Preliminary Investigation (PI-0340)

Caltrans Division of Research, Innovation and System Information

Enhancing Caltrans Worker Visibility: Integrating Safety Lighting on High-Visibility Garments

Requested by
Larry Schwartz, Division of Maintenance Safety, Equipment and Training

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Table of Contents

List of Tables

List of Figures

Executive Summary

Background

State transportation agencies use high-visibility clothing to enhance safety in work zones. The California Department of Transportation (Caltrans) is exploring lighted garments to enhance worker safety in low-visibility conditions. While enhancing worker visibility is crucial for safety, it is equally important to ensure that any lighting added to workers' clothing does not distract drivers.

Caltrans is interested in identifying commercially available lighting systems and garment technologies in use or being tested to improve workers' visibility without compromising drivers' attention. To assist Caltrans' assessment of different garment lighting systems, CTC & Associates conducted a national survey of state transportation agencies to inquire about the use and impact of these lighting systems on the safety of both workers and drivers. Survey findings are supplemented by the results of a literature search that examined domestic research, state practices and commercial garment lighting products.

Summary of Findings

Survey of Practice

An online survey was distributed to state department of transportation (DOT) members of the No Boundaries Transportation Maintenance Innovations pooled fund study, supplemented by state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance for those states not participating in No Boundaries. The survey received responses from transportation agencies in 16 states:

- Alabama
- Arizona
- Arkansas
- Colorado
- Idaho
- Illinois
- Kansas
- Michigan
- Nebraska
- Nevada
- Ohio
- Pennsylvania
- Rhode Island
- South Dakota
- Texas
- Utah

Survey findings are presented below in two categories:

- Agencies using garment lighting systems
- Agencies not using garment lighting systems

Agencies Using Garment Lighting Systems

Survey respondents from six state DOTs described using or testing garment lighting systems. While two agencies have tested or plan to test lighted safety vests conceptually similar to the lighted harnesses Caltrans is considering (*Alabama* and *Nevada*), the most commonly reported garment lighting systems are lights that attach to hard hats or clothing.

The lighting systems used by respondents are organized into four categories:

- Lighted safety vests
- Guardian Angel wearable/mountable safety lights
- Halo personal lighting system
- Other personal lighting systems

Below are highlights of respondents' use of these lighting systems.

- *Lighted safety vests.* Similar to the lighted harness Caltrans is considering, these safety vests incorporate LED lights and are worn over clothing or outerwear.
    - Alabama DOT is preparing to use a new product—the 360 Degree LED Safety Vest—that uses a rechargeable battery to provide visibility from all angles. The agency will soon distribute 300 vests across the state to interested maintenance crew members and will survey those workers after they use the vests for two to three weeks.
    - Nevada DOT tested two lighted safety vests—the LED Hi-Vis Safety Vest, which uses AA batteries, and the Stop Lite ANSI Class 3 LED Hi Vis Vest, which has a rechargeable battery. The agency does not plan to continue their use due to worker concerns with glare, weight and general comfort.
- *Guardian Angel wearable/mountable safety lights.* These small lighting units with rechargeable batteries can be attached to clothing, hats or equipment. Two responding agencies currently use them (*Nevada* and *Pennsylvania*); a third agency is piloting the product (*Kansas*).
    - Nevada DOT employees have used Guardian Angel lights for two years, attaching them to vests, helmets, pockets, shoes and equipment. Though no formal assessments have been conducted, the agency has found the clip-on lights to be extremely effective, cost-efficient and easy to use. Reported concerns include glare and vehicle reflections in certain conditions.
    - Pennsylvania DOT has used Guardian Angel lights for approximately three years. Employees attach the lights to hard hats, with maintenance crews using white and amber lights and flaggers using all amber lights. Guardian Angel lights have been effective in bringing attention to employees in work areas. Workers prefer the helmet strap over the magnetic clip and do not favor the Velcro arm strap.
    - Kansas DOT is conducting an informal trial of Guardian Angel lights. While the agency has received minimal employee feedback thus far, Kansas

DOT may include the lights in agencywide nighttime traffic control kits if the trial is successful.

- *Halo personal lighting system.* Designed to be worn on a standard hard hat, this personal lighting system with a rechargeable battery offers a 50-foot spotlight. Pennsylvania DOT currently uses Halo lights and two other agencies have tested them.
    - Pennsylvania DOT has used Halo lights for six years and has found the lights effective in calling attention to employees in work areas. At times, the lights can draw insects at night. The newer Halo models weigh less and cause less stress on a worker's neck.
    - Alabama DOT tested Halo lights attached to hard hats, but employees found the weight uncomfortable.
    - Utah DOT tested a Halo light model that offered an associated wired battery pack. With workers expressing concern regarding the weight the light added to hard hats and noting that the battery pack was "a bit cumbersome," this lighting system has not been adopted for use across the agency.
- *Other personal lighting systems.* The Freakin' Beacon, recently adopted for use by Pennsylvania DOT, is a palm-sized, AAA battery-operated unit that attaches to a hard hat.

Agencies Not Using Garment Lighting Systems

Ten of the 16 responding agencies do not use and are not testing garment lighting systems. Of these agencies, the Illinois DOT respondent noted that general concerns with wearable lighting systems causing glare or other distractions have prompted the initiation of a new research project to explore the effectiveness of lighting technologies used on high-visibility garments. The Arizona DOT respondent described the agency's practice to use stand-alone work area lights that are placed to highlight workers but pointed away from motorists to avoid distraction.

Related Research and Resources

A literature search of publicly available domestic research and related resources identified a sampling of publications that are organized into the following categories:

- Related Research
- State Research and Practices
- Commercial Products

The table that begins on page 7 summarizes these publications. The table provides the publication or resource title, the year of publication, if applicable, the publication's category and a brief description of the resource. Significantly more detail about each resource can be found in the **Detailed Findings** section of this report.

Gaps in Findings

Almost two-thirds of the 16 survey respondents reported no experience with garment lighting systems that enhance safety for maintenance workers during nighttime or other low-visibility conditions.

Of the six respondents describing experiences with these lighting systems, none reported targeted efforts to determine impacts of the lights on drivers. Similarly, while a few studies have explored the effectiveness of garment lighting systems to enhance worker visibility, potential issues with these lights causing glare or other driver distractions do not appear to have been formally addressed by researchers.

While two state DOTs have tested, or plan to test, lighted safety vests that are conceptually similar to the lighted harness Caltrans is evaluating, none of the responding agencies have experience with lighted harnesses.

Next Steps

Moving forward, Caltrans could consider:

- Following up with the agencies reporting experience with lighted safety vests:
    - *Alabama DOT*. The agency will soon receive 300 units of the 360 Degree LED Safety Vest that will be distributed to and tested by maintenance crews.
    - *Nevada DOT*. The agency tested two types of lighted safety vests and opted not to offer them for statewide use.
- Consulting with the agencies acknowledging the potential for driver distraction when using garment lighting systems:
    - *Illinois DOT*. The agency is preparing to launch a research project on the effectiveness of lighting technologies used with high-visibility garments.
    - *Nevada DOT*. The respondent reported concerns about safety lighting causing glare and distracting drivers.
- Engaging with Kansas DOT to inquire about the agency's ongoing informal trial of Guardian Angel lights.
- Reaching out to selected agencies not responding to the survey to seek additional feedback that may inform Caltrans' evaluation of garment lighting systems.

Related Research and Resources

Publication or Resource (Year)	Category	Excerpts from Abstract or Description of Resource
Impacts of Emergency Vehicle Marking Characteristics and Wearable Lights on Driver Responses (2024)	Related Research	Presents key findings from the 2023 research cited below, including the impacts of emergency vehicle marking color, retroreflectivity level and spatial patterns on drivers' ability to see nearby emergency responders as well as the impacts of a wearable flashing LED light. Researchers noted that "[w]earable flashing LED lights can make emergency responders easier to see at night, provided they do not increase glare to approaching drivers."
Impacts of Emergency Vehicle Marking Color, Patterns and Retroreflectivity on Safety-Related Driver Responses (2023)	Related Research	Describes a field experiment to investigate the impacts of emergency vehicle marking color, retroreflectivity level and spatial patterns on drivers' ability to see emergency responders working near their vehicles. Also addresses the use of wearable flashing LED lights and recommends that the "ideal properties of these lights should be investigated further."
Protecting Roadside Workers: Field Evaluation of Flares, Cones and Tow Truck Light Patterns (2023)	Related Research	Identifies a series of countermeasures "to improve the safety of towing, recovery, and other incident response personnel," including the worker-based countermeasure W-05 Wearable Safety Light.
Effects of Wearable Light Systems on Safety of Highway Construction Workers (2020)	Related Research	Evaluates the effectiveness of wearable lighting systems in work zone applications. Findings indicate that wearable lights could increase the visibility of dump operators, spotters and density technicians if placed in optimal locations.
When a Little Light Serves as Your Guardian Angel (2021)	State Research and Practices (Iowa)	Describes a pilot project that found Guardian Angel lights effective at alerting drivers to workers and easy to use, prompting an Iowa DOT district to purchase 190 devices to provide to each road crew member.
Use of Additional Lighting for Traffic Control and Speed Reduction in Work Zones (2018)	State Research and Practices (Oregon)	Evaluates different types of lighting systems on vehicle speeds, including a personal, wearable light that is recommended for workers who are located away from large equipment and other light sources.
Wearable Safety Light: Guardian Angel (Archangel Device LLC, 2024)	Commercial Products	Describes the wearable and mountable personal safety lighting devices used or tested by five responding agencies (Alabama, Arkansas, Kansas, Nevada and Pennsylvania DOTs).
LH150, Ultralight Rechargeable Lighted Rope Vest (COAST Products, 2024)	Commercial Products	Describes a rechargeable lighted rope vest that illuminates for up to 13 hours providing visibility up to a quarter mile away. Caltrans is evaluating a similar prototype product.

Publication or Resource (Year)	Category	Excerpts from Abstract or Description of Resource
Specifications: Halo SL (ILLUMAGEAR, Inc., 2023)	Commercial Products	Describes a lightweight and cord-free headlamp used or tested by three responding agencies (Alabama, Pennsylvania and Utah DOTs).
The Freakin' Beacon (KBS Innovations, undated)	Commercial Products	Describes a personal lighting system that attaches directly to a helmet or hard hat. Recently adopted for use by Pennsylvania DOT.
Stop Lite ANSI Class 3 LED Hi Vis Vest (PalmFlex, 2024)	Commercial Products	Describes a lighted safety vest that includes 16 white LEDs and offers a three-year battery life. Tested by Nevada DOT but not adopted for further use.
LED Hi-Vis Safety Vest (Uline, undated)	Commercial Products	Presents a high-visibility safety vest with 16 LED lights embedded in 2-inch reflective tape and powered by two AA batteries. Tested by Nevada DOT but not adopted for further use.
Tomorrows Safety Vest for Today's Worker (VisionVest, LLC, 2024)	Commercial Products	Describes the addition of LED/laser lighting to a safety vest that is powered by a removable and rechargeable power source.
360 Degree LED Safety Vest (Washington Enterprise, undated)	Commercial Products	Describes a wearable lighting system equipped with 360-degree illumination and also meets ANSI Class 3 reflective material standards; available as a yellow vest with orange stripes or an orange vest with yellow stripes. Alabama DOT will soon test this vest and survey its crew members to assess the vest's effectiveness and crew members' satisfaction.

Detailed Findings

Background

The California Department of Transportation (Caltrans) uses high-visibility clothing to enhance the safety of its workers in work zones. To improve the visibility and safety of these workers, especially in challenging weather and environmental conditions, Caltrans is exploring the integration of artificial lighting over workers' garments. While enhancing worker visibility is crucial for safety, it is equally important to ensure that any lighting added to workers' clothing does not distract drivers.

Caltrans is particularly interested in identifying commercially available lighting systems and garment technologies in use or being tested to improve workers' visibility without compromising drivers' attention. One option Caltrans is considering is an LED-lighted harness worn to make workers and others visible to traffic during nighttime hours (Figure 1).

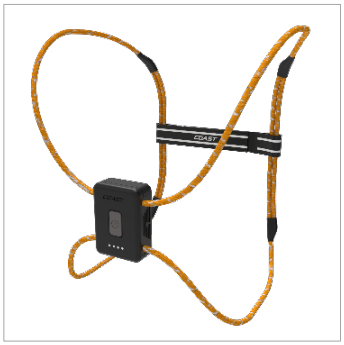

Figure 1. COAST Products LH250 Rechargeable LED Lighted Harness Prototype
(*Source*: Caltrans.)

This Preliminary Investigation gathered feedback from other state transportation agencies using garment-based safety lighting. Consultations with selected survey respondents provided details of their experiences with garment lighting systems. Survey findings are supplemented by the results of a literature search that examined domestic research, state practices and commercial garment lighting products.

Survey of Practice

An online survey distributed to state department of transportation (DOT) members of the No Boundaries Transportation Maintenance Innovations pooled fund study sought information about agency experience with lighting used on high-visibility safety garments. To provide a national pool of potential respondents, state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance for those states not participating in No Boundaries also received the survey.

Survey questions, which are provided in Appendix A, inquired about agency experience with garment lighting systems worn over or applied to safety garments. The survey received responses from 16 state transportation agencies:

- Alabama
- Arizona
- Arkansas
- Colorado
- Idaho
- Illinois
- Kansas
- Michigan
- Nebraska
- Nevada
- Ohio
- Pennsylvania
- Rhode Island
- South Dakota
- Texas
- Utah

Survey findings are presented below in two categories:

- *Agencies using garment lighting systems.* The experiences of the six agencies currently using or testing garment lighting are presented immediately below. Alabama and Nevada DOTs are the only agencies using or testing a vest-based lighting system.
- *Agencies not using garment lighting systems*. Ten responding agencies reported no experience with garment lighting. Respondents from two of these agencies described alternate means to call attention to workers in work zones or identified concerns regarding garment lighting used in work zones. This feedback is highlighted on page 16.

Agencies Using Garment Lighting Systems

Six state DOT representatives described using or testing the garment lighting systems identified in Table 1. Two of these agencies have tested, or plan to test, lighted safety vests that are conceptually similar to the lighted harness Caltrans is considering (*Alabama* and *Nevada*). The most frequently used garment lighting systems are the Guardian Angel and Halo personal lighting products that are most often attached to a hard hat. Nevada DOT maintenance crews also attach Guardian Angel lights to the front and back of safety vests, pockets and shoes.

Table 1. Respondents' Experience with Garment Lighting Systems

State	Garment Lighting Product Used	Garment Lighting Product Tested
Alabama	Guardian Angel	• 360 Degree LED Safety Vest[1] • Halo
Arkansas	Guardian Angel	None
Kansas	None	Guardian Angel
Nevada	Guardian Angel	• LED Hi-Vis Safety Vest • Stop Lite ANSI Class 3 LED Hi Vis Vest
Pennsylvania	• Freakin' Beacon • Guardian Angel • Halo	None
Utah	None	Halo

1 Alabama DOT has ordered and is awaiting delivery of 300 units of this lighted safety vest.

The garment lighting systems identified in Table 1 are described below in four categories:

- Lighted safety vests
- Guardian Angel wearable/mountable safety lights
- Halo personal lighting system
- Other personal lighting systems

Details of agency use are presented below along with selected product details and agency assessments, when available. Further details of each lighting product are provided in the **Related Research and Resources** section of this report beginning on page 17.

Lighted Safety Vests

Three agencies reported experience with lighted safety vests, described in more detail below, that are similar in concept to the lighted harness Caltrans is evaluating:

- *360 Degree LED Safety Vest.* Alabama DOT is preparing to distribute 300 units of this lighted safety vest.
- *LED Hi-Vis Safety Vest*. Nevada DOT tested this vest but has not adopted it for statewide use.
- *Stop Lite ANSI Class 3 LED Hi Vis Vest*. Nevada DOT tested this vest but has not adopted it for statewide use.

360 Degree LED Safety Vest (Washington Enterprise): Alabama Department of Transportation

Alabama DOT will soon begin testing the 360 Degree LED Safety Vest (Figure 2).This lighted vest, which meets ANSI Class 3 reflective material standards, was developed by Washington Enterprise in response to discussions with Alabama DOT safety staff seeking a wearable lighting system that makes a worker visible from any angle. The product is available as a yellow vest with orange stripes or an orange vest with yellow stripes.

Figure 2. 360 Degree LED Safety Vest
(*Source*: Washington Enterprise.)

The agency will distribute 300 vests across the state to interested maintenance crew members. As with any equipment with flashing or strobe lights, the agency will provide a caution that workers with certain conditions may be adversely affected by flashing lights. Alabama DOT plans to survey crew members wearing the lighted vests after two to three weeks of use during nighttime operations.

Attribute	Description
Light Colors:	White
Flashing Pattern:	Solid light, slow flash, rapid flash
Light Intensity:	15 foot candles of light
Wireless?	Yes
Light Power Source:	Lightweight rechargeable battery
Recharging Method:	USB. Provides up to nine hours on a full charge; replacement batteries available.
Quick Release/Breakaway?	Yes. Provides four Velcro breakaway connections.

LED Hi-Vis Safety Vest (Uline) Lighted Safety Vest: Nevada Department of Transportation

Nevada DOT tested this lighted safety vest but has not adopted it for statewide use. See *Assessment* below for further details.

Attribute	Description
Light Colors:	Not specified
Flashing Pattern:	Steady, slow flashing, fast flashing
Light Intensity:	Sixteen LEDs; intensity unknown.
Wireless?	No
Light Power Source:	Two AA batteries
Recharging Method:	Not applicable
Quick Release/Breakaway?	Not known

Stop Lite ANSI Class 3 LED Hi Vis Vest (Palm Flex): Nevada Department of Transportation

Nevada DOT tested this lighted safety vest but has not adopted it for statewide use. See *Assessment* below for further details.

Attribute	Description
Light Colors:	White
Flashing Pattern:	Steady
Light Intensity:	Sixteen LEDs; intensity not specified
Wireless?	Yes
Light Power Source:	Rechargeable lithium-ion battery
Recharging Method:	Employees plug in units after each shift.
Quick Release/Breakaway?	Not known

Assessment

Although there have been no formal assessments, crew members reported concerns regarding glare and the weight of each vest. The respondent noted that these vests were "not comfortable," highlighting the vests' tendency to shift on workers' arms and shoulders.

Guardian Angel Wearable/Mountable Safety Lights

Guardian Angel wearable and mountable safety lights offer four levels of front work lights that emit up to 800 lumens (Figure 3).

Details of the Guardian Angel garment lighting products used by Nevada and Pennsylvania DOTs are provided below. Kansas DOT's ongoing informal trial of Guardian Angel lights is also addressed.

Figure 3. Guardian Angel Construction Safety Light
(*Source*: Archangel Device LLC.)

Guardian Angel Personal Lighting System: Nevada Department of Transportation

Nevada DOT is beginning its second year of use for 200 units of the Guardian Angel wearable security light/safety beacon described below.

Attribute	Description
Light Colors:	Yellow, red, green
Flashing Pattern:	Steady on, flashing, SOS
Light Intensity:	Dim to high intensity
Wireless?	Yes
Light Power Source:	Rechargeable battery
Recharging Method:	Plug-in chargers and USB
Quick Release/Breakaway?	Not applicable

Assessment

Crew members use Guardian Angel lights in all weather conditions and attach them to the front and back of Class 3 vests, helmets, pockets and shoes. The lights may also be used to call attention to broken-down equipment. While Nevada DOT has not conducted formal or informal assessments of the lighting systems, the survey respondent reports that the clip-on systems are extremely effective, cost-efficient and easy to use.

Some staff members have reported issues with glare and vehicle reflections from the lights. The agency previously identified distracting reflections in snow-covered areas when using strobe lights to call attention to road closures in high elevations. Some drivers commented that glare from these lights may have been a contributing factor in accidents and near-misses.

Guardian Angel Personal Lighting System: Pennsylvania Department of Transportation

Pennsylvania DOT has used the Guardian Angel lighting system described below for approximately three years. These lights offer multiple attachments for hard hats, with two new attachment options that the agency piloted and now uses.

Attribute	Description
Light Colors:	*Crews*: White in front; amber in rear. *Flaggers*: Amber front and back.

Flashing Pattern:	Steady or flashing
Light Intensity:	800 lumens
Wireless?	Yes
Light Power Source:	Rechargeable lithium-ion battery
Recharging Method:	Employees plug in units after each shift.
Quick Release/Breakaway?	Not applicable

Assessment

District surveys indicate the Guardian Angel system is very effective, with the respondent commenting that the light "brings your attention to them as you approach and enter the work area." While crew members prefer the helmet strap instead of the magnetic clip to attach the lights to their hard hats, they do not favor the Velcro arm strap as the strap is not large enough to fit over a winter coat. As with the Halo lighting system, maintenance workers in the state's 67 counties may use a combination of lighting systems depending on individual crew members' preferences.

Guardian Angel Personal Lighting System: Kansas Department of Transportation

While Kansas DOT performs little nighttime work other than for emergency response traffic control when garment lighting systems might be helpful, the agency is conducting an informal trial of the Guardian Angel lighting system in two locations where these lights have not been used. To date, there has been little feedback from the crews using these personal safety lights. If the trial is successful, Guardian Angel lights may be included in nighttime traffic control kits used agencywide.

Note: While Iowa DOT was unable to respond to the survey, the literature search for this Preliminary Investigation identified a blog post that describes an agency pilot of 10 Guardian Angel lights in Iowa DOT's District 5 in southeast Iowa (see the citation for this blog post on page 19). After positive reviews, the district purchased 190 units for distribution to all crew members in the region. In addition to being easy to operate, the lights provide another safety tool to alert drivers to employees in work zones.

Halo Personal Lighting System

The Halo SL personal lighting system offers a 50-foot spotlight and is compatible with standard hard hats (Figure 4).

Described below are the experiences of three agencies: Pennsylvania DOT currently uses Halo lights; Alabama and Utah DOTs tested Halo products.

Figure 4. Halo SL Personal Lighting System
(*Source*: ILLUMAGEAR, Inc.)

Halo Personal Lighting System: Pennsylvania Department of Transportation

Pennsylvania DOT has used Halo lights for six years.

Attribute	Description
Light Colors:	White
Flashing Pattern:	Steady or flashing
Light Intensity:	406 lumens (front); 262 lumens (around the light).
Wireless?	Yes
Light Power Source:	Rechargeable lithium-ion battery
Recharging Method:	Employees plug in units after each shift.
Quick Release/Breakaway?	Not applicable

Assessment

The Halo lights work well and newer models are lighter weight and cause less stress on a worker's neck. As the respondent also noted in connection with the Guardian Angel product, the light emitted is very effective and "brings your attention to them as you approach and enter the work area." However, the Halo light can draw insects at night. Some maintenance crews in the state's 67 counties prefer one lighting system over another, while others use a combination of lighting systems depending on individual crew members' preferences.

Other Agency Tests

Two state DOTs tested Halo lighting systems:

- *Alabama*. The agency tested Halo lights on hard hats, but maintenance crews found the weight uncomfortable.
- *Utah*. Two construction crews in Region 2 tested 20 Halo light units that included a wired battery pack. User feedback highlighted several concerns:
    - The battery pack was "a bit cumbersome."
    - The wire running from the battery pack to the light "would snag on things."
    - The light added weight to the hard hat.

  The survey respondent also noted that the Halo light was not very effective as a headlamp to see plans or other documents in darker areas outside of the work zone, but did help with increasing worker visibility for others outside the work zone.

  Agency specifications call for "full lighting of every construction project by means of light plants and existing overhead lighting." Halo lights were not implemented across the agency; instead, Utah DOT workers are required to wear a Class 3 vest and hard hat.

Other Personal Lighting Systems

Pennsylvania DOT recently added a third lighting system to its garment lighting toolbox—KBS Innovations' Freakin' Beacon. Described by the vendor as a "palm-sized, lightweight, personal safety beacon" that can be attached with a metal or plastic spring clip, plastic clasp or magnet mount, the light offers steady, random flashing and steady flashing modes. Powered by two AAA alkaline batteries, the light attaches to a band placed around a hard hat. See page 21 for more information about this personal lighting system.

Agencies Not Using Garment Lighting Systems

Two of the 10 agencies not using garment lighting to call attention to maintenance crews in work zones described alternative practices or highlighted concerns with this type of lighting:

- *Arizona*. Instead of garment lighting, Arizona DOT uses work area lights that are placed to avoid shining directly at motorists. These lights work well by clearly highlighting workers and equipment in the work area and creating visibility for approaching motorists.
- *Illinois*. The respondent described general agency concerns that wearable lighting systems could cause glare or other distractions. Illinois DOT is initiating a research project to explore the effectiveness of lighting technologies used on high-visibility safety garments.

Related Research and Resources

A literature search of publicly available domestic in-progress and published research identified a small sampling of publications that are organized into the following categories:

- Related Research
- State Research and Practices
- Commercial Products

Related Research

"Impacts of Emergency Vehicle Marking Characteristics and Wearable Lights on Driver Responses," John D. Bullough and Scott A. Parr, *Transportation Research Record*, March 2024.
Citation at https://doi.org/10.1177/0361198124123357
From the abstract: Retroreflective markings provide important visual information to drivers about emergency vehicles and the incidents at which they are working. A stationary outdoor field study to investigate the impacts of emergency vehicle marking color, retroreflectivity level and spatial patterns on drivers' ability to see nearby emergency responders was carried out. The study also examined the impacts of a wearable flashing LED light. Based on the results, agencies should use materials with higher levels of retroreflectivity carefully, especially when they will be covering large areas vehicle surfaces. Limiting the maximum retroreflectivity level to no greater than ASTM Type III may help lessen negative impacts of bright reflective materials on drivers' ability to see emergency responders. As long as the average reflectivity of different color combinations is similar to that of red and yellow reflective markings, chevron patterns with those color combinations will not reduce emergency responder visibility. Outline patterns of reflective markings on vehicles performed similarly at night to patterns covering most of the vehicle surface. The effectiveness of using high-retroreflectivity materials in an outline pattern in combination with lower- (or non-) retroreflectivity materials elsewhere on the surface should be studied. Wearable flashing LED lights can make emergency responders easier to see at night, provided they do not increase glare to approaching drivers.

Related Resource:

> **Impacts of Emergency Vehicle Marking Color, Patterns and Retroreflectivity on Safety-Related Driver Responses**, Study Report, Emergency Responder Safety Institute, June 2023.
> https://www.respondersafety.com/Download.aspx?id=9db8833f-7233-4893-af25-4ececd5ee2b2
> This report's summary notes, "The use of wearable flashing LED lights may make emergency responders easier to see at night, without increasing glare to approaching drivers. The ideal properties of these lights should be investigated further."
>
> Beginning on page 11 of the report, the authors describe a stationary field experiment in which a simulated firefighter's gear is "fitted with a small wearable

flashing light containing yellow LEDs and when activated, produced a slow flashing pattern. The wearable light (Figure 6) had multiple intensity level settings; the lowest intensity setting was used in the experiment. From a distance the yellow light appeared to increase in intensity gradually over a duration of just under a second and then switched off immediately, remaining dark for a fraction of a second before repeating the cycle."

Protecting Roadside Workers: Field Evaluation of Flares, Cones and Tow Truck Light Patterns, Richard D. Blomberg, Timothy J. Wright, Kraig Finstad, Emily Brunsen, Ron Van Houten, Nastaran Radmehr, Juan Yepez and Terry Johnson, AAA Foundation for Traffic Safety, January 2023.
https://aaafoundation.org/wp-content/uploads/2022/12/Protecting-Roadside-Workers_Field-Evaluation-of-Cones-Flares-Lighting-Report.pdf
Researchers identified a series of countermeasures "to improve the safety of towing, recovery and other incident response personnel," including the following worker-based countermeasure (see page 89 of the report, page 98 of the PDF):

W-05 Wearable Safety Light
The following are excerpts from the countermeasure idea:

Description:	Wearable safety lights consist of shoulder mounted lights, as can be seen here. [The idea form includes this link to Guardian Angel personal safety lights: https://www.guardianangeldevices.com/.] Lights attach magnetically to a point on the top of a worker's shoulder and project light to the front and back. Steady burn or flashing lights can be deployed.
Level of Evidence:	Wearable safety lights appear to increase the visibility of construction zone workers. [The idea form references *Effects of Wearable Light Systems on Safety of Highway Construction Workers,* which is cited below.] Also, crash incidence rate was 19% lower for bicyclists with permanent lighting equipment compared to bicyclists without it.
Cost to Deploy/Install:	Known cost: $100.
Cost to Maintain:	Recharging and possible periodic repair or replacement for wear-and-tear.
Review:	**Pros:** Available in a variety of colors and flashing patterns. The front light can illuminate work area while the rear light alerts drivers. Battery life relatively good. Already in use in highway, marine and recreational environments. **Cons:** Might interfere with job performance (e.g., get in the way as worker completes service).

"Effects of Wearable Light Systems on Safety of Highway Construction Workers," Chukwuma Nnaji, Ali Jafarnejad and John Gambatese, *Practice Periodical on Structural Design and Construction*, Vol. 25, Issue 2, May 2020.
Citation at https://doi.org/10.1061/(ASCE)SC.1943-5576.0000469
From the abstract: Despite the work zone lighting standards and regulations developed and adopted by [s]tate departments of transportation and the Federal Highway Administration (FHWA), the number of accidents and injuries in work zones has increased in recent years. Studies in other industries indicate that wearable devices, such as wearable lighting systems (WLSs), could help improve worker safety. However, an understanding of the effectiveness of these devices and the manner by which to efficiently implement them in work zone operations is currently lacking in the construction industry. The present study proposes to fill this gap in knowledge and practice by evaluating the effectiveness of WLSs in different work zone applications. Results indicate the absence of standards or regulations for the use of WLSs. Findings from qualitative assessments of results from multiple tests and live projects show that WLSs could increase the visibility of dump operators, spotters and density technicians. The study recommends optimum locations for WLSs accordingly.

State Research and Practices

Iowa

"When a Little Light Serves as Your Guardian Angel," Blog Post, *Transportation Matters*, Iowa Department of Transportation, December 10, 2021.
https://www.transportationmatters.iowadot.gov/2021/12/when-a-little-light-serves-as-your-guardian-angel.html
From the blog post: Matt Heuvelmann, who was recently promoted to highway maintenance supervisor in Southeast Iowa, previously worked as a garage operations assistant with a focus on safety training. While in this role, he found and tested a personal lighting device to help our workers be more visible when they are out on the road.

These wearable devices are lightweight and can be clipped to the shoulder of a safety vest or attached using magnets to the front of a vest. They are commonly used by first responders and the reviews of the brand of devices we chose were very positive.
….
The pilot project with the initial 10 lights proved to be successful, so the district purchased 190 devices allowing each crew member working on the road to have one. Cory Steele, the garage operations assistant in Washington, says his crews are using the devices regularly. He said, "We were out on a closure the other day at dusk. We needed to finish up and it was dark by the time we were done. They're really easy to operate. You just switch them on when you're in the work area and switch them off when you're done. We take them out with us every day and then plug them in to recharge between shifts. Using these lights is another tool we can use to catch a driver's attention and help them see that we're working."

Oregon

Use of Additional Lighting for Traffic Control and Speed Reduction in Work Zones, John A. Gambatese and Ali Jafarnejad, Oregon Department of Transportation, February 2018.
https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR791_AdditionalWorkzoneLighting.pdf
From the abstract: Performing roadway construction work at night exposes workers to hazards that are not present or as great during the daytime. Working at night requires illuminating the area where work is taking place in order to provide sufficient lighting for the workers to see their work and to illuminate the workers. Work area lighting may also have a positive impact on the speed of passing vehicles. Based on previous studies (e.g., SPR 751 and 769) vehicle speed reduction in the work zone during nighttime operations is assumed to be due in part to the lighting provided to conduct the work. The present study evaluated the impact of temporary work zone lighting on vehicle speeds. The study includes case studies on multi-lane preservation projects in Oregon in which different types of lighting systems were implemented: a light tower, balloon light and a personal, wearable light. The research findings indicate that additional temporary roadway lighting helps to make workers more visible to motorists and equipment operators and leads to slightly higher vehicle speeds. Implementation of additional temporary roadway lighting is recommended where the work operations contain concerns regarding visibility. Personal, wearable lights are also recommended for workers who are located away from large equipment and other light sources.

Commercial Products

Highlighted below are the vendors providing the garment lighting products used, tested or considered by Caltrans and survey respondents:

- Archangel Device LLC (Guardian Angel)
- COAST Products (Ultralight Rechargeable Lighted Rope Vest)
- ILLUMAGEAR, Inc.(Halo SL)
- KBS Innovations (The Freakin' Beacon)
- PalmFlex (Stop Lite ANSI Class 3 LED Hi Vis Vest)
- Uline (LED Hi-Vis Safety Vest)
- Washington Enterprise (360 Degree LED Safety Vest)

Also included is the vendor website describing the VisionVest vest, which uses LED/laser lighting "to significantly increase the visibility of the worker proactively and without reliance on reflectivity."

Wearable Safety Light: Guardian Angel, Archangel Device LLC, 2024.
https://www.guardianangeldevices.com/m/
From the website: We created these 2-in-1 wearable and mountable personal safety devices to be shockproof and waterproof to withstand anything you can put them through. We made sure they provided 5+ miles of visibility so every one of you can be seen when you need to be.

LH150, Ultralight Rechargeable Lighted Rope Vest, COAST Products, 2024.
https://coastportland.com/collections/all-products/products/lh150
From the website: Announce your presence—with light. Featuring rechargeable, wireless, wearable lighting technology, the LH150 High-Vis Lighted Rope Vest wraps the upper body in an assortment of bright illuminating light for up to 13 hours from a full charge. Wear the one-size-fits-most harness for high-intensity work in dim environments, for emergencies, or for staying safe on runs and rides in the dark. 6+ light modes provide options for making yourself visible up to a quarter mile away. The LH150 features a quick-release buckle to make it easy to go on and off, and a reflective stretch strap at the sternum combines with adjustable sizing brackets to ensure a great fit. The harness is built with high-vis woven fabric encasing proprietary light tube technology, which is powered by an integrated rechargeable ZITHION lithium battery and controlled by the lighted power button. Monitor the battery life indicator as you work or play to know when to power back up via USB-C.

Specifications: Halo SL, ILLUMAGEAR, Inc., 2023.
https://illumagear.com/wp-content/uploads/2020/05/Specifications-Sheet.pdf
This document provides the specifications for the Halo SL headlamp and identifies these features:

- Lightweight and cord-free
- 360° visibility for a quarter-mile
- 50-foot spotlight
- Powerful flood task lighting
- Compatible with any standard hard hat
- Battery life indicator
- Charger included
- Matte black
- Water resistant

The Freakin' Beacon, KBS Innovations, undated.
https://www.kbsinnovations.com/product/freakin-beacon-non-msha-apporved/
From the website: It can signal the location of a worker in a low light situation when attached to the back of their hard hat or harness and can be used to identify teams by assigning them each a different color.

The Freakin' Beacon comes in multiple colors and it runs up to 25 work days! The green color runs 36 hours on steady and 144 hrs. on flash. The blue color runs 48 hours on steady and 192 hours on flash. The red, white and amber colors run 65 hours on steady and 200 hours on flash. Powered by just 2 AAA alkaline batteries, the Freakin' Beacon is a Class I, Division 1 light with an IP67 rating. That means it is dust proof, waterproof and will be able to survive underwater at one meter's depth for 30 minutes.

The large push-button switch is designed for easy operation with a gloved hand. The Freakin' Beacon attaches directly to helmet or hard hat. You can choose from several back attachments, including a metal clasp, plastic or spring clip or a magnet mount. A 3M dual lock is included standard with all attachments.

Stop Lite ANSI Class 3 LED Hi Vis Vest, PalmFlex, 2024.
https://www.palmflex.com/vests/stop-lite-ansi-class-3-led-hi-vis-vest.html#product-details-tab-description
The spec sheet, available at https://www.palmflex.com/product_flyers/WSL-LED-Vest.pdf, identifies key features of this lighted safety vest:

- 16 white LEDs
- 360-degree visibility
- Rechargeable lithium-ion battery
- 3M reflective tape on front and back
- Three-year battery life

LED Hi-Vis Safety Vest, Uline, undated.
https://www.uline.com/BL_1143/LED-Hi-Vis-Safety-Vest
This online catalog page describes a high-visibility safety vest with 16 LED lights embedded in 2-inch reflective tape. Powered by 2 AA batteries, the vest's lighting lasts up to 150 hours and is visible from 2,000 feet away.

"Tomorrows Safety Vest for Today's Worker," VisionVest, LLC, 2024.
https://visionvest.com/
From the website: Standard safety vests rely on reflective properties of the material and the reflecting of an outside light source (commonly headlights on vehicles) to [aid] in protecting the worker. VisionVest vests, however, uses [the] addition of LED/laser lighting to significantly increase the visibility of the worker proactively and without reliance on reflectivity. This is important in poor weather and low light conditions where the distance that an outside light source extends is decreased.

Additionally, the lights provide two different color of lights allowing to have new workers easily identified in the field. This is a powerful visual tool that can be used in new worker service programs that focus on tackling the problem that newer workers to a job site have a statistically increased chance of obtaining an injury.

A removable and rechargeable power source allows for various technology components that will promote increased mobility and productivity of the worker. Many projects have limited sources of power sometimes requiring workers to return to their cars or trailers to recharge their smart devices and tablets. The mobile power source provided in VisionVest vests allows a worker to continue throughout their day without interruption.

360 Degree LED Safety Vest, Washington Enterprise, undated.
(The document has been provided to Caltrans separately.)
This manufacturer's fact sheet describes a wearable lighting system that is equipped with 360-degree illumination and also meets ANSI Class 3 reflective material standards. The safety vest is available as a yellow vest with orange stripes or an orange vest with yellow stripes. Alabama DOT will soon test this vest and survey its crew members to assess the vest's effectiveness and crew members' satisfaction.

Contacts

CTC contacted the people below to gather information for this investigation.

State Agencies

Alabama

Tracy Marie Fletcher
Assistant State Maintenance Administrator
Alabama Department of Transportation
334-544-9016, fletchert@dot.state.al.us

Arizona

Raul Amavisca
Engineering Administrator
Arizona Department of Transportation
602-206-2543, Ramavisca@azdot.gov

Arkansas

Deric Wyatt
State Maintenance Engineer
Arkansas Department of Transportation
870-822-0217, deric.wyatt@ardot.gov

Colorado

Jim Fox
Deputy Director of Maintenance
Colorado Department of Transportation
720-241-6309, james.fox@state.co.us

Idaho

Steve Spoor
Maintenance Services Manager and Equipment Fleet Manager
Idaho Transportation Department
208-334-8413,
steve.spoor@itd.idaho.gov

Illinois

Steve Kunkler
Bureau of Operations Equipment Manager
Illinois Department of Transportation
217-557-9685, steven.kunkler@illinois.gov

Kansas

Troy Whitworth
Director of Employee Safety
Kansas Department of Transportation
785-296-1009, troy.whitworth@ks.gov

Michigan

Matt C. Pratt
Maintenance Coordinator
Michigan Department of Transportation
517-643-5372, prattm@michigan.gov

Nebraska

Tom Renninger
Operations Division Manager
Nebraska Department of Transportation
402-479-4339,
tom.renninger@nebraska.gov

Nevada

John E. Coder
Safety Coordinator, Operations
Nevada Department of Transportation
775-720-8147, john.coder@dot.nv.gov

Ohio

Bert Tooms
Highway Management Administrator
Ohio Department of Transportation
740-516-5445, bert.tooms@dot.ohio.gov

Pennsylvania

Dennis J. McArdle
Safety Specialist Manager, Employee Safety and Training Division
Pennsylvania Department of Transportation
610-871-4404, dmcardle@pa.gov

Rhode Island

Victor Lepore
Health and Safety Officer
Rhode Island Department of Transportation
401-734-4877, victor.lepore@dot.ri.gov

South Carolina

Christina Bennett
Construction and Maintenance Engineer
South Dakota Department of Transportation
605-280-9665,
christina.bennett@state.sd.us

Texas

Kent Clements
Regional Crew Section Director
Texas Department of Transportation
737-285-6195, kent.clements@txdot.gov

Utah

Ryan Ferrin
Statewide Maintenance Engineer
Utah Department of Transportation
801-910-2562, Rferrin@utah.gov

Appendix A: Survey Questions

The survey below was distributed to state transportation agency members of the No Boundaries Transportation Maintenance Innovations pooled fund study, supplemented by state DOT members of the AASHTO Committee on Maintenance for those states not participating in No Boundaries.

Caltrans Survey on Integrating Safety Lighting on Workers' High-Visibility Safety Garments

The California Department of Transportation (Caltrans) is gathering information about state transportation agency experiences with lighting used on high-visibility safety garments worn by workers in work zones. This garment-based lighting is intended to improve the visibility and safety of workers, especially during nighttime hours and in challenging weather and environmental conditions. Caltrans is particularly interested in identifying commercially available lighting systems and garment technologies in use or being tested to improve workers' visibility without compromising drivers' attention.

The survey below inquires about your agency's experience with garment lighting systems. We estimate the survey will take 20 minutes to complete (if describing two garment lighting systems). We would appreciate receiving your responses by **Friday, June 21**.

If someone else in your agency would be more appropriate to address questions related to this issue, please forward this survey to that person.

The final report for this project, which will include a summary of the responses received from all survey participants, will be available on the Caltrans website.

If you have questions about completing the survey, please contact Chris Kline at chris.kline@ctcandassociates.com. If you have questions about Caltrans' interest in this issue, please contact Tori Kanzler at tori.kanzler@dot.ca.gov.

Thanks very much for your participation.

(Required) Please provide your contact information.

Name:
Agency:
Title/Division:
Email Address:
Phone Number:

Note: Responses to the question below determined how respondents were directed through the survey.

(Required) Caltrans is piloting an LED lighted breakaway harness worn as a vest over Class 3 safety garments to improve the visibility of its workers in work zones. Does your agency have experience with this type of garment lighting system or others that are worn over or applied to maintenance workers' safety garments?

- Yes (Skipped the respondent to **Garment Lighting System 1** and the remaining questions.)
- No (Skipped the respondent to **Wrap-Up**.)

Garment Lighting System 1

1. Please describe the garment lighting system your agency has tested or used, including how the lighting system is worn over or applied to safety garments.
2. If applicable, please provide the vendor and product names of the garment lighting system.
3. How long has your agency used this garment lighting system?
4. How many units of this garment lighting system are in use?
5. Please describe the lighting colors, lighting patterns and lighting intensity the garment lighting system employs.

   Lighting colors:
   Lighting patterns:
   Lighting intensity:
6. Please describe the power source.
7. Is the power source rechargeable?
   - No
   - Yes (Please describe how and when workers recharge the garment lighting system.)
8. Is the garment lighting system wireless?
   - No
   - Yes
9. Does the garment lighting system have a quick-release or breakaway feature?
   - No
   - Yes (Please describe how this feature works.)
10. Please provide images or links to documents associated with this garment lighting system. Send any files not available online to chris.kline@ctcandassociates.com.

Assessing Garment Lighting System 1

1. Has your agency conducted, or is your agency aware of, an assessment of the garment lighting system your agency uses?
   - Yes, we have conducted or are aware of formal research.
   - Yes, we have gathered or are aware of anecdotal evidence of workers' experiences.
   - We have not conducted, nor are we aware of, formal or informal assessments.
   - Other (Please describe.)

1A. If you responded "Yes" to the preceding question, please describe this formal research or anecdotal evidence.

2. Does your agency have any concerns regarding the possible distraction the garment lighting system may pose to drivers?
    - No
    - Yes (Please describe these concerns and how your agency has addressed them.)
3. Has your agency benefited from the experiences of emergency responders in your state or elsewhere who also use or have tested a garment lighting system like the one your agency uses?
    - No
    - Yes (Please describe the emergency responders' experiences.)
4. How effective is the garment lighting system?
    - Extremely effective
    - Very effective
    - Somewhat effective
    - Not so effective
    - Not at all effective
5. Please provide any comments below you wish to share about the effectiveness of this garment lighting system.
6. What are your top three recommendations for another agency planning to use a similar garment lighting system?

    Recommendation 1:

    Recommendation 2:

    Recommendation 3:

(Required) 7. Does your agency have experience with a second garment lighting system?

- Yes (Skipped the respondent to **Garment Lighting System 2**, **Assessing Garment Lighting System 2** and **Wrap-Up**.)
- No (Skipped the respondent to **Wrap-Up**.)

Note: The two preceding question blocks were repeated for respondents with a second garment lighting system to describe.

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.