Deliverable D3.11c:
Safety Performance Indicators for Daytime Running Lights: Theory Update

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Executive Summary

The report published in 2007 (Hakkert et al, 2007) provided details about the theory behind the development of safety performance indicators (SPIs) in seven predefined road safety domains, including daytime running lights (DRL). The current report presents an update to the basic SPIs Theory report, in part concerning the development of the DRL SPIs. This reports sums up the general theory behind the development of the DRL SPIs, including a more detailed insight into the reported effects of DRL on vulnerable road users (pedestrians, two-wheelers).

Based on the literature review and recent experiences of several European countries, it is stated that DRL can contribute to the improvement of road safety. There is no scientific evidence for the frequently mentioned negative effects for vulnerable road users (pedestrians, cyclists or motorcyclists). The widespread introduction of DRL could be optimal if the behavioural measures for older vehicles are coincided with the installation of an advanced DRL unit on new cars. This would result in a combination of accident casualty reduction and reduced vehicle emission, especially when LED lamps are used. However, vehicle requirements can only be introduced at the European Union level.

The DRL SPIs are defined as the percentage of vehicles using daytime running lights, where the value is estimated for different road categories and for different vehicle types. The background information on the DRL legislation is essential for a correct interpretation and comparison of the results. Comparing the countries' DRL usage rates it is reasonable to take into account whether the countries have a law/ regulation on obligatory use of DRL and if they do, when and where.

Besides, in countries, where automatic DRL was introduced a long time ago (e.g. Sweden, Norway), current DRL usage rate is close to 100%, thus the DRL usage rate as a behavioural safety performance indicator does not have practical implications any more. In general, once the option of automatic DRL is introduced Europe-wide, the DRL indicators will lose their importance as an indicator of safety performance.

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1 The DRL use for improving road safety

1.1 The problem of daytime visibility

Many traffic crashes occur because road users do not notice each other in time or do not notice each other at all. This is true not only for traffic crashes in the dark but for traffic crashes in daylight as well. Vehicle visibility is therefore one of the factors which affects the number of crashes (Attwood 1981; Rumar 1980; Helmers 1988; Elvik and Vaa 2004).

The eye reacts to contrasts and changes in contrast in the field of vision. When light conditions are particularly difficult, such as at dusk, in rain, or in fog, it becomes difficult to see all traffic elements (Elvik and Vaa 2004).

Use of daytime running lights (DRL) for cars in all light conditions is intended to reduce the number of multi-party accidents by increasing the cars' visibility and making them easier to notice (Elvik and Vaa 2004). Besides, the DRL use could increase the reliability of the estimation of other motorised road users' moving direction, distance and speed.

Koornstra et al (1997) evaluated all the earlier experiments regarding visual perception, road user behaviour, and DRL. Their most important conclusions were as follows.

Conclusion 1

> Vehicles with DRL are **more visible** than vehicles without DRL.
>
> With regard to the hypothesis that DRL increases visual contrast between vehicles and their background, and therefore conspicuity /visibility, subjective assessments have shown that, in general – both depending on the level of ambient illumination and DRL intensity – vehicles with DRL are more visible than vehicles without DRL.

Conclusion 2

> DRL results in **increased detection distance** and angle.
>
> The detection experiments have shown that detection distance is greater for vehicles with DRL when compared to unlit vehicles (under relatively low ambient illumination levels). Moreover, vehicles in the periphery of the visual field are earlier detected with DRL than without.

Conclusion 3

> DRL probably results in some **'safer' judgements.**
>
> Regarding the hypothesis that DRL results in more accurate or 'safer' judgments, it has been shown that vehicles with lights on are estimated to be closer than unlit vehicles; and in overtaking situations the minimal gap acceptance is greater when DRL is used than when lighting is not used. The acceptance of a larger gap and estimating a vehicle to be 'closer' can be interpreted as a 'safer' performance with respect to the situation without lighting. However, the results of studies concerned with gap acceptance in situations other than overtaking are less clear-cut.

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1.2 Accident reduction potential of the DRL use

Elvik and Vaa (2004) summarized the results of about twenty studies, which evaluated the effects on accidents of DRL-equipped cars. The studies were carried out in different countries such as USA, Canada, Sweden, Norway, Denmark, Israel, Austria, Hungary, and considered two types of effects: the effect on the accident rate for each car of using DRL and the effect on the total number of accidents in a country where the DRL use is mandatory – Table 1.1. The researchers found that the DRL use reduces the number of multi-party accidents by around 10-15%.

Percentage change in the number of accidents			
Accident severity	**Type of accident affected**	**Best estimate**	**95% confidence interval**
Effect for each car which uses daytime running lights			
All levels of severity	Multi-party accidents in daytime	-13	(-18; -8)
Mandatory usage of daytime running lights (increase in use from around 35-40% to around 85-90%)			
Injury accidents	Pedestrians hit by cars	-15	(-17; -13)
Injury accidents	Cyclists hit by cars	-10	(-15; -5)
Injury accidents	Front- or side collisions	-10	(-12; -8)
Injury accidents	Rear-end collisions	+9	(+5; +14)
Injury accidents	Multi-party accidents in daylight	-8	(-9; -7)

Table 1.1 Effects of daytime running lights for cars on accidents (percentage change in the number of accidents).

The problem of visibility is especially pertinent to mopeds and motorcycles. Poor visibility was indicated as a contributing factor to many accidents involving these vehicle types. The DRL use is accepted to be one of the ways of increasing moped and motorcycle visibility (Elvik and Vaa 2004). Twelve studies, from the USA, Australia, Great Britain and Malaysia, considered the effects on accidents of using DRL on mopeds and motorcycles. Summing up their findings, it was stated (Elvik and Vaa 2004) that mopeds and motorcycles using DRL have a 10% lower accident rate than those not using it. However, this estimate is considered as uncertain, because the confidence interval of the summary value was very wide making the result statistically insignificant.

Another study commissioned by the European Commission (EC) involved a meta-analysis of 41 studies of the DRL safety effect for cars and 16 studies of the DRL safety effect for motorcycles (Elvik et al., 2003). This study showed that for cars the DRL use reduced the number of daytime injury crashes by 3%-12%, and for motorcycles - by 5%-10%. For both findings we should mention that the results found per individual studies differed greatly. The reduction observed refers to daytime crashes in which more than one road user was involved. A greater effect on fatal crashes was estimated.

The only accident type which shows an increase in association with the DRL use is the rear-end collision. A possible explanation for this is that when the taillights are on, it might be more difficult to recognise the brake lights (Attwood 1981; Elvik 1993). According to Hungarian research results (Hollo 1998), following the introduction of mandatory DRL use, the number of frontal and crossing collisions decreased without a simultaneous increase in rear-end collisions. The latter number has changed not significantly.

Probably the possible increase in the rear-end collisions will not be a problem anymore in the future due to the presence of the extra high-mounted stop lamps. These lamps are obligatory for new cars in almost all European countries since 1998.

1.3 The DRL influence on vulnerable road users

Brouwer et al. (2004) performed experiments to examine suspicions on possible negative effects of DRL, e.g. a poorer conspicuity of other road users in the vicinity of vehicles with the DRL switched on. It is sometimes suggested that road users who do not have their lights on in daytime are visually “pushed aside” by the DRL using vehicles, i.e. a masking effect is expected. TNO carried out a laboratory experiment (Brouwer et al., 2004) in which subjects were shown slides with pictures of traffic situations in daylight circumstances. The slides contained a car with or without DRL and another road user: a pedestrian, a cyclist, or a motorcyclist. The subjects were instructed to determine as quickly as possible if there was another road user present. The time needed to do this was registered.

The results were that subjects were able to identify the traffic situation of cars with DRL more accurately and quickly than that of cars without DRL. No indications were found of a lesser conspicuousness of vulnerable road users when those are near a car with DRL. On the contrary, the results pointed in the opposite direction: road users without lighting in fact profited from DRL for cars. It is also an advantage that vulnerable road users can see cars with DRL sooner than cars without DRL.

Similarly, the meta-analysis study by Elvik et al (2003) concluded, although with some reservations, that DRL probably reduces the number of car crashes involving cyclists and pedestrians.

Motorcyclists in the Netherlands, who nearly all have their headlight on during daytime, sometimes express the fear that their conspicuousness lessens if cars also have their lights on during daytime (SWOV, 2008). The TNO laboratory experiment (Brouwer et al., 2004) showed that the subjects saw both motorcycles with their lights off and motorcycles with their lights on sooner if cars also had DRL. However, the motorcycles with DRL were spotted faster. Wildervanck (1994) already explained this phenomenon: by having his headlight on a motorcyclist separates himself from the static surroundings and thus is noticeable as a moving vehicle, and that is what it continues to be, even if the surrounding vehicles also have their lights on.

European motorcycle organizations (FEMA, British Motorcyclists Federation en Motorcycle Action Group UK) strongly criticize the recent EU study (Elvik et al, 2003). Although nearly all points of this criticism could be refused, these organizations are expected to continue opposing DRL.

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1.4 General effects of DRL

The Directorate-General for Energy and Transport of the EC issued a consultation paper titled "Saving lives with Daytime Running Lights" (DRL, 2006). The EC is seeking the views of interested parties on its intention to propose measures to foster the rapid introduction of daytime running lights for motor vehicles.

In the Executive Summary of the paper the following facts are presented:

- According to the research available, DRL[1] has a high potential to increase road safety: using DRL helps road users to better and earlier detect, recognise and identify vehicles.

- Research studies estimate the life-saving potential of DRL to be in the order of 3% to 5% of the yearly number of road fatalities. If measures are undertaken to require the use of DRL throughout the European Union (EU), it could help saving between 1,200 and 2,000 road fatalities per year and, thus, make an important contribution to the European target of saving 25,000 lives per year on European roads.

The paper (DRL, 2006) emphasised the following research results:

- Road users not having lighting devices, i.e. pedestrians, cyclists, mopeds do not become less conspicuous if all vehicles feature DRL.
- A negative effect of DRL on the visibility of motorcyclists cannot be ascertained.
- Dedicated DRL and dipped headlines do not cause glare.
- It is true that DRL increases fuel consumption and CO_2 emissions. However, the increase is by up to 1.5% if dipped headlamps are used, and by up to 0.3% only in the case of dedicated DRL.

Nevertheless, even taking into account the effect on fuel consumption and CO_2 emissions, the safety benefits of a legal obligation to use dipped headlights on existing vehicles and to equip new vehicles with automatic dedicated DRL outweigh the costs by the factor 2 to 1, i.e. for one Euro invested into DRL, there is a benefit to society of 2 Euros.

[1] In the paper DRL (2006), the term DRL is used to describe the concept of using any lighting devices during daytime, in particular existing headlamps or dedicated lights.

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2 Background for developing DRL SPIs

2.1 What can be measured and quantified?

Safety performance indicators (SPIs) are measures (indicators), reflecting those operational conditions of the road traffic system, which influence the system's safety performance (Hakkert et al, 2007). SPIs are aimed to serve as assisting tools in assessing current safety conditions of the road traffic system, monitoring the progress, measuring impacts of various safety interventions, making comparisons, and so on.

The basic idea in developing the SPIs for Daytime Running Lights (DRL) is the stated relationship between the level of DRL use and road safety. According to Elvik et al (2003), we can talk about the effects of DRL for each vehicle using it (intrinsic effects) and the effects of laws or campaigns that lead to an increased use of DRL in a country or part of a country (aggregated effects).

Koornstra et al (1997) found a relationship between the intrinsic DRL effects and latitude as presented in Figure 2.1.

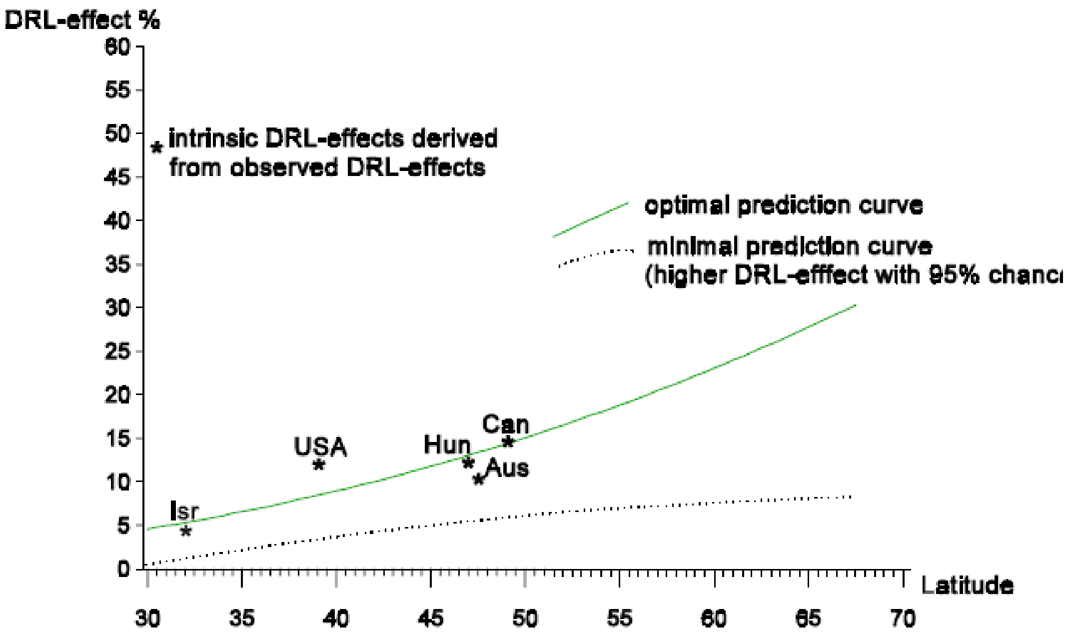

Figure 2.1: Prediction curves for intrinsic effects of DRL on all multi-party daytime accidents in different countries: an optimal and a minimum prediction curves (with a 95% confidence interval). Source: Koornstra et al (1997).

Later, Elvik et al (2003) examined the above relationship and stated that there is hardly any relationship between the latitude and effects of DRL. Their results can be seen in Figure 2.2. It can be concluded that there is no general agreement in the literature on the relationship between latitude and the effect of DRL.

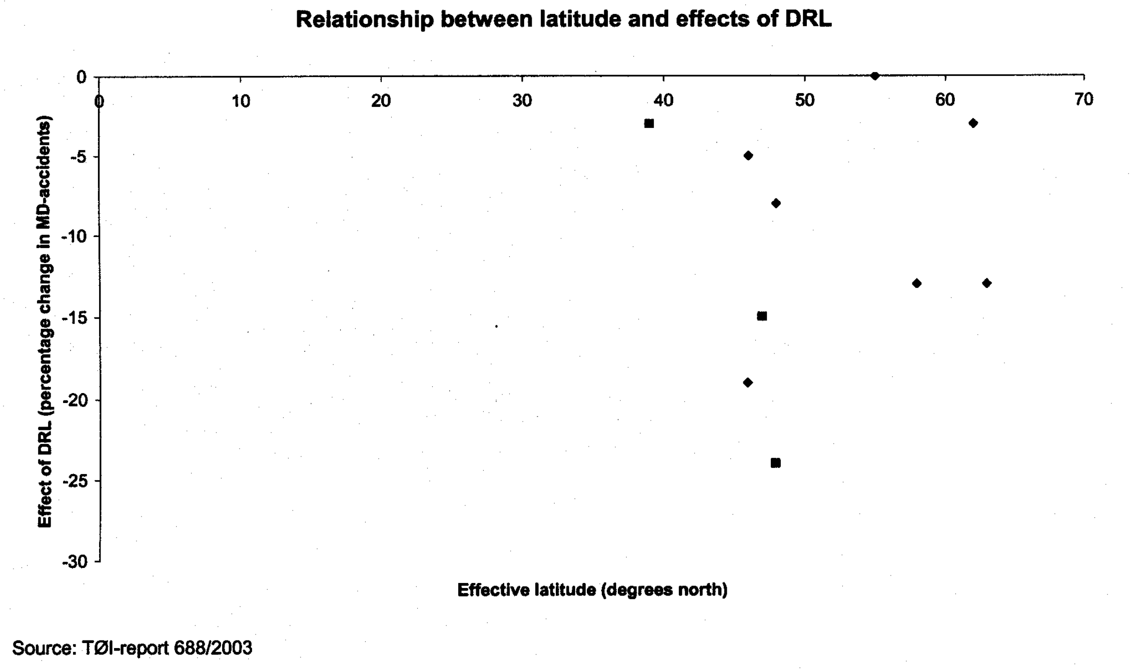

Figure 2.2: The relationship between geographical latitude and effects of DRL for cars. Source: Elvik et al (2003).

Besides, the daytime visibility of motor vehicles cannot be measured directly but the level of DRL use can. In other words, the indicator of the DRL use can be considered as an indirect indicator for visibility.

On the basis of both literature survey and current practices, the DRL SPI was suggested in the form of percentage of vehicles using daytime running lights.

2.2 Examples of SPIs in use

An examination of the literature reveals that the DRL use is generally discussed among the road accident preventive measures. For example, ETSC (2003) provided a cost-benefit analysis of a number of road safety measures which can be considered as the most promising for the application in the EU. A legal obligation for all motor vehicles to drive with low beam headlights or special DRL lamps during the whole year was evaluated in this context.

Later, an extension of the DRL use was included in the test cases of the EU project ROSEBUD which developed the efficiency assessment tools for road safety measures (Winkelbauer and Stefan, 2005). In this project, the test cases were selected accounting for interest to these measures in different EU countries. The economic evaluation of safety benefits of the DRL application (for the whole year) was performed for two countries: the Czech Republic and Austria.

Increasing the DRL use frequently appears among the measures which are parts of the national road safety programs. Based on positive effects of DRL on road safety the Department of Transport & Mobility in Kuratorium für Verkehrssicherheit (KfV) has been demanding for nearly 20 years that in Austria the obligation to drive with lights on during the day be introduced. The Austrian Road Safety Programme 2002-2010 supported the mandatory use of DRL in rural areas during winter period and expected safety benefits from this measure, e.g. the annual potential reduction of up to 30 fatalities by the year 2010. The federal government has committed itself to this traffic safety measure. From the 15th November 2005 to the 31st December 2007, driving with lights on during the day has been obligatory on all Austrian roads and for the whole year (KfV, 2008).

According to results of a recent survey, the DRL usage rates in Austria are relatively high: in 2006, it was 95% for motorways, 97% for rural roads, 88% for urban roads and 93% as a combined value for all roads. This is partly due to the fact that the lamps are switched on automatically in most cars when starting the engine.

In spite of the decision of the Austrian Federal Government that DRL use is no more obligatory in Austria, the KfV has a clear message on its webpage (KfV, 2008): "Every traffic participant profits from ligths on during the day. It is not just the safety of others, but it is the personal safety of everyone."

In general, the use of DRL indicators is not common in the road safety decision-making practice. When Elvik et al (2003) performed a quality assessment of 41 studies from different countries which quantified the effects on accidents of the DRL use by cars and motorcycles, one of the criteria for assessing the studies was the availability of information on DRL-use. It was found that more than half of the reviewed studies provided no information on the DRL use. In the studies providing such data, the indicator usually had a form of the proportion of vehicles using DRL.

Examples of the use of DRL indicators can be found in traffic behaviour monitoring systems. One of the most comprehensive systems of this kind exists in Finland. The system was launched in 1992. Presently, Liikenneturva – the Central Organisation for Traffic Safety in Finland – maintains the system for monitoring traffic safety work. Traffic behaviour data are annually collected using the same methods and the same measuring points. The use of daytime running lights is among the ten behaviours which are monitored by the system (Luukkanen, 2003).

Annual DRL observations cover more than 21,000 vehicles over the country. A DRL indicator applied is the percentage usage rate, inside and outside built-up areas, where the rates are estimated by proportioning the number of observations to the population of the provinces to which they refer to (Luukkanen, 2003). Figure 2.3 presents the monitoring results for the years 1993-2002.

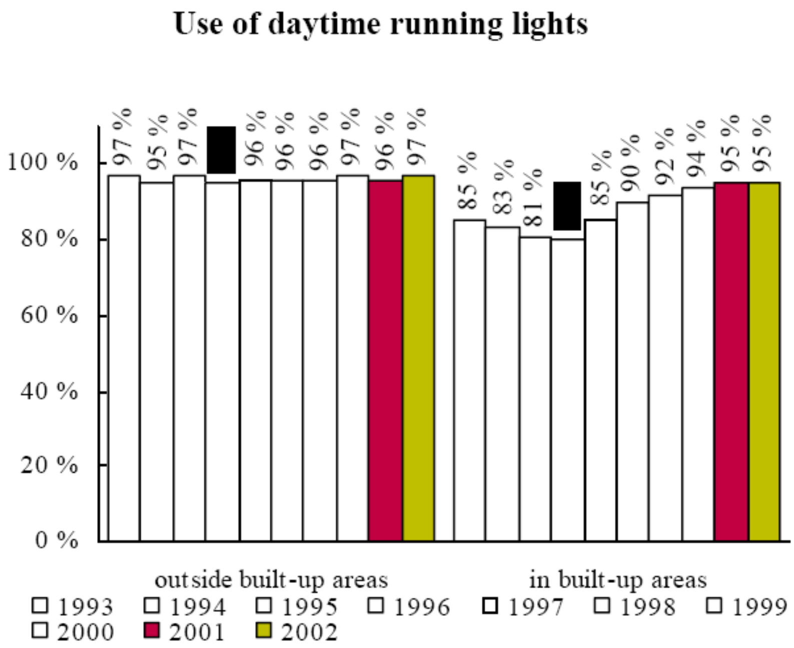

Figure 2.3: Use of daytime running lights in Finland - Results of systematic surveys in 1993-2002. Source: Luukkanen (2003).

In Hungary, the DRL usage rates have been observed since 1993, the year of the introduction of this measure. Each year more than 10,000 vehicles are being observed during the surveys. For example, in Figure 2.4, the DRL usage rates in Hungary can be seen according to road categories. Interpreting the figures, one should remember that in Hungary, DRL is obligatory outside built-up areas only.

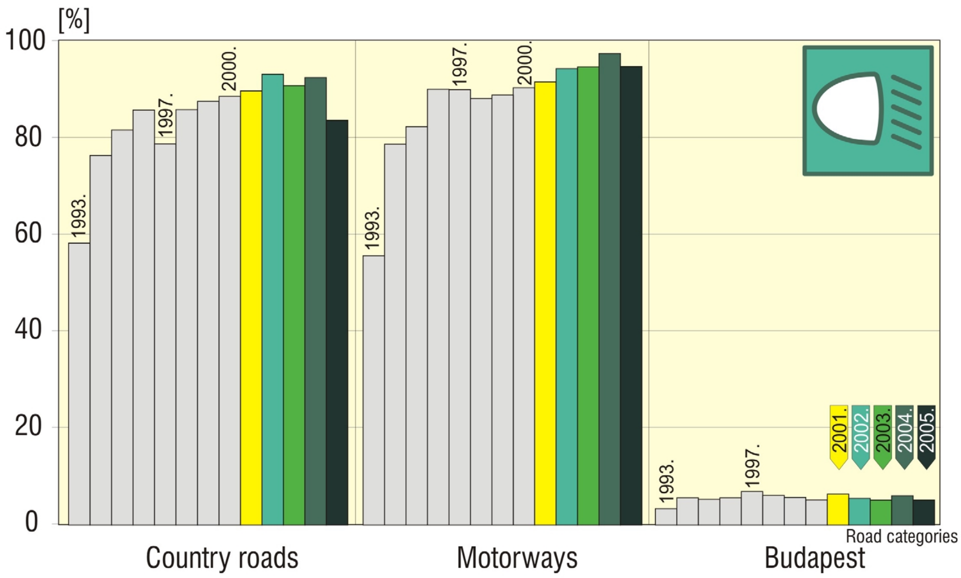

Figure 2.4: Use of daytime running lights in Hungary - Results of systematic surveys from 1993 to 2005.

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3 Constructing DRL SPIs

3.1 General concept

DRL SPIs are usually considered in the form of the percentage of vehicles using daytime running lights. A general indicator can be estimated for the whole sample of vehicles, which were observed in the country. Similar values can be calculated for different road categories and for different vehicle types.

The road categories to be considered are: motorways, rural roads, urban roads, and DRL-roads, where the term "DRL roads" implies the road categories where the usage of DRL is obligatory. For example, in Hungary, DRL roads are ones, which are outside built-up areas.

The vehicle types to be considered are: cars, heavy good vehicles (including vans), motorcycles and mopeds.

Besides, the background information on the DRL legislation is essential for a correct interpretation and comparison of the results. For example, comparing the countries' DRL usage rates it is reasonable to take into account whether the countries have a law/ regulation on obligatory use of DRL and if they do, when and where. Besides, DRL usage rates cannot be interpreted practically in countries where the lights are switched on automatically.

In countries where the automatic DRL was introduced long time ago (e.g. Sweden, Norway), according to expert estimates, the current DRL usage rate is close to 100%, thus the DRL usage rate as a behavioural safety performance indicator does not have practical implications any more. In general, once the option of automatic DRL is introduced Europe-wide[2], the DRL indicators will lose their importance.

3.2 Information provided by countries

To consider the context of the DRL use in different countries and to examine the potential for the application of DRL SPIs, a DRL questionnaire was built and distributed to national safety experts in the European countries. The questionnaire was composed in a way enabling to obtain information on a wide spectrum of issues, which are relevant to the DRL use in a country.

The main issues on which the information was collected are:

1. Legislative background, i.e. whether the DRL use is obligatory in a given country, and for which vehicle types; whether the automatic switch on was introduced, when, in which form and what is the current state of usage; sanctions for non-use of the DRL.

2. Surveying circumstances of the DRL usage rate, i.e. the frequency and the structure of the DRL survey (if applicable); sampling rules and available results.

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[2] For example, according to the consultation paper DRL (2006), by means of scenario 3: "The use of DRL is required by all motor vehicles from a certain date", where "new cars sold after the same date are required to have dedicated DRL that are switched on automatically".

3. Evaluation details of the DRL usage rate, i.e. how the DRL survey data are processed; whether the DRL use rates are available for separate road types and vehicle categories.
4. State of the application of means for increasing the DRL use, i.e. whether information and/ or enforcement campaigns on the issue are carried out; whether special road signs are applied to stimulate the DRL use.

After two DRL questionnaire surveys (in 2005 and in 2008), the information on the DRL use related issues was provided, in total, by experts from 23 (out of 29) countries, which are: Belgium, Czech Republic, Denmark, Germany, Estonia, Greece, Spain, France, Cyprus, Latvia, Hungary, Malta, Austria, Portugal, Sweden, the United Kingdom, Norway, Poland, Switzerland, the Netherlands, Bulgaria, Romania and Slovenia.

Considering the information provided by the countries it was found that:

a) A law or regulation concerning the use of DRL exists in 17 countries. Table 3.1 presents fourteen Member States, which have mandatory rules on the DRL use, according to the DRL paper (2006). Based on the DRL questionnaire responses, also Norway, Bulgaria and Romania can be added to this list. Other countries such as Greece, Cyprus, Malta, the United Kingdom and the Netherlands do not have a law on obligatory use of DRL. As we mentioned previously, the obligatory use of DRL in Austria was valid by the end of 2007.

b) The majority of countries with the DRL use related law/ regulation apply them for the whole year, where some countries have different rules. For example, Poland, Bulgaria, Czech Republic (as for cars) apply the law for winter time only; Spain defines special suppositions for obligatory lighting, as follows: "there is a legal obligation to use the lighting under adverse weather conditions as fog, hard rain, snowfall, smoke or dist clouds, or under similar conditions".

c) In many cases, the DRL law/ regulation has specifics for motorcycles. For example, in Czech Republic, Germany, France, Hungary the obligation is valid for motorcycles on any road or for the whole year, where for regular vehicles the DRL use is obligatory only for winter period, only for some road categories or not obligatory at all (e.g. in France, Germany).

d) In the majority of countries with a law/ regulation for the DRL use for cars, DRL should be used for the whole year and everywhere (on any road type). However, in some countries, the DRL law concerns certain vehicle types or certain road categories only.

e) At least five countries such as Denmark, Estonia, Sweden, Norway, Finland, reported that the majority of the vehicles have lights that are automatically switched on when starting the engine. All these countries have a law concerning the use of DRL, which is applied for the whole year and all vehicle types.

According to information reported by countries, regular DRL surveys take place in several countries such as Latvia, Hungary, Bulgaria, Estonia, Switzerland, where in the majority of countries, including those having a DRL law, such surveys are not carried out.

Country	DRL use: where?	DRL use: when?
Denmark	All roads	All year
Estonia	All roads	All year
Finland	All roads	All year
Italy	Motorways and out-of urban roads	All year
Latvia	All roads	All year
Lithuania	All roads	November-March
Austria*	All roads	All year
Poland	All roads	October-February
Portugal	Indicated roads	All year
Sweden	All roads	All year
Slovakia	All roads	October-March
Slovenia	All roads	All year
Czech Republic	All roads	All year
Hungary	Out-of urban roads	All year

**valid by end of 2007*

Table 3.1. Fourteen European countries with mandatory use of DRL. Source: DRL (2006).

Following two DRL questionnaire surveys, DRL usage rates are available for eight EU countries which are: Austria, Czech Republic, Estonia, Latvia, France, Hungary, Switzerland and Bulgaria, where three more countries (Poland, Sweden and Finland) stated that their DRL usage rates are about 100 percent – see Vis and Eksler (2008).

Most countries delivered the data on the DRL usage rates according to road categories. The Czech Republic and Switzerland also have DRL usage rates according to vehicle types. Most countries (of those who provided the data) have specific DRL legislation for types of vehicles and types of areas, where in France and Switzerland the DRL use (for cars) is only recommended.

3.3 DRL SPIs suggested for application

Following the general concept of the DRL SPIs (Sec. 3.1) and accounting for current practices on the DRL use and measurement in different countries (Sec. 3.2), the DRL SPIs suggested for application are as presented in Figure 3.1.

In total, nine DRL SPIs are recommended for application, which are: the total usage rate and the percentages of vehicles using DRL according to four road types and according to four vehicle categories. As mentioned above, the DRL use rate at the road type 'DRL roads' consists of the DRL rates at the road types at which the usage of DRL is obligatory by law in a country.

To estimate the above SPIs, a country should perform an annual survey of the DRL use. Recommendations on such survey's performance are given in the SPI Manual report (Hakkert and Gitelman, eds., 2007).

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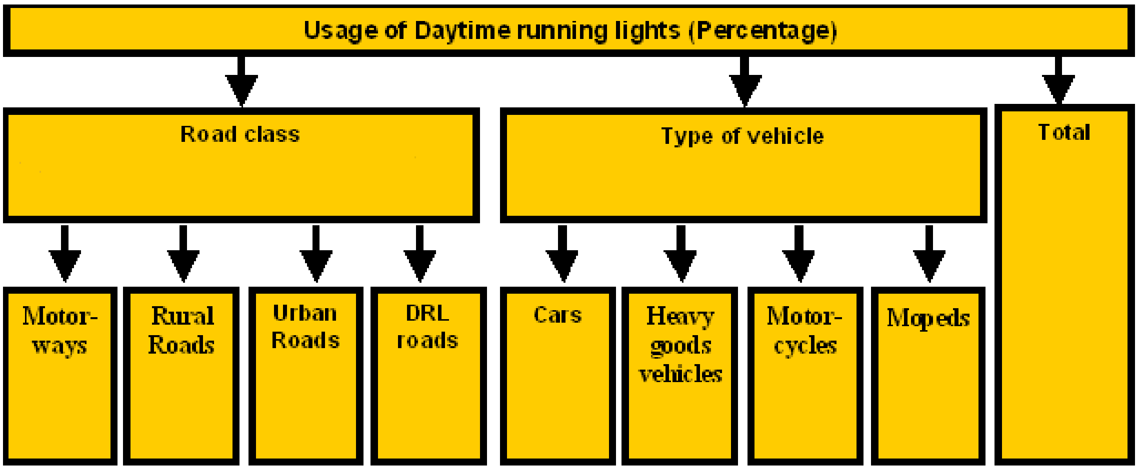

Figure 3.1 Overview of DRL SPIs.

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4 Conclusions

This reports sums up the general theory behind the development of the DRL SPIs, including a more detailed insight into the reported effects of DRL on vulnerable road users (pedestrians, two-wheelers).

Based on the literature review and recent experiences of several European countries, it can be stated that DRL can contribute to the improvement of road safety. There is no scientific evidence for the frequently mentioned negative effects for vulnerable road users (pedestrians, cyclists or motorcyclists).

The widespread introduction of DRL could be optimal if the behavioural measures for older vehicles are coincided with the installation of an advanced DRL unit on new cars. This would result in a combination of accident casualty reduction and reduced vehicle emission, especially when LED lamps are used. However, vehicle requirements can only be introduced at the EU level.

The DRL SPIs are defined as the percentage of vehicles using daytime running lights, where the value is estimated for different road categories and for different vehicle types. The background information on the DRL legislation is essential for a correct interpretation and comparison of the results. For example, comparing the countries' DRL usage rates it is reasonable to take into account whether the countries have a law/ regulation on obligatory use of DRL and if they do, when and where.

Besides, in countries, where automatic DRL was introduced a long time ago (e.g. Sweden, Norway), current DRL usage rate is close to 100%, thus the DRL usage rate as a behavioural safety performance indicator does not have practical implications any more. In general, once the option of automatic DRL is introduced Europe-wide, the DRL indicators will lose their importance as an indicator of safety performance.

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