



# Law Enforcement Vehicle Lighting and Reflectivity Studies: An Overview

This report was funded through a grant from the U.S. Department of Justice, Office of Justice Programs, National Institute of Justice. Neither the U.S. Department of Justice nor any of its components operate, control, are responsible for, or necessarily endorse, this report (including, without limitation, its content or conclusions.)



# INTRODUCTION

The Justice Technology Information Center (JTIC) undertook this study on lighting and reflectivity pertaining to emergency vehicles and first responders at the request of the National Institute of Justice (NIJ); NIJ has a long history of supporting standards for emergency vehicle and lighting equipment, going back to the early 1980s.

This document explores the history of lighting and reflectivity, the current state of adoption and future trends. Although this report deals with all three first responder disciplines (fire, EMS and law enforcement) it deals primarily with law enforcement.

This document discusses the following:

- The history of illumination and reflectivity of emergency vehicles, from simple paint color patterns to highly reflective materials.
- The status of emergency lighting and reflectivity, including current trends among law enforcement, fire and EMS.
- The future of emergency vehicle lighting and reflective materials.
- Reflectivity as it pertains to first responders at emergency scenes, particularly roadway scenes such as accidents, natural disasters, directing traffic and so on.



# LAW ENFORCEMENT VEHICLE LIGHTING AND REFLECTIVITY STUDIES


Emergency lights and sirens have been around almost since fire and law enforcement agencies began to use vehicles<sup>1</sup>. Emergency vehicle lights first became popular on police vehicles in the 1940s. The Michigan State Police had emergency lights on their first marked patrol vehicles: red spotlights mounted on the right front fender with the word "Stop" on the glass. The department began using overhead lights with front and rear red bulbs in the 1940s.<sup>2</sup>

A 1978 report by the National Bureau of Standards (now the National Institute of Standards and Technology) provided an overview of the then-current state of emergency vehicle warning lights.<sup>3</sup> At that time, there was an ongoing discussion about having different flash patterns to signal different actions to be taken by a driver. The report suggested no more than three or four different signal systems "in order to avoid a significant percentage of delayed or incorrect reactions." These included a pattern indicating something unusual ahead; an emergency vehicle is approaching; prepare to slow down; prepare to stop; and something is off the road, but slow down as you pass.<sup>4</sup>

The NBS report listed three types of emergency lights available at the time: rotating, oscillating and flashing.<sup>5</sup> Oscillating and rotating lights have largely been replaced by LED and strobe lights in today's emergency vehicles. An NIJ-sponsored Federal Emergency Management Agency (FEMA) report more than 30 years later lists four main types of lights used in the United States, with oscillating lights replaced by LED.<sup>6</sup>

The NBS' 1978 supplemental report, *Emergency Vehicle Warning Systems*, discussed the problems associated with the functional use of emergency vehicle warning systems and recommended a national standard system of warning light signals. It also described the types of lights commercially available at the time.<sup>7</sup> To date, no such standard has been developed.

Effective lighting and reflectivity aim to increase drivers' ability to see emergency vehicles so that they may react appropriately. This ability is also called *conspicuity*, or the degree to which a vehicle can easily be seen and recognized. There are two types of conspicuity: search conspicuity and attention conspicuity. *Search conspicuity* is the ability of a person who is searching for an object to be able to pick it out from other objects in the field of vision. *Attention conspicuity* is the ability to create awareness of an object for which an individual is not actively looking.<sup>8</sup>



Three main elements affect emergency vehicles and reflectivity: vehicle color, vehicle reflectivity and emergency lighting. A review of available research, reports and data indicates that the majority of available information pertains to lighting, with the least information available on color.

## Vehicle Color


Due to the advent of better, more visible lighting options, little research has been done about vehicle color. A common belief is that the first mass-produced cars came only in white or black. The subsequent production of "black and white" police vehicles set them apart from civilian vehicles.<sup>9</sup> Later, the addition of emergency lighting eliminated the need for the offsetting colors. Unlike the limited and less-effective emergency lights of decades ago, today's emergency lights and retroreflective markings have eliminated the need for specified paint schemes.

The United Kingdom has instituted a standard for emergency vehicles pertaining to vehicle visibility and conspicuity. The checkered pattern on emergency vehicles is known as the *Battenberg pattern*. This pattern is both fluorescent in the daytime and retroreflective at night. No similar standard exists in the United States.<sup>10</sup> Some of the research included in the report concerned whether the Battenberg pattern could reduce conspicuity due to possibly camouflaging a vehicle against a visually cluttered background.<sup>11</sup>

## Reflectivity

Unlike fire and rescue vehicles, no U.S. industry standard on the color or markings of law enforcement vehicles with regard to reflectivity exists.<sup>12</sup> Today's law enforcement vehicles use three main types of reflective markings:

- Contrasting chevrons on the rear of vehicles. Agencies should place these chevrons (mandated on fire and rescue apparatus<sup>13</sup>) low on the vehicles to optimize interaction with approaching vehicles' headlights.<sup>14</sup>
- Retroreflective decals such as police badges or patches. Agencies can concentrate retroreflective material on the rear to maintain stealth when facing traffic or patrolling.<sup>15</sup> According to an NIJ-sponsored study conducted by FEMA, the use of retroreflective agency logos or emblems could help improve emergency vehicle visibility and recognition.<sup>16</sup>
- Thin reflective striping that outlines the vehicle perimeter. This allows drivers not only to see the police vehicle better, but also gives them a sense of the vehicle's size and shape.<sup>17</sup>



An Arizona Blue Ribbon Panel suggested that chevron markings on the rear bumper of an emergency vehicle gave the appearance of a traffic barricade or bridge abutment, which a motorist would be inclined to avoid. The panel also favored the use of contour markings to outline the shape of a police vehicle. Additionally, members liked the new markings on Arizona Department of Public Safety vehicles: State troopers' cruisers had "HIGHWAY PATROL" in large, reflective lettering added to the trunks.<sup>18</sup>


## Emergency Lighting

Emergency lighting has two purposes: One, to alert motorists of the approach of an oncoming emergency vehicle; and two, to alert motorists of an emergency vehicle stopped in the roadway. These lights come in various colors and use different types of lighting. In the United States, agencies use five main colors of emergency vehicle lighting.<sup>19</sup>

- **Red:** The most common color used in the United States to denote an emergency vehicle. With the exception of law enforcement vehicles in certain states, police, fire and EMS vehicles commonly all use red lights.
- **Amber:** Typically have the broadest range of acceptable use in most motor vehicle codes. Amber lights typically are considered cautionary warning lights, and other motorists are not required to yield or stop for them.
- **White:** Typically used in contrast to other colors. No emergency vehicle should be equipped with only white lights.
- **Green:** Typically limited to fire service or emergency management applications. Green lights most commonly signal the dedicated position of an Incident Command Post (ICP).
- **Blue:** Probably have the widest variety of uses in the United States. In many states, they serve as a contrasting color with red and/or other colors of lights on all types of emergency vehicles. In a small number of states, law enforcement vehicles use all blue lighting. In other states, personally owned vehicles operated by volunteer firefighters and EMS personnel use blue lights.

Emergency vehicles also use four main types of lighting.<sup>20</sup>


- **Rotating lights:** The oldest basic type of warning lights used on emergency vehicles, they catch people's attention because of the flashing sensation created as the light beacon(s) turns within the housing.

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- **Fixed flashers:** Fixed flashing lights project a beam of light in a single direction. These lights create attention by flashing on and off.
  - **Strobe lights:** Strobes flash in only one direction. Agencies may use them in single fixed flashers or in combination within a light bar arrangement.
  - **Light-Emitting Diode (LED) lights:** Each individual LED is a nickel- to quarter-sized solid-state light that has no filament to burn out. LEDs emit a powerful beam of light, yet use a minimal amount of electrical energy and have exceptionally long life spans. Light colors can be intrinsically designed into each individual LED light; thus, many LED warning devices are covered with a clear dome. In addition to their brightness and high level of visibility, they create an exceptionally low level of draw on the vehicle's electrical system compared to strobes or traditional flashing lights. This reduces the amount of electrical overload problems, which previously were common when vehicles used older styles of lighting.

Regarding the flash rate of emergency lights, the 1978 NBS study mentioned that the Society of Automotive Engineers (SAE) recommended flash rates between 60 and 120 flashes per minute (fpm), which is 1-2 hertz (Hz). In a 1996 handbook, SAE updated that recommendation to flash rates ranging from 2.2 to 8 Hz, twice the rate suggested in the 1978 study. The fire service's National Fire Prevention Association (NFPA) standards 1901 and 1917 specify that fire apparatus must have emergency lighting that flashes at least 75 times per minute, but not more than 150 times per minute.<sup>21</sup> There is no similar standard for law enforcement vehicles.

The advent of LED lighting has helped emergency lighting to become much more visible and brighter, and it has become the preferred lighting type for emergency vehicles for several reasons:

- **Compact size:** The reduced size requirements fit the growing demand for smaller, lower profile, more aerodynamic emergency vehicle lighting systems.
- **Greater efficiency:** LEDs produce more light per watt than incandescent bulbs, thereby reducing the drain on vehicle battery and auxiliary electrical systems. Unlike other types of bulbs and tubes, size and shape do not affect their performance and efficiency.
- **More intense colors:** Unlike traditional methods of illumination, LEDs do not require filters to produce a variety of strong, intense colors. This is particularly evident with regard to blue, which is becoming increasingly popular for a wider variety of emergency warning applications. This ability to produce strong, intense colors without the need for filtering not only makes LEDs more efficient with regard to power requirements, but also reduces initial cost.



In addition to color schemes, research has also focused on flash patterns. Drivers tend to view faster flashing sequencing as a higher priority.<sup>22</sup> Some suggest that emergency lights should flash faster when the vehicle is in transit to an emergency and slower when stopped on the roadway for an incident. Drivers would then know that an emergency vehicle is stopped ahead versus being in route to the scene of an incident.<sup>23</sup> A 1999 study by the Loughborough University in the United Kingdom found that strobe lights gave motorists the impression of a greater sense of urgency as opposed to other types of lights. The study also found that lights that flashed simultaneously gained motorists' attention more quickly than lights that flashed alternately.<sup>24</sup>

## A Word About Reflective Vests

Federal law requires law enforcement officers to wear reflective vests under certain conditions. In 2006, the American National Standards Institute and the International Safety Equipment Association issued the ANSI/ISEA 207-2006 standard. This standard established certain specifications for highly visible vests used by various first responder industries. It also lists special features specific to law enforcement service. These features include shorter coverage of the torso, as well as tear-away shoulders should the officer have a tactical reason to doff the vest.<sup>25</sup>

A 2010 study by the Institute for Policy Research, sponsored by the Police Executive Research Forum, looked into the use of reflective vests by law enforcement in order to document officers' perspectives on wearing the vests. The goal of the IPR study was to develop policy and training recommendations. It also acted as an assessment of what law enforcement needs in various tactical situations. Findings include:

- Officers must be able to easily don and doff the vests as conditions warrant.
- Officers do not want reflectivity built into their duty uniforms for safety reasons, primarily because they think it makes them targets.
- Vests must not interfere with officers' need to access their duty belts.
- Some officers polled mentioned that they would like a law enforcement-designated color (possibly blue), a badge and/or radio attachment tab, and easy access to their duty belts.<sup>26</sup>





# CONCLUSIONS

The following are key findings from the research for this report.

## Reflectivity

- Contrasting chevrons warn approaching drivers of a stopped emergency vehicle.
- Reflective striping that outlines the emergency vehicle gives drivers a better sense of an emergency vehicle's size and shape.
- Retroreflective badges or agency seals improve visibility and recognition.
- Retroreflective material concentrations low on emergency vehicles optimize oncoming vehicles' headlights.

## Emergency Lighting

- LED lighting is preferable for compact size, efficiency, variable flash patterns and color intensity.
- Red lights are more visible in the daytime and blue lights are more visible at night. Agencies should use a combination of colors.
- Flash rates for emergency vehicles should be faster for approaching vehicles and slower for those stopped in the roadway.
- Drivers should not be drawn to an emergency vehicle's flashing lights.
- Scientific studies show that there is no proof that strobe lights on emergency vehicles cause seizures in epileptics.



## Reflective Vests

- Federal law requires reflective vests for law enforcement officers under certain conditions.
- Officers are willing to don a reflective vest if it can be easily doffed.
- Vests cannot interfere with accessibility of officers' duty belts.
- Some uniform outer garments (such as jackets) with built-in reflectivity are currently available. However, officers tend not to want reflectivity on duty uniforms due to safety concerns.



## GLOSSARY

**Conspicuity:** The degree to which a vehicle can easily be seen and recognized.

**EMS:** Emergency medical services, such as ambulances, paramedics and emergency medical technicians.

**Fixed Flashers:** Lights that project a beam in a single direction. These lights create attention by flashing on and off.

**High-Visibility Safety Apparel (HVSA):** Personal protective clothing that provides visual conspicuity to reduce the risk of being injured or killed at a roadside crash scene.

**Hz:** Hertz, the standard unit of frequency in the International System of Units, equal to one cycle per second.

**ICP:** Incident command post.

**LED:** A semiconductor that emits light when conducting current. The color, intensity and flash rate can all be manipulated to a specified pattern.


**Phototaxis:** The belief that a driver will be drawn to an emergency vehicle's lights the way a moth is drawn to a flame.

**Rotating Lights:** Steady illumination that turns within a housing, creating a flashing sensation.

**Strobe Lights:** Lamps capable of producing an extremely short, brilliant burst. The speed and intensity of the flash can be manipulated.

## ENDNOTES

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