Scenarios for the implementation of daytime running lights in the European Union

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Summary

This report is the last part of the documentation of a project funded by the European Commission, designed to assess the effects of Daytime Running Lights (DRL) and possible strategies for implementing the use of DRL in the European Union (EU).
The general objective of the present report is to produce implementation scenarios for DRL in the EU, as well as further specific recommendations for implementation that would maximize the positive effects, while minimizing the negative effects.

The report starts off by summarizing the results of previous work done in this project.
First, the results of a meta-analysis of 41 evaluation studies of the effects of DRL on road safety are presented. The main conclusions of the meta-analysis are that, given the evidence provided by the evaluation studies, the use of DRL is associated with a reduction in multi-party daytime accidents, and that it is likely that DRL have a favourable effect on accidents involving pedestrians, cyclists, and motorcyclists.
Then, the results of an experimental study on the possible adverse effects of DRL on vulnerable road users are discussed. The conclusion from this study is that no evidence was found of a reduced conspicuity of vulnerable road users in the vicinity of a vehicle using DRL.
Next, an overview of possible DRL implementation scenarios for the EU is presented, as well as of arguments against DRL, and of expected acceptance levels of these scenarios, based on a survey that was conducted in countries that already have DRL legislation, and in other countries of the EU. The main conclusions of this survey are that most of the opposition against DRL greatly subsided in countries after DRL legislation was implemented, and that most DRL countries used a gradual approach to the implementation of DRL. As concerns the results of the survey for non-DRL member states of the EU, it is concluded that the installation of automatic dedicated DRL on new cars should be made at least part of the DRL implementation scenarios to be developed for the EU.
Finally, the results of a cost-benefit analysis of five policy options for the implementation of DRL in the EU are presented and discussed, and it is concluded that the policy option with the second best benefit-cost ratio is likely to yield the largest acceptance. This policy option consists of the mandatory use of dipped headlights as DRL for the current car stock, together with the installation of automatic dedicated DRL in accordance with ECE-87 regulations on new cars, both to be implemented at the same time from a certain date onwards, and preceded by a period of recommended DRL usage combined with a large-scale publicity campaign.
Should the technical part of the implementation take too long, however, the report recommends to start imposing the use of dipped headlights as DRL as soon as possible, thus avoiding an unnecessary delay in the expected road safety benefits of DRL.

Contents

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1. Introduction

This report is part of the project for the European Commission on Daytime Running Lights (DRL), with Contract No. ETU/B27020B-E3-2002-DRL-S07.18830. The general objective of the present report is to produce implementation strategies for DRL in the EU, as well as further specific recommendations for implementation that would maximize the positive effects, while minimizing the negative effects.

Based on the results of Work Packages 1-3 (WP1-3) of the project, realistic implementation scenarios are discussed and evaluated. Apart from these results per se, these scenarios incorporate additional elements, notably:

- The acceptance of specific scenarios among road users;
- The cost-benefit aspects associated with specific scenarios.

The final results and implementation strategies have been formulated in consultation with a number of national experts as identified in WP1 and with selected relevant international bodies (e.g., European Cyclists Federation (ECF), Federation of European Motorcyclists' Associations (FEMA), Association des Constructeurs Européens d' Automobiles (ACEA).

Work Package 4 consisted of the following tasks:

1. The determination, definition, and reporting of realistic implementation scenarios based on the results of WP1, WP2 and WP3.
2. The qualitative determination and reporting of the acceptance level of each scenario, based on the results of WP1.
3. The quantitative determination, valuation, and reporting of the costs and benefits of various implementation scenarios, based on the results of WP2 and WP3.
4. The production of a deliverable, WP4-report, describing feasible and cost-effective implementation strategies for daytime running lights.
5. The organization of a workshop of national experts, as identified in WP1, and of selected international bodies, in order to discuss the draft WP4-report.

Chapter 2 of this report presents the road safety effects and environmental impact of DRL, as determined in WP2 and WP3, and reported in Elvik, Christensen & Olsen, (2003) and Brouwer, Janssen, Duistermaat, & Theeuwes (2004), respectively.
Chapter 3 contains an overview of possible DRL implementation scenarios, of arguments against DRL implementation as expressed by EU countries, and of expected acceptance levels of these scenarios. The overview results from a literature review and from a questionnaire that has been completed by experts in various EU countries, as part of WP1, and reported in Commandeur (2004).
Based on the possible DRL implementation scenarios discussed in *Chapter 3*, the costs and benefits of five policy options for the mandatory use of DRL in the European Union are presented in *Chapter 4*. The cost-benefit analysis formed part of WP2.
Chapter 5 contains conclusions regarding the road safety effects and the cost-benefit rates of the five policy options, as well as specific

recommendations for DRL implementation that would maximize the positive effects, while minimizing the negative effects.

2. Road safety effects and environmental impact of DRL

The road safety effects of DRL have been investigated in two studies:

1. An updated review of studies that have evaluated the safety effects of DRL on cars and motorcycles, in the form of a meta-analysis of those studies (Elvik, Christensen & Olsen, 2003)
2. An experimental study regarding possible perceptual, cognitive, and behavioural side-effects of DRL (Brouwer, Janssen, Duistermaat, & Theeuwes, 2004).

In addition, the environmental impact of DRL was investigated (Brouwer et al., 2004).

2.1. Results of the meta-analysis

The meta-analysis was aimed at answering the following questions:

- Are the effects attributed to DRL novelty effects that are likely to erode over time?
- What is the relationship between the usage rate for DRL and the effects on road safety (dose-response function)?
- Do the effects of DRL vary systematically, depending on geographical latitude?
- Do the effects of DRL vary, in terms of accident severity?
- Do the effects of DRL vary with respect to season (winter/summer)?
- What are the effects on accidents involving motorcyclists of requiring DRL for cars?
- What are the effects on accidents involving pedestrians or cyclists of requiring DRL for cars?
- 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. Of these studies 25 evaluated the effects for cars, and 16 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 on 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 material-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 vague.
   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 tail lights can counteract this effect, as well as the use of high mounted brake lights.

2.2. Results of the experimental study

In the experimental study, 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 classification at leasure, indicating which other road user was present.

The effect of DRL on the conspicuity of other road users was investigated under various conditions, namely:

- The expectancy of DRL (DRL-expectancy);
- The expectancy of other road users (OR-expectancy);
- The type of background;
- The type of (other) road user; and
- 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 subjects 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 experimental 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 benefited 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 a general sense and with respect to interactions that could have occurred in specific situations.

2.3. Environmental impact of DRL

The following aspects of the environmental impact have been considered:

- 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.
- The effect on bulb service life, 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 extra cost per car per year.

3. Scenario definition

This chapter contains an overview of possible DRL implementation scenarios for the EU, of arguments against DRL implementation, and of expected acceptance levels of these scenarios (Commandeur, 2004).

3.1. Possible implementation scenarios

Figure 3.1 contains a schematic overview of the possible implementation strategies that can be distilled from the completed questionnaires, as well as from the literature discussed in Commandeur (2004). In this scheme, three types of countries are identified. Underlined countries are those countries that currently have DRL legislation (Canada, Czech Republic, Denmark, Finland, Hungary, Israel, Italy, Lithuania, Norway, Poland, and Sweden). The place of their names in *Figure 3.1* corresponds to the strategy these countries used to implement DRL. Bold printed countries in the diagram currently do not have DRL legislation for all motorized vehicles (Austria, France, Germany, the Netherlands, and Spain). Their place in the diagram is determined by plans or scenario preference if DRL should be proven to be effective, as expressed in the completed questionnaires or in the literature mentioned in the questionnaires. Finally, the third type of country is where there is currently no DRL legislation, but where the use of DRL is explicitly recommended. There is only one such country, which is Switzerland.

The first distinction in *Figure 3.1* is that between the implementation of DRL as a technical versus a behavioural measure. When implemented as a technical measure, DRL are switched on automatically when the engine is started. In this case DRL are de facto imposed on all roads during the whole year. The federal government of Canada is the only government that consequently decided for this implementation strategy, on the grounds that it would be the least costly and the most reliable long-term solution.
Figure 3.1 also shows an alternative technical measure, as discussed in France, Germany, and the Netherlands. According to Robert (2000), if DRL are proven to be effective, then the implementation strategy with the largest acceptance level in France would be an automatic on-switch of dedicated daytime running lights with an intensity somewhere between dipped headlights and parking lights, combined with the installation of receptors which switch on the dipped headlights in case of reduced ambient light (and automatically switch off the dedicated daytime running lights).
With a very strong emphasis on the condition that dedicated DRL complying to ECE-87 regulation (ECE, 1993) should first be proven to be effective in improving road safety, the position of the official experts from Germany (GRE, 2003) is identical to that of France. If the latter condition is not satisfied, however, Germany would still be interested in the separate installation of receptors which switch on the dipped headlights in reduced ambient light conditions. The Dutch authorities also favour automatic dedicated DRL, and view the light sensitive switch for dipped headlights as a sensible option.

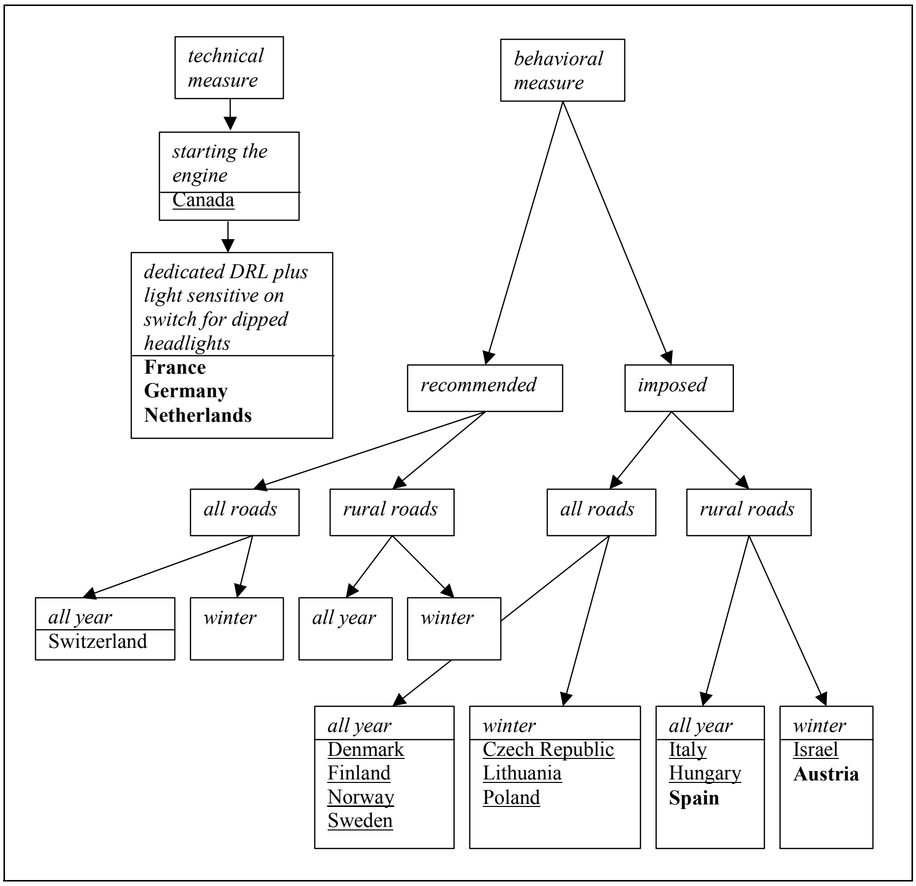

Figure 3.1. *Classification of possible DRL implementation scenarios, including those already applied in DRL countries.*
Underlined*: countries with DRL legislation.*
Standard*: countries without DRL legislation, but DRL recommended.*
Bold*: countries without DRL legislation; plans, or expressed scenario preference if DRL proven to be effective*

The advantage of a technical measure is that it results in uniform behaviour, but only in the long run. The disadvantage, of course, is the time lapse involved before all car models are equipped with automatic DRL. However, this problem can be solved by combining a technical measure on new cars with a second technical measure (e.g., the installation of a DRL switching kit, as was done in Canada) and/or a behavioural measure for the current car stock.

If DRL are implemented as a behavioural measure, there are several options. First, the measure can be either recommended or imposed, or even first recommended and then later imposed. Second, the use of DRL can be recommended or imposed on all roads, or on some roads only (in practice, these are always roads outside built-up areas), and during the whole year or only during part of the year (in practice, this is always winter time). Moreover, the implementation of DRL as a behavioural measure can also be executed using a gradual approach, where, for example, DRL are imposed on rural roads and in winter time only in the first year, on rural roads during the whole year in the second year, and on all roads during the whole year in

the third year. Such a gradual approach was applied in Finland and Hungary, for example.
As *Figure 3.1* shows, all Scandinavian countries currently impose year-round DRL on all roads, while the Czech Republic, Lithuania, and Poland impose DRL on all roads but during winter time only, Italy and Hungary impose year-round DRL but on rural roads only, and Israel imposes DRL on rural roads and in winter time only.
Moreover, Spain expressed plans for the strategy already implemented in Italy and Hungary, while Austria expressed plans for the strategy as implemented in Israel, at least in the medium term. Finally, Switzerland is the only country where the use of year-round DRL on all roads is only recommended.

When compared to a technical measure, the advantage of a behavioural measure is that the use of low beams can be imposed straight away for all motorized vehicles, thus avoiding the possible problem of mixed circulation of lit and unlit vehicles. This advantage no longer strictly applies, however, if the use of dipped headlights is only imposed on some roads, and/or part of the year. In the latter situation the risk of mixed circulation of lit and unlit vehicles may well increase due to inconsistent behaviour. At the same time, the enforcement efforts required from the authorities could be considerably larger than in the case of a technical measure. On the other hand, experience in the Scandinavian countries shows that DRL usage is also enforced by car drivers themselves, by flashing their lights when they encounter a motor vehicle with switched-off lights during daytime. Again, the possible problem of mixed circulation of lit and unlit vehicles is completely solved by combining a technical measure for new cars from a certain date onwards with a behavioural measure on the current car stock.

3.2. Arguments against DRL implementation

Table 3.1 contains an inventory of all the arguments against DRL that were mentioned in the completed questionnaires and in the reports sent by both DRL and non-DRL countries.

The list of arguments against DRL is important since these have to be dealt with if DRL implementation in all EU countries is recommended.
The results of the meta-analysis of studies on the safety effects of DRL, which mainly concern the use of standard low beam headlights, do not indicate adverse effects for vulnerable road users (see *Section 2.1* and Elvik et al., 2003). The same conclusion applies to the results of the experimental study discussed in *Section 2.2* and in Brouwer et al. (2004).
Problems with glare were only mentioned by Canada and the U.S.A. (see Commandeur, 2004) where high intensity lamps of up to more than 3000 candela are allowed to be used as DRL. Current European regulations, on the other hand, specify a much lower range of 400 to 800 candela for DRL, explaining why glare is not mentioned as an issue by European DRL countries.

Arguments against DRL	(Partially) resolved with
Reduced conspicuity of pedestrians, cyclists and mopedists	
Reduced conspicuity of motorcyclists	
Glare	
Increased fuel consumption	Dedicated DRL based on low energy light sources like low wattage bulbs or LEDs on cars, in combination with switched-off tail lights
Increased CO_2 emission	Dedicated DRL based on low energy light sources like low wattage bulbs or LEDs on cars, in combination with switched-off tail lights
More frequently burned-out lamps	Dedicated DRL based on low energy light sources like low wattage lamps or LEDs on cars, in combination with switched-off tail lights
Flat batteries	Warning device or automatic switch-off when the engine is stopped
Brake lights less conspicuous	Switched-off tail lights in good daytime visibility conditions combined with high mounted brake lights
Automatic dedicated DRL will make drivers forget to switch on low beams in reduced visibility conditions (e.g., at night)	Automatic ambient light dependent de-activation of dedicated DRL and activation of low beam headlights
'Masking' of unlit vehicles by lit ones	Dedicated DRL on new cars, in combination with the mandatory use of low beam DRL for the current car stock in all EU countries

Table 3.1*. Inventory of all the arguments against DRL, and suggestions for solving the problems.*

As *Table 3.1* shows, the use of dedicated DRL has a number of important advantages. It allows for the minimization of the adverse environmental effects of DRL (i.e., increased fuel consumption, increased CO_2 emission, and more frequently burned-out lamps). It prevents flat batteries (by automatically switching off the lights when the engine is stopped). It allows for the optimization of the luminous requirements of the DRL in moderate to good daytime visibility conditions. Finally, it allows for dedicated daytime tail light specifications, and can be combined with the installation of an automatic on-switch for the low beam headlights in reduced visibility conditions, thus eliminating the risk of cars driving at night with dedicated DRL (and the risk of cars using no lights at all).
The adverse environmental effects of DRL could especially be minimized by the use of low energy-consuming light sources like low wattage lamps and LED (Light-Emitting Diode) based DRL. According to Rumar (2003), for 13 Watt lamps and LEDs (and no other lights) the increase in fuel consumption and CO_2 emission would be less than 0.5%, while with LEDs the extra costs for lamps would be almost negligible (the service life of LEDs being practically identical to that of the vehicle).

3.3. Acceptance of DRL

In DRL countries, it was found that the opposition against DRL greatly subsided and that acceptance levels were generally high after its implementation (see Commandeur, 2004). This is true irrespective of whether DRL were implemented as a technical measure (as in Canada) or as a behavioural measure (as in Czech Republic, Denmark, Finland, Israel, Italy, Hungary, Norway, and Sweden).
As discussed in Commandeur (2004), 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 and advantages of DRL, thus probably also contributing in obtaining broader public acceptance for DRL legislation.

These findings, combined with the experience that most of the opposition against DRL greatly subsided in countries after DRL legislation was implemented, lead us to recommend that the implementation of DRL in non-DRL countries is preceded with a period of recommended DRL usage, accompanied with media campaigns clearly explaining how the visual workings of DRL contribute to the improvement of road traffic safety.

As far as non-DRL member states of the EU are concerned, Robert (2000), estimated that the implementation strategy with the largest acceptance level in France would be a technical measure, where dedicated DRL with an intensity somewhere between dipped headlights and parking lights are switched on automatically, and where receptors are installed which switch on the dipped headlights in case of reduced ambient light (and automatically switch off the dedicated DRL). With a strong emphasis on the condition that dedicated DRL complying to ECE-87 (ECE, 1993) regulations should first be proven to be effective in improving road safety, the position of the national DRL experts from Germany (GRE, 2003) is very similar to that of France. The Dutch authorities also favour automatic dedicated DRL, and consider the light sensitive switch for dipped headlights to be a sensible option. Implementing DRL as a technical measure is therefore expected to raise acceptance levels in these member states of the EU. Since automatic dedicated DRL also minimize or even completely solve the adverse effects used in the arguments against DRL (see *Section 3.2*), it is recommended to make the installation of automatic dedicated DRL on new cars –combined with a light sensitive switch automatically activating the low beam headlights in reduced visibility conditions (and deactivating the DRL)- at least part of the DRL implementation scenarios to be developed for non-DRL member states of the EU. As concerns the technical specifications of automatic dedicated DRL on new cars, these should be made in accordance with the already existing European ECE-87 (1993) regulations for daytime running lights. Moreover, of the current non-DRL member states of the EU, France, Germany, the Netherlands, and Spain expressed concerns about the environmental effects of DRL. Since automatic dedicated DRL result in the smallest environmental effects (see *Chapter 4*), it is expected that the incorporation of dedicated DRL in the implementation of DRL will also help to improve their acceptance in these countries.

Finally, in a recently published French interim report (Conseil National de la Sécurité Routière, 2003) on DRL, it is suggested that the implementation of DRL in France could possibly best be started by recommending their use outside built-up areas first (unfortunately, the report does not provide any definitive recommendations).

4. DRL policy options

Based on the possible DRL implementation scenarios discussed in *Chapter 3*, it was decided to further investigate the following five policy options for the mandatory use of DRL in the European Union (Elvik et al., 2003):

1. The mandatory use of DRL is introduced for all motor vehicles from a certain date onwards. 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 mandatory use of DRL is introduced for all motor vehicles from a certain date onwards. 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 mandatory use of DRL is introduced for all motor vehicles from a certain date onwards. 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 their 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 4.1*. The results in *Table 4.1* are based on the following assumptions.

It is assumed that only Multi-party Daytime (MD)-accidents are affected by the use of DRL, and that these accidents represent 40% of all fatal and injury accidents in the EU. It is further assumed that mandatory use of DRL will be associated with a:

- Reduction of 15% in MD-accidents leading to fatal injury.
- Reduction of 10% in MD-accidents leading to serious injury.
- Reduction of 5% in MD-accidents leading to slight injury.
- No reduction in MD-accidents leading to property damage only.

These reductions are assumed to be the result of an increase in DRL-use from 10% to 90%. The overall effect for all levels of injury severity taken together is a reduction of 5.9%, which corresponds very well to the summary estimates of aggregate effects derived from the meta-analysis. For the 12 EU countries that do not require the use of daytime running lights, the total effects on the annual number of injured road users have been estimated to:

- The prevention of 2,359 fatal injuries per year.
- The prevention of 17,507 serious injuries per year.
- The prevention of 51,113 slight injuries per year.

These are the best estimates of effect for DRL as a behavioural measure.

Benefits and costs	Alternative policy options				
	1. Behavioural	2. Behavioural + low beam	3. Behavioural + dedicated DRL	4. Technical low beam	5. Technical dedicated DRL
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

Table 4.1. *Results of cost-benefit analysis of five alternative DRL policy options.*

As far as the technical policy options combined with the behavioural are concerned, the total effect has, again conservatively, been assumed to be 5% higher than estimated above, since these options will, in principle, ensure a 100% level of DRL-use.
For the purely technical policy options, again effects are assumed to be 5% higher than estimated above. However, in the case of the purely technical options, these effects will accrue more slowly than when a behavioural measure is used, taking 12 years to reach full effect.
For small and large vehicles taken together, fuel consumption and pollution has been estimated to increase by 1.35%. Dedicated DRL use less energy than standard low beam headlights. When lamps of 25 W are used for dedicated DRL, these are estimated to consume 38% less fuel and cause 38% less air pollution than standard low beam headlights. For all policy options it was estimated that bulb replacement would be needed twice as frequently, resulting in € 6 extra cost per car per year.
For the monetary valuation of all these figures, as well as for the estimated costs for the installation of automatic DRL and other details, we refer to Elvik et al. (2003).
Results of benefit-cost analyses are always surrounded by uncertainty. In the present case, Elvik et al. (2003) estimated that the probability that the benefit/cost ratio is actually greater than 1 for each policy option is high, with a range of 0.75 to 0.88 for the five policy options.

It may be concluded that the benefits are clearly greater than the costs for all five policy options. The highest B/C-ratio is that of option 1 (1.96), followed by options 2 and 3 (1.71 and 1.72, respectively). The lowest B/C-ratios are those for options 4 and 5 (1.42 and 1.55, respectively).

However, the size of the B/C-ratio is not the only criterion for selecting a policy option, two other important issues being the expected acceptance levels of these policy options in the non-DRL countries of the EU, and the size of their estimated effects on road safety.
With regard to accident reduction, options 2 and 3 are superior to 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.
It may be noted that the use of lower energy-consuming light sources like 13 Watt lamps or LEDs for dedicated DRL would yield even smaller costs for fuel consumption, air pollution, and light bulb consumption than assumed in *Table 4.1* (see also *Section 3.2*). However, the current costs of such light sources would also be higher than for the 25 Watt lamps considered in the cost-benefit analysis.
Since option 3 combines the largest accident reductions with the smallest environmental effects (see also *Section 3.3*), we expect this policy option to result in the largest acceptance in the EU.

5. Conclusions and recommendations

The objective of the present report was to produce implementation strategies for DRL in the EU, as well as further specific recommendations for implementation that would maximize the positive effects, while minimizing the negative effects.

5.1. Conclusions

5.1.1. *Road safety effects*

In *Chapter 4*, the road safety effects of the following types of mandatory DRL implementation have been discussed:
- *The behavioural option*: drivers are simply required to switch on low beam headlights at any time.
- *The behavioural plus low beam option*: all drivers of existing cars are required to switch on low beam headlights at any time and new motor vehicles are required to have an automatic low beam activation device.
- *The behavioural plus dedicated DRL option*: all drivers of existing cars are required to switch on low beam headlights at any time and new motor vehicles are required to have an automatic dedicated DRL activation device.
- *The technical low beam option*: new cars are required to have an automatic low beam activation device. Drivers of cars without such a device will not be required to switch on low beam headlights.
- *The technical dedicated DRL option*: new cars are required to have an automatic dedicated DRL activation device. Drivers of cars without such a device will not be required to switch on low beam headlights.

A meta-analysis of studies that have evaluated the safety effects of DRL comes to the conclusion that all five options will result in a significant decrease in multi-party daytime accidents (Elvik et al., 2003). Other conclusions of the meta-analysis are:
- The effects of DRL are probably greater for fatal accidents than for injury accidents, and they are greater for injury accidents than for material-damage-only accidents.
- The effects of DRL are likely to be greater at latitudes further away from the Equator than at latitudes close to the Equator.
- It is likely that DRL have a favourable effect on accidents involving pedestrians, cyclists, or motorcyclists. This finding was confirmed by the results of a special experimental study (see *Section 2.2*).
- An adverse effect on rear-end collisions has been found in studies of the aggregate effects of DRL. This effect can be counteracted, though, by using high mounted brake lamps.

5.1.2. *Costs and benefits*

A cost-benefit analysis has been conducted, mainly based on the meta-analysis mentioned in *Section 5.1.1*. In the cost-benefit analysis, it is estimated that DRL will increase fuel consumption and CO_2 emission by approximately 0.5-1.5%. The service life of (low beam) bulbs is estimated to

be halved, which would result in an extra cost of € 6 per car per year (Brouwer et al., 2004).
The results of the cost-benefit study show that, for all five DRL implementation options mentioned in *Section 5.1.1*, the benefits are clearly greater than the costs, although there are differences between the various options (Elvik et al., 2003). Option 1 has the highest benefit/cost-rate of 1.96, but option 3 results in a greater accident reduction and a smaller increase of pollution, while still having a benefit/cost ratio of 1.72 (See *Chapter 4*). Furthermore, option 3 is likely to result in higher acceptance levels than option 1 in EU-countries like Germany and France, for the reasons explained in *Section 3.3*.

5.1.3. *Possible adverse effects*

Section 3.2 contains an overview of all the possible adverse effects mentioned in arguments against DRL-implementation (Commandeur, 2004). The most serious objection is probably that DRL on cars would make pedestrians, cyclists, mopedists, and motorcyclists less conspicuous. However, no evidence for this was found, neither in the meta-analysis where, on the contrary, accidents involving these road users are estimated to be reduced by DRL on cars (see Elvik et al., 2003), nor in the special experimental study (Brouwer et al., 2004).
A realistic objection against DRL concerns increased fuel consumption, CO_2 emission, and bulb consumption. Although the estimated increases for low beam DRL are already relatively small, and are clearly outweighted by the benefits of DRL, they would be even further reduced by the use of automatic dedicated DRL for headlights in combination with switched-off tail lights. The latter would also reduce the risk of possible reduced conspicuity of brake lights, which might result in an increase of rear-end collisions.
The possible 'masking' of unlit vehicles by lit ones would be prevented by the mandatory use of DRL by all motorized vehicles.

5.2. **Recommendations**

5.2.1. *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 consisting of the mandatory use of low beams for existing cars. As a technical measure, automatic dedicated DRL are preferred above automatic low beams because dedicated DRL result in the lowest increase in fuel consumption and CO_2 emission. Therefore, the proposed technical measure of automatic dedicated DRL is expected to result in the highest level of public and government acceptance.
Defining the exact technical specifications of dedicated DRL, especially regarding light intensity, and the ambient daylight conditions where the dedicated DRL are automatically switched off (and the low beam headlights are automatically switched on), was outside the scope of this research project. For these technical specifications we refer to Vehicle Regulations of the Transport Division of the Economic Commission for Europe (UN-ECE) in Geneva. For a comprehensive discussion of dedicated DRL specifications, we also refer to Rumar (2003). However, we recommended the following features:

- 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 tail lights (see *Section 5.1.3*). This will also reduce pollution and bulb consumption. New cars in EU countries are already required to have a third high-mounted brake light which also helps preventing rear-end collisions.
- In order to prevent drivers from forgetting to switch-on low beams under reduced visibility conditions, automatic dedicated DRL should be combined with automatic activation of the low beam headlights at a predetermined reduced level of ambient light intensity.
- In order to prevent flat batteries, both dedicated DRL and dipped headlights should automatically be switched on/off when starting/stopping the engine.
- Due to its favourable effect on fuel consumption, air pollution and bulb service life, future dedicated DRL should preferably be based on LED technology.

5.2.2. *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 (Elvik et al., 2003). 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 only have a small percentage of voluntary DRL use. In France, this period of recommendation could be started outside built-up areas first (see *Section 3.3*).

5.2.3. *Publicity campaigns*

The introduction of recommended DRL should be preceded and accompanied by a large-scale publicity campaign on television, radio, and in the newspapers, emphasizing the importance of contrast in aiding visual perception and the resulting road safety benefits (Commandeur, 2004). The campaign should also show that the arguments that pedestrians and two-wheeled road users would not benefit from DRL are unfounded.

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.

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