Can Luminous Signs Improve Traffic Safety?

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Overview

Traffic safety is a life-or-death matter at the intersection of our activities with strangers and the outside world. Weather, construction and impaired drivers all merge with us on public roads. The consequences can be deadly: in the United States, over 30,000 fatalities occur in traffic annually, with over 1 million fatalities in the US in the past 24 years [FARS]. Traffic safety is one effective way to improve the chance that careful drivers can reach their destinations without mishap.

> ***In 2013, 3,154 people were killed in motor vehicle crashes involving distracted drivers. This represents a 6.7 percent decrease in the number of fatalities recorded in 2012. Unfortunately, approximately 424,000 people were injured, which is an increase from the 421,000 people who were injured in 2012.***
>
> distraction.gov

The tools of traffic safety include many approaches toward improving both vehicles and roadways. Some improvements in vehicles or roadways are considered 'crash protection', intended to reduce the scale and intensity of crashes when they occur. Other improvements are described as 'crash prevention', intended to avoid crashes altogether. In the majority of crashes, the primary cause is human error. Anything we can do to improve human responsiveness can save lives. While it is always preferable to avoid a crash entirely, all approaches can help. Given how much carnage is involved, every tool deserves consideration.

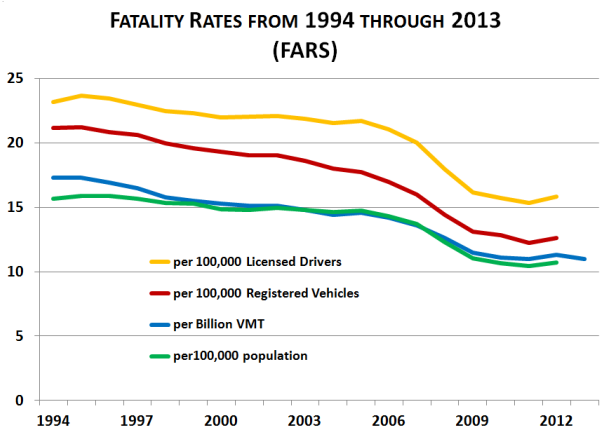
Because improving traffic signs and their readability is an effective approach to reducing traffic incidents [CRS, Gates, HIF, IITS, LRRB_11, LRRB, LRRB_b, VTRC], luminous signs might be a useful tool to improve safety on our roadways. This paper discusses some of the current issues with traffic signs and how luminous signs might bring improvements to traffic safety.

What are Luminous Signs?

Luminous traffic signs have lighting applied 'inside' to improve sign visibility performance at twilight, at night and during bad weather. Either the legend or the background are continuously luminous panels. These signs are MUTCD-compliant and can be powered and controlled like other LED systems.

Background

All the casualties from all of our wars are fewer than the number of fatalities on US roadways since 1945 [FARS, CRS]. To help address this ongoing problem, in 2013 the Federal Highway Administration started a national campaign to reduce traffic fatalities, "Towards Zero Deaths" [TZD].

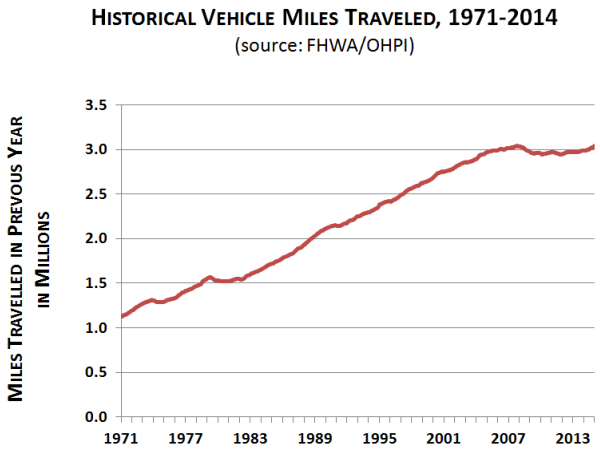


Can Luminous Signs Improve Traffic Safety?

Some of the current trends in traffic safety are encouraging for this campaign, while others may be challenges. Vehicles and roads are getting safer, in terms of fatality rates per population or distance traveled [FARS]. The number and percentage of older drivers has reached unprecedented levels [Fuels] even though 'motorization' is decreasing [Sivak]. The driving environment is getting more adaptive [VTRC, HIF, LRRB] and distracted driving continues to be a problem [dis]. The roads are more crowded [OHPI] and roadway construction is increasingly happening at night [NCHRP].

> ***"Fatalities among the 55+ community increased from 2012 to 2013."***
>
> "2013 Motor Vehicle Crashes: Overview", NTHSA

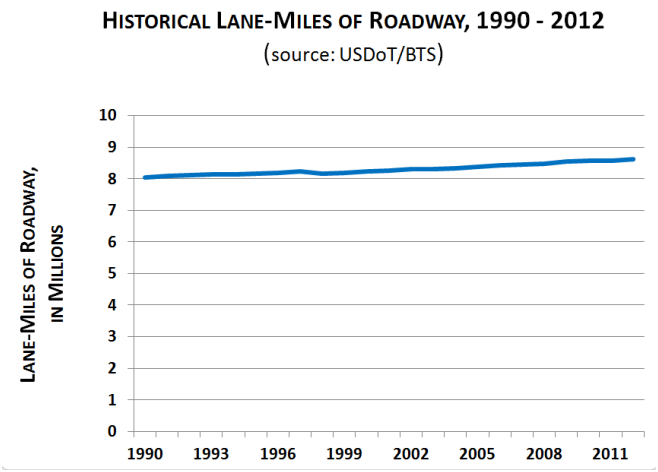
The vehicles and roads are providing much more information and stimulation to drivers, with many more demands on drivers' attention. There is great potential for improving safety using a system that responds to driver speed with appropriate displays on coordinated signs [HIF], especially on a dark mountain switchback in a winter snow storm. There may be equal potential for degrading safety due to digital billboards near multi-lane freeways or on-dash computer displays or numerous other distractions.



Vehicle miles travelled (VMT) has increased historically, although annual VMT has been relatively unchanged since 2008 [OHPI]. At the end of 2014, annual VMT had matched the previous maximum from 2007, and probably will surpass it in 2015.

> ***'Since 1990, total [lane-]miles have increased only 2.1%, while travel has increased 28.9%."***
>
> 'The Highway System', FHWA/OHPI

Construction on roads in the US continues at a consistent pace recently, although some years the lane-miles in the US have decreased [BTS]. Considering vehicle miles travelled (VMT), the historical data indicate that compared to 1990, 2015 has 126% more vehicle travel for each lane-mile.



> ***"More and more, agencies are doing roadway work on high-volume facilities at night to reduce adverse traffic impacts and complaints by the public that typically occur when the same work is being done during the day."***
>
> NCHRP Report 627,
> **Traffic Safety Evaluations of Nighttime and Daytime Work Zones**

In 2013, 51% of the deaths on the nationôs roadways occurred during dusk, dark or dawn [FARS]. Since traffic volumes are three to four times greater during the day-light periods than comparable twilight-and-

night-time periods [NHTSA_b], this corresponds to a crash death exposure index three to four times greater at night. This means that for the same distance travelled, the risk of being involved in a fatal crash is at night is 300% to 400% of the risk during the day. Obviously, improvements to night-time safety offer greater potential for reducing crashes, as well as contributing during twilight and bad weather. Traffic safety equipment should be performing at its best when conditions are at their worst.

Signs for Traffic Safety

Traffic signs that are visible during the periods of twilight, night and inclement weather extend the safety benefits of those signs into these higher-risk periods. Historically, retroreflective materials were used for traffic signs so headlights could produce adequate sign reflection luminance [CRS_b]. Excluding beacons and VMS, lighting has not been part of traffic signs themselves until recently, when it was applied to some traffic signs by locating LEDs around the sign border or in the legend. These LED-enhanced signs have been applied where jurisdictions want to make dramatic improvements to the traffic situation [Gates, LRRB_11, LRRB, LRRB_b, VTRC]. Now new technology enables installing lighting inside traffic signs, internally illuminating a sign's legend or background, so the sign becomes luminous on its own.

In Section 2A.07 of MUTCD:

"Regulatory, warning, and guide signs and object markers shall be retroreflective .. or illuminated to show the same shape and similar color by both day and night, .. requirements for sign illumination shall not be considered to be satisfied by street or highway lighting."

The images below illustrate MUTCD-compliant signs with either LEDs or internal lighting added, and demonstrate some of the differences between these types of signs.

LED-enhanced
>>>>>>>>

Luminous
<<<<<<<<

Among these options for traffic signs, each has strengths and weaknesses.

Retroreflective Signs

Retroreflective signs rely on an external light source and geometry to be effective. Retroreflective technologies have improved tremendously over past years and currently the federal government is promoting the installation and maintenance of retroreflective signs across the country [CRS_b].The maintenance of traffic signs with retroreflective finishes is part of the requirements in the MUTCD.

"The ability for a sign to properly retroreflect light in conditions of frost or dew is significantly diminished."

NCHRP Synthesis 431: Practices to Maintain Traffic Sign Retroreflectivity

Unfortunately, the retroreflective performance of surfaces is significantly compromised by materials that collect on the sign face [FHWA, NCHRP]. This certainly includes frost and dew, and probably magnesium chloride, used to melt snow and also known to make cars sticky and filthy. Retroreflectivity doesn't always work well under adverse weather conditions.

LED-enhanced signs

LED-enhanced signs have LEDs added to the face of the traffic sign in view of oncoming drivers. In accordance with Table 2A-1 of the MUTCD, the LEDs are placed on portions of the sign border, or across the symbol or word message. White LEDs are allowed for all applications, while yellow is also allowed for warning signs and school area signs. Yellow and orange are allowed for temporary warning signs, and red for STOP or YIELD signs.

Table 2A-1. Illumination of Sign Elements

Means of Illumination	Sign Element To Be Illuminated
Light behind the sign face	▪ Symbol or word message ▪ Background ▪ Symbol, word message, and background (through a translucent material)
Attached or independently mounted light source designed to direct essentially uniform illumination onto the sign face	▪ Entire sign face
Light emitting diodes (LEDs)	▪ Symbol or word message ▪ Portions of the sign border
Other devices, or treatments that highlight the sign shape, color, or message: Luminous tubing Fiber optics Incandescent light bulbs Luminescent panels	▪ Symbol or word message ▪ Entire sign face

While the LED-enhanced signs are being applied by jurisdictions in locations where extraordinary efforts are warranted [Gates, LRRB_11, LRRB, LRRB_b, VTRC], these signs are still comparatively rare and are not yet widely adopted. As of April 2015, the FHWA has web pages on Safety, Nighttime Visibility [FHWA_b] and Safety, Sign Visibility [FHWA_c]. These pages mention sign retroreflectivity and even roadway lighting, but there is no discussion about signs that generate their own luminance.

Luminous Signs

Luminous signs have internally illuminated elements for either the legend or background. This approach increases the contrast between the legend and background of the sign, improving conspicuity and readability. This provides the benefits associated with LED-enhanced signs without creating glare or visual confusion for motorists. Luminous signs also address some problems associated with retroreflective signs, particularly those due to inclement weather.

Compatibility of Lighted Signs

The internally illuminated luminous signs are MUTCD-compliant. Power supply issues from solar panels or the grid are the same for luminous and LED-enhanced signs. They have comparable weight and EPA and can be mounted on the same posts as conventional traffic signs, subject to the solar power system requirements. If the lighting fails, the luminous signs revert to 'standard' MUTCD retroreflective signs.

Features of Luminous Signs

Luminous signs are different than existing signs. Unlike retroreflective signs, luminous signs do not require an external light source to be effective. Unlike LED-enhanced signs, luminous signs enhance

and reinforce both the sign and its legend (message), promoting both visibility and legibility and still offering all the opportunities of LED systems.

Luminous signs and LED-enhanced signs have greater conspicuity and visibility compared to retroreflective signs. These signs are typically detected and identified as signs from greater distances than corresponding retroreflective signs [FHWA_b]. This is particularly important under inclement or compromised weather conditions, since sign detection in the dilemma zone is the critical first step in driver reaction and response.

Luminous signs provide greater contrast between legend and background, promoting content recognition and better communication to the driver. The contrast produced by retroreflective signs is only increased for luminous signs, since they combine internal lighting and retroreflection.

"Drivers middle-aged and older are more sensitive to glare than younger drivers because their eyes take longer to adjust to changing light levels. For example, a 55-year-old takes eight times longer to recover from glare than a 16-year-old."

"How to Avoid Headlight Glare", AAA Foundation for Traffic Safety

On the other hand, the experience of LED-enhanced signs includes glare that 'veils' the sign message. Veiling luminance produced by glare decreases contrast, so the legend is less legible. Since the effects of glare persist after the glare source is out of view, the consequences of glare are not always evident.

Glare is a problem for older drivers in particular because the decrease in visual performance is more severe and the recovery period is longer [AAA]. Glare is also a problem for people with conditions such as cataracts, diabetes, retinopathy and even many people who have had vision-correcting corneal surgery [AOA, ASCRS].

On luminous signs, the lighted area is increased significantly so glare disappears and the sign is not making itself hard to read. Furthermore, the sign shape and message are reinforced by the luminous panels. For example, eight points of red light may appear as a circle instead of as vertices of an octagon. Luminous STOP signs have eight bright lines joined together as a border.

"Improving the visibility of road signs and pavement markings through lettering, size or color can be particularly important for older drivers who may have visual impairments due to macular degeneration, glaucoma, cataracts or other health factors."

'Older Drivers', IIHS/HLDI

Luminous signs should perform as well or better in inclement or compromised conditions compared to 'fair weather' conditions. While retroreflection is significantly decreased by conditions such as surface moisture, frost, de-icing films or precipitation [FHWA, NCHRP_b], luminous signs may not have such notable changes in performance. Compared to LED-enhanced signs, the legend and sign form should be more recognizable and legible. These aspects become more important as conditions deteriorate. As with LED-enhanced signs, programming for the controller could respond to sensors and activate enhanced features. These could include increased luminance, vehicle detection and effects such as blinking signs or sequencing for chevrons. This could allow traffic signs to improve performance as conditions warrant.

Some of the evident opportunities for luminous signs include:

- STOP signs: when getting drivers' attention is critical, the LED-enhanced and luminous signs are considerable improvements over retroreflection.

- Regulatory signs: in particular, 'DO NOT ENTER' signs responding to a vehicle's approach.

- Warning signs: from curve ahead symbols to chevrons, luminous signs may help with guidance at night and in adverse or severe conditions, as well as providing greater visibility and legibility for significant messages e.g. at pedestrian crossings.

- Work Zone signs: luminous signs could be tuned to the situation e.g. from glowing to bright to flashing.

- Flaggers' paddles: combining STOP and SLOW signs into portable units that are highly conspicuous when waved, with controls that offer additional features like flashing in different ways, at different rates, for both signs or for just the STOP sign.

- Emergency Incident signs: carried as a kit in a responder's vehicle and ready to deploy on the vehicle when necessary, luminous signs can display any of the legends available to help improve motorists' comprehension of the situation ahead.

- Railroad crossing signs: increase the conspicuity of these signs as much as possible.

Certainly the costs for luminous signs will be greater than for retroreflective signs, and probably a bit more than for LED-enhanced signs. Costs associated with the power supply, sensors and controller will be the same as for LED-enhanced sign systems. It is likely that any cost/benefit analysis addressing LED-enhanced signs can be easily extended to consider luminous signs.

"Given the general positive results of the installations, the report recommends that flashing LED stop signs .. be considered as safety countermeasures at appropriate locations where the numbers of crashes or crash rates are higher than expected or where excessive speeding occurs.

A costs and benefits assessment indicated that, generally, the benefits in terms of reduced crashes exceeded the costs of the installed measures if only one crash was prevented."

Evaluation of Best Practices in Traffic Operations and Safety: Phase I: Flashing LED Stop Sign and Optical Speed Bars, VTRC

Conclusions

Traffic signs are an integral part of traffic safety, which is a real concern to us all. Current traffic sign options are significantly better than those that used to be available, but have different strengths.

Retroreflection improves sign performance, but can be compromised by problems with geometry or by films, dirt, dew or frost on the sign face. LED-enhanced signs improve conspicuity, but the LEDs may also be creating glare or confusing drivers due to the visibility of the LEDs as separate points of light.

Luminous signs inherently increase sign brightness and contrast, corresponding to greater conspicuity and readability. They also reinforce the sign shape and message without creating glare for drivers. The cost of luminous signs will undoubtedly be more, like LED-enhanced signs.

There appear to be opportunities for luminous traffic signs to improve traffic safety. Additional research to evaluate the performance of luminous signs is needed to document available benefits and to identify weaknesses.

Although luminous signs alone will not solve the most significant concerns in traffic safety, they may contribute in ways that are not available from the current options, and even in ways not yet considered.

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