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‘Daytime Running Lights’
Deliverable 3: Final Report

1. Objectives of the DRL Project

The project, which started on january 1 2003, pursued the following objectives:

(a) To assess the effectiveness of the currently legislated requirements for the use of DRL in the EU and elsewhere, and how that legislation has been implemented in these countries.

(b) To assess the various evaluations and make specific cost-effectiveness recommendations for the introduction of DRLs, taking into account the various positive and possible negative road safety impacts (casualty reduction ranges for various types of road users) and environmental impacts (increased fuel consumption and CO2 production). To investigate possible negative environmental impacts of the use of DRLs relative to other in-vehicle electrical equipment, such as air conditioners, etc.

(c) To collate the work done under (a) and (b), and produce various implementation strategies for DRLs in the EU, as well as further specific recommendations for implementation maximising the positive effects, while minimising the negative effects.

These objectives have been elaborated as separate Workpackages, as follows:
WP 1 State-of-the-art with respect to DRL-regimes
WP 2 Review of accident analysis studies
WP 3 Investigation of (possible) adverse effects
WP 4 Development of implementation regimes

The results of these will be briefly reviewed on the basis of Internal reports (IRs) that have been produced within the Workpackages, and which are attached in full to this text.

2. Summary of results

2.1 WP 1: State-of-the-art with respect to DRL-regimes

The first objective of WP 1 was to provide an inventory of the currently legislated requirements for the use of DRL in the EU and elsewhere, and how that legislation has been implemented in these countries. Such an inventory is provided in the figure below (Commandeur, IR1).

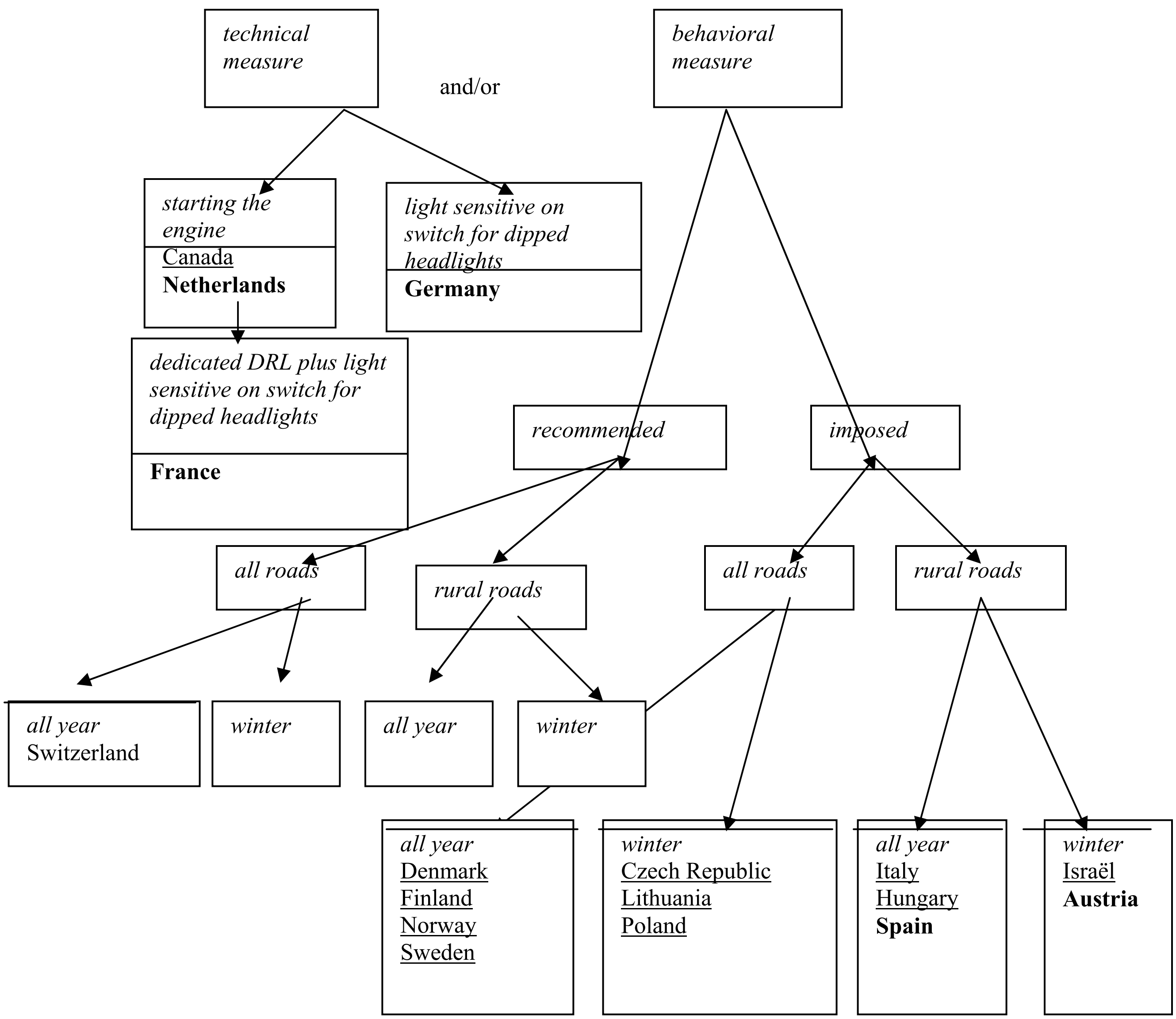

Fig. 1: Classification of DRL implementation scenarios, including countries. Underlined: countries with DRL legislation. Standard: countries without DRL legislation, but DRL recommended. **Bold**: countries without DRL legislation; plans, or expressed scenario preference if DRL proven to be effective.

The figure shows that DRL has been implemented both as a technical and as a behavioral measure. So far, the majority of DRL countries chose to impose DRL as a behavioral measure although most cars in the Scandinavian countries (Denmark, Finland, Norway and Sweden) are sold with an automatic DRL switch as well. The countries which currently have legislation on the use of DRL can be further distinguished in whether they impose DRL during the whole year or in winter time only, and on all roads or on rural roads only.

The second objective of WP 1 was to assess what can be learned under the existing DRL regimes, so as to take these findings into account in the later development of realistic implementation strategies.
It appeared that, when setting up European guidelines for the implementation of DRL, it is clear that the following issues will have to be addressed:

- pedestrians, cyclists, mopeds less conspicuous;
- motorcyclists less conspicuous;
- glare;
- increased fuel consumption;
- increased CO_2 emission;
- more frequently burned out bulbs;
- flat batteries;
- reduced conspicuity of brake lights;
- if carrying dedicated reduced intensity DRL, drivers forget to switch on dipped headlights in reduced visibility conditions;
- "masking" of unlit vehicles by lit ones in mixed daytime circulation.

In DRL countries the use of media campaigns during the introduction of DRL was found to range all the way from no media campaigns at all in Hungary to massive media campaigns in Canada. Since all DRL countries indicate not having met with much resistance and opposition against DRL after its implementation, there does not seem to be much that can be learned in terms of what type of media campaign would be optimal when introducing DRL in a non-DRL country. However, according to the person responsible for completing the questionnaire in Canada, "it is recommended that other countries intending to implement DRL policies take steps to inform their citizenry about the basic workings of visual perception relative to the driving task, since some of the comments from the Canadian public about DRL seemed to reflect a lack of understanding of the role and importance of contrast in aiding visual perception."
Most DRL countries used a gradual approach to the implementation of DRL, either by encouraging the voluntary use of DRL before the introduction of DRL legislation, or by a gradual extension of compulsory DRL usage over more and more types of roads, over more and more months of the year, and/or for more and more types of road users.
Such gradual implementation strategies allow road users to gain personal experience in the visual workings of DRL, thus probably also contributing to obtain broader public acceptance for DRL legislation.

2.2 WP 2 Review of accident analysis studies

A meta-analysis was performed on the available accident statistics literature, aiming at answering the following questions (Elvik et al., IR 2):

1. Are the effects attributed to DRL novelty effects that are likely to erode over time?
2. What is the relationship between the usage rate for DRL and the effects on road safety (dose-response function)?
3. Do the effects of DRL vary systematically, depending on geographical latitude?
4. Do the effects of DRL vary, in terms of accident severity?
5. Do the effects of DRL vary with respect to season (winter/summer)?
6. What are the effects on accidents involving motorcyclists of requiring DRL for cars?
7. What are the effects on accidents involving pedestrians or cyclists of requiring DRL for cars?
8. Are there adverse effects of DRL on cars for other types of accident, in particular rear-end collisions?

The main findings of the systematic review of evidence concerning effects of daytime running lights on accidents can be summarised as follows:

1. A total of 41 studies that have evaluated the effects on road safety of DRL, have been retrieved. 25 of these studies have evaluated the effects for cars, 16 have evaluated the effects for motorcycles. A distinction is made between estimates of the intrinsic effects of DRL and estimates of the aggregate effects. Intrinsic effects are the effects for each car or motorcycle using DRL. Aggregate effects are the effects of an increased rate of use of DRL in a country, brought about, for example, by a law making the use of DRL mandatory.
2. The use of DRL reduces the number of multi-party daytime accidents for cars by about 5-15%. All studies that have evaluated the effects of using DRL for cars have found a reduction of the number of accidents, but the size of the estimated reduction varies from study to study.
3. Laws or campaigns designed to encourage the use of DRL for cars are associated with a 3-12% reduction in multi-party daytime accidents resulting in personal injury.
4. The use of DRL on motorcycles reduces the number of multi-party daytime accidents by about 32%. This estimate is highly uncertain and based on a single study only. Only three studies were found, but two of these studies were so poor that no confidence can be placed in their findings.
5. Laws or campaigns designed to encourage the use of DRL for motorcycles are associated with a 5-10% reduction in multi-party daytime accidents.
6. The robustness of the summary estimates of effect given above have been tested with respect to some potential sources of error in meta-analyses, including:
    a. Publication bias;
    b. Varying quality of the studies included;
    c. The statistical weights assigned to each estimate of effect; and
    d. The contribution of a single study to the overall estimate of effect.

In general, the summary estimates of effect were very robust. It is therefore concluded that the estimates of effect based on the meta-analysis are the best current estimates of the effects of DRL, given the evidence provided by the evaluation studies.

7. Various sources of variation in the effects of DRL for cars have been examined. It was concluded that:
    a. The effects of DRL are greater for fatal accidents than for injury accidents, and greater for injury accidents than for property-damage-only accidents. Evidence of effects for fatal accidents is, however, highly uncertain.
    b. The effects of DRL are likely to be greater at latitudes further away from the Equator than at latitudes close to the Equator. The evidence for such a relationship is, however, somewhat noisy.
    c. It is likely that DRL has a favourable effect on accidents involving pedestrians, cyclists or motorcyclists. An adverse effect on rear-end collisions has been found in studies of the aggregate effects of DRL. DRL combined with switched-off taillights can counteract this effect, as well as the use of high mounted brake lights.

2.3 WP 3 Investigation of (possible) adverse effects

Study on the conspicuity of vulnerable road users in the vicinity of DRL-vehicle

In this lab study (Brouwer et al., IR 3) subjects viewed colour slides depicting natural daylight scenes of traffic intersections. The slides contained a vehicle with or without DRL and possibly other road users such as a bicyclist, pedestrian or motorcyclist. Subjects were instructed to determine as fast as possible whether other road users were present or not. Search time was recorded. After each trial, subjects made a non-speeded classification indicating which other road user was present.
The effect of DRL on the conspicuity of other road users was investigated under various conditions, namely:

1. The expectancy of DRL (DRL-expectancy);
2. The expectancy of other road users (OR-expectancy);
3. The type of background;
4. The type of (other) road user; and
5. The distance between the other road user and the car.

In order to investigate the effect of expectancies about the presence of DRL (car with low beam headlights on) and the presence of other road users, the participants were assigned to one of four groups. The groups were based on the occurrence of slides with DRL and the presence of other road users (OR present/not present). Thus, the effect of expectancies was investigated between subjects. The other effects were investigated within subjects.

The main result of the study is that no evidence was found of a reduced conspicuity of road users in the vicinity of a DRL-vehicle. In fact, the evidence pointed in the opposite

direction – other road users actually benefitted from DRL -, although the effect was small. Apart from this, there were significant effects of OR-expectancy and of DRL on/off itself which were as expected, confirming the positive effects associated with them.
Although the overall effect of DRL on the conspicuity of road users was in the positive direction, this does not prevent a possible negative effect in specific situations. Inspection of the obtained significant interactions involving DRL, however, showed that such a negative effect did not occur. Therefore, it can be concluded that the absence of a negative effect on the conspicuity of other road users was a general phenomenon, at least over the range of situations studied in the experiment.

A similar absence of adverse effects was found with respect to driver visual capacities, as measured in elderly drivers by UFOV (useful field of view) and static visual acuity scores. Again, this was true both in an average sense and with respect to interactions that could have occurred in specific situations.

Environmental aspects of DRL

The following aspects of the environmental impact have been considered:
1. The effect of DRL on fuel consumption and CO_2 emission. For both aspects, an increase in the order of 0.5-1.5 % was estimated.
2. The effect on bulb lifespan, in comparison to corresponding effects of other in-vehicle electrical equipment. It was estimated that bulb replacement would be needed twice as frequently, resulting in € 6.00 extra cost per car per year.

3. Conclusions and recommendations

The results from the separate Workpackages appeared to converge to a degree that it was warranted to develop implementation regimes (in the form of policy options) for the EU. The following five policy options were investigated for the mandatory use of DRL in the European Union (Commandeur & Mathijssen, IR 4):
1. The use of DRL is required by all motor vehicles from a certain date. This is a simple behavioural measure, which does not include any new technical standards for vehicles. Drivers are simply required to turn on headlights at any time. This option will be referred to as the behavioural option.
2. The use of DRL is required by all motor vehicles from a certain date. In addition, new motor vehicles sold after the same date will be required to have an automatic switching-on of low beam headlights. This option will be referred to as the behavioural plus low beam option.
3. The use of DRL is required by all motor vehicles from a certain date. In addition, new cars sold after the same date will be required to have dedicated DRL that are switched on automatically. This option will be referred to as the behavioural plus dedicated DRL option.

4. New cars sold after a certain date are required to have an automatic switching-on of low beam headlights. Cars that do not have automatic DRL will not be required to turn on low beam headlights. This policy option will be referred to as the technical low beam option.
5. New cars sold after a certain date are required to have dedicated DRL that are turned on automatically. Cars that do not have dedicated DRL will not be required to turn on headlights. This policy option will be referred to as the technical dedicated DRL option.

A cost-benefit analysis was performed for each of these five options. The results are summarized in Table 1.

Table1. Results of cost-benefit analysis of five alternative DRL policy options.

	Alternative policy options				
Benefits and costs	**Behavioural measure**	**Behavioural + low beam**	**Behavioural + dedicated**	**Automatic low beam only**	**Automatic dedicated**
Benefits (negative amounts denote negative benefits – million Euro, present values)					
Accident reduction	47,076	49,430	49,430	38,355	38,355
Increased pollution	-12,619	-13,250	-10,252	-10,276	-6,371
Total benefit	34,458	36,181	39,178	28,059	31,964
Costs (million Euro, present values)					
Installation of automatic DRL	0	2,728	6,829	2,728	6,829
Fuel consumption	9,014	9,465	7,324	8,630	5,350
Light bulb consumption	8,562	8,990	8,562	8,436	8,436
Total costs	17,576	21,183	22,715	19,794	20,615
Ratio of benefits to costs					
Benefits/costs	1.96	1.71	1.72	1.42	1.55

For all five options, the benefits are clearly greater than the costs, but there are rather big differences between the C/B-rates of the various options.

The highest B/C-rate is that of option 1 (1.96), followed by options 2 and 3 (1.71 and 1.72, respectively). The B/C-rates for options 4 and 5 are substantially lower (1.42 and 1.55, respectively).
But the B/C-rate is not the only, and maybe not even the most important selection criterion, since the main goal of DRL implementation is road accident reduction. Another important criterion is the increase of pollution.
With regard to accident reduction, options 2 and 3 score better than option 1: an accident-related cost reduction of € 49,430 million for options 2 and 3, versus a reduction of € 47,076 million for option 1. With regard to pollution, option 3 is superior to options 1 and 2, the increased pollution of option 3 being 19% lower than that of option 1 and 23% lower than that of option 2.

Preferable policy option

The preferable policy option for DRL implementation is the technical measure of automatic dedicated DRL for new cars, combined with a behavioural measure requiring the mandatory use of low beams for existing cars. The light intensity of dedicated DRL is somewhere between the intensity of low beams and the intensity of parking lights. As a technical measure, automatic dedicated DRL are preferred above automatic low beams because dedicated DRL not only result in the highest accident reduction and the lowest increase in pollution (CO_2 emission), but also in the fairest distribution of road safety benefits over the various road user categories. For these reasons, the proposed technical measure of automatic dedicated DRL is expected to result in the highest level of public acceptance.
Defining the exact technical specifications of dedicated DRL, especially regarding light intensity, was outside the scope of this research project. It should be left over to technical specialists. The following features, however, are recommended:

- In order to prevent reduced conspicuity of unlit vehicles, the implementation of dedicated DRL on new cars should be accompanied or preceded by mandatory low beam DRL on all other motorized vehicles
- In order to prevent the possible 'masking' of brake lights, which might result in an increase of rear-end collisions, automatic dedicated DRL for headlights should be combined with switched-off taillights. This will also reduce pollution and bulb consumption.
- In order to prevent drivers from forgetting to switch-on low beams under reduced visibility conditions, automatic dedicated DRL should be combined with automatic low beam activation at a predetermined reduced level of ambient light intensity.
- In order to prevent flat batteries, both dedicated DRL and normal lights should automatically be switched on/off when starting/stopping the engine.

Implementation scenario

Since the use of DRL is controversial in some EU-countries, a gradual approach may be desirable in order to give people time to adjust to the changes and accept these as an improvement. In some countries with DRL legislation, the use of DRL was recommended before it became mandatory. In other countries, DRL was first required in winter before it became mandatory during the whole year. This implementation scenario is not feasible, though, if the *behavioural plus dedicated DRL policy option* is chosen. Another possible implementation scenario is to require automatic DRL for new cars first, and then after a while, require all cars to use it. This scenario option, however, is not very attractive since it would involve an unnecessary delay in the expected road safety benefits of DRL usage, especially if the technical part of the implementation cannot be realized within a reasonable time span. We therefore recommend to implement the behavioural part as soon as possible.

The most logical starting point for mandatory low beam DRL use is somewhere between the beginning of autumn and the beginning of winter. During a preceding period of one year maximum, it might be advisable to only recommend low beam DRL in order to allow people to adjust to the new situation and accept DRL as an improvement. This might especially be advisable in EU countries that currently have a very low degree of voluntary DRL use.

Publicity campaigns

The introduction of recommended DRL should be preceded and accompanied by a large-scale publicity campaign on TV, radio and in the newspapers, emphasizing the importance of contrast in aiding visual perception and the resulting road safety benefits. The campaign should also meet the arguments that pedestrians and two-wheeled road users would not benefit from DRL. And, finally, the campaign should stress that these road user categories will benefit even more as increasing numbers of new cars equipped with dedicated DRL emerge on the roads.
Another important element of the publicity campaign should be the placing of billboards along main roads, reminding drivers and motorized riders of recommended/mandatory low beam DRL use.