

# 3M Research Synopsis

Title: **A Market-Weighted Description of Tungsten-Halogen and LED Low-Beam Headlighting Patterns in the US**

Reference: **University of Michigan Transportation Research Institute (UMTRI)**

Report Date: **June 2019 (In Press)**

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Conducted by: **The University of Michigan Transportation Research Institute**

Keywords: **Headlight illumination, headlight patterns, LED headlights**

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## Key Findings:

1. Compared to 2011 tungsten halogen (TH) low-beam headlights, the 2019 low-beam headlights provide lower levels of illumination to typical roadway signs.
2. 2019 median TH headlights are, on average, 20% lower in sign illumination than their 2011 counterparts. 2019 Light Emitting Diode (LED) headlights are about 14% lower than 2011 median headlights.
3. The reduction is more amplified for the 2019 lower quartile headlights. On average, 2019 headlights are 24% lower than their 2011 counterparts.
4. The reduction in headlight illumination translates to a reduction in sign brightness at night. Consequently, to provide drivers with the same level of service as in 2011, the level of sign retroreflectivity may need to be increased.

## Bottom Line:

Agencies should know the most modern low-beam headlight illumination is lower than those as recently as 2011 roadway signs. The reduction ranges from 14 to 24% lower levels of sign illumination and is computed by comparing 2019 low beam lights with their 2011 counterparts. Lower levels of illumination mean lower sign brightness. To mitigate this, agencies may consider upgrading sign sheeting to types that will serve the rapidly growing group of drivers of new cars.

# Illumination of typical roadway signs: A comparison of 2019 and 2011 headlight beam patterns

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## Background

Nighttime performance of retroreflective traffic signs is highly dependent on the illumination from vehicle headlights. In general terms, the luminance, or brightness, observed by the driver is the product of the retroreflectivity and the headlight illumination.

In the US, the National Highway Traffic Safety Administration (NHTSA) regulates the headlights for vehicles sold in the US through the Federal Motor Vehicle Safety Standard 108 (FMVSS 108). This regulation requires certain levels of illumination for key test points on a beam pattern to ensure adequate visibility performance while reducing headlight glare, while also allowing for some variability on the beam pattern. Over the years, there have been analysis of headlights to better understand the trends or potential implications of any changes and trends.

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One of the organizations that is renowned for conducting such headlight analysis is the University of Michigan Transportation Research Institute (UMTRI). Over the years, UMTRI has periodically sampled headlamps from brand-new production vehicles in a given year and reported the headlight beam illuminations in 25th, 50th, and 75th percentiles.

UMTRI has recently conducted another headlamp analysis for a wide number of 2019 model year vehicle headlights, sampling from a mix of TH and LED light sources. Their prior report was for 2011 model year vehicle headlights, all with tungsten-halogen light bulbs.

This paper discusses the differences between the 2011 and 2019 model year headlamps for the 25th and 50th percentile beam patterns for typical traffic sign locations. While any increase in the headlight illumination toward traffic signs might be welcome for safety improvements, reduction might need to be mitigated with increased retroreflectivity.

## Method

3M analyzed the illuminance and luminance of a typical roadway sign in 9 distinct scenarios:

- 3 vehicle types: passenger sedan, light truck/SUV, and heavy truck
- 3 sign locations: right shoulder, overhead, left shoulder

In each of these scenarios, 3M determined the sign illumination (lx) and resulting luminance observed by the driver for the 25th and 50th percentile beam patterns using a computer model (Tarvip) for three UMTRI headlight datasets:

- 2011 model year TH headlights
- 2019 model year TH headlights
- 2019 model year LED headlights

Both the illuminance and luminance were analyzed from a sign viewing distance from about 640 ft to 240 ft. This range is selected to represent a reasonable sign reading distance. 640 ft represents 40 ft/in legibility index for a 16" letter height and 240 ft represents 20 ft/in legibility index for a 12" sign.

## Changes in headlight illumination on signs

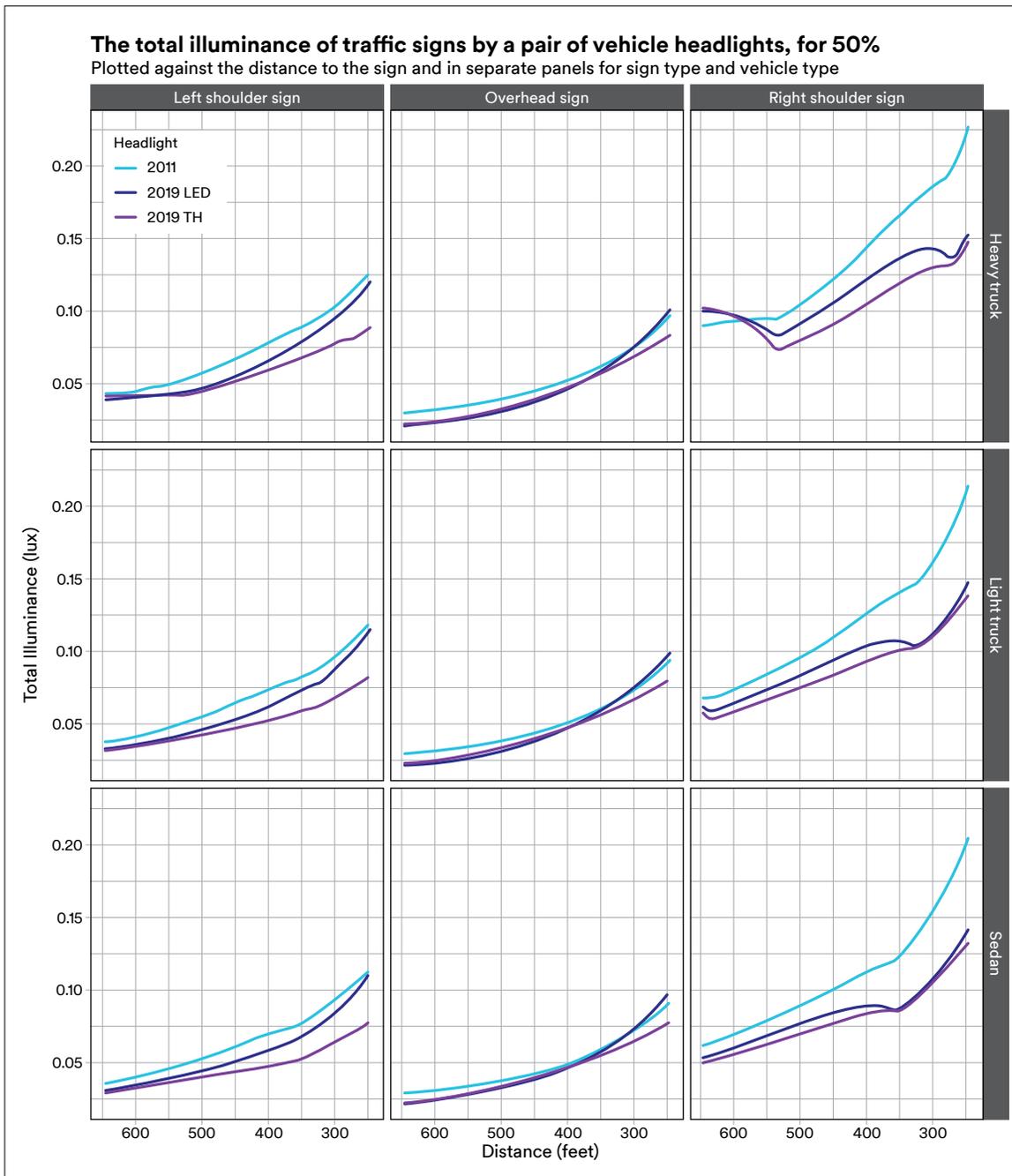
Figure 1 shows the sign illuminance for each of the nine scenarios for the median (50th percentile headlights).

Across the sign mounting locations for a given vehicle, as expected, the illumination on overhead signs is the lowest in general. Left shoulder mounted signs get slightly higher

illumination than the overhead signs, but the improvement is marginal. These two sign locations (overhead and left shoulder) are typically known as “disadvantaged sign locations” for low-beam headlamp illumination. Right shoulder mounted signs typically get higher illumination. In general terms, the illuminance on a right shoulder mounted is about twice that of the overhead and left

shoulder mounted signs for a given scenario.

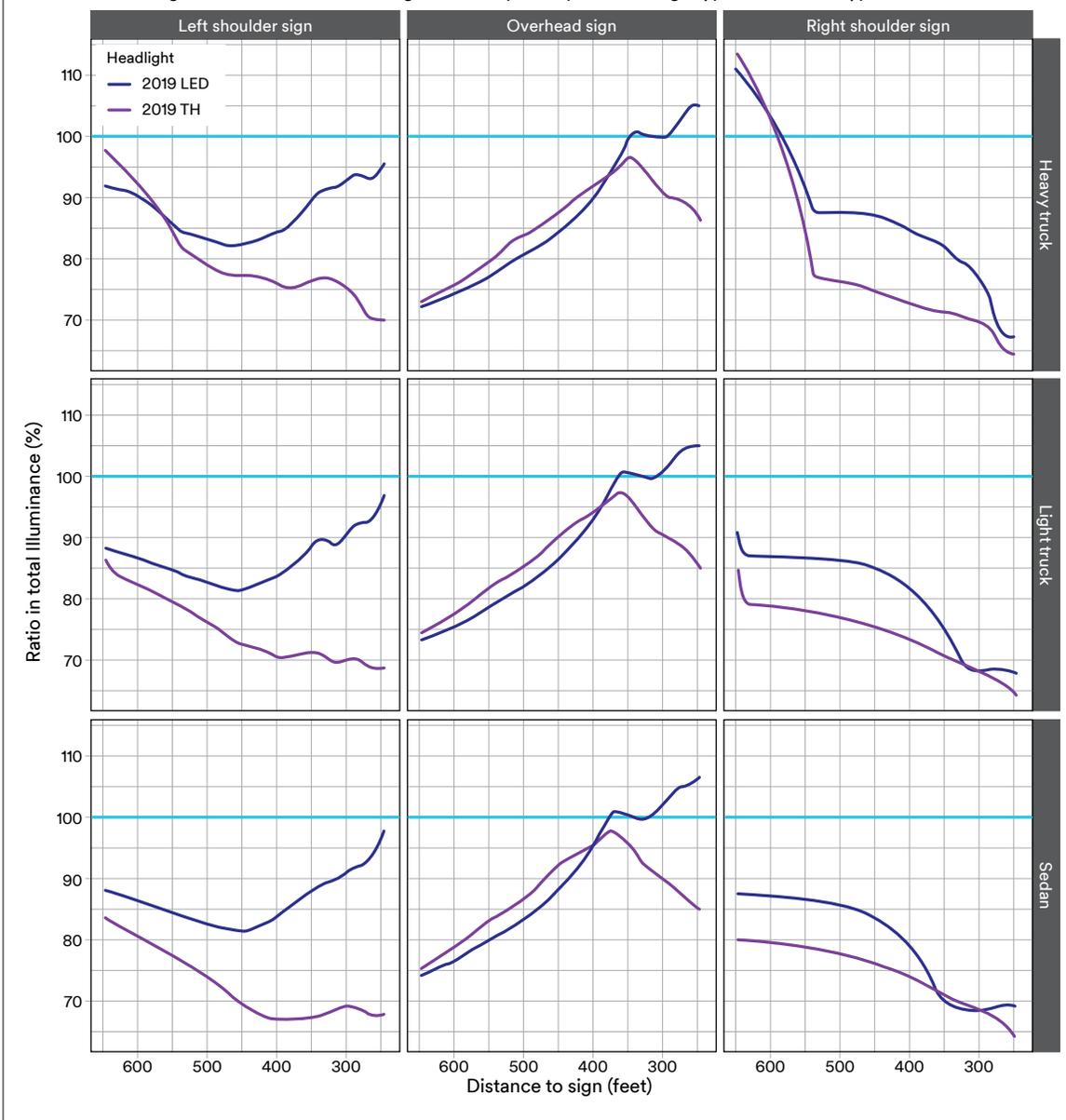
As for the vehicle types, the illuminance on the sign for all three sign locations (right shoulder, overhead, and left shoulder) has a slight increase as the headlight mounting height increases. For each sign location, heavy truck headlights provide slightly higher illumination.



**Figure 1.** The total illuminance of traffic signs by a pair of vehicle headlights, for 50% percentile

### The ratio in illuminance relative to 2011 headlights, for 50%

Plotted against the distance to the sign and in separate panels for sign type and vehicle type



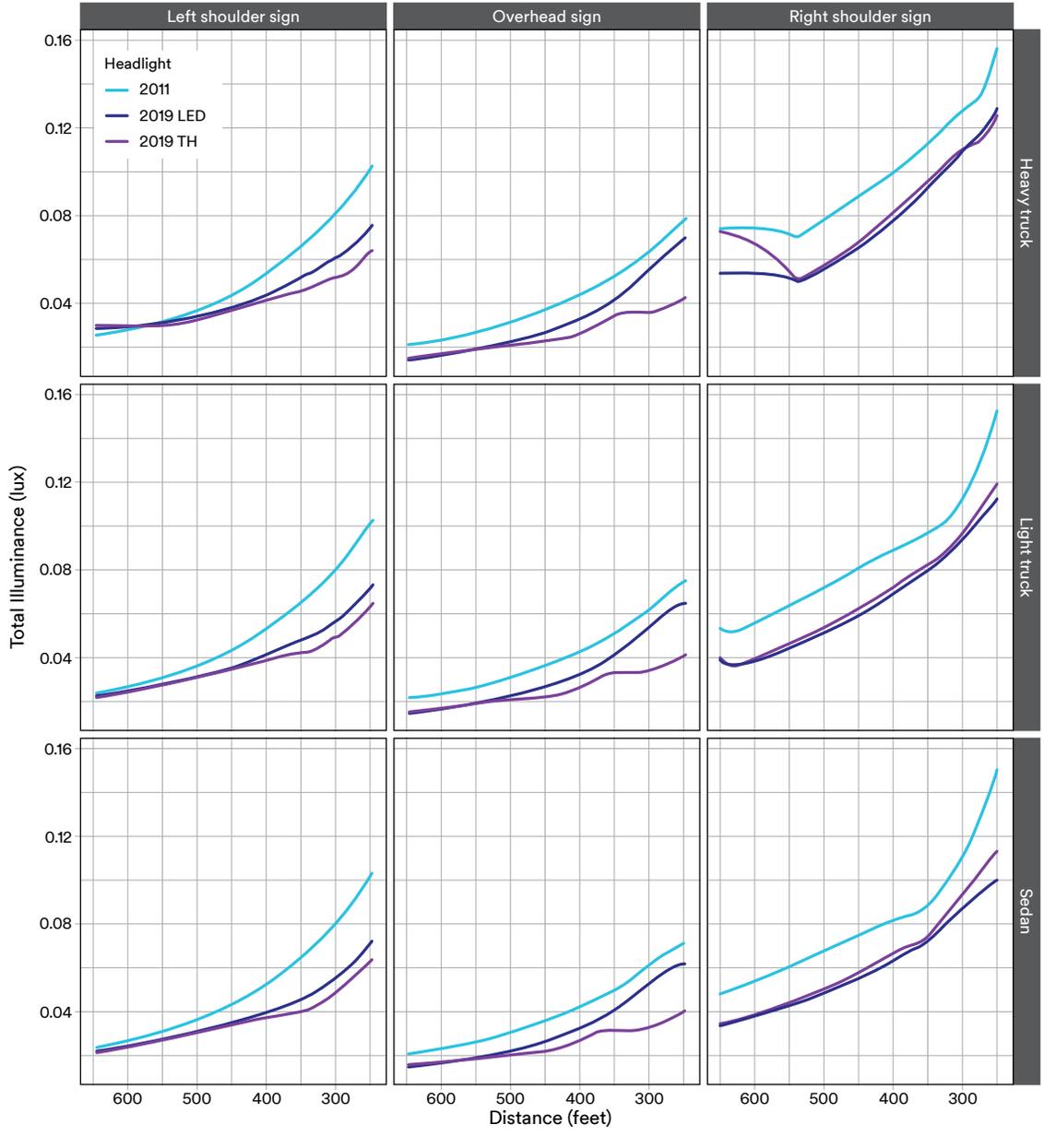
**Figure 2.**  
The ratio in illuminance relative to 2011 headlights, for 50% percentile

Figure 2 provides the illuminance of the 2019 median headlights as a percentage of the 2011 median headlights across the viewing distance for each of the nine scenarios. In general, sign illumination from 2019 headlights are noticeably lower than those of 2011 median headlights.

For the left shoulder sign scenario, 2019 TH median headlights provide lower illumination than the 2011 TH headlights across the viewing distance. The difference is over 30% in some cases and, on average, the reduction in illumination for the left shoulder sign is about 20%. While 2019 LED median headlights provide higher illumination than the 2019 TH median beams, they are still lower than the 2011 levels. On average, the illumination is about 10% lower than the 2011 levels.

For the overhead sign scenario, 2019 median headlights illumination is generally lower than their 2011 counterparts. 2019 THs were lower than the 2011 THs across the entire viewing distance. The only exception is that for closer viewing distances (350 ft or less), 2019 LED headlight illumination was slightly higher than the others. Overall, 2019 median THs are about 15% lower than their 2011 counterparts on

**The total illuminance of traffic signs by a pair of vehicle headlights, for 25% Plotted against the distance to the sign and in separate panels for sign type and vehicle type**



**Figure 3.**  
The total illuminance of traffic signs by a pair of vehicle headlights, for 25% percentile

average, whereas the 2019 LEDs were about 10% lower than the 2011 THs.

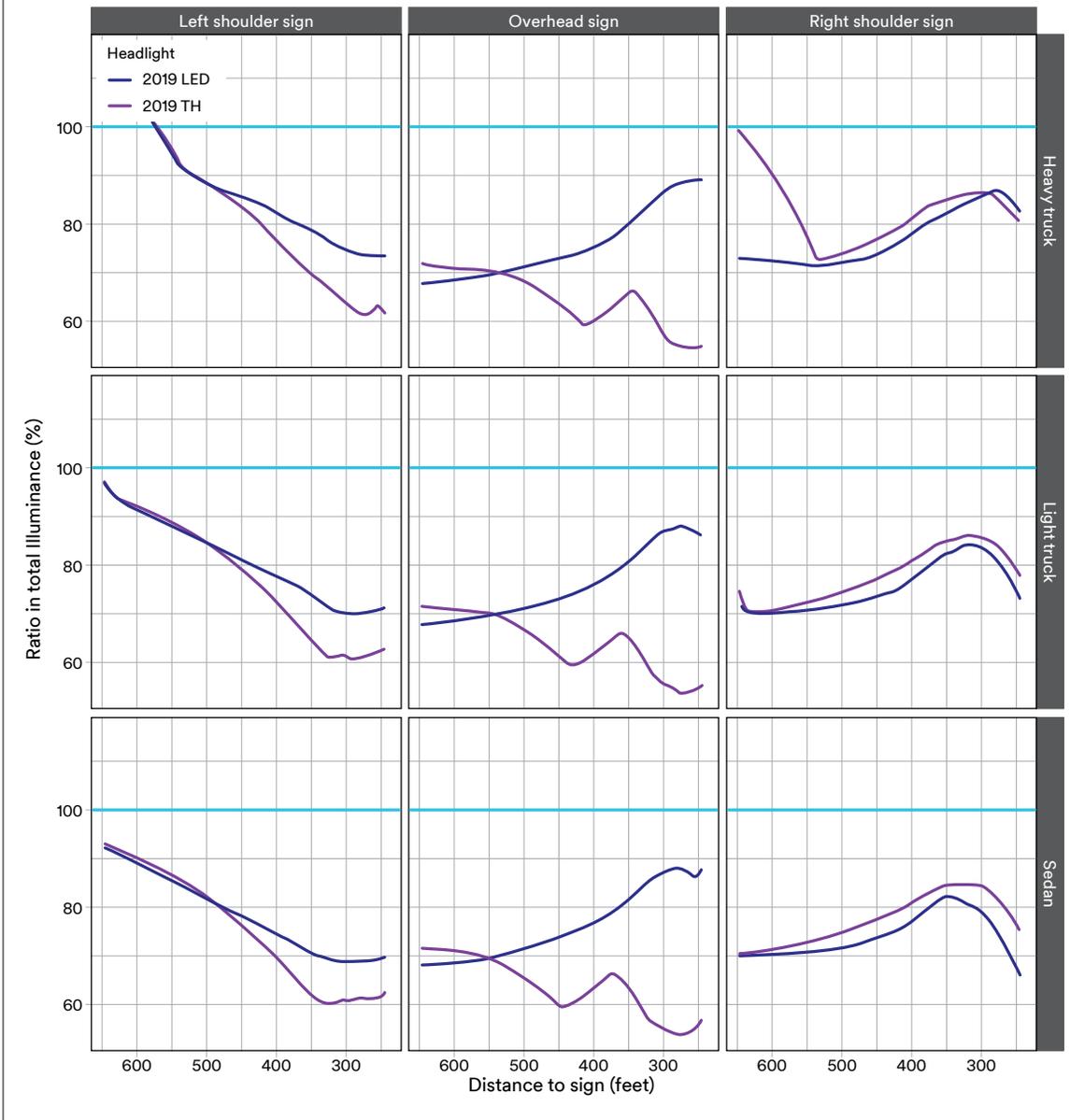
For the right shoulder sign scenario, 2019 median headlight illumination was also generally lower than their 2011 counterparts for all three vehicles across the viewing distance with the only exception being the truck scenario at

viewing distances over 600 ft. On average, the illumination of 2019 median headlights are about 20-25% lower than the 2011 median headlights.

Figure 3 and Figure 4 provide the same analyses for the 25th percentile headlights. These headlights represent the lower quartile of headlights, which might be more appropriate for a design case than the median headlights for a safety-oriented approach. It is important to note that in roughly quarter of the cases, the headlight illumination on signs will be lower than the 25th percentile illumination.

### The ratio in illuminance relative to 2011 headlights, for 25%

Plotted against the distance to the sign and in separate panels for sign type and vehicle type



**Figure 4.**  
The ratio in illuminance relative to 2011 headlights, for 25% percentile

In general, the illuminance of the 25th percentile headlights across these sign scenarios are about 30% lower than the median headlights of the same model year. Furthermore, the 25th percentile 2019 headlights were lower than those of 2011 across all scenarios and distances. In some cases, the reduction in illumination was over 40%.

This suggests that the variability in the headlight illumination toward traffic signs have somewhat increased in the newer 2019 models compared to 2011.

While understanding the trends in sign illumination is important, what matters to the driver is the luminance or the sign brightness. Headlight illumination works together with

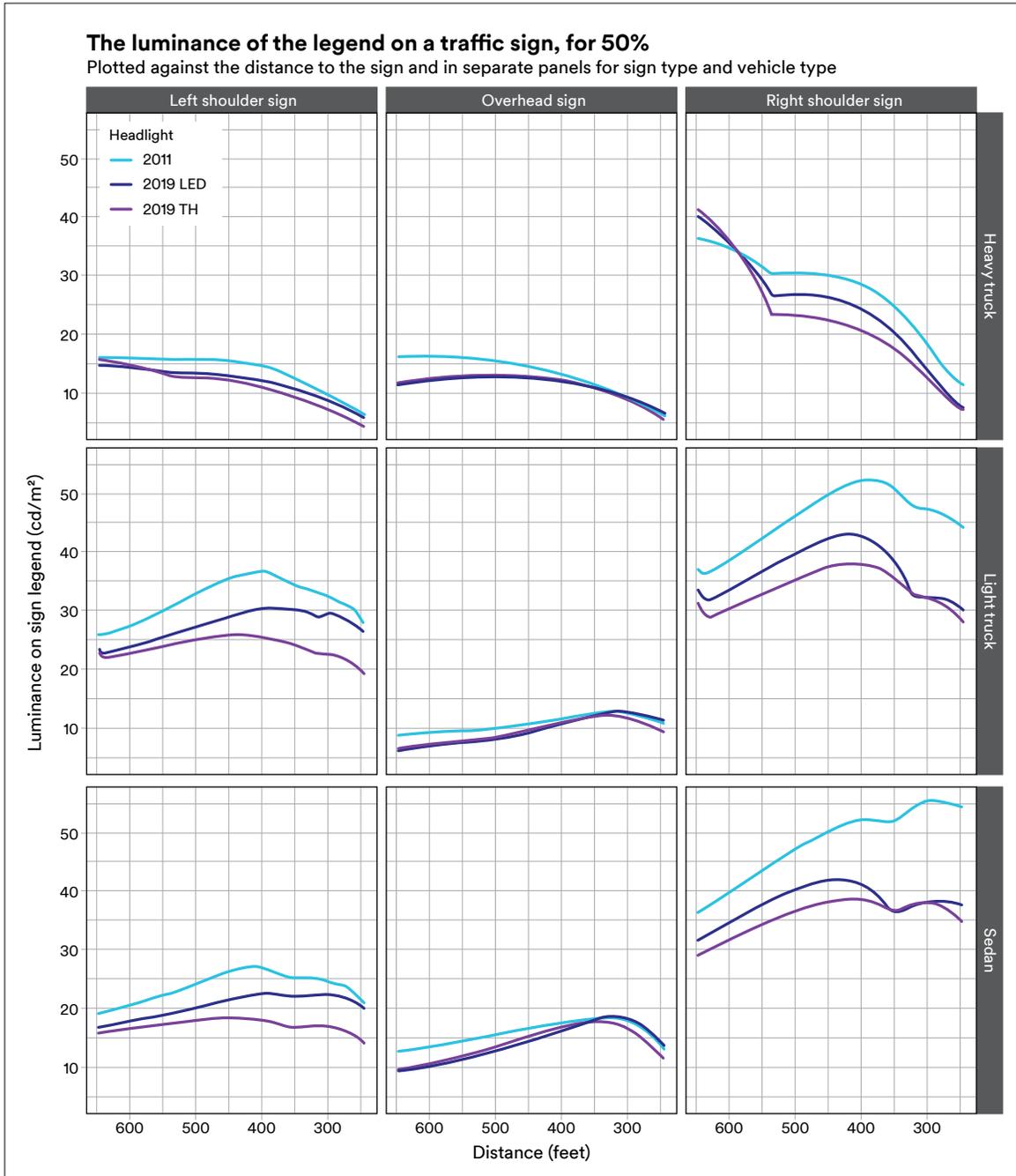
sign retroreflection to provide luminance, and it is important to understand the eventual effect of change in illumination on the sign luminance as observed by the driver.

Figure 5 and Figure 6 provide the luminance as observed by the driver behind the windshield for a modern, prismatic sheeting conforming to the ASTM D4956 Type XI standard.

The percent change in “luminance” in a given scenario is identical to the change in “illuminance” at the same distance in the scenario, because the retroreflectivity is identical in both cases.

However, it is important to not jump to conclusions based solely on illuminance as retroreflectivity plays an important role.

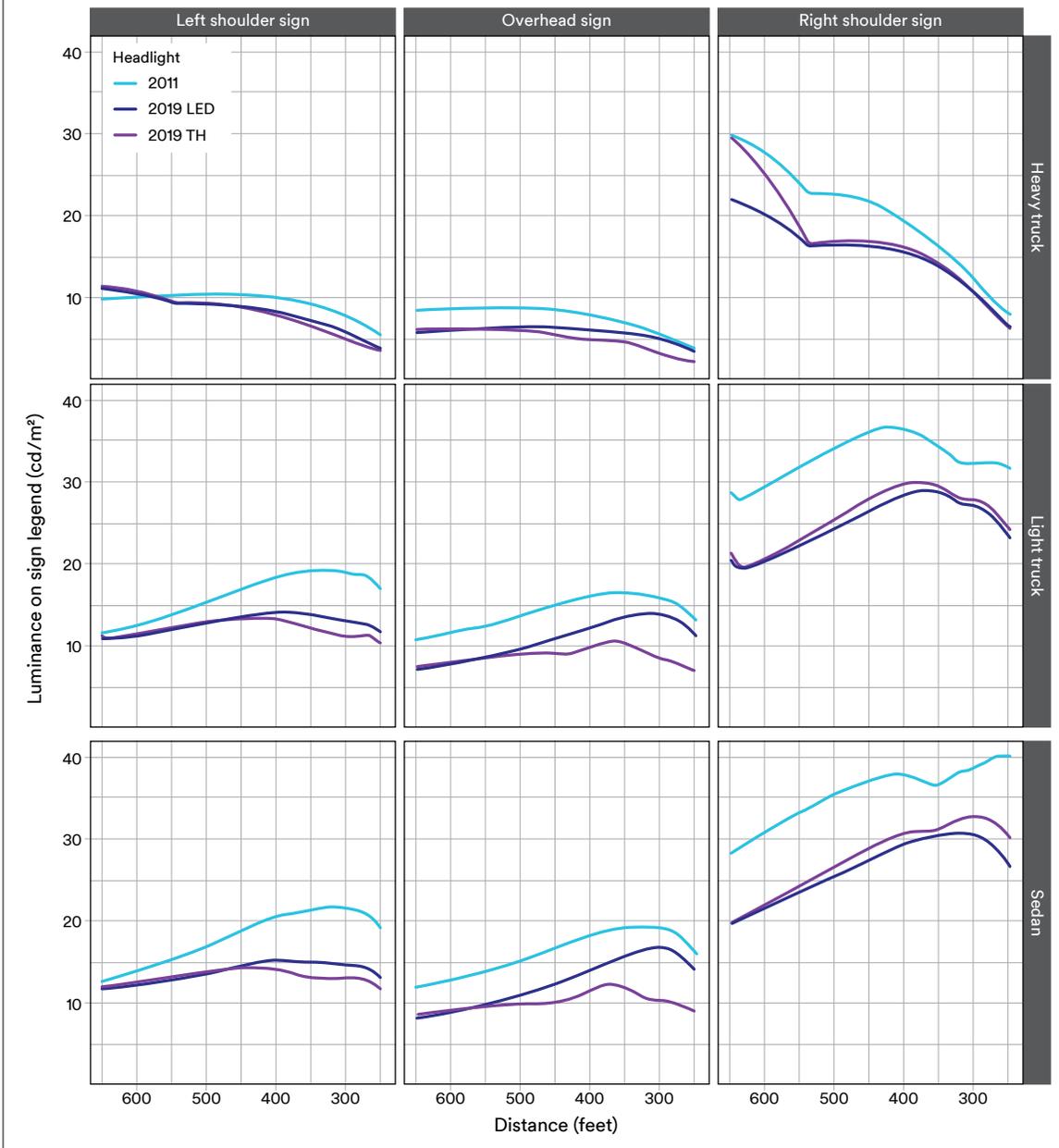
For instance, while illumination from a heavy truck is highest overall for each of the sign locations, the luminance observed by the truck driver is still the lowest when compared to the two other vehicles, all others being equal.



**Figure 5.** The luminance of a white sign legend on a traffic sign, for 50% percentile

### The luminance of the legend on a traffic sign, for 25%

Plotted against the distance to the sign and in separate panels for sign type and vehicle type



**Figure 6.** The luminance of a white sign legend on a traffic sign, for 25% percentile

## Conclusions

- The breakdown of sign illumination should allow for the decision makers to evaluate each scenario based on its likelihood. Depending on the roadway, the likelihood of each scenario may vary.
- It is important to note that in roughly quarter of the cases, the headlight illumination on signs will be lower than the 25th percentile illumination. If one were to address a significant portion of the cases, a lower percentile headlight illumination provides a better basis than an average or median headlight.
- The 25th percentile low-beam headlights are about 30% lower than the medians. Furthermore, 2019 headlights are about 20% lower than the 2011 headlights. Therefore, if a sign retroreflectivity design decision was made based on the 2011 median headlights, the driver of a new 2019 vehicle is seeing that sign at nearly half the brightness level of the intended design.



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