ROAD SAFETY IMPLICATIONS OF DAYTIME RUNNING LIGHTS

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1 A BRIEF STATEMENT OF THE ISSUE

Daytime running lights (DRL) increase the visual contrast between the vehicle and its background, thereby making the vehicle more visible to other road users. The research evidence strongly suggests that this increase in visibility results in a decrease in most types of daytime multi-vehicle crashes.

DRL are now mandatory in many countries but have yet to be accepted in Australasia as a mandatory road safety countermeasure.

2 AN ASSESSMENT OF THE ROAD SAFETY ISSUE

2.1 The origins of DRL

The concept of encouraging drivers to use their vehicles' lights during daytime as a road safety countermeasure can be traced to the United States (Prower 1985). In the early 1960s the State of Texas launched a 'Light Up and Live' campaign as a means to reduce the high road tolls expected during peak holiday times, an idea which was quickly adopted by several other states over the following years. At around the same time, a number of fleet operators and especially, the Greyhound Bus Company, used early versions of DRL on their vehicles as an explicit accident reduction measure. Further, a series of individual States passed compulsory motorcycle lights-on legislation, again, as a means to increase vehicle conspicuity.

The use of DRL for vehicles remains optional in the United States (although they were made mandatory for new vehicles in Canada since 1989). The concept also met with a more enthusiastic response in Europe, particularly in Scandinavia (Prower 1985), to the point that they are now universal in that region. Increasingly, other countries around the world are also introducing DRL requirements, at least for new vehicles.

2.2 The rationale for DRL

Laboratory-based studies have shown that the greater the brightness contrast between an object and its background, the greater the probability of the object being detected. Further, the lower the ambient illumination, the greater the contrast ratio between object and background needs to be if detection is to occur (Rumar 1980). This increase in visual contrast is seen as the essential characteristic leading to a reduction in many types of daytime crashes (Arora et al. 1994).

Although many factors are likely to influence the effectiveness of DRL as an accident-reduction measure, ambient illumination levels are particularly pertinent. The lower the ambient illumination, the greater the tendency for contrast ratios to be reduced and the greater the risk of non-detection of a given object. Ambient illumination itself is the function of numerous variables, foremost amongst them altitude of sun (and hence latitude) and season of the year. The closer countries are to the North or South Poles, the longer are the twilight periods and the periods generally with lower sunlight - and the greater the benefits of DRL (Rumar 1980). The association between DRL benefits and latitude has been quantified via the following formulae (Koornstra, Bijleveld, & Hagenzieker 1997).

- % decrease in fatalities = $0.00331(\text{degrees})^{2.329}$
- % decrease in casualties = $0.00279(\text{degrees})^{2.329}$
- % decrease in all multi-vehicle daytime crashes = $0.00166(\text{degrees})^{2.329}$

2.3 Options for DRL

Conventional options for DRL include:

- headlights on full-intensity low-beam
- headlights on reduced-intensity low-beam
- headlights on reduced-intensity high-beam
- indicators
- increased-intensity parking lights
- separate DRL.

These conventional options generally entail the lights automatically switching on with the ignition and being doused whenever the ignition is turned off. However the benefits of DRL are most evident when ambient illumination falls below certain levels. Thus there is an increasing interest in DRL perhaps being restricted to these periods, especially dusk and dawn (Cairney & Styles 2003). If only for practical purposes, this will require 'smart' DRL: that is, lights that automatically switch on and off in response to ambient light levels. This technology is not yet available in the market place.

3 CURRENT POLICIES AND PRACTICES IN AUSTRALASIAN JURISDICTIONS

As early as 1991, it was argued that (Cairney & Johnston 1991):

- Failure to see vehicles is demonstrably a substantial factor in vehicle-vehicle and vehicle-pedestrian crashes in Australia.
- DRL are an effective means to improve vehicle conspicuity.
- There is ample evidence that DRL are effective in reducing crashes.
- Based on the Swedish experience, DRL could have saved Australia between 80 and 170 fatalities, between 700 and 1300 serious injuries and between 1400 and 2200 other injuries in 1988 - a saving of between $132 million and $297 million.

During the early 1990s, many of the Australasian jurisdictions expressed an interest in DRL, either as a measure to be implemented more or less immediately at jurisdictional level, or to be further investigated as a possible national road safety countermeasure. However, this growing momentum was largely stopped by the Australian national government’s decision in 1996 to rescind ADR 19/01 which had mandated DRL for motorcycles sold after 1 March 1992.

Currently DRL are not mandatory in any Australasian jurisdiction, although individual jurisdictions continue to show interest.

4 A REVIEW OF THE RESEARCH

4.1 Fleet studies

The best known fleet study relates to the United States Greyhound Bus Company (Sparks et al. 1989), which for one year in the early 1960s ran all its buses with headlights constantly on - and subsequently reported a 12% drop in crashes. Since then, there have been numerous analyses of the relationship between use of DRL and changes in fleet accident rates, the results varying between around 10% and 40%.

A review published in 1993 looked at the results of five fleet studies conducted in Austria, Israel and Canada (Koornstra 1993):

- Two of the studies employed a control group method, whereby a group of cars equipped with DRL was compared to a control group. The first control group study, conducted in Israel found a 13% decrease in crashes in the DRL group, the second study conducted in Canada found a 15% reduction in crashes in the DRL group.
- A study in Austria used a similar design but looked at the crash histories of the cars before and after the DRL intervention and found a 21% decline in crashes in the DRL group compared to the control group.
- The remaining two fleet studies were also conducted in Austria. Both studies involved a before/after design whereby the crash history of the fleet before introducing DRL was compared with the crash history of the fleet after DRL had been introduced. In one study a 2% reduction in multi-vehicle crashes was found, in the other no change in crash rates was found.

Overall, the findings from fleet studies generally indicate that introducing DRL has a positive impact on crashes. These findings have been reinforced by the results of a meta-analysis of seven fleet studies (Elvik 1996). This analysis revealed a 10% to 15% reduction in multi-vehicle daytime crashes when DRL were introduced to fleets.

However it has been noted that:

> True fleet studies have some methodological problems in that they may have been introduced as part of a package of measures following an adverse crash history, so the effects of DRL may be confounded with other measures and be subject to regression to the mean effects. Other possible problems are assignment of best (or worst) drivers to the treated vehicles, thus biasing the results. Finally, there is the possibility that drivers are aware they are part of a trial, and so drive more carefully as a result (p. 19) (Cairney & Styles 2003).

Certainly the effect on crashes of DRL introduced into specific vehicle fleets is likely to be much higher than the effect of DRL introduced into a country's entire vehicle population. Vehicle fleets with DRL will be more conspicuous than the remainder of the vehicle population without DRL, thus giving them a safety advantage: if the entire vehicle population uses DRL, all vehicles would have a similar level of conspicuity and thus the safety effect of DRL would be smaller.

4.2 Whole-of-country studies

An early study based upon Finnish data for the years 1968-74 (Rumar 1980), set the pattern for later efforts. The researchers reasoned that DRL should have the greatest impact upon multi-vehicle crashes occurring during daylight hours and hence devised an impact measurement based upon an interaction between four subsets of crashes: daytime multi-vehicle, daytime single-vehicle, night time multi-vehicle and night time single-vehicle crashes. These sub-sets of crash data were used to show that the movement towards DRL which had strengthened over the period and achieved a compliance of almost 100% by 1974, was primarily responsible for the following changes:

- overall, a 21% reduction of daytime multi-vehicle crashes
- more specifically - a 28% reduction in head-on crashes, a 17% reduction in crashes involving vehicles crossing paths, a 24% reduction in daytime pedestrian crashes and a 9% increase in rear-end crashes.

An equivalent method was used to evaluate the situation in Norway (Elvik 1993). Norway legislated installation of DRL for new vehicles in January 1985 and then in April 1988, required all vehicles not equipped with DRL to use headlights during the day. No overall reduction in multi-vehicle daylight crashes was found when a ‘before’ period of 1980-81 was compared to the two ‘after’ periods, 1984-85 and 1989-90. However, when crashes were separated into seasons, there was approximately a 15% decrease in all summer-time multi-vehicle daylight crashes. The analysis also revealed that rear-end crashes increased by approximately 20%, ‘before’ and ‘after’.

Denmark mandated DRL use for all motor vehicles in October 1990. Fifteen months after the change, multi-vehicle crashes had reduced by 7% and crashes involving left-turn across oncoming vehicles, had reduced by 37% (Williams & Lancaster 1995). After thirty-three months, there was a 6% reduction in daytime multiple vehicle crashes, a 34% reduction in left-turn crashes, a 4% reduction in motor vehicle-cyclist crashes and a statistically significant increase of 16% in motor vehicle-pedestrian crashes.

Canada mandated that DRL be installed on all new passenger cars, multi-purpose vehicles, buses and trucks manufactured in Canada after December 1, 1989. Comparing the changes between successive years over the period 1988 to 1991, it was found that the only significant year-to-year reduction in multi-vehicle daytime crashes occurred between 1989 and 1990 (Collard 1996). All other successive year comparisons yielded no difference. The reductions in multi-vehicle crashes between 1989 and 1990 were:

- for daylight and twilight crashes combined, 9.2%
- for daylight crashes only, 8.3%
- for twilight crashes only, 16.5%.

The year-to-year changes for three types of multi-vehicle crashes (head-on, left-turn conflict and right-turn conflict crashes) were also examined. Statistically significant reductions were found between 1989 and 1990 in regard to head-on and left-turn conflict crashes when daylight and twilight were combined, and also a significant reduction in head-on crashes during daylight alone. No reduction was found for right-turn conflict crashes.

4.3 The recent research

The finding that DRL are effective in reducing daytime multi-vehicle crashes when introduced for all vehicles has been reinforced by a meta-analysis (Elvik 1996), entailing ten national studies that examined crashes in countries having either a DRL law or a campaign designed to promote the use of DRL. The weighted mean effect of DRL laws or campaigns was found to be a 2% to 12% reduction in multi-vehicle crashes and a 3% to 20% increase in the number of rear-end crashes.

Another review published in 1997 reviewed twenty-four independent empirical studies of DRL (Koornstra, Bijleveld, & Hagenzieker 1997).

1997). In brief, the following conclusions were reached:

- There were positive road safety benefits from the introduction or increased use of DRL.
- The effect of DRL on rear-end crashes was less than the effect on other crash types.
- DRL have an even greater impact on casualties than on crashes, probably due to reduced crash speeds because of earlier perception of the vehicles.
- The benefits of DRL were determined by latitude, such that the closer to the South or North Poles, the greater the crash reductions, due particularly to the longer periods of reduced ambient illumination.
- On balance, neither non-motorised road users nor motorcyclists were disadvantaged.
- The DRL effect does not diminish over time.
- There was no evidence of any substantial impact of DRL on single-vehicle and night crashes.

A third review in 2004 (Elvik & Vaa 2004), selected nineteen studies conducted in Europe, Scandinavia, the USA or Canada between 1964 and 1995. The results from a joint consideration of all studies are summarised in Table 4.1.

4.1: Effects of daytime running lights for cars on casualty crashes

Casualty crash type	Percentage change in the type of casualty crash affected	
	Best estimate	95% confidence intervals
Pedestrians hit by cars	-15	(-17,-13)
Cyclists hit by cars	-10	(-15,-5)
Front- or side-crash	-10	(-12,-8)
Rear-end crash	+9	(+5,+14)
Multi-party, daylight	-8	(-7,-9)

Note: The estimates assume that the use of DRL increased from around 35-40% to around 85-90%.

While the overall crash impact on multi-party daytime casualty crashes was a reduction of 8%, it needs to be noted that this net fall includes a 9% increase in rear-end crashes.

In addition to estimating the likely crash impact of DRL, the reviewers reached the following conclusions:

- DRL had no impact on mobility.
- DRL lead to a 1-2% increase in fuel consumption and an overall increase of exhaust emissions by up to 2%.
- DRL have an overall benefit/cost ratio (BCR) of about 3:1.

The research into DRL impact on crashes continues. For example, an Australian review (Cairney & Styles 2003) identified four major studies published between 1997 and 2002, conducted in Canada or the USA. Although the reviewers identified various methodological limitations, these recent studies generally further confirmed that DRL were associated with (usually modest) crash reductions:

- A country-wide study which compared ‘opposing’ and ‘angle’ crash rates for vehicles registered immediately before DRL became mandatory in Canada with crash rates for vehicles registered after the legislation, found an overall 5.5% reduction for DRL-equipped vehicles (Tofflemire & Whitehead1997).
- A United States study compared the fatal crash performance of a group of vehicles known to be equipped with DRL with other vehicles manufactured in the same years without DRL. It was found that target crash types were lower by between 5% and 23% for vehicles with DRL (National Highway Traffic Safety Administration 2000).
- Another United States study compared the crash rates of specific vehicle models ‘before’ and ‘after’ the introduction of DRL. Again the reported results were positive – a 5% and over reduction in relevant multiple-vehicle crashes and a 9% reduction in urban vehicle-pedestrian crashes (Bergkvist 2001).
- An independent United States study using a similar research design found that DRL were associated with a 3.2% reduction in multiple-vehicle daytime crashes, representing a 1.6% reduction in overall crash risk (Farmer & Williams 2002).

The Australian review (Cairney & Styles 2003) explicitly questioned whether the growing body of research findings can be generalised particularly to Australia, given the bright daylight conditions over most of the country for most of the year. After reviewing the limited research from New Zealand (Patterson (undated) and Australia (Paine 2003), it set about estimating the likely benefits of DRL for Australian conditions.

Four options for DRL were considered. Based on estimated operating costs, crash reductions and crash cost savings, the following BCRs were calculated:

- purpose-designed DRL fitted to all new vehicles which operate whenever the engine is running (unless night lights are operating): BCR = 1.35 to 2.03, depending upon bulb wattage
- day-long use of headlights on low beam: BCR = 1.18
- all new vehicles fitted with a purpose-designed DRL, together with a triggering device to ensure that the DRL operate only under low ambient light conditions: BCR = 2.80 to 4.59, depending upon bulb wattage
- required use of DRL only immediately prior to sunset and following sunrise: BCR = 3.47.

5 POLITICAL, SOCIAL AND OTHER FACTORS

In response to lobbying from motorcyclist groups, the Australian national government decided in 1996 to rescind mandatory DRL for motorcycles – a decision which has two major implications for Australian jurisdictions. In the event of any introduction of DRL for cars, the logical need to reverse the 1996 decision affecting motorcycles would require considerable political commitment to the concept. This in turn would be likely to revive opposition from some motorcycle groups – which may or may not spill over into motorists’ groups.

Motorists who would bear the additional direct costs of DRL if they were mandated in Australasia (i.e. increased fuel usage and installation if retrofitting were required), may vary in their willingness to accept these costs, depending particularly upon their geographic location. Motorists in Darwin, for example, would receive minimal benefits relative to motorists in Hobart.

At least some opposition may also come from non-transport groups. The use of DRL entails increased fuel usage and thus, increased CO_2 emission. A recent New Zealand analysis for example, estimated that DRL fitted to a vehicle fleet of around 2.6 million vehicles, would produce almost 400,000 tons of additional CO_2 annually (Bergkvist 2001).

Most road safety countermeasures come at some cost, either directly or otherwise. By and large, if the benefits sufficiently outweigh the costs, the countermeasures are likely to be accepted by the general public. While the weight of research evidence supports the proposition that DRL have safety benefits and positive BCRs, the case is not totally closed: many of the evaluations have methodological limitations and there is some disparity in the extent of benefits. Further at least some of the studies suggest low BCRs, usually below 2:1 (Koornstra, Bijleveld, & Hagenzieker 1997). A recent New Zealand analysis suggested that the benefits of requiring special purpose DRL on new vehicles would not outweigh the costs for the life of a vehicle (assumed to be 15 years) (Patterson, undated). Because most of Australia is at a considerably higher latitude than New Zealand, the recouping of costs is likely to take even longer this side of the Tasman.

'Smart' DRL which automatically switch on only in low-light conditions, may represent a more acceptable option, given their lower running costs and lower emission levels.

6 CONCLUSIONS

DRL have commonly been shown to have (usually modest) road safety benefits and positive (usually low) BCRs. As well as reducing crashes, they may have a greater impact on casualties, probably because of the lower crash speeds in crashes involving vehicles with DRL due to earlier perception of the vehicles. With most Australasian jurisdictions now subscribing to a Safe System approach which emphasizes a minimal level of casualty outcomes, DRL have an additional appeal. For these reasons, policies leading to the universal installation of DRL are recommended - political and other difficulties notwithstanding.

In the meantime, it is considered that there are two immediate avenues for their promotion, through:

- targeting owners whose vehicles feature warning devices for lights left on/automatic dousing of lights when the ignition is turned off
- encouraging the installation and use of 'smart' DRL on all vehicles.

Both options will impact on only a part of the vehicle fleet and thus are likely to produce only very modest crash reductions.

It is further considered that fleet-wide installation of DRL can be achieved only through changes to Australian and New Zealand Design Rules, whereby DRL become a mandatory feature for all new vehicles. This is achievable only at a national level and will require substantial political commitment.

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