

Are traffic signs too bright?

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Abstract

The world is changing, the population is ageing and technology transforms our lives rapidly. What level of traffic sign brightness best satisfies the changing needs - ageing population, different road users and more challenging road conditions? This paper will look at how bright a traffic sign needs to be to meet the maximum number of road users' needs. This literary study draws on research from key factors effecting sign brightness:

- Sign condition – How much impact does the cleanliness, age, installation and positioning of a sign effect the clarity of information to a driver?
- Human factors - Marland (1967) found that human vision, perception and reaction time declines with advancing age; around the age of 60, the amount of light reaching the photoreceptors is only 25% of the amount seen at age 20.
- Road users – The proportion and weight of freight traffic on road networks at night is increasing. Advancing headlight technology is affecting the illumination levels of retroreflective signs. Truck drivers are disadvantaged when viewing signs at night due to the large vertical displacement their seating positions have relative to the truck's headlights.
- Headlight configuration – There have been significant technological development in the design and output of vehicle headlights, as well as the ability to design the light distribution profile of the headlights, thus directing light into specific areas of the roadscape.
- Illuminated vs. retroreflective signs – with the increase in LED and illuminated signs how can the best luminance level for the driver be achieved?

Introduction

The world is changing, the population is ageing and technology is transforming our lives rapidly. In the past couple of years, traffic engineers and regulators have several options to choose from when it comes to road signage; improved technology enables them to specify better performing retroreflective traffic signs. However, what level of brightness best satisfies the changing needs - ageing population, different road users and more challenging road conditions? Some road users might feel a few signs are too bright and cause a glare hazard, whilst those same signs are viewed very differently from a truck driver's vantage point.

Objectives

This paper will look at how bright a traffic sign needs to be to meet the maximum number of road users' needs. Influencing factors such as the changing driving environment, aging drivers, improved headlamp performance, diverse vehicle sizes and types as well as the differences between theoretical performance and effective performance will be considered, so that what is perceived by the road user is better understood.

We will consider all these factors, drawing on previous research, studies and papers, as well as extensive knowledge and understanding of lighting and optics held within 3M.

- Sign condition – How much impact does the cleanliness, age, installation and positioning of a sign effect the clarity of information to a driver? Each scenario is unique and the effectiveness of a sign can vary widely between day and night, modeling and reality.

- Human factors - Marland (1967) states that human vision, perception and reaction time declines with advancing age and that around the age of 60 the amount of light reaching the photoreceptors is only 25% of the amount seen at age 20. Research studies have proven that the elderly experience significant decline in their eyes' optics, can this be overcome by installing brighter signs on the roads? Would brighter signs shorten drivers' reading and reaction time and ensure faster information acquisition?
- Road users – The proportion and weight of freight traffic on road networks at night is increasing. Advancing headlight technology is affecting the illumination levels of retroreflective signs. Truck drivers are disadvantaged when viewing signs at night due to the large vertical displacement their seating positions have relative to the truck's headlights. This results in a significant reduction in the amount of returned light received by truck drivers, compared to that received by car drivers. When reading traffic signs, does a lower returned light compromise a drivers' ability to detect, recognize and react to a sign? Are traffic signs being designed to today's traffic needs?
- Headlight configuration – There have been significant technological developments in the design and output of vehicle headlights, as well as the ability to design their light distribution profile. These changes have resulted in differing levels of illumination of traffic signs, dependent on road location.
- Illuminated vs. retroreflective signs – with the increase in LED and illuminated signs how can the best luminance level for the driver be achieved? Does increased brightness command more attention from the driver?

This paper looks at which of these factors are the most critical and influential, and initiates debate into the suitability of current standards and specifications for today's and the future road users' needs. A variety of best practice documents and studies from around the globe demonstrate how best the compromise between good traffic sign visibility and maximum tolerable sign brightness can be achieved.

Background – basic principles of retroreflectivity

The performance of a traffic sign at night and whether it meets the visual requirements of a driver is based on several factors but primarily the luminance of the sign, more specifically the luminance contrast between the background sign and the legend being depicted on the sign face. This luminance is affected and determined by many factors including the retroreflectivity of the sheeting, the illuminance output from the vehicle headlights, the distance between drivers' eye level and headlights and the position of the signs themselves. Therefore in order to discuss this topic we need to be familiar with some of the factors below:

Retroreflectivity

A retroreflective surface returns a proportion of the total light it receives (shown in diagram 1). The distribution pattern of the returned light is unique to each type of retroreflective material, and is determined by its optical design. Diagram 2 shows how light is internally reflected within a prismatic material to deliver the retroreflection of the light source. The position of a driver's eyes within the distribution pattern of the retroreflected light determines how bright a sign appears and thus how it is perceived and processed by the road user.

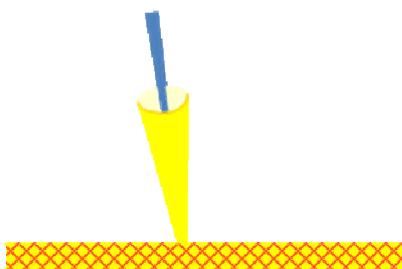


Diagram 1: Retroreflectivity is when the light is returned in the direction of its source, forming a cone of light.

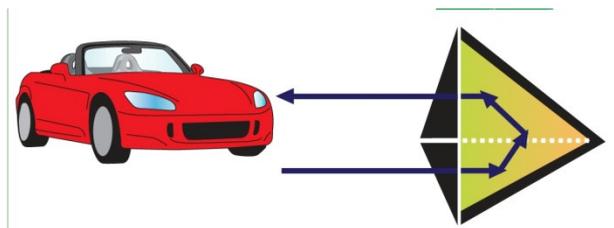


Diagram 2: Optics within the micro-prismatic structure return the light to its source.

Efficiency of retroreflective surfaces

A retroreflective surface can only return a proportion of the total light they receive, an illustration of this is shown in diagram 3. In addition to the overall efficiency the distribution of that returned light within the cone is unique to the retroreflective surface, and is determined by its design. The position of the road users eyes within the cone of retroreflected light determines how much light the user actually sees and whether it is sufficient for them to read and understand the sign.

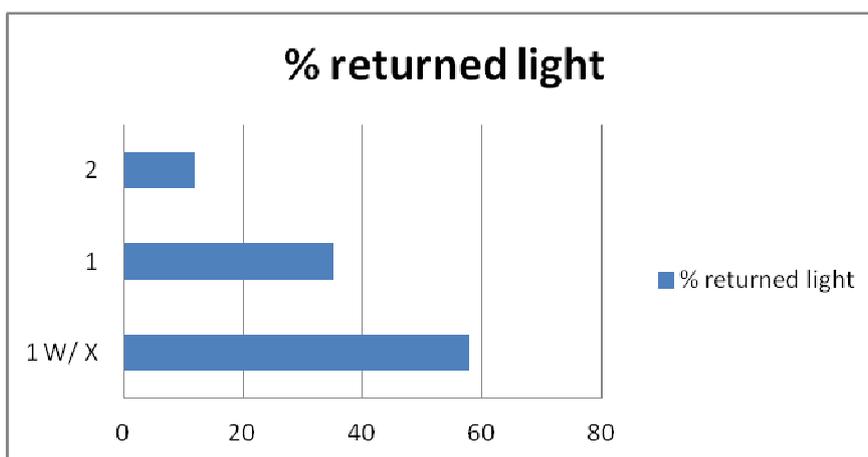


Diagram 3: Representation of the varying efficiencies of different classes of retroreflective materials.

Luminance

Luminance is the brightness apparent to the road user from the retroreflective surface.

Traffic sign recognition

It is commonly accepted that there are three stages in the recognition and acknowledgement of a road sign, as referenced by Aktan and Burns from Schieber et al.(2004):

- Look 1: Acknowledgement of a sign ahead on the driver’s route.
- Look 2: Recognition of the traffic sign and its relevance to the driver’s situation are determined. This normally occurs at a distance greater than the threshold legibility distance (ie before the driver can fully determine all characters on the sign).

- Look 3: Driver actually acquires the information from the sign - the sign is now with the functional legibility range. This look often continues until the driver requires no further information from the sign or the driver reaches a point that is too close for the sign to be legible. This is the longest look. The duration of Look 3 is determined by a number of variables including font size, drivers visual acuity and contrast sensitivity as well as the amount of information present on the sign.

Literature Review

Sign Condition

Sign performance v reality

Aktan et al. undertook extensive comparisons of the field luminance values of a variety of sign sheeting materials with theoretically established luminance values from the TarVIP software. Results showed systematic differences between the theoretically derived luminance for a reflective sheeting and its measured luminance in the field. Empirically measured field luminance levels were significantly lower at both long and short distances than the suggested theoretical values. The authors concluded that new traffic signs of AS/ANZ 1906.1 Class 1 W reflective sheeting would only achieve luminance values of 40cd/m² when on the nearside of the vehicle – as compared to the maximum theoretical planning value of 70cd/m². Diagram 4 shows the trends of measured luminance for a shoulder mounted sign against the modelled luminance value using TarVIP:

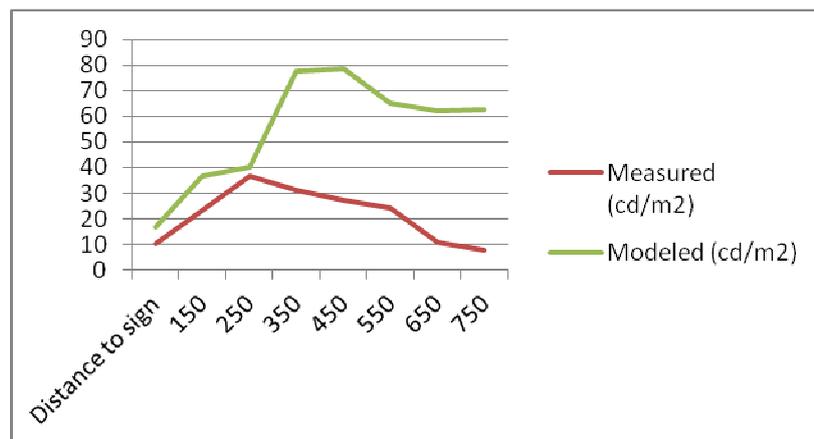


Diagram 4: Graph of measured sign performance against modelled performance for a new signface at increasing distances (feet).

Degrading factors.

There are many different surfaces which can accumulate dirt along the light path from headlights to drivers eye. With regards to sign cleanliness Woltman (1982) references independent studies conducted by Rumar (1974) which determine that dirt can reduce sign brightness by up to 50%. Compounding to this his paper states that dirt on the vehicle windscreen can be attributed with further 10% losses in luminance. UK best practise, as detailed in Design Manual for Roads and Bridges TD25/01 requires all road signs to be cleaned every 2 years to ensure the retroreflectivity is not degraded too significantly to impair legibility to drivers.

Signage material degradation

A study conducted by the Australian Research Board detailed by Jenkins and Gennaoui in 1992 evaluated the rate of degradation of the signing materials used on signs across the Australian Road network. They found that the following environments increased the rate of sign degradation –

locations north of Rockhampton (increased UV exposure), sighting of signs near industrial facilities and in addition the accumulation of dirt on the sign surface all reduced the performance of a sign at a greater rate. The study also considered what life expectancy could be achieved from a sign face, and found that in all but one cases sign performance met the requirements of the AS/NZS 1906.1:1993 standard for performance at end of specified life.

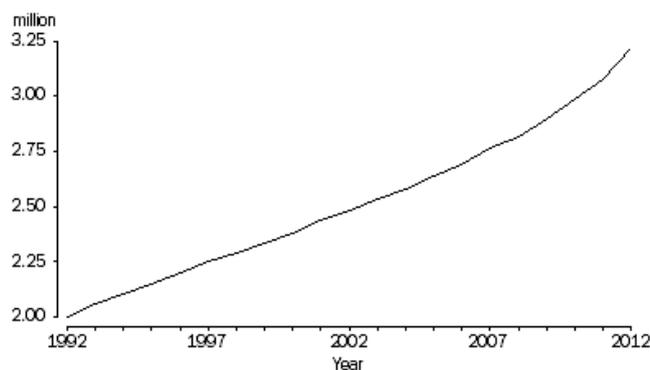
Human Factors

Drivers ability

Work undertaken by Horswill, Anstey, Hatherly, Wood, Pachana (2011) suggests that older drivers' self-monitoring judgements on hazard perception performance appear to have little or no correspondence to objective measures of hazard perception skill. Drivers are unaware of their actual reactive ability in driving situations, implying that often additional time than anticipated is needed to execute the needed reaction. This suggests the need for signage to give warning as far in advance as possible. Wood, Chaparro, Lascherez and Hickson (2011) conclude that there is compelling evidence that older drivers are most likely to have crashes in complex situations such as intersections and yielding rights of way as a result of their inability to filter and focus on the most relevant information within the driving environment. This tendency is a result of older drivers not being able to focus on the relevant critical information related to the road whilst inhibiting the impact of irrelevant distractions. Driving more slowly is not guaranteed to reduce crash rates, and indeed could lead to traffic incidents due to other drivers having to manoeuvre around the slow vehicle.

Population Megatrends

Australia's population is set to change substantially over the next 50 years, with around one in four Australians being 65 years or older by 2056, according to the latest population projections released today by the Australian Bureau of Statistics (ABS). These projections are based on a series of assumptions that take into account recent trends in fertility, mortality and migration. The proportion of people aged 65 years and over has increased from 11.5% to 14.2%, due to the first cohort of the 'Baby Boom' generation. During the same period, the proportion of population aged 85 years and over has more than doubled from 0.9% in 30 June 1992 to 1.9% of the total population at 30 June 2012 (www.abs.gov.au). In 2005 61% of Australians over 70 years old are licensed to drive. (AustRoads, Factsheet 2005)



Graph showing population growth of persons aged 65 Years and Over

Owens et al cite from the National Safety Council statistics that adjusted for mileage the fatality rate at night is two to four times higher than the daytime rate (National Safety Council 1990-1998, 1999-2004).

Older drivers experience the most limited vision at night, due to natural visual deterioration, with a 60 year old person requiring eight times the amount of light needed by a 20 year old (Marland 1967). Diagram 5 illustrates Marlands findings that the amount of light requires to see during the hours of darkness doubles every 13 years of age.

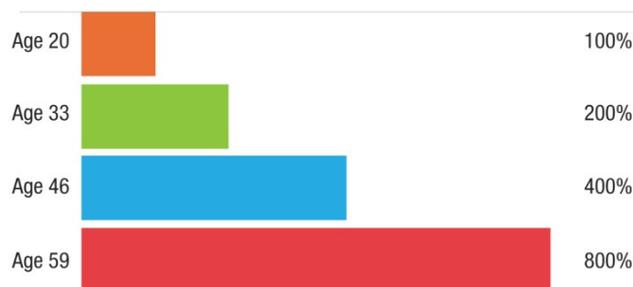


Diagram 5: Schematic showing the amount of light required to see during the hours of darkness as age increases.

Luminance level

Various studies have been conducted to determine optimal and minimum luminance levels, Schnell et al (2009) agree that the minimum luminance level required is 3.2 cd/m² and optimum is 80 cd/m², though the higher the luminance level the faster the information acquisition time by the driver, especially for drivers over 65 years of age. A 50% reduction in luminance level required an additional 20% reading time.

Other studies on traffic sign luminance worked with subjective ratings of visibility.

Table 1 is from the 1990 IRF report that summarizes results obtained at subjective rating experiments at the University of Darmstadt, Germany. The results relate to dark surroundings with a luminance of 0.01 cd/m², with varying luminance level of the signface under test.

Rating Scale	Subjective Response	Luminance cd/m ² (estimate from graphic)
1	Too Bright not recognisable	3,000
2		600
3	Bright Recognisable	300
4		70
5	Optimal Luminance	25
6		7
7	Dark Recognition	2
8		0.7
9	Too dark, not recognisable	0.3

Table 1 Summary of Subjective Rating Responses

Further studies done at the University of Darmstadt by Frank (1994) confirmed that the above results in a brighter environment or in the presence of glare from oncoming vehicles, the required sign luminance levels are increased by a factor 4, as illustrated in diagram 6.

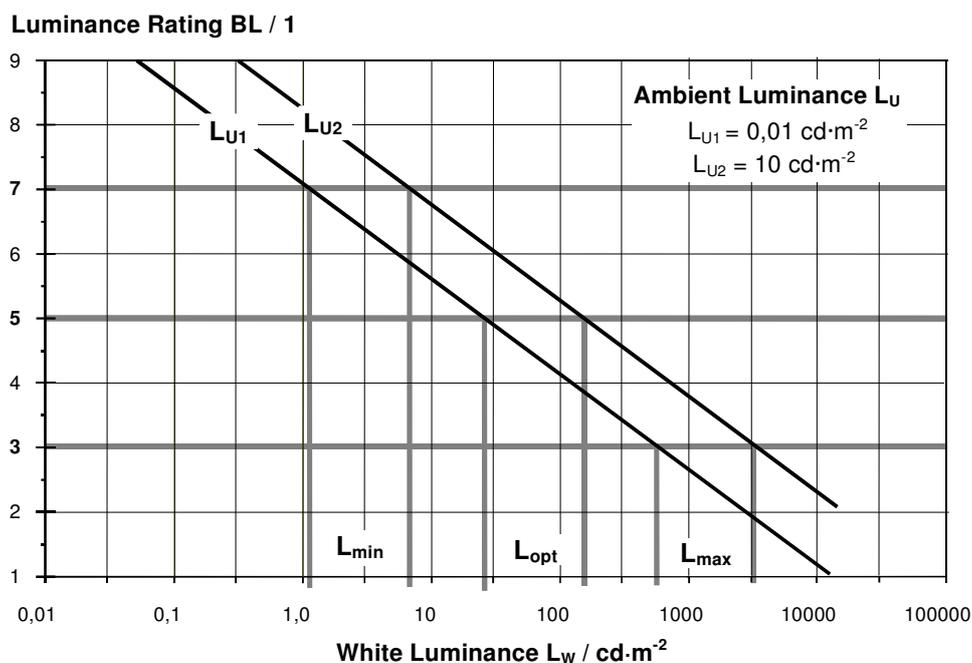


Diagram 6: Luminance Rating of Test Signs

Two discrete ambient luminance levels of 0.01 cd/m^2 and 10 cd/m^2 are shown with an observation distance of 70 m without glare. The minimum luminance level, making the sign 'dark, recognizable' is 8 cd/m^2 in the bright environment. This study gave the optimum range to be between $40\text{-}250 \text{ cd/m}^2$.

Related to sign luminance, and some might say more importantly is sign contrast, of which there are two main categories: legend versus background on a signface, and the contrast between the sign itself and its environmental background. Wood et al (2009) found during their closed road study that high contrast of road obstacles, against their background environment, could provide adequate visual indication of hazards to those drivers with visual impairments. The outcomes indicated a direct relationship between sign luminance and the luminance of the surrounding environment, where it can be established that a non reflective sign in a night time environment will have half the recognition distance to an illuminated or retroreflective sign in the same environment.

Schnell et al. found that the sign contrast ratio of 6:1 (legend : signface) gave shortest information acquisition time for a range of luminance levels. Sign luminance values recorded by Aktan and Burns for retroreflective sheeting with coloured overlay saw that the use of traffic industry transparent coloured overlay generates a 6:1 contrast ratio for the green coloured overlay when placed onto white substrate sheeting.

Road Users

Roaduser type

The drivers vantage point from different vehicles varies greatly, as the vehicle becomes larger it can be assumed the observation angle between the light source and the drivers eye increases. As has been indicated earlier in this paper the retroreflected light profile is unique to each different microprismatic sheeting, therefore it is key for specifiers to identify the correct retroreflective sheeting for the need. The USA has a more complex structure of categories within its signage performance standard (ASTM D4956-11a), compared to performance classes in Europe and Australia which have predominately 3 performance classes.



Diagram 7: Demonstrates differences in observation angle for a driver of a car compared to a truck

The AS/NZS 1906.1:2007 standard sets the performance levels of retroreflective sheetings for different observation and entrance angle combinations. These combinations help traffic designers to specify the materials that will best suit the range of road users in various sign positions. Using the simplifications illustrated in diagram 7 showing eye positions of different vehicle drivers it can be expected that a truck driver receives a much lower luminance level than that received by a car driver from a retroreflective sign. In prEN 12899-6:2012 it is estimated that drivers in large vehicles receive only 35% of the luminance level seen by passenger car drivers.

Diagram 8 gives the proportion of different classes of vehicles registered in Australia in 2012. It shows that 24% of Australian vehicles are not passenger cars, indicating a high proportion of road users are exposure to more disadvantaged levels of light return. (Australian Bureau of Statistics).

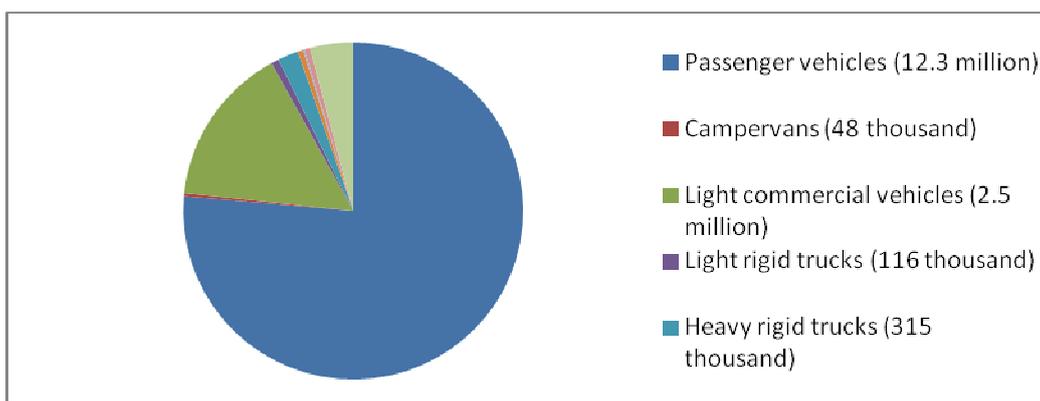


Diagram 8: Percentage of vehicles registered within Australia in 2012.

Headlights

Headlight output

Owens et al 2007 cite research conducted by Sullivan in 2004 into the habits of headlight beam level they used by drivers, with a significant number of motorists continuing to use low-beam even when high beam would be better suited to the conditions. They also cite that studies by Rumar in 1968 in Scandinavia saw that the luminous intensity of highlights could be reduced by up to 60% and the light distribution profile altered due to dirt on headlight units.

The sign placement relative to the vehicle position will have the greatest influence on the illuminance on the sign and proportionally affect the retroreflected light seen by the driver. In prEN 12899-6:2012 it is estimated that shoulder mounted signs on the right receive 63% and overhead gantry signs 47% of light compared to the standard sign position (2.5 m high and 5 m to the left from the vehicle axis). The ratios are approximated over the relevant distance range and representative of average European low beam headlamps as illustrated in diagram 9.

The sharp cut_off of modern headlamps also result in stronger differences in traffic sign illuminance when comparing low-beam to high beam headlamp pattern. Schoettle, B., Sivak, M.,

and Flannagan in 2001 reported average headlamp outputs as market-weighted percentile distribution. Comparing this data at test angles relevant for traffic sign illumination, it can be shown that traffic sign illuminance with high beams is a factor 25 to 30 greater compared to low-beam. Generally for retroreflective traffic signs, this increase is proportional to the observed traffic sign brightness. It can be concluded that subjective reports on too bright traffic signs can be associated with high beam use.

The profile of the headlight effects what proportion of light is returned back to the driver from different sign locations. Traffic scheme designers need to be aware of this when deciding on sign placement, from diagram 9 it can be seen that a sign correctly mounted on the left hand shoulder can return up to 100% of the exposed light from the headlights, however an overhead sign has a very much reduced return of up to 47%.

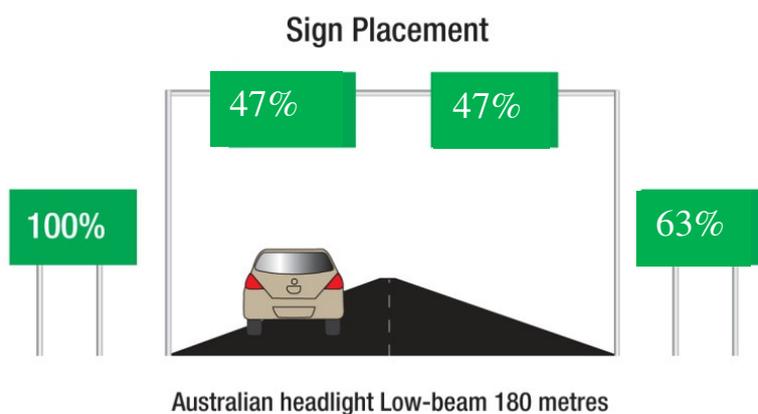


Diagram 9: Schematic of modelled light return percentages from different sign locations

Passive versus Active Sign Illumination

There are a variety of specifications in place for internally and externally illuminated signs. A regular assumption is that internally illuminated sign designers have total control over the amount of luminance they can provide from a sign.

The requirements for internally illuminated signs in Europe can be found in EN 12899-1:2007 and range from 40 – 900 cd/m² for the white luminance with 40 – 150 cd/m² being the lowest luminance output class. Sometimes external lighting is used for shoulder mounted signs. In these cases often a luminance of about 25 cd/m² is available. The requirements for such signs in the USA can be found in IESNA RP-19, which recommends for low ambient conditions 22 to 44 cd/m²: For medium ambient conditions, recommendations range from 44 to 89 cd/m², and for high ambient conditions recommendations reach 178 cd/m². Both standards from Europe and USA were consulted in the publishing of the RTA specification document TSI-SP-008.

In the recent decade LED signage has become more apparent on the roads due to improved performance and efficiencies and the reduced size of LED lamps compared to the previous incandescent varieties. LED technology has seen the growth of variable message and driver feedback signs. In Europe the EN 12966-1 was written to standardise the output and performance of such signs. A driver speed feedback LED sign meeting the L2, B2 classes of this standard gives a head-on luminance output of 600 cd/m². In general, luminance levels of traffic signs with active illumination are much higher than what can be expected with retroreflective signs.

Following studies in 1957 by The Bureau of Public Roads in the US found that the use of

retroreflective sign sheeting for sign backgrounds lead to detection distances being four times greater than for non reflective backgrounds, it has been standard practise to use such sheeting for traffic signage. However since the first retroreflective sheeting developed in 1939 there have been endless improvements in manufacture and technologies resulting in micro-prismatic, truncated cube corner and full cube corner materials which have a much higher light return efficiency compared to traditional embedded glass bead technology especially at small observation angles. These changes will move retroreflective traffic sign performance closer to the optimum luminance levels for sign legibility.

Discussion

As can be seen there is a wealth of research conducted in these and related areas, all of which are unified in the statement that each road user as well as road situation is unique. Thus there is no 'one size fits all' solution and appreciation must be taken of the type and likely age of the road user as well as the siting location of the sign itself. Data drawn upon here highlights the growing population who benefit from the higher luminance signage as well as freight traffic which represents the largest proportion of night time road users.

There are several factors which can degrade the retroreflective performance of a traditional traffic sign, the literary research given above indicates that a newly installed AS/NZS 1906.1 Class 1X sign, installed in optimum locations (near side shoulder mounted) will deliver 40 cd/m^2 , which is mid-range in the optimum luminance needed to gain minimum sign recognition time. Factoring in the trends of headlight performance and the impact of dirt on both the sign face and vehicle effective luminance experienced by the driver could be down to 20 cd/m^2 . This research supports the specification of Class 1X materials for signage on road networks carrying significant freight or night traffic.

Schnell et al. (2003) discuss the impact of signs being reported as too bright, an effect often called 'overglow'. Research from Frank (1994) for very dark surround showed 300 cd/m^2 of traffic sign brightness as maximum tolerable, a value considerably higher than what could be achieved with any retroreflective sheeting and low beam headlamps. However, when driving with high beam headlamp, the surround luminance level in front of the vehicle is raised, leading to eye adaptation level at that higher ambient luminance. This will in turn raise the maximum tolerable traffic sign luminance.

Therefore in answer to the question 'Are Traffic Signs too bright?' Perceived sign brightness is increasing but it could be argued it is at the same rate as the population is aging. Care and consideration must ultimately be taken to ensure the sign is fit for purpose and positioned correctly to provide the best performance to the widest spectrum of road users.

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