evaluator's scored each question on a one to five scale. One equals less then average, three equals average to other vehicles, and five is greater then average.

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<sup>1</sup> Due to a wide variety of responses, the Least and Most Visible light colors are not individually listed for each vehicle. Overall color sensitivity is summarized in the previous section.

<sup>2</sup> Due to the relatively quick pace of the evaluation, it is unlikely that viewer's eyes became truly night adjusted. Therefore it is suggested that readers add an extra point this rating total

<sup>3</sup> The "pedestrian" was simulated by positioning a Mn/DOT type-B 36" channelizer drum approximately 2 feet from the driver's door of each vehicle.

## EMS

HCMC EMS Ambulance – Standard Flashers			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	1.9	1.8	2.3
Conveys shape of vehicle?	2.3	1.9	2.7
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	1.7	1.5	2.2
Near - 150 feet			
Day	Twilight	Dark	
How noticeable?	2.3	1.6	2.2
Conveys shape of vehicle?	2.9	2.8	3.2
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.1	1.1	1.2
Blocks pedestrian?	1.1	1.1	1.5
Overall lighting	1.8	1.6	2.2



Allina EMS Ambulance - LED Flashers			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	4.7	4.7	4.5
Conveys shape of vehicle?	4.2	3.9	3.6
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	3.3	3.4	3.9
Near - 150 feet			
Day	Twilight	Dark	
How noticeable?	5.0	4.4	4.6
Conveys shape of vehicle?	4.5	3.7	3.9
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.6	1.3	2.6
Blocks pedestrian?	1.2	1.1	2.0
Overall lighting	3.4	3.1	3.9



## Fire

Maple Grove Fire Engine - Flashers & Rotators			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	2.6	2.2	3.0
Conveys shape of vehicle?	2.9	3.1	3.8
Effectiveness of Arrowstick/board?	2.0	3.2	2.8
Overall lighting	2.4	2.3	3.1
Near - 150 feet			
Day	Twilight	Dark	
How noticeable?	2.1	2.3	3.1
Conveys shape of vehicle?	3.2	3.5	3.8
Effectiveness of Arrowstick/board?	2.0	2.9	3.3
Discomfort?	1.2	1.3	1.7
Blocks pedestrian?	1.2	1.1	2.0
Overall lighting	2.3	2.4	3.2



New Brighton Fire Engine - LED & Rotators			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	2.4	2.7	3.3
Conveys shape of vehicle?	2.7	3.4	3.7
Effectiveness of Arrowstick/board?	2.0	2.3	2.3
Overall lighting	2.0	2.5	3.1
Near - 150 feet	Day	Twilight	Dark
How noticeable?	2.9	3.1	3.4
Conveys shape of vehicle?	3.4	3.7	3.6
Effectiveness of Arrowstick/board?	n/a	3.0	2.6
Discomfort?	1.4	1.3	2.3
Blocks pedestrian?	1.3	1.1	1.5
Overall lighting	2.4	2.8	3.5



Minneapolis Fire Mobile Command - LED Flashers			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	4.1	3.9	3.7
Conveys shape of vehicle?	4.3	4.0	3.9
Effectiveness of Arrowstick/board?	2.0	2.6	2.0
Overall lighting	3.1	3.1	3.4
Near - 150 feet	Day	Twilight	Dark
How noticeable?	3.9	3.6	3.9
Conveys shape of vehicle?	4.1	3.9	4.2
Effectiveness of Arrowstick/board?	n/a	2.7	2.6
Discomfort?	1.5	1.5	2.1
Blocks pedestrian?	1.2	1.1	1.6
Overall lighting	2.8	2.9	3.3



Minneapolis Fire Spare Ladder 12 - Flashers			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	1.3	1.3	1.8
Conveys shape of vehicle?	2.3	2.2	2.7
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	1.4	1.5	1.9
Near - 150 feet	Day	Twilight	Dark
How noticeable?	1.6	1.9	2.1
Conveys shape of vehicle?	2.7	2.7	3.1
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.1	1.1	1.5
Blocks pedestrian?	1.0	1.1	1.9
Overall lighting	1.6	1.9	2.4





## Police

Minneapolis Police Squad - Federal Solaris LED light bar			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	4.4	4.5	4.6
Conveys shape of vehicle?	2.1	3.0	2.7
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	2.8	3.5	3.8
Near - 150 feet	Day	Twilight	Dark
How noticeable?	4.1	4.5	4.1
Conveys shape of vehicle?	3.2	3.6	3.2
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.8	3.0	3.5
Blocks pedestrian?	1.0	1.4	2.4
Overall lighting	3.0	3.6	3.8



Minneapolis Police Squad - Code-3: Code 360 light bar			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	1.9	2.5	2.4
Conveys shape of vehicle?	1.9	2.7	2.8
Effectiveness of Arrowstick/board?	1.6	1.9	1.5
Overall lighting	1.8	2.9	2.9
Near - 150 feet	Day	Twilight	Dark
How noticeable?	2.2	2.8	2.5
Conveys shape of vehicle?	3.1	3.4	3.0
Effectiveness of Arrowstick/board?	2.8	2.1	1.8
Discomfort?	1.1	1.9	1.6
Blocks pedestrian?	1.0	1.3	1.6
Overall lighting	2.3	2.8	2.7



Minneapolis Police Squad - EP911 LED rear window			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	1.4	2.8	2.9
Conveys shape of vehicle?	1.9	2.9	3.1
Effectiveness of Arrowstick/board?	1.5	2.3	1.3
Overall lighting	1.5	2.7	3.0
Near - 150 feet	Day	Twilight	Dark
How noticeable?	2.8	3.3	3.2
Conveys shape of vehicle?	3.6	3.7	3.4
Effectiveness of Arrowstick/board?	2.7	3.3	3.0
Discomfort?	1.1	1.6	1.6
Blocks pedestrian?	1.0	1.1	2.1
Overall lighting	2.5	3.1	3.0





# Mn/DOT

Mn/DOT Plow - Whelan 2006 LED Flasher				
Far - 1000 feet	Day	Twilight	Dark	
How noticeable?	2.6	3.1	3.5	
Conveys shape of vehicle?	2.8	2.7	3.4	
Effectiveness of Arrowstick/board?	n/a	n/a	n/a	
Overall lighting	2.4	2.7	2.9	
Near - 150 feet	Day	Twilight	Dark	
How noticeable?	2.9	3.4	3.4	
Conveys shape of vehicle?	2.7	2.8	3.3	
Effectiveness of Arrowstick/board?	n/a	n/a	n/a	
Discomfort?	1.2	1.3	1.9	
Blocks pedestrian?	1.0	1.1	2.3	
Overall lighting	2.6	2.7	2.9	



Mn/DOT Plow - PSE 2006 LED Flasher				
Far - 1000 feet	Day	Twilight	Dark	
How noticeable?	4.6	4.6	4.3	
Conveys shape of vehicle?	2.9	3.1	3.6	
Effectiveness of Arrowstick/board?	n/a	n/a	n/a	
Overall lighting	2.9	2.9	3.3	
Near - 150 feet	Day	Twilight	Dark	
How noticeable?	3.9	4.3	3.6	
Conveys shape of vehicle?	2.8	2.8	3.4	
Effectiveness of Arrowstick/board?	n/a	n/a	n/a	
Discomfort?	1.2	1.3	2.4	
Blocks pedestrian?	1.0	1.1	2.4	
Overall lighting	2.8	2.9	3.1	



Mn/DOT FIRST - Federal Vista & Lite-Sys LCD Board				
Far - 1000 feet	Day	Twilight	Dark	
How noticeable?	4.5	4.3	4.3	
Conveys shape of vehicle?	2.9	2.7	2.9	
Effectiveness of Arrowstick/board?	5.0	5.0	4.5	
Overall lighting	3.5	3.4	3.7	
Near - 150 feet	Day	Twilight	Dark	
How noticeable?	4.5	4.5	4.7	
Conveys shape of vehicle?	3.0	3.1	3.3	
Effectiveness of Arrowstick/board?	4.9	5.0	4.8	
Discomfort?	1.9	2.5	3.3	
Blocks pedestrian?	1.0	1.4	2.9	
Overall lighting	3.6	3.4	4.0	



(Note: The arrow board on the FIRST truck is equipped with an auto dimmer that should reduce the brightness of the sign during dark periods. It is unknown if this was functioning properly during the test period)

Mn/DOT Plow - Whelan 2006 Strobe			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	3.6	2.9	3.2
Conveys shape of vehicle?	2.9	2.9	3.5
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	2.9	2.5	3.1
Near - 150 feet	Day	Twilight	Dark
How noticeable?	3.4	3.2	3.4
Conveys shape of vehicle?	2.7	2.9	3.4
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.6	1.5	2.9
Blocks pedestrian?	1.0	1.1	2.6
Overall lighting	2.4	2.7	3.0



Mn/DOT Plow - Federal 2001 Strobe			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	2.9	2.9	3.2
Conveys shape of vehicle?	3.1	3.1	3.5
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	2.6	2.7	3.0
Near - 150 feet	Day	Twilight	Dark
How noticeable?	3.0	3.1	3.4
Conveys shape of vehicle?	3.1	3.1	3.3
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.5	1.6	2.9
Blocks pedestrian?	1.0	1.1	2.7
Overall lighting	2.6	2.8	3.0



Mn/DOT TMC pickup Federal Streethawk			
Far - 1000 feet	Day	Twilight	Dark
How noticeable?	3.3	2.9	3.0
Conveys shape of vehicle?	2.3	2.5	2.6
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Overall lighting	2.7	2.5	2.9
Near - 150 feet	Day	Twilight	Dark
How noticeable?	3.4	3.2	3.0
Conveys shape of vehicle?	2.4	2.3	2.5
Effectiveness of Arrowstick/board?	n/a	n/a	n/a
Discomfort?	1.2	1.5	1.7
Blocks pedestrian?	1.0	1.1	2.8
Overall lighting	2.5	2.8	2.9

