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White Paper

Maximizing Brightness of Retroreflective Traffic Signs to Help Serve the Driving Population

By Gernot Sauter, 3M Senior Regulatory Affairs Specialist

Summary

Supported by 14 reputable references, including the University of Michigan Transportation Research Institute, the Ohio Research Institute for Transportation, and international conferences on automotive lighting, this white paper explores multiple concepts, arguments and conclusions showing the need for brighter road signage solutions. It explores various ASTM D4956 classified sign sheeting material solutions, Type III solutions and signage material ranging from the minimum threshold for Type XI through the latest wet retroreflective pavement markings.

Key points

- The concept of Percent Drivers Served is intended to help evaluate how effectively a sign conveys its message to drivers. This approach highlights that higher grades of retroreflective sign sheeting help more drivers understand signs sooner, especially in real-world, dynamic driving conditions.
- Sign nighttime retroreflection (brightness) contributes to sign luminance, or how the sign is perceived by a driver.
- Larger and brighter signs are more efficient at transferring the message, so drivers need less time to understand it and go back to focusing on the road.
- Developments in vehicle low-beam headlamps require higher sign brightness to achieve the same sign illumination in 2019 than in 2011.
- It is impractical to have negative glare from signs anecdotally deemed “too bright” because one would need 10 to 20 times more luminance than optimum levels
- 3M™ Diamond Grade™ DG^3 Type XI Reflective Sheeting helps a larger percentage of drivers understand signs more efficiently than other ASTM D4956 classified sheeting, including the minimum threshold for Type XI.

Introduction

To effectively communicate vital information to drivers, roadway signage must function properly in all light conditions and in all driving environments. The visibility and legibility of signs is especially important during nighttime hours, when visibility is low, even in ideal weather. Testing and results were performed in some cases using premium 3M™ Diamond Grade™ DG³ Reflective Sheeting ("DG3"), 3M™ High Intensity Prismatic Reflective Sheeting ("HIP") and the previous generation of 3M™ High Intensity Beaded ("HIB") sheeting.

The reduced overall visibility necessitates timely transfer of information to the driver to allow them enough time to respond and make critical decisions. Retroreflective materials are extensively used for nighttime sign visibility as they redirect the light provided by the vehicle headlamps back to the driver, leading to enhanced nighttime sign luminance. The increased luminance of signs leads to enhanced visibility and legibility.

1. Studies in Luminance

The luminance of a traffic sign is perceived by a driver as being at a certain brightness, depending on the adaptation luminance. In addition, the visual acuity of the driver to read the sign legend also depends on the sign luminance [1].

Traffic sign luminance requirements for drivers in darkness have been evaluated by many different research groups. Schmidt-Clausen et al. conclude that the optimal area of luminance of L ≈ 10 cd*m^{-2} is required for optimal performance of written information on traffic signs at night" [1]. This is based on the De Boer rating scale from 1 to 9. The acceptable area ranges on a logarithmic scale from: 3 cd*m^{-2} rated as "dark, recognizable" to 30 cd*m^{-2} rated as "optimal", and 300 cd*m^{-2} rated as "bright, recognizable".

It should be noted that for this dark ambient surround condition, the step from the minimum luminance (just legible) to optimum luminance is a factor of 10. The step from the optimum luminance to the maximum luminance (bright, still legible) is again a factor of 10. Thus, the acceptable luminance range for drivers to allow legibility is large, approximated to a factor 100 from minimum to maximum. Reports of drivers stating that retroreflective signs are perceived as "too bright" are probably more subjective than factual.

The luminance values found by Schmidt-Clausen are not considered as a threshold value, but as a range. As the luminance demand will vary with adaptation luminance, e.g. from the car headlamp or street lighting, and the glare illumination from oncoming traffic.

The study gives no information about the age and visual capabilities of the test subjects. However, it is acknowledged that an increase of elderly drivers is expected in the future. Data is given on the degradation of visual acuity and increased glare sensitivity with age, but the effect on the traffic sign luminance demand of elderly drivers is not provided.

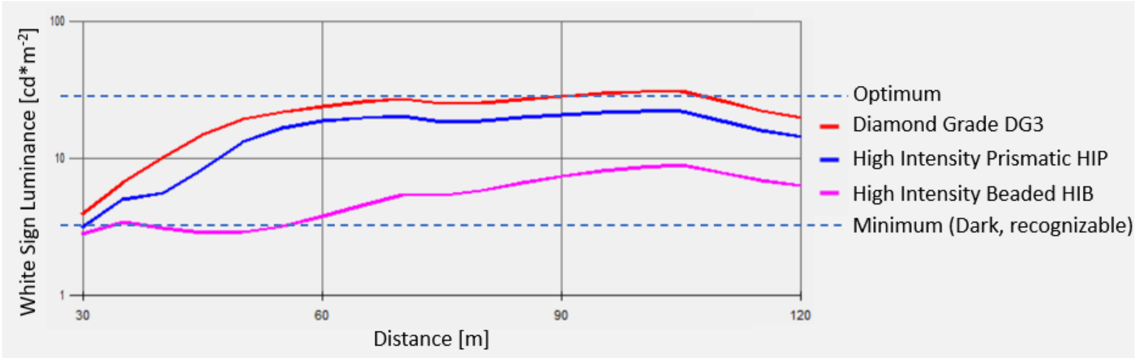

Figure 1: Traffic sign luminance for right shoulder sign, as seen from a standard passenger car with median European headlamps. The luminance data generated for these models is based on an analysis of samples of 3M sheeting materials.

Figure 1 shows typical traffic sign luminance of 3M retroreflective sheeting products relative to the minimum and optimum levels [1]. **3M™ Diamond Grade™ DG³ Reflective Sheeting ("DG³") does provide optimum levels over a wide range of distances.** 3M™ High Intensity Prismatic Reflective Sheeting ("HIP") provides luminance in the range between minimum to optimum. The previous generation of High Intensity Beaded ("HIB") sheeting, which was based on glass bead technology (encapsulated lens sheeting) provides significantly lower luminance and falls below the minimum level at closer distances for this traffic scenario.

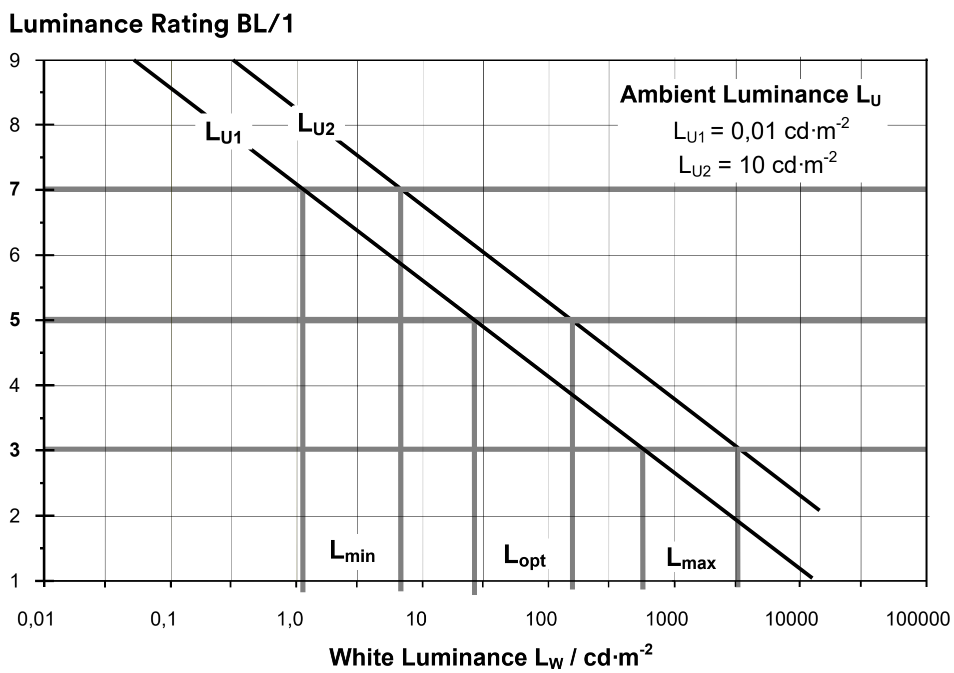

Figure 2: Luminance rating of test signs for two discrete ambient luminance with an observation distance of d = 70 m, without glare [2]

Figure 2 shows further research at the university of Darmstadt by Frank et. al. [2] that evaluated the luminance range for higher ambient surround luminance of 10 cd*m^{-2}. The minimum level for sign recognition in that condition (rating 7) is 8 cd*m^{-2}, the optimal luminance 150 cd*m^{-2} (rating 5) and the maximum acceptable level 3,000 cd*m^{-2} (rating 3). To provide the same recognition and legibility rating in brighter ambient surrounds, the traffic sign luminance must be 3 to 5 times higher, compared to a dark rural road environment. This is relevant for most roads with street lighting, or high traffic volume.

2. Traffic Sign Brightness and Acquisition Time

Gatscha et al. have analyzed driver's eye movement characteristics when reading two different performance levels of traffic signs using ASTM D4956 classified sheeting (HIB Type III and DG³ full-cube microprismatic Type XI) [7]. They could quantify the specific impact on gaze duration in real night-time driving situations. The results were based on 63 subjects and were derived from an in-vehicle observation system. The dependent variables were first and last glance distances to signs as well as gaze duration at signs.

Significant differences with regard to last glance distances could be proven. Eye movements deviated significantly earlier (approx. 8 meters) when looking at Type XI traffic signs. Type III traffic signs were viewed significantly longer – on average about 0.3 seconds longer.

The researchers concluded that the Type XI material has a positive impact on observation behavior and thus on traffic safety itself. The information presented on brighter traffic signs was perceived faster. Hence, drivers have potentially more time to concentrate on other essential stimuli in traffic.

Schnell et al. studied the effect on information acquisition time of traffic signs with legend luminance ranging from 3.2 to 80 cd*m^{-2} [8]. Their aim was to quantify the positive effects of brighter traffic signs that are offering brightness above the threshold level and reaching into the optimal range.

For the evaluation of visual acuity in the optometrist office, there are very definite recommendations developed for the level of illumination provided on the eye chart. Generally, these recommendations are from 80 cd*m^{-2} to 100 cd*m^{-2}. It is believed that any greater luminance will not result in any improvement in visual acuity for the subject being tested. It can be assumed, that luminance exceeding an optimum level of 80 cd*m^{-2} will not further improve the legibility.

The findings by Schnell suggest that increasing the traffic sign luminance significantly reduced the time to acquire information. Similarly, increasing the sign size (or reducing the legibility index) also reduced the information acquisition time. These findings suggest that larger and brighter signs are more efficient in transferring their message to the driver by reducing information acquisition time, or alternatively, by increasing the transfer accuracy. In return, reduced sign viewing durations and increased reading accuracy is likely to improve roadway safety.

Overall, a 50% reduction in luminance required an additional 20% reading time on average. This effect was also statistically significant at each step from 3.2 cd/m^2 to 80 cd/m^2, with the following percentage differences at 84th percentile accuracy level and at 6:1 contrast ratio:
Reducing sign luminance from 80 cd*m^{-2} to 40 cd*m^{-2} required 21% additional reading time,

- from 40 cd*m^{-2} to 20 cd*m^{-2} required 7.1% additional reading time
- from 20 cd*m^{-2} to 10 cd*m^{-2} required 15% additional reading time
- from 10 cd*m^{-2} to 3.2 cd*m^{-2} required 50% additional reading time

Larger and brighter signs are efficient and require less time in providing very high reading accuracy.

Considering that the ambient or surround luminance in this experiment was chosen as 2 cd*m^{-2} to 3 cd*m^{-2} and comparing both sign luminance and ambient luminance of Frank [2] in Figure 2, it can be concluded that a sign legend luminance of 3.2 cd*m^{-2} can be considered the minimum (or threshold) level. And 80 cd*m^{-2} is approaching the optimum level according to Figure 2.

3. Headlamp Developments

Sign luminance is a result of the sign illumination from the vehicle headlamps and the retroreflection provided by the sign sheeting material. The University of Michigan Transportation Research Institute (UMTRI) provides periodical reviews of the luminous intensities of U.S. and European low-beam headlamps. The most recent report for European beams dates back to 2003 [3]. In the example in Figure 1, we used the European median (50th percentile) low-beam headlamp from 2002 model year vehicles. **Figures 1 and 2 show that right shoulder mounted signs constructed with DG^3 Type XI retroreflective sheeting can provide traffic sign luminance at close to optimal level.**

The data provided by these graphs suggests that under the illumination of the median European low-beam headlamp, meeting optimal luminance levels presents a challenging task for some other sign sheeting materials.

In 2019, UMTRI published a report with photometric information for low-beam LED and tungsten halogen (TH) headlamps on U.S. light vehicles [10]. It could be seen that 2019 low-beam headlamps provide lower levels of illumination to typical roadway signs compared to 2011 headlamps. The reduction ranges from 14% to 24% and is computed by comparing 2019 low beam lights with their 2011 counterparts.

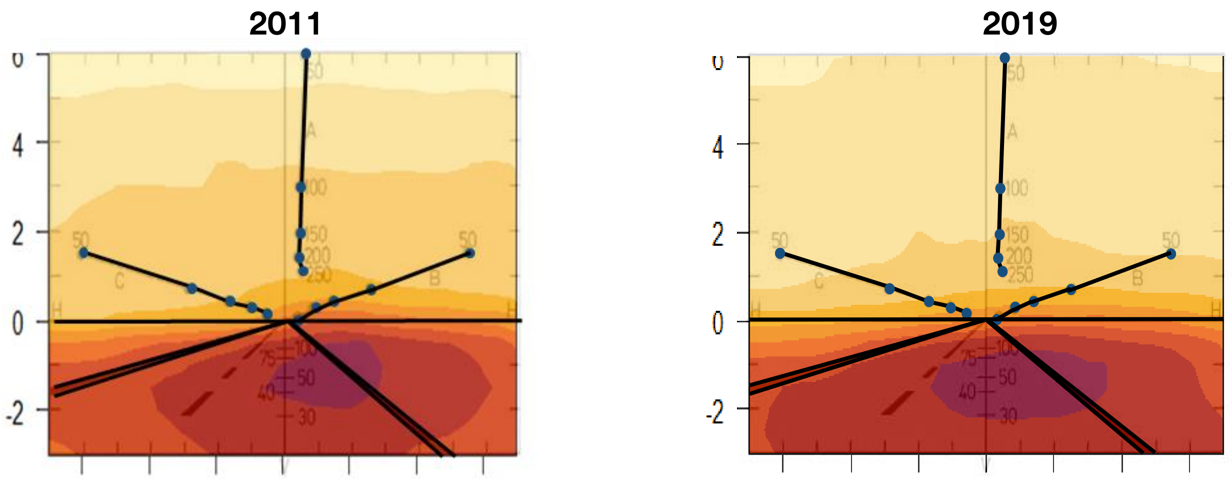

*Figure 3: Contour plots of Log2 transformed luminous intensity distributions (log2*cd); Circles mark the position where signs are located at the given distance [11].*

The reduction in headlamp 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.**

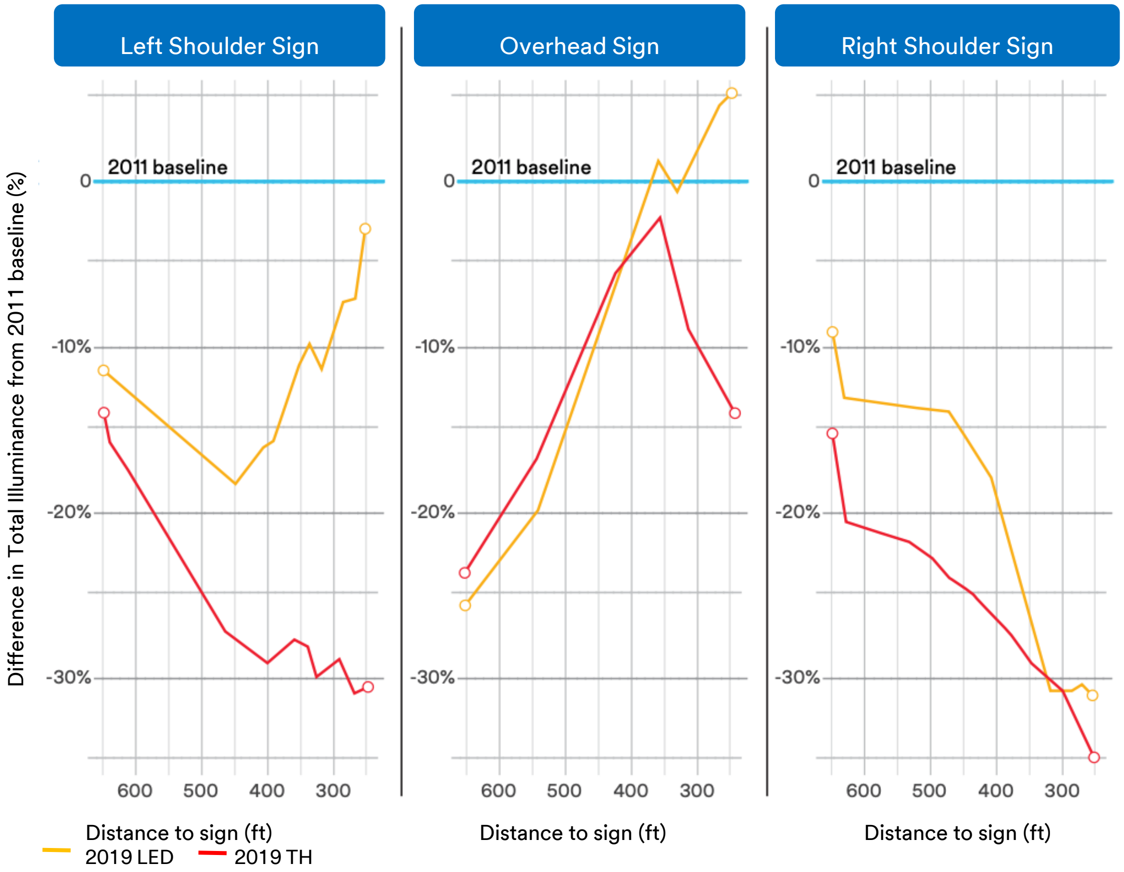

Figure 4: Reduction in illumination to signs (2019 vs 2011 low-beam headlights) from a light truck.

The 25th percentile low-beam headlamps are about 30% lower than the medians. Furthermore, 2019 headlamps are about 20 % lower than the 2011 headlamps. Therefore, if a sign's retroreflectivity design decision was made based on the 2011 median headlamps, one quarter of the drivers of a new 2019 vehicle are seeing that sign at nearly half the brightness level of the intended design. Lower levels of illumination mean lower sign brightness. To mitigate this, agencies may consider upgrading sign sheeting to performance classes that will serve the rapidly growing group of drivers of new cars.

It can be expected that similar trends for the illumination of high mounted roadway signage exist for modern LED or HID European headlamps. More total light output translates to better illumination of the roadway or pavement, but more pronounced cut-off and less illumination to signs or objects mounted above the cut-off line. See illustration in Figure 5.

Figure 5: Typical ECE passing beam light distribution with pronounced cut-off line for typical sign locations / HID Projector Lens / Model Year 2015 [11].

The effect of better roadway illumination on the adaptation levels for drivers has been studied by Schmidt-Clausen et al. in 2004 with the arrival of HID (Xenon) headlamps producing about 3 times more light compared to traditional halogen headlamps [5]. It could be shown that modern HID headlamps increased the roadway luminance by a factor of 1.5 to 4 on dark asphalt surfaces and up to a factor of 6 on lighter concrete road surfaces. This will increase the adaptation level of the driver's eye and thus the general visual capabilities in the mesopic range. However, raising the general adaptation level for drivers will make it even more difficult to see objects and traffic signs that are located outside the direct headlamp beam and located "in the dark", above the headlamp cut-off line.

4. Luminance Requirements for Traffic Signs

Zwahlen et al. investigated traffic sign performance between elderly drivers in a rating experiment. It could be shown that the best rated retroreflective material at that time (truncated microprismatic cube corner sheeting Type IX) was deemed acceptable for 80% of the drivers. In the same experiment, the glass beaded sheeting with additional external sign lighting was only acceptable for 40%-45% of evaluators [4].

Later research has utilized distribution of visual acuity in the driving population to calculate the "Percent Drivers Served" for certain signing scenarios. This concept provides an aggregated performance metric that can be easily interpreted and goes beyond the static minimum and optimum level in the earlier chapter.

In that context, the remaining “Percent Drivers Not Served” meant that this portion of drivers will not be able to read the traffic sign at the design legibility distance (i.e. first look) and have less time to understand and react to the sign. Also, the acquisition time to read and understand the sign is likely to be longer for this portion of drivers.

The concept of Percent Drivers Served is intended to provide traffic engineers, retroreflective sheeting designers and headlamp designers an approach to evaluating performance that may relate more directly to end users. Often the present system of presenting information, such as luminance curves based on driving scenarios alone, is not easily interpreted in the context of the end user - those who drive the roads. Based on this metric, a greater level of driving safety can be expected when using materials with a higher Percent Drivers Served level.

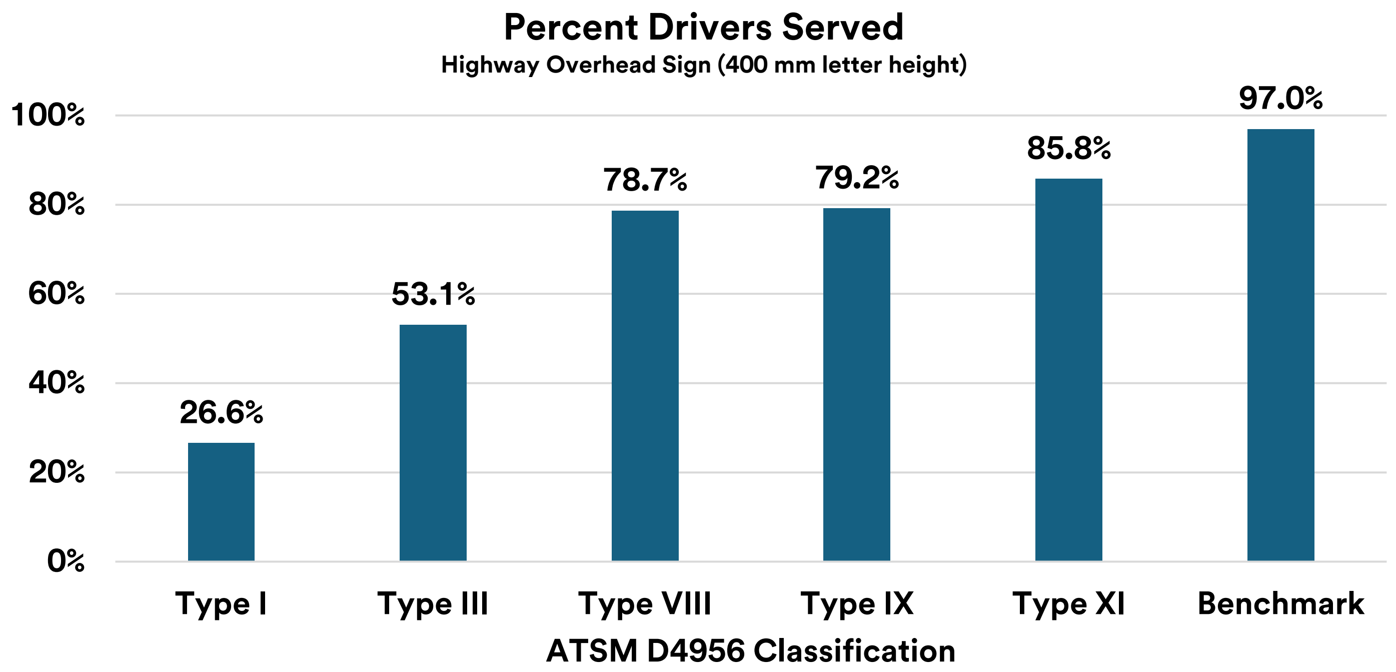

Figure 6: ‘Percent Drivers Served’ metric, exemplarily developed for a motorway overhead sign and for different retroreflective performance levels.

Figure 6 gives the calculated Percent Drivers Served level for an overhead sign with large letters (representative of motorways). It is shown that glass bead technology (e.g. Type I and Type III in the chart) can only satisfy the performance expectations of a small percentage of drivers, while microprismatic materials provide service to a much wider range of drivers, closer to the benchmark performance - an internally illuminated sign with high optimal brightness. The Percent Drivers Served metric utilizes a methodology that is based on populations of driver ability, populations of headlamps in service, and estimates of vehicle mixes (car and truck) on the road for the type of sign considered [6]. **The results in this overhead sign example show the significant improvement in Percent Drivers Served level by the use of higher grades of retroreflective materials. Such improvements can be expected to directly impact road safety.**

The Percent Driver Served metric has been further developed by the CIE Technical Committee 4-40. Unfortunately, the final report has never been published due to several organizational issues. Paul Carlson, the former chairman of the TC, finally decided to present some key findings and conclusions from the draft CIE 4-40 report at the annual meeting of the Transportation Research Board in 2015 [9].

After a thorough review of the available studies, the committee settled on a combination of data provided by Carlson et al. and supported by Forbes [12]. The data from these studies were mostly consistent and they also complimented one another in such a way that their combined results provided threshold luminance levels across a range of conditions that could be used to develop a performance index (see Figure 7).

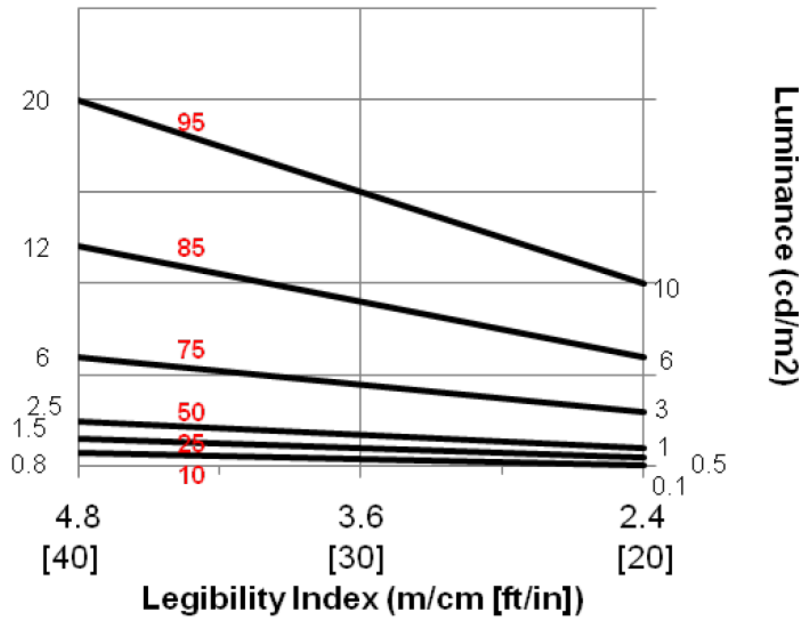

Figure 7: Example of Required Luminance in respect of percentile of elderly drivers in low complex surround. The luminance curves are shown over the relevant legibility distance and expressed as 'legibility index' to make the distance scale independent of the letter size of the traffic sign.

Following the concept developed by CIE TC 4-40, the required luminance ("Demand Luminance") will be assessed versus "Supply Luminance", as provided in a given scenario for a specific sheeting type or grade.

Figure 8 shows dashed curves for the Demand Luminance in the legibility zone between 200 m and 100 m (legibility index from 4.8 m/cm down to 2.4 m/cm for a 420 mm letter height on the overhead sign) for the 95^{th}, 85^{th}, 75^{th} and 50^{th} percentiles of drivers. It then shows solid curves for the Supply Luminance for the typical performance of 3M Diamond Grade DG^3 sheeting, and the approximated minimum required performance levels of ASTM D4956 Types IX and XI [14].

The performance index can loosely be interpreted as the percent of older drivers served by the retroreflective sheeting material. The assessment technique allows a direct comparison of sheeting materials across the legibility zone.

When comparing the dashed-gray 85% Percentile Drivers Served curve with the solid-red Supply Luminance curve for a typical sample of Diamond Grade DG³, it is shown that the Supply Luminance is partly above and below the Demand Luminance. The aggregated performance level, calculated according to the provisions of TC 4-40, would be 87% of drivers served in this example. The minimum ASTM D4956 retroreflective performance for Type XI would serve 80% of drivers and Type IX would serve only 67% of drivers.

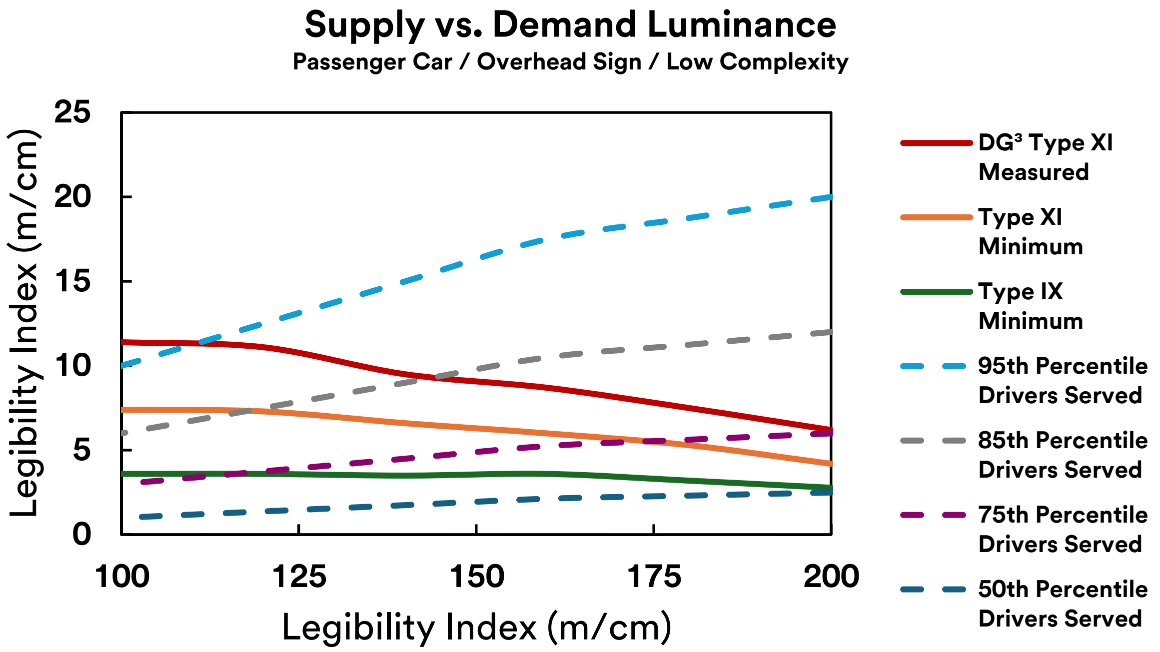

Figure 8: Supply versus demand luminance for highway sign seen from a passenger car, legibility zone for an overhead sign with 420 mm letter height.

5. Traffic Sign Legibility Under Dynamic Condition

The primary task while driving, is not to read traffic signs. Drivers must focus their attention mainly on maneuvering their vehicle, which includes tasks like lane keeping, navigating, watching for other vehicles, pedestrians and obstacles on the road etc.

Looking for signs, reading and understanding the sign is a secondary task. Furthermore, each time the driver is ready to move the eyes back to the sign to continue reading or confirming the sign content, the sign must be located again as it has moved within the visual field. This constant shifting of attention imposes a cognitive demand that can, to a certain extent, be compensated for with a higher sign luminance.

In their research, "Traffic Signs and Real-World Driver Interaction', Schnell et al. have investigated driver luminance demand during a dynamic driving task [13]. The purpose of the study was to compare nighttime traffic sign legibility under static (non-driving) and dynamic (slow driving) conditions using legibility as a measure of performance.

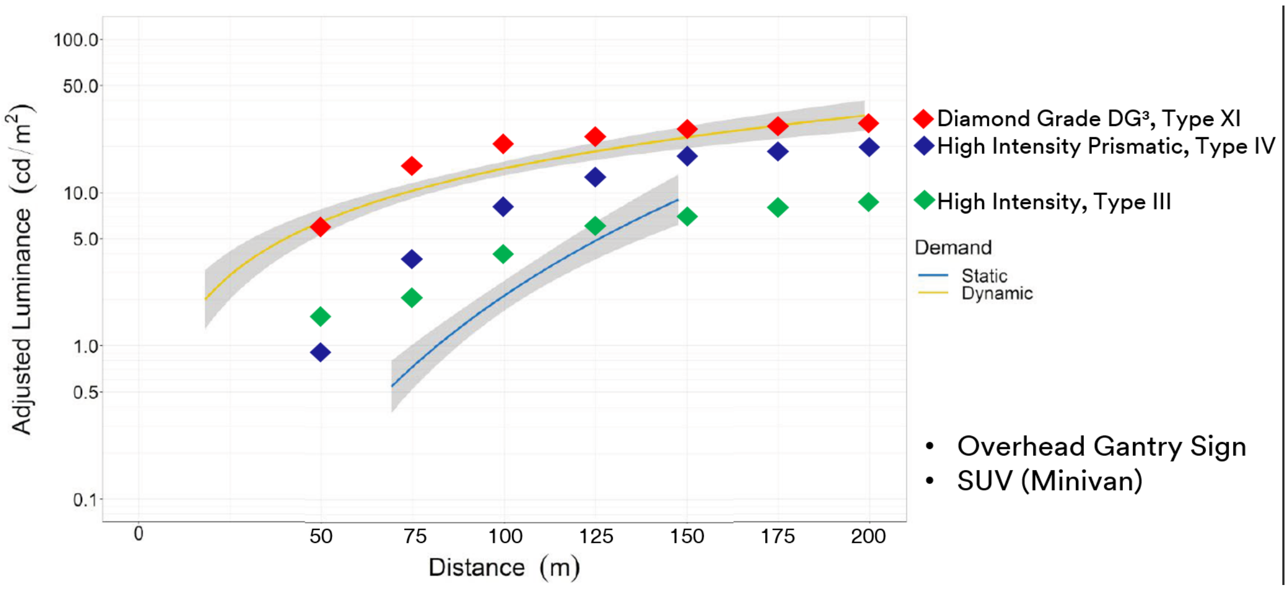

Figure 9: Supply versus demand luminance for static (non-driving) and dynamic (slow driving) conditions.

Figure 9 is a plot of the static and dynamic demand curves, with 95% confidence intervals in gray. It shows that participants needed more luminance during the dynamic conditions (yellow curve) to read the traffic sign text at the same distances that they were able to during the static condition (blue curve).

In Figure 9, the Demand Luminance curves have been overlayed with Supply Luminance from three sheeting types in a given highway scenario (overhead gantry sign, observed from SUV with median headlamps).

It is shown that traditional HIB Type III sheeting may only satisfy the luminance demand for a static condition. While driving, the luminance demand may be satisfied with 3M Diamond Grade DG^3 full-cube microprismatic Type XI sheeting over the entire range of useful sign distances from 200 m down to 50 m.

6. Conclusion

Findings suggest that larger and brighter signs are more efficient in transferring their message to the driver by reducing information acquisition time, or alternatively, by increasing the transfer accuracy. In return, reduced sign viewing durations and increased reading accuracy is likely to improve roadway safety.

Minimum and optimum levels of traffic sign luminance have been evaluated by several researchers. Increasing the traffic sign luminance from minimum to optimum levels significantly reduces the time needed to acquire information.

It is believed that any greater luminance beyond optimum levels will not result in further improvement in legibility. However, negative glare effects from too bright signs are expected only at extremely high luminance, 10 to 20 times more than optimum and out of the realistic range for retroreflective signs.

The concept of Percent Drivers Served provides an aggregated performance metric that can be easily interpreted and goes beyond the static minimum and optimum level in the earlier chapter. Percent Drivers Served is typically assessed for certain signing scenarios and may be used for a direct comparison of sheeting materials across the legibility zone. Based on this metric, a greater level of driving safety can be expected when using materials with a higher Percent Drivers Served level.

For one overhead sign example, significant improvement in Percent Drivers Served by use of higher grades of retroreflective materials could be demonstrated. High performance retroreflective sheeting such as 3M Diamond Grade DG³ has been shown to serve as much as 87% of drivers for the highway overhead sign scenario. Such improvements can be expected to directly impact road safety and navigation.

3M Diamond Grade DG³ can also satisfy the luminance demand of drivers following more recent experiments for dynamic conditions (real-world driving).

7. About 3M

3M Commercial Branding and Transportation is dedicated to improving transportation infrastructure and mobility to help road users arrive at their destinations safely. Our high-performance materials help you bring the best roadway systems into reality. For over 85 years, we have shared in your mission to make our roadways safer.

3M's retroreflective technology has raised the bar on visibility and durability in road traffic signage for the modern world. As we continuously improve our products, we will evolve with changing modern technology to help keep roads safe, day or night. Our high-performance retroreflective sheeting can help you efficiently and effectively improve traffic safety by serving more drivers.

If you would like further information on any of the products mentioned in this whitepaper or to discuss how they could be applied to your road projects, then please arrange a call with a 3M expert.

References

1. Hans-Joachim Schmidt-Clausen, M.W. Westerhuis and Michael Bernard, 1991. Retroreflective Road Traffic Signs: Minimum and Optimal Luminance Requirements, IRF International Road Federation, Geneva, Switzerland.
2. Helmut Frank and Jürgen Ewald, 1995. Determination of the minimum Coeffeicient of Retro-reflection during Use for Retro-reflecting materials for Road Safety Purposes. Forschung Straßenbau und Verkehrstechnik Hext 713, 1995, Bundesministerium für Verkehr.
3. B. Schoettle, M. Sivak, M. J. Flannagan and W. J. Kosmatka, 2003. A Market-Weighted Description of Low-Beam Headlighting Patterns in Europe: 2003, University of Michigan Transportation Research Institute, Ann Arbor, Report UMTRI 2003-37.
4. Helmut Zwahlen, Andrew Russ and Sahika Vatan, 2003. Field Evaluation of Unlighted Overhead Guide Signs using Older Drivers, Human Factors and Ergonomics Laboratory Ohio Research Institute for Transportation and the Environment, Report OH-2003.
5. Hans-Joachim Schmidt-Clausen and Achim Freiding, 2004. Sehvermögen von Kraftfahrern und Lichtbedingungen im nächtlichen Straßenverkehr. Mensch und Sicherheit Heft M 158, ISBN 3-86509-102-4.
6. Norbert Johnson and Gernot Sauter, 2005. “Percent Drivers Served” for Headlamp Illuminated Retroreflective Overhead Signs. 6th International Symposium on Automotive Lighting, 2005, Darmstadt University of Technology. ISAL 2005: Volume 11, ISBN 3-8316-0499-1.
7. Michael Gatscha, Günther Schreder, Sandra Reichenauer, 2008. Analysis of eye movement characteristics at different laminated retroreflective traffic signs under realistic nighttime driving conditions, 87th Annual Meeting of the Transportation Research Board, TRB 2008.
8. Tom Schnell, Lora Yekhshatyan, Ron Daiker, 2009. The Effect of Luminance and Text Size on Information Acquisition Time from Traffic Signs, 88th Annual Meeting of the Transportation Research Board, TRB 2009.
9. Paul J. Carlson, 2015. Performance Evaluation of Retroreflective Traffic Signs, 94th Annual Meeting of the Transportation Research Board, TRB Paper #15-2963.
10. M. J. Flannagan, 2019. A Market-Weighted Description of Tungsten-Halogen and LED Low Beam Headlight Patterns in the US, University of Michigan Transportation Research Institute, Ann Arbor, Michigan, Report UMTRI 2019-5.
11. Hugo Bruggeman, Gernot Sauter, The Legibility of Traffic Signs under LED Headlamp Illumination, Intertraffic Summit 2022, Amsterdam, Conference Proceedings.
12. Forbes, T.W. (1976) “Luminance and Contrast for Sign Legibility and Color Recognition.” 18 Highway Res. Record No. 611, Transp. Res. Board, Nat. Acad. Sciences, Washington, D.C.
13. Schnell, T. et al. 2022. Traffic Signs and Real-World Driver Interaction; Manuscript Draft for Transportation Research Board Annual Meeting 2023.
14. ASTM International, Standard Specification for Retroreflective Sheeting for Traffic Control, ASTM D4956-19.

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