DAYTIME RUNNING LIGHTS FOR MOTORCYCLES

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ABSTRACT

The daytime use of motorcycle headlights has had mixed success in various countries. Dedicated lights that are optimised for use as daytime running lights (DRLs) can be far more effective and energy-efficient than low beam headlights.

A difficulty with motorcycles is a lack of space for fitting extra lights at the front. In the USA many General Motors cars use bright yellow front turn signals as DRLs. The feasibility of applying this approach to motorcyles is examined. Initial research suggests that bright yellow DRLs could be highly cost effective for preventing motorcycle accidents. Technology improvements such as Light Emitting Diodes and ambient light sensors would make them even more effective.

INTRODUCTION

Motorcycle accidents

Motorcycle riders make up about 17% of vehicle operator fatalities in Australia. Per kilometre travelled, motorcycle riders are 29 times more likely to be killed than operators of other vehicles. Motorcycle operators in in the 17 to 25 age range have almost 100 times greater risk than operators of other vehicles (ATSB 2002).

About two-thirds of Australian motorcycle accidents occur in daylight and 65% involve more than one vehicle. It was reported that in 21% of daytime multi-vehicle collisions the driver of the other vehicle claims to have not seen the motorcycle (Hendtlass 1992).

More recently, an in-depth study of motorcycle crashes in Europe found that in 37% of all cases the primary contributing factor was the failure of another vehicle operator to detect the motorcycle (ACEM 2004). 73% of accidents occurred in daylight and a further 8% at dawn or dusk. It is notable, however, that the headlights were in use in 69% of these accidents. Unfortunately any link between detection failure and lack of headlights is not reported by the authors but it is evident that many cases involve motorcycles with illuminated headlights that are not seen by other motorists.

Daytime running lights

Daytime running lights (DRLs) are bright white or yellow forward-facing lights that improve the forward conspicuity of vehicles in the daytime. They are intended to increase the chance of other road users seeing the approach of the vehicle.

Four main types of DRLs are currently in use:

a) low-beam headlights that illuminate when the vehicle is started

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

d) increased intensity yellow turn signals. These illuminate constantly until the turn signal control is activated and then they flash on one side.

In each case the vehicle is usually wired so that the DRLs illuminate whenever the engine is running. DRLs that do not utilise low-beam headlights must deactivate whenever normal headlights come on.

In the case of motorcycles DRLs are almost always low-beam headlights.

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 and only allows white lamps to be used as DRLs.

SAE Recommended Practice J2087 'Daytime running lights for use on motor vehicles' is an optional standard.

Canada Motor Vehicle Safety Standard 108 specifies requirements for the mandatory fitting of DRLs to vehicles built from 1st December 1989.

Several countries require the use of DRLs (mainly low beam headlights) under traffic laws but they are not required to be 'hard wired':

In 1992 Australia introduced mandatory "hard-wired" headlights for motorcycles - low-beam headlights were required to illuminate whenever the engine was running. This requirement was rescinded in 1996, due mainly to pressure from motorcycle lobby groups: "The Motorcycle Council of NSW (MCC) counts amongst its major achievements... Convincing the Federal government in 1996 to provide an alternative to ADR 19/01 (requiring hard wired lights on for motorcycles) in the form of ADR 19/02 (which does not require hard wired headlights)" (MCC website).

Effectiveness studies – cars

Overseas studies have generally 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 a European study (Koornstra 1997) the potential savings are:

- 25% of daytime multi-vehicle fatal accidents
- 28% of daytime fatal pedestrian accidents
- 20% of daytime multi-vehicle injury accidents
- 12% of daytime multi-vehicle property accident

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.

In Australia 64% of fatal crashes and 79% of non-fatal crashes occur during the daytime and about 3/4 of these are multi-vehicle crashes. If the savings estimated for Europe could be achieved in Australia this would equate to savings of:

11% of all fatal accidents

15% of all other accidents

Effectiveness studies – motorcycles

Rumar (2003) reviews the effectiveness of motorcycle DRLs. He reports that there are relatively few applicable studies. For example, Henderson and others (1983) showed that motorcycle crashes were reduced by about 5% after the introduction of the DRL legislation for motorcycles in North Carolina in 1973. Other crashes were not influenced. Williams (1996) reports an estimated 13% reduction in motorcycle crashes through the use of motorcycle DRLs (mostly headlights) in the USA.

Rumar points out that motorcycles have a significant conspicuity disadvantage due to their smalller front cross-sectional area. This also leads to speed and distance estimation errors by other drivers. Rumar notes that a single headlamp does not provide adequate distance information and he suggests that three lamps, mounted in a triangular pattern, may assist in speed and distance estimation.

This observation by Rumar, combined with the recent studies of motorcycle accidents where most motorcycles had headlights illuminated in the daytime, indicates that single low-beam headlights might not be particularly effective as motorcycle DRLs. It is therefore necessary to consider the visual ergonomics of on-road situations when accessing the functional requirements for motorcycle DRLs.

FUNCTIONAL REQUIREMENTS OF DRLS

Vehicle signal lights need to be designed to meet the conflicting requirements of:

- providing sufficient signal range to be seen and recognised and
- avoiding undue glare that hinders the vision of other road users

This must be achieved throughout a very large range in background lighting conditions (Paine and Fisher 1996).

The luminous intensity of lights is measured in candela. Research with traffic signals found that yellow lights require three times the luminous intensity of red lights to achieve the same signal range (Fisher and Cole 1974). White light signal range lies between these extremes.

In 1993 a detailed report on DRLs was issued by the Commission Internationale de l'Eclairage (CIE) - the international authority on lighting standards. Prof Rumar was chair of the CIE committee that prepared the report. The committee recommended that dedicated DRLs be encouraged with the following features:

- Relatively high intensity: up to 1200cd along the central axis
- 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.

Paine (2003) reviewed the functional and operational issues associated with DRLs. Road design guidelines provide a benchmark for determining the required signal range for DRLs:

Table 1. Road Design Sight Distances - metres (Lay 1991)

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

These required sight distances can be compared with the signal range of various colours of light under a range of background lighting conditions. With DRLs the worse case is a bright day (background luminance 10,000cd/m^2).

Using the formula provided by Paine and Fisher (1996), Table 2 sets out the estimated signal range of a selection of automotive lamps on a bright day.

Table 2. Australian 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.

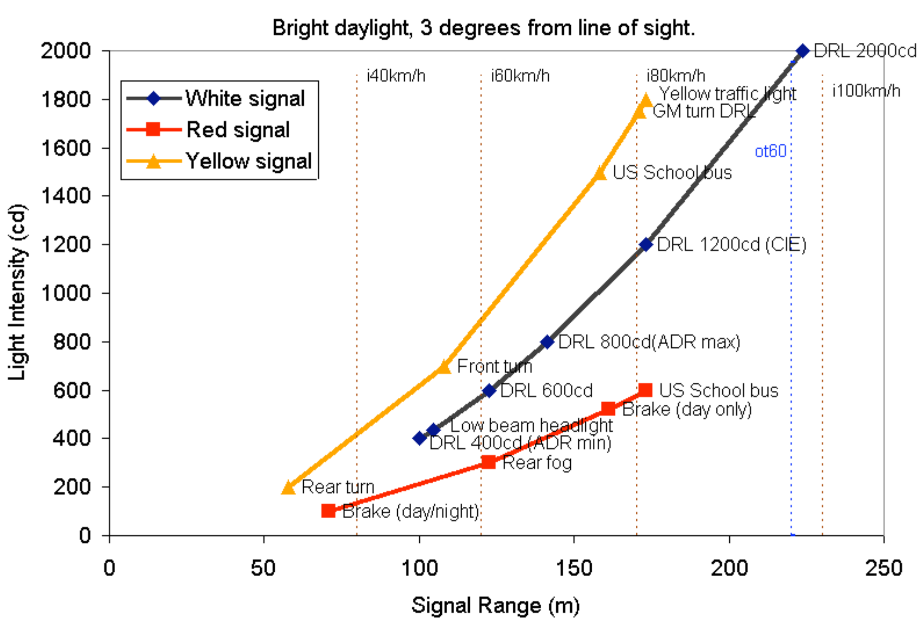

Figure 1. Light intensity and signal range for a selection of vehicle lights

These are illustrated in Figure 1, together with the sight distances from Table 1 (e.g. i40 = intersection with 40km/h traffic speeds, ot60 = overtaking with 60km/h traffic speeds).

Notable from this analysis is that *on bright days*, low-beam headlights which are at their maximum permitted intensity (437cd in the direction of other road users) are barely adequate for intersection situations where traffic is travelling at about 50km/h. They are inadequate for traffic speeds of 60km/h or higher. This outcome could go some way to explain the so-called latitude effect where DRLs have generally been found to be more effective in high latitude countries (Koornstra 1997). If this is the case then brighter DRLs can be expected to overcome this latitude effect.

On cloudy days, or near dawn or dusk, most potential DRL lights can be expected to be effective for the range of signal ranges set out in Table 1. An exception is for overtaking in traffic travelling at 80km/h or more. In this case low beam headlights (437cd) are likely to be marginally effective.

This analysis is supported by a US study reported by Thompson (2003). The effectiveness of several types of DRL now fitted as standard to GM cars was evaluated by comparing the collision rates of models built before and after DRLs became standard:

Table 3. Effectiveness of DRLs on GM cars (from Thompson 2003)

DRL Type	Change in Collision rate
Dedicated DRL (900cd)	-8.76%
Low beam headlight	-3.23%
Reduced intensity low beam	-2.31%
Reduced intensity high beam*	-4.86%
Yellow turn signal #	-12.4%

* Although reduced intensity high beams are bright (around 5000cd) they have a very narrow beam angle that limits their effectiveness as a DRL (CIE 1993)L

GM uses high intensity turn signals (around 900cd).

Subject to sample size limitations, the GM study suggests that dedicated DRLs are nearly three times as effective as low beam headlights and bright turn signals are nearly four times as effective.

It is therefore important that the type of DRL be taken into account when considering DRLs for motorcycles.

DRLS FOR MOTORCYCLES

Low beam headlights are the most popular form of DRL on motorcycles. Although these are the easiest to implement they have several disadvantages:

1. As demonstrated in the previous section, they have marginal photometric performance, even at the brightest intensity permitted by regulation. In any case, it is likely that most motorcycle headlights are well below this maximum permitted value.
2. Headlights waste energy when used as DRLs because, on low beam, they are designed to direct most light below the horizontal and away from the eyes of other road users. Tail lights and number plate lights also illuminate with the headlights but are not needed in daylight.
3. There is increased risk of a headlight bulb failure and this is a more serious night-time issue with motorcycles than cars.

Dedicated DRLs overcome these disadvantages but motorcycles generally do not have sufficient space at the front for these additional lamps.

Turn signal DRLs also overcome the disadvantages of headlight DRLs. Furthermore they do not require extra space at the front of the motorcycle. All that is required is the replacement of normal motorcycle turn signals (which are likely to have relatively poor photometric performance) with much brighter ones.

Turn signal DRLs would unambiguously indicate to other motorists that the approaching vehicle was a motorcycle and the intended direction of turn (conventional motorcycle turn signals are so close together that, sometimes, the intended direction of turn is not evident to other motorists).

Yellow DRLs are not currently permitted in Australia. There is therefore the one-off opportunity to regulate to allow optional yellow DRLs on motorcycles and ensure that these vehicles are uniquely identified to other road users. A pair of yellow DRLs will also assist other road users to judge the speed and distance of an approaching motorcycle.

CRITICISMS OF DRLS

There are several myths and misunderstandings about DRLs that need to be addressed by policy makers.

Increased fuel consumption not an issue with energy-efficient dedicated or turn signal DRLs that send light in exactly the direction where it is most effective. Recent developments in LED technology should mean that a pair of DRLs with excellent photometric performance will consume less than 20W.

Concern about masking of vulnerable road users has been shown to be unfounded (Williams 1996). In any case vulnerable road users benefit most from being able to see approaching vehicles with DRLs.

Masking of brake lights by tail lights (that come on with headlights) and premature failure of headlight globes are not issues with dedicated/turn signal DRLs

Glare could be a problem at dawn and dusk (Stern 2002). This is easily overcome by automatic headlights with an ambient light sensor. Many new cars now have this feature. If turn signal DRLs are to remain continuously illuminated at night then they should have reduced intensity (maximum 700cd) when the headlights are illuminated. Bright turn signals that only illuminate when they flash would not need to have reduced intensity at night and may provide increased signal effectiveness.

CONCLUSION

Bright yellow turn signal DRLs should be encouraged for motorcycles. These should have an on-axis luminous intensity of not less than 1000cd and not more than 1800cd. Automatic headlights should also be encouraged so that a light sensor is used to switch from DRL operation to headlights. To avoid glare, bright turn signals should not be continuously illuminated at night.

In Australia bright yellow DRLs should be permitted on motorcycles but should continue to be disallowed on other vehicles. These would be far more effective as DRLs than headlights and have the potential to reduce fatal motorcycle crashes by more than 13%.

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APPENDIX (ADDED AFTER PUBLICATION IN ESV PROCEEDINGS)

This appendix contains a brief comparison of data that can be used to calculate the potential effectiveness of motorcycle DRLs. As noted by Rumar (2003), there is a paucity of data on motorcycle crashes relevant to DRLs.

Sources of data

The following reports contain material that can be used in the estimate:

ACEM, 2004, "In-depth study of motorcycle accidents (MAIDS)", http://maids.acembike.org

In-depth study of 921 European motorcycle accidents

a. 73% of accidents occurred in daylight, a further 8% at dawn or dusk
b. 69% of motorcycles in daytime accidents had headlights on
c. In 37% of all accidents a primary contributing factor was failure of another vehicle operator to detect the motorcycle

Koornstra M., Bijleveld F. and Hagenzieker M, 1997, “The Safety Effects of Daytime Running Lights”, SWOV Institute for Road Safety, The Netherlands, R-97-36 (SWOV)

Comprehensive review of DRLs for cars. Mostly low-beam headlights

a. DRLs can save 25% of daytime multi-vehicle fatal accidents
b. DRLs can save 20% of daytime multi-vehicle injury accidents
c. DRLs can save 28% of daytime fatal pedestrian accidents
d. DRLs are more effective in the most serious accidents, including vulnerable road users

Hentlass J., 1992 "Literature Review for Inquiry into Motorcycle Safety:, Appendix to Inquiry into Motorcycle Safety in Victoria, Parliament of Victoria, Australia, January 1992. (Hentlass)

Analysis of Victorian (Australia) accident data from late 1980s

a. 65% of motorcycle casualty accidents involve another vehicle
b. 67% of multi-vehicle motorcycle accidents occur during the day
c. In 21% of daytime multi-vehicle motorcycle accidents the other vehicle operator claims they did not see the motorcycle
d. In 37% of the cases where the other driver did not see the motorcycle there was an obstruction of that driver's view (this suggest that there was no obstruction in 63% of collisions).
e. In 10% of cases where the other driver failed to see the motorcycle, and there was no obstruction, the motorcycle's headlights were on.
f. Based on these values, DRLS have the potential to affect about 2% of motorcycle collisions in Victoria.

Thompson P., 2003, "Daytime Running Lamps for Pedestrian Protection", SAE paper 2003-01-2072, Society of Automotive Engineers, Warrendale.

Retrospective study of accidents involving General Motors cars in the USA. During the late 1990s GM began fitting DRLS to its new cars. Accident histories were compared for the same model without and without DRLS.

a. Low beam headlights reduced collisions by 3.23%
b. Dedicated white DRLS (900cd) reduced collisions by 8.76%
c. Bright yellow turn signals reduced collisions by 12.4%

Paine, 2003, "A Review of Daytime Running Lights", NRMA and RACV, Sydney, July 2003. http://www4.tpg.com.au/users/mpaine/drl.html

Comprehensive review of DRLs: accident research, ergonomics and photometrics

a. On a bright (not necessarily sunny) day low beam headlights can be expected to have a signal range of about 100m

b. For 60km/h traffic speeds, Australian road design practice is to have intersection sight distances of 120m (ie low beam headlights have insufficient signal range for 60km/h traffic speeds on a bright day)
c. On dull days signal range improves and low beam headlights can be expected to become effective as DRLs.
d. This marginal effectiveness of low-beam headlights helps to explain the so-called "latitude effect" noted in some DRL effectiveness studies. Well-designed dedicated DRLs (white around 1000cd) can be expected to be effective under most daytime lighting conditions and therefore eliminate any "latitude effect".
e. Flashing (or flickering) lights demand more attention *once they are detected*. However, the flashing light needs to be brighter to be detected at the same range as a steady light (assuming the "on" time is less than half a second) and the cycle time of the flash adds to the recognition time (the system needs to undergo a full cycle before its meaning is recognised).

Discussion

It is noted that there is a substantial difference between Hentlass and MAIDS in the proportion of cases where the other driver did not see the motorcycle. Hentlass reports 21% of daytime multi-vehicle accidents whereas MAIDS reports 37% of all daytime accidents (equivalent to 44% of daytime multi-vehicle accidents). It is unlikely that there would be such a large difference between Australian and Europe accident characteristics. The MAIDS study appears to be based on more thorough investigation and is considered more reliable.

By design, low beam headlights direct most light below the horizontal. The amount of light directed in the most useful direction for DRLs (horizontal) is limited by regulation to no more than 437cd but in practice is usually much lower than this. One consequence is that low beam headlights can be expected to be ineffective when viewed via a car's rear view mirror in the daytime. Well-designed dedicated or turn signal DRLs can be expected to be much more effective in these circumstances. Hentlass notes that 12% of daytime multi-vehicle accidents the motorcycle should have been visible in the rear view mirror.

Hentlass reports that in 28% of multi-vehicle collisions the motorcycle was travelling the opposite direction to the other vehicle. In 28% it was travelling at right angles and in 28% is was travelling in the same direction. However, the estimate of DRL effectiveness appears to only consider the cases of vehicles travelling in opposing directions or where the motorcycle should have been visible in the rear view mirror. The 28% of right angle crashes would involve many cases of cars moving into the path of a motorcycle (eg entering a road from a side street). Well-designed DRLs have the potential to prevent many of these accidents.

Estimates of potential accident savings

Two methods of estimating the potential savings from motorcycle DRLs are set out in the table overleaf:

1. Applying the SWOV estimated effectiveness of DRLs on cars to motorcycle statistics

2. Recalculating the Hentlass estimates, taking into account the issues discussed above. Two scenarios were examined: using mostly Hentlass's data ("Revised A") and substituting some of the more recent data from Europe ("Revised B").

Applying the SWOV estimates to the Hentlass motorcycle accident statistics for Victoria in the late 1980s gives a potential saving of 9% of all injury motorcycle crashes

Applying the SWOV estimates to the MAIDS motorcycle accident statistics in Europe in the late 1990s gives a potential savings of 12% of all injury motorcycle crashes

It should be noted that the SWOV estimate of DRL effectiveness is based largely on studies of low beam headlights. The GM study suggests that well-designed dedicated DRLs can much more effective so the SWOV estimates are considered to be conservative. Also th eSWOV study found higher savings for vulnerable road users.

Recalculating the Hentlass analysis to take into account the issues raised above gives 8% of all motorcycle crashes potentially influenced by DRLs (using accident data from Victoria in the 1980s). Applying the analysis to the more recent MAIDS data gives 12% of all motorcycle crashes potentially influenced by DRLs.

Motorcycle DRL - potential savings

Application of SWOV & MAIDS data to Australia

	SWOV & NSW Accident data		Hentlass	MAIDS
Factor	Cars - fatal	Cars - Inj	M/C - Inj	M/C - Inj
Daytime	64%	79%	67%	73%
Multi-vehicle	75%	75%	65%	85%
Day Multi-vehicle	48%	59%	44%	62%
Day_MV_savings*	25%	20%	20%	20%
O'all savings	12%	12%	9%	12%

Recalculation of Hentlass estimate

	Hentlass	Revised A	Revised B
Dayime	67%	67%	73%
Multi-vehicle	65%	65%	85%
Failed to see	21%	44%	44%
No obstruction	63%	63%	63%
Accident type - Opposing or mirror	40%	40%	40%
Accident type - Right angles	0%	28%	28%
Total relevant	40%	68%	68%
Potential accidents saved	2%	8%	12%

* SWOV 1997 (cars)

Conclusion

The estimate of 13% savings in all motorcycle injury accidents provided in the main report is a little higher than the conservative estimates provided in this appendix.

In any case the break-even point for cost-effectiveness of factory-fitted turn-signal (or dedicated) DRLs is a saving of about 2% of all motorcycle crashes (based on Paine 2003) so all of the revised estimates are cost-effective. The original Hentlass estimate (2%) is at the break-even point (benefit/cost=1) but it should be noted that this is still better than most well-recognised safety features such as a driver airbag (benefit/cost calculated using the same methods about 0.8). There is therefore a very strong case for promoting dedicated (or turn signal) motorcycle DRLs.