



A REVIEW OF DAYTIME RUNNING LIGHTS



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Executive Summary

Introduction

Daytime running lights (DRLs) are bright white forward-facing lights that improve the forward conspicuity of vehicles in the daytime. That is, they are intended to increase the chance of other motorists seeing the approach of a vehicle fitted with DRLs.

In 2002, the National Roads and Motorists' Association Limited (NRMA) commissioned research on the use of DRLs, that focused on the following issues:

- The application of the generally favourable effectiveness studies from high-latitude countries to mid-latitudes such as Australia.
- *Possible* disadvantages of using DRLs: increased fuel consumption, decreased bulb life, masking of other lights, effects on vulnerable road users.
- Recent technology that might improve the effectiveness or decrease the disadvantages of DRL use.
- The visual ergonomics of DRLs - theoretical analysis of the effective range of DRLs under a variety of lighting conditions.
- Benefits and (tangible) costs of DRL.
- Practical issues affecting motorists - availability of DRL systems, tips for using them etc.

In order to explore the issue thoroughly, data on illumination theory and effectiveness of DRLs was sourced from both Australian and international literary databases, government organisations, road safety stakeholders and motorists' organisations. The findings of the research study are outlined below.

Types of Daytime Running Lights (DRLs)

Three main types of DRLs are currently in use around the world:

- a) low-beam headlights that illuminate when the car is started ("immediate headlights").
- b) dimmed high beam headlights - the voltage to the high-beam headlights is regulated so that they have greatly reduced intensity.
- c) dedicated lights with a defined beam pattern and light intensity.

Increased intensity yellow turn signals have also been used for DRLs. These illuminate constantly until the turn signal control is activated and then they flash (Bergkvist 1998).

In each case the vehicle is usually wired so that the DRLs illuminate whenever the engine is running.

DRLs that do not utilise normal low-beam headlights must deactivate whenever normal headlights come on.

Lamps that use Light Emitting Diodes (LEDs) are now being fitted to commercial vehicles as rear and side marker lamps (Decker 2000). They are claimed to require much less power for the equivalent performance. However, with current technology, this is only true with coloured LEDs (there are inefficiencies in producing a white light from LEDs). As this technology develops, LEDs may be utilised to provide a more energy efficient type of DRL.

International use of DRLs

Several countries in high northern latitudes have mandatory use of DRLs. Finland was the first to introduce mandatory DRLs in 1972, which were at that time confined to rural roads in winter. In those countries where DRLs are mandatory, numerous studies of their effectiveness have been conducted over the past three decades.

Availability of DRLs in Australia

Immediate DRL (either headlights or dedicated DRL) are not available as standard equipment on any vehicle models sold in Australia. However, several vehicle manufacturers offer immediate headlights as a dealer-fitted option.

Retrofit kits for immediate headlights are available, but are not common. The ease of fitting the systems varies considerably between vehicle models, and some vehicles with new electronic wiring systems are unsuitable for any modification that is not provided by the vehicle manufacturer.

In short, the technology available in Australia is not quite ready for the optimum implementation of dedicated DRLs that automatically switch over to the headlights when light levels fall.

Regulations and standards

Particular standards and regulations around the world govern the specifications for acceptable DRLs.

Australian Design Rule 76/00 'Daytime Running Lamps' sets out requirements for optional lamps fitted to vehicles sold in Australia. The ADR calls up Europe (UN ECE) Regulation 87 'Uniform provisions concerning the approval of daytime running lamps for power driven vehicles'.

The Society of Automotive Engineers has published a Surface Vehicle Recommended Practice J2087 (revised July 1997) 'Daytime running lights for use on motor vehicles'.

Canada Motor Vehicle Safety Standard 108 specifies requirements for the mandatory fitting of DRLs to vehicles built from 1st December 1989. The USA has a similar standard but DRLs are not compulsory in the USA.

Several countries require the use of DRLs under traffic laws but, apparently, they are not required to be 'hard wired': Denmark, Finland, Hungary, Iceland, Norway and Sweden.

Benefits of using DRLs

Overseas studies have shown that daytime running lights reduce daytime accidents by making vehicles more conspicuous to other road users.

The greatest benefits are with the more severe accidents, including head-on and intersection crashes and collisions with pedestrians and cyclists.

According to European studies on the effectiveness of DRLs in improving road safety, the potential savings are:

- 25% of daytime multi-vehicle fatal accidents (11% of all non-pedestrian fatal accidents)
- 28% of daytime fatal pedestrian accidents (12% of all fatal pedestrian accidents)
- 20% of daytime multi-vehicle injury accidents
- 12% of daytime multi-vehicle property accidents

These are remarkable savings for a relatively simple vehicle safety feature.

DRLs also provide safety benefits for pedestrians that arise from the improved conspicuity of approaching vehicles. Similar benefits apply to other vulnerable road users such as bicyclists and motorcyclists and there is a strong case for fitting dedicated low-wattage DRLs to motorcycles to reduce motorcycle crashes.

Additional important benefits of DRLs reported in the studies are outlined below:

- DRLs provide not only improved visibility (detection) but also improved reaction times and estimation of speed and distance.
- In addition to increasing the distance at which vehicles could be reliably detected, DRLs make vehicles appear closer. This makes drivers more likely to reject short gaps for a potentially hazardous manoeuvre.
- The initial positive effects of DRLs do not dissipate over time (i.e. there is unlikely to be a novelty effect).

Varying Effectiveness of DRLs

While all types of DRLs are likely to produce road safety benefits in Australia, some types of DRLs can be expected to be much more effective than others, particularly under the brighter daylight conditions generally experienced in Australia, compared with high-latitude countries.

Visual ergonomic analysis, which measures the effective range of DRL under a variety of lighting conditions, suggests there is likely to be a wide variation in the effectiveness of these devices due to factors such as:

- the intensity of light produced,
- the direction of the beam,
- the diameter of the globe,
- the amount of glare produced, and
- the lighting conditions of the environment in which the vehicle is driven.

In particular, the poorest performing options, such as low beam headlights, are probably ineffective on bright days. This hinders the application of overseas effectiveness studies to Australia. Similarly there is a wide variation in the disadvantages of these devices, such as increased fuel consumption, decreased globe life, glare and masking of other lights.

On the basis of these investigations it is recommended that *immediate* headlights (that is, low beam headlights that automatically turn on when the vehicle starts) not be encouraged in Australia. Although immediate headlights have been shown to produce crash reductions in overseas studies, the effectiveness of their ability to increase a vehicle's visibility can be shown to be marginal, at best, in many road situations that are encountered in Australia. Other concerns about the use of low beam headlights are:

- They waste energy, with most light directed at the roadway (the tail lamps are also unnecessarily illuminated).
- They can produce confusing reflections from wet roads (also due to most light being directed at the roadway)
- There is an increased frequency of globe failure. This may result in a larger proportion of vehicles operating with one headlight at night.

- The latest European style low beam headlights produce much less light in the direction of oncoming road users than older designs of headlights (particularly US designs). They are probably less effective as a DRL than the ones involved in the effectiveness studies.

The Best Type of DRLs for Australian Conditions

If any modifications are to be conducted to a vehicle (either on the production line or by retrofit) then dedicated DRLs offer the best all-round performance under the range of lighting and road conditions typically encountered in Australia. This is because they direct the light in the most appropriate direction and are therefore much more energy efficient than headlights. In 1993 an expert working group of Commission Internationale de l'Eclairage (CIE) made a strong recommendation for dedicated DRLs and pointed out why alternatives such as low beam headlights and dimmed high beam headlights are less desirable.

Issues with introducing dedicated DRLs in Australia

Several issues need to be addressed before motorists (and vehicle manufacturers) are encouraged to fit dedicated DRLs:

- a) The maximum permitted intensity specified in ADR76 (actually ECE Regulation 87) needs to be reviewed. An intensity of 1200cd for a universal system (bright day to dusk) is considered appropriate, based on scientific recommendations and signal range theory for road conditions generally encountered in Australia. For example, on cloudy days (or early dusk) such lights could be expected to be highly effective for overtaking situations on 100km/h roads whereas 800cd lights are likely to be marginally effective.
- b) A light sensor should be used to automatically switch from DRLs to headlights at dusk. This would eliminate concerns about DRLs being left on at dusk and producing undue glare. There could also be provision for increased intensity (beyond 1200cd) where a light sensor is provided to detect bright ambient lighting conditions.
- c) The minimum area of illumination required by ADR76/ECE87 should be reviewed to provide for the possible use of new technology such as LEDs
- d) Dedicated DRLs should have priority over fog lights as a purchase decision.

Some of these issues are currently being discussed in Europe as part of a review of ECE Regulation 87.

Conclusion

Daytime running lights have been proven to make an effective contribution to the reduction of daylight accidents and overall road safety. Pending the introduction of suitable dedicated DRLs for Australian vehicles, it is considered that the voluntary (manual) use of headlights during the day should continue to be encouraged.

Introduction

Daytime running lights (DRLs) are bright white forward-facing lights that improve the forward conspicuity of vehicles in the daytime. That is, they are intended to increase the chance of other motorists seeing the approach of a vehicle fitted with DRLs. Three main types of DRLs are in use:

1. low-beam headlights that illuminate when the car is started ("immediate headlights").
2. dimmed high beam headlights - the voltage to the high beam headlights is regulated so that they have greatly reduced intensity.
3. dedicated lights with a defined beam pattern and light intensity.

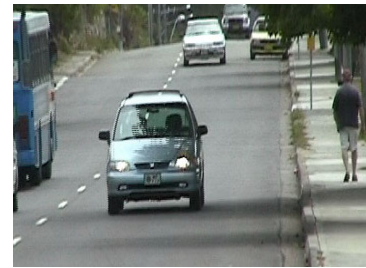
Increased intensity yellow turn signals have also been used for DRLs. These illuminate constantly until the turn signal control is activated and then they flash (Bergkvist 1998).



Dedicated DRL



High beam headlight (reduced intensity)



Low beam headlight (sometimes reduced intensity)

In each case the vehicle is usually wired so that the DRLs illuminate whenever the engine is running.

DRLs that do not utilise normal low beam headlights must deactivate whenever normal headlights come on.

Several countries in high northern latitudes have mandatory use of DRLs - the first being Finland in 1972 (at that time confined to rural roads in winter). In those countries numerous studies of the effectiveness of DRLs have been conducted over the past three decades.

The NRMA recently conducted research on the use of DRLs that focused on the following issues:

- The application of the generally favourable effectiveness studies from high-latitude countries to mid-latitudes such as Australia.
- *Possible* disadvantages of DRLs: increased fuel consumption, decreased bulb life, masking of other lights, effects on vulnerable road users.
- Recent technology that might improve the effectiveness or decrease the disadvantages of DRLs.
- The visual ergonomics of DRLs - theoretical analysis of the effective range of DRL under a variety of lighting conditions.



Increased intensity turn signals

- Benefits and (tangible) costs of DRL.
- Practical issues affecting motorists - availability of DRL systems, tips for using them etc.
- Options for promoting DRLs (if appropriate) - encouraging voluntary use, changes to regulations etc.

Sources of data

Literature databases were searched for references to daytime running lights and conspicuity. Internet searches were conducted, including government publications such as the US National Highway Transport Safety Administration (NHTSA) and the UK Department of Transport, Environment and Regions.

Key road safety people (mostly from government departments) were contacted throughout Australia and in New Zealand, UK, Belgium, Germany, Japan, Sweden, Canada, USA and the Netherlands. Visual ergonomics and lighting experts in Australia, UK and USA were also contacted.

A request for information was also posted on the Road Transport Technology email network. This is run by Cambridge University in the UK and has more than 200 subscribers. This generated a lively debate and provided some useful extra references.

The NRMA provided some references. The RACV provided a draft report on its recent policy investigations into DRL.

Illumination Theory

In order to fully appreciate the findings of this project a basic understanding of illumination theory is desirable, as set out below. This section is based on Ryer (1998) and Scieber (2000).

Light is visible electromagnetic radiation and covers wavelengths from 380 (violet) to 730 (red) nanometres. The human eye is more sensitive to the middle wavelengths (green and yellow) and perceives these colours as being brighter for the same radiant energy. To account for this the measurement of light (known as photometry) involves the application of a bell-shaped weighting formula to the radiant energy. The weighting system was developed by Commission Internationale de l'Eclairage (CIE) and is known as the spectral luminosity function.

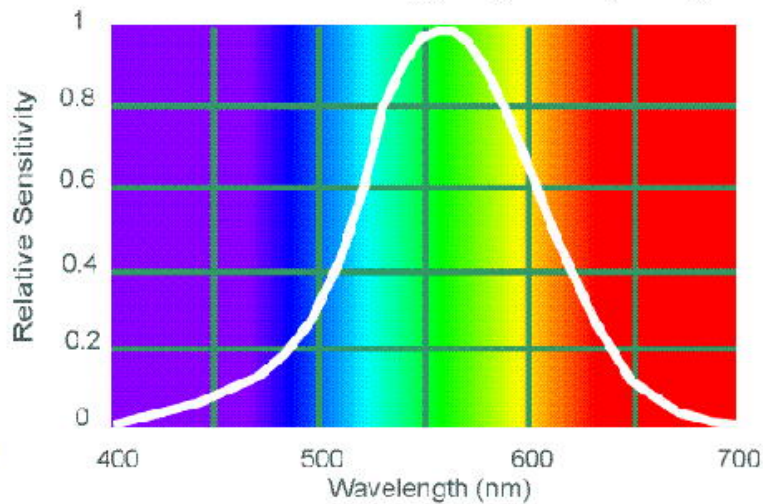


Figure 1. CIE Spectral Luminosity Function

<http://www.usd.edu/~schieber/trb2000/sld022.htm>

Radiant energy (Watts) is converted to luminous flux (light), measured in lumens by analysing the radiant energy at each wavelength. A lumen is the photometric equivalent of the Watt and takes into account the eye's sensitivity. Like the wattage of a light globe, it applies to all of the light emitted by a source.

Luminous intensity is the amount of luminous flux emitted in a specific direction. It therefore takes into account the uneven distribution of light typical of most sources - the headlight is an extreme example. Luminous intensity is measured in **candela**. One candela is one lumen emitted through one steradian (a steradian is a cone with an apex angle of approximately 45 degrees). The manner in which it is measured means that luminous intensity is independent of the distance from the object - it is a measure of a property of the light source. The characteristics of light sources, including the beam pattern, are therefore usually expressed in candela.

Illuminance is a measure of the light falling upon a specific surface area. Illuminance is measured in lux. One lux is one lumen per square meter. Illuminance is important for assessing the effectiveness of street lighting and the like but is not directly relevant to the assessment of vehicle signal lights.

Luminance is a measure of luminous flux from a diffuse light source such as the sky. It is measured in candela per square metre (**cd/m²**). Typical values for the sky are set out in Table 1. Background luminance affects the conspicuity of light signals. It is important that signal design takes into account the large range in luminance encountered during a typical day.

Table 1. Typical Luminance (Cole 1972)

Sky Conditions	Luminance (cd/m ²)
Bright day	10,000
Cloudy day	1,000
Heavily overcast	100
Sunset	10

The upper limit to human tolerance is around 70,000 cd/m², as is sometimes encountered on a beach or on snow during a sunny day.

If light intensities are too high they can cause discomfort or even partial blindness. "**Discomfort glare**" is annoying to oncoming drivers but is unlikely to affect driving performance. "**Disability glare**" impedes the driving task. There is no clear distinction between the two types of glare but as light intensity increases discomfort glare becomes disability glare. In practice, discomfort glare can be tolerated for short times, such as with flashing turn signals or flashing lights on emergency vehicles (the flashing does not reduce the discomfort but the signals will usually only be visible for a short time). Disability glare should be avoided at all times.

The human eye adjusts to the level of background luminance and so a light that is quite acceptable by day can cause discomfort at night. For this reason, vehicle regulations limit the maximum luminous intensity of lights that are used at night. In some cases, such as rear tail lamps, the light is barely discernible if illuminated during a bright day.

Results of literature review

Regulations and standards

Australian Design Rule 76/00 'Daytime Running Lamps' sets out requirements for optional lamps fitted to vehicles sold in Australia. The ADR calls up Europe (UN ECE) Regulation 87 'Uniform provisions concerning the approval of daytime running lamps for power driven vehicles'.

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Effectiveness studies

There have been numerous studies of the effectiveness of DRL. Below is a selection of reports that have either reviewed the studies or provide findings that are relevant to Australia.

SWOV

In 1997 a thorough review of effectiveness was conducted by SWOV (Institute for Road Safety Research, The Netherlands - Koornstra, Bijleveld and Hagenzieker, 1997). The authors re-evaluated numerous DRL studies and reported on accident reductions, latitude effects, costs and benefits and some technical issues. Key findings related to effectiveness were:

- Failing to see another road user in time (or at all) is a contributing factor in 50% of all daytime accidents and 80% of all daytime intersection accidents.
- DRLs improve visibility (detection) but also improve reaction times and estimation of speed and distance.
- Meta analysis of mid-latitude effectiveness studies revealed statistically significant accident reductions but a reasonably strong latitude effect. For example, the USA and Israel had about one third of the reduction in relevant accidents of that experienced in Scandinavian countries.

- The largest savings are in high severity accidents

The authors estimate that full application of DRLs across all EU countries would prevent:

- 24.6% of fatalities in multi-vehicle daytime accidents
- 20.0% of casualties in multi-vehicle daytime accidents
- 12.4% of all multi-vehicle daytime accidents (i.e. about half the rate of serious accidents)

The authors note that DRL-influenced accidents such as head-on collisions and intersection collisions tend to be the most severe. For similar reasons DRL benefits for pedestrians are probably greater than for motor vehicle occupants.

A benefit cost analysis (revised in an Erratum apparently issued after 1998) estimated that dedicated DRLs with two 21W lamps would have a benefit/cost ratio of 1.76.

Insurance Institute for Highway Safety

The Insurance Institute for Highway Safety (IIHS), based in Virginia USA, has been promoting the concept of DRLs since the mid 1980s. Dr Allan Williams from IIHS provided a copy of paper he co-authored for the journal Public Health Reports (Williams A and Lancaster K, 1995). In personal correspondence Dr Williams advised that the paper sets out the Institute's current policy. Key points in that paper were:

- The crash reduction potential of DRLs is a function of their ability to attract attention, especially in the peripheral visual field, and to enhance detectability.
- Nearly all published studies indicate that DRLs reduce daytime multiple vehicle crashes but nearly all the studies have design or analysis weaknesses, or small sample sizes.
- Most of the studies were in high latitude countries and the applicability of the results to lower latitudes is uncertain. However, positive effects can be expected (the authors suggest between 5 and 10% of daytime multiple vehicle crashes).
- Most of the observed crash reductions were at the low end of the predicted savings, made prior to the introduction of DRLs.
- The initial positive effects of DRLs do not dissipate over time (i.e. there is unlikely to be a novelty effect).
- Based on all of the evidence from DRL studies, the concern that DRLs would make vulnerable road users (such as pedestrians and pedalcyclists) less conspicuous does not appear to translate into a crash problem. On the contrary, these road users probably benefit most from DRLs because they are better able to detect hazardous approaching vehicles.
- Motorcyclists who currently use DRLs might lose some of their conspicuity advantage but again this may be more than offset by the benefit of early detection of approaching vehicles.
- Headlight DRLs have the disadvantage that tail lights are also illuminated (unless specially wired). This can partially mask the brake lights in bright daylight. The authors note however that high-mounted brake lights eliminate this problem.
- Increased risk taking is unlikely to occur because there is no direct feedback to the driver of the improved conspicuity of their vehicle.

- State laws requiring the use of motorcycle headlights in the daytime have been found to reduce fatal motorcycle crashes by about 13%.

General Motors, USA

DRLs have been standard on all General Motors vehicles produced since 1995 and more than 23 million vehicles now have them. A mixture of the three main types of DRL, plus increased intensity turn signals, have been used during this period. Bergkvist (1998) reports on a study of the effects of implementation of DRLs on certain models of GM, Saab, Volvo and Volkswagen passenger cars. This study showed:

- a reduction in relevant multiple vehicle crashes in excess of 5% and
- a reduction in urban vehicle-to-pedestrian collisions of approximately 9%.

The author notes that DRL-influenced collisions tend to be the most severe: head-on collisions and intersection collisions.

Paul Thompson, Regulatory Standards and Consumer Information Manager for GM, advised that a further effectiveness study had recently been conducted and that the results would be presented at the 2003 Conference on the Enhanced Safety of Vehicles (ESV). GM is lobbying for DRLs to be made mandatory on all vehicles in the USA. They are also critical of NHTSA investigations into complaints of undue glare from some DRL systems (see next item).

The estimated proportion of GM vehicles fitted with various types of DRLs are set out in the following table (from personal correspondence with Thompson).

Table 2. DRLs fitted to General Motors vehicles in the USA

Type of DRL	% of fleet	Maximum intensity
Dimmed high beam	18%	5,000 - 6,000cd
Dimmed low beam	15%	10,000-12,000cd *
Increased intensity turn signal	41%	800 - 1,000cd
Dedicated DRL	26%	800 - 1,000cd

- Low beam directed downwards. Normally less than 600cd directed towards oncoming drivers for US vehicles.

National Highway Traffic Safety Administration (NHTSA), USA

In 2000 NHTSA issued a technical report "A Preliminary Analysis of the Crash-Reducing Effectiveness of Passenger Car Daytime Running Lamps" (NHTSA 2000). The report concluded that:

- no difference was found in the risk of two-vehicle opposite direction crashes comparing vehicles with and without DRL
- a statistically significant 7% reduction in the risk of non-fatal two vehicle crashes was found
- DRLs are associated with 28% fewer pedestrian fatalities. The result was statistically significant.

The study compared DRL-equipped GM vehicles with similar Ford vehicles (assumed to not have DRLs).

More recently NHTSA (2002) has noted that "a significant number of people have complained to NHTSA about the problem of glare from DRLs". NHTSA proposes to limit the maximum

intensity of DRLs to overcome this problem and is looking for "the optimal balance between improved visibility [conspicuity] and nuisance glare."

Comment: Given that about one fifth of DRL-equipped GM vehicles use dimmed high beams at 5,000cd or more it is not surprising that some complaints are being received. Most people would find 1,500cd annoying in dull lighting conditions (see the section "Glare").

Transport Canada

Canada introduced mandatory DRLs for all new cars in December 1989. In an unpublished technical report Transport Canada reviewed the policy several years after implementation (White 1998). Key points were:

- In addition to increasing the distance at which vehicles could be reliably detected, DRLs make vehicles appear closer. This makes drivers more likely to reject short gaps for a potentially hazardous manoeuvre.
- Unlit vehicles are more likely to be overlooked if other vehicles are lit (mainly a problem at dusk when the lit vehicles had low beam headlights on).
- The Canadian regulation requires hard-wired DRLs (i.e. driver operation of DRLs is not permissible). Options include: low beam headlights, dimmed low beam headlights (75% to 92% of normal lights), dimmed high beam headlights (max 7000cd), turn signals, bright parking lights (max 1200cd), fog lights and dedicated DRL (max 1200cd).
- The maximum permitted intensity of high beam headlights is considerably higher than other types of lights. This is because the high intensity portion is somewhat narrower than other types of lights and needs to be brighter so that it can be detected when viewed from an angle.
- Headlight dimming through reduced supply voltage greatly increases bulb life and moderates the glare from high beams, while retaining sufficient light intensity for conspicuity. It was estimated that dimmed headlights would need to be replaced every six years, on average, compared with every two years if normal headlights were illuminated day and night.
- DRL must operate automatically when the engine is switched on (optionally only when the vehicle starts to move forward or forward gear is engaged). They must switch off when the parking lights or headlights are switched on. Some vehicles in Canada have a photocell system to automatically switch to normal headlights when ambient light is low. Systems can also switch DRL off if the transmission is shifted to "park" or the parking brake is engaged, since DRL are of limited use when the vehicle is stationary.
- Low contrast driving situations are surprisingly common, even in broad daylight.
- Prior to the introduction of mandatory DRLs in Canada, an analysis of ambient daylight revealed that in Canada 54% of total daylight hours were classified as "bright" or "very bright", compared with 40% for Sweden (Environment Canada 1986). It was concluded that the Swedish results could be applied directly to Canada. Subsequent analysis of Canadian accident data confirms its effectiveness across the range of latitudes in Canada (45 degrees to 60 degrees)
- It was estimated that total accident costs would need to reduce by 11.9% to offset the cost of operating normal headlights (and associated lights) in the daytime.
- Initial concerns about the inferior quality of some aftermarket DRL kits resulted in the preparation of Canadian Standard CAN/CSA--D603-88 "Daytime running light systems:

Standard for retrofit DRL kits". The standard has since been withdrawn because it was superseded by the regulations.

- Glare is not a problem during the daytime but it is important that drivers switch to normal headlights when light levels fall.
- "Masking" of unlit vehicles was not found to be a problem. In any case it is generally only a concern around dawn and dusk when there is a mix of vehicles with and without headlights.
- "Veiling glare" that masks pedestrians and cyclists was not found to be a problem with the DRL used in Canada. These road users benefit from being able to see the DRL equipped vehicles sooner than unlit vehicles.
- DRLs have not had any associated effect (either positive or negative) on rear-end collisions (this arose from concern about tail lights not being illuminated when front DRLs are used).
- Mandatory DRLs were found to reduce head-on and turning collisions by 8.3% in daylight and 16.6% during twilight, giving an overall effectiveness of 9.2%. These results were statistically significant. By taking into account the 29% voluntary headlight use before the regulation was introduced the overall effectiveness increased to 12.5% (Arora and others 1994).

A less-supportive report by Tofflemire and Whitehead (1997) found a statistically significant 5.3% reduction in relevant collisions when 1989 cars were compared with 1990 cars. They claimed this was substantially less than the 10 to 20% reductions predicted when the legislation was introduced. They also noted that the reductions mostly involved opposing collisions and that angle (intersection) collisions appeared to be unaffected.

The authors considered the costs of DRLs and concluded that "there is room to disagree over whether the costs of DRLs are outweighed by the benefits".

Australian Road Research Board

Cairney (1990) estimated the possible benefits of introducing DRLs in Australia. Cairney based the analysis on Swedish research. He acknowledged latitude effects but argued that the Swedish results (13% reduction in multiple vehicle accidents) could be used directly for Australia because of the high proportion of Swedish vehicles that had DRLs before they became compulsory. The resulting benefit/cost ratio estimate was between 1.5 and 2.35. Operating costs were assumed to be \$20 per year.

The author suggested that consideration should be given to a light-sensing control that extinguished the DRLs when ambient light was above a certain level. This would reduce the operating costs.

Visual Ergonomics

Several of the reviewed reports covered the subject of visual ergonomics. There are two main issues with DRLs:

- increased conspicuity
- glare affecting other road users

These tend to place conflicting demands on any vehicle lighting system.

Commission Internationale de l'Eclairage (CIE)

In 1993 a thorough report on this subject was issued by the CIE - the international authority on lighting standards (CIE 1993). The CIE report discussed peripheral vision and central vision and concluded that peripheral vision was the most crucial for accident avoidance. The factors affecting signal detection were listed as:

- contrast of the object against its background
- angular size
- motion
- change of intensity (flashing)

The report pointed out that, in practice, contrast (in effect maximum light intensity) and change in intensity are the only factors that are able to be varied. The authors noted, however, that flashing lights are not appropriate for use as DRLs.

Other key findings of the CIE committee were:

- Low beam headlights have been found to be at least as effective as contrasting backgrounds against unlit vehicles (e.g. dark vehicles in snow or light vehicles in a dark forest). More efficient DRLs can be expected to produce better contrast.
- Light intensities of 5000cd are unlikely to create glare problems in bright conditions but should be no more than 1500cd at dawn or dusk.
- Tests by the Society of Automotive Engineers revealed that 2000cd was judged effective for detection in all conditions. 500cd was "not quite acceptable in broad daylight at short ranges."
- Another test program in the USA concluded that at least 1600cd was needed to enhance conspicuity in Californian sunshine.
- Studies of the effectiveness of different colour of DRL were inconclusive. Similarly, the effective illuminated area of the DRL has no effect on performance.

The committee recommended that dedicated DRLs be encouraged. Recommended features were:

- Relatively high intensity: not more than 1200cd in any direction and not less than 400cd along the central axis (the higher value was evidently preferred), decreasing to not less than 100cd at 20 degrees to the side.
- Two white lights mounted at the front of the vehicle
- Minimum area of illumination 40cm².
- Motorists should be encouraged to switch to low beam headlights at dawn and dusk to minimise potential glare problems.

The CIE report briefly commented on alternative DRL systems:

- Standard low beam headlights have proved effective in Sweden and Finland but the (intentional) low intensity in the direction of other road users is "bad as a DRL". They are a waste of energy if used as DRLs. They are considered an acceptable but non-optimum alternative to dedicated DRLs.

- Reduced intensity low beam. Similar to standard low beam but even less effective as DRLs
- Reduced intensity high beam. These have a very narrow beam that is not very effective in urban areas, particularly if the intensity is limited to the recommended 1200cd. If intensity is not reduced glare could be a problem at twilight.
- Combined low and high beams of reduced intensity. These would offer slightly better visual performance than either low or high beam but energy efficiency is poor.
- Standard fog lights. These are similar to low beam headlights but the light pattern tends to be less well controlled so glare might be a greater problem.
- Reduced intensity fog lights. Similar to fog lights.
- Increased intensity position (parking) lights. Light intensity would need to be raised considerably for these to be effective as DRLs. The light pattern is likely to be inefficient.
- Increased intensity turn signals. These would have good light distribution (being essentially the same as that recommended for dedicated DRLs). Yellow colour and confusion when lights flash would be a concern.
- Cornering lights have poor light distribution in the straight ahead direction.

Schug and Sischka (2000) reach similar conclusions about the effectiveness of non-dedicated DRLs:

- "the spatial distribution of today's high beam and the required pattern for DRLs are significantly different",
- "the dimming of the high beam is not an optimal solution for a DRL",
- "The overall shape of the light intensity distribution [of position lamps built into high beam headlights] does not fit [DRL needs] and the absolute values are much too low",
- "an additional globe in a low beam reflector has a strong negative effect on the performance of low beam [if optimised for DRL use]".

In personal correspondence the former chairman of the committee, Professor Rumar, he has pointed out that low beam headlights do have a slight advantage with regard to attracting attention. This is because oncoming motorists continually move into different parts of the beam as the vehicles move along the roadway. This has the effect of modulating the light signal and this modulation can attract more attention (but it does not increase the signal range - see Paine and Fisher 1996).

SWOV

Koornstra and others (1997) reviewed the visual ergonomics of DRLs. Key findings were:

- Visibility does not necessarily imply conspicuity. An object might be visible between similar objects (that is, detectable if the observer is looking for it) but may not be conspicuous (that is, attract the attention of the observer).
- The angle between the object and the direction of view is an important factor in conspicuity, as is contrast between the object and its background.

- For objects illuminated solely by ambient light the conspicuity can change markedly under the diversity of background encountered on the road. On the other hand light sources can be constant and therefore maintain their conspicuity. Unlike unlit objects, the conspicuity of lights will increase as light levels drop.
- The Californian experiments (referred to under "Effectiveness") found a statistically significant improvement in vehicle detection with 1600cd DRLs but no improvement with 800cd DRLs in bright daylight. This was for cars approaching at 20 degrees (peripheral vision).
- SAE tests in Florida found that in bright daylight, when viewed at 8 degrees from 152m: 600cd lamps were hardly noticed while 1500cd lamps were noticed. 5000cd lamps were more noticeable and yet were not considered "too bright". The 600cd lamps became noticeable when light level fell to dusk values. Similar tests in Washington found that 1000cd lamps were considered by most observers to be "glaring" at twilight.
- Dimmed high beams give a very concentrated beam of light. If limited to 1000cd, to avoid glare, hardly any visible light is emitted at angles greater than 5 degrees to each side.

The authors provide a schematic diagram showing the results of conspicuity and glare investigations (Koornstra's Figure 5). This is reproduced in Figure 2 below, with some extra information.

The black triangle (added to the original figure) illustrates the narrow range of light intensity that provides reasonable conspicuity (i.e. typically better than with no DRL) in bright daylight while avoiding discomfort glare at dusk. As recommended by the CIE committee, a DRLs with an intensity of about 1200cd should meet both conspicuity and glare avoidance needs. A brighter DRL in bright daylight is preferred (say 2000cd) but would need to be dimmed under low ambient light levels to avoid discomfort glare.

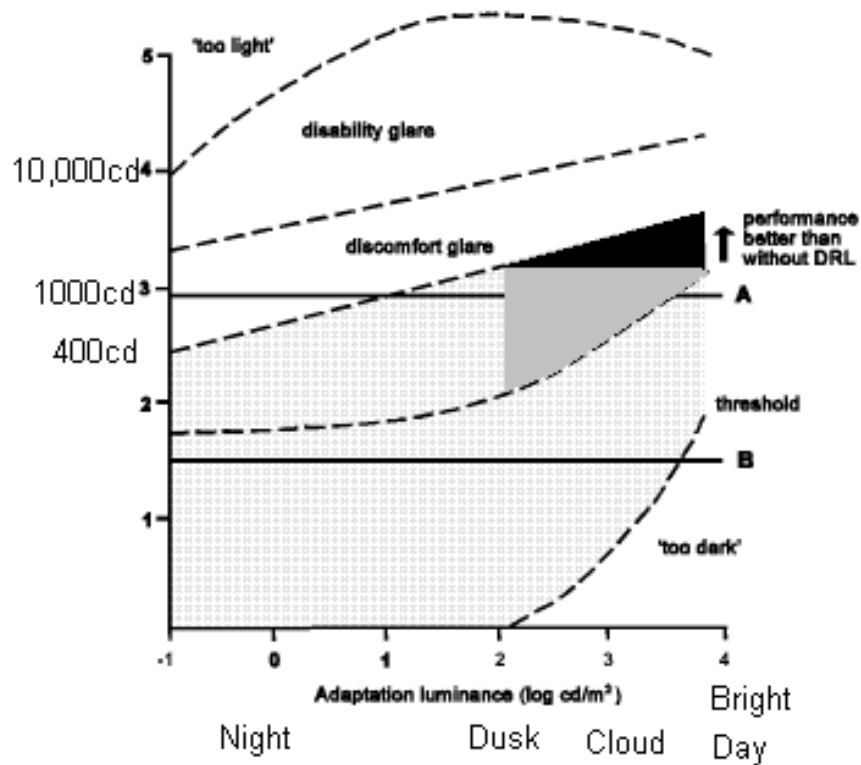


Figure 2. Schematic representation of the balance between conspicuity and glare (adapted from Koornstra and others 1997)

Flashing lights on school buses

Paine and Fisher (1996) carried out an analysis of the performance of potential flashing light systems for school buses. The functional requirements of a signalling system were described. The function is to alert other motorists of the possibility of a hazard. This must occur at a sufficient distance to enable the motorist to take appropriate action (in the case of a school bus, to slow down to about 40km/h - in the case of DRLs, to not move in to the path of the approaching vehicle). To be effective the system must satisfy three requirements:

1. It must be readily seen by the other motorists and it must command their attention. It must stand out in adverse lighting conditions such as bright daylight.
2. It must be recognised in a clear, credible and unambiguous manner.
3. It must elicit an appropriate response, such as not moving in to the path of the vehicle.

Findings relevant to DRLs were:

- "Sufficient distance" for the school bus scenario is 250m for roads with a 100km/h speed limit and 100m for roads with a 60km/h speed limit.
- Considerable research has been conducted on the signal range of traffic lights and that work is applicable to lights fitted to vehicles.
- The human eye is better able to detect a light source if it is close to the line of sight.
- For a given signal range the necessary light intensity is directly proportional to the brightness of the background. If the background luminance doubles then the signal intensity will need to double in order to maintain the same signal range. Since the background luminance can vary from less than 100cd/m² at dusk to 10,000cd/m² on a bright day, the minimum intensity can vary be a factor of 100 (for the same signal range). However, since signal range is proportional to the square root of intensity (and background luminance) then the range of a given signal can vary by a factor of 10 over the range of encountered background conditions.
- Signal detection tests indicate that a yellow light must have three times the intensity of a red lamp in order to achieve the same signal range. Note that the measurement of light intensity (the candela) takes into account the varying sensitivity of the eye to different colours. In effect luminous intensity is a measure of the perceived brightness of a light and it gives more weight to colours in the middle of the spectrum such as yellow. For the same radiant energy a yellow light appears about three times brighter than the red one. From the work with traffic light signals, it appears that the radiant energy of the light is more important *for detection* than its perceived brightness - hence a yellow light needs three times the luminous intensity of a red one to be detected at the same distance. The luminous intensity of a white light could be expected to be about half way between that of a red and yellow light, for the same signal range.

Costs of DRL

Several of the reviewed reports provided estimates of the cost of installing and operating DRL systems.

Transport Canada

White (1998) reports the following cost estimates

- DRLs increase manufacturer's costs by AU\$15 to AU\$40 for a typical passenger car.
- Dimmed headlights add about AU\$4 to AU\$20 to the annual cost of running a car or light truck, compared with no lights.
- Average fuel consumption increases by between 0.15% (for 30 watts of lighting) to 2% (for 100 watts of lighting typical of dimmed headlights).
- Normal low beams, plus tail and side lights that illuminate when the headlights are switched on, increase fuel consumption by about 4.6%.

SWOV

Koornstra and others (1997) provide the following information about costs:

- Dedicated DRLs (400-800cd) usually use two 21W globes (giving a total load of 42W), compared with 55W each for low beam headlights. However, several other lights are usually illuminated with low beam headlights (On its website, lighting manufacturer Hella suggests a total of 145W for dipped low beams plus other lights. They market a dedicated DRLs with a total power consumption of 12W).
- Dimmed high beam headlights consume less power than low beam headlights (value not stated but assumed to be about 90W).
- Retrofit headlight "on" kits cost about AU\$50 to AU\$100 for parts and take about half an hour to install. Headlight "on" alarms are generally standard on most vehicles. Retrofit kits cost about AU\$20 and take 15 minutes to install.
- Production line costs for immediate headlights are estimated to be less than AU\$30. This would be less for the estimated 80% of vehicles that already have the necessary wiring connections in place.
- Annual globe replacement costs (low beam headlights and tail lights) are estimated at AU\$12.
- German and Dutch studies found that low beam headlights (and associated lights) increased fuel consumption by 0.17 and 0.15 litres per 100km respectively, for typical conditions. On the basis that 55% of total vehicle kilometres are driven in daylight Koornstra estimated that overall fuel consumption is increased by 0.9% for low beam headlights and 0.4% for dedicated DRLs (with 21W globes). Emissions are increased by the same amount.

Discussion

Signal range of lamps

The Australian Standard for Traffic Signals (AS2144-1989) specifies the following minimum luminous intensities for traffic signals (Hulscher 1974):

Table 4. Traffic Signal Requirements in Australia

Type of signal	Signal Range (bright daylight)	Red Lamp	Yellow Lamp
General Purpose	100m	200cd	600cd
Extended Range	250m	600cd	1800cd

From this it is estimated that a white signal would need a luminous intensity of 1200cd in order to have the same range as extended range traffic signals. This is in agreement with the maximum DRL intensity recommended by CIE.

The Australian Design Rules specify minimum and maximum intensity values for a range of vehicle lamps. These values, and corresponding signal ranges in bright daylight for the maximum values, are set out in Table 5.

Table 5. Australian Design Rule Requirements for Vehicle Lamps

Type of lamp	Minimum Intensity	Maximum Intensity	Estimated Range*
Front turn signal (yellow, not flashing)	175cd	700cd	110m
Rear turn signals (yellow, not flashing)	50cd	200cd	60m
Rear brake lamp (red, day/night)	40cd	100cd	70m
Rear brake lamp (red, day only)	130cd	520cd	160m
Rear fog lamp (red)	150cd	300cd	120m
Low beam (white, upper portion)	-	437.5cd	100m
Dedicated DRL (white)	400cd	800cd	140m

*Estimated range in bright daylight with light 3° from observer's line of sight and at maximum permitted intensity. Note that the angle is less for the typical roadside geometry of extended range traffic signals and this increases their signal range.

Applying the formula for signal range provided by Paine and Fisher (1996) (derived from Fisher and Cole, 1974) to a range of lamps and light intensities gives the following estimates of signal range, assuming bright daylight and that the light is 3 degrees from the observer's line of sight. Note that duller light conditions would increase the range. Also reducing the angle from the line of sight would increase the range. In each case, however, the relative performance between the lamps is maintained.

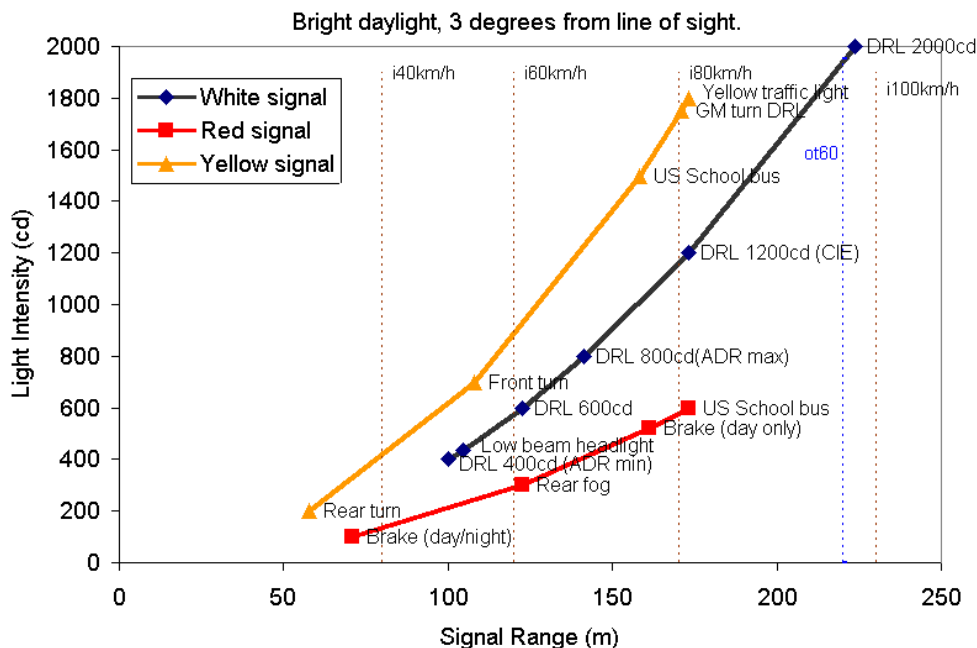


Figure 3. Estimated signal range for a selection of lights on a bright day (background luminance 10,000cd/m²). The vertical dotted lines are explained in the next section.

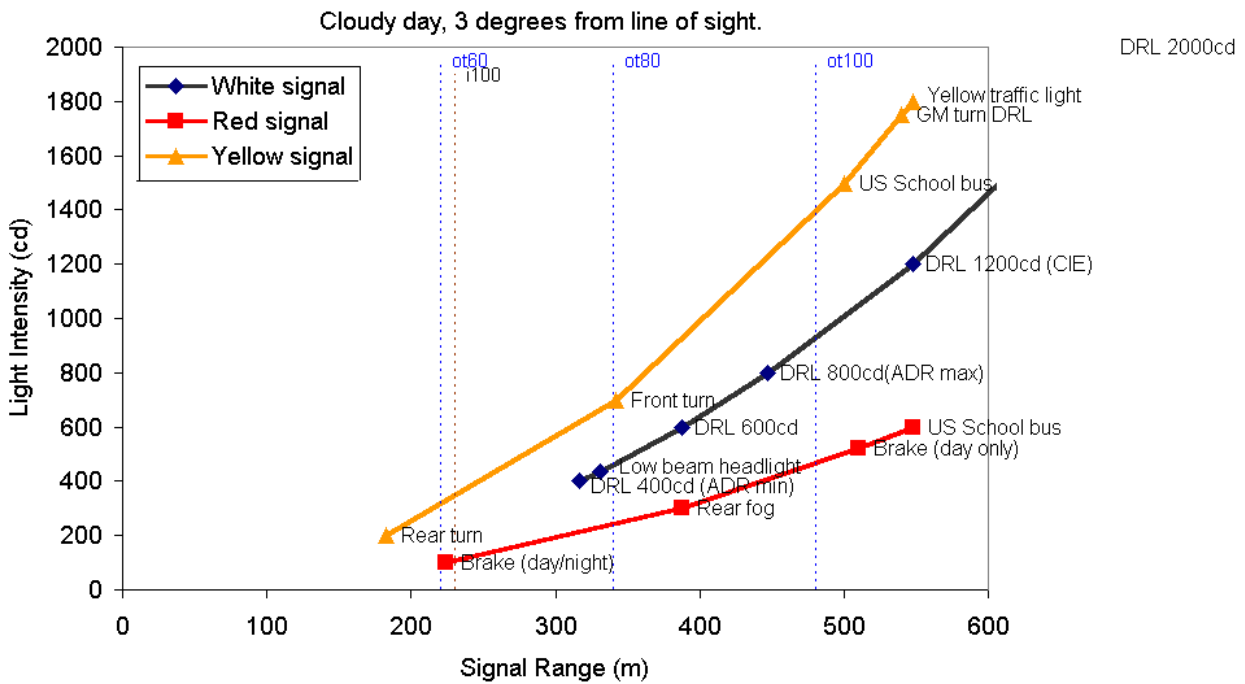


Figure 4. Estimated signal range for a selection of lights on a cloudy day (background luminance 1,000cd/m²)

Required signal range

The signal ranges necessary for safe driving are similar to the "sight distances" used in road design. According to Lay (1991) the "intersection sight distance" provides vehicles stopped at an intersection with sufficient sight distance for them to cross the road safely. The guideline is that the sight distance, in metres, is twice the road design speed, in km/h.

The overtaking situation is more complicated, since the overtaking driver has, up to a point, an opportunity to abort the manoeuvre and return to the correct side of the road. The "continuation sight distance" is the point of no return, beyond which the overtaking driver is committed to passing the vehicle that is being overtaken and returning to the correct side of the road before colliding with an oncoming vehicle.

The continuation sight distance is about twice that for the intersection sight distance, mainly because the closing speed between the overtaking and oncoming vehicles is about twice that of the intersection situation. In both cases the time to collision is between seven to eight seconds.

Table 6. Road Design Sight Distances - metres (Lay 1991)

Design Speed	Intersection sight distance	Overtaking (continuation) sight distance
40km/h	80	160
60km/h	120	220
80km/h	170	340
100km/h	230	480

Several of these sight distances are shown in figures 3 and 4. Tables 7 and 8 summarise the suitability of various lamps for a range of roads and background lighting (worst case).

Table 7. Suitability of lamps for a range of road conditions - bright day.

Type of lamp	Light	Range	Intersection			Overtaking		
			60km/h	80km/h	100	60km/h	80km/h	100
GM Bright turn signal	Yellow 1750cd	170m	Y	Y	N	N	N	N
US School bus	Yellow 1500cd	160	Y	Y?	N	N	N	N
Front turn signal	Yellow 700cd	110m	Y?	N	N	N	N	N
US School bus	Red 600cd	170m	Y	Y	N	N	N	N
CIE DRL	White 1200cd	170m	Y	Y	N	N	N	N
ADR 76 DRL (max)	White 800cd	140m	Y	N	N	N	N	N
Low beam headlight	White 437cd	105m	N	N	N	N	N	N
ADR 76 DRL (min)	White 400cd	100m	N	N	N	N	N	N

Table 8. Suitability of lamps for a range of road conditions - cloudy day.

Type of lamp	Light	Range	Intersection			Overtaking		
			60k m/h	80km/ h	100k m/h	60km/ h	80km/ h	100km/ h
GM Bright turn signal	Yellow 1750cd	540m	Y	Y	Y	Y	Y	Y
US School bus	Yellow 1500cd	500m	Y	Y	Y	Y	Y	Y
Front turn signal	Yellow 700cd	340m	Y	Y	Y	Y	Y	N
US School bus	Red 600cd	550m	Y	Y	Y	Y	Y	Y
CIE DRL	White 1200cd	550m	Y	Y	Y	Y	Y	Y
ADR 76 DRL (max)	White 800cd	450m	Y	Y	Y	Y	Y	Y?
Low beam headlight	White 437cd	330m	Y	Y	Y	Y	Y?	N
ADR 76 DRL (min)	White 400cd	320m	Y	Y	Y	Y	Y?	N

Key points arising from this analysis are (subject to assumptions about background illumination and angle of line of sight):

- On a bright day (background luminance 10,000cd/m²) none of the assessed lamps provides a signal range that would assist the overtaking manoeuvre for traffic speeds of 60km/h or more. A much brighter lamp would be needed to cover the worse situation - overtaking on 100km/h roads with a bright sky behind the oncoming vehicle. High beam headlights (maximum permitted intensity 140,000cd) would be suitable for this situation and this suggests that it is important for drivers to be able to flash their high beam headlight if they detect a potentially dangerous overtaking manoeuvre from an oncoming vehicle.
- On a bright day only the brightest of the assessed lamps provides reliable detection for the intersection situation for traffic speeds up to 80km/h. None are likely to be effective for traffic speeds of 100km/h.
- On a bright day DRLs at the brightest permitted under ADR76 (800cd) would not be effective for intersection situations with traffic speeds of about 70km/h or more. DRLs with an intensity of 1200cd would extend this to traffic speeds of 80km/h.
- On a bright day low beam headlights at the brightest permitted under the ADRs (437cd) would not be effective for intersection situations with traffic speeds of about 50km/h or more.

- On a cloudy day (background luminance 1,000cd/m²) the signal range for a given lamp increases by about three times compared with a bright day. This means that nearly all lamps can be expected to be effective under all road conditions on a cloudy day (or darker).
- On a cloudy day front turn signals (normal intensity), low beam headlights and DRLs at the minimum permitted by ADR76 are likely to be ineffective for the overtaking where traffic speeds are 100km/h. DRLs at the maximum permitted by ADR76 (800cd) are likely to be marginally effective at 100km/h. *Brighter 1200cd DRLs would be highly effective at this traffic speed on a cloudy day.*
- At dawn and dusk (background luminance 100cd/m² or less) all assessed lamps could be expected to be effective for all road conditions.

Note that generally on bright, sunny days, the reflection of sunlight off shiny surfaces of the vehicle will provide very long range conspicuity (hundreds of metres). However, even on bright days, situations are frequently encountered where the approaching vehicle is in shade but the background is still bright. In these circumstances the vehicle may not be readily detected without bright DRLs. The illustration on the cover demonstrates this problem.

Overall, white DRLs with an intensity of 1200cd are considered desirable because they will cover intersection situations on bright days with traffic travelling up to 80km/h and they cover all situations on cloudy days. These would have a similar signal range to flashing lights on school buses in the US (associated with high traffic speeds and a wide range of traffic conditions) and extended range traffic lights. This analysis supports the recommendation of the CIE - that DRLs have a maximum intensity of 1200cd. It is also in agreement with Canadian Motor Vehicle Safety Standard 108 that requires dedicated DRLs to have an intensity between 500 and 1200cd (Canada permits a dimmed high beam to have an intensity up to 7000cd but this is because it is a very narrow beam and motorists are encouraged to switch to low beam headlights at dawn and dusk to avoid glare).

The question that arises from this analysis is why did ECE Regulation limit the maximum intensity of dedicated DRLs to 800cd? Professor Kare Rumar, who chaired the CIE Working Party was contacted for advice. In his reply he expressed disappointment that ECE Regulation 87 did not incorporate the committee's recommendation of a maximum intensity of 1200cd. In his opinion the decision was due to an exaggerated scare about glare - the regulators probably justified lowering the maximum value because low beam headlights had been shown to reduce accidents and they did not want to introduce much more glare than occurs with low beam headlights.

Koornstra and others (1997) reported that ECE Regulation 87 had not been agreed to by Austria, Denmark, France, Italy and Spain.

Technology issues

Unwanted light emissions from low beam DRL

Low beam headlights direct most of the light slightly downwards. This is normally not a concern to other motorists because the light is readily dispersed by the rough surface. When the road is wet, however, the brightest part of the beam can be reflected off the roadway. Under some conditions the reflected light can be a much higher intensity than the light reaching oncoming drivers directly from the headlamps (limited to not more than 437cd). This could cause confusion about the actual source of the light. This problem may negate any conspicuity advantage that low beam headlights have under wet conditions in daytime.

reaching oncoming drivers directly from the headlamps (limited to not more than 437cd). This could cause confusion about the actual source of the light. This problem may negate any conspicuity advantage that low beam headlights have under wet conditions in daytime.

Of course, the problem of low beams reflecting off a wet roadway would also occur at night but it is unavoidable then. During the daytime there are better alternatives that do not cause the reflection problem. None of the reviewed studies raised this issue but it is a further concern about the use of normal low beam headlights as DRL.

Parking lights

If dedicated DRLs are to be fitted to vehicles then room needs to be found for them. Many vehicles have a separate lamp unit for the mandatory parking light (also known as a position light). Schug and Sischka (2000) evaluated the possibility of combining DRLs into front parking lights and concluded that the typical light distribution current parking lights was poorly suited to DRLs. This is particularly the case with parking lights built into the high beam headlamp where the beam has an inefficient donut shape (reduced central intensity). There may, however, be an opportunity to incorporate a parking light function within dedicated DRLs.

Parking lights are very rarely used in Australia (note that Australian road rules require parked vehicles to face the same direction as traffic movement). They are sometimes used on moving vehicles during daylight. This may be on the mistaken understanding that they improve conspicuity during marginal lighting conditions. However, visual ergonomics suggests that parking lights are totally inappropriate for such circumstances and, in Australia, motorists should be discouraged from using parking on any moving vehicle.

LEDs

Lamps that use Light Emitting Diodes (LEDs) are now being fitted to commercial vehicles as rear and side marker lamps (Decker 2000). They are claimed to require much less power for the equivalent photometric performance. However, with current technology, this is only true with coloured LEDs (there are inefficiencies in producing a white light from LEDs).

Decker (2000) reports that current LED emit far too little light to be useful as a DRL - about 75 LEDs would be needed for each lamp. Recently developed high intensity LEDs are more promising but would still require about 20 LEDs in each lamp unit. Heat dissipation may be a problem with such configurations.

Furthermore, ADR76/ECE87 requires each lamp to have a minimum illuminated area of 40cm² and LED packages may have difficulty meeting this requirement. This minimum area was also a CIE recommendation. Professor Rumar advises that some European lighting manufacturers are seeking to reduce the minimum area in order to allow more flexibility in lamp design (frontal area of vehicles is at a premium). Personal communications with Dr Rainer Krautscheid from the German road authority BAST confirm this advice. The proposal is that DRLs with an illuminated area of 40cm² or more would be permitted a maximum intensity of 1200cd. Those with an illuminated area between 25 cm² and 40 cm² would be limited to 800cd. *This proposed change is subject to ongoing discussions.*



Figure 5. Prototype turn signal lamp with high intensity LEDs (from Decker 2000)

High beam headlights such as HID lamps

High intensity discharge (HID) headlights are becoming available on some vehicle models. These operate in a similar manner to mercury vapour street lights. A severe limitation is that current designs produce much greater luminous flux than is needed for DRL. Schug (2000) cautions that dimming conventional high beam headlights to intensities that are suitable for DRL applications can severely degrade bulb life (Schug works for Philips - a light bulb manufacturer). Dimmed HID lamps may be worse.

Control with light sensors

Many Canadian vehicles have ambient lighting sensors that switch from DRLs to headlights automatically when light levels fall (ambient light on a horizontal surface less than 1000 lux according to SAE J2087). This overcomes the criticism that DRLs could be inadvertently used at night and cause undue glare. The cost of adding light sensor control is relatively small, compared with the cost of a complete DRL installation.

It appears feasible to adapt this technology to increase DRL light intensity (beyond the 1200cd recommended by CIE) under very bright conditions when glare is not an issue.

Light globes for dedicated DRL

Schug (2000) examines the luminous flux of globes for dedicated DRLs. He concludes that a luminous flux of about 150 lumen is needed to achieve the beam pattern and intensity specified in ECE87 (but with a peak intensity of 600cd rather than 800cd to allow for performance variation). Schug notes that there are currently no conventional automotive light globes with a luminous flux between 125 lm and 300 lm when operating at design voltage. Possible outcomes are:

- A low output globe is used, giving a lower peak intensity (ECE 87 allows a minimum of 400cd) - this would reduce the effectiveness of the DRLs.
- A high output globe is used at a reduced voltage - this could affect globe life and requires voltage regulation (but there is an opportunity to use a light sensor to control the voltage and therefore the lamp intensity).
- A low efficiency reflector is used in conjunction with a high output globe - this would waste energy
- A high output globe is used in conjunction with an efficient reflector - peak intensity would exceed the ECE 87 limit of 800cd but such a signal would be more effective as a DRL.

DRLs in Australia

Availability of DRLs

Immediate DRL (either headlights or dedicated DRL) are not available as standard equipment on any vehicle models sold in Australia. However, several vehicle manufacturers offer immediate headlights as a dealer-fitted option.

For several years Telstra Fleet Services has required immediate low beam headlights on all new vehicle purchases. Advice from Telstra is that none of the vehicle manufacturers has had difficulty complying with the requirement. Telstra insists that the system is factory installed so it is covered by the vehicle warranty.

Retrofit kits for immediate headlights are available, but are not common. Auto-electricians that were approached knew they could acquire the kits but did not have information readily at hand. They also advised that the ease of fitting the system varied considerably between vehicle models. Some vehicles with new electronic wiring systems were unsuitable for any modification that was not provided by the vehicle manufacturer.

Hella Australia recently added a dedicated DRL kit to its catalogue at a retail cost of about \$80 (Part No. 1000). However, enquiries revealed it is not the same as the one being offered by Hella in Europe. Arrangements were made to acquire a European system for assessment since it appears to be much more efficient than the Australian product (less than half the power consumption) and may have a better beam pattern. Appendix B sets out the results of a brief evaluation of the European product. At this stage, Hella have no plans to sell this model in Australia but they would evidently be interested if dedicated DRLs were encouraged by motoring organisations and government.

Vehicles exhibited at the 2002 Sydney Motor Show were checked for DRLs. It appears that none had dedicated DRLs although many had fog lights that are of questionable benefit in fog and tend to cause glare problems due to poor design or inappropriate use (Stern 2002). Some vehicles had headlight switching that facilitated the use of headlights during the daytime (for example, with Subaru vehicles the headlights turn off when the key is removed from the ignition switch. Some models of the following makes had "auto" headlights that measure ambient light and switch on automatically when the light levels are low: BMW, Mercedes Benz, Jaguar, Rover, Renault, Peugeot and Lexus. In each case the headlight control needed to be set to "auto" for this feature to work. All variants of the new VY Holden Commodore have the "twilight sentinel" system that achieves this function. It would, however, be preferable for the function to always be active, if used in conjunction with DRLs. This would then eliminate the possibility of DRLs being inadvertently used at night or dusk.

Enquiries revealed that a light-sensor control unit can be purchased in Australia for about \$16 each (bulk order). Only one dedicated DRL after-market kit is currently available in Australia (Hella Part No. 1000 - considered to be photometrically inferior to the new European model described in Appendix B). This does not have a light sensor function.

In short, the technology available in Australia is not quite ready for the optimum implementation of DRLs - dedicated lights, as recommended by the CIE Working Party, that automatically switch over to the headlights when light levels fall.

Application of effectiveness studies

It is evident from visual ergonomic considerations that most of the DRLs, as used in Scandinavia, Canada and the USA are, at best, marginally effective on bright days and some popular ones such as low beam headlights can even be expected to be marginally effective on cloudy days. A wide range in effectiveness could therefore be expected and this appears to be the case in the studies that have been carried out in those countries.

In theory, the DRL system recommended by CIE (with peak intensity of 1200cd and a spread beam) should be considerably more effective over the range of daylight conditions encountered in Australia than all existing systems (note the GM dimmed high beam is brighter but the beam is very narrow). However, there is no indication of the real world effectiveness of the CIE system since none are in use.

Koornstra and others (1997) applied latitude effects to derive an estimate of accident savings for all EU countries. On the basis that the population centre of Europe is approximately 50°N (Paris) and that of NSW (and Australia) is 35°S (Sydney) then Koornstra's latitude data suggests that the Australian accident savings would be about half of those for Europe. On the other hand, if more effective DRLs (than the low beam headlights that are popular in Europe and North America) are introduced in Australia then the latitude effects would be overcome and the full savings predicted for Europe should be achievable in Australia. In any case, it was noted that Canada experienced similar crash reductions to Sweden, despite being at a lower latitude.

Stern (2002 - personal correspondence) cautions that European low beam headlights produce much less upward light than US low beam headlights. Similarly European high beam headlights are much more centre weighted than US ones (Stern also recommended that, in Australia, consideration be given to side marker lights that are mandatory in the USA - that recommendation is beyond the scope of the present project.). Since Australian vehicles tend to be based on European equipment it is possible that North American DRL studies (and even early European studies) would not be directly applicable to Australia if they involved a high proportion of vehicles that utilise headlights as DRLs. This concern would be overcome if the CIE-recommended DRLs are introduced.

Urban traffic speeds in Australia tend to be higher than those in Europe (for example urban speed limits are typically 60km/h in Australia compared with 50km/h in Europe - McLean and others 1994). Low beam headlights could therefore be expected to be less effective in urban areas of Australia than in Europe, since theoretical analysis suggests they have insufficient signal range on a bright day when traffic is travelling at 60km/h or more.

In view of the uncertainty about the application of overseas data to Australia it is considered appropriate that high and low values for effectiveness be evaluated. It was decided to use the upper values based Koornstra's predictions for Europe (for multi-vehicle daytime accidents: 25% of fatal accidents, 20% of injury accidents and 12% of property accidents). The lower values are NHTSA's estimates (7% for all multi-vehicle daytime accidents).

Overseas experience suggests that pedestrian and cyclist accidents are reduced through DRL. The upper value for pedestrian accidents is that reported by NHTSA (28% of daytime pedestrian *fatalities*) and the lower value is based on the General Motors study (9% of daytime pedestrian accidents).

Relevant crashes in Australia

NSW accident data (RTA 2000) indicates that 64% of fatal crashes and 79% of non-fatal crashes occur during the daytime. 70% of fatal crashes are multi-vehicle and 75% of non-fatal crashes are multi-vehicle. It is therefore estimated that $64\% \times 70\% = 45\%$ of fatal crashes and $79\% \times 75\% = 59\%$ of non-fatal crashes could be influenced by DRL.

In the case of pedestrians, RTA data indicates that 44% of pedestrian fatalities occur during daylight hours (RTA 2001).

Estimated accident savings

Based on the assumptions set out above, it is estimated that full implementation of DRL in Australia would save:

- Between 3% and 11% of all non-pedestrian fatal crashes
- Between 4% and 15% of all non-pedestrian non-fatal crashes
- Between 4% and 12% of all pedestrian fatalities.

Since pedestrian fatalities comprise about 20% of all road fatalities, the overall savings translate to between 3% and 11% of all fatal crashes (including pedestrians).

These estimated savings have been applied to a benefit/cost analysis for DRLs in Australia.

Benefit cost analysis for Australia

In 1998 Vehicle Design and Research carried out some related investigations for the Roads and Traffic Authority of NSW (Paine and Gibbs, 1998). The RTA's Economic Analysis Manual (RTA 1998) was used as a basis for that work. However, the Manual was primarily intended for assessment of roadworks and it was not directly applicable to vehicle safety features. It was therefore adapted for the 1998 project in consultation with the RTA's economic analysis personnel. In essence, the methodology involved converting the annual cost of road crashes to an annual dollar risk *per vehicle*. The benefits of applying a safety feature to a particular vehicle could then be estimated, based on the types of crashes that the safety feature was likely to influence, and the effectiveness of the feature in such crashes (the percent that are likely to be saved).

A significant advantage of this approach is that it is independent of the proportion of the fleet fitted with the safety feature.

Briefly, the steps involved are:

Estimate the initial cost of the feature and the annual cost of the feature (maintenance or amortised replacement)

1. Identify the group(s) of vehicles to which the safety feature is applicable
2. Calculate the annual crash risk, in terms of road crash dollars, for fatal, serious injury, minor injury and non-injury crashes for a single vehicle.
3. Determine the types of crashes potentially influenced by the safety feature. For example, driver airbags are generally only of benefit in a frontal crash.
4. Estimate the proportion of the influenced crashes that are likely to be saved by use of the safety feature. This step usually has the greatest uncertainty.
5. Calculate the crash savings, based on steps 3, 4 and 5.
6. Calculate the net annual savings by subtracting the annual (maintenance) cost from the estimated crash savings
7. Determine appropriate financial values to use in the benefit/cost analysis (7% discount rate and 10 year evaluation period)
8. Calculate the benefit/cost ratio by applying the Present Value formula to the net annual savings and dividing by the installation cost.

$$B/C = \frac{PV(\text{annual crash savings} - \text{annual maintenance, 7\% for 10 years})}{\text{Installation cost}}$$

Cost of road crashes

The RTA Economic Analysis Manual uses generalised crash costs - namely a generic cost of each fatal, serious injury, minor injury and non-injury crash. In most cases no attempt is made to identify the costs for particular types of crashes, although some information is available for crashes involving heavy trucks.

The RTA Manual gives costs per crash. For a safety feature analysis it is necessary to convert this to a cost per car involved. The following table shows the derivation of these costs.

Table 9. Estimated crash costs per registered vehicle
(Based on NSW crash statistics for 1999)

Cars on register: 2,661,000.00

Crash Type	Car crashes	Cars in crashes	Ratio Car/Crash	Cost per crash#	Cost per car invol.	Rate per 10K cars	Cost per car reg.
Fatal	402	528	0.76	\$937,000	\$713,398	1.98	\$141.55
Hosp Inj*	3,825	5,750	0.67	\$175,000	\$116,413	21.61	\$251.55
Other inj*	13,413	20,386	0.66	\$27,000	\$17,765	76.61	\$136.10
Non-Injury	31,226	52,875	0.59	\$12,200	\$7,205	198.70	\$143.16
						<u>298.91</u>	<u>\$672.36</u>

* Estimated from 17238 total with 22% being hospital admissions

Based on RTA Economic Analysis Manual, 1999, Table 8

This analysis indicates that the "average" car represents a crash risk valued at \$672 per year. This is the maximum amount that could be saved if all crashes were eliminated. This is somewhat less than the typical amount that vehicle owners pay in insurance premiums to cover personal injury and property losses. Furthermore it does not take into account the traumatic effects that a fatal or serious crash can have on business, family and friends.

Costs of DRL

The costs of DRLs in Australia will depend on the type of system installed, whether it is fitted during vehicle manufacture or afterwards and on the usage and performance characteristics of the vehicle. All retrofit cost estimates include labour at \$80/hour. Estimates of labour times were verified by two Sydney auto-electricians but can vary considerable between different models of vehicle.

The costs of dealer-fitted immediate headlight kits are likely to be between the "production line" and "retrofit" values.

In order to derive useful estimates of benefits and costs, the following two scenarios have been analysed. Other scenarios such as dimmed high beams, lie between these two.

Immediate low beam headlights (headlights on)

- Supply and installation: production line \$15 per vehicle, retrofit \$150.
- Annual costs: \$12 for globe replacement, \$13 for extra fuel (assuming that a typical 8,250 km per year is driven in daytime and that low beam headlights plus associated lights consume an extra 0.15 litres per 100km - note this is half the Canadian estimate). Total extra annual cost \$25.

Dedicated DRLs (21W each light):

- Supply and installation: production line \$50 per vehicle, retrofit \$200.
- Annual cost: \$2 for globe replacement (nominal), \$11 for extra fuel (45% of low beam value based on wattage comparison - note that Hella low wattage DRLs could reduce this to less than \$5). Total extra annual cost \$13 (less than \$7 for Hella system).

Estimated benefit/cost ratios

Appendix A sets out the calculations for the benefit/cost ratio analysis. The results are set out in Table 8.

Table 10. Estimated benefit cost for DRLs in Australia

Type of DRL	Factory Fitted		Retrofit	
	Low B/C	High B/C	Low B/C	High B/C
Immediate low beam headlights	0.66	18.95*	0.07	1.89*
Dedicated front light units	1.88	7.37	0.47	1.84

* Large uncertainty for Australian application

For comparison, under this methodology (and using conservative values), a driver airbag has a benefit cost ratio of 0.79 (Paine and Gibbs 1998).

Only retrofitted immediate headlights have a worse-case benefit cost ratio that is substantially worse (lower) than that for a driver airbag. This particular scenario produced net annual savings of only \$1.40 per year and it is very sensitive to the assumed costs and savings. Factory-fitted immediate headlights have similar sensitivity, although the lower installation costs resulted in a more favourable benefit cost ratio.

Although factory-fitted immediate headlights produced the highest best-case benefit cost ratio of all scenarios, this option has the greatest uncertainty in the application of overseas crash reductions to Australia. In other words, although it looks good on paper it may not translate into real world accident savings. The same concerns apply to retrofitted immediate headlights, under the best-case scenarios.

Conclusions

Daytime running lights reduce daytime accidents by making vehicles more conspicuous to other road users. The greatest benefits are with the more severe accidents, including head-on and intersection crashes and collisions with pedestrians and cyclists. There are a variety of DRLs in use around the world, from headlights to dedicated additional lights. Visual ergonomic analysis suggests there is likely to be a wide variation in the effectiveness of these devices. In particular the poorest performing options, such as low beam headlights, are probably ineffective on bright days and marginally effective on cloudy days. This hinders the application of overseas effectiveness studies to Australia. Similarly there is a wide variation in the disadvantages of these devices, such as increased fuel consumption, decreased globe life, glare and masking of other lights.

On the basis of these investigations it is recommended that *immediate* headlights not be encouraged in Australia. Although immediate headlights (that is, low beam headlights that automatically turn on when the vehicle starts) have been shown to produce crash reductions in overseas studies, their photometric performance can be shown to be marginal, at best, in many road situations that are encountered in Australia. Other concerns about the use of low beam headlights are:

- They waste energy, with most light directed at the roadway (the tail lamps are also unnecessarily illuminated).
- They can produce confusing reflections from wet roads (also due to most light being directed at the roadway)
- There is an increased frequency of globe failure. This may result in a larger proportion of vehicles operating with one headlight at night.
- The latest European-style low beam headlights produce much less light in the direction of oncoming road users than older designs of headlights (particularly US designs). They are probably less effective as a DRL than the ones involved in early effectiveness studies.

If any modifications are to be conducted to a vehicle (either on the production line or by retrofit) then dedicated DRLs offer the best all-round photometric performance under the range of lighting and road conditions typically encountered in Australia. They direct the light in the most appropriate direction. They are therefore much more energy efficient than headlights and less likely to cause glare problems. In 1993 an expert working group of Commission Internationale de l'Eclairage (CIE) made a strong recommendation for dedicated DRLs and pointed out why alternatives such as low beam headlights and dimmed high beam headlights are less desirable.

Several issues need to be addressed before motorists (and vehicle manufacturers) are encouraged to fit dedicated DRLs:

- The maximum permitted intensity specified in ADR76 (actually ECE Regulation 87) needs to be reviewed. An intensity of 1200cd for a universal system (bright day to dusk) is considered appropriate, based on CIE recommendations and signal range theory for road conditions generally encountered in Australia. For example, on cloudy days (or early dusk) such lights could be expected to be highly effective for overtaking situations on 100km/h roads whereas 800cd lights are likely to be marginally effective.
- A light sensor should be used to automatically switch from DRLs to headlights at dusk. This would eliminate concerns about DRLs being left on at dusk and producing undue glare. There could also be provision for increased intensity (beyond 1200cd) where a light sensor detects bright ambient lighting conditions.
- The minimum area of illumination required by ADR76/ECE87 should be reviewed to provide for the possible use of new technology such as LEDs
- Dedicated DRLs should have priority over fog lights as a purchase decision. Many vehicles now have provision for fog lamps in the front bumper and the space would be better utilised for DRLs.



Figure 6. Provision for fog lights within the front bumper of many models

Some of these issues are currently being discussed in Europe as part of a review of ECE Regulation 87.

Daytime running lights are a good idea and, pending the introduction of suitable dedicated DRLs, it is considered that the voluntary (manual) use of headlights during the day should continue to be encouraged in Australia. The issue with hard-wired, immediate headlights is that dedicated DRLs are a much better and more cost-effective way to improve daytime conspicuity.

If brighter (1200cd) DRLs are introduced then there is the potential to exceed the high effectiveness observed in some European countries. This is because most of DRLs involved in those studies would have had lower intensity than the recommended system and they would have been of marginal benefit on bright days (around 50% of daylight hours). Observed "Latitude effects" (reduced effectiveness at lower latitudes) are likely to have arisen from the marginal effectiveness of DRLs involved in the studies and these effects would be eliminated by brighter DRLs.

Based on the European studies, the potential savings are:

- 25% of daytime multi-vehicle fatal accidents (11% of all non-pedestrian fatal accidents)
- 28% of daytime fatal pedestrian accidents (12% of all fatal pedestrian accidents)
- 20% of daytime multi-vehicle injury accidents
- 12% of daytime multi-vehicle property accidents

These are remarkable savings for a relatively simple vehicle safety feature.

The large benefits to pedestrians arise from improved conspicuity of vehicles - the pedestrian is less likely to move into the path of an approaching vehicle that is equipped with DRLs. Similar benefits would apply to other vulnerable road users such as bicyclists and motorcyclists. Claims that cars with DRLs would seriously "mask" unlit road users have been shown to be unfounded. Such effects, if any, would be small and would be overwhelmed by the benefits from improved conspicuity of DRL-equipped vehicles.

There is also a strong case for fitting dedicated low-wattage DRLs to motorcycles, since they overcome concerns about power consumption that have been the main objection to daylight use of headlights on motorcycles. Studies in the US indicate that the use of motorcycle headlights in the daytime reduces fatal crashes by about 13%. Dedicated DRLs on motorcycles could be expected to achieve greater savings since they have better photometric performance than low beam headlights. The combination of cars and motorcycles with dedicated DRLs could lead to exceptional motorcycle crash reductions.

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Appendix A - Details of Benefit Cost Analysis

The following pages are from a custom database that calculates the benefit cost ratios of vehicle safety features.

SAFETY FEATURE ANALYSIS

FEATURE CODE NRMA-DRL1 **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DRL USING LOW BEAM HEADLAMPS, FACTORY INSTALLED
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$15.00 **MAINTENANCE/YR** \$25.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS LOW VALUE BASED ON NHTSA

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	7%	7%	7%	7%
\$ SAVED PER VEHICLE/YEAR	\$4.47	\$10.41	\$5.62	\$5.91
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$26.40
BENEFIT/COST RATIO	0.66	NET SAVINGS/YR		\$1.40

FEATURE CODE NRMA-DRL1B **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DRL USING LOW BEAM HEADLAMPS, FACTORY INSTALLED
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$15.00 **MAINTENANCE/YR** \$25.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS HIGH VALUE BASED ON SWOV (PROBABLY TOO HIGH FOR AUSTRALIA)

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	25%	20%	12%	12%
\$ SAVED PER VEHICLE/YEAR	\$15.98	\$29.74	\$9.63	\$10.12
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$65.46
BENEFIT/COST RATIO	18.95	NET SAVINGS/YR		\$40.46

SAFETY FEATURE ANALYSIS

FEATURE CODE NRMA-DRL2 **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DRL USING LOW BEAM HEADLAMPS, RETROFIT
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$150.00 **MAINTENANCE/YR** \$25.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS LOW VALUE BASED ON NHTSA

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	7%	7%	7%	7%
\$ SAVED PER VEHICLE/YEAR	\$4.47	\$10.41	\$5.62	\$5.91
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$26.40
BENEFIT/COST RATIO	0.07	NET SAVINGS/YR		\$1.40

FEATURE CODE NRMA-DRL2B **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DRL USING LOW BEAM HEADLAMPS, RETROFIT
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$150.00 **MAINTENANCE/YR** \$25.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS HIGH VALUE BASED ON SWOV (PROBABLY TOO HIGH FOR AUSTRALIA)

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	25%	20%	12%	12%
\$ SAVED PER VEHICLE/YEAR	\$15.98	\$29.74	\$9.63	\$10.12
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$65.46
BENEFIT/COST RATIO	1.89	NET SAVINGS/YR		\$40.46

SAFETY FEATURE ANALYSIS

FEATURE CODE NRMA-DRL3 **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DEDICATED DRL, FACTORY FITTED
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$50.00 **MAINTENANCE/YR** \$13.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS LOW VALUE BASED ON NHTSA

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	7%	7%	7%	7%
\$ SAVED PER VEHICLE/YEAR	\$4.47	\$10.41	\$5.62	\$5.91
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$26.40
BENEFIT/COST RATIO	1.88	NET SAVINGS/YR		\$13.40

FEATURE CODE NRMA-DRL3B **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DEDICATED DRL, FACTORY FITTED
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$50.00 **MAINTENANCE/YR** \$13.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS HIGH VALUE BASED ON SWOV

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	25%	20%	12%	12%
\$ SAVED PER VEHICLE/YEAR	\$15.98	\$29.74	\$9.63	\$10.12
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$65.46
BENEFIT/COST RATIO	7.37	NET SAVINGS/YR		\$52.46

SAFETY FEATURE ANALYSIS

FEATURE CODE NRMA-DRL4 **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DEDICATED DRL, RETROFIT
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$200.00 **MAINTENANCE/YR** \$13.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS LOW VALUE BASED ON NHTSA

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	7%	7%	7%	7%
\$ SAVED PER VEHICLE/YEAR	\$4.47	\$10.41	\$5.62	\$5.91
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$26.40
BENEFIT/COST RATIO	0.47	NET SAVINGS/YR		\$13.40

FEATURE CODE NRMA-DRL4B **CATEGORY** HAZARD RECOGNITION BY OTHERS
DESCRIPTION DEDICATED DRL, RETROFIT
READINESS HARVEST **ACCEPTANCE** GOOD
NET COST (1 OFF) \$200.00 **MAINTENANCE/YR** \$13.00
INFLUENCE SEE MAIN REPORT

EFFECTIVENESS HIGH VALUE BASED ON SWOV

CRASH SAVING ANALYSIS	FATALS	SERIOUS	MINOR	PROPERTY
CRASH COST/VEHICLE/YEAR	\$142.00	\$252.00	\$136.00	\$143.00
% OF CRASHES INFLUENCED	45%	59%	59%	59%
% EFFECTIVENESS	25%	20%	12%	12%
\$ SAVED PER VEHICLE/YEAR	\$15.98	\$29.74	\$9.63	\$10.12
DISCOUNT RATE 7.00%	OVER 10 YEARS	TOTAL SAVINGS/YR		\$65.46
BENEFIT/COST RATIO	1.84	NET SAVINGS/YR		\$52.46

Appendix B - Evaluation of Hella Dedicated DRL

Hella Australia acquired a sample of the European "Daytime Running Lamp Set" (Part No.2PT 008 362-801) and provided it to VDR for evaluation.

Description of product

The set consists of two lamp units, each with a 6W halogen globe, mounting brackets, wiring and a relay. The circuit diagram indicates the method of installation to ensure that the DRLs illuminate whenever the ignition is on and the headlights are off.

It took less than an hour to install the system on a 1997 Honda Odyssey vehicle. With practice the installation should take less time.

The lamps appear to be marginally brighter than low beam headlamps (in the straight ahead position). They are likely to be somewhat less than the maximum 800cd allowed under ECE Regulation 87. Normal practice is to design lamps for about 80% of the regulation limit to ensure conformity during production. This would mean the Hella lights have a luminous intensity of approximately 600cd.

The beam pattern is clearly optimised for DRL use with the maximum intensity in the straight ahead position and as fan-shaped beam that gives good horizontal spread.



Installed dedicated DRL



Vertical and horizontal distribution of beam

On road performance

Informal observation of the DRLs confirms that they appear to be slightly brighter than normal low-beam headlights, when viewed from the straight ahead position. They were not considered to be glaring under any daylight conditions. Some drivers might consider them slightly annoying after sunset (when low beam headlights should be used in place of the DRLs).

A series of on-road evaluations were videoed to gain an idea of the relative performance of the Hella DRLs against the other options: low beam headlights, high beam headlights (but not dimmed, as they would be in the USA and Canada) and turn signals. A straight, relatively flat section of a suburban road was used. It was a very bright day but a thin cloud cover softened the shadows. The sun was almost directly overhead. The following snapshots from the video illustrate each of the systems when the vehicle passed a group of trees about 170m from the observer.



No lights



Low beam headlights



High beam headlights



Hella DRLs



Car with low beam headlights

(Vehicle with Hella DRLs following)



Van with no lights

The image of the van without lights (above) illustrates the problem of vehicles moving in and out of shadows. In this case the road was relatively light coloured and so the outline of the van stood out. In other circumstances it might be less conspicuous. The advantage of all of the tested DRL systems is that they remain conspicuous when the vehicle moves in and out of the shadows.

The high beam case was clearly the most conspicuous but would have been annoying to other drivers, even on such a bright day. Although not readily evident in the snapshots, the Hella dedicated DRLs did appear to have higher intensity than the low beam headlights and were judged to be more conspicuous.

Driving experiences

When driving a DRL-equipped vehicle it is difficult to judge whether the DRL has prevented a potential conflict situation. However, the author was involved in one situation with pedestrians where the presence of the DRL may have prevented an accident.

While driving along the Pacific Highway near Raymond Terrace I noticed that a road maintenance truck was parked beside the road. No warning lights were operating on the truck but I slowed to less than the 100km/h speed limit. Suddenly a pedestrian emerged from the front of the truck. He ran across two lanes to the median strip but it was evident that he realised he taken a grave risk. Then a second pedestrian started to follow - again hidden from my view by the truck. As he stepped onto the roadway that person looked in my direction and fortunately made a split-second decision to stop walking. It was a bright day but thin cloud meant that there was no reflection of sunlight off my vehicle. It is therefore entirely possible that the DRLs contributed to the quick decision made by the second pedestrian. I had started to brake heavily but may not have been able to stop in time if the second pedestrian had continued walking.