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Roadside Assistance Vehicle Lighting: Review of Scientific Research and State Regulations

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Title

Roadside Assistance Vehicle Lighting: Review of Scientific Research and State Regulations

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Foreword

Towing and service technicians and other responders are at high risk of being struck by passing motorists while working at the roadside. The fatal and serious injury rate is about 16 times higher than for other industries. With the goal to significantly improve the safety of roadside responders, the AAA Foundation for Traffic Safety has conducted multiple research studies during the past several years, including the work presented in this report.

Service vehicle warning lights are an important part of raising the conspicuity of roadside workers, alerting drivers of their presence well in advance. However, too much light or certain flash patterns can create glare or distractions for approaching motorists, among other effects. This report describes the results of a review of the available scientific evidence regarding different characteristics of service vehicle lighting, such as color, flash patterns, and intensity. This is augmented by a review of state regulations and statutes related to allowable light properties in each region. This report should be of interest to roadside assistance professionals as well as first responders, road authorities with responsibility for traffic incident management, and policymakers.

C. Y. David Yang, Ph.D.

President and Executive Director

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About the Sponsor

AAA Foundation for Traffic Safety
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Founded in 1947, the AAA Foundation for Traffic Safety in Washington, D.C., is a nonprofit, publicly supported charitable research and educational organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies, and other organizations or sources.

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Executive Summary

Tow trucks and other roadside service vehicles (RSVs) must safely operate in a wide range of roadway environments and conditions, from sunny afternoons to combinations of darkness, smoke, fog, rain, and snow. RSV visibility in these diverse operating conditions is paramount and static and flashing emergency or hazard vehicle lighting are common countermeasures to enhance the conspicuity of vehicles stopped or working on the roadside. Numerous factors related to lighting influence approaching motorists' ability to distinguish operational personnel from the rest of the visual scene. There have been efforts to evaluate various aspects of service and emergency vehicle lighting (color, pattern, frequency, intensity); however, existing research does not clearly point to the best lighting solutions for safety, especially when considering limitations of individual studies as well as state laws or regulations that impose constraints on some aspects of lighting available for use on tow trucks and other roadside assistance vehicles. The current project aimed to (a) review and synthesize available studies on different properties of RSV lighting and (b) review state regulations that currently guide the selection of warning lights for roadside service vehicles, for all 50 states, the District of Columbia, and Puerto Rico.

For the literature review, over 1200 articles were screened from scholarly databases and from the gray literature and 30 were deemed relevant to RSV lighting. Key outcomes were distilled according to the following:

- Device type
- Number of lights and their mounting location
- Size and shape of the warning lights
- Warning light color
- Flash rate
- Flash pattern and modulation
- Lighting intensity
- Vehicle markings

Overviews of the individual studies, their approach or design and limitations were noted, along with an assessment of critical knowledge gaps and areas where more research is merited.

Although results from many of the studies reviewed are mixed, the preponderance of evidence suggests that several techniques are successful in drawing attention to a special-purpose vehicle, especially at night. These include using lightbars with LED lighting, using a faster flash rate (typically ~4 Hz), increasing the luminous intensity of the warning light(s), increasing the number of lights (2 to 4 lights per display), and increasing the amount of retroreflective sheeting on the vehicle. Replacing some of the amber lights with green or blue also appears to help draw attention to the vehicle, but it is unclear how much of this is a novelty effect. Increasing the complexity of flash patterns does not appear to be helpful to road users. Rather, alternating flash patterns (left/right “wig-wag”) were generally found to be better detected by drivers than simultaneous flashing of two or more lights. Alternating patterns also appear to improve the ability for drivers to detect other objects in the scene compared to random flash patterns.

The most important take-away from prior research is that interventions intended to improve the long-distance visibility of special-purpose vehicles often appear to have adverse effects on the visibility of personnel near the vehicles. For example, increased RSV lighting can increase glare, increase the time it takes for drivers to perceive the presence of a person on foot near the vehicle, and decrease the overall visibility of personnel on foot. Moreover, current work light practices in the towing industry potentially exacerbate the problem of nighttime glare at towing scenes.

The review of state regulations sought to identify statutes and administrative rules related to the color of RSV warning lights or other properties. Summary tables are provided for each state. In contrast to the extensive efforts that have been made to standardize traffic signs and traffic signals over the past century, U.S. state laws and regulations related to RSV warning lights are remarkably inconsistent. States differ not only regarding the allowable warning light colors, but also regarding when warning lights are to be used. While amber lights are traditional in most states, several states have added additional colors such as blue or red—often with stipulations that these colors can only be used while standing at the roadside, loading a disabled vehicle, or blocking a lane. In several states, white lights can be used under the same circumstances as amber lights; in some cases, it is legal for an RSV to be equipped only with flashing white warning lights. Most state statutes are silent about other key technical parameters such as luminous intensity, flash patterns, and mounting location. The variability of state requirements frequently results in situations where lighting equipment that is permissible in one state cannot be used legally in a neighboring state.

Introduction

Roadside assistance is high-risk occupation. Bunn et al. (2018) found that the fatal and serious occupational injury rate for the motor vehicle towing industry is about 16 times higher than the rate for general industry, and about double the rate for other first responders such as police and fire, which they suggested may be due to high exposure to roadside hazards, motorist indifference to yellow warning lights, and tow truck light bars becoming obscured while vehicles are being loaded onto flatbeds.

Chandler and Bunn (2019) analyzed tow truck operator injury events found in the U.S. Occupational Safety and Health Administration (OSHA) database. They identified 106 cases of tow truck operators being killed or severely injured between 2002 and 2017, and were able to obtain detailed reports for 41 cases. Two major event types accounted for the vast majority of identified cases. These were (a) “struck-by” incidents, which were primarily injuries resulting from contact with roadway traffic, rolling vehicles and equipment, or other non-motorized objects; and (b) “caught-in” or “caught-between” incidents, which were primarily injuries resulting from being pinned beneath and between vehicles and being caught in moving parts.

Tow trucks and other roadside service vehicles (RSVs) must operate safely in an extremely diverse range of roadway environments, from lightly travelled rural roads to congested urban freeways with severe traffic incidents. These operations occur in wide-ranging environmental conditions, from sunny afternoons with almost unlimited visibility to murky combinations of darkness, smoke, fog, and snow. RSV visibility in these diverse operating conditions is paramount and static and flashing emergency or hazard vehicle lighting are common countermeasures to enhance the conspicuity of vehicles stopped or working on the roadside.

Although daytime RSV conspicuity is important, the safety of personnel on foot working next to the RSV at night is paramount. In a study of 126 roadside assistance provider struck-by fatalities in years 2015 through 2021, Tefft et al. (2024) found that nearly two-thirds occurred in darkness. Numerous factors influence approaching motorists’ ability to distinguish operational personnel from the rest of the visual scene. These include the following:

- Spillover light from roadside development
- Headlights from opposing traffic
- Roadside service vehicle color, markings, and equipment
- Operator apparel
- The intensity, color, and flash patterns used on light bars or beacons
- The design of work lights

As vehicles near the towing scene, glare and distraction from flashing warning lights and work lights can make it difficult to see personnel on foot, potentially contributing to worker casualties.

There have been efforts to evaluate various aspects of service and emergency vehicle lighting (color, pattern, frequency, intensity); however, existing research does not clearly point to the best lighting solutions for safety, especially when considering limitations of individual studies as well as state laws or regulations that impose constraints on some aspects of lighting available for use on tow trucks and other roadside assistance vehicles.

Objectives

To gain an understanding of the current state of knowledge and practice related to RSV warning lights and vehicle markings, the current project aimed to (a) review and synthesize available studies on different properties of RSV lighting and (b) review state regulations that currently guide the selection of warning lights for roadside service vehicles, for all 50 states, the District of Columbia, and Puerto Rico.

The literature review sought to address two main questions:

- Which lighting combinations, in terms of color, flash pattern, and luminous intensity, among other properties are most effective at promoting RSV conspicuity without compromising the visibility of roadside workers?
- Which vehicle markings are most effective at promoting RSV conspicuity for passing motorists?

The outcomes from the literature review and the regulatory scan are presented in two standalone sections presented below.

Review of Roadside Assistance Vehicle Lighting Research

To gain an understanding of the current state of knowledge and practice related to RSV warning lights and vehicle markings, the project team completed a systematic review of the academic literature and a manual review of “grey literature” such as agency reports. Relatively little material directly addressing RSVs was identified, but publications were found discussing warning lights and markings for snowplows, highway maintenance trucks, firefighting vehicles, ambulances, and police vehicles. In the subsections below, concepts or characteristics that are relevant to or emerged from the review are defined and discussed. This is followed by a description of the review process and specific details of the studies identified.

Definitions and Discussion

Warning Light Colors

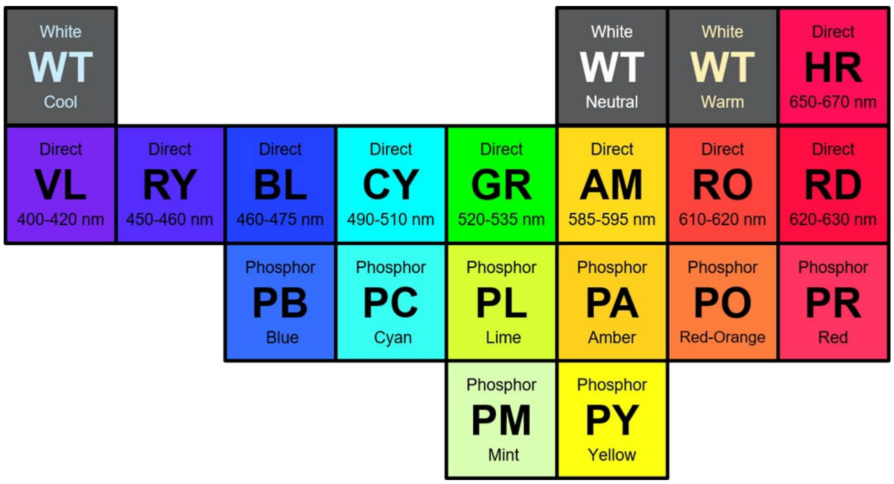
The U.S. automotive industry standard issued by the Society of Automotive Engineers (SAE), SAE J578, and the international standard issued by the United Nations Economic Commission for Europe (UNECE), UNECE Regulation 65, establish technical definitions for five vehicle lighting colors: white, red, amber/yellow, “selective yellow,” and blue. Amber is an orangish shade of yellow, universally familiar as the color of turn signals. Selective yellow is a light-yellow color, historically (1939–1993) the mandatory color for headlamps in France and still used in various countries for foglamps.

Figure 1. Commercially-produced warning beacon colors (Sources: Federal Signal Corporation, Tomar Industrial).

Single-color warning lights are currently produced commercially in at least six colors: white, red, amber, green, blue, and purple (Figure 1). In addition, some vendors produce beacons based on tri-color light-emitting diodes (LEDs), which in principle are capable of producing blended colors such as cyan (blue+green), magenta (red+blue), and orange (red+green). In all cases, this refers to the color of the output light—not the color of the lens. For example, some products transmit amber light through a clear lens.

Numerous LED colors are available from upstream manufacturers of the lighting modules incorporated in commercial warning light products. For example, LED module colors produced by Cree Lighting include PC purple, far red, photo red, red-orange, PC mint, PC lime, cyan, royal blue, and violet (Figure 2). "PC" indicates that an LED module includes a layer of phosphorescent coating, which converts light generated by blue LEDs to the desired output color.

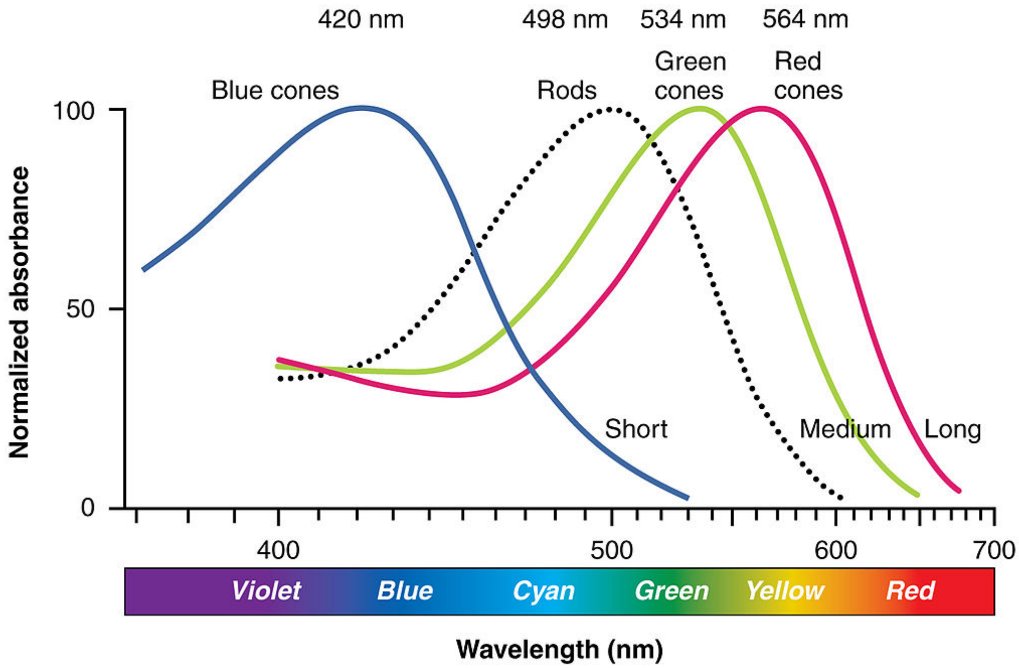
Figure 2. LED module colors available from Cree Lighting.



Night Vision

The human retina has two types of photoreceptors: rods and cones. Rods are the primary visual mechanism for night vision. Although rods are monochromatic, they are more sensitive to light than cones. Their peak sensitivity is at a wavelength of approximately 498 nanometers (nm), which corresponds to a cyan color (Figure 3). In contrast, there are three types of cones, commonly referred to as blue, green, and red. Peak sensitivities of these cones are approximately 420 nm (purplish blue), 534 nm (bluish green), and 564 nm (greenish yellow), respectively (Figure 3).

Figure 3. Relationship between human photosensitivity and color (Source: Anatomy & Physiology, Connexions (2013) (CC 3.0)).



Under photopic (daytime) conditions, amber is a favorable color for warning lights because it activates both the green and red cones (Figure 3). Under fully scotopic (nighttime) conditions, blue is believed to be a favorable color because the eye's rods are most sensitive in the blue-cyan range. Since scotopic vision is monochromatic, the blue color is itself unlikely to be perceived; the observer simply notices that there is light. A considerable amount of night driving occurs under mesopic (mixed) vision conditions. In mesopic vision there is blunted perception of color, so drivers may gradually become aware that a light is blue as they approach (Figure 4).

Figure 4. Simulation of photopic, mesopic, and scotopic vision (Source: Eclat Digital).

Photopic (streetlights off) Mesopic (streetlights on) Scotopic (streetlights on)

Warning Light Technologies

The included studies and reports examined warning lights based on three technologies: rotating incandescent beacons (Figure 5), xenon flash tubes (Figure 6), and flashing light LEDs (Figure 7). All three technologies are currently in commercial production, with many variants. For example, the number of lamps used in rotating beacons varies from one to four, with single-lamp devices making use of a reflector that rotates around the lamp. Warning lights based on xenon flash tubes vary in shape, intensity, and flash pattern. LED technologies include warning lights and lightbars with a very wide range of sizes, configurations, and photometric characteristics. Recently, some LED warning light vendors have introduced rotating LED beacons or products that simulate rotation by sequentially flashing a ring of LEDs, but no evaluations of these devices were found.

Figure 5. Rotating beacon (source: Acroterion / Wikimedia Commons)

Figure 6. Xenon flash tube (source: C30/Wikimedia Commons)

Figure 7. LED beacon (source: indeedous / Wikimedia Commons)

The three warning light types are quite different in terms of the way the light intensity changes over time. Viewed from a single point, the intensity of a rotating beacon slowly rises and falls in a sinusoidal pattern as the lamp comes into view and then rotates away. Xenon flash tubes deliver brief, sharp, intense pulses of light. The waveform for a flashing LED beacon can be varied based on the control electronics; most products use a square-wave generator that turns the LEDs fully on instantaneously, sustains the light for a preset duration, and then allows the LEDs to go dark instantaneously (Ullman et al., 2024). These differences could affect optical perception of the emitted light, particularly at night, as the sinusoidal pattern of a rotating beacon gives the eye a bit more time to react to the changing luminance. Conversely, the afterimage from viewing a xenon tube discharge is familiar to anyone who has been the subject of a flash photo.

Warning Light Functions and Meanings

The included studies identified several potential functions for warning lights. A useful way to group these functions is to consider the role of the warning light in the following:

- **Alerting** drivers and other road users to a hazard (e.g., the light must draw the attention of the driver to an incident with adequate time and distance from the incident)
- **Informing** road users (e.g., the light must provide cues related to the activity or incident, such as the different agencies present at an incident site and the directions the vehicles are moving)
- **Managing** road users (e.g., the light must encourage a suitable speed when navigating the towing site and encourage drivers to give the tow vehicle ample space)

Howett, Kelly et al. (1978) advocated standardization of warning lights and their messages. They argued that the messages conveyed by vehicle warning light systems are ambiguous, or at least contextual. For example, a flashing amber beacon on a tow truck could indicate that drivers are expected to slow down, or serve as a request to clear a path for the truck as it maneuvers to reach a disabled vehicle, or warn drivers to move out of a blocked lane, or warn that the truck is moving more slowly than other traffic, or warn that there is a hazard such as protruding equipment on the vehicle being towed. In practice, all of these meanings could be required over the duration of a single towing service call. Moreover, while some of these messages overlap with those conveyed by an amber warning light on a highway maintenance vehicle, others are unique to roadside assistance. Howett's group hypothesized that these mixed messages increase the time required for road users to determine an appropriate response to the warning light, especially if the traffic situation is already complicated, and also increase the probability of an erroneous road user response.

Operating Environments

The diversity of operating environments has clearly presented challenges for the authors of the studies included in this review. Many studies focused on a single situation such as daytime road maintenance operations. Others tried to assess lighting and marking needs for more extreme conditions such as snow plowing during heavy snowfall. Research study designers have also struggled with the large number of potential combinations of warning light color, lighting equipment type (such as rotating beacons, flashing beacons, and light bars), lighting device placement, flash pattern, and luminous intensity.

Vehicle Markings

The vast number of potential vehicle-marking schemes is also challenging. Markings explored in previous research have included solid colors, contour markings (retroreflective tape along the vehicle edges/corners), horizontal stripes, diagonal stripes, horizontal chevrons, and checkerboards. Numerous color combinations can be implemented using commercially available materials such as retroreflective tape. A further complication is that designs tested on boxy vehicles such as fire trucks or ambulances can be difficult to implement on vehicles with irregularly-shaped exterior surfaces such as tow trucks. Much of the research focuses on drawing attention to the vehicle, with little consideration of whether this might draw driver attention away from people working on foot near the vehicle. In addition, the research has focused on markings for the back of the vehicle, with almost no mention of marking patterns for the sides and front.

Luminous Intensity and Glare

Several of the studies referenced in this review evaluated effects of warning light characteristics such as color, flash rate, flash pattern, and luminous intensity on drivers' ability to see details in a traffic scene. As when driving directly toward the rising or setting sun, more light is not always better. High luminous intensity in one part of a scene can make it difficult to see less intensely illuminated parts of the scene. For example, if the sun is shining directly into a driver's eyes, it may become impossible for that driver to determine the distance to a vehicle ahead, or even distinguish that vehicle from the rest of the roadway. This condition is perceived as ***glare***. This section briefly explains these terms.

Luminous intensity, typically measured in candela, is the technical term for the amount of light emitted by a source in a specific direction. It is perceived by the viewer as brightness. Because luminous intensity is directional, it differs from **luminous output** which is the total amount of light emitted by a source in all directions combined (typically measured in lumens).

Reflectors, lenses, and diffusers control the directionality of light sources. These devices can increase output in useful directions by redirecting light that would otherwise have been emitted toward directions where it is not needed. For example, the LEDs used in most modern emergency vehicle warning lights are often encapsulated in semi-circular plastic lenses to focus the beam.

Another method for measuring the output of a flashing light is **optical power**. This is a time-weighted metric (measured in candela-seconds per minute), which takes into consideration the peak luminous intensity, the waveform of the light pulse, and the flash rate. For example, as noted, a xenon flash tube releases a short burst of very intense light, while the output from a rotating beacon (viewed at one location) rises and falls gradually.

By definition, **glare** is excessive contrast between two parts of a scene. It occurs because the human eye cannot simultaneously adjust to very bright and very dim light:

- ***Discomfort glare***, the milder type, describes a situation where viewing the scene becomes uncomfortable but objects can still be seen. Several studies reference the De Boer scale for rating discomfort glare (Table 1).
- ***Disability glare***, the more severe situation, impacts the ability to see objects or details. For example, viewers experiencing disability glare may become unable to distinguish one object from another, or in the most extreme cases, temporarily blinded.

Glare is associated with neurological responses to the stimulus and chemical changes in the eye's photoreceptors. Full recovery from disability glare can take several minutes, i.e. several miles of driving. Older people are more susceptible to glare than young people and require longer to recover from its effects.

Table 1. De Boer scale for rating discomfort glare.

1	Unbearable
2	-
3	Disturbing
4	-
5	Just acceptable
6	-
7	Satisfactory
8	-
9	Just noticeable

Selecting warning lights and work lights with appropriate luminous intensity can be a challenge. A flashing or rotating warning light needs to contrast with its background under ambient conditions. By day, this requires relatively intense light, especially if the background is a clear sky. At night the intensity needs to be lower to avoid glare.

Camouflaging Effects

The objective of the present research is to identify ways to make roadside service vehicles—and the people who next to them—more visible to approaching traffic. Before delving into the research literature on ways to improve the visibility of vehicles and personnel, it is useful to consider what is known regarding the opposite problem: deliberately obscuring their visibility. Techniques for camouflaging people, artillery, encampments, vehicles, aircraft, and ships are of considerable importance to the world's militaries. Camouflage is also crucial to the survival of numerous animal and plant species (Pettersson, 2018). This is relevant to the current study because it is important to avoid unintentionally camouflaging RSVs or workers.

In urban and suburban environments, RSVs are rarely the only object in a driver's field of view. Porathe and Strand (2011) underscore the importance of considering visual complexity when evaluating the effectiveness of traffic control devices. For example, a yellow and red traffic sign may stand out well when its background is an evergreen forest, but can become lost in a pool of visual clutter when viewed against a cluttered background of advertising signs (Figure 8). To account for this effect, they proposed using a conspicuity index developed by Wertheim (2010), which is based on the angle in peripheral vision where a target first becomes visible against its background. For example, the sign in the top image of Figure 8 has a conspicuity index of about 43 degrees, while the sign in the lower image has a conspicuity angle of less than 14 degrees.

Figure 8. An object's conspicuity depends on the background environment (Source: Porathe and Strand, 2011).

The U.S. Army Camouflage, Concealment, and Decoy Manual (U.S. Army, 2010) identifies six factors important to optical (in)visibility. Several points from the manual are paraphrased below:

- **Visual reflectance** is related to the color of a target. Color contrast can be important, particularly at close ranges and against homogeneous backgrounds such as snow or desert terrain. The longer the range, the less important color becomes. At very long ranges, all colors tend to merge into a uniform tone. Also, the human eye cannot discriminate color in poor light.

- **Shape.** Natural background is more random, but equipment has regular features with hard, angular lines. Size, which is implicitly related to shape, can also distinguish a target from its background.
- **Shadow** can be divided into two types:
  - *A cast shadow* is a silhouette of an object projected against its background. It is the more familiar type and can be highly conspicuous. In desert environments, a shadow cast by a target can be more conspicuous than the target itself.
  - *A contained shadow* is the dark pool that forms in a permanently shaded area, such as the shadows under a vehicle. Contained shadows show up much darker than their surroundings and are easily detected.
- **Movement** attracts attention against a stationary background. Slow, regular movement is usually less obvious than fast, erratic movement.
- **Texture.** A rough surface appears darker than a smooth surface, even if both surfaces are the same color. For example, vehicle tracks change the texture of the ground by leaving clearly visible marks. Under normal conditions, very smooth [shiny] surfaces stand out from the background.
- **Patterns.** Geometric patterns are easier to detect than random patterns. The critical relationships that determine the contrast between a piece of equipment and its background include luminance differences, the distance between the observer and the equipment, and the distance between the equipment and its background. Since these distances usually vary, it is difficult to paint equipment with a pattern that always allows it to blend with its background. As such, no single pattern is ideal for all situations.

In consideration of the factors noted above, the Army manual further discusses five basic camouflaging techniques, briefly summarized below:

- **Hiding**, such as placing a dark-colored vehicle in the shadow of a tree
- **Blending** to make an object look similar to its background
- **Disguising** an important piece of equipment to look like a common, low-value object
- **Disrupting,** such as using patterns or shapes that distract the observer's eye
- **Decoying** (also called distraction), such as placing extra objects at a scene to confuse the observer about which items are important

Counter-illumination camouflage is also important in the road safety context. This occurs when the luminous intensity of a distant object is similar to its background or other nearby objects. For example, military aircraft have been equipped with systems that automatically adjust the output from blue lights to match the luminous intensity of the sky (Pettersson, 2018).

An understanding of how to avoid camouflaging can help improve the safety of roadside assistance operations. For example, camouflaging effects can occur in various types of towing scenes:

- During night towing operations, **shadows** cast by high intensity work lights can create dark areas that unintentionally conceal a bending or kneeling tow operator. Making the light more uniform can reduce shadows and glare. For example, diffusers can be added to spread the light over a wider area, or a single high-intensity lamp can be replaced with several smaller lights distributed across a work area.
- **Blending** can occur if the tow operator's apparel and the tow vehicle have similar colors. A yellow-green jacket that is highly visible against dark pavement is less likely to stand out when its background is a yellow-green truck. Safety can likely be enhanced by increasing color contrast between operators and their vehicles.
- Light from flashing or rotating warning lights can **disrupt** the attention of approaching motorists, particularly at crash scenes where multiple emergency vehicles are displaying warning lights at the same time. Reducing over-lighting requires collaboration among first responder organizations, including towing services.
- Visual clutter from buildings, advertising signs, oncoming traffic, emergency vehicles, and roadside activities can have a **disguising** or **decoying** effect. For example, the visual clutter of multiple vehicles parked at an incident scene can confuse approaching drivers. Staging not-yet-needed response vehicles upstream can help reduce visual clutter at incident scenes.

Evidence Review Methodology

The evidence review utilized systematic review strategies to locate relevant academic literature, combined with manual searches to locate additional "grey literature" from sources not indexed in academic databases. Through this process the team sought to address two research questions:

- Which lighting combinations, in terms of color, flash pattern, and luminous intensity, are most effective at promoting RSV conspicuity without compromising the visibility of roadside workers?
- Which vehicle markings are most effective at promoting RSV conspicuity for passing motorists?

Systematic Search Strategy

The literature search was conducted using four electronic databases: Ovid Transport, ProQuest, SAGE Journals, and Google Scholar. Indexed terms and keywords were identified for three domains:

- **Vehicle/worker domain:** Tow truck* OR tow operator* OR road* service* vehicle* OR work vehicle* OR maintenance vehicle*
- **Intervention domain:** Light* OR Warning* OR Beacon* OR Retroreflective* OR Marking* OR Flash*
- **Intervention characteristics/effects domain:** Conspicuity OR Recognition OR Visibility OR Glare OR Frequency OR Speed OR Pattern* OR Color* OR Colour* OR Lumino* OR Lumen* OR Intensit* OR Brightness

Terms within each of the domains were combined with the Boolean operator ‘OR’ and the final search was conducted by combining each of vehicle/worker, intervention, and characteristics/effects domains with the Boolean operator ‘AND.’

All original research articles published in peer reviewed journals with an available abstract and full text were eligible for inclusion. Suitable non-academic publications identified from the search strategy were included in the grey literature sources. Articles not available in the English language were excluded. No limits to the date of publication were applied.

The project team considered all studies focused on tow truck, road service, and maintenance operators and vehicles. Although not the focus of this research, relevant studies that focused on emergency services vehicles (police, fire, and ambulance) were also included.

Studies that reported no measure of a lighting intervention (color, pattern, luminosity, frequency, rate, visibility, recognition etc.) were excluded. Similarly, studies that with no focus on vehicle lighting, color, or markings were excluded. In addition, studies that focused only on worker apparel or light emitting objects placed on the road (e.g., traffic cones) were excluded.

Database Search Results

The results returned by each of the database searches were as follows:

- Ovid Transport (n=41)
- SAGE Journals (n=594)
- ProQuest Science (n=565)
- Google Scholar (n=4)
- *Total = 1204*

After screening the 1204 results, the project team identified 19 relevant items (Table 2).

Table 2. Relevant publications identified in database searches (see References for full citations).

1	Blomberg et al. (2023): Protecting Roadside Workers: Field Evaluation of Flares, Cones, and Tow Truck Light Patterns.
2	Bullough et al. (2001): Rear Lighting Configurations for Winter Maintenance Vehicles.
3	Bullough (2015): Intelligent Warning Lights and Driving Safety.
4	Bullough et al. (2022): Flashing Emergency Lights: Influence of Intensity, Flash Rate and Synchronization on Driver Visibility, Comfort and Confidence.
5	Bullough and Parr (2024): Impacts of Emergency Vehicle Marking Characteristics and Wearable Lights on Driver Responses
6	Bullough and Rea (2016): Impacts of Fog Characteristics, Forward Illumination, and Warning Beacon Intensity Distribution on Roadway Hazard Visibility.
7	Bullough et al. (2019): Impacts of Flashing Emergency Lights and Vehicle-Mounted Illumination on Driver Visibility and Glare.
8	Bullough et al. (2023): Impacts of Coordinating the Colors of Flashing Warning Lights and Vehicle Markings on Driver Perception.
9	Bullough et al. (2024): Responses to Flashing Warning Lights and Colors of Service Vehicles (No. 2024-01-2229).
10	Chandler and Bunn (2019): Motor vehicle towing: An analysis of injuries in a high-risk yet understudied industry.
11	Fakhrmoosavi et al. (2021): Effectiveness of Green Warning Lights with Different Flashing Patterns for Winter Maintenance Operations.
12	Kersavage et al. (2018): Investigation of flashing and intensity characteristics for vehicle-mounted warning beacons.
13	McCullouch and Stevens (2008): Investigation of The Effective Use of Warning Lights on Indiana Department of Transportation (InDOT) vehicles and equipment.
14	Rea and Bullough. (2016): Toward performance specifications for flashing warning beacons.
15	Terry et al. (2020): Evaluation of traffic behavior in response to alternative police lighting.
16	Turner et al. (2014): Determining Optimum Flash Patterns for Emergency Service Vehicles: An Experimental Investigation Using High Definition Film.
17	Ullman (2000): Special flashing warning lights for construction, maintenance, and service vehicles: Are amber beacons always enough?
18	Ullman et al. (2024): Development of Guidelines for Vehicle and Equipment Marking and Lighting (No. NCHRP Project 05-24).
19	Ullman et al. (1998): Recommendations for Highway Construction, Maintenance, and Service Equipment Warning Lights and Pavement Data Collection System Safety.

Grey Literature

Through prior knowledge, manual searches, and recommendations from project stakeholders, the research team identified eleven additional information sources relevant to the present review that were not indexed in academic databases (Table 3). These mainly consisted of project reports published by government or industry.

Table 3. Additional sources identified through prior knowledge and manual searches (see References for full citations).

1	Cook et al. (2000): Motor Vehicle and Pedal Cycle Conspicuity Part 3: Vehicle mounted warning beacons.
2	Emergency Responder Safety Institute (2019): Fire Apparatus Emergency Lighting Study Report.
3	Emergency Responder Safety Institute (2021): Effects of Emergency Vehicle Lighting Characteristics on Driver Perception and Behavior.
4	Howett et al. (1978): Emergency Vehicle Warning Lights: State of the Art.
5	Flannagan and Devonshire (2007): Effects of Warning Lamps on Pedestrian Visibility and Driver Behavior: Interim Report of Work on Non-Blinding Emergency Vehicle Lighting (NBEVL).
6	Flannagan et al. (2008): Effects of Warning Lamp Color and Intensity on Driver Vision: Report of Work on Non-Blinding Emergency Vehicle Lighting (NBEVL).
7	Gibbons et al. (2008): Selection and Application of Warning Lights on Roadway Operations Equipment.
8	Bullough and Skinner (2009): Final Report. Evaluation of light-emitting diode beacon light fixtures (Research study no. C-08-22).
9	Steele et al. (2013): Improving the Effectiveness of Nighttime Temporary Traffic Control Warning Devices, Volume 2: Evaluation of Nighttime Mobile Warning Lights (Research Report No. FHWA-ICT-13-032).
10	Muthumani et al. (2015): Use of Equipment Lighting During Snowplow Operations.
11	Rubin and Howett (1981): Emergency Vehicle Warning Systems.

The findings of the included studies were synthesized narratively and are presented in chronological order in the pages that follow.

Overview of Sources

Many of the included sources address two or more aspects of warning light configurations, such as device type, color, and flash pattern. This section provides brief overviews of the research questions and methodologies adopted in each study.

Two related reports, Howett et al. (1978) and Rubin and Howett (1981) were the earliest emergency vehicle lighting studies found in this review. Howett et al. (1978)

discuss the characteristics of the warning light technologies available in the late 1970s, which included incandescent and halogen rotating beacons, incandescent flashing beacons, and xenon flash tubes. Howett et al. (1978) also discuss vision science and photometry as they relate to vehicle warning lights, including methods for measuring the light output of commercial devices. The later report by Ruben and Howett (1981) discusses the warning light practices of several U.S. jurisdictions, focusing mainly on police and fire. Neither report presents data on the field performance of warning lights.

Hanscom and Pain (1990) focused on daytime short-term roadwork operations requiring lane closures lasting about 15 minutes. Various combinations of lighting devices and vehicle markings were tested, first on a closed test track and then in field studies. Apparently only dump trucks were used as test vehicles. The study's main performance measure was how promptly the test drivers moved over (changed lanes) when they encountered a work vehicle that was blocking a lane.

Cook et al. (2000) used mixed methods to evaluate the performance of vehicle warning lights. To allow variation in the amount of spillover light and urban clutter, initial tests were performed by having participants view a 1:20 scale model of an urban commercial district mounted in a lightproof box. This was followed by real-world field trials. The group evaluated the effects of several warning light characteristics on performance metrics including participant perceptions of conspicuity, discomfort glare (DeBoer scale), annoyance, urgency, color association, and measurements of disability glare (measured as pedestrian recognition time), distraction, and potential for provoking epileptic seizures. Both night and day scenes were considered.

Ullman et al. (1998) [also summarized in Ullman (2000)] surveyed Texas drivers about their perceptions of the degree of hazard conveyed by various warning light colors and color combinations. This was followed by field studies at freeway sites in two cities (Houston and San Antonio), which measured speeds—and nighttime brake applications—for traffic passing road maintenance and law enforcement vehicles displaying various warning light colors and color combinations.

Flannagan and Devonshire (2007) conducted a dynamic closed-course experiment to evaluate the effect of different warning light characteristics on driver vision and performance around an emergency vehicle scene. They measured the visibility of pedestrians in the scene under different light intensities, colors, and flash patterns. The performance of drivers when passing the scene was also measured under different light conditions. The study also compared the use of photopic and scotopic photometric units to measure nighttime light levels.

Flannagan et al. (2008) conducted a static field test to measure driver responses to different warning light characteristics displayed on an emergency vehicle in a simulated traffic scene during day and nighttime conditions. Participants were asked to identify the position of an emergency vehicle (to their left or right) as quickly as possible under different light colors and levels of intensity, and also the position of a pedestrian in the simulated scene. Participants also rated the level of lamp conspicuity.

McCullouch and Stevens (2008) tested differences in the perceived brightness of warning lights from different suppliers that were in use on Department of Transportation (DOT) maintenance vehicles. Other variables included light color and weather conditions. This limited expert-consensus study compared the products side-by-side in the field, with observers rating the relative brightness of each package in snow, cloudy, bright sun, and night conditions.

Bullough and Skinner (2009) compared photometric characteristics and driver detection of rotating beacons and LED lights typical of a roadside vehicle display. The study aimed to identify differences between these light types in drivers' ability to detect the remaining distance (closure distance) when approaching a roadside vehicle.

Steele et al. (2013) studied the effectiveness of warning lights used at mobile lane closures, incident response scenes, and police activities, on driver performance and perception. The study included field observations at two mobile lane closures and one incident response scene, a survey of drivers, and focus groups. This was followed by field experiments to test different changes to warning light characteristics.

Turner et al. (2014) used footage of emergency vehicles displaying a blue LED light bar to explore whether drivers perceive some flash frequency and pattern combinations as more urgent than others. Participants were shown a series of film clips with emergency vehicles displaying lights at either slow or fast frequency and with different patterns (single pulse, triple pulse). The clips were filmed from the visual perspective of a driver exiting a side road. Participants were asked to rate the level of urgency and hazard of each condition, and also identify a road user in the scene along with the moment they would feel comfortable pulling out in front of the vehicle.

Bullough (2015) summarized the outcomes of five separate studies of different photometric qualities of warning lights to identify potential photometric criteria for enhanced functionality. Lighting conditions were contrasted to then-current Society of Automotive Engineers (SAE) standards. The studies focused on vehicle visibility, with photometric qualities related to either warning light intensity, modulation, spatial extent, or pattern. The effectiveness measures under study included driver response time to beacon onset and the time taken for an approaching driver to respond when closing in on a slower vehicle.

Rea and Bullough (2016) examined driver detection of warning beacons and their judgement of the onset of motion of an approaching vehicle using computer-based simulation techniques. The time to react from the onset of flashing warning beacons was measured for different peak intensity randomly (from 80 to 3100 candela (cd) at a viewing distance of 100 meters [328 feet]), and across different environmental conditions. Participants also rated the visibility of a low-contrast object when looking directly at it or when fixated at a location 5 degrees to the side of the object. Separately, participants were asked to identify when a vehicle initially stationary in front of them began moving under warning beacon displays that varied by modulation and the number of beacons (one or two).

Bullough and Rea (2016) assessed the ability of drivers to detect targets (simulated pedestrians) near a warning beacon under different conditions of fog, forward lighting, beacon luminous intensity and distribution. Computer-based simulation techniques were used, with study participants viewing the scene from a real-world equivalent of 100 meters (328 feet). The luminous intensity of the beacon was equivalent to either 150 cd or 750 cd and three different intensity distributions were tested. Participants rated the visibility of pedestrian targets located at two different offsets from the warning beacon on a visual performance scale calibrated for the study.

Kersavage et al. (2018) estimated driver recognition of a silhouette representing a roadside worker at night under different LED warning beacon conditions. Participants were asked to drive along a test track and identify when they observed the worker. The accuracy and recognition distance were measured as an indicator of performance. The flash frequency and peak-trough intensity of the beacon were varied along with the presence and apparel of the worker (present with/without vest, not present).

Bullough et al. (2019) used an O-scale model of a police vehicle to measure participants' recognition of a model police officer adjacent to the vehicle under various red and blue light conditions. Participants also rated the discomfort glare on the DeBoer scale. The intensity of the blue or red light was either near the minimum or in excess of photometric performance standards for emergency flashing lights. Participants' recognition of the police officer and perception of discomfort glare were also measured with and without a low-level white light that was configured to allow the figure to be seen at a real-world equivalent distance of 75 meters (246 feet). The model police officer was wearing a reflective vest and the model depicted a nighttime environment.

The Emergency Responder Safety Institute (2019) published a Fire Apparatus Emergency Lighting study report providing recommendations for changes to National Fire Protection Association (NFPA) standards 1901 and 1906 in relation to maximum and minimum lighting intensity and flash patterns. The recommendations are based on a review of literature and a static field test where participants rated the performance of 60 different light combinations with respect to visibility, conveying navigation, and glare. The focus was on lighting at night.

Terry et al. (2020) conducted a naturalistic observation study to determine the effect of different lighting configurations on driver behavior around police vehicles. Marked and unmarked police vehicles were used to simulate a police scene on a public road both in daytime and nighttime, which included a second vehicle posing as a vehicle that has been intercepted. Modifications to the police vehicles included changes to the light color, light type, and the addition of extra lights. Lane change behavior and speed choice were the main outcome measures.

Fakhrmoosavi et al. (2021) evaluated the use of amber+green warning lights for Michigan DOT snowplows. Their study began with static testing of the visibility and glare associated with 37 combinations of light type, color, and flash pattern. Six well-performing combinations were taken forward to a dynamic experiment on a closed test track.

Bullough et al. (2022) used field experiment methods to examine the effect of different red and blue light settings on alerting, informing, and managing drivers around roadside incidents (the AIM framework). A simulated roadside event with three genuine police vehicles and a silhouette of a police officer was set-up in an asphalted parking area. The vehicles displayed red and blue lights with varying intensity, flash rate, and flash pattern. Participants located in a stationary vehicle 220 feet (67 meters) from the simulated scene were asked to identify the position of the silhouette as quickly as possible. They also rated the level of attention-getting, visual comfort (DeBoer scale), and likely confidence in navigating the scene for each light combination.

Bullough et al. (2023) used a scale model of a highway scene with first response vehicles to measure drivers' ability to identify which of two simulated scenes represented an emergency, given differences in vehicle color and light color, intensity, and flash rate. The scene included two pairs of vehicles that varied in color (red and/or yellow) and light characteristics, and participants were required to identify which pair represented a "fire emergency."

Blomberg et al. (2023) conducted an on-road study in Connecticut to observe driver behavior in response to different lighting and advanced warning conditions at a mock tow truck scene. They also administered an online survey to towing industry personnel to assess their attitudes, knowledge, experience, and willingness to use select countermeasures designed to protect operators. Lane choice, vehicle speed, and vehicle lateral position relative to the tow truck under different study conditions were measured in the on-road study. The study conditions were based on differences in the tow truck's bar light pattern and intensity, and the use of two types of advanced warning countermeasures (flares and cones). The study was undertaken both at nighttime and daytime across three days.

Bullough and Parr (2024) conducted an outdoor field study simulating a fire emergency scene to test drivers' ability and time to observe a fire fighter near the fire engine under different combinations of vehicle marking color, pattern, and retroreflectivity. In some conditions the simulated fire fighter was also wearing a yellow flashing LED light. Participants were seated 150 feet (46 meters) from the scene, which comprised two 3x6 foot retroreflective panels and a propped fire fighter outfit that could be positioned in different locations. Forward lighting from two halogen headlights was also provided from the location at which the participants were seated to resemble vehicle headlamps.

Bullough et al. (2024) used an O-scale model of first response vehicles in a highway scene to measure driver identification of an emergency scene and their expected behavior towards the scene. The scene included either red or yellow vehicles displaying either red and yellow lights, with either a standard intensity and flash rate or configurations that emphasize the red light over the yellow light.

Ullman et al. (2024) evaluated several aspects of driver performance and perceptions of different vehicle marking and light configurations related to work zones. The research was conducted in both a closed course and public road setting. Driver speed and lane choice were measured for each treatment condition. Based on the findings of the field studies, the authors proposed guidelines for the selection of vehicle marking and light characteristics for combinations of roadway operations and equipment and environmental conditions (e.g., daytime, nighttime).

Comparison of Study Designs

Several study designs were used in the included studies. Each design has strengths and weaknesses, which are briefly discussed below.

Opinion Surveys

Some of the vehicle lighting studies included surveys of specific practitioner groups or the driving public. This is typically a relatively inexpensive way to obtain baseline information about road user attitudes, beliefs, or perceived problems. For example, this method was used to assess the level of urgency conveyed by various warning light colors. In most cases, this methodology is limited to gathering information about conditions that are already familiar to drivers, or incrementally different from the familiar conditions. An important limitation is that survey participants often have difficulty visualizing entirely novel designs or the way a roadside scene would look at night.

Scale Models

Several studies utilized scale models of roadside scenes, typically at either 1:20 scale or O-scale (1:43 to 1:48). Both scales are commonly used in the toy/hobby industry, allowing experimenters to build up a scene by combining custom items with off-the-shelf models of cars, buildings, trees, and the like. The viewing distance and light intensity must be carefully adjusted to create a realistic illusion of being present in a real location. Advantages of this approach include the ability to conduct the research indoors, high levels of control over scene elements and illumination levels, and the ability to modify the variables of interest sequentially over an extended number of days. A key disadvantage is that the observer's location is fixed, thus omitting dynamic aspects of the driving experience (e.g., lights coming into view or disappearing as a vehicle crests a hill or drives around a bend). Additionally, the task is purely a visual one—research participants do not need to divide their attention between visually assessing the scene and other driving tasks.

Photos or Videos

A few studies showed drivers slides or film/video clips of driving scenes from the driver's perspective, accompanied by questions designed to identify how drivers might behave in the depicted situation. This method has limitations. For example, the participant is stationary and does not need to divide their attention between visually assessing the scene and other driving tasks. Importantly, the image luminance will never exceed the optical output of the monitor or projector; as a result, glare levels are likely to be considerably lower than in the real world.

Driving Simulators

Driving simulators typically include a computer-generated visual display, a set of vehicle controls, and varying levels of auditory and tactile feedback to emulate a driving experience. Simulator specifications vary widely, ranging from single-monitor configurations similar to a home video gaming console to very sophisticated systems that include a multitude of projectors, sensors, and mechanical actuators arranged around an actual vehicle chassis. The core of the simulation is a three-dimensional digital model of a road segment or small traffic network, typically augmented with buildings and other terrain features. Using this equipment, research participants drive through the scene and interact with other traffic. Dynamic elements such as the appearance of a deer at a random location can be programmed into the simulation.

A key advantage of simulators is that they allow assessment of driver behavior in situations that would be dangerous to evaluate in the real-world. For lighting studies, an important limitation is that the image luminance cannot exceed the optical output of the monitor(s) or projector(s). As a result, glare levels may be considerably lower than in the real world. Additionally, some participants experience "simulator sickness" (vertigo), so simulated drives usually need to be kept relatively short. In addition, experimenters frequently exclude populations that are prone to motion sickness, such as older adults.

Closed Test Track

The closed test track studies used for vehicle lighting evaluations have taken various forms. In the most conservative approach, the test subjects are passengers in a van driven by a person already familiar with the site layout. This allows several subjects to be driven through the site at the same time. In this design, the participants typically self-record the variables of interest, such as the location where they were first able to see a mock towing scene. A second option is for the test subject to drive a vehicle that has been pre-equipped with sensors and cameras that record the subject's interaction with the scene. A third approach is for the researcher to sit as a passenger in a vehicle driven by the test subject, recording the subject's interaction with the scene during the drive.

The size and configuration of the test track influence what is feasible in terms of speed, horizontal and vertical curvature, traffic control, and so forth. Similarly, the physical layout can influence whether it is possible to present the test subjects with "unexpected" conditions along the drive. In principle, the test track could range from a section of a parking lot to a challenging motor racing course. To date, lighting studies appear to have been done on tracks at the simpler end of this spectrum.

Closed test track studies allow researchers to explore the dynamic aspects of subjects' interactions with the study site. They give researchers a degree of control over the complexity of the driving environment. An advantage of this study design is the ability to simulate the lighting conditions of real roads, which is particularly important when examining night driving. The test subject is usually the only driver on the track, so interactions with other traffic cannot be evaluated. Additionally, environmental variables such as weather cannot be fully controlled.

Field Observation

This study design typically involves setting up a mock towing scene at the roadside and using a combination of live observation, cameras, radar, or lidar to monitor driver interactions with the scene. For safety, if a "worker" or "tow truck operator" is included in the scene, it is usually a mannequin. This method allows researchers to gain insights on real-world driver behavior and provides the highest level of realism. Conversely, it offers very little control over site conditions such as weather, ambient lighting, and traffic density. Metrics from this type of study typically include the speed of approaching vehicles, the upstream distance where vehicles move over to get around the towing operation, and the percentage of vehicles who fail to move over.

Results from Warning Light Studies

As noted in the introduction, several aspects of vehicle warning light design require consideration in the context of RSV safety. These include the following:

- Device type
- Number of lights and their placement on the vehicle
- Target size and shape (physical size of the warning lights)

- Warning light color
- Flash rate
- Flash pattern
- Lighting intensity

Each of these topics is addressed separately in the text that follows. Within each lighting characteristic category, some major takeaways are provided followed by detailed study findings arranged chronologically to allow the reader to follow the progress of technology.

Device Type

Overview

Main finding 1: Although halogen, xenon flash tube, and LED warning lights all remain commercially available as of 2024, cross-sectional surveys indicate that LED devices are the predominant warning light type currently used on state DOT road maintenance vehicles. Earlier surveys reported state DOTs were transitioning from halogen and xenon to LED. Trends in the towing industry are likely similar.

Main finding 2: There are few examples of research where the device type was a study variable. Research studies investigating different light configurations in a roadside environment have increasingly used LED as the sole device type under study, making differentiation between the effect of different devices more challenging.

Main finding 3: There is some evidence that LED lights are perceived as brighter than other common light types.

Howett et al. (1978) discuss the characteristics of the warning light technologies available in the late 1970s, which included incandescent and halogen rotating beacons, incandescent and halogen oscillating beacons, incandescent flashing beacons, and xenon flash tubes. Key challenges were the high-power consumption of incandescent/halogen systems and the short flash duration of xenon discharge tubes. A related report by Rubin and Howett (1981) provided an overview of the warning light practices of several U.S. jurisdictions, focusing mainly on police and fire.

Hanscom and Pain (1990) conducted a stakeholder survey to identify the types of warning lights then in use for highway construction and maintenance vehicles such as dump trucks. The report predates the development of LED vehicle warning lights by more than a decade. At the time, the main sources were rotating beacons using tungsten or tungsten-halogen filament lamps, and flashing beacons using xenon flash tubes. The report also discusses the “Ohio light,” a double-faced side-mounted flashing beacon consisting of two yellow headlamps mounted back-to-back in a cylindrical housing (Figure 10). The Ohio light differs from other contemporary devices in that it was bi-directional, with output aimed toward the front and back of the work vehicle but none toward the sides. Additionally, Ohio lights were mounted on the sides of the dump box, not the cab roof. After conducting field tests, the authors stated that rotating lights and flashing lights affected drivers’ perception differently; however, it was not entirely clear how they reached this conclusion. They reported that rotating lights were more attention-grabbing, but simple flashing lights made it easier for drivers to judge their approach speed and distance to the work vehicle. In addition, they reported that it was difficult to judge approach speed with the double-flash xenon halogen beacons they tested. The performance of light bars varied depending on the test environment. The report concluded that a combination of two rotating beacons and one flashing incandescent light (upper right drawing in Figure 10) was superior to other options they tested (light bar, double flash strobe, and four-way with single flasher combination). Little improvement in lane-changing behavior was obtained with light bar use, except in slow moving (~8 mph) work operations. Neither the double flash xenon strobe nor the four-way flasher with single flasher combination improved move-over (lane changing) behavior.

Along with other lighting design characteristics, Cook et al. (2000) compared the performance of rotating beacons (see Figure 5) with that of xenon strobe flashers (see Figure 6) in a laboratory and field setting. One aim of the study was to determine warning light characteristics (number, position, intensity, flash rate, flash pattern, and color) that optimize performance, which included the ability for a driver to detect a pedestrian in a mock roadside scene. Performance measures included participant ratings of discomfort glare measured on the DeBoer scale, attention-getting, sense of urgency, and annoyance. The authors also gathered objective measurements of disability glare and distraction for different warning light characteristics. Disability glare was measured as the time taken for the participant to detect a pedestrian in the scene. They found that participants perceived rotating beacons to be less annoying by day than the strobe lights, and single-flash strobe lights were rated as less annoying than double-flash strobes. The beacons were also reported to result in less disability glare and less discomfort glare at night than the strobe lights, but strobe beacons were rated as conveying a greater sense of urgency by day.

Gibbons et al. (2008) conducted a study to evaluate the effectiveness of warning lights on maintenance vehicles with different light types. There were three experimental phases to the study. The first was a test track study using a real stationary vehicle with a light display. Participants were seated in a vehicle at two different setbacks from the maintenance vehicle and were asked to rate the level of attention-getting, the likely function of the vehicle, and discomfort glare for different light configurations displayed on the vehicle. Participants also performed a peripheral detection angle task, which required identifying whether they could detect the warning light at various horizontal angles from 0 degrees to 90 degrees from the forward view. The study was conducted in a daytime and nighttime setting. The type of light was varied in the study between LED, a halogen panel light, a strobe panel light, and rotating beacons. The intensity, flash frequency, and pattern were also varied. In this static experimental setting, there was a difference in peripheral detection between light types, but only in interaction with the light color (amber, white, red, or blue). The light type was found to have no effect on the other outcomes, including the participants' rating of attention-getting and discomfort glare.

In the same study (Gibbons et al., 2008), four light combinations from the static experiment were then tested on a closed test track. The scene included a truck displaying lights and a pedestrian standing either 40 feet or 80 feet behind the truck. The light type was varied between a high-mounted beacon, low-mounted beacon, an LED, and a strobe light display. Participants were asked to drive around the track and were given instructions on how to respond when coming across the truck. The main outcome measures were differences in lane-change distance, vehicle identification distance, pedestrian recognition distance, perceived urgency, discomfort glare (DeBoer scale), confidence in observing the warning light, and the level of attention-getting. The authors reported that LED lights on the truck resulted in longer lane change distances compared to the beacons and strobe lights. However, they also found that pedestrian recognition distances were shorter (i.e., worse) with LED lights. Participants rated the LED lights as highest attention-getting, and also highest in their level of confidence in identifying warning lights. They also rated LED lights as resulting in the highest level of discomfort glare on average. Thus, compared to the other types of lighting, the LEDs were beneficial in terms of attention-getting and move-over behavior but detrimental in terms of pedestrian recognition distance and glare.

Bullough and Skinner (2009) compared photometric characteristics and driver detection of rotating beacons and LED lights typical of a road maintenance vehicle display. The study was undertaken on a road closed to the public. Participants were seated in a vehicle located 120 meters (393 feet) behind a road maintenance vehicle. The maintenance vehicle would randomly move slowly towards the participants' vehicle and participants were asked to indicate when they observed its motion. The study aimed to compare differences in drivers' ability to detect the motion of the maintenance vehicle (measured as closure distance) for light displays with a single rotating beacon, pair of rotating beacons, and pair of LEDs. The study found that there were no differences in closure distance between the rotating beacons and LED light displays, with the exception of the single beacon display, which had a shorter (poorer) closure distance.

Howell et al. (2015) conducted a survey of State DOT agencies to understand the prevalence of different light colors and types on highway maintenance vehicles across the United States. Thirteen state DOTs were represented in the 16 responses to the survey, and respondents indicated that their vehicles used halogen, incandescent, and LED light types. The survey found a more generalized use of LED lights than the other types, with all agencies reporting LED light use, while only 31% reported use of the other light types. Although the survey only represented a cross-section of device use, it suggested LED lights will likely be used with increased prevalence over time. For example, the authors reported that Minnesota DOT had recommended a transition from incandescent to LED lights on maintenance vehicles.

Number of Lights and Mounting Locations

Overview

Main finding 1: Light displays with two to four lights have been found to better alert drivers of the presence of a road event than displays with fewer lights. Displays with at least two lights visible to the driver improve a drivers' ability to detect the relative motion of a roadside vehicle compared to a single light.

Main finding 2: There was some evidence that displays with more than four lights may result in increased levels of discomfort glare. The effect of multiple-light displays on driver performance and discomfort is understudied.

Main finding 3: Higher mounting positions on the vehicle (above the driver eye height) may improve visibility of the vehicle, provided there is consistent background contrast.

There are many ways warning lights can be mounted on a work vehicle, and the number of lights used can also vary. These arrangements often differ across vehicle types, sizes, and functions, and can also differ among similar vehicles. In the late-1980s, the National Cooperative Highway Research Program (NCHRP) commissioned research by Hanscom and Paine (1990) to provide empirical guidance on the use of lights on service vehicles operating in short-term lane closures and slowly moving mobile work operations (such as pothole patching), recognizing that up until that point in time the focus had been on long-term work zones. The resulting report included examples of late-1980s warning light practices for service vehicles.

The research conducted by Hanscom and Pain (1990) had two phases. The first aimed to identify the types of warning systems that were currently in use or emerging, and to establish typical use-cases. This information was captured through a literature review, a survey of a representative sample of practitioners, and a survey of material from warning light manufacturers. Findings of this phase of the study were used to inform the design of indoor experiment and two field experiments. The field experiments aimed to determine the effect of displaying a different number of lights—

amongst changes to other warning light characteristics—on select driver performance and perception measures.

The practitioner survey identified 12 warning light mounting configurations that were typically used on road maintenance vehicles (Figure 9). Five of these were selected for further study in the field experiments (Figure 10). One of the field experiments was designed to estimate how well drivers detect the speed and point of closure (the time at which a vehicle moves towards another) of a maintenance vehicle for different mounting arrangements. Findings indicated that the number of lights, which ranged from one to four, had no significant effect on drivers' estimate of speed or closure rate.

Figure 9. Typical warning light mounting locations (Source: Hanscom & Pain, 1990).

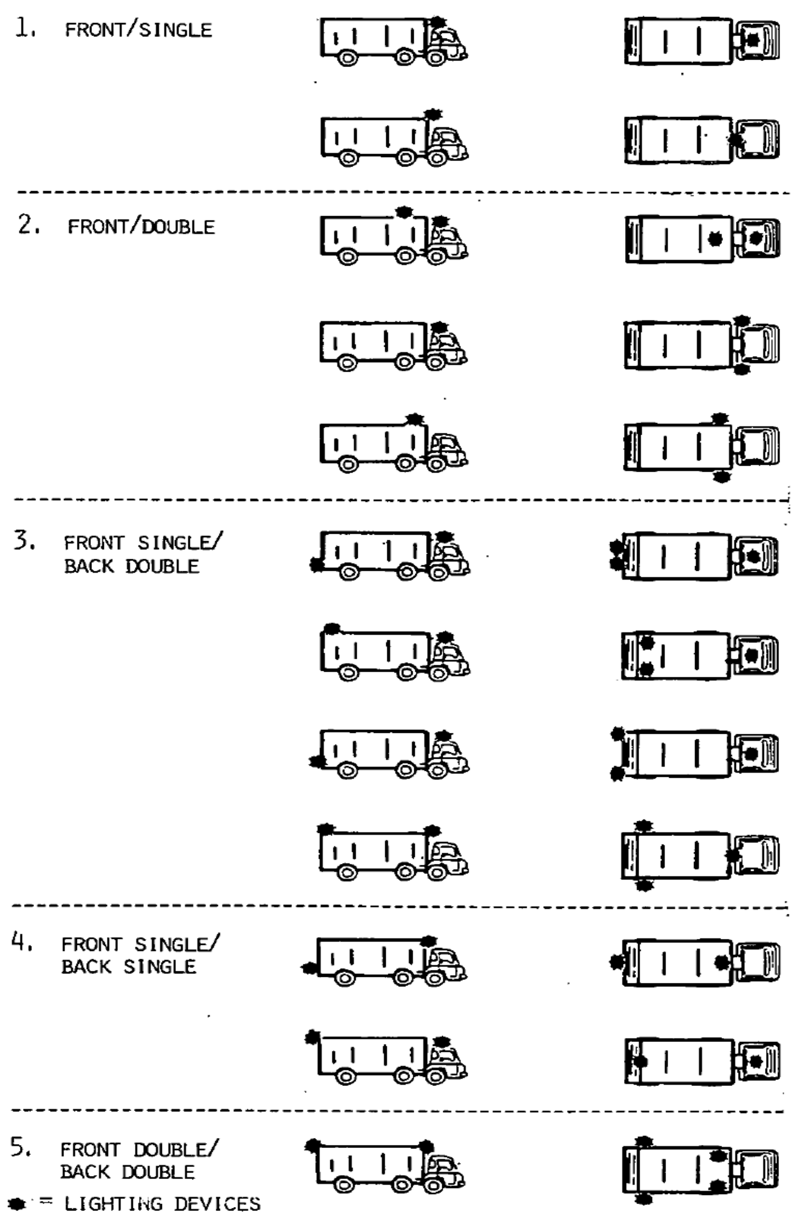
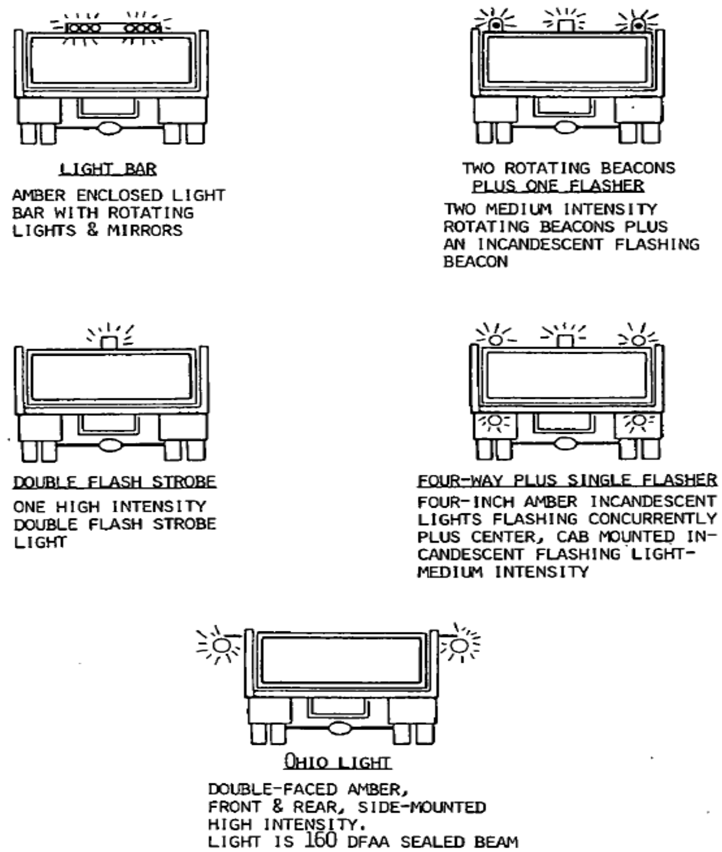


Figure 10. Road work vehicle lighting devices and configurations tested by NCHRP (Source: Hanscom & Pain, 1990).



The second field test undertaken by Hanscom and Pain (1990) measured drivers' lane change behavior around a roadwork site with different light configurations. This study was conducted on a public road. The study reported that the multiple-light treatments outperformed single-light treatments with respect to lane change behavior. The results suggest this may be expected given drivers' tendency to continually scan and search the environment, which would make it more likely that they would detect a light if there were more than one.

Field studies by Cook et al. (2000) also sought to understand whether the number of lights had an impact on how well a light display alerted drivers to a simulated road scene on a test track, and how well the arrangement informed drivers of the conditions at the scene. Drivers were asked to rate the level of conspicuity, disability glare, discomfort glare, annoyance, urgency, and color association of various light displays. The study also provided an expert assessment of the risk of the lights triggering an epileptic seizure. The number of beacons varied between one and eight. Participants' subjective ratings indicated that the greater the number of warning beacons present, the greater the perceived attention-getting quality, both day and night. They also rated displays with eight warning beacons as resulting in more daytime discomfort glare based on the

DeBoer scale, but there was no difference in discomfort glare at night. The authors did not report any effects of the number of warning beacons on the other outcome measures.

Bullough et al. (2001) augmented the existing flashing beacons on a snowplow with two sets of four steady-burn LED lights arranged vertically on the back of the plow truck (one set on the left rear and one set on the right rear). Passengers in a vehicle trailing the snowplow were asked to identify when the plow ahead slowed. When the steady burn lights were illuminated, they found a statistically significant improvement in the passengers' ability to detect a change in the following distance.

In the dynamic field study by Gibbons et al. (2008), participants were asked to drive on a test track on which there was a truck displaying lights that varied in type and mounting location (from low-mounted to high-mounted). The main outcome measures were the distance from the truck at which the participant changed lanes, detected the truck, and detected a pedestrian near the truck (either 40 feet or 80 feet behind the truck). Participants were also asked to rate the sense of urgency, discomfort glare (DeBoer scale), confidence in observing the warning light, and the level of attention-getting. They found that participants were able to identify the truck at longer distances with high-mounted lights compared to low-mounted lights. They also found that the high-mounted beacons were rated poorest at attention-getting compared to the other light combinations. Based on these findings, the authors proposed guidelines for warning light characteristics on roadway operations vehicles and other road maintenance equipment. This included guidelines on photometric qualities of the light, the lighting layout, and positioning on the vehicle. They suggested that lighting should be positioned against a background that is consistent in contrast and should not be contrasted to the sky. This may require mounting lights on the front, back, and sides of the vehicle to enable visibility from all directions. They recommended keeping warning lights away from ordinary vehicle lights such as taillights. Warning lights should also be placed on the extremities of the vehicle to minimize masking by overhanging vehicle structures. They also suggested lights be positioned high on the vehicle but above driver eye height, as a balance between enhanced visibility and disability glare.

The effect of paired lighting displayed on top of vehicles to improve the quality of information to drivers was a focus of the field study by Bullough and Skinner (2011) [also discussed in Bullough (2015)]. The study tested the effects of different light characteristics on drivers' ability to quickly detect a closing vehicle on a test track. Recognition distance was measured for different lighting combinations displayed on a truck. This included a single rotating warning beacon displays and pairs of either rotating or LED warning beacons mounted on the passenger and driver side of the vehicle. Recognition distance was measured as the distance remaining after a driver sitting in a stationary vehicle was able to identify that a truck had started moving towards them. The truck was initially located 120 meters (393 feet) in front of the participant’s vehicle. The single beacon condition was found to have significantly shorter distances (the truck was closer) than the paired beacon conditions (when pooled). This indicated that drivers are better able to detect the motion of a closing vehicle with paired lights rather than a single light.

The Minnesota Department of Transportation (MnDOT, 2013) conducted a field study comparing eight combinations of warning light configuration and color for work vehicles. These included a double rotator (the incumbent design), paired LED beacons, paired mini lightbars, all-amber light bar, amber light bar with amber lowers, amber+blue light bar, and amber+blue light bar with blue lowers (Figure 11). Tests were conducted “several times in 2011 and 2012” at an isolated site on a rural multilane divided highway. Based on photos included in the report, the MnDOT research appears to have been conducted during daylight hours. The amber bar with amber and blue lowers and the amber+blue light bar (see Figure 11) were reportedly the most effective in terms of move-over behavior and reducing the speed of passing vehicles, but the details of how this was determined are not discussed in the report. The amber bar with amber lowers, all-amber bar, and mini bar were also reported to be more effective than the incumbent dual rotator design. Due to the limited geographical scope and duration of the research, it is possible that adding blue lights had a novelty effect. The “lowers” appear to be larger and have more background contrast than other devices in the array.

Figure 11. Work vehicle lighting configurations tested by Minnesota DOT (MnDOT, 2013).

Double Rotator The standard incandescent amber double rotator used by MnDOT.	
LED Beacon A pair of amber lights, similar in appearance to the double rotator, but using LEDs instead of incandescent lights.	
Mini Bar A pair of small amber light bars mounted on each side of the vehicle.	
All Amber Bar A wide bar, extending nearly the full width of the patrol vehicle, that includes only amber lights.	
Amber Bar with Amber Lowers The same wide bar as the All Amber Bar configuration, with an additional amber light below the bar on both driver and passenger side.	
Amber Blue without Lowers A wide bar, similar to the All Amber Bar, but with a blue light on the passenger side.	
Amber Blue with Additional Amber Blue Lowers Similar to the Amber Bar with Amber Lowers, but the passenger-side light on the wide bar and the lower passenger-side light are blue instead of amber.	

Steele et al. (2013) conducted driver surveys and focus groups to identify potential improvements to warning light displays at roadside and emergency response scenes. One suggestion for improvement was to reduce the number of lights displayed on individual vehicles. A field experiment was conducted to test differences in driver performance between a roadside vehicle displaying an arrow board with and without a strobe light. The speed and lane position of vehicles passing the roadside vehicle were observed from an overhead position during the test condition and also in the absence of the roadside vehicle. There was no difference in the average speed of vehicles between the two test conditions (strobe on, strobe off). There was also no difference in the distribution of traffic at the site between the two test conditions. Following the experiment, six drivers were shown a video of the scene and asked to rate how effective the different light characteristics were at conveying different messages; namely, caution/alert, slow down, and change lanes/move right. There were no differences between the two test conditions.

Bullough et al. (2024) used an O-scale model of a highway scene with first response vehicles to understand how drivers perceive the urgency of a scene under different light and vehicle conditions. They measured driver identification of a probable emergency scene and then asked each participant to identify their likely response to the scene (e.g., slow down, stop). The model vehicles were either red or yellow with retroreflective marking in the corresponding color on the rear. The lights displayed on the vehicles were either red or yellow, and the intensity of the lights varied in different tests. There were 10 experimental conditions that varied in the number of vehicles at the scene (one or three), the color of the vehicle(s) (yellow or red), the light color (yellow, red, or no light), and the vehicle on which the lights were displayed (all vehicles, only left, only center, or only right vehicle). These trials were undertaken in a simulated daytime, nighttime, and wet nighttime scene. For each trial, participants were asked to identify whether the scene presented was an emergency scene as quickly as possible. Participants were also asked to identify how they would drive past the scene (i.e., proceed with caution or prepare to slow/stop). Results showed a main effect of the number of vehicles on the percentage of drivers who stated that they would slow or stop, with participants more likely to slow/stop with three vehicles than one vehicle in the scene. There was no effect of the number of vehicles on response time. The percentage of participants that would slow/stop increased as the number of vehicles displaying lights increased. No effect of the number of light displays on response time was found. In scenes in which only one of the three vehicles had a light display, the participants were more likely to slow/stop when the vehicle with the light display was positioned closest to the passing traffic. The vehicle position did not affect response time.

Ullman et al. (2024) conducted a field experiment to assess whether different light and marking configurations better supported driver perception, recognition, and behavior around work zones. A static closed-course experiment was undertaken to measure the performance of different light and vehicle marking configurations. This included how accurately and quickly drivers could detect a roadside worker positioned amidst a simulated work zone with different light and marking displays. The scene included lights displayed on an arrow board that varied in number between 2, 4, and 8. Drivers participating in the experiment also rated the level of visibility, distraction, and glare discomfort for each condition across a five-point scale. The study indicated that an increased number of warning lights caused a greater level of discomfort glare and distraction in drivers, but did not affect their ability to detect workers on foot.

Warning Light Size and Shape

Overview

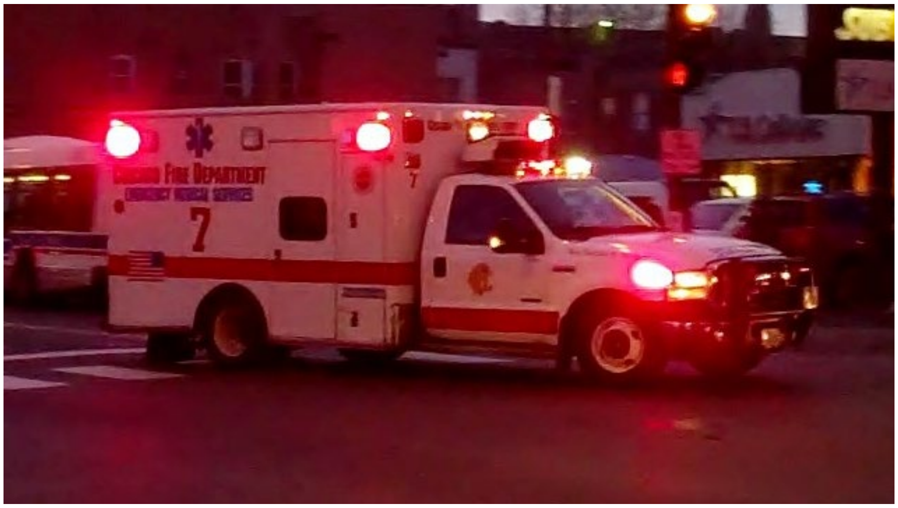
Main finding: The effect of warning light size and shape on alerting, informing, and managing drivers at roadside scenes requires further research.

The apparent size of an object decreases with distance, making distant objects more difficult to distinguish from the background. Nevertheless, there is a surprising lack of research on the effects of warning light size on warning light visibility metrics or safety outcomes. No research exploring the effects of warning light shape was found.

A wide range of practices can be observed in the field. For example, Figure 12 illustrates a work truck equipped with an amber light bar with LED modules, which is only about ½ inch tall. In contrast, Figure 13 shows an ambulance based on the Federal "Star of Life" specification, which requires several large lights encircling the roofline.

Figure 12. Low profile warning light on a work truck (Source: John Shaw/Safety Analytics International).

Figure 13. Ambulances based on the Federal "Star of Life" specification use several large lights mounted around the perimeter of the vehicle (Source: Arvell Dorsey, Jr./Wikimedia Commons (CC 2.0)).



The effect of target size has been examined in the context of traffic signals. Traffic safety research indicates that increasing the nominal diameter of traffic signal heads from 8 inches to 12 inches (200mm to 300mm) significantly reduced crashes at intersections (Sayed et al., 1998; Srinivasan et al., 2008). As a result, U.S. national standards were revised to require the larger size for all new signal installations, equipment replacements, and high-speed roads (Federal Highway Administration [FHWA], 2009). The increase in diameter more than doubles the luminous area of the signal head. The implication is that "compact" or "low-profile" vehicle warning lights (e.g., those shown in Figure 12) could be less effective than full-size lights with equivalent luminous intensity.

Warning Light Color

Overview

Main finding 1: Although there were mixed results, the color of the light display may affect the ability of a driver to detect and identify conditions at a roadside scene. Warning lights in amber or green have generally been found to be highly visible from a distance and to support early lane changing. Unfortunately, this long-distance visibility comes at a cost: compared to other colors, amber and green appear to result in more glare, which increases the time required for road users to detect workers and other details in the scene. As discussed in the next item, these effects could be due to differences in optical output, rather than the color itself.

Main finding 2: Much of the research appears to conflate the effects of warning light color and photometric output. Prior to LED lighting technology, colors were produced by installing colored domes over white lights. However, colored domes transmit only a fraction of the light. This effect is compounded by the unequal sensitivity of the human eye to specific colors.

Main finding 3: Consistent with historical practice, drivers strongly associate red or blue warning lights with fire or police, and strongly associate yellow/amber warning lights with road maintenance, construction, and towing. The color also influences driver perception of the level of urgency of the scene and how they may respond.

Main finding 4: Short-term tests suggest color schemes other than amber alone might be perceived as indicating a somewhat more urgent scene, but long-term evaluations are required to determine whether this is simply a novelty effect.

Main finding 5: Different ambient light conditions require different combinations of intensity and flash pattern to balance the need for daytime conspicuity with the need to avoid excessive nighttime glare.

In the statutory and regulatory scan conducted for this project (described in the next major section), the project team found that color is the primary focus of state laws and regulations governing warning lights for RSVs, maintenance vehicles, and emergency vehicles. The statutes and regulations are often silent on other aspects of warning light design, such as intensity, flash rate, and photometrics. Similarly, color has been the most-studied aspect of warning light design.

Prior to the development of LEDs, most commercial warning light products consisted of colored domes mounted over white lamps (a few products used a tungsten filament molded inside colored glass). The manufacturer would simply change the dome color for different markets (law enforcement, police, towing, etc.), but the resulting photometric output differed greatly for each variant of the product. For example, according to Rubin and Howett (1981), light transmission was approximately 50% for yellow domes, 20% for red domes, and only 3 to 6% for blue domes. Similarly, Ullman et al. (2024) reported the peak luminous intensity values for a green warning light to be nearly 20% higher than a comparable amber light (499 vs 421 cd for the product tested). As noted earlier, the sensitivity of the human eye also varies greatly by color. Thus, in reviewing the results of the studies that follow—most of which examined light sources comprising a colored dome over a white filament (as opposed to colored LEDs)—it is important to note that color is often confounded with intensity.

Ullman et al. (1998) [also summarized in Ullman (2000)] surveyed Texas drivers about their perceptions of various warning light colors and color combinations. In general, the degree of hazard was perceived to be greatest for vehicles displaying red lights, followed by blue. Yellow warning lights were perceived to convey only a moderate degree of hazard. Combinations of yellow+red or yellow+blue were perceived as conveying a modestly higher level of hazard than yellow lights alone. Combinations of red+blue or red+blue+yellow were perceived as conveying slightly less hazard than red alone. They also found that Texas drivers strongly associated red lights with fire and ambulance services; red+blue with law enforcement; and yellow with towing, roadside assistance, and road maintenance.

Using field studies at freeway sites in Houston and San Antonio, Ullman et al. (1998) measured the speeds of vehicles passing a Texas DOT maintenance truck displaying yellow, yellow+blue, or yellow+red+blue lights. Most of the speed differences were not statistically significant. Additionally, speeds were the same for vehicles passing a maintenance vehicle, compared with those passing a Texas Department of Public Service (DPS) law enforcement vehicle displaying its standard red+blue+amber lights.

At night, Ullman et al. (1998) examined the number of brake activations upstream in response to vehicles displaying the various color combinations. Brake activations were more frequent in the presence work trucks with two-color (yellow+blue) or three-color lights (yellow+blue+red), or when passing the law enforcement vehicle. The authors surmised that nighttime drivers might assume the trucks with three-color lights were law enforcement vehicles until they were close enough to see the vehicle well.

Cook et al. (2000) tested for differences in the performance of warning lights of different colors in a simulated busy daytime and nighttime urban scene in a laboratory. This included lights that were amber, blue, green, or red, and that also varied in flash rate, pattern, location, and intensity. The main outcome measures were the time to detect the simulated beacon and the participants' rating of disability glare, annoyance, and perceived urgency. In this experimental setting, the authors reported the following findings for warning light color when luminous intensity was held constant:

- Amber lights had the poorest detection time (of the beacon), both day and night.
- Blue minimized disability glare by night and discomfort glare by day.
- Green was detected the most quickly by day but performed worst for night disability glare, night discomfort glare, and daytime discomfort glare.
- Red was detected the most quickly by night, and produced the least discomfort glare (day and night).

The authors then simulated a busy road scene in a closed field to validate the findings of the laboratory test. This was undertaken in view of expected differences in the photometric output of commercial warning lights given their color. The same performance outcomes were measured in this field experiment. The authors reported that when colored domes were used over white light sources, the following effects were observed:

- Amber lights had the fastest detection times (day and night) and the most nighttime disability glare.
- Blue lights had the least discomfort glare (day and night).
- Green had the least discomfort glare (night) but the slowest nighttime detection time.
- Red minimized night disability glare.
- Magenta was the slowest to detect (day and night).
- Using an additional flashing color in conjunction with amber improved detection times compared with flashing amber only. Red, white, and blue were tested; red was believed to offer the best compromise in terms of detection and glare.

Comparing the results of the lab and field studies by Cook et al. (2000) indicates that when a commercial product is tested with different dome colors, the issues of light color and luminous output are difficult to disentangle. In the field tests, amber likely produced more glare because the light was more intense, while the dimmer blue light produced less glare.

Flannagan and Devonshire (2007) conducted a closed-course experiment of the effect of different warning light characteristics on driver vision and performance around a night emergency vehicle scene. The scene was an emergency vehicle displaying a warning lamp at high intensity with a mannequin representing a pedestrian near the vehicle. A bank of LED lights displayed on top of the emergency vehicle varied in color (blue or red) and flash pattern. Eight participants were asked to identify as quickly as possible when they observed the mannequin, which was not present in all situations and had varying levels of retroreflective clothing. They were also asked to rate the level of pedestrian conspicuity for different lighting conditions. Participants were driving an instrumented vehicle. Participants detected the mannequin sooner under the blue light than the red, and this difference was statistically significant. The effect of color on lamp conspicuity was also found to be significant, with blue lamps rated as more conspicuous than red lamps. The authors suggested scotopic (night vision) illumination values may better represent this effect than photopic (daytime vision) values, if it is assumed that more intense lights are more conspicuous than less intense lights. The color of the light did not impact the lateral clearance of the participants' vehicle when passing the emergency vehicle.

Flannagan et al. (2008) conducted a static field test to measure driver day and nighttime responses to different light characteristics displayed on an emergency vehicle in a simulated traffic scene. The scene was designed to simulate conditions where the position of the emergency vehicle was unknown. Participants were asked to identify the position of an emergency vehicle displaying warning lights as quickly as possible under different light colors and intensity levels; they were also asked to identify the position of a pedestrian. The emergency vehicle displaying the lights was located either to the left or right of the participant, at positions comparable to the orientation of the left and right side-mirrors. The pedestrian was located either to the left or right of the emergency vehicle. The vehicle's LED lights varied among four colors: white, yellow, blue, or red. These were displayed at one of two intensities. The authors found that during the night, a blue LED display would require a much lower level of intensity than a white, yellow, or red display to achieve the same subjective rating of lamp conspicuity. The red LED display required the highest intensity.

McCullouch and Stevens (2008) tested differences in the perceived brightness of warning lights from different suppliers that were in use on DOT maintenance vehicles. Other variables included light color and weather conditions. This limited expert-consensus study compared the products side-by-side in the field, with observers rating the relative brightness of each package in snow, cloudy, bright sun, and night conditions. The authors reported that in challenging field of vision conditions (storm, snow, bright sun), amber lighting achieved the best results for visibility to drivers, followed by blue light.

Gibbons et al. (2008) evaluated the effectiveness of maintenance vehicle warning lights with varied characteristics including color. One phase of the study was done at a test track using a real stationary vehicle with a light display. Participants seated in a vehicle at two different setbacks from the maintenance vehicle were asked to rate the level of attention-getting, the likely function of the vehicle, and discomfort glare for different lighting equipment during the daytime and nighttime. Participants also performed a peripheral detection angle task. The attributes that were varied depended on light source (LED, halogen panel lights, strobe panel lights, or rotating beacons), but generally included changes in intensity, flash frequency, and pattern. Results showed that color affected participants' ability to detect the light in their peripheral vision. Amber or white lights performed better than red or blue, independent of light type.

Nevertheless, there was an interaction between light color and light type, with the red LED combination resulting in the best peripheral detection. There was also an interaction between light color and light type in terms of attention-getting, with the strobe light type rated higher on attention-getting than the other light types except the red LED. The authors noted that this may be attributed to the red LED being displayed as a steady light source, and therefore appearing similar to brake lights. The color of light was not associated with differences in discomfort glare in this experiment.

Howell et al. (2015) conducted a survey of state DOTs inquiring about the light types and light colors used on highway maintenance vehicles. They found that all DOTs responding to the survey used amber/yellow lights on maintenance vehicles. Respondents also indicated that white, red, and blue lights were also used on these vehicles (44%, 38%, and 25%). No respondents reported the use of green warning lights.

Muthumani et al. (2015) surveyed the light technologies and configurations used in snow plowing and other winter maintenance operations. The study focused mainly on characteristics of auxiliary headlights and also reviewed best practice related to rear-facing warning lights. They found that amber was the warning light color most commonly used on snowplows. Respondents indicated that blue, white, and green were also of interest and being tested. The survey also indicated that white lights may be preferred by snowplow operators because of perceived conspicuity improvement during low visibility conditions such as fog.

Bullough et al. (2019) used an O-scale model to measure participants' ability to detect a model police officer wearing a reflective vest, positioned adjacent to a model vehicle displaying either red or blue warning lights. In addition to blue or red LED lights on top of the vehicle, a low intensity white LED light was provided on the side of the vehicle. Forward-lighting equivalent to a vehicle headlamp was provided from the position of the participant. Participants were asked to identify the presence and position of the police officer relative to the vehicle (left, right, not present), and also rate discomfort glare using the De Boer scale. They found that the presence and position of the police figure was more accurately reported when there were no flashing lights (57% accuracy) than when there were either red or blue flashing lights (45% accuracy). Independent of the light color, there was a higher level of accuracy when the low-level white light was illuminated (81% accuracy). There was a statistically significant main effect of the light array color (red or blue) on discomfort glare. The blue LED lights were rated as causing higher levels of discomfort glare than the red LED lights. There were no differences between the two light colors in the accuracy of detecting the police figure.

Terry et al. (2020) conducted a naturalistic observation study to determine the effect of different lighting configurations on driver behavior around police vehicles. Marked and unmarked police vehicles were used to simulate a police scene on six different public roads, which included a second vehicle posing as a vehicle that the police had pulled over. Modifications to the police vehicles included changes to the light color, light type, as well as the addition of extra lights. Lane change behavior and speed choice were the main outcomes. Four light and vehicle configurations were tested for the marked vehicle, and two for the unmarked vehicle. The four marked vehicle conditions were as follows:

- As currently in operation (blue lights)
- Light color changed from blue only to blue and red
- Maximum lighting (additional blue lighting on light bar and on vehicle)
- A single blue beacon (and removal of blue light bar).

The findings indicated that adding red to the blue police light bar resulted in an increased number of vehicles changing lanes away from the scene. Because of variations between the sites, the extent to which the observed associations between lighting and driver behavior are actually attributable to the lighting configurations is unclear.

A closed field study by the Emergency Responder Safety Institute (2021) simulated a traffic incident at night to measure how drivers navigated the scene and perceived the incident under different light configurations. Four light colors were included in the study (blue, white, yellow, and red), which also varied in intensity, modulation, flash rate, and position on the response vehicle. The presence of reflective marking also varied. The main outcome measures of the study were lateral offset between the participants' vehicle and the response vehicle, the distance at which the participants were able to observe a simulated firefighter at the scene, and participants' ratings of visibility, discomfort glare, and general scene visibility. The study indicated that there were significant differences in the rated level of visibility of the flashing light display amongst the four light colors. Blue and red lights were rated as more visible than white or yellow lights, with yellow lights rated as the least visible. Blue and white colored lights were rated as having the greatest discomfort glare. The authors reported that the color of the light did not affect the overall visibility of the scene, the lateral distance vehicles travelled from the simulated vehicle, nor the distance at which the firefighter was detected.

Fakhrmoosavi et al. (2021) evaluated the use of amber+green warning lights for Michigan DOT snowplows. Their results suggested a direct correlation between conspicuity and glare levels. In general, adding green increased both conspicuity and glare compared to the all-amber case. Glare was exacerbated when a quadruple flash pattern was used. The authors concluded that different ambient light conditions require different combinations of intensity and flash pattern to balance the need for daytime conspicuity with the need to avoid excessive nighttime glare.

Bullough et al. (2023) used a scale model to evaluate the effect of color on driver identification of emergency conditions. Red or yellow model vehicles equipped with simulated red or yellow LED warning lights were placed on both sides of the highway. Participants were asked to identify which vehicles represented a fire emergency.

Experimental variables included light color, light intensity, and light flash frequency. In two conditions, the color of the light on the vehicle was same as that of the vehicle, and in one condition the color of the light was the opposite of the vehicle's color (e.g., yellow light on red vehicle). When the light color matched the vehicle color, pairs of red vehicles were identified as the fire emergency scene over pairs of yellow vehicles and also pairs with one of each color. When one pair was red and yellow and the other pair was both yellow, the red and yellow pair was identified as the target. This trend was also observed when the intensity and flash frequency of the red lights was increased. When the light color opposed the vehicle color, the authors reported that there was no overall preference for different vehicle and light pairings.

Using scale models, Bullough et al. (2024) measured driver identification of an emergency scene and likely response under 10 combinations of vehicle color (yellow or red), warning light color (yellow, red, or off), and flash frequency. In this experiment, the red or yellow vehicles were equipped with retroreflective marking on the rear in the corresponding color. These trials were undertaken in a simulated daytime scene, nighttime scene, and nighttime scene with wet pavement. For each trial, participants were asked to identify if the scene presented was an emergency scene (yes or no) as quickly as possible. The time to respond was logged as an indicator of certainty. Participants were also asked to identify if they would proceed past the scene with caution or prepare to slow/stop. When vehicles were present but did not display lights, participants were more likely to slow/stop when vehicle was red than when it was yellow. There was no effect of vehicle color on response time. The percentage of slow/stop responses increased when a warning light was displayed. Scenes combining a red vehicle with a red light resulted in the highest percentage of slow/stop responses, while the combination of a yellow vehicle and yellow light had the lowest. Results for a red vehicle with yellow light were intermediate.

As part of a larger study, Ullman et al. (2024) conducted nighttime static testing of lighting colors. The colors of lights tested were amber-only and an amber/green alternating arrangement. Drivers participating in the study found the combination of amber/green warning lights to be more distracting but to have a greater sense of urgency than amber alone. The warning light color did not change the drivers' ability to identify workers on foot. It was also found that warning light color did not affect a driver's ability to identify the nominal speed of a work vehicle (stationary, moving slowly, moving faster) when tested in a closed test track during day and nighttime conditions.

Flash Rate, Flash Pattern, and Modulation

Overview

Main finding 1: Faster flash rates convey greater urgency and are more attention-getting than slower flash frequencies. Conversely, a slower flash frequency of approximately 1 Hz (1 flash per second; 60 flashes per minute) may enhance the quality of information provided to the driver, such as the relative motion of vehicles at a roadside scene.

Main finding 2: Flash frequencies ranging from 1 to 4 Hz are recommended. Frequencies over ~4 Hz have rarely been studied due to concerns about provoking epileptic seizures in susceptible individuals. Flash rates over ~15 Hz are perceived as steady lights.

Main finding 3: Alternating flash patterns (left/right) appear to be better detected by drivers than simultaneous flashing of two or more lights. Complex flash patterns such as double-flash or random patterns appear to make it more difficult for drivers to judge approach distance and detect workers near the vehicle.

Main finding 4: Evidence is limited that modulation (dimming) to ~90% of peak luminance can improve warning light visibility compared to letting the light source go completely dark during the "off" portion of the flash cycle.

The control electronics used in warning lights have changed over time. Older studies typically evaluated simple flashing of a single lamp at a uniform rate, simultaneous flashing of two or more lights at a uniform rate, or two lights flashing in an alternating (wig-wag) pattern at a uniform rate. All of these patterns could be achieved with simple electromechanical circuits.

In contrast, the current generation of microprocessor-based light bar controllers can produce very complicated flash patterns, sometimes with dozens of options. For example, a series of LED modules spanning the width of a light bar can be programmed to scroll, flash several times and then pause, or illuminate in random combinations. Some manufacturers offer controllers capable of generating dozens of flash patterns.

Another relatively recent feature is called *modulation*. Older controls simply turned each module in a light assembly on or off. At least one manufacturer now offers a control system that can widely vary the intensity of each element in a light bar. For example, a light display at 90% modulation involves a cycle of 100% of peak luminous intensity followed by 10% of peak, whereas 100% modulation involves a cycle of 100% of peak followed by 0% of peak.

Flash Rate. In a closed-track study measuring driver behavior in response to a simulated work vehicle displaying different light characteristics, Hanscom and Pain (1990) found no difference in the driver move-over behavior for flash rates between 1.0 and 1.83 Hz, but suggested that flashing lights (as opposed to rotating beacons) made it easier for drivers to judge their distance as they approached the work vehicle.

Based on a laboratory and closed track field experiment, Cook et al. (2000) found that there were differences in the level of attention-getting, sense of urgency, and perceived annoyance for different flash rates. They found that high flash rates improved detection time (detection of the beacon) and were more attention-getting than lower flash rates. Higher flash rates were also found to convey a greater sense of urgency. However, they also noted that flash rates in excess of 5 Hz are not recommended due to increased risk of epileptic seizure in susceptible individuals. Other sources report that flash rates around 10 Hz present great risk to people with epilepsy, while rates above approximately 15 Hz are perceived as steady lights (Howett et al. 1978; Epilepsy Action, 2022; Epilepsy Foundation, 2023). The authors also found that when more than one warning beacon was present on a vehicle, beacons which flashed simultaneously were detected significantly more quickly than those which flashed alternately. Simultaneously flashing beacons were also subjectively rated as more attention-getting (day and night), whilst those which flashed alternately minimized discomfort glare (day and night). In an environment that included permanent flashing lights near the roadside, using a static amber warning beacon in combination with a flashing amber warning beacon did not make the vehicle easier to differentiate from the environment.

Gibbons et al. (2008) conducted daytime and nighttime research to evaluate the effectiveness of warning lights on maintenance vehicles with different lighting equipment. The study was conducted at a test track using a real stationary vehicle with a light display. Participants were seated in a vehicle at two different setbacks from the maintenance vehicle and were asked to rate the level of attention-getting, discomfort glare, meaning, and ability to detect (using peripheral vision) for different light conditions. Four LED flash patterns were tested with a flash frequency that varied between 1 Hz, 4 Hz, or steady. Two flash patterns of strobe lights were also tested along with two beacon rotation speeds. They found that the higher LED flash frequency may have been slightly better than the lower flash frequency in terms of a drivers' ability to detect the beacon in their periphery. Flashing LED lights were rated as more attention-getting than the steady LED display, although there were only minor differences between the flash frequencies in terms of attention-getting. The steady LED condition was rated as resulting in higher glare than the flashing LED conditions, suggesting that flashing LED is better at getting attention without resulting in increased discomfort glare. There were no differences in the study outcomes between the two strobe light flash frequencies or the two rotating beacon speeds.

Using footage of police vehicles, Turner et al. (2014) tested for differences in drivers' gap acceptance and perceived urgency under different blue LED flash frequency and pattern combinations. Police vehicles were filmed from the perspective of a driver exiting a side road. The blue LED light varied in flash frequency (1 Hz or 4 Hz) and flash pattern (single or triple pulse). The study indicated that drivers rated the higher flash frequency as being more urgent. The single pulse with the lower flash frequency was rated least urgent.

Bullough (2015) reported outcomes of two studies of closure detection response times for different lighting modulation:

- In a winter field study in New York, response times to a randomly scheduled change in the distance between participants' vehicle and a leading snow plow were measured [previously described in Bullough et al. (2001)]. This included differences in response time between a steady light bar and a flashing light under nighttime and snowing conditions. The steady light bar condition was found to have a lower (i.e., faster) mean closure detection time compared to the flashing light condition.
- A separate laboratory study [also reported in Bullough and Rea (2015)] examined closure detection response times for different lighting modulation arrangements. This study observed response times to lights with 0% (steady on) or 90% modulation were 1 to 2 seconds shorter (faster) than response times to lights with 100% modulation (on–off flashing).

A field study by Kersavage et al. (2018) required drivers to identify when they detected simulated workers located on a closed track. Experimental variables included LED warning beacon flash frequencies (1 Hz or 4 Hz) and luminous intensity (0 cd to 700 cd at 90% modulation). The study was conducted on a test track at night and the mock workers (life-sized silhouette boards) were either (a) not present, (b) present and wearing a high visibility vest, or (c) present and not wearing a high visibility vest. The authors identified a main effect of beacon intensity and the status of the worker silhouette on recognition distance, but no effect of flash frequency.

A closed track field study by the Emergency Responder Safety Institute (2021) simulated a traffic incident at night to measure how drivers navigated the scene and perceived the incident under different light configurations. Two flash frequencies were included. The faster flash rate and pattern was four short pulses of 30 millisecond (ms) duration followed by one longer 200ms pulse, repeating 75 times per minute. The slower pattern was a single 400ms pulse repeating 60 times per minute. The color, intensity, and modulation of the light was also varied in the study, along with the presence of reflective marking. Findings indicate no effect of flash rate or pattern on lateral offset between the participants' vehicle and the simulated vehicle or the distance at which the participants were able to observe a simulated firefighter at the scene. In addition, participants' ratings of visibility, discomfort glare, and general visibility of the scene were similar for both flash rates.

Fakhrmoosavi et al. (2021) evaluated the use of amber+green warning lights for Michigan DOT snowplows. With regard to flash pattern, they found that “quad flash” (four flashes per second and a pause) produced better visibility than a simple one-flash-per-second pattern, but also produced more glare. They concluded that use of different combinations of intensity and flash pattern should be based on ambient light conditions to balance the need for daytime conspicuity and for avoiding excessive nighttime glare.

Bullough et al. (2023) used an O-scale model of a highway scene to explore the effect of flash frequency for either red or yellow lights displayed on vehicles in a roadside scene. The main focus of the study was the effect of vehicle and light color combinations on identification of an emergency condition. The model included a pair of vehicles that were either red and/or yellow, placed on both sides of the highway with the color combination varied during the study. LED lights on top of each vehicle were either red or yellow depending on the experimental condition. The intensity and flash rate of the lights were varied, and participants were required to identify the pair of vehicles that represented a “fire emergency.” Three experimental conditions were differentiated by the light color, light intensity, and light flash frequency. In two conditions, the flash frequency was 1 Hz for both the yellow and red lights; in the third, the flash frequency was increased to 2 Hz with the same pulse pattern as the 1 Hz condition. The luminous intensity of the red and yellow LEDs were increased by 50% and decreased by 50%, respectively. It was found that the presence of a red vehicle with red lights was identified by participants as the “fire emergency” over combinations that focused on yellow vehicles and lights. This finding was of statistical significance and the effect was strengthened when the intensity and flash frequency of the red LED light on a red vehicle increased.

A field study by Ullman et al. (2024) explored the effect of warning light and marking configurations on driver perception, recognition, and behavior around work zones. A static experiment on a test track was undertaken to measure the performance of different light and vehicle marking configurations. This included how accurately and quickly drivers could detect a roadside worker positioned amongst a simulated work zone. In this study, which was conducted at night, the flash frequency varied between 1.25 Hz and 2.5 Hz while the flash pattern varied between an alternating (left/right) pattern and an asynchronous pattern. Neither the flash frequency nor the flash pattern was found to affect the time to detect a worker or ratings of worker visibility. Confirming findings from earlier studies, higher flash frequencies were rated as more distracting, resulting in more discomfort glare, and suggesting a higher level of urgency.

Flash Pattern. When a vehicle is equipped with more than one warning light, various flash patterns can be envisioned. In the simplest case with one beacon mounted on the left side of a vehicle and another on the right, the beacons can be flashed either simultaneously or the flashes can alternate between the two sides (i.e., a wig-wag pattern). Light bars with multiple lamps and sophisticated controllers can produce much more complex flash patterns. For example, some current commercial products can produce more than 30 patterns such as single flash, double flash, triple flash, quad flash, crisscross, scrolling, and random effects. Vendor videos posted on YouTube demonstrate the wide array of available flash patterns.

Flannagan and Devonshire (2007) explored the effect of warning light patterns (and color) on nighttime driver vision and performance around an emergency vehicle scene in a closed-course setting. The scene was an emergency vehicle displaying a warning lamp at high intensity with a mannequin representing a pedestrian near the vehicle. The flash pattern for a bank of four rows of LED lights displayed atop the emergency vehicle was varied between steady (constantly on), flash-together (alternating between two rows on and all off), and flash-alternate (equivalent of one row on but alternating rows). The authors reported a statistically significant effect of flash pattern on participants' recognition of the mannequin. Specifically, participants were able to detect the mannequin sooner under the flash-together pattern. The flash-alternate pattern was second-best, followed by the steady light display. The authors also reported an interaction effect between flash pattern and the level of retroreflectivity of the mannequin's apparel. There was also an effect of flash pattern on the level of lamp conspicuity as rated by the participants. Participants rated the flash-together pattern as more conspicuous than the steady and flash-alternate patterns. The authors suggested this may be attributed to there being an all-off period in the flash sequence, providing a greater contrast than the displays with no all-off periods.

Gibbons et al. (2008) tested for differences in drivers' perception of LED displays on a work vehicle in a static field test, including differences in LED flash rate, pattern, and intensity. The flash pattern was either synchronous or asynchronous. The authors found a statistically significant effect of the light pattern on participants' perceived level of attention-getting, with asynchronous patterns rated as more attention-getting than synchronous flash patterns.

In a field experiment by Steele et al. (2013), speed and lane position were measured on a public road under two different flash patterns displayed on a police vehicle at night. The flash pattern was either random or directional. The speed and lane position of vehicles passing the police vehicle were the main outcome measures. The investigators found that there was no difference in the average speed of vehicles between the two test conditions. They did find, however, that there were proportionally fewer vehicles approaching the scene in the lane closest to the police vehicle under the directional light display, as compared with the random light display.

Muthumani et al. (2015) conducted a literature review and survey of snowplow agencies and operators to determine best practice with respect to the use of different light technologies and configurations and vehicle markings in snow plowing operations.

Based on this review, the authors suggested that rear-facing warning lights on snowplows should include both flashing lights and steady burning lights that are spaced apart. This was recommended as a way of alerting drivers to the presence of the snowplow (primarily the flashing light), and also allowing better estimation of the snowplow speed (primarily the constant light).

A Fire Apparatus Emergency Lighting study conducted by Emergency Responder Safety Institute (2019) provided recommendations for changes to the National Fire Protection Association standards in relation to maximum and minimum lighting intensity and flash patterns. The authors asked participants to observe the light display in a demarcated area and rate the performance of 60 different light combinations with respect to visibility, likely ease of navigation, and glare. Participants viewed the lights at 10 meters (33 feet) and 100 meters (328 feet) from the source. The different light combinations included changes in intensity, flash pattern, and modulation. Participants rated the random and on-off patterns as less desirable than the alternating and “X” patterns. They also found that the ease of navigation and glare were rated as better with a 100%/10% modulation rather than 100%/0% modulation.

A closed field study by Emergency Responder Safety Institute (2021) simulated a traffic incident at night to measure how drivers navigated the scene and perceived the incident under different light configurations. Two flash frequencies were included in the study. The faster flash rate and pattern was four short pulses of 30ms duration followed by one longer 200ms pulse, repeating 75 times per minute. The slower pulse rate and pattern was a single pulse 400ms in duration repeating 60 times per minute. The color, intensity, and modulation of the light also varied in the study, along with the presence of reflective marking. The main outcome measures of the study were lateral offset between the participants vehicle and the simulated vehicle, the distance at which the participants were able to observe a simulated firefighter at the scene, along with the participants rating of visibility, discomfort glare, and general visibility of the scene. The study reported that the flash pattern did not affect any of the study outcomes.

In a closed parking lot study, Bullough et al. (2022) simulated a roadside event with three genuine police vehicles and a police officer silhouette. The vehicles displayed red and blue lights with two levels of intensity, three flash frequencies, and different flash patterns. Participants located in a stationary vehicle 220 feet from the simulated scene were asked to identify the position of the silhouette as quickly as possible. They also rated the level of attention-getting, visual comfort, and likely confidence in navigating the scene for each light combination. The flash rate was either slow (approximately 1 Hz), fast with rapid pulses, or progressive. The progressive flash rate started at the slow rate then increased to the fast rate over a duration of approximately 6 seconds. The level of synchronization of the flash pattern varied between random and synchronized, and there were also sequential flashing amber lights that were either present or not present at the scene. Sessions occurred during daytime with dry pavement, nighttime with dry pavement, and nighttime with wet pavement and simulated rainfall on the participants' vehicle windshield. The findings of the study indicated that flash frequency, synchronization, and/or the sequencing of lights have an effect on alerting, informing, and managing drivers around roadside events in either daytime, dry nighttime, or wet nighttime conditions:

- In the daytime and dry nighttime conditions, synchronized flashing and higher flash rates were found to have a main effect on attention-getting, indicating these light patterns are better at alerting drivers to the roadside scene than random flash patterns and a low flash frequency. This effect was not identified in the wet nighttime condition.
- The flash pattern and frequency had no effect on the time participants took to identify the position of the silhouette during the daytime. In both nighttime conditions (dry and wet), synchronized flashing and slower flash rates were found to have shorter (i.e., faster) detection times. A statistically significant interaction between the flashing synchronization and light intensity on detection time was observed in the wet nighttime condition.
- By day, there was an interaction between the flash rate and the presence of sequential flashing lights on visual comfort. Participants reported greatest comfort for the slowest flash rate when sequential flashing lights were not present. When they were present, visual comfort was independent of flash rate. Slower flash rates were also rated as more comfortable than faster flash rates in the wet nighttime condition, but there were no effects of flash rate or pattern on comfort in the dry nighttime condition.
- The flashing pattern and frequency were found to not affect the participants' confidence in navigating the roadside scene during the daytime condition. Slower flash rates were rated as providing greater confidence during the dry nighttime condition and confidence was rated higher in the wet condition when both synchronized and sequential flashing were used.

An on-road study by Blomberg et al. (2023) observed driver behavior in response to different lighting and advance warning conditions at a staged towing scene. Two lighting conditions (daylight and nighttime) were tested. The two conditions were differentiated by the lighting intensity and flash frequency. The report indicated that the lights can display bright, intense, random flashes during the day, and slower synchronized, lower-intensity flashes during the night. The specific patterns and intensities of the lights were not reported, although it is noted that the Whelen SmartLogic™ system was used to determine the light parameters. The daylight light configuration was tested in both a daylight and nighttime scene, while the nighttime light configuration was tested only in the nighttime scene. Although the study did not separate the light pattern from the light intensity, it did identify that there was no difference in the occupancy of the traffic lane nearest the scene between the daylight setting and nighttime setting when used at night.

Bullough et al. (2024) used an O-scale model of an emergency scene to evaluate the effects of vehicle color (red or yellow with rear retroreflective markings in the corresponding color), luminous intensity, and flash frequency on adult drivers' reports of how they would navigate the scene (proceed with caution or prepare to slow/stop). The trials were undertaken in a simulated daytime, nighttime, and wet nighttime scene. For each trial, participants were asked to identify if the scene presented was an emergency scene (yes or no) as quickly as possible, with the time to respond logged as an indicator of certainty. Effects of light color were summarized in an earlier section of this review. The intensity and flash frequency of the lights was either standard (both lights producing 2000 cd and flashing at 1 Hz) or enhanced (red light producing 4000 cd and flashing at 1.5 Hz, yellow light producing 1000 cd and flashing at 0.5 Hz). The authors reported that for the conditions with three red vehicles with zero, one, or three of the vehicles displaying red light(s), participants were more likely to slow/stop in the daytime setting with the enhanced light condition. Similarly, in the condition with three red vehicles and only one red light, participants were more likely to slow/stop in the daytime setting with the enhanced light condition. These effects were statistically significant.

The nighttime static test track study undertaken by Ullman et al. (2024) measured how quickly and accurately drivers could detect a roadside worker amongst a simulated work zone. The flash frequency varied between 1.25 Hz and 2.5 Hz, along with the flash pattern which varied between an alternating (left/right) pattern and an asynchronous flashing pattern. Neither the flash frequency or pattern was found to affect the time to detect a worker or ratings of worker visibility. Alternating flash patterns were, however, rated as resulting in lower discomfort glare than the asynchronous flash pattern.

Luminous Intensity

Overview

Main finding 1: The intensity of a light display is a commonly included study variable but comparisons between studies tend to be confounded by differing test conditions.

Main finding 2: Higher intensity warning light displays have greater attention-getting performance. They are likely to be seen from a greater distance, giving drivers more time to adjust their position before reaching the incident scene. Nevertheless, in night driving conditions they have been found to increase disability glare and to increase the time it takes for drivers to detect personnel on foot at the incident scene.

Main finding 3: Lower warning light intensity is recommended during nighttime to reduce discomfort glare and disability glare, and to enhance the quality of information provided by the light display to the driver. Dimming warning lights has also been recommended in conditions of fog or similar atmospheric perturbations.

As noted earlier, the selection of appropriate luminous intensity for warning lights and work lights requires careful consideration. By day, substantial output is required to provide contrast against the sky. By night, excessive contrast between the lights and their surroundings can result in glare, adversely impacting the ability of drivers to see towing operators and other personnel on foot.

Several studies have explored the effects of luminous output on warning light performance. The wide range of luminous intensity ranges, measurement methods, and ambient lighting conditions used in these studies make study-to-study comparisons relatively difficult.

Hanscom and Pain (1990) found that “medium” vs “high” intensity lights did not affect drivers’ ability to estimate preceding vehicle speed or gap closure rate at daytime lane closures for road work.

Cook et al. (2000) concluded that high flash intensities minimize warning beacon detection times (day and night), but intense lighting was also found to worsen disability glare.

In a field experiment by Steele et al. (2013), speed and lane position were measured on a public road under two different light intensities displayed on a police vehicle at night. The light intensity was set to either “normal” or “dimmed” and the speed and lane position of vehicles passing the police vehicle were observed. The investigators found no difference in the average speed of vehicles between the two test conditions. However, they found that there were proportionally fewer vehicles approaching the scene in the lane closest to the police vehicle under the normal light intensity compared to the dimmed light intensity. Drivers shown a video of the scene reported higher levels of glare and anxiety related to the normal intensity compared to the dimmed intensity. These results suggest that more intense lights give drivers more advance notice as they approach an incident scene, but also make it more difficult to see the scene when they are close to it.

Rea and Bullough (2016) measured participant reaction times to the onset of a yellow LED warning beacon in a computer-simulated roadside scene. The intensity of the warning beacon randomly varied between 80, 190, 850, or 3100 cd. This study identified significant differences in participants' reaction time to the warning beacon for different beacon intensities and fixation points. Higher beacon intensities were found to reduce reaction times, and there were significant interactions between peak intensity and ambient light level, peak intensity and fixation location, and ambient light level and fixation location. The authors noted that reaction times across these conditions were similar and decreasing at a similar rate above a peak intensity of 190 cd. The study also identified significant differences in visibility ratings for different beacon intensities, ambient light conditions, fixation point, and level of clutter. Visibility was found to increase with higher beacon intensities, nighttime conditions, an on-axis fixation point, and for uncluttered roadway conditions. The perceived visibility of the low-contrast target (a C-shaped figure called a Landolt ring) was found to decrease with an increase in beacon intensity. Conversely, the rated visibility of the low-contrast target was higher for off-axis fixation and for scenes with no visual clutter.

A simulation study by Bullough and Rea (2016) explored the visibility effects of using warning beacons in foggy weather. Specifically, the group modelled scenarios differentiated by beacon intensity (150 cd or 750 cd), forward lighting intensity (low or high-beam headlamps), pedestrian target position, fog density (no fog and meteorological visibility distances of 50, 200, and 600 meters [164, 656, and 1968 feet]), and spatial intensity distribution (unshielded, baffle, and beam). Visibility was measured against the Relative Visual Performance (RVP) scale. Results showed that with fog visibility at 200 meters and 600 meters, RSV values were better with a warning beacon intensity of 150 cd compared to one emitting 750 cd under the same forward light and warning beacon distribution. The researchers concluded that directing too much light in non-required directions can reduce the contrast of a hazard. Nevertheless, some low-level light should be emitted in all directions to allow people to be able to observe the beacon irrespective of their position. In addition, the warning beacon's luminous intensity should be reduced in fog or other perturbed atmospheric conditions.

Under varying LED warning beacon intensities and flash frequencies, a field simulation study by Kersavage et al. (2018) asked drivers to identify when they detected life-sized silhouette boards representing workers. The peak/trough intensity of the beacons was based on 90% modulation and varied between 0 cd, 25/2.5 cd, 150/15 cd, and 700/70 cd. The study was conducted at night on a test track and the simulated workers were either (a) not present, (b) present and wearing a high visibility vest, or (c) present and not wearing a high visibility vest. Compared to a condition where there was no beacon, mean distance for drivers to detect the worker was similar for peak beacon intensities of 25 cd (442 ft) and 150 cd (422 ft). When the peak intensity was increased to 700 cd, the mean recognition distance deteriorated to 380 ft. The authors also found a significant interaction between beacon intensity and worker condition. Specifically, when the worker was not wearing a reflective vest, the highest peak intensity was associated with a lower mean recognition distance. The authors concluded that the combination of workers wearing a reflective vest with peak beacon intensities of 25 cd or 150 cd (at 1 Hz or 4 Hz) provided the longest recognition distance compared to the no beacon and highest intensity condition.

Bullough et al. (2019) used an O-scale model to evaluate the effects of warning lights on the visibility of a police officer wearing a reflective vest. The roof of the model police vehicle was equipped with blue or red LEDs, while its sides had low-intensity white LEDs to allow the police figure to be seen. Forward-lighting equivalent to a vehicle headlamp was provided from the position of the participant. Participants were asked to identify the presence and position of the figure relative to the police vehicle (left, right, not present) and to rate discomfort glare using the De Boer scale. The main LED array was blue or red, while the low-level white LED was either on or off. In the lower intensity scenario, emission from the warning lights was equivalent to 400 cd, while the higher intensity condition was equivalent to 4000 cd. The accuracy of detecting the police figure's presence and position was significantly better with lower LED intensity, particularly when low-level illumination was provided. Participants also rated discomfort glare as significantly worse for the higher intensity condition. The authors concluded that low-level white illumination of the area around the vehicle may significantly improve recognition accuracy (e.g., of a person outside of a vehicle), and that limits on the maximum warning light intensity should be included in the relevant standard.

A closed field study by Emergency Responder Safety Institute (2021) simulated a traffic incident at night to measure how drivers navigated and perceived an incident scene under different light configurations. Four combinations of luminous intensity were included: a lower and upper intensity for lights displayed high on the vehicle and a lower and upper intensity for lights displayed low on the vehicle. The higher intensity was approximately 33% above the levels specified in NFPA Standard 1901, while the lower intensity was approximately 33% to 50% of the standard. The flash pattern, color, modulation, and presence of reflective marking also varied. The main outcome measures were lateral offset between the participants' vehicle and the emergency vehicle, the distance at which the participants were able to observe a simulated firefighter at the scene, and participants' ratings of visibility, discomfort glare, and general visibility of the scene. Light intensity affected both the visibility of the light display and discomfort glare. High intensity displays were found to increase light display visibility, although the light display was highly visible at both intensity levels. The higher intensity display was also rated as resulting in higher discomfort glare. The distance at which the firefighter was detected showed an interaction between the light intensity and the presence of a reflective marker on the vehicle. Recognition distance was worse when reflective markings were used in combination with the higher intensity warning lights.

Bullough et al. (2022) simulated a roadside event in a parking lot using three genuine police vehicles and a silhouette of a police officer. The vehicles displayed red and blue lights with two levels of intensity, three flash frequencies (slow, fast, progressive), and different flash patterns (random or synchronized; with or without a flashing sequence). Participants located in a stationary vehicle 220 feet from the simulated scene were asked to identify the position of the silhouette and to rate the level of attention-getting, visual comfort, and likely confidence in navigating the scene for each light combination. The intensity level of the red and blue lights was configured to either high (SAE Class 1 requirements) or low (60% of SAE standard). Sessions occurred during the daytime with dry pavement, nighttime with dry pavement, and nighttime with wet pavement and simulated rainfall on the participants' vehicle windshield. The high intensity level was rated as higher in attention-getting than the low intensity in the daytime, dry nighttime, and wet nighttime conditions. Conversely, participants were able to detect the position of a simulated police officer more rapidly when the warning light intensity was lower, and this difference was statistically significant.

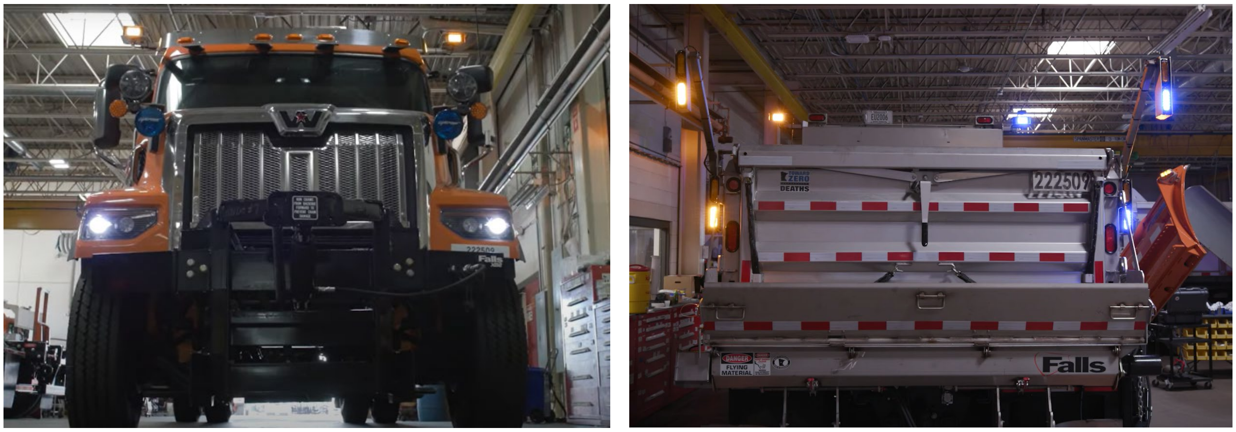
In the same study (Bullough et al, 2022), intensity level did not have a main effect on detection time in the wet nighttime condition, but there was an interaction between intensity and synchronization on detection time. With a random flash pattern, higher intensity increased detection times. With a synchronized flash pattern, both levels of intensity reduced detection times. There was no effect of intensity on detection time during the daytime condition. Consistent with previous findings, participants reported the high lighting intensity to be less comfortable than the low intensity. There was also an interaction between intensity and the presence of sequential flashing on visual comfort in the daytime condition. Participants reported greater confidence in potentially navigating the roadside scene with the higher intensity condition in the daytime condition. Light intensity otherwise did not affect reported confidence.

The on-road study by Blomberg et al. (2023) observed driver behavior in response to different lighting and advanced warning conditions at a staged tow truck scene under daylight and nighttime conditions, differentiated by the lighting intensity and flash frequency. The report indicated that the lights can display bright, intense, random flashes during the day, and slower synchronized, lower-intensity flashes during the night. The specific patterns and intensities were not reported, although it was noted that a Whelen SmartLogic™ proprietary warning light controller was used to determine the parameters. The daylight light configuration was tested in both daylight and nighttime scenes, and the nighttime light configuration was tested only in the nighttime scene. Whilst the study did not separate the light pattern from the light intensity, it did identify that there was no difference in the occupancy of the traffic lane nearest the scene between the daylight setting and nighttime setting when used at night.

A laboratory experiment by Bullough et al. (2024) used an O-scale model of an incident scene to ask adult drivers whether they would proceed with caution or slow/stop. As noted earlier, the experiment focused mainly on light color but also established a "standard" scenario and an "enhanced" scenario with both higher intensity and higher flash frequency. By day, participants said they were more likely to slow/stop when the "enhanced" lighting was displayed. Since the intensity and flash pattern variables were not tested separately, it is unclear how much of this effect was related to luminous intensity.

A video produced by Minnesota DOT (MnDOT, 2024) provides some insights into proprietary research and development currently being conducted in the warning light industry. The video describes the implementation of a "dynamic variable intensity" system for highway maintenance vehicle warning lights, evidently based on a control system marketed by Whelen. At the vehicle's rear, the arrangement uses four pairs of lights: upper left pair [amber+amber], lower left pair [amber+amber], upper right pair [amber+blue], and lower right pair [amber+blue] (Figure 14). Within each pair the lights flash in an up-down wig-wag configuration. Single roof-mounted lights facing the front and sides are displayed at the upper front corners of the vehicle. The system uses a photocell to detect ambient illuminance. Higher warning light intensity and a faster flash rate are activated in daytime conditions; when operating at night the warning lights are automatically dimmed and the flash rate is reduced. The lower pairs of rear lights automatically go dark when the brake or turn signal lights are activated. In addition, the warning lights are driven by a sinusoidal oscillator, which is said to reduce the harshness of the flash pattern (as compared to the square wave oscillators used in most LED systems).

Figure 14. Minnesota DOT highway maintenance vehicle lighting (Source: MnDOT 2024).



Vehicle Markings

Overview

Main finding 1: Various marking configurations have been studied, but most focus on boxy vehicles such as dump trucks and fire apparatus. The transferability of this research to irregularly-shaped tow vehicles may be limited (for example, compare Figure 12 and Figure 13). Studied marking combinations include the following:

- Contour markings (edge/corner outlines)
- Horizontal Chevrons
- Diagonal stripes (such as inverted V patterns)
- Checkerboard (“Battenburg”) patterns

Compared to checkerboards, the inverted V pattern appears to have less adverse impact on night visibility of personnel on foot behind the vehicle. A 1990 study found driver confusion resulting from horizontal chevron markings (some drivers thought it meant they could go around either side of the work vehicle).

Main finding 2: Some evidence shows that vehicle marking colors affect drivers’ ability to identify personnel on foot behind the vehicle, particularly at night. Red+white markings appear to be more distracting than black+yellow markings. Many other color combinations are possible, but based on the information found for this review, none have been tested thoroughly.

Main finding 3: The use of retroreflective vehicle markings has been shown to make the vehicle more visible at night. Nevertheless, there is some evidence that increasing the retroreflectivity of the sheeting material (from ASTM Type I to ASTM Type III) increases the time required for drivers to detect workers and other objects in the scene.

Main finding 4: Some evidence shows that the reflectivity of the brighter color in a pair of markings influences driver perception of the scene more than the average reflectivity of the color pair. It has been suggested that a combination of higher and lower retroreflective markings might provide a reasonable balance between visibility and glare. An outline of higher retroreflectivity infilled by lower (or non) retroreflective material has also been suggested.

Most of the research literature addressing vehicle markings appears to be motivated by concerns about rear-end collisions involving snowplows or fire trucks. As illustrated by Figure 15, the relevance of this research to the present study must be tempered by some unique characteristics of tow trucks:

- Some tow truck models—especially flatbeds—have limited space for rear markings.
- When hook-and-chain type tow trucks are unladen, the loading apparatus tends to be a visually prominent feature.
- While loading, the disabled vehicle can block the visibility of most of the lower portion of the tow vehicle.
- After loading, the disabled vehicle limits the visible portion of the tow vehicle.

Figure 15. Loading equipment and the vehicle being towed/hauled often block the view of much of a tow truck's rear (Source: Tony Webster/Wikimedia Commons).

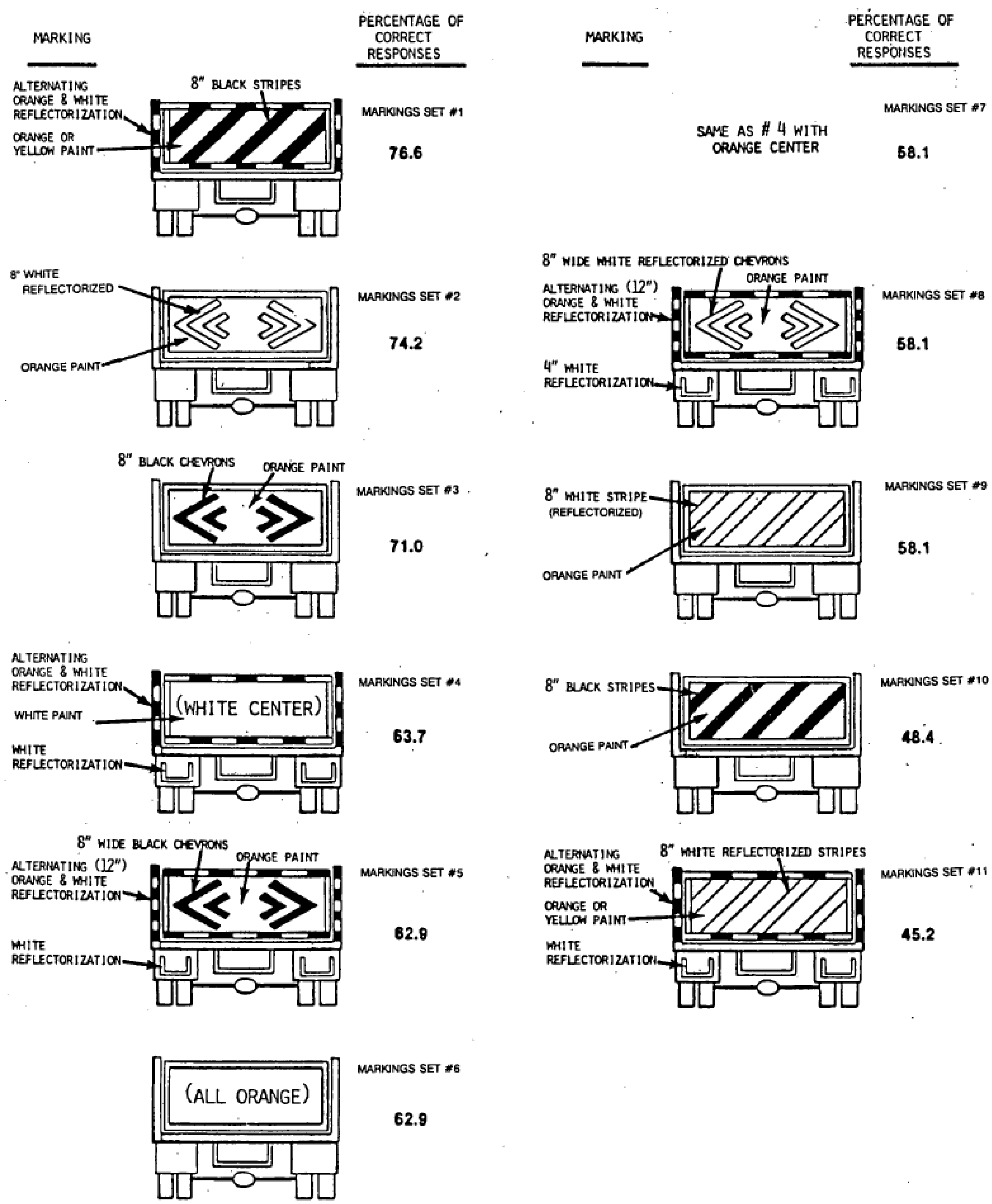
The effects of vehicle marking size, color, pattern, and retroreflectivity have often been combined in the research, so this section will treat these subjects together. Marking patterns explored in previous research include diagonal stripes (Figure 16), checkerboard patterns (Figure 17), "contour markings" that outline the perimeter of a vehicle, and horizontal chevrons. Large checkerboard patterns are frequently used on emergency vehicles in the United Kingdom, where they are often called Battenberg markings (the name refers to a colorful pastry called Battenberg cake). In British and Western European practice, Battenberg markings are generally used only on the sides of the vehicle, while diagonal stripes are used on the rear (Figure 18).

Figure 16. Diagonal stripes on the back of a tow truck (Source: Reise Reise/Wikimedia Commons).

Figure 17. Battenberg (checkerboard) markings on the tailgate of a dump truck Source: IDontScript/Wikimedia Commons).

Figure 18. Checkerboard (Battenburg) markings (sides) and inverted-V markings (rear) of a Belgian Civil Protection vehicle (Source: Watopia2451/Wikimedia Commons (CC 3.0)).

Figure 19. Back-of-vehicle markings tested by NCHRP, including horizontal chevrons (Source: Hanscom and Pain, 1990).



The study by Hanscom and Pain (1990) included a laboratory experiment where subjects were shown photographic slides of dump trucks with various combinations of tailgate markings and tailgate-mounted signs, and asked to explain what they should do in the depicted situation. Eleven vehicle marking configurations were tested, including solid colors, contour markings (stripes outlining the perimeter of the tailgate), diagonal stripes, and chevrons (Figure 19). Recognition was reported to be best with the design that combined orange and black diagonal stripes with reflectorized white and orange markings around the perimeter of the tailgate (top left image in Figure 19). Horizontal chevron markings were problematic: a substantial minority of respondents thought the chevrons indicated the driver had a choice of passing the work truck on either side.

A closed field study by Emergency Responder Safety Institute (2021) simulated a traffic incident at night to measure how drivers navigated the scene and perceived the incident under different light configurations. Four light colors were included (blue, white, yellow, and red), which also varied in intensity, modulation, flash rate, and position on the simulated vehicle. The presence of retroreflective marking also varied. The study indicated that the presence of retroreflective marking on a firefighting vehicle allowed drivers to detect its presence more quickly.

A field simulation study by Bullough and Parr (2024) measured drivers' ability to identify the position of a simulated fire fighter near two panels of retroreflective markings that represented a fire engine. The color, pattern, and retroreflectivity of the panels was varied in the study. The scene also included a light bar displaying a red flashing LED light at an intensity that met SAE standards for flashing emergency lights, as well as forward lighting from two halogen headlights intended to resemble vehicle headlamps. In some conditions, the simulated fire fighter was also wearing a yellow flashing LED light. There were six main experimental conditions that varied the color pattern (red+yellow or blue+white), the type of pattern (full coverage of panel or outline only), and the level of retroreflectivity (low [ASTM Type I] or high [ASTM Type III]). A wearable yellow LED light was also included in some trials. The full marking was an alternating chevron pattern of 6-inch stripes that covered both halves of the 3-foot x 6-foot panels. The outline marking was a pattern of 6x12 inch strips along three sides of the panels (excluding the inside border). For each condition, participants were required to identify the position of the fire fighter (in-between the panels, or to one side) from a seated position 150 feet from the scene, and the time to identify the position was recorded. The participants also rated how visually uncomfortable the panel and light display was, how difficult or easy it was to see the fire fighter, and how bright the scene was. The main findings were as follows:

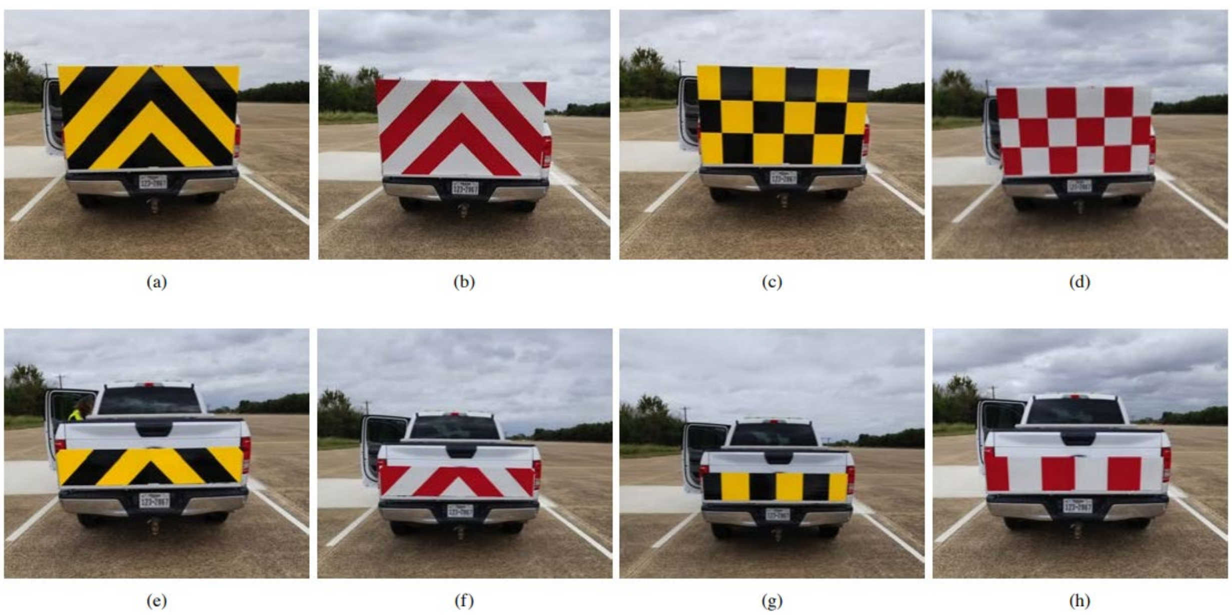
- The participants were able to identify the correct position of the fire fighter in all conditions.
- Analysis identified a statistically significant effect of the marking pattern on the rated level of brightness, with the full pattern display rated as brighter than just the outline.
- A second analysis identified a statistically significant effect of color on the rated brightness of the marking. Although the red+yellow and blue+white color combinations used in the study had similar average coefficients of

reflection and were expected to produce similar levels of disability glare, participants' ratings of brightness may have been more related to the brightest color in the combination (white or yellow), rather than the average of reflectance the displayed combination. There was no effect of the interaction between color and marking pattern.

- The analysis identified an effect of retroreflectivity on response time. The average time to identify the position of the firefighter was 0.5 seconds longer (slower) with the higher level of retroreflectivity than the lower level. The level of ease in seeing the fire fighter was rated more difficult with the high-retroreflective (ASTM Type III) material.

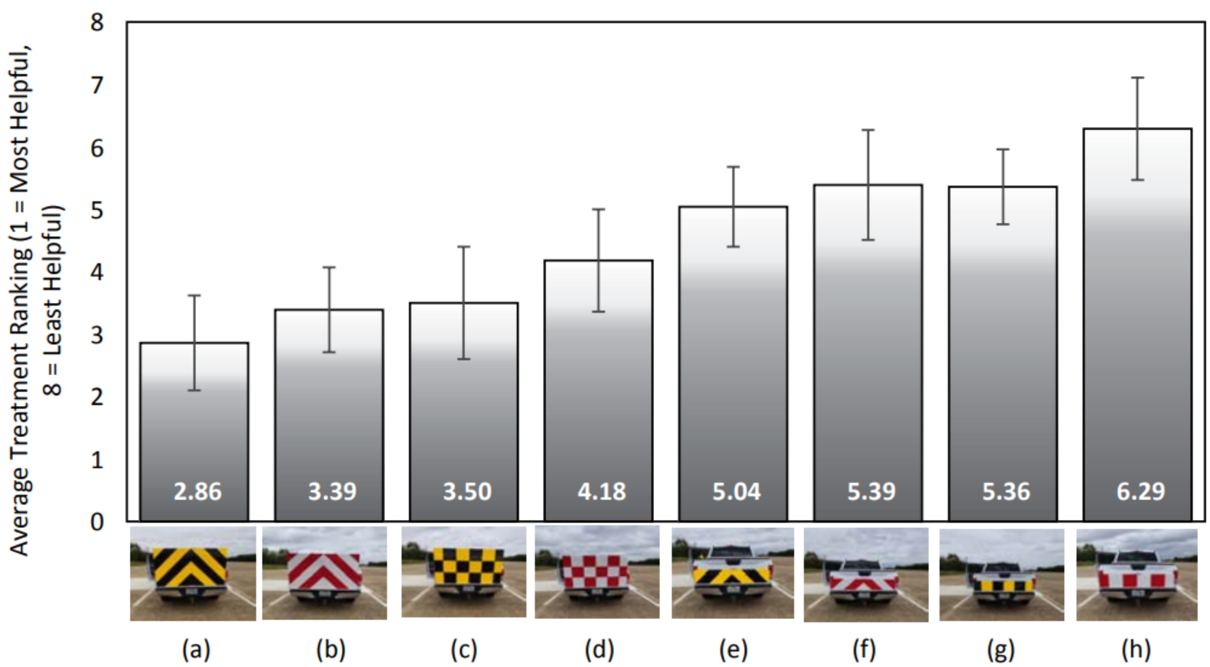
Based on these results, Bullough and Parr (2024) advised that the use of highly retroreflective materials on vehicles should be approached carefully, particularly if the marking is to cover a large area of the vehicle surface. They noted that a pattern with a lower retroreflectivity with an outline of higher retroreflectivity on the rear of an emergency vehicle may provide a balance between night and day visibility needs, but this requires further investigation.

Figure 20. Marking combinations tested by Ullman et al. (2024)



A recent NCHRP report by Ullman et al. (2024) included a static study of several combinations of marking color, pattern, and size (Figure 20). They found that checkerboard patterns and red+white color combinations performed significantly worse for worker conspicuity than inverted-V patterns and black+yellow color combinations. This was based on participants' ratings of worker conspicuity and accurate detection of the worker's position relative to a work vehicle. The authors suggested that if the colors and marking are familiar to drivers, they are less distracting, making it easier for drivers to identify workers on foot. In subjective rankings (Figure 21), black+yellow markings were consistently ranked "more helpful" than red+white markings, larger panels (3 x 6 feet) were consistently ranked as more helpful than small panels (1 x 6 feet), and inverted V patterns were consistently ranked as more helpful than checkerboards. The best pattern according to these subjective rankings was the 3x6 foot inverted V in black+yellow, while the worst was the 1x6 foot checkerboard in red+white.

Figure 21. Subjective rankings of how "helpful" different marking combinations are (1=best, 8=worst) (Source: Ullman et al., 2024).



Ullman et al. (2024) also conducted a static field experiment to compare the effect of the above-described vehicle marking schemes on a driver's ability to detect and correctly identify the position of a roadside worker. The roadside worker was dressed in a high visibility safety vest but was otherwise wearing black clothes. The study was conducted on a closed track with participants seated in a vehicle 400 feet from a pickup truck with retroreflective markings. Participants were asked to identify as quickly as possible the presence or non-presence of the worker, and if present, the position of the worker relative to the vehicle (to the left, center, or right). Participants were able to correctly identify the position of the worker in the high majority of cases (91%). The study indicated that participants were more likely to detect the position of the worker correctly with the inverted V pattern than the checkerboard pattern. Findings indicate that the intensity of the retroreflective markings could negatively impact the ability of drivers to recognize the location of a roadside worker.

Characteristics and Limitations of Previous Studies

Much of the previous visibility research focuses on snowplows and fire trucks. For example, studies have examined whether adding blue or green flashing lights can improve the conspicuity of snowplows. Often the focus is on the visibility of the truck itself, since it is rare for a snowplow operator to get out of the truck and stand behind it as is common in towing operations.

Some of the previous warning light research focused on the visibility of personnel at a roadside scene, and some also explored how drivers may perceive the meaning of the warning light. For example, research has explored whether using two or more colors conveys warning messages more effectively than a single color.

Research on green warning lights raises a central quandary: once the meaning of a color is defined by law or tradition, repurposing that color is difficult. In photopic (daytime) vision, the human eye is highly sensitive to yellow-green light, and in field tests green warning lights were perceived to be highly visible. Nevertheless, most of the concepts associated with the color green are the opposite of warnings: examples include "start" (green light in a motor race, green button on an industrial machine), "proceed" (green traffic signal), "situation normal" (green status indicator light) or "comfortable environment" (green grass and trees). As a result, there are concerns about whether green should be used as a warning color (SAE 2013).

Research approaches used in previous studies have included both laboratory and field methods, which are described in more detail in other sections. Some of the field studies were conducted on closed test tracks, others on public roads. Other research methods included computer simulations, video clips, and scale models. Physical models were typically built at what the toy and hobby industry calls O-scale (1:43 to 1:48), presumably to allow the use of off-the-shelf components (for reference, an O-scale model of a standing adult person is about 1.5 inches [38 mm] tall).

There was a notable lack of prospective studies examining performance changes after the lighting was changed for a vehicle fleet. In addition, no research was found that used injury incidence as the primary outcome measure. This is consistent with research in occupational safety in the road environment, where injury incidence is a rare outcome and randomizing treatment is a challenge.

Literature based on laboratory studies typically tested for effects across a relatively expansive range of lighting devices. Test track studies tended to focus on the efficacy of different light and marking conditions in informing drivers of specific conditions at a simulated scene. Studies conducted on public roads tended to be more limited in the conditions under study, with outcome measures generally limited to driver behavior variables such as speed and lane choice. There were no studies conducted on a public road that measured a driver's ability to observe a roadside worker under different warning light characteristics.

Some of the test track studies used mannequins or cut-outs to gauge the visibility of "workers" near a vehicle displaying warning lights—usually from the vantage point of a stationary vehicle. It is important to note that research participants' visual performance on these worker-recognition tasks could differ from real-world conditions, since neither the vehicle nor the "worker" was in motion. In addition, towing vehicle operators often need to crouch to accomplish their tasks, resulting in a profile that is less conspicuous than a standing figure.

Most of the previous warning light studies have been relatively small-scale efforts. For many of the studies, a notable difficulty has been the lack of detailed photometric data for the devices under study. This lack of information is particularly important when interpreting the results of studies about light color. Many lighting equipment manufacturers offer the same device in various colors. Often this is achieved by varying the color of a plastic dome placed over a white light source. Since plastics of different colors have very different light transmission rates, the resulting optical output varies greatly. It can thus be expected that an amber dome will appear brighter, be visible from a greater distance, and produce more glare than a blue dome installed over the same source.

When interpreting the results of previous studies, it is also important to consider the diversity of traffic environments. Beam spread is one example. For a given amount of light output, the reflectors and lenses used in a lighting device can be designed to focus the light into a narrow area or spread it across a wide area. Viewed straight on, the narrow beam will appear brighter than the wide beam. Nevertheless, traffic approaching from off-angles (for example cars rounding a curve) will potentially benefit from relatively wide beam spread.

Discussion

This review aimed to identify research literature describing the relationship between warning light and vehicle marking characteristics for special-purpose vehicles (law enforcement vehicles, fire apparatus, maintenance trucks, and towing vehicles) and measures of driver performance and perception. A modest number of academic studies met the inclusion criteria, along with a small number of project reports and other grey literature items. The information extracted from these publications provides insight into characteristics that may contribute to the following:

- **Alerting** road users to the presence of a roadside vehicle
- **Informing** road users of the conditions at the scene, such as the presence of a worker on foot

- **Managing** road user behavior at the scene, such as encouraging earlier lane change behavior

The review also aimed to understand the types of outcome measures that have been studied and the associated study designs. Where possible, the review aimed to quantify the lighting and marking characteristics in terms of metrics that can be replicated in a lighting simulation model and field study.

The most important take-away from the prior research is that interventions intended to improve the long-distance visibility of special-purpose vehicles often appear to have adverse effects on the visibility of personnel on foot near the vehicles. Some sources, such as Fakhrmoosavi et al. (2021) have characterized this as a direct trade-off between visibility and glare, but the relationship is probably more complicated due to factors that have not been thoroughly explored in previous research. Examples of these factors include warning light mounting height, beam spread, and the waveform of the light pulses.

Although results from the primary studies are mixed, the preponderance of evidence suggests that several techniques are successful in drawing attention to a special-purpose vehicle, especially at night. These include using a faster flash rate, increasing the luminous intensity of the warning light(s), increasing the number of lights, increasing the amount of retroreflective sheeting on the vehicle, and using sheeting materials with higher retroreflectivity. Replacing some of the amber lights with green or blue also appears to help draw attention to the vehicle, but it is unclear how much of this is a novelty effect. By helping motorists become aware of the vehicle further upstream, these techniques give drivers more time to reduce speed or move over as they approach the vehicle. Unfortunately, during night operations they also increase glare, increase the time it takes for drivers to perceive the presence of a person on foot near the vehicle, and decrease the overall visibility of personnel on foot. No studies of safety outcomes resulting from changes in warning light parameters were found, making the net effects on road user and worker safety unclear.

Current work-lighting practices in the towing industry potentially exacerbate the problem of nighttime glare at towing scenes. Many tow vehicles are equipped with two sets of flood lights. One is often mounted near the rear of the cab roof, angled slightly downward to project light onto the truck bed and the engine compartment of a nearby disabled vehicle. A second light (or set of lights) is often mounted low on the tow vehicle's rear, projecting light horizontally to illuminate the undercarriage of the disabled vehicle. As drivers pass the tow vehicle, glare from these lights can potentially make it more difficult to observe a tow operator on foot.

Relatively small changes in lamp position and intensity can have major effects on glare. More work is needed to help determine whether there are ways to overcome the conspicuity–glare paradox. For example, it may be possible to use downward-mounted work lights to reduce glare while providing uniform illumination of the truck bed and disabled vehicle.

Other Key Findings

Other key findings of this review are summarized below by theme.

Device Type. Although tungsten halogen and xenon flash tube warning lights remain commercially available as of 2024, the literature review indicated that LED warning lights are currently the preferred choice of most public agencies. This also appears to be the case in the private towing industry. Some early research aimed to identify performance differences between light types, although more recent studies tend to focus on varying the characteristics of LED lights rather than varying the device type.

The three main device types are quantitatively different in terms of the waveforms of the emitted light pulses. Viewed at any given point, the light intensity from a rotating beacon rises and falls in a slow sinusoidal pattern. Xenon discharge tubes produce sharp, intense flashes of light accompanied by a characteristic popping sound. LED devices have traditionally been pulsed by square wave generators that turn the lamp on and off abruptly, but at least one manufacturer now appears to be transitioning to a sinusoidal waveform that reduces what that company terms "harsh edge flash."

LED warning lights offer a number of operational advantages. The initial transition to LEDs was probably motivated mainly by the substantial reduction in power consumption compared to halogen lamps. This reduces the need to idle the vehicle's engine while the warning light is in use, and the associated risk of completely discharging the vehicle battery if the warning lights are left on while the engine is off. In general, LEDs are quieter than xenon discharge tubes. Moreover, LED lights have great potential for flexible control over the warning light characteristics in different conditions. This includes control over flash pattern, flash frequency, luminous intensity, and color. Importantly, these adjustments can be programmed to occur automatically in response to data from ambient light sensors, or manually overridden by a vehicle operator to respond to conditions such as smoke or fog.

Number of Lights and Mounting Locations. With the exception of a small number of laboratory studies, the literature tended to focus on the number of lights on an individual vehicle. The number of lights that were used in these studies typically ranged from one to eight, with more recent literature focused on displays with at least two lights and typically no more than four.

The use of paired warning lights (typically one on each side of the vehicle) was generally found to provide drivers with more information to judge their speed and closing distance as they approach a special-purpose vehicle. Light displays with more than a single light were also more likely to get the attention of drivers than displays with just a single light. In general, authors of cited works tended to recommend either two or four lights per display. Displays with eight lights appear to produce more discomfort glare and distraction without necessarily adding information. More research is required on the effect of multiple vehicle attendance at a scene—and therefore a greater number of lights—on driver perception and performance.

Mounting lights high on the vehicle with a static contrasting background is considered to provide the best visibility of the roadside vehicle, providing this is above the typical eye height of the driver. It is suggested that lights at eye level will only increase discomfort and disability glare. The practical implication of this approach may be that in lieu of the traditional omnidirectional beacons, lights on each side of the vehicle are required, similar to the Star of Life ambulance design (Figure 13) or the Minnesota DOT maintenance vehicle design (Figure 14). Positioning lights near other vehicle lights (e.g., tail lights) is to be avoided so that these functional lights are not overlooked.

Light Size and Shape. The effect of different light sizes and shapes is understudied, although there are some examples of this type of research in the context of traffic signals. This may be attributed to the use of ready-made products in field studies rather than custom-made light displays.

Warning Light Color. Although findings in the primary studies were not completely consistent, the literature generally suggests that warning light color affects drivers' ability detect a scene and identify the conditions at the scene. Brighter colors were generally found to be more conspicuous, but also to result in greater discomfort glare. This in turn appears to increase the time needed to detect objects in the scene, such as simulated road workers.

These effects could have more to do with luminous intensity than with color itself. Many warning light products continue to use colored translucent domes mounted over a white light source. The transmission rates for domes of various colors differ greatly. Amber and (especially) green are highly visible colors—and they are also the colors that transmit most efficiently through colored glass or colored polycarbonate.

Interpretations of various vehicle marking colors and warning light colors have a long social history. From early childhood, people learn to associate red with fire services, blue with police, and so forth. Perhaps as a result, light color was found to influence driver perception of the level of urgency of the scene, with blue and red light displays tending to be perceived as conveying greater urgency than amber. The message ambiguity concerns expressed by Howett et al. (1978) remain timely: a towing scene may indeed be less *urgent* than a roadside vehicle fire, but it can still present considerable *hazard* to passing traffic.

Flash Rate and Pattern. Warning light flash frequency was typically 1 to 4 Hz (60 to 240 flashes per minute). Slower flash frequencies (typically 1 Hz) were generally found to enhance the quality of information provided to the driver, such as the relative motion of vehicles at a roadside scene. Higher flash frequencies (typically 4 Hz) were considered to convey greater urgency and were rated as more attention-getting than slower flash frequencies. Flash frequencies over 4 Hz are not recommended due to the risk of provoking epileptic seizures in susceptible people, and frequencies over about 15 Hz are perceived as steady lights.

Increasing the complexity of flash patterns does not appear to be helpful to road users. Alternating flash patterns (left/right “wig-wag”) were generally found to be better detected by drivers than simultaneous flashing of two or more lights. Alternating patterns also appear to improve the ability for drivers to detect other objects in the scene compared to random flash patterns.

Luminous Intensity. The values of luminous intensity evaluated in research varied substantially. Notwithstanding this, it was generally found that higher intensity light displays have greater attention-getting qualities than lower intensity displays. At night, high intensity lights usually increased disability glare, and as a result road users needed more time to detect workers on foot and other details of the scene. Lower intensity light displays are recommended during night towing operations to reduce discomfort glare and disability glare, and to enhance the quality of information provided by the light display to the driver.

Vehicle Markings. The widely varied vehicle marking practices of public agencies and towing companies could be due in part to corporate branding. Nevertheless, there appear to be non-trivial differences in the performance of different patterns with respect to the visibility of personnel on foot near the vehicle. The recent study by Ullman et al. (2024) found that vehicle rear markings in an inverted V pattern were superior to a checkerboard pattern in terms of worker visibility, and were preferred by drivers. Additionally, the Ullman et al. study found that black+yellow markings performed better than red+white markings, and large (3 x 6 foot) panels performed better than small (1 x 6 foot) panels. No literature on vehicle side markings was identified.

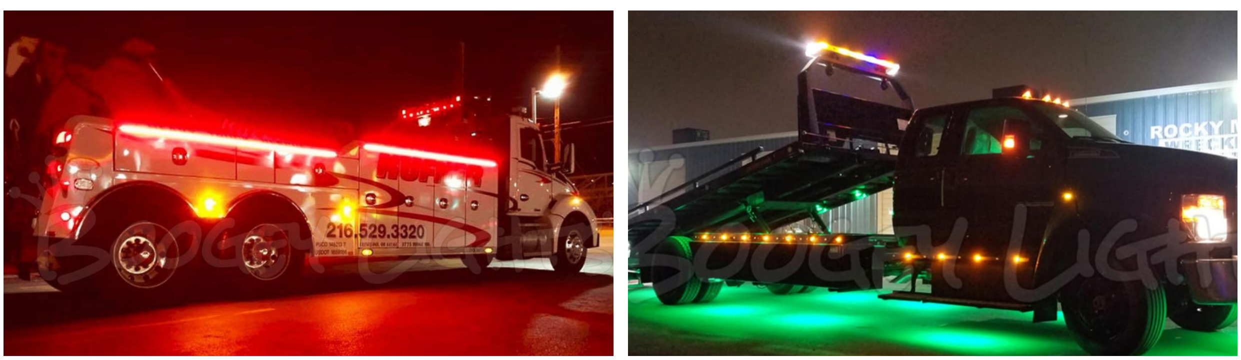
Although retroreflective markings appear to improve the visibility of special purpose vehicles from a distance, extensive use of retroreflective sheeting appears to exacerbate glare—especially if the sheeting material is highly retroreflective (e.g., ASTM Type III or higher).

Knowledge Gaps

The objective of the present review was to understand what is known about the effects of roadside service vehicle lighting on the visibility of RSVs and personnel working on foot near them. However, during the review several aspects of this problem appear to be unresearched or under-researched. In particular, no research was found on the following topics:

- Effects associated with work lights (floodlights and spotlights) including factors such as position, intensity, and beam spread
- Effects of the physical size and shape (“target value”) of warning lights
- Effects of adding shrouds to increase contrast between warning lights and their surroundings
- Effects of the warning light beam spread
- Effects of warning light position relative to the vehicle centerline
- Effects of warning light position relative to the front/back of the vehicle
- Interactions between RSV lighting and spillover light from roadside development
- Effects of supplementary vehicle lighting such as clearance lights, body lights, and under-glow lights (Figure 22)
- Effects of markings on the side of the vehicle
- Interactions between RSV lighting and lighting used on other first response vehicles operating at the same incident scene

Figure 22. Vehicle body lights (left) and under-glow lights (right) (Source: Boogey, Inc.).



Limited, incomplete, or inconclusive research was found on the following topics:

- Effects of warning light mounting height
- Benefits or disbenefits of using light bars vs individual beacons
- Effects related to traffic speed
- Interactions between warning light color and the color/marking pattern of the RSV
- Interactions between warning light color, vehicle markings, and RSV operator apparel such as retroreflective jackets

- Effects of vehicle marking patterns other than diagonal stripes or checkerboards
- Effects of vehicle marking color combinations other than red+white and black+yellow

Another challenging aspect of the research is incomplete information about the test subjects enrolled in the studies. Human vision is affected by age, with notably increased sensitivity to glare at older ages. In addition, vision is affected by a wide range of eye conditions, which can be permanent (e.g., colorblindness) or acquired (e.g. macular degeneration). Given the scale of the studies completed to date, it is unlikely the results fully represent the entire spectrum of road users.

Conclusion

The review strongly indicates that no single lighting or vehicle marking combination is ideal for all operational conditions. For warning lights, in particular, there is strong support for a system that adapts to ambient lighting conditions and atmospheric perturbations such as fog or smoke. Although an adaptive system is currently available from at least one manufacturer, the specific attributes that these systems should incorporate still require further non-proprietary research.

As noted earlier, there is strong evidence of conflicts between warning light characteristics that inform distant drivers of the presence of a special purpose vehicle at roadside, and characteristics that assist road users near the scene with detecting workers on foot and safely navigating the area. Increases in light intensity, flash rate, and vehicle retroreflectivity have traditionally come at the cost of increased glare near the vehicle. Further research, including lighting modeling, can help determine the extent to which these conflicts can be reduced through judicious lighting design. By definition, glare occurs when a scene includes very bright and very dim light at the same time. The work by Bullough et al. (2019) suggests that this glare can be reduced by providing infill lighting around the tow vehicle.

The review also identified specific gaps in the types of study designs used to understand the effect of light and vehicle markings on driver performance and perception. In addition to the lack of prospective research or research with injury incidence as the primary outcome measure, there was a gap in the breadth of on-road studies. For example, there is a need for a wider range of driver behavior and perception metrics from on-road studies.

Although a few studies used mannequins or cut-outs to simulate workers on foot, these studies were generally conducted using static figures observed from a stationary vantage point. As a result, they do not capture the high cognitive demands of driving at speed in heavy traffic. Further, the nearly all of studies found for this report were conducted in laboratory settings or on closed test tracks where the environment was free of light trespass from oncoming vehicles and roadside development.

State Regulations for Roadside Assistance Vehicle Lighting

To gain an understanding of the state regulations that currently guide the selection of warning lights for roadside service vehicles, the project team reviewed relevant laws and administrative rules (regulations) for all 50 states, the District of Columbia, and Puerto Rico. For the purposes of this review, the team defined "warning lights" as any type of light or beacon intended to warn road users of the presence of an RSV. In general, this means flashing beacons or light bars mounted high on the vehicle. The team also attempted to identify state statutes affecting the use of flood lights or work lights mounted on the RSV. The team did not include headlights, tail lights, brake lights, turn signals, or other lighting devices that are required for all motor vehicles. The team also excluded "tow away lamps," the portable brake/turn signal/tail light packages that temporarily attach to a disabled vehicle while it is being towed by a hook-and-chain type truck.

The identified statutes and administrative rules focus mainly on the color of RSV warning lights, with much less emphasis on the number of lights, their intensity, how they are mounted, or their flash pattern. Work lights are rarely mentioned in the statutes.

Where possible, the review included information about laws and regulations related to the photometric requirements of RSV lighting, such as luminous intensity. Table 4 briefly summarizes the definitions and units of measure for these lighting characteristics.

Table 4. Units of Measure for Illumination

Quantity	Definition	SI Units	Customary Units
Flux	Total amount of light emitted by a lamp	lumen = candela steradian/meter^2	
Luminous intensity	Amount of light emitted by a lamp in a specific direction	candela	Candlepower
Illuminance	Amount of light striking a surface	lux = lumens/m^2	foot-candles = lumens/ft^2
Luminance	Amount of light striking an observer's eye	nit = candela/m^2	foot-lambert= $1/\pi$ • candela/ft^2
Contrast	Difference in luminance between 2 or more areas seen simultaneously or in sequence	Contrast = $\frac{(\text{luminance}_2 - \text{luminance}_1)}{\text{luminance}_1}$	
Glare	Excessive Contrast	Threshold Illuminance	Veiling Luminance Ratio
Color	Wavelength of the light	Nanometers	

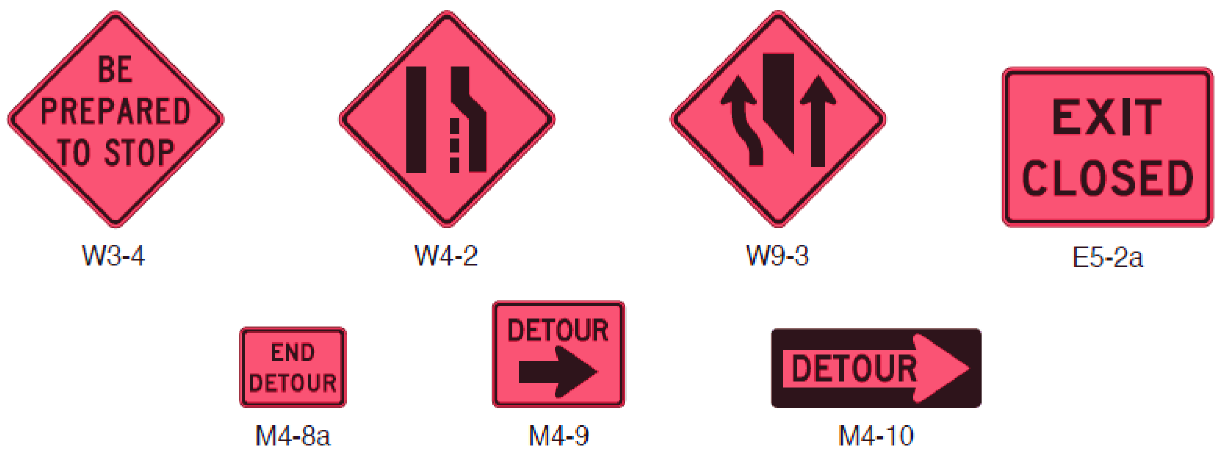
National Regulatory Requirements

Section 6O.05 of the 2023 Manual on Uniform Traffic Control Devices (MUTCD) (FHWA, 2023) provides the following support and guidance on the use of emergency vehicle lighting:

> ***Support:*** *The use of emergency-vehicle lighting (such as high-intensity rotating, flashing, oscillating, or strobe lights) is essential, especially in the initial stages of a traffic incident, for the safety of emergency responders and persons involved in the traffic incident, as well as road users approaching the traffic incident. Emergency-vehicle lighting, however, provides warning only and provides no effective traffic control. The use of too many lights at an incident scene can be distracting and can create confusion for approaching road users, especially at night. Road users approaching the traffic incident from the opposite direction on a divided facility are often distracted by emergency-vehicle lighting and slow their vehicles to look at the traffic incident posing a hazard to themselves and others traveling in their direction.*
>
> *The use of emergency-vehicle lighting can be reduced if good traffic control has been established at a traffic incident scene. This is especially true for major traffic incidents that might involve a number of emergency vehicles. If good traffic control is established through placement of advance warning signs and traffic control devices to divert or detour traffic, then public safety agencies can perform their tasks on scene with minimal emergency-vehicle lighting.*
>
> ***Guidance:*** *Public safety agencies should examine their policies on the use of emergency-vehicle lighting, especially after a traffic incident scene is secured, with the intent of reducing the use of this lighting as much as possible while not endangering those at the scene. Special consideration should be given to reducing or extinguishing forward facing emergency-vehicle lighting, especially on divided roadways, to reduce distractions to oncoming road users.*
>
> *Because the glare from floodlights or vehicle headlights can impair the nighttime vision of approaching road users, any floodlights or vehicle headlights that are not needed for illumination, or to provide notice to other road users of an incident response vehicle being in an unexpected location, should be turned off at night.*

The MUTCD encourages the use of traffic incident management signs with black legends on fluorescent pink backgrounds (Figure 23). Montana requires the use of specific black-on-pink signs for towing operations that block a lane (see the Montana entry in Appendix 1).

Figure 23. Examples of MUTCD-compliant incident management signs.



Overview of State RSV Lighting Statutes and Regulations

To obtain a complete understanding of the roadside service vehicle lighting requirements nationwide, the project team reviewed the statutes (laws), and where applicable the administrative rules (regulations), for all 50 states, the District of Columbia, and Puerto Rico. Where administrative rules exist, they are typically more specific than the laws that enable them.

This section summarizes the main findings, with jurisdiction-by-jurisdiction details presented in Appendix 1. Appendix 2 presents comparative findings for airport service vehicles at U.S. and international airfields, along with automotive photometric standards for flashing warning lights published by SAE International and the United Nations Economic Commission for Europe (UNECE).

Nomenclature

State statutes use diverse terms to describe RSVs, such as tow cars, tow trucks, and wreckers. In some states, tow vehicles are designated as emergency vehicles, while others explicitly exclude them from the definition of an emergency vehicle. These definitional differences appear be largely unrelated to warning lights—rather they relate to the way legislation granting special authority to emergency vehicles is written. For example, the vehicle definitions are sometimes used to clarify that police cars, fire trucks, and ambulances (but not tow trucks) are allowed to exceed speed limits, ignore stop signs, and run traffic signals.

Administration

Most state laws and regulations apply to tow vehicles categorically; that is to say, if a vehicle is used for towing or roadside assistance, it is automatically allowed to use specific types of warning lights. A few states regulate the use of warning lights through a permitting process:

- **Georgia:** An amber light permit costs $2 and must be renewed annually.
- **New Jersey:** An amber light permit costs $25 and must be renewed every four years.
- **Rhode Island:** An amber light permit costs $25 and must be renewed annually.
- **Utah:** A biennial tow truck inspection/certification is required; amber lights are required for certification.

In most of these states, improper use of warning lights can result in permit revocation, and use of warning lights without a permit can result in a traffic citation. Government-owned vehicles are typically exempt from the permitting requirements.

Color Requirements

As enumerated in Table 5, allowable warning light colors and configurations vary considerably from state to state. State statutes often reserve the colors blue and red for vehicles associated with law enforcement or firefighting. With the exception of Oregon and Missouri, all states either allow or require amber or yellow flashing lights to be installed on RSVs. In Oregon, red flashing lights are required. In Missouri, flashing red and blue lights are allowed on tow vehicles operated by police agencies, and flashing amber and/or white lights are allowed on tow vehicles operated by the Department of Transportation, but no Missouri law authorizing the use of flashing lights on commercial RSVs was found.

Several states allow the use of an additional color such as white, green, red, and/or blue. In many cases, use of the additional color is restricted to specific operations such as standing on the roadside to provide assistance, blocking a traffic lane, loading a vehicle, or re-entering the traffic lanes after standing on the shoulder. For example, Minnesota requires tow trucks to be equipped with both flashing red and flashing amber lights; the red lights *must* be displayed while providing emergency service at the roadside, while the amber light *may* be displayed while moving a disabled vehicle.

In New Mexico, RSVs are allowed to use warning lights of any color *except* red. Similarly, Hawaii law appears to allow any color except blue or red.

The terms “amber” and “yellow” appear to be used interchangeably in many of the state statutes. It is often unclear whether this is intended as a reference to the technical definitions found in the SAE J578 standard, or whether other yellow hues such as selective yellow or lime might be permissible.

In many states the use of the lights is at the discretion of the RSV operator. Others *require* their use by night, by day, or both. In several cases, warning lights must be used during specific operations such as loading a disabled vehicle or actively providing roadside assistance. The authority to operate flashing lights while towing/hauling a disabled vehicle varies considerably from state to state:

- Some states completely *prohibit* warning light activation while towing/hauling.
- Some states allow the use of the lights while towing with a hook-and-chain type trucks, but not while hauling on a flatbed.
- Some states allow or require the use of warning lights if the disabled vehicle has a defect that presents a hazard to other traffic, such as overhanging equipment.
- Some states allow or require warning light activation at night.
- Some states allow but do not require warning light activation any time a tow truck is towing/hauling.
- Some states *require* warning light activation at all times while towing/hauling.
- Several states say nothing about when warning lights should or should not be used.

Table 5. Overview of state statutes and regulations related to allowable warning light colors.

Jurisdiction	Yellow[1]	Amber	Red	Green	Blue	Purple	White	Comments
Alabama	✓	✓						
Alaska	✓							
Arizona		✓	To Rear				To Front	
Arkansas		✓	✓				?	White authorized for construction vehicles; use of white on tow trucks is unclear
California		✓						Very specific photometric requirements in administrative rules
Colorado	✓						?	Conflict between statutes and regulations regarding use of flashing white lights
Connecticut	✓	✓						
Delaware		✓					?	White mentioned in "move over" law but not addressed in administrative rules
District of Columbia		✓	To Rear				To Front	
Florida		✓						
Georgia		✓						Annual permit required
Hawaii	✓	✓		✓		✓	✓	Blue and red are reserved for law enforcement vehicles; no other restrictions
Idaho		✓	To Front					Red to be used only during recovery operations or while blocking traffic
Illinois		✓					Supple-mental	White lights supplement amber
Indiana		✓	To Rear				To Front	
Iowa		✓						
Kansas		✓	While stationary					Use of red flashing lights limited to stationary tow trucks while responding/loading
Kentucky	✓							
Louisiana		✓						
Maine		✓		Supple-mental				Green lights supplement amber when loading or stationary; only amber can be displayed while towing
Maryland	✓	✓						
Massachusetts		✓						
Michigan		✓	✓					Red to be used only during recovery operations
Minnesota		✓	✓					Red can only be displayed when engaged in emergency service

Jurisdiction	Yellow[1]	Amber	Red	Green	Blue	Purple	White	Comments
Mississippi		✓						
Missouri		DOT Vehicles	Police Vehicles		Police Vehicles		DOT Vehicles	No clear statutory authority for use of warning lights on privately-owned tow trucks
Montana		✓	✓					A rear-facing amber or red flashing light should be displayed while towing
Nebraska		✓						
Nevada		✓			Non-flashing			Amber flashing lamp(s) are permitted; while preparing a disabled vehicle for towing, a non-flashing blue lamp may be displayed to the rear
New Hampshire		✓						
New Jersey		✓	To rear				✓	A permit is required for flashing warning lights on a commercial tow truck
New Mexico	✓	✓		✓	✓	✓	✓	Any color except red, but only while standing at the roadside or loading a disabled vehicle
New York		✓			To Rear			
North Carolina		✓						
North Dakota		✓					✓	Tow trucks may disregard certain traffic rules if amber and white lights are displayed
Ohio		✓						
Oklahoma		✓	✓		✓			Red/blue flashing lights may only be displayed while at the scene of an emergency
Oregon		✓	✓					Lights may only be used when necessary to warn approaching traffic
Pennsylvania		✓			To rear		✓	Rear-facing blue lights may be used only while providing roadside assistance
Puerto Rico		✓						
Rhode Island		✓						A permit is required for flashing amber lights
South Carolina		✓	✓				✓	Red lights to be used at an accident scene
South Dakota		✓			Limited use			Blue lights may be used only when clearing debris from a public roadway
Tennessee		✓					✓	
Texas		✓	✓		✓			Red and blue lights can only be used only when stopped at an incident

Jurisdiction	Yellow[1]	Amber	Red	Green	Blue	Purple	White	Comments
Utah		✓						Biennial certification and inspection process
Vermont		✓						
Virginia		✓						
Washington			✓		To rear			Flashing red and blue lights may be displayed while providing roadside service; flashing red lights while re-entering the roadway
West Virginia	✓	✓						
Wisconsin		✓	✓					Amber to be displayed while towing at a speed slower than other traffic; amber+red to be displayed while standing at the roadside
Wyoming		✓	✓		✓		✓	Blue and red lights to be used only at emergency scenes

[1]*Hue not specified.*

Visibility and Luminous Intensity

There is little consistency in the way states treat the maximum and minimum luminance levels for warning beacons. Only California describes the requirements in technical terms, specifically through an administrative rule defining specific criteria for the output in candela. Several states provide no criteria. Others define the requirements in terms of a specific visibility distance such as 500 feet or 1000 feet.

The distance-based requirements are difficult to interpret because they do not specify test conditions such as the ambient lighting level and whether the intensity is to be measured against a black background or a color pattern more representative of roadway environments. In comparison, automotive industry and aviation standards are very specific as to luminous intensity (Table 6).

Table 6. Overview of regulations related to amber/yellow warning light photometrics.

Jurisdiction		Color	Luminous Intensity at Azimuth (cd)				Flash Rate (Hz)		Comments
			Night		Day				
			Min	Max	Min	Max	Min	Max	
California	Class B	SAE Yellow	750	–	750	–	1.0	2.0	Includes tow trucks
	Class C	SAE Yellow	1500	–	1500	–	1.0	2.0	
	FAA Airports	Amber	40	400	40	400	1.0	1.5	Airfield service vehicles
	IACO Airports	Amber	40	400	40	400	1.0	1.5	Mobile obstacles except security
	Pennsylvania	Various	–	–	–	–	1.0	4.33	See Table 5 for colors
SAE J845	Class 1A and 1S	SAE Yellow	338	–	338	–	1.0	4.0	U.S. automotive industry standard
	Class 2A and 2S	SAE Yellow	83	–	83	–	1.0	4.0	
UNECE	Types T and HT	Amber	100	700	230	1700	2.0	4.0	International standard
	Type X	Amber	200	1500	400	3000	2.0	4.0	

Visibility is affected by luminance, contrast, and glare. By definition, contrast is the difference in luminance between two parts of a scene, and excessive contrast is glare. More contrast improves visibility up to a saturation point, but excessive contrast can cause discomfort and even temporary blindness because the human eye cannot adjust to very bright and very dim light at the same time.

Figure 24. Effect of contrast on visibility.

Under daylight conditions, numerous factors affect visibility distance analysis. One major factor is the degree of contrast between the warning light and its surroundings (Figure 24). For example, a light that is easily visible against a black background can be nearly impossible to distinguish against the setting sun. Daytime visibility distance is also affected by the physical size of the light and the distance between the light and the observer: because of the limited resolution of human vision, tiny or very distant objects are hard to see even when they are brightly illuminated. For these reasons, traffic signals have long been equipped with shrouds and backplates to improve contrast against the sky (Figure 25). In addition, in the 2000s the standard traffic signal roundel (lens) diameter was increased from 8 inches to 12 inches to improve target value.

Figure 25. Traffic signal heads incorporate shrouds and backplates to increase background contrast. (Source: aismallard/Wikimedia Commons (CC 3.0)).

Some state laws stipulate that tow truck beacons must be visible from a distance of 500 feet. However, the luminous intensity needed to meet this requirement can vary by orders of magnitude depending on the ambient lighting conditions.

Flash Rate

Warning lights with inappropriate flash rates likely contribute to driver distraction and mesmerization. In addition, rates of 3 to 60 Hz can trigger epileptic seizures in sensitive individuals, with the greatest risk occurring at rates greater than 10 Hz (Epilepsy Action, 2022; Epilepsy Foundation, 2023).

As shown in Table 5, only the states of California and Pennsylvania regulate the flash rates for RSV lighting. Maryland stipulates a maximum flash rate of 5 Hz for construction and maintenance vehicles, but this requirement does not appear to apply to RSVs. The maximum allowable rate in the automotive industry (SAE and UNECE) standards is 4 Hz, while the FAA and IACO standards for aviation support vehicles are more conservative with a maximum rate of 1.5 Hz.

Mounting Location

While most states are silent about where RSV warning lights should be mounted, a few stipulate that they should be mounted as high as possible on the cab of the vehicle.

Work Lights

Night towing operations generally require work lights for troubleshooting and loading disabled vehicles. Poorly positioned work lights have considerable potential to cause blinding glare for motorists, which could obscure a tow operator on foot. Most state statutes are silent on the use and technical characteristics of these lights.

Statutory language regulating vehicle work lights was found for California. Work lights are called “utility flood and loading lamps” in the California Vehicle Code. Section 25110 allows tow trucks to be equipped with lamps that project a white light illuminating an area to the side or rear of the tow vehicle for a distance not to exceed 75 feet at the level of the roadway. In California towing operations, the use of floodlights is limited to the period of preparation for towing at the location from which a disabled vehicle is to be towed.

Connecticut requires each RSV to be equipped with a spotlight directed toward the hoisting equipment but does not specify its photometrics.

Comparative Requirements

SAE J845

SAE International establishes industry standards for the automotive sector. SAE J845 addresses flashing warning lights in five colors: red, yellow, green, signal blue, and white. The standard cautions against the use of isolated green lights due to the association between the color green and “go” in traffic settings or “system operating normally” in industrial settings.

SAE J845 establishes minimum luminous intensity requirements for six classes of warning lamps: Classes 1A and 1S (338 cd), Classes 2A and 2S (83 cd) and Classes 3A and 3S (38 cd). Classes 3A and 3S apply primarily to warning lights for indoor equipment such as warehouse forklifts. The “A” designation indicates the device produces 360° beam spread, while the “S” designation identifies devices with a directional pattern. The flash rate must be 1.0 to 4.0 Hz.

UNECE Regulation 65

UNECE maintains a set of technical specifications for vehicle safety. The standards are currently applicable in 54 countries worldwide, including automotive markets such as Australia, Egypt, Korea, Japan, Malaysia, Norway, Russia, New Zealand, South Africa, Thailand, the United Kingdom, and all 27 countries of the European Union.

UNECE Regulation 65 addresses the photometrics of special vehicle lighting. This standard has been adopted in numerous countries across the world and forms the basis for global efforts to harmonize automotive standards. This work is overseen by the Working Party on Lighting and Light-Signaling, which conducts lighting-related research and prepares regulatory proposals.

UNECE Regulation 65 currently establishes photometric specifications for three classes of warning lights, Category T, HT, and X:

- Measured at azimuth (the brightest point), Category T (rotating) and HT (rotating or stationary) flashing amber beacons are required to have a luminous intensity of 100 to 700 cd by night and 230 to 1700 cd by day.
- Measured at azimuth, Category X (directional) flashing amber beacons are required to have a luminous intensity of 200 to 1500 cd by night and 400 to 3000 cd by day.

The standard also includes requirements for the drop-off in luminous intensity at various horizontal and vertical angles. The flash rate must be 2.0 to 4.0 Hz.

Many of the warning lights currently sold in the United States likely exceed the UNECE maximums for luminous intensity, especially the limitations on night intensity.

Federal Aviation Administration

Federal Aviation Administration (FAA) Advisory Circular AC 150/5210-5D establishes rules for the color and luminous intensity of warning lights used on airfield service vehicles.

The standard for identification lighting is a yellow flashing light mounted on the uppermost part of the vehicle structure. A steady yellow light designates vehicles limited to non-movement areas. Other requirements are as follows:

- Warning lights must be visible from any direction, day and night.
- Warning lights must have a peak intensity within the range of 40 to 400 cd (effective) from 0 degrees (horizontal) up to 10 degrees above the horizontal and for 360 degrees horizontally. The advisory also includes requirements for the drop-off in luminous intensity at other vertical angles.

- The flash rate must be 60 to 90 flashes per minute (1 to 1.5 Hz).

The FAA states that the upper limit of 400 cd (effective) is necessary to avoid damage to night vision.

International Civil Aviation Organization

The International Civil Aviation Organization (IACO) is a United Nations agency that provides technical guidance on aviation matters. Technical standards for aerodromes (airfields) are established in Annex 14 to the Convention on International Civil Aviation. Sections 6.2.2.5 to 6.2.2.8 establish rules for the color and luminous intensity of warning lights used on service vehicles and other mobile objects, excluding aircraft.

Flashing blue lights are required on emergency and security vehicles, and flashing yellow is to be displayed on all other vehicles. The technical requirements for vehicles are similar to those stipulated by FAA:

- The effective luminous intensity of these lights must range from 40 to 400 cd between 2° and 20° vertical, with 360° horizontal coverage.
- Peak intensity should be located at approximately 2.5° vertical, with a minimum vertical beam spread of 12° and intensity of 20 cd.
- The flash rate must be 60 to 90 flashes per minute (1 to 1.5 Hz).

Discussion

In contrast to the extensive efforts that have been made to standardize traffic signs and traffic signals over the past century, U.S. state laws and regulations related to RSV warning lights are remarkably inconsistent. States differ not only regarding the allowable warning light colors, but also regarding when warning lights are to be used. While amber lights are traditional in most states, several states have added additional colors such as blue or red—often with stipulations that these colors can only be used while standing at the roadside, loading a disabled vehicle, or blocking a lane. In several states, white lights can be used under the same circumstances as amber lights; in some cases, it is legal for an RSV to be equipped only with flashing white warning lights. Most state statutes are silent about other key technical parameters such as luminous intensity, flash patterns, and mounting location.

The variability of state requirements frequently results in situations where lighting equipment that is permissible in one state cannot be used legally in a neighboring state. This can add complexity for tow operators that do business near a state border or in a metropolitan area that straddles a state line. For example, the Chicago metropolitan area includes portions of Indiana, Illinois, and Wisconsin. Indiana and Wisconsin allow the use of red lights on tow trucks under certain circumstances, but Illinois does not.

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Appendix 1: Vehicle Lighting Regulations by State

Jurisdiction	**Statutory Reference**
State of Alabama	Ala/bama Code § 32-5A-115 (1981)
Colors Permitted	**General Requirements**
Amber/Yellow (unspecified shade)	Blue and red warning lights are reserved for law enforcement; red is reserved for fire and EMS. Amber/yellow warning lights are permitted on any other vehicle but serves only to caution other traffic.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
An amber or yellow light may be installed on any vehicle or class of vehicles designated by the Director of Public Safety, but such light shall serve as a warning or caution light only, and shall not cause other vehicles to yield the right-of-way.	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Alaska	13 Alaska Admin. Code § 04.095 (1979)
Colors Permitted	**General Requirements**
Yellow (unspecified shade)	The use of a flashing yellow warning light is mandatory while preparing to tow a disabled vehicle or while towing a vehicle at a speed slower than other traffic. The warning light must also be used after dark if the towed vehicle's taillights are inoperable or if the taillights, stop lights or turn signals on the tow truck are obscured by the towed vehicle.
Position	**Intensity**
Unspecified	A tow car must be equipped with a flashing yellow warning light visible at 500 feet in normal sunlight to the front, rear, and both sides.
Text of Statute or Regulation	
A tow car must be equipped with a flashing yellow warning light visible at 500 feet in normal sunlight to the front, rear and both sides. The tow car must illuminate the yellow warning light during preparation at the location from which a disabled vehicle is to be towed, and the yellow warning light must be illuminated when the tow car is towing a vehicle at a speed slower than the normal flow of traffic, during the hours of darkness when the towed vehicle does not have taillights illuminated to the rear, or when the taillights, stop lights, or turn signals on the tow car are obscured by the towed vehicle. The flashing warning light may not be illuminated except as provided in this section.	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Arizona	Ariz. Rev. Stat. § 28-624 (undated) Ariz. Rev. Stat. § 29-923 (undated) Ariz. Rev. Stat. § 29-936 (undated) Ariz. Rev. Stat. § 28-947 (2019) Ariz. Admin. Code § 13-3-1201 (2006-2019)
Colors Permitted	**General Requirements**
To Front: Amber or White To Rear: Amber or Red	Red and blue warning lamps are reserved for emergency vehicles. § 29-947 allows any other vehicle to display amber/white (front) and amber/red (back) lights to warn road users to exercise unusual care, but this is limited by Administrative Code § 13-3-1201, which declares that warning lights on tow trucks may only be displayed while at the scene of service or while transporting a vehicle that presents a hazard.
Position	**Intensity**
Two lamps at the same vertical level, laterally spaced as widely as practicable	Visible from a distance of 1500 feet at night. This applies to a straight, level, and unlighted highway under normal atmospheric conditions.

Text of Statute or Regulation
Ariz. Rev. Stat. § 28-947 (2019) A vehicle may have lamps that may be used to warn the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing. The vehicle may display these lamps as a warning in addition to any other warning signals required by this article. The lamps used to display the warning to the front shall be mounted at the same level and as widely spaced laterally as practicable and shall display simultaneously flashing white or amber lights or any shade of color between white and amber. The lamps used to display the warning to the rear shall be mounted at the same level and as widely spaced laterally as practicable and shall show simultaneously flashing amber or red lights or any shade of color between amber and red. These warning lights shall be visible from a distance of at least one thousand five hundred feet under normal atmospheric conditions at night. Ariz. Admin. Code § 13-3-1201 (2006-2019) A tow truck agent shall not … activate warning light assembly except at the scene of service, or when transporting a vehicle that presents a hazard from a collision scene.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Arkansas	Ark. Code § 27-36-301 (2020) Ark. Code § 27-36-305 (2020)
Colors Permitted	**General Requirements**
Amber; Red White?	Flashing amber lights are permitted on tow vehicles. A tow vehicle may also be equipped with a red flashing or rotating light, but the red light can only be during roadside recovery or loading. Blue lights are reserved for emergency vehicles and purple lights are reserved for funeral processions.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation

(a) All state, county, and municipal agencies and private persons and businesses that operate any other type of vehicle in this state that is required or permitted to be equipped with flashing or rotating emergency or warning lights shall equip the vehicles with white or amber flashing or rotating emergency or warning lights only.

(b)

(1) In addition to amber flashing or rotating emergency or warning lights, wreckers or tow vehicles permitted or licensed under § 27-50-1203 that respond to traffic incidents may, but are not required to, be equipped with red flashing or rotating emergency or warning lights in addition to amber warning lights.

(2) Red flashing or rotating emergency or warning lights on a wrecker or tow vehicle shall be operated only at times the wrecker or tow vehicle is stopped on or within ten feet (10’) of a public way and engaged in recovery or loading and hooking up an abandoned, an unattended, a disabled, or a wrecked vehicle. A wrecker or tow vehicle shall not operate forward-facing red flashing or rotating emergency or warning lights while underway, except as may be expressly authorized by law otherwise.

Additional Information

Flashing white lights appear to be permitted on construction vehicles, but their use on tow vehicles is unclear in the statute; compare (a) and (b)(1) above.

Jurisdiction	Statutory & Regulatory References
State of California	California Vehicle Code 25253 (1983) California Vehicle Code 25253.1 (1985) California Code of Regulations § 810 (2002)
Colors Permitted	**General Requirements**
Amber	Tow trucks must be equipped with flashing amber warning lamps. They may display the flashing amber warning lamps while providing service to a disabled vehicle. A tow truck shall not display flashing amber warning lamps on a freeway except when an unusual traffic hazard or extreme hazard exists.
Position	**Intensity**
Unspecified	California regulations differ for flashing, rotating, and gaseous discharge (xenon) lamps: Flashing Lamps The regulations define two classes of flashing warning lights, Class B and Class C. In both cases the flash rate must be 60 to 120 flashes per minute (1 to 2 Hz). Measured at horizontal and vertical angles of 0°, the minimum luminance is as follows: • Class B Lamps: 750 cd • Class C Lamps: 1500 cd Revolving or Oscillating Lamps The minimum output for yellow revolving warning lamps is 12,500 cd. The rate of rotation is not specified. Gaseous Discharge Lamps (Xenon Flash Tubes) Measured at horizontal and vertical angles of 0°, the minimum luminance is 125 cd. The minimum flash rate is 70 per minute (1.17 Hz).

Text of Statute or Regulation
25253. (a) Tow trucks used to tow disabled vehicles shall be equipped with flashing amber warning lamps. This subdivision does not apply to a tractor-trailer combination. (b) Tow trucks may display flashing amber warning lamps while providing service to a disabled vehicle. A flashing amber warning lamp upon a tow truck may be displayed to the rear when the tow truck is towing a vehicle and moving at a speed slower than the normal flow of traffic. (c) A tow truck shall not display flashing amber warning lamps on a freeway except when an unusual traffic hazard or extreme hazard exists. 25253.1. An automobile dismantler's tow vehicle used to tow a disabled vehicle may be equipped with flashing amber warning lamps. A flashing amber warning lamp upon an automobile dismantler' tow vehicle may be displayed to the rear when the automobile dismantler's tow vehicle is towing a vehicle and moving at a speed slower than the normal flow of traffic.
Additional Information
California's 12,500 cd luminance requirement for revolving/oscillating yellow lamps is extremely stringent. In comparison, the required outputs for blue and red revolving/oscillating lamps are 2,500 cd and 5,000 cd, respectively. The required output for yellow xenon flash tube devices is 125 cd, just 1% of the required output for the rotating/oscillating types.

<table>
<tr><th>Jurisdiction</th><th>Statutory Reference</th></tr>
<tr><td>State of Colorado</td><td>Colo. Rev. Stat. § 42-4-214 (2019)
2 CCR 601-20 (2012)</td></tr>
<tr><th>Colors Permitted</th><th>General Requirements</th></tr>
<tr><td>Yellow (unspecified)
White?</td><td>Every “authorized service vehicle” (including tow trucks) must be equipped with one or more warning lamps mounted as high as practicable and displaying in all directions. The lights can be illuminated only when the vehicle is operating upon the roadway so as to create a hazard to other traffic.
Colorado Revised Statutes § 42-4-214 says these lights must be yellow and no other color is permitted. This conflicts with the regulations in 2 CCR 601-20 which say both yellow and white are permitted. Blue and red are clearly prohibited.</td></tr>
<tr><th>Position</th><th>Intensity</th></tr>
<tr><td>Mounted as high as practicable and capable of displaying in all directions.</td><td>Lights must have sufficient intensity to be visible at 500 feet in normal sunlight.</td></tr>
<tr><th colspan="2">Text of Statute or Regulation</th></tr>
<tr><td colspan="2"><u>Colo. Rev. Stat. § 42-4-214 (2019)</u>
Every authorized service vehicle must, in addition to any other equipment required by Article 4, be equipped with one or more warning lamps mounted as high as practicable, which must be capable of displaying in all directions one or more flashing, oscillating, or rotating yellow lights. Only yellow and no other color or combination of colors may be used as a warning lamp on an authorized service vehicle; except that an authorized service vehicle snowplow operated by a state, county, or local government may also be equipped with and use no more than two flashing, oscillating, or rotating blue lights as warning lamps. Such lights must have sufficient intensity to be visible at five hundred feet in normal sunlight.
<u>2 CCR 601-20 (2012)</u>
4.01 Every Authorized Service Vehicle shall, in addition to any other required equipment, be equipped with:
4.01.1 One or more warning lamps mounted as high as possible, capable of displaying in all directions one or more flashing, oscillating, or rotating yellow lights.
4.01.2 Only yellow and white lamps and no other color or combination of colors shall be used as a warning lamp on an Authorized Service Vehicle. White lamps may be used on a light bar to heighten the visibility of the yellow lamps.
4.01.3 With regard to 7.01.1 above, a snowplow designated as an Authorized Service Vehicle operated by a general purpose government may also be equipped with and use no more than two flashing, oscillating, or rotating blue lights as warning lamps.
4.01.4 Lighted directional signs used by police and highway departments to direct or control traffic need not be visible except to the front or rear.
4.01.5 Lights shall have sufficient intensity to be visible at 500 feet in normal sunlight.</td></tr>
<tr><th colspan="2">Additional Information</th></tr>
<tr><td colspan="2">Blue lights are allowed on snowplows operated by government agencies.</td></tr>
</table>

Jurisdiction	Statutory Reference
State of Connecticut	Conn. Gen. Stat. § 14-66 (2019) Conn. Gen. Stat. § 14-96 (2023)
Colors Permitted	**General Requirements**
Amber; Yellow (unspecified shade)	Each wrecker (tow truck) must be equipped with two flashing yellow lights mounted high on the cab, as far apart and as far back as possible. Vehicle owners except government agencies are required to obtain a permit before installing warning lights on their vehicles. Permits costs $20/year. No permit is required to install flashing amber/yellow lights on a wrecker (tow truck), but the truck itself is subject to a biennial registration costing $125.
Position	**Intensity**
Two omnidirectional beacons are required, spaced as far apart as possible and mounted at least 8 feet above the road surface and as close to the back of the cab as possible.	Unspecified
Text of Statute or Regulation	
A wrecker shall be deemed properly equipped if there are two flashing yellow lights installed and mounted on such wrecker that (1) show in all directions at all times, and (2) indicate the full width of such wrecker. Such lights shall be mounted not less than eight feet above the road surface and as close to the back of the cab of such wrecker as practicable. Such lights shall be in operation when such wrecker is towing a vehicle and when such wrecker is at the scene of an accident or the location of a disabled motor vehicle. In addition, each wrecker shall be equipped with a spot light mounted so that its beam of light is directed toward the hoisting equipment in the rear of such wrecker. The hoisting equipment of each wrecker shall be of sufficient capacity to perform the service intended and shall be securely mounted to the frame of such vehicle. A fire extinguisher shall be carried at all times on each wrecker which shall be in proper working condition, mounted in a permanent bracket on each wrecker, and have a minimum rating of eight bc. A set of three flares in operating condition shall be carried at all times on each wrecker and shall be used between the periods of one-half hour after sunset and one-half hour before sunrise when the wrecker is parked on a highway while making emergency repairs or preparing to pick up a disabled vehicle to remove it from a highway or adjoining property.	
Additional Information	
Each wrecker must be equipped with a spotlight mounted so that its light is directed toward the hoisting equipment. At night, flares must be used while parked at the roadside or loading. Flashing green lights are permitted (in addition to amber) on DOT maintenance vehicles. Flashing white lights are permitted (in addition to red, white, and yellow) on emergency vehicles.	

Jurisdiction	Statutory Reference
State of Delaware	Del. Code Title 21 § 4134 (2023) 2 Del. Admin. Code § 1301-3.0 (2023)
Colors Permitted	**General Requirements**
Amber White?	Administrative rules issued by the Delaware State Police require an amber rotating or flashing light on each tow vehicle. It is to be used “only when there is a hazardous condition.” Delaware’s “move over” law stipulates that drivers are required to slow down or move over when they encounter a tow truck displaying alternately flashing amber, white, or amber and white lights. Taken together, the two rules seem to indicate that white flashing lights can be used as a supplement to amber.
Position	**Intensity**
“Mounted on top so as to be seen from front, rear, and both sides”	Unspecified

Text of Statute or Regulation

Administrative Rules

3.2.4.1 Each tow vehicle shall be commercially lettered with the operator’s business name, city, state, and telephone number visible from both sides of the vehicle, in permanent letters at least 2½ inches high.

3.2.4.2 Each tow vehicle shall be equipped at all times as required by the Delaware motor vehicle code and with the following accessories:

- 3.2.4.2.1 An amber rotor beam or strobe light mounted on the top so as to be seen when in use from front, rear, and both sides. Such beam or light is to be used only when there is a hazardous condition.
- 3.2.4.2.2 Minimum of two work lights on the rear.

Statute

Drivers must slow down or move over for “A stationary tow truck which is giving a signal by displaying alternately flashing amber, white, or amber and white lights.”

Additional Information

Green flashing lights are allowed on snowplows and emergency vehicles.

Jurisdiction	Statutory Reference
District of Columbia	DC Regs 707.10 - 707.13 (1972)
Colors Permitted	**General Requirements**
Amber, White, Red	If one lamp is used, it must display amber or white to the front and amber or red to the back. If two lamps are used, they can be amber or red. Intermediate colors (e.g., light yellow, orange) are allowed.
Position	**Intensity**
Centered on top of cab if one light is used. On top of cab and as widely spaced as possible if two lights are used.	Visible from a distance of 500 feet

Text of Statute or Regulation
707.10 When two (2) lamps are used to display the warning on a tow crane or tow truck, they shall be mounted at the same level on the top of the cab and as widely spaced laterally as practicable and shall display a flashing, blinking, or alternating white or amber light or any shade of color between white and amber to the front.
707.11 The lamps used to display the warning to the rear on a tow crane or tow truck shall be mounted at the same level on the top of the cab and as widely spaced laterally as practicable and shall display a flashing, blinking, or alternating amber or red light or any shade of color between amber and red.
707.12 When a single warning lamp is used on a tow crane or tow truck, it shall be mounted on the top of the cab as near center as practicable and shall display a flashing, blinking, or alternating white or amber light or any shade of color between white and amber to the front, and an amber or red light or any shade of color between amber and red to the rear.
707.13 The warning light or lights on a tow crane or tow truck shall be visible from a distance of not less than five hundred feet (500 ft.) under normal atmospheric conditions.
Additional Information
n/a

<table>
<tr><th>Jurisdiction</th><th>Statutory Reference</th></tr>
<tr><td>State of Florida</td><td>Fla. Stat. § 316.2397 (2022)
Fla. Stat. § 316.2398 (2021)</td></tr>
<tr><th>Colors Permitted</th><th>General Requirements</th></tr>
<tr><td>Amber</td><td>Use of amber lights is required day and night while performing roadside recovery or loading. Amber lights are not to be used while driving to/from the scene unless authorized by law enforcement or there is a hazardous condition such as objects protruding from a vehicle being hauled on a flatbed.</td></tr>
<tr><th>Position</th><th>Intensity</th></tr>
<tr><td>Unspecified</td><td>Unspecified</td></tr>
<tr><th colspan="2">Text of Statute or Regulation</th></tr>
<tr><td colspan="2">Wreckers, mosquito control fog and spray vehicles, and emergency vehicles of governmental departments or public service corporations may show or display amber lights when in actual operation or when a hazard exists provided they are not used going to and from the scene of operation or hazard without specific authorization of a law enforcement officer or law enforcement agency.
Wreckers must use amber rotating or flashing lights while performing recoveries and loading on the roadside day or night, and may use such lights while towing a vehicle on wheel lifts, slings, or under reach if the operator of the wrecker deems such lights necessary. A flatbed, car carrier, or rollback may not use amber rotating or flashing lights when hauling a vehicle on the bed unless it creates a hazard to other motorists because of protruding objects.</td></tr>
<tr><th colspan="2">Additional Information</th></tr>
<tr><td colspan="2">Blue lights are reserved for police; red or red + white for fire and EMS; green + amber for private security agencies; amber for maintenance equipment and amber + white for maintenance equipment “in operation and where a hazard exists.” Construction equipment on roadways 55 mph or higher may display green + amber + red when workers are present. Buses and farm worker transportation vehicles may display flashing white.</td></tr>
</table>

Jurisdiction	Statutory Reference
State of Georgia	Ga. Code § 40-8-92 (2022) Ga. Comp. R. & Regs. 570-11-.14 (1977)
Colors Permitted	**General Requirements**
Amber	In Georgia the use of amber lights is handled through a permitting process. The tow operator must apply for an amber light permit annually, and must display the permit in the lower-left-hand corner of the windshield. Amber lights may only be used while “involved in emergency operations.”
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation
Statute The [Department of Public Safety] shall authorize the use of red or amber flashing or revolving lights only when the person or governmental agency shall demonstrate to the commissioner a proven need for equipping a vehicle with emergency lights. The fee for such lights shall be $2.00, provided that no federal, state, county, or municipal governmental agency or an ambulance provider, as defined in Code Section 31-11-2, shall be required to pay such fee. Administrative Rule Just cause for revocation of emergency vehicle designations and flashing light permits shall include, but not be limited to:(a) Improper use.(b) Failure to remove decal upon change of use or ownership.(c) Falsified, inaccurate, or improper application.(d) Use of flashing or revolving lights when not involved in emergency operations.(e) Any violation of law or unsafe conduct with respect to a flashing or revolving light.(f) Use of emergency lights for purpose other than stated on application and statement of use.
Additional Information
n/a

Jurisdiction	**Statutory Reference**
State of Hawaii	Haw. Rev. Stat. § 291-31.5 (2022)
Colors Permitted	**General Requirements**
Any color except blue or red	The statute prohibits the use of blue or red lights except by police, fire, and EMS. It does not address any other colors.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
No person shall knowingly operate, affix, or cause to be affixed, display, or possess any lamp, reflector, or illumination device that appears to be the color blue, or colors blue and red, upon any motor vehicle, motorcycle, motor scooter, bicycle, electric foot scooter, or moped.	
Additional Information	
A requirement for tow trucks to be equipped with flashing amber warning lamps when used to tow vehicles from an emergency incident zone was proposed as part of Hawaii's "move over" law, but does not appear to have been included in the final text of the law.	

Jurisdiction	Statutory Reference
State of Idaho	Idaho Code § 49-910A (2000)
Colors Permitted	**General Requirements**
Amber, Red (to front only)	Amber lights are permitted on any motor vehicle as a warning to use extra caution near the vehicle. Forward-facing red lights are permitted on tow trucks while engaged in recovery operations or blocking traffic.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
[W]reckers, as defined in section 49-124, Idaho Code, which are engaged in motor vehicle recovery operations and are blocking part or all of one or more lanes of traffic, are designated emergency vehicles [and] may display red flashing lights or red lenses or globes which are visible from the front of the vehicle. Any motor vehicle may have attached to it a flashing amber light to warn motorists of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking, or passing the vehicle displaying such lighting. The driver of an approaching vehicle shall yield the right-of-way to any stationary vehicle displaying a flashing amber light.	
Additional Information	
Blue lights are reserved for police vehicles. Red lights are reserved for fire and EMS, except as noted above.	

Jurisdiction	Statutory Reference
State of Illinois	625 ILCS 5/12-215 (2023)
Colors Permitted	**General Requirements**
Amber, White (supplemental)	Amber flashing lights, which may be supplemented with white flashing lights, must be used while on-site at a crash or disablement. They cannot be used at any other time, except by hook-and-chain type trucks towing at night. Out-of-state tow trucks equipped with red lights cannot display them while operating in Illinois.
Position	**Intensity**
Unspecified	All oscillating, rotating, or flashing lights shall be of sufficient intensity, when illuminated, to be visible at 500 feet in normal sunlight.

Text of Statute or Regulation

The use of red or white oscillating, rotating, or flashing lights, whether lighted or unlighted, is prohibited except on … tow trucks licensed in a state that requires such lights; furthermore, such lights shall not be lighted on any such tow truck while the tow truck is operating in the State of Illinois.

The use of amber oscillating, rotating, or flashing lights, whether lighted or unlighted, is prohibited except on … second division vehicles designed and used for towing or hoisting vehicles; furthermore, such lights shall not be lighted except … when such vehicles are actually being used at the scene of a crash or disablement; if the towing vehicle is equipped with a flat bed that supports all wheels of the vehicle being transported, the lights shall not be lighted while the vehicle is engaged in towing on a highway; if the towing vehicle is not equipped with a flat bed that supports all wheels of a vehicle being transported, the lights shall be lighted while the towing vehicle is engaged in towing on a highway during all times when the use of headlights is required under Section 12-201 of this Code; in addition, these vehicles may use white oscillating, rotating, or flashing lights in combination with amber oscillating, rotating, or flashing lights as provided in this paragraph.

The use of a combination of amber and white oscillating, rotating, or flashing lights, whether lighted or unlighted, is prohibited except on second division vehicles designed and used for towing or hoisting vehicles or motor vehicles or equipment of the State of Illinois, local authorities, contractors, and union representatives; furthermore, such lights shall not be lighted on second division vehicles designed and used for towing or hoisting vehicles or vehicles of the State of Illinois, local authorities, and contractors except while such vehicles are engaged in a tow operation, highway maintenance, or construction operations within the limits of highway construction projects, and shall not be lighted on the vehicles of union representatives except when those vehicles are within the limits of a construction project.

Additional Information

Red and white warning lights are reserved for law enforcement, fire, and EMS and are not permitted on other vehicles registered in Illinois. Blue lights are reserved for law enforcement, fire, and other specific applications. Out-of-state tow trucks equipped with red lights are not allowed to display them while operating in Illinois.

<table>
<tr><th>Jurisdiction</th><th>Statutory Reference</th></tr>
<tr><td>State of Indiana</td><td>Indiana Code § 9-19-6-19 (2022)</td></tr>
<tr><th>Colors Permitted</th><th>General Requirements</th></tr>
<tr><td>Amber
White (to front)
Red (to back)</td><td>Any vehicle may be equipped with warning lamps to identify the presence of a vehicular hazard. Lamps displayed to the front can be white, amber, or any color between white and amber. Lamps displayed to the back can be red, amber, or any color between red and amber.</td></tr>
<tr><th>Position</th><th>Intensity</th></tr>
<tr><td>At the same level and as widely spaced laterally as practicable.</td><td>Visible from a distance of not less than five hundred (500) feet under normal atmospheric conditions at night.</td></tr>
<tr><th colspan="2">Text of Statute or Regulation</th></tr>
<tr><td colspan="2">Sec. 19.
(a) A vehicle may be equipped with lamps that may be used for the purpose of warning the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking, or passing. The vehicles, when so equipped, may display the warning in addition to any other warning signals required by this article.
(b) A lamp used to display a warning to the front must be mounted at the same level and as widely spaced laterally as practicable, and must display simultaneously flashing white or amber lights or any shade of color between white and amber.
(c) A lamp used to display a warning to the rear must be mounted at the same level and as widely spaced laterally as practicable, and must show simultaneously flashing amber or red lights or any shade of color between red and amber.
(d) A warning light must be visible from a distance of not less than five hundred (500) feet under normal atmospheric conditions at night.</td></tr>
<tr><th colspan="2">Additional Information</th></tr>
<tr><td colspan="2">n/a</td></tr>
</table>

Jurisdiction	Statutory Reference
State of Iowa	321.423(2h) (2023)
Colors Permitted	**General Requirements**
Amber	Flashing amber lights are permitted on towing/recovery vehicles.
Position	**Intensity**
Not specified	Not specified
Text of Statute or Regulation	
A flashing amber light is permitted on a towing or recovery vehicle, a utility maintenance vehicle, a municipal maintenance vehicle, a highway maintenance vehicle, a construction vehicle, a solid waste or recycling collection service vehicle, or a vehicle operated in accordance with subsection 6 or section 321.398 or 321.453.	
Additional Information	
Rear-facing blue lights are allowed on snowplows in combination with amber and white. White lights are allowed on maintenance vehicles.	

Jurisdiction	Statutory Reference
State of Kansas	Kan. Stat. § 8-1720 (2005) Kan. Stat 8-2010 to 2010c (2003)
Colors Permitted	**General Requirements**
Amber; Red	Any vehicle may be equipped with flashing amber lamps to warn passing vehicles of a traffic hazard requiring unusual care. Wreckers, tow trucks, and car carriers are considered to be emergency vehicles when they have been issued a certificate of public service from the state corporation commission, are stationary, and are providing wrecker or towing service at the scene of a vehicle accident or providing emergency service on the side of a highway. Under these circumstances, red flashing lights may be displayed.
Position	**Intensity**
Mounted at the same level and as widely spaced as possible.	Visible at 500 feet in normal sunlight.

Text of Statute or Regulation

8-1722. Vehicular hazard warning lamps; warning lamps on police vehicles; trash trucks.

(a) Any vehicle may be equipped with lamps for the purpose of warning the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing.

(b) Every bus, truck, truck tractor, trailer, semitrailer or pole trailer 80 inches or more in overall width or 30 feet or more in overall length shall be equipped with lamps meeting the requirements of this section.

(c) Vehicular hazard warning signal lamps used to display such warning to the front shall be mounted at the same level and as widely spaced laterally as practicable, and shall display simultaneously flashing amber lights. On any vehicle manufactured prior to January 1, 1969, the lamps showing to the front may display simultaneously flashing white or amber lights, or any shade of color between white and amber.… The lamps used to display such warning to the rear shall be mounted at the same level and as widely spaced laterally as practicable, and shall show simultaneously flashing amber or red lights, or any shade of color between amber and red. Such warning lights shall be visible from a distance of not less than 500 feet in normal sunlight.

8-1720. Lamps and lights on authorized emergency vehicles; alternately or simultaneously flashing head lamps.

(a) Except as provided in subsection (b), every authorized emergency vehicle, in addition to any other equipment required by this act, shall be equipped with signal lamps mounted as high and as widely spaced laterally as practicable, which shall be capable of displaying to the front two alternately flashing red lights located at the same level and to the rear two alternately flashing red lights located at the same level, or in lieu thereof, any such authorized emergency vehicle shall be equipped with at least one rotating or oscillating light, which shall be mounted as high as practicable on such vehicle and which shall display to the front and rear of such vehicle a flashing red light or alternate flashes of red and white lights or red and blue lights in combination. All lights required or authorized by this subsection shall have sufficient intensity to be visible at 500 feet in normal sunlight. Every authorized emergency vehicle may, but need not, be equipped with head lamps which alternately flash or simultaneously flash.

Kansas (Continued)

(b) A police vehicle when used as an authorized emergency vehicle may, but need not, be equipped with:

(1) head lamps which alternately flash or simultaneously flash;

(2) flashing lights specified in subsection (a), but any flashing lights, used on a police vehicle, other than the flashing lights specified in K.S.A. 8-1722, and amendments thereto, rotating or oscillating lights or alternately flashing head lamps or simultaneously flashing head lamps, shall be red in color; or

(3) rotating or oscillating lights, which may display a flashing red light or alternate flashes of red and blue lights in combination.

8-2010c. Wreckers, tow trucks or car carriers; operation of emergency lights; when:

(a) Wreckers, tow trucks or car carriers designated as authorized emergency vehicles under subsection (c) of K.S.A. 8-2010, and amendments thereto, shall operate such lights authorized under K.S.A. 8-1720, and amendments thereto, only when such wreckers, tow trucks or car carriers are stationary and providing wrecker or towing service at the scene of a vehicle accident or providing emergency service on the side of a highway.

(b) The provisions of this section shall be part of and supplemental to the uniform act regulating traffic on highways.

Additional Information

White and red flashing beacons are allowed on tow trucks manufactured before January 1, 1969.

Jurisdiction	Statutory Reference
State of Kentucky	Ky. Rev. Stat. § 189.910 (2022) Ky. Rev. Stat. § 189.920 (2011) Ky. Rev. Stat. § 198.950 (2022)
Colors Permitted	**General Requirements**
Yellow (unspecified shade)	Unspecified
Position	**Intensity**
Unspecified	Visible under normal atmospheric conditions from a distance of five hundred (500) feet to the front of the vehicle.

Text of Statute or Regulation
§ 189.910. (2) As used in KRS 189.920 to 189.950, "public safety vehicle" means public utility repair vehicle; wreckers; state, county, or municipal service vehicles and equipment; highway equipment which performs work that requires stopping and standing or moving at slow speeds within the traveled portions of highways; and vehicles which are escorting wide-load or slow-moving trailers or trucks. § 189.920. All public safety vehicles shall be equipped with one (1) or more flashing, rotating, or oscillating yellow lights, visible under normal atmospheric conditions from a distance of five hundred (500) feet to the front of the vehicle. § 189.950. (4) No motor vehicle, except those designated under KRS 189.910 to 189.950 as public safety vehicles, shall be equipped with, nor shall any person use upon any vehicle any yellow flashing, revolving, or oscillating light. This subsection shall not apply to the use of yellow lights for turn signals; or to emergency flasher lights for use when warning the operators of other vehicles of the presence of a vehicular traffic requiring the exercise of unusual care in approaching, overtaking, or passing; or to vehicles operated by mail carriers while on duty; funeral escort vehicles and church buses.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Louisiana	La. Admin. Code Title 55 § I-1919 (2014) La. Stat. Title 32 § 309 (1974)
Colors Permitted	**General Requirements**
Amber	Only amber lights are permitted. Tow truck operators and towing services shall ensure warning lights are operable at all times and shall only be activated after arriving at a disabled vehicle or when towing or recovering a vehicle.
Position	**Intensity**
At least one light mounted to the roof or at a higher location	Visible at 360° at a distance of no less than 1,000 feet under normal atmospheric conditions.

Text of Statute or Regulation

A. Tow truck operators and towing services shall ensure tow trucks are equipped with, and use, required lighting, pursuant to state law and CFR Title 49. Auxiliary tow lighting shall be required and used if the rear tail lamps, stop lamps or turn signals on a combination of vehicles are obscured, inoperative, or not visible to the rear by approaching traffic. When auxiliary tow lights are required, they shall include a minimum of two properly functioning tail lamps, stop lamps and turn signals, which may be combined and shall be attached as far apart as practical on the rearmost portion of the towed vehicle and visible to the rear by approaching traffic.

B. Tow trucks shall comply with all equipment requirements found in, or adopted pursuant to Louisiana Revised Statutes Title 32, Chapter 1, Part V (Equipment of Vehicles), 32:1711 et seq., and, if applicable, CFR Title 49.

C. Tow truck shall be equipped with only amber colored flashing warning lights, strobes, light bars or beacons with sufficient strength and mounted in a location to be visible at 360° at a distance of no less than 1,000 feet under normal atmospheric conditions. Each tow truck shall be equipped with at least one amber colored light bar or beacon mounted to the roof or a higher location on a tow truck. Tow trucks used solely to transport vehicles on an attached trailer are exempt from this requirement provided they do not conduct roadside recovery operations or participate on any law enforcement rotation list.

D. Tow truck operators and towing services shall ensure warning lights are operable at all times and shall only be activated after arriving at a disabled vehicle or when towing or recovering a vehicle. Slide back tow trucks solely transporting vehicles on their beds may opt to activate their tow truck’s warning lights.

Additional Information

Statutory and administrative code language are the same.

Jurisdiction	**Statutory Reference**
State of Maine	Me. Stat. tit. 29-A § 2054 (2023)
Colors Permitted	**General Requirements**
Amber; Green	Each tow truck must be equipped with an amber flashing light, and may also be equipped with a flashing green light. Use of the amber light is mandatory when servicing, loading, or towing a vehicle. Use of the green light is permitted only when stationary at the roadside or when loading.
Position	**Intensity**
A wrecker must be equipped with a flashing light mounted on top of the vehicle in such a manner as to emit an amber light over a 360-degree angle.	Unspecified
Text of Statute or Regulation	
(2) A wrecker must be equipped with a flashing light mounted on top of the vehicle in such a manner as to emit an amber light over a 360-degree angle. The light must be in use on a public way or a place where public traffic may reasonably be anticipated when servicing, freeing, loading, unloading or towing a vehicle. (2-A) A wrecker may be equipped with a flashing green auxiliary light mounted on top of the vehicle in such a manner as to emit a green light over a 360-degree angle. A flashing green auxiliary light on a wrecker equipped in accordance with this subparagraph may be used only when: (a) The operator is assisting another vehicle operator or loading a vehicle onto the wrecker; and (b) The wrecker is pulled to the side of, or off, a public way and has halted in a location where it can safely remain stationary.	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Maryland	Md. Code, Transp. § 22-218 (2022)
Colors Permitted	**General Requirements**
Amber; Yellow (unspecified shade)	Tow trucks may be equipped with yellow or amber warning lights.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
Service vehicles, waste or recycling collection vehicles, rural letter carrier vehicles, slow-moving farm vehicles, and tow trucks may be equipped with or display yellow or amber lights or signal devices.	
Additional Information	
Maryland standard specifications for highway construction limit the flash rate of maintenance vehicles to 5 Hz and require the use of SAE Class I lighting devices.	

Jurisdiction	Statutory Reference
State of Massachusetts	540 CMR 22.00 (2018) Mass. Gen. Laws ch. 90 § 7E (2021)
Colors Permitted	**General Requirements**
Amber	Tow trucks may be equipped with amber warning lights.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
(2) Flashing, rotating or oscillating amber light(s) may be mounted and displayed on: (a) motor vehicles used for emergency or service purposes operated by members or employees of an auxiliary police force, charitable organizations, private burglar alarm companies, private detective and private security agencies, agencies of the Commonwealth or its political subdivisions, persons and garages providing motorists assistance services or towing services, public and private utility companies for emergency or service purposes, persons and companies that are transporting human blood or organs for emergency purposes, oxygen, explosives or other hazardous materials; (b) motor vehicles that have the owner's name displayed so as to be plainly visible from each side or from the front and rear of the motor vehicle, and which are actually engaged in the performance of a service, public or private, where the display of such lights would be in the best interest of public safety; and (c) such other motor vehicles as authorized by written permit of the Registrar, which shall be carried by the operator upon his or her person or in the vehicle in some easily accessible place. No person shall mount or display any flashing, rotating or oscillating light of any color other than amber, except blue and red lights as provided in M.G.L. c. 90, § 7E, unless by written permit of the Registrar, which shall be carried by the operator upon his or her person or in the vehicle, in some easily accessible place. (3) The Registrar may order the removal of any colored light, including amber, at any time he deems necessary, upon written notice to the registrant, with a copy to the chief of police where said motor vehicle is principally garaged. Any registrant so notified, who fails to remove such colored lights, and who operates or permits the operation of such lights on the public way, shall be in violation of the Registrar's rules and regulations as provided in M.G.L. c. 90, § 20.	
Additional Information	
Red and blue lights are reserved for emergency vehicles.	

Jurisdiction	Statutory Reference
State of Michigan	Mich. Comp. Laws § 257.698 (2020)
Colors Permitted	**General Requirements**
Amber; Red	Tow trucks may be equipped with yellow or amber warning lights. Tow trucks may also be equipped with red warning lights, which can only be activated only when removing or assisting a vehicle at the scene of a traffic accident or disablement. Lights can only be used when they are required for public safety.
Position	**Intensity**
Not specified	Not specified
Text of Statute or Regulation	
(f) A vehicle to perform public utility service, a vehicle owned or leased by and licensed as a business for use in the collection and hauling of refuse, an automobile service car or wrecker, a vehicle of a peace officer, a vehicle operated by a rural letter carrier or a person under contract to deliver newspapers or other publications by motor route, a vehicle utilized for snow or ice removal under section 682c, a private security guard vehicle as authorized in subsection (7), a motor vehicle while engaged in escorting or transporting an oversize load that has been issued a permit by the state transportation department or a local authority with respect to highways under its jurisdiction, a vehicle owned by the National Guard or a United States military vehicle while traveling under the appropriate recognized military authority, a motor vehicle while towing an implement of husbandry, or an implement of husbandry may be equipped with flashing, rotating, or oscillating amber lights. However, a wrecker may be equipped with flashing, rotating, or oscillating red lights that must be activated only when the wrecker is engaged in removing or assisting a vehicle at the scene of a traffic accident or disablement. The flashing, rotating, or oscillating amber lights must not be activated except when the warning produced by the lights is required for public safety. A vehicle engaged in authorized highway repair or maintenance may be equipped with flashing, rotating, or oscillating amber or green lights. This subdivision does not prohibit the operator of a vehicle utilized for snow or ice removal under section 682c that is equipped with flashing, rotating, or oscillating amber lights from activating the flashing, rotating, or oscillating amber lights when that vehicle is traveling between locations at which it is being utilized for snow or ice removal.	
Additional Information	
Green lights allowed on highway maintenance vehicles. White lights allowed on emergency vehicles.	

Jurisdiction	Statutory Reference
State of Minnesota	Minn. Stat. § 168B.16 (2012)
Colors Permitted	**General Requirements**
Amber; Red	Tow trucks must be equipped with red and amber warning lights. The flashing red light can only be displayed when engaged in emergency service on or near the traveled portion of a highway. The flashing amber light may be displayed when the tow truck or towing vehicle is moving a disabled vehicle.
Position	**Intensity**
On the dome of the vehicle at the highest practicable point.	Visible from a distance of 500 feet.
Text of Statute or Regulation	
A tow truck or towing vehicle must be equipped with flashing or intermittent red and amber lights of a type approved by the commissioner of public safety. The lights must be placed on the dome of the vehicle at the highest practicable point visible from a distance of 500 feet. The flashing red light must be displayed only when the tow truck or towing vehicle is engaged in emergency service on or near the traveled portion of a highway. The flashing amber light may be displayed when the tow truck or towing vehicle is moving a disabled vehicle.	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Mississippi	Miss. Code § 63-7-19 (2018) Miss. Code § 63-7-23 (2019)
Colors Permitted	**General Requirements**
Amber	Tow trucks may be equipped with amber warning lights. Rear-mounted auxiliary white lights may be used when the vehicle is stationary.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
Miss. Code § 63-7-19 Every wrecker or other vehicle used for emergency work, except vehicles authorized to use blue or red lights, shall be marked with blinking, oscillating, or rotating amber-colored lights to warn other vehicles to yield the right-of-way, as provided in Section 63-3-809. Miss. Code § 63-7-23 (2) Auxiliary white lights mounted on or near the rear of a motor vehicle, or visible from the rear of the vehicle, shall not be prohibited under the provisions of this section if (a) the vehicle's gross weight is less than twelve thousand one (12,001) pounds, and (b) the lights are designed by the motor vehicle manufacturer or an after-market parts manufacturer so that they may only be illuminated whenever the vehicle is not in motion and the transmission of the vehicle is not capable of transmitting power to the wheels.	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Missouri	Mo. Rev. Stat. § 304.022 (2022) Mo. Rev. Stat. § 307.080 - 100 Mo. Rev. Stat. § 307.175 (2021)
Colors Permitted	**General Requirements**
Blue; Red (police-operated vehicles) Amber? White? (state DOT vehicles)	No clear authorization was found in the Missouri statutes for the use of flashing warning lights on privately-owned tow vehicles. The statutes allow the use of amber or amber+white lights on vehicles operated by the Missouri Department of Transportation and its contractors, but this provision appears to be directed primarily toward highway maintenance vehicles. A tow truck owned and operated by a "public utility or public service corporation" is an "emergency" vehicle and may display blue and red warning lights while responding to an incident. In practice, the latter provision appears to be used to justify the use of flashing blue and red lights on tow trucks operated by government agencies (Figure A1). It appears that private tow operators in Missouri often rely on non-flashing auxiliary lights mounted on the cab roof (the statute limits this to three auxiliary lights, but some operators appear to use five). A further complication is that both of Missouri's major metropolitan areas (Kansas City and St. Louis) straddle state lines, so some of the vehicles operating in Missouri appear to be equipped with lights that can only be legally used in the adjoining states.
Position	**Intensity**
Unspecified	Visible from 500 feet under normal atmospheric conditions.

Text of Statute or Regulation
§ 304.022 defines any wrecker, or tow truck or a vehicle owned and operated by a public utility or public service corporation while performing emergency service as an emergency vehicle. § 304.022 also states that vehicles and equipment owned or leased by the state highways and transportation commission and operated by an authorized employee of the department of transportation may use or display fixed, flashing, or rotating amber or amber and white lights. § 307.080. Auxiliary lamps—number—location—violation, penalty.—1. Any motor vehicle may be equipped with not to exceed three auxiliary lamps mounted on the front at a height not less than twelve inches nor more than forty-two inches above the level surface upon which the vehicle stands. § 307.090. Spotlamps—restrictions, penalty.—1. Any motor vehicle may be equipped with not to exceed one spotlamp but every lighted spotlamp shall be so aimed and used so as not to be dazzling or glaring to any person. § 307.100. Limitations on lamps other than headlamps—flashing signals prohibited except on specified vehicles—penalty.—1. Any lighted lamp or illuminating device upon a motor vehicle other than headlamps, spotlamps, front direction signals or auxiliary lamps which projects a beam of light of an intensity greater than three hundred candlepower shall be so directed that no part of the beam will strike the level of the roadway on which the vehicle stands at a distance of more than seventy-five feet from the vehicle. § 307.175: The following vehicles may use or display fixed, flashing, or rotating red or red and blue lights: (a) Emergency vehicles, as defined in section 304.022, when responding to an emergency.
Additional Information
Vehicles with amber or amber+white lights are mentioned in Missouri's "move over" law.

Figure A1. Tow truck operated by the City of St Louis, Missouri. Source: City of St. Louis / X.

Jurisdiction	Statutory Reference
State of Montana	Mont. Code § 61-9-416 (2022)
Colors Permitted	**General Requirements**
Amber, Red	Tow trucks are required to have amber, red, or amber+red flashing warning lights. Adjustable lights can be used to allow repositioning in the most advantageous direction while at a response location. While towing, the light must be oriented to the rear. Side-facing lights may also be displayed.
Position	**Intensity**
Montana has conflicting orientation requirements with one section requiring lights be visible from the front and rear, while another says the light can face any desirable direction while standing at the roadside, but must face the rear while towing. Additional side-facing lights are permitted. Lights must be mounted on the cab or hoist, as high and as widely spaced laterlly as possible.	Montana has two conflicting intensity requirements with one stating that lights must be visible from 500 feet in normal sunlight and the other stating the lights must be visible from 1000 feet under normal atmospheric conditions.

Text of Statute or Regulation

61-9-402 (7). Blue, red, and amber lights required in this section must be mounted as high as and as widely spaced laterally as practicable and be capable of displaying to the front two alternately flashing lights of the specified color located at the same level and to the rear two alternately flashing lights of the specified color located at the same level or one rotating light of the specified color, mounted as high as is practicable and visible from both the front and the rear. These lights must have sufficient intensity to be visible at 500 feet in normal sunlight. Except as provided in 61-9-204(6), only police vehicles, as defined in 61-8-102, may display blue lights, lenses, or globes.

61-9-416. A commercial tow truck must be equipped with … a lamp emitting a flashing red or amber light meeting the requirements of 61-9-402(7), or both a red and amber light, mounted on top of the cab of the tow truck or on the top of the crane or hoist if the light can be seen from the front of the tow truck. The light from the lamp must be visible for a distance of 1,000 feet under normal atmospheric conditions and must be mounted so that it can be securely fastened with the lens of the lamp facing the rear of the tow truck upon which it is mounted. When standing at the location from which the disabled vehicle is to be towed, the operator of the tow truck may unfasten the red light and place it in a position considered advisable to warn approaching drivers. When the disabled vehicle is ready for towing, the red light must be turned to the rear of the tow truck upon which it is mounted and securely locked in this position. Additional red or amber lights of an approved type may be displayed at either side or both sides of the tow truck during the period of preparation at the location from which the disabled vehicle is to be towed.

61-9-431. Use of warning signs, flares, reflectors, lanterns, and flag persons.

(1) The operator of a commercial tow truck … shall, when rendering assistance at a hazard on the highway that necessitates the obstruction of a portion or all of the roadway exclusive of the berm or shoulder, place at least two warning signs as required in this section as soon as is practicable under the circumstances. Flag persons and cones may be used to augment the warning signs.

Montana (Continued)

(2) Highway warning signs must be of a uniform type, with dimensions of 3 x 3 feet, lettering 5 inches high, and reflectorized orange or reflectorized fluorescent pink background and black border, as prescribed by the department. The signs must be designed to be visible both during the day and at night. The warning signs must bear the words “accident ahead,” “emergency vehicle ahead,” “lane closed ahead,” “road closed ahead,” “wreck ahead,” “tow truck ahead,” or “wrecker ahead,” as prescribed by the department. (3) The operator of a commercial tow truck used for the purpose of rendering assistance at a hazard on the highway that necessitates the obstruction of a portion of the roadway shall place a highway warning sign as required in subsection (2): (a) in an area in which the posted speed limit is 45 miles an hour or less, not less than 600 feet in advance of the hazard and an equal distance to the rear of the hazard; and (b) in an area in which the posted speed limit is more than 45 miles an hour or no speed limit is posted, 1,000 feet in advance of the hazard, except on a divided highway where the hazard does not cause disruption of traffic traveling on the opposite side of the divided highway, and an equal distance to the rear of the hazard. (4) A local government unit may adopt an ordinance exempting an operator of a commercial tow truck from the requirements of subsection (2) within the limits of an incorporated city or town. (5) When a hazard exists on the highway during the hours of darkness, the operator of a commercial tow truck called to render assistance shall place warning signs upon the highway as prescribed in this section and shall also place at least one red flare, red lantern, or warning light or reflector in close proximity to each warning sign. (6) A violation of warning signs placed as provided in subsection (3) is considered reckless endangerment of a highway worker, as provided in 61-8-301(4), and is punishable as provided in 61-8-715.
Additional Information
When blocking a lane, tow trucks must place at least two 3x3 foot fluorescent pink warning signs with the legend “accident ahead”, “emergency vehicle ahead”, “lane closed ahead”, “road closed ahead”, “wreck ahead”, “tow truck ahead”, or “wrecker ahead”. The advance warning distances for these signs are specified in the statute. When blocking a lane at night, flares must be placed.

Jurisdiction	Statutory Reference
State of Nebraska	Nebraska Revised Statute § 60-6,232 (2024)
Colors Permitted	**General Requirements**
Amber	Amber warning lights are permitted on tow trucks.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation
A rotating or flashing amber light or lights may be displayed on (1) any vehicle of the Military Department while on any state emergency mission, (2) any motor vehicle being operated by any public utility, vehicle service, or towing service or any publicly or privately owned construction or maintenance vehicle while performing its duties on or near any highway, (3) any motor vehicle being operated by any member of the Civil Air Patrol, (4) any pilot vehicle escorting an overdimensional load, (5) any vehicle while actually engaged in the moving of houses, buildings, or other objects of extraordinary bulk, including unbaled livestock forage as authorized by subdivision (2)(f) of section 60-6,288, (6) any motor vehicle owned by or operated on behalf of a railroad carrier that is stopped to load or unload passengers, or (7) any motor vehicle operated by or for an emergency management worker as defined in section 81-829.39 or a storm spotter as defined in section 81-829.67 who is activated by a local emergency management organization.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Nevada	NV Rev Stat § 484D.475 (2019)
Colors Permitted	**General Requirements**
Amber	Flashing amber warning lights should be used when preparing a vehicle for towing. While towing at speeds below the normal traffic speed, a flashing amber lamp may be displayed to the rear. A non-flashing blue light may also be displayed to the rear while responding to a traffic hazard or preparing a vehicle for towing, but must not be used while towing.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation

1. Tow cars used to tow disabled vehicles must be equipped with:
   (a) Flashing amber warning lamps which must be displayed as may be advisable to warn approaching drivers during the period of preparation at the location from which a disabled vehicle is to be towed. A flashing amber warning lamp upon a tow car may be displayed to the rear when the tow car is towing a vehicle and moving at a speed slower than the normal flow of traffic.
   (b) At least two red flares, two red lanterns or two warning lights or reflectors which may be used in conjunction with the flashing amber warning lamps or lamps that emit nonflashing blue light, or both, or in place of those lamps if the lamps are obstructed or damaged at the location from which a disabled vehicle is to be towed.
2. A tow car used to tow disabled vehicles may be equipped with rear facing lamps that emit nonflashing blue light. Lamps that emit nonflashing blue light to the rear of the tow car may only be displayed when the tow car is at the scene of a traffic hazard or during the period of preparation at the location from which a disabled vehicle is to be towed, and must not be displayed when the tow car is being operated on a highway.

Additional Information

n/a

Jurisdiction	Statutory Reference
State of New Hampshire	NH Rev Stat § 266:78-h (2008) NH Rev Stat § 266:78-i (2008)
Colors Permitted	**General Requirements**
Amber	Tow trucks (wreckers) and other highway service vehicles are authorized to be equipped with amber warning lights.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation

266:78-h Amber Warning Lights Authorized for Certain Vehicles.

No person other than those authorized in this section or in RSA 266:78-c shall operate a vehicle equipped with amber colored warning lights. Amber warning lights are authorized for the following vehicles:

I. Vehicles owned by or leased to state, county, or municipal public works departments and used to maintain the highways including, but not limited to, pickup trucks, snow plows, graders, loaders, sand trucks, sweepers, and tar trucks.

II. Vehicles used by telephone, electrical, and cable utilities and tree services for maintenance of utility, sewer, and water lines.

III. United States Postal Service delivery vehicles.

IV. Wreckers and emergency highway service vehicles.

V. Vehicles escorting oversize loads.

VI. Privately owned vehicles used for snow removal on or adjacent to ways.

VII. Refuse collection vehicles and compacters.

VIII. Vehicles owned by or leased to contractors and construction companies and regularly used to provide warning of road obstructions or hazards at road or utility construction sites.

IX. Such other vehicles as may be authorized by the director.

266:78-i Use of Amber Lights.

Vehicles authorized to use amber colored warning lights authorized by RSA 266:78-h may only illuminate the warning lights when their duties require them to be stopped or parked on or immediately adjacent to a way at a road, water, or sewer line construction or maintenance site in a manner that may impede or cause a hazard to traffic, when actively engaged in the delivery of United States mail, or when actively engaged in snow removal or ice treatment or when entering or leaving a way during plowing operations, or during repair or placement of official traffic control devices, pavement marking, or escorting an oversize load or slow moving vehicle, or in the case of wreckers and emergency road service vehicles when maneuvering through congested traffic to reach a disabled vehicle, providing roadside service, or loading or unloading a vehicle.

Additional Information

n/a

<table>
<tr><th>Jurisdiction</th><th>Statutory Reference</th></tr>
<tr><td>State of New Jersey</td><td>N.J. Stat. § 39:3-54.7 (2005)
N.J. Stat. § 39:4-92.1 (2023)</td></tr>
<tr><th>Colors Permitted</th><th>General Requirements</th></tr>
<tr><td>Amber, Red (to rear)</td><td>Any vehicle may be equipped with flashing lamps for the purpose of warning other vehicles of a traffic hazard requiring unusual care. The lamps may only be used at the scene of an accident/breakdown, while preparing for removal, or while towing/transporting. Lamps may be amber or white; those displaying to the rear may be amber or red. A permit is required to install flashing the lights on commercially-registered vehicles.</td></tr>
<tr><th>Position</th><th>Intensity</th></tr>
<tr><td>At the same level and as widely spaced laterally as possible. At least one light must be visible from every direction.</td><td>Visible from 500 feet at any time when lighted lamps are required.</td></tr>
<tr><th colspan="2">Text of Statute or Regulation</th></tr>
<tr><td colspan="2">39:3-54. Warning lights on vehicles—a. Any lighted lamp or illuminating device upon a motor vehicle other than a headlamp, spot lamp or auxiliary driving lamp which projects a beam of light of an intensity greater than 300 candlepower shall be so directed that no part of the beam will strike the level of the roadway on which the vehicle stands at a distance of more than 75 feet from the vehicle. Flashing lights are prohibited on motor vehicles, motorcycles and motor-drawn vehicles except as a means for indicating a right or left turn; provided, however, any vehicle may be equipped, and when required under this article shall be equipped, with lamps for the purpose of warning the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing, and when so equipped, shall display such warning in addition to any other warning signals required by law. The lamps used to display such warning shall be of a type approved by the Director of the Division of Motor Vehicles; those used to display warning to the front shall be mounted at the same level and as widely spaced laterally as practicable, and shall display simultaneously flashing white or amber lights, or any shade of color between white and amber. The lamps used to display such warning to the rear shall be mounted at the same level and as widely spaced laterally as practicable, and shall show simultaneously flashing amber or red lights, or any shade of color between amber and red. These warning lights shall be visible from a distance of not less than 500 feet at any time when lighted lamps are required. The two front and two rear turn signals shall be flashed simultaneously to display such warning on vehicles of the types mentioned in section 39:3-64.

13:24-4.1. Permit eligibility—(a) Owners or lessees of the following types of vehicles are eligible for flashing amber light permits [include] Tow trucks bearing commercial registration … The use of the flashing amber light is restricted to operation on a public highway at the scene of an accident or breakdown while preparations are being made for vehicle removal and while the tow truck is towing or transporting the disabled vehicle from the scene of an accident or breakdown to the place of storage or repair.

13:24-4.4 Mounting specifications—A flashing amber light utilized on a vehicle shall be mounted so that at least one such light is clearly visible from every direction when the vehicle is being used for the type of employment or service for which the permit was issued. Alternately flashing or strobe headlights are prohibited and shall not be incorporated into the housing of any lighting permitted.</td></tr>
<tr><th colspan="2">Additional Information</th></tr>
<tr><td colspan="2">The cost of a four-year amber light permit is $25.</td></tr>
</table>

Jurisdiction	Statutory Reference
State of New Mexico	N.M. Stat. § 66-3-835 (2021)
Colors Permitted	**General Requirements**
Amber; Yellow (unspecified shade); White; Blue; Green; Purple	Tow trucks standing on a highway removing a disabled vehicle may display flashing lights in any color except red. Flashing lights cannot be displayed while traveling to a tow site or towing/transporting.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation

N.M. Stat. § 66-3-835

A. Lighted lamps or illuminating devices upon a motor vehicle, other than headlamps, spot lamps, auxiliary lamps, flashing turn signals, emergency vehicle warning lamps and school bus warning lamps, that project a beam of light of an intensity greater than three hundred candle power shall be directed so that no part of the high-intensity portion of the beam strikes the level of the roadway on which the vehicle stands at a distance of more than seventy-five feet from the vehicle.

B. A person shall not drive or move upon a highway a vehicle or equipment with a lamp or device displaying a red light visible from directly in front of the center of the vehicle or equipment, except as expressly authorized or required by the Motor Vehicle Code.

C. Flashing lights are prohibited except as provided in this section and except on authorized emergency vehicles, school buses, snow-removal equipment and highway-marking equipment. Except as otherwise provided in this section, flashing red lights may be used as warning lights on disabled or parked vehicles and on any vehicle as a means of indicating a turn.

D. A recovery or repair vehicle standing on a highway for the purpose of removing, and actually engaged in removing, a disabled vehicle may display flashing lights in any color except red. This provision shall not be construed as permitting the use of flashing lights by recovery or repair vehicles in going to or returning from the location of disabled vehicles or while engaged in towing a disabled vehicle.

E. Only fire department vehicles, law enforcement agency vehicles, ambulances and school buses may display flashing red lights visible from the front of the vehicle. All other vehicles authorized by the Motor Vehicle Code to display flashing lights visible from the front of the vehicle may use any other color of light that is visible.

Additional Information

n/a

Jurisdiction	Statutory Reference
State of New York	NY Veh & Traf L § 117-A (2022) Consolidated Laws of New York - 71-3-9 (2017)
Colors Permitted	**General Requirements**
Amber; Blue (to rear)	Amber flashing lights are allowed on tow trucks and can be supplemented with a blue light that projects to the rear. The blue light can only be used when “engaged in a hazardous operation” and the amber light must be used when the blue light is on. By day, two red flags visible from 500 feet can be substituted for the amber beacon.
Position	**Intensity**
Not specified	Visible to all approaching traffic under normal atmospheric conditions from a distance of 500 feet.

Text of Statute or Regulation

NY Veh & Traf L § 117-A—Hazard vehicle. Every vehicle owned and operated or leased by a utility, whether public or private, used in the construction, maintenance and repair of its facilities, every vehicle specially equipped or designed for the towing or pushing of disabled vehicles, every vehicle engaged in highway maintenance, or in ice and snow removal where such operation involves the use of a public highway, vehicles driven by rural letter carriers while in the performance of their official duties, and every sani-van and waste collection vehicle while engaged in the collection of refuse and/or recyclable materials on a public highway.

Consolidated Laws of New York - 71-3-9.41(3)—One or more amber lights may be affixed to a hazard vehicle, and such a light or lights which display an amber light visible to all approaching traffic under normal atmospheric conditions from a distance of five hundred feet from such vehicle shall be displayed on a hazard vehicle when such vehicle is engaged in a hazardous operation. Such light or lights shall not be required to be displayed during daylight hours provided at least two red flags visible from a distance of five hundred feet are placed both in or on the front of, and to or on the rear of the vehicle and two such flags are placed to each side of the vehicle open to traffic. Such lights or flags need not be displayed on the vehicle when the vehicle is operating, or parked, within a barricaded work area and said lights or flags are displayed on the barricade. The provisions of this subdivision shall not prohibit the temporary affixing and display of an amber light to be used as a warning on a disabled motor vehicle or on a motor vehicle while it is stopped on a highway while engaged in an operation which would restrict, impede or interfere with the normal flow of traffic.

Consolidated Laws of New York - 71-3-9.41(4)—In addition to the amber light authorized to be displayed pursuant to paragraph three of this subdivision, one or more blue lights or combination blue and amber lights may be affixed to a hazard vehicle designed for the towing or pushing of disabled vehicles provided that such blue light or lights shall be displayed on such a hazard vehicle for rear projection only. Such blue light or lights may be displayed on a hazard vehicle designed for the towing or pushing of disabled vehicles when such vehicle is engaged in a hazardous operation and is also displaying the amber light or lights required to be displayed during a hazardous operation pursuant to paragraph three of this subdivision. Nothing contained in this subparagraph shall be deemed to authorize the use of blue lights on hazard vehicles designed for the towing or pushing of disabled vehicles unless such hazard vehicles also display one or more amber lights as otherwise authorized in this subdivision.

New York (Continued)

The commissioner is authorized to promulgate rules and regulations relating to the use, placement, power and display of blue lights on a police vehicle, fire vehicle, and hazard vehicle designed for the towing or pushing of disabled vehicles.
Additional Information
Green lights are permitted in combination with amber on snowplows.

Jurisdiction	Statutory Reference
State of North Carolina	N.C. Gen. Stat. § 20-130.2 (2019)
Colors Permitted	**General Requirements**
Amber	A flashing amber light shall be activated at the scene of an accident or recovery operation or when towing a wide or overhanging vehicle. The light may also be used when proceeding at 15 mph below the speed limit or otherwise impeding traffic.
Position	**Intensity**
Unspecified	Visible in all directions from a distance of 500 feet
Text of Statute or Regulation	
a. All wreckers operated on the highways of the State shall be equipped with an amber-colored flashing light, which shall be so mounted and located as to be clearly visible in all directions from a distance of 500 feet, which light shall be activated when at the scene of an accident or recovery operation and when towing a vehicle that has a total outside width exceeding 96 inches or which exceeds the width of the towing vehicle. It shall be lawful to equip any other vehicle with a similar warning light, including, but not by way of limitation, maintenance or construction vehicles or equipment of the Department of Transportation engaged in performing maintenance or construction work on the roads, maintenance or construction vehicles … and any other vehicles required to contain a warning light. b. Except as otherwise permitted under this Article, it shall be unlawful for any vehicle to operate a flashing or strobing amber light while in motion on a street or highway unless one of the following conditions apply: ⋮ 3. When any vehicle, or vehicle's load exceeds a width of 102 inches, including oversize loads in accordance with G.S. 20-116. 4. When the use of flashing or strobing lights is required by the Department of Transportation. 5. When the vehicle must travel 15 miles per hour or more below the posted speed limit for safety reasons or is otherwise impeding traffic which could cause a danger to the public, in performing the vehicle's intended service	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of North Dakota	N.D. Cent. Code § 39-10-03 (2019)
Colors Permitted	**General Requirements**
Amber; White	When necessary for public safety, stopped on the highway to provide roadside assistance, or traveling at a speed slower than the normal traffic flow, tow trucks may disregard certain traffic regulations if they are displaying an amber and white light.
Position	**Intensity**
Unspecified	Visible under normal atmospheric conditions for at least 500 feet

Text of Statute or Regulation
39-01-01 Definitions. b. "Class B" authorized emergency vehicles means wreckers and such other emergency vehicles as are authorized by the local authorities. 39-10-03.1. Class B authorized emergency vehicles. 1. The driver of a class B authorized emergency vehicle may: a. Park or stand, irrespective of the provisions of this chapter. b. Exceed the speed limit so long as the driver does not endanger life or property during the time of a local or national disaster. c. Disregard regulations governing direction of movement or turning in specified directions. 2. The exceptions granted in this section to a class B authorized emergency vehicle apply only when the authorized emergency vehicle is displaying an amber and white light visible under normal atmospheric conditions for a distance of five hundred feet [152.4 meters] in any direction, and: a. When it is necessary for the authorized emergency vehicle to use these exemptions for the immediate protection of life or property; b. When an authorized emergency vehicle is stopped on a highway for the purpose of performing a duty as required of the driver; or c. When traveling at a speed slower than the normal flow of traffic. 39-21-17. Spot lamps and auxiliary lamps. 1. Spot lamps. Any motor vehicle may be equipped with not to exceed two spot lamps and every lighted spot lamp must be so aimed and used so that no part of the high-intensity portion will strike the windshield, or any windows, mirror, or occupant of another vehicle in use.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Ohio	Ohio Rev. Code § 4513.17 (2023)
Colors Permitted	**General Requirements**
Amber	Flashing amber lights are permitted on tow trucks in Ohio. The wording of the statute is somewhat unusual: it is written as the negation of a general prohibition on the use of flashing warning lights, rather than an expressed authorization for tow trucks to use them.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation
A flashing, oscillating, or rotating amber light [is not prohibited on] [e]mergency vehicles, road service vehicles servicing or towing a disabled vehicle, stationary waste collection vehicles actively collecting garbage, refuse, trash, or recyclable materials on the roadside, rural mail delivery vehicles, vehicles as provided in section 4513.182 of the Revised Code, highway maintenance vehicles, and similar equipment operated by the department or local authorities
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Oklahoma	Okla. Stat. Title 47 § 12-218.1 (2023) Oklahoma Dept of Public Safety Wrecker & Towing Services Manual (2023)
Colors Permitted	**General Requirements**
Amber; Blue; Red	A wrecker or wrecker support vehicle may display flashing red and/or blue lights at the scene of an emergency. It may display an amber light when leaving the scene of a tow service call or to warn other vehicles to approach and overtake with care.
Position	**Intensity**
Unspecified	Visible from a distance of not less than 500 feet to the front or the rear of the vehicle.
Text of Statute or Regulation	
Flashing red or blue lights or a combination of flashing red and blue lights may be used on licensed Class AA wreckers or wrecker support vehicles at the scene of an emergency. Any licensed Class AA wrecker or wrecker support vehicle may be equipped with a lamp displaying an amber light, visible from a distance of not less than five hundred (500) feet to the front of the vehicle or from a distance of not less than five hundred (500) feet to the rear of the car. Such lamp shall only be used when leaving the scene of a tow service call and for the purpose of warning the operators of other vehicles to exercise care in approaching, overtaking, or passing such vehicle.	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Oregon	ORS § 811.515 ORS § 816.280 Oregon Administrative Rule 257-050-200
Colors Permitted	**General Requirements**
Amber; Red	Tow vehicle warning lights may be amber or red. By statute, the lights shall be activated when “connecting with other vehicles and drawing such vehicles onto highways or servicing disabled vehicles.” By administrative rule, the lights may only be used at the scene when necessary to warn approaching traffic.
Position	**Intensity**
Unspecified	Warning lights shall provide an intermittent light that may be either of a revolving or flashing type or any other type that provides an intermittent light. All warning lights shall be visible from a distance of not less than 500 feet under normal atmospheric conditions at night, and must be visible from 360°.

Text of Statute or Regulation

ORS 811.515. When lights must be displayed

(5) Tow vehicle warning lights on tow vehicles shall be activated when the tow vehicles are engaged in connecting with other vehicles and drawing such vehicles onto highways or while servicing disabled vehicles.

Oregon Revised Statute 816.280 Warning lights —This section establishes standards for different types of warning lights. Each of the following is a requirement for warning lights as described:

(1) The following are the colors for the indicated type of warning light:
- (a) Public vehicle warning lights, pilot vehicle warning lights and commercial vehicle warning lights shall be amber.
- (b) Tow vehicle warning lights may be amber or red.
- (c) Weighmaster and motor carrier enforcement officer warning lights shall be red.
- (d) Warning lights on vehicles engaged in the removal, containment or cleanup of a hazardous materials release, and on vehicles at the scene of a potential release of hazardous materials, may be red or amber.
- (e) Warning lights on vehicles being used by medical examiners to reach the scene of an accident or of a death investigation may be red.

(2) Warning lights shall provide an intermittent light that may be either of a revolving or flashing type or any other type that provides an intermittent light.

(3) All warning lights shall be visible from a distance of not less than 500 feet under normal atmospheric conditions at night.

Administrative Rule 257-050-0200

(8) LED, strobe or rotator lights. These lights must meet the following requirements:
- (a) At least one set of portable lights for the unit being towed. The portable light set must include taillights, brake lights and directional signal lights.
- (b) Be red or amber in color;
- (c) Be capable of being visible from 360 degrees;
- (d) May only be used at the scene when necessary to warn approaching traffic.

Oregon (Continued)

Additional Information
The format of the Oregon Revised Statute 816.280 provides high clarity as to which lighting equipment is associated with each type of vehicle, and is a potential model for other states seeking to modernize their laws.

Jurisdiction	Reference
State of Pennsylvania	75 Pa.C.S. § 4572(b) (2020) 67 Pa. Code § 173.3 (1993)
Colors Permitted	**General Requirements**
Yellow (unspecified shade); White; Blue (to rear)	A tow truck may be equipped with one or more flashing or revolving yellow and/or white lights. In addition it may be equipped with rear-facing blue lights. The amber/white lights can only be used when providing roadside assistance, towing, or carrying a vehicle with overhanging equipment. The blue lights can only be used while standing at the roadside or responding to a disablement, and cannot be used while the tow truck is in motion.
Position	**Intensity**
On the cab or cab protector, not more than 18 inches above the top of the vehicle.	Must be visible from 360°; color must be consistent with SAE J578; other photometrics unspecified

Text of Statute or Regulation

75 Pa.C.S. § 4572.1 Flashing or revolving lights on tow trucks.

(a) Colored lights.

(1) Subject to subsection (b), tow trucks may be equipped with one or more flashing or revolving yellow lights and one or more flashing or revolving white lights. The manner in which the light or lights shall be displayed shall be determined by regulation of the department.

(2) Subject to subsection (b.1), tow trucks may be equipped with one or more flashing or revolving yellow lights and one or more flashing or revolving blue lights. The blue lights shall only be equipped in the rear of the vehicle.

(b) Limitations on white lights.—The flashing or revolving yellow and white lights under subsection (a)(1) on tow trucks shall be activated only when the vehicle is actively performing the type of work which is the basis of the designation of the vehicle as an authorized vehicle or is within the vicinity of an emergency response area. Tow trucks shall not operate with activated flashing or revolving yellow and white lights under subsection (a)(1) when:

(1) Not engaged in the act of towing a vehicle.

(2) Brake lights, turn signals and operating lights are visible from the rear and not obstructed.

(3) The vehicle being towed does not trail behind the tow truck and is securely positioned on the flatbed of the tow truck with no parts of the towed vehicle overhanging.

(b.1) Limitations on blue lights.—A tow truck may only operate with blue lights under subsection (a)(2) while the tow truck is stationary on the side of the road or highway while responding to a disabled vehicle. A tow truck shall not operate with blue lights under subsection (a)(2) at any time while the tow truck is in motion.

(c) Penalty.—Unauthorized use of the lights specified in this subsection shall be a summary offense punishable by a fine of $50.

Pennsylvania (Continued)

67 Pa. Code § 173.3 (1993)

(b) 360° visibility. Except for unmarked police vehicles, when flashing or revolving red, blue, yellow or amber lights are mounted on a vehicle, one or more of these lights shall be mounted to provide visibility to vehicles approaching from any direction (360° visibility), regardless of the method of mounting.

(1) When only one light is used to provide 360° visibility, this light must be in compliance with SAE Standard J845, 360° Emergency Warning Lamps, May 1997, or subsequent SAE Standards.

(2) When more than one light is used to provide 360° visibility, the number of lights used may not exceed those specified in 75 Pa.C.S. § § 4571 and 4572.

(c) Visibility for unmarked police vehicles. When the combination of lights are mounted on an unmarked police vehicle, these lights shall be mounted to provide visibility to vehicles approaching from the front and rear, regardless of the method of mounting.

(d) Flash rate. The flash rate, when observed from a fixed position, must be between 60 and 260 flashes per minute. When the flash rate is produced by the interruption of current, the period of illumination must be long enough to permit the bulb to come to full brightness.

(e) Mounting location. The following applies to mounting locations for flashing or revolving lights:

(3) Authorized vehicles.

(i) Flashing or revolving lights may be permanently mounted on the vehicle or attached to a mounting device, in the following locations only:

(A) On a cab, cab protector or roof of the vehicle.

(B) No more than 18 inches above the highest fixed point of the vehicle.

(C) On the front or rear of the bed or body of an authorized vehicle.

(D) On the tailgate of an authorized vehicle.

(E) In a location other than as set forth in clauses (A)—(D) as needed to comply with the 360° requirement in subsection (b).

(ii) The installation or use of additional flashing or strobe lights in existing vehicular lighting modules/assemblies, such as headlights, parking lights, taillights, is expressly prohibited.

Additional Information

Changes in Pennsylvania statutes made in 2023 are not reflected in the corresponding sections of the Pennsylvania Code (administrative rules) dating from 1993.

Jurisdiction	Statutory Reference
Puerto Rico	PR Laws Title 9 § 5412 (2013)
Colors Permitted	**General Requirements**
Amber	Amber lights reserved for tow trucks, maintenance vehicles, school buses, and private security agencies. Blue lights reserved for police and senior government officials. Green lights reserved for Corrections Administration, municipal police, and Department of Natural & Environmental Resources rangers. Red lights reserved for other emergency vehicles.
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
5412 (d). The use of an amber light is reserved for official vehicles used by the Public Service Commission, the Traffic Ordinance Corps, tow trucks authorized by the Commission while transporting vehicles, the government agencies and instrumentalities rendering public services, school vans or buses, regardless of their dimension, and private security agencies. 5413. It shall be illegal to equip a vehicle with more than two (2) spot lamps or to use these as substitutes for [headlights], or to aim them directly at vehicles approaching from the opposite direction.	
Additional Information	
A fine for misuse of flashing colored lights is $100.	

Jurisdiction	Statutory Reference
State of Rhode Island	R.I. Gen. Laws § 31-24-31 (2018)
Colors Permitted	**General Requirements**
Amber	Private tow operators may purchase an amber light permit at a cost of $25/year per vehicle; there is no permit fee for tow trucks operated by government agencies. Flashing amber lights can be displayed at the front and rear of the vehicle, to be activated only in the course of providing assistance to or transportation for a disabled vehicle.
Position	**Intensity**
Not specified	Not specified

Text of Statute or Regulation

(b) Forward viewing or rotating beam lights may be installed on and shall be restricted to the following categories of vehicles, and these lights shall be of color designated:

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(2) Wrecker trucks, service station trucks, state and town safety and maintenance vehicles; snowplows and tractors; light company trucks, telephone company trucks, water company trucks, oil company trucks, and other utilities' trucks; vehicles of television, radio and press photographers; newspaper motor route carriers; rural mail carriers; all motor-propelled vehicles owned by the Northern Rhode Island REACT (radio emergency associated citizens team); all motor-propelled vehicles owned by or under contract to the Rhode Island department of transportation when on official state business; and vehicles marking the beginning and end of funeral processions: Amber, provided, however, that wrecker and transportation vehicles operated pursuant to a public utilities commission license, and roadside assistance vehicles of any type operated for that purpose by the American Automobile Association shall be permitted to use flashing amber lights at the front and rear of the vehicle, to be activated only in the course of providing assistance to or transportation for a disabled vehicle. A fee of twenty-five dollars ($25) shall be charged for the issuance of a flashing lights permit to every vehicle identified in this subsection, with the exception of flashing lights permits issued to state, town or fire district safety and maintenance vehicles, which shall not be charged a fee.

Additional Information

n/a

Jurisdiction	Statutory Reference
State of South Carolina	SC Code of Laws - Title 56 - Chapter 5 § § 4710, 4740 (2022) SC Administrative Code - Article 7 - § 38-600 (1976)
Colors Permitted	**General Requirements**
Amber; White; Red	Any vehicle may be equipped with flashing white or amber lamps to warn other vehicles of a hazard. In addition, a flashing red light may be used at an accident scene only.
Position	**Intensity**
Mounted at the same level and as widely spaced laterally as practicable	Visible in all directions for a distance of 500 feet in normal sunlight.

Text of Statute or Regulation
SECTION 56-5-4710. Use of mounted oscillating, rotating, or flashing red light by wreckers. Wreckers may use a mounted oscillating, rotating or flashing red light only at the scene of accidents. SECTION 56-5-4740. Warning lamps. Any vehicle may be equipped with lamps which may be used for the purpose of warning the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing, and when so equipped may display such warning in addition to any other warning signals required by this chapter. The lamps used to display such warning to the front shall be mounted at the same level and as widely spaced laterally as practicable and shall display simultaneously flashing white or amber lights or any shade of color between white and amber. The lamps used to display such warning to the rear shall be mounted at the same level and as widely spaced laterally as practicable and shall show simultaneously flashing amber or red lights or any shade of color between amber and red. These warning lights shall be visible from a distance of not less than five hundred feet under normal atmospheric conditions at night. Administrative Code § 7-380-600 (applicable to towing operators on the state rotation list) All wrecker services utilized by the South Carolina Department of Public Safety … shall have appropriate safety equipment, fire extinguishers, warning devices, flashlights, and all other equipment necessary to protect the motoring public and be equipped with amber flashing lights visible in all directions for a distance of 500 feet in normal sunlight. Such equipment shall be maintained in good working order. All authorized amber flashing lights shall be activated and wrecker operators shall wear reflective traffic safety vests while performing recovery operations or when circumstances are such that the vehicle(s) being transported create a potentially hazardous condition for other motorists.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of South Dakota	S.D. Codified Laws § 32-17-10 (2020
Colors Permitted	**General Requirements**
Amber; Blue	Amber flashing lights may be used by a tow truck or wrecker when actually engaging, towing, hauling, or pushing a disabled motor vehicle, or when ordered by a law enforcement officer for safety purposes to warn other motorists of the presence of the tow truck or wrecker. Blue lights may be used when removing debris from a public road.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation
Unless the context otherwise requires, a tow truck or wrecker means any motor vehicle which is specially equipped to tow, haul, or push disabled automobiles, trucks, or tractors for commercial considerations, or operated by any person, for the purpose of towing or servicing any automobiles, trucks, or tractors owned by him. Any tow truck or wrecker may be equipped with and use an amber rotary beacon light or lights or other amber flashing or blinking light or lights of the type or similar to the type of lights used on emergency vehicles in this state. The amber lights may be used by a tow truck or wrecker only when actually engaging, towing, hauling, or pushing a disabled motor vehicle, or when ordered by a law enforcement officer for safety purposes to warn other motorists of the presence of the tow truck or wrecker. Any tow truck or wrecker may be equipped with and use a blue rotary beacon light or lights or other blue flashing or blinking light similar to the type of lights used on emergency vehicles in this state. The blue lights may be used by a tow truck or wrecker only when removing debris from a public road. A violation of this section is a Class 2 misdemeanor.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Tennessee	Tenn. Code § 55-8-132 (2021) Tenn. Code § 55-8-402 (2023)
Colors Permitted	**General Requirements**
Amber; White	Unspecified
Position	**Intensity**
Unspecified	Unspecified
Text of Statute or Regulation	
<u>Tenn. Code § 55-8-132</u> (d)(2) "Recovery vehicle" means a truck that is specifically designed for towing a disabled vehicle or a combination of vehicles. <u>Tenn. Code § 55-8-402</u> (d)(1)(C) A highway maintenance or utility vehicle or recovery vehicle may display flashing white or amber lights or any combination of flashing white and amber lights pursuant to subsection (e). (d) (3) No spotlight or auxiliary lamp shall be so aimed upon approaching another vehicle that any part of the high intensity portion of the beam therefrom is directed beyond the left side of the motor vehicle upon which the spotlight or auxiliary lamp is mounted, nor more than one hundred feet (100') ahead of the motor vehicle. (e)(1)(B) Notwithstanding any law to the contrary, a recovery vehicle designed for towing a disabled vehicle, as defined in § 55-8-132, while in the performance of duties involved with towing an abandoned, immobile, disabled or unattended motor vehicle is authorized to display an amber light that is a strobe, flashing, oscillating or revolving system or any combination of white and amber lights. Such authorized light or lights may be displayed on any location on the vehicle or equipment, other than within the headlight assembly or grill area of the vehicle, in the tail light lamp or stoplight area, or factory installed emergency flasher and backup light area	
Additional Information	
n/a	

Jurisdiction	Statutory Reference
State of Texas	Tex. Transp. Code § 547.105 (2019) Tex. Transp. Code § 547.305 (2023) TxDOT Lighting Standards (2019)
Colors Permitted	**General Requirements**
Amber; Blue; Red	Tow trucks must be equipped with a roof-mounted light bar that displays amber warning lights, and may be equipped with flashing red and blue lights. The red and blue lights can only be used only when stopped at an incident.
Position	**Intensity**
Roof mounted	Unspecified

Text of Statute or Regulation

Tex. Transp. Code § 547.105

(a) The Texas Department of Transportation shall adopt standards and specifications that:

(1) apply to lamps on highway maintenance or construction vehicles and service vehicles; and

(2) correlate with and conform as closely as possible to standards and specifications approved by the American Association of State Highway and Transportation Officials.

(b) The Texas Department of Transportation may adopt standards and specifications for lighting that permit the use of flashing lights for identification purposes on highway maintenance or construction vehicles and service vehicles.

(c) The standards and specifications adopted under this section are in lieu of the standards and specifications otherwise provided by this chapter for lamps on vehicles.

Tex. Transp. Code § 547.305

(d) A vehicle may be equipped with alternately flashing lighting equipment described by Section 547.701 or 547.702 only if the vehicle is:

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(4) a tow truck while under the direction of a law enforcement officer at the scene of a collision or while hooking up to a disabled vehicle on a roadway; or

(5) a tow truck with a mounted light bar which has turn signals and stop lamps in addition to those required by Sections 547.322, 547.323, and 547.324, Transportation Code.

(f) (3) [In this section] “Tow truck” means a motor vehicle or mechanical device that is adapted or used to tow, winch, or move a disabled vehicle.

Texas DOT Lighting Standards

Vehicles that may be equipped with alternately flashing red, white, and blue lighting include school and church buses, authorized emergency vehicles, certain tow trucks, and escort flag vehicles. Use of flashing amber lights is not prohibited under the Texas Transportation Code. Highway maintenance or construction vehicles and service vehicles are prohibited from using or being equipped with flashing white lights. See Texas Transportation Code § 547.305 for detailed requirements.

Tow trucks shall be equipped with a roof-mounted light bar that displays amber warning lights. Tow trucks may be equipped with flashing red and blue lights, which shall be used only when stopped at an incident. Amber lights should be set up to operate independently from blue/red lights.

Additional Information

n/a

Jurisdiction	Reference
State of Utah	Utah Code § 41-6a-1610 (2015) R909-19-9. (2024)

Colors Permitted	General Requirements
Amber	In Utah, the requirements for tow truck lighting are established in an administrative rule (not in the state statutes). Tow trucks are subject to biennial certification. Amber flashing/rotating lights are part of the equipment required to pass certification. The Utah Code reserves red and blue lights for use on "authorized emergency vehicles," which are defined as police, fire, and EMS vehicles.

Position	Intensity
Unspecified	Unspecified

Text of Statute or Regulation

41-6a-1610. Spot lamps

(1) A motor vehicle may not be equipped with more than two spot lamps.

(2) A lighted spot lamp may not be aimed or used so that any part of the high intensity portion of the beam strikes the windshield, or any windows, mirror, or occupant of another vehicle in use.

(3) This section does not apply to spot lamps on an authorized emergency vehicle.

(4) A violation of this section is an infraction.

R909-19-9. Required Tow Truck Vehicle Certification.

(1) Tow trucks shall receive and pass a tow truck certification inspection biannually.

(2) Tow trucks must be equipped with the required safety equipment. Safety Equipment List can be found at https://www.udot.utah.gov/connect/business/motor-carriers/tow-trucks/tow-truck-certification/ or by calling 801-965-4892.

(3) Upon vehicle certification, an UDOT certification sticker will be issued and shall be affixed to the driver's side rear window.

(4) Documentation of UDOT tow truck vehicle certification shall be retained and available upon request by Department personnel.

Required Equipment

Amber rotating/oscillating lights – used to alert public of emergency situations; permanent fixtures mounted on vehicle at the highest point; at least one 6″ diameter light.

Additional Information

A tow truck driver certification is also required.

Jurisdiction	Statutory Reference
State of Vermont	Vt. Stat. tit. 23 § 1252 (2021)
Colors Permitted	**General Requirements**
Amber	Unspecified
Position	**Intensity**
Unspecified	Amber lamps shall be mounted so as to be visible to all sides of the motor vehicle.

Text of Statute or Regulation
A. The following vehicles may be equipped with flashing, blinking, or alternating amber warning lights of types approved by the Superintendent: 1. Amber signal lamps shall be used on road maintenance vehicles, service vehicles, and wreckers and shall be used on all registered snow removal equipment when in use removing snow on public highways, and the amber lamps shall be mounted so as to be visible from all sides of the motor vehicle. ⋮ B. Except as otherwise provided in this section, such amber lights shall be lit only when performing the functions which qualify them to be equipped with such lights.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Virginia	Va. Code § 46.2-1025 (2023)
Colors Permitted	**General Requirements**
Amber	Tow trucks may be equipped with flashing amber lights, which shall be lit only when performing the functions that qualify them to be equipped with such lights.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation

A. The following vehicles may be equipped with flashing, blinking, or alternating amber warning lights of types approved by the Superintendent:
   1. Vehicles used for the principal purpose of towing or servicing disabled vehicles;

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B. Except as otherwise provided in this section, such amber lights shall be lit only when performing the functions which qualify them to be equipped with such lights.

Additional Information

n/a

Jurisdiction	Statutory Reference
State of Washington	Wash. Rev. Code § 46.37.196 (2023)
Colors Permitted	**General Requirements**
Red; Blue	Tow trucks in Washington State may be equipped with flashing red lights and rear-facing blue lights. The red and blue lights may be displayed at the scene of an emergency/accident, and the flashing red lights may be used when re-entering the roadway from an emergency or accident scene.
Position	**Intensity**
Unspecified	360-degree visibility at a distance of 500 feet under normal atmospheric conditions

Text of Statute or Regulation
All emergency tow trucks shall be identified by an intermittent or revolving red light capable of 360-degree visibility at a distance of 500 feet under normal atmospheric conditions. The emergency tow trucks may also operate rear-facing blue lights for use only at the scene of an emergency or accident. The red lights may be used when the tow truck is reentering the roadway from the scene of an emergency or accident for a reasonable distance to reach operating speed from the scene, and the combination of red and blue lights may be used only at the scene of an emergency or accident. It is unlawful to use a combination of lights when traveling to or from the scene of an accident or for any other purpose.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of West Virginia	W. Va. Code § 17C-15-26 (2024)
Colors Permitted	**General Requirements**
Amber; Yellow (unspecified shade)	Yellow/amber lights may be used on tow trucks if authorized "by the sheriff of the county of residence."
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation
(4) Yellow or amber flashing warning lights are restricted to the following: (A) All other emergency vehicles, including tow trucks and wreckers, authorized by this chapter and by § 17C-15-27 of this code; ⋮ (5) The use of yellow or amber flashing warning lights shall be authorized as follows: (A) Authorization for tow trucks, wreckers, rural newspaper delivery vehicles, flag car services, vehicles providing road service to disabled vehicles, service vehicles of a public service corporation, and postal service vehicles shall be designated by the sheriff of the county of residence.
Additional Information
n/a

Jurisdiction	Statutory Reference
State of Wisconsin	Wis. Stat. § 347.26 (2021)
Colors Permitted	**General Requirements**
Amber; Red	A tow truck must be equipped with flashing amber lamps to warn other traffic of vehicular hazard. The lamps must be lighted when moving a disabled vehicle at less than the prevailing speed, but cannot be lit at other times. In addition, the use of a combination of flashing amber and flashing red lamps is mandatory when standing at the roadside in preparation for towing/hauling a disabled vehicle. Further, a truck with a gross weight of 26,000 pounds or more may display flashing amber lamps when traveling at 10 mph or more below the speed limit, standing, or backing.
Position	**Intensity**
At the highest practicable point	Visible from a distance of 500 feet

Text of Statute or Regulation

(1) General Restrictions.

A vehicle need not be equipped with the lamps specified in this section, but if a vehicle is equipped with any such lamps, no person shall operate such vehicle on a highway during hours of darkness unless such lamps comply with the requirements of this section and no person shall use such lamps in a manner inconsistent with this section.

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(6) Warning Lamps On Tow Trucks And Service Vehicles.

(a) Any vehicle which by reason of its use upon a highway creates a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing shall be equipped with a flashing or rotating amber lamp of the dome type at the highest practicable point, visible from a distance of 500 feet, or 2 flashing amber lamps, one showing to the front and one showing to the rear, visible from a distance of 500 feet and mounted approximately midway between the extremities of the width of the vehicle and at the highest practicable point. Such amber lamp or lamps shall be lighted when such vehicle is moving a disabled vehicle along or upon a public highway at a speed below the average speed of motor vehicle traffic on such street or highway and may not be lit at other times.

(b) Operators of tow trucks or towing vehicles shall equip each tow truck or towing vehicle with a flashing or rotating red lamp, in addition to flashing type amber lamps. Such lamp shall be placed on the dome of the vehicle at the highest practicable point visible from a distance of 500 feet. This flashing red lamp shall be used only when such vehicle is standing on or near the traveled portion of a highway preparatory to towing or servicing the disabled vehicle.

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(11) Flashing Warning Lamps.

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(am) In addition to any other lamps authorized under this subsection, a motor truck having a gross vehicle weight rating of more than 26,000 pounds may be equipped with a 360-degree flashing or rotating amber light mounted at the highest practicable point. The flashing or rotating amber lamp may be lighted only when the motor truck is upon a highway having a maximum speed limit of more than 35 miles per hour and the motor truck is traveling 10 or more miles per hour below the maximum speed limit, is stopped, or is backing on such highway. The flashing or rotating amber lamp may not be lit at other times.

Wisconsin (Continued)

Additional Information
There appears to be a conflict between paragraph (1) which says that equipping tow trucks with flashing lights is optional and paragraph (6) which says amber and red lights are mandatory and must be used in certain frequently occurring towing situations.

Jurisdiction	Statutory Reference
State of Wyoming	Wyo. Stat. § 31-5-928 (2021)
Colors Permitted	**General Requirements**
Amber; White; Blue; Red	Tow trucks are authorized to display flashing white and amber lights, and are authorized to display flashing red and blue lights at an emergency scene.
Position	**Intensity**
Unspecified	Unspecified

Text of Statute or Regulation

(f) The following vehicles are authorized to display flashing white and amber lights in addition to those otherwise authorized by law:

(i) Vehicles of civil emergency preparedness agencies;

(ii) Vehicles of municipalities and public service corporations;

(iii) Wreckers;

(iv) Funeral cars.

(g) In addition to these lights otherwise authorized by law, a wrecker is authorized to display flashing red and blue lights at the scene of any emergency.

Additional Information

n/a

Appendix 2: Comparative Regulations

Authority	Statutory Reference	Most Recent Update
United Nations Economic Commission for Europe (UNECE)	UNECE Regulation 65: Uniform Provisions Concerning the Approval of Special Warning Lamps for Power-Driven Vehicles and Their Trailers	2023
Colors Addressed	**General Requirements**	
Amber, Blue, Red	UNECE has developed international standards for vehicle design. The UNECE standards are applicable in 54 countries worldwide and serve as the basis for ongoing international standards harmonization efforts. UNECE Regulation 65 establishes upper and lower limits for the luminous intensity of red, blue, and amber flashing warning lights.	
Position	**Intensity**	
Not specified	Photometric measurements are performed at a distance of at least 25 meters. Amber lamps of Types T and HT (omnidirectional): 230–1700 cd by day and 100–700 cd by night at horizontal, 170–1500 cd by day and 70–600 cd by night at 8° above or below horizontal; beyond 8° maximum intensity is 300 cd by night and 1000 cd by day. Amber lamps of Type X (directional with 10 to 20° beam spread): 400–3000 cd by day and 200–1500 cd by night at horizontal. Maximum intensity at 8° vertical is 1500 cd by day and 600 cd by night. Beyond 8° vertical and 20° horizontal the maximum intensity is 1000 cd by day and 300 cd by night. Flash rates: min: 2 Hz, max 4 Hz. Min off time is 0.1sec, max on time is 0.4 sec/flash. Red and blue lamps are also addressed in the standard. The requirements are similar except that the minimum intensity is 120 cd by day and 50 cd by night.	

Jurisdiction	Statutory Reference	Most Recent Update
Federal Aviation Administration - Aircraft Support Vehicles	FAA AC 150/5210-5D Advisory Circular: Painting, Marking, and Lighting of Vehicles Used on an Airport	2010
Colors Permitted	**General Requirements**	
Yellow (unspecified shade)	Mandatory day and night	
Position	**Intensity**	
The standard for identification lighting is a yellow flashing light that is mounted on the uppermost part of the vehicle structure. A steady yellow light designates vehicles limited to non-movement areas. The light must be visible from any direction, day and night.	Lights must have peak intensity within the range of 40 to 400 cd (effective) from 0° (horizontal) up to 10° above the horizontal and for 360° horizontally. The upper limit of 400 cd (effective) is necessary to avoid damage to night vision. From 10° to 15° above the horizontal plane, the light output must be 1/10th of peak intensity or between 4 and 40 cd (effective). Lights must flash at 75 ± 15 flashes per minute.	
Text of Statute or Regulation		
1. The standard for identification lighting is a yellow flashing light that is mounted on the uppermost part of the vehicle structure. A steady yellow light designates vehicles limited to non-movement areas. 2. The light must be visible from any direction, day and night, including from the air. 3. Color specifications for vehicle identification lights are per Appendix B. 4. For aircraft tow vehicles (TLTVs), an LED light bar placed above the operator's cab may be used in place of the rotating yellow flashing light. In addition, a yellow flashing light (of any type) must be installed on the upper left-rear and right-rear corners of the TLTV, and must be activated when an aircraft is in tow. The size of the rear flashing lights must be large enough to meet the luminance requirements, but not so large as to interfere with the normal or towing operations of the TLTV. Aircraft Support Vehicles are "Vehicles that are routinely used in the AOA [airport operations area] to support aircraft operations (e.g. aircraft pushback tractors, baggage/cargo tractors or trucks, air conditioning and aviation fuel trucks). These vehicles are typically owned by airlines, vendors, or contractors."		
Additional Information		
To further improve night-time recognition of vehicles, a minimum 8 inch (200 mm) wide horizontal band of high gloss white paint or white reflective tape must be used around the vehicle's surface. Figures 1, 2, and 3 in Advisory Circular 150/5210-5D show suggested locations for the horizontal reflective band.		

Jurisdiction	Statutory Reference	Most Recent Update
International Civil Aviation Organization (IACO)	Annex 14 to the Convention on International Civil Aviation—Volume 1—Chapter 6	2016
Colors Permitted	**General Requirements**	
Yellow	"Mobile obstacles" must display Type C warning lights during conditions of twilight and darkness. Blue lamps are reserved for security vehicles and amber for all other airfield support vehicles.	
Position	**Intensity**	
Not specified	40 to 400 cd at azimuth and not less than 20 cd at 12° beam spread	
Text of Statute or Regulation		
6.1.1.1 Vehicles and other mobile objects, excluding aircraft, on the movement area of an aerodrome are obstacles and shall be marked and, if the vehicles and aerodrome are used at night or in conditions of low visibility, lighted, except that aircraft servicing equipment and vehicles used only on aprons may be exempt. ⋮ 6.2.2.6 Low-intensity obstacle lights, Type C, displayed on vehicles associated with emergency or security shall be flashing-blue and those displayed on other vehicles shall be flashing-yellow.		
Additional Information		
The light distribution for these lamps is described in Tables 6-1 and 6-2 of the regulation.		