SWOV Fact sheet

Public lighting

Summary
Visual perception is very important for road users and in the dark it can be facilitated by public lighting. Public lighting has a mostly positive road safety effect. Installing public lighting on roads that were previously unlit generally results in fewer and less serious crashes. This effect seems to be stronger for roads in rural than in urban areas. Furthermore, the effect seems to be greater on the risk of vulnerable road users (pedestrians, cyclists, (light) moped riders) than on that of drivers of motor vehicles. Increasing the luminance on roads that are already lit, has a considerably smaller effect. Decreasing the existing luminance, however, appears to lead to an increase in the number of crashes. It seems to be possible to apply public lighting cost-effectively on the majority of roads in the Netherlands. However, increasing luminance on already lit rural roads is not cost-effective.

Background and content
Public lighting is defined as “all artificial lighting on roads and streets, intersections and crossings” (Elvik et al., 2009). Other light sources also play a role in road traffic, like lighting inside and outside the car and reflection by traffic signs and the road surface itself. This fact sheet focuses on public lighting by means of lampposts. Alternative kinds of lighting, e.g. lighting installed in the road surface, will not be discussed in this fact sheet. First the necessity of and reasons for applying public lighting will be discussed and then we will look at the effects of both increasing and decreasing luminance on the crash rate as well as on human road behaviour. The effect of public lighting in the form of lampposts as collision objects will also be investigated, as well as the effects of public lighting on social safety. Public lighting in tunnels is not discussed in this fact sheet; this is already part of the fact sheet on road safety in tunnels (see SWOV fact sheet *The road safety of motorway tunnels*).

The visibility of the road environment does not only depend on the public lighting and the strength of these light sources. The visibility of the road surface is mainly determined by how much light is reflected by the road surface. The visibility of objects is mainly determined by a contrast in luminance, so that an object shows lighter or darker against its background (Fors & Lundkvist, 2009). This fact sheet will not go into the various technical aspects of public lighting, like the different types of lamp and the height and position of public lighting. Different CROW publications may be consulted for an overview of such technical aspects (see CROW, 2002a; 2002b; 2002c; 2002d; 2004a).

Why public lighting?
Observation and processing of visual information in traffic is very important for road users. This is also illustrated by the fact that most countries have restrictions for the blind and the visually impaired on performing traffic tasks like driving a car, whereas there are no such restrictions for the deaf or the hearing impaired (Boyce, 2009). In the dark the eyes are less capable of distinguishing objects, colours and movements than in daylight (CROW, 2002a; Elvik et al., 2009). Public lighting can be used to facilitate visual observation on times and in places where the natural light sources are insufficient. Also in these conditions public lighting makes it possible for people to sufficiently distinguish the road, other road users and the environment. The higher the illumination, the faster another object is observed. Moreover, the presence of public lighting reduces glare caused by the large contrast between headlights of other cars and the dark conditions; this is also called ‘headlight glare’ (Boyce, 2009). Such glare increases the risk of a crash, especially for older road users (see SWOV fact sheet *Visual impairments and their influence on road safety*). Improved visibility due to public lighting also influences behaviour: as the quality of the lighting improves, drivers not only observe intersections earlier, they also adapt their speed earlier (Rockwell, 1969, as described in Beyer & Ker, 2009).

What is the risk of travelling in the dark?
Research consistently indicates that travelling in the dark is subject to a higher risk than travelling during daylight. Also in the Netherlands the risk is higher at night than during daytime: it ranges from twice as high on weekdays to even four times higher on the weekend (Weijermars et al., 2008, see

Table 1). The same is the case for cyclists: they are also subject to a higher risk in the dark than during daylight (Reurings, 2010). Furthermore, Weijermars et al. (2008) have found that nighttime crashes in the Netherlands are more serious than crashes during the daytime.

Time	**Fatality rate (fatalities per billion km)**
Weekday daytime	3,4
Weekday nighttime	6,8
Weekend daytime	2,7
Weekend nighttime	10,6

Table 1*. Fatality rate by day and time, corrected for exposure (Weijermars et al., 2008).*

Differences in crash severity have also been found in other countries. For example, in Great Britain nighttime crashes are fatal twice as often as daytime crashes (Plainis & Murray, 2002). Several studies have found that the nighttime fatality rate (corrected for distance travelled) is 3 to 4 times higher than the fatality rate during daytime (Owens, 2003; Tignor, 1999). Furthermore, several international studies have indicated that certain groups of road users have a higher nighttime risk than others. In the United States fatality rate in the dark appears to be higher for young drivers than for older, more experienced drivers (Massie, Campbell & Williams, 1995). The crash rate during nighttime is higher for pedestrians than for motorized traffic (Elvik et al., 2009).

What is the road safety effect of public lighting?

A higher nighttime risk is not automatically due to lesser visibility. Matters like fatigue and alcohol use are also factors that are related to nighttime (Massie, Campbell & Williams, 1995). Many studies into the effects of public lighting therefore investigate the risks at nighttime or in the dark[1] on roads where the luminance is adapted. It must be noted that public lighting during daytime does not have an influence on behaviour or risk (Beyer & Ker, 2009).

Studies into the road safety effect of public lighting often investigate increased luminance of a road. This is often a comparison between the risk on a road that was not lit earlier and the risk on that same road after public lighting has been installed. A meta-analysis including studies from several countries indicates that the number of crashes in the dark decreases considerably after public lighting has been installed (Elvik et al., 2009; Beyer & Ker, 2009). The size of the effect of public lighting depends on the crash type, the road type, and the population density (see *Table 2*). Public lighting appears to be more effective for fatal crashes than for crashes with injuries or material damage only. Public lighting also seems to have more influence in urban than in rural areas, particularly in relation with fatal crashes.

Elvik et al. (2009) have also investigated the effect of public lighting at intersections. The number of material damage only crashes was shown to decrease by about 30% in both rural and urban areas. The effect of public lighting on injury crashes appeared to be greater in urban areas: there the number of injury crashes decreased by 40%. In rural areas that number was 22%.

An increase of public lighting was also shown to have a greater effect on the risk of pedestrians than on that of motorized traffic (Elvik, 1995; Elvik et al., 2009). Research in the Netherlands also indicates that public lighting has a greater protective effect on vulnerable road users (pedestrians, cyclists, moped riders) than on drivers of motor vehicles (Wanvik, 2009).

[1] Studies into the effects of public lighting usually mention the effects during nighttime or in the dark. However, it is usually unclear whether these two terms are interchangeable. This fact sheet discusses crashes and risks during nighttime, unless a study explicitly uses the term dark.

Type of road/environment	Fatal crashes	Injury crashes	Material damage only crashes
All road types	-60%	-23%	-16%
Motorways	Not determined	-13%	Not determined
Rural areas	-87%	-26%	-27%
Urban areas	-43%	-29%	-14%

Table 2*. Effect of public lighting on previously unlit roads*[2] *(Elvik et al., 2009).*

Not only the effect on previously unlit roads was investigated, study was also made of the road safety effect on roads where the existing luminance was increased. The results clearly indicate that the effect on the number of crashes is dependent on the increase in luminance (Elvik et al., 2009). Redoubling the investigated luminances was found to have only a limited effect on the number of injury crashes in the dark. The best estimate of this effect is a 5% decrease, but this is not statistically significant. When the luminance is increased to two to five times the original luminance, the number of crashes in the dark decreases by about 10%. An increase of more than five times the original luminance results in an approximately 30% decrease of the number of injury crashes.

What is the effect of public lighting on behaviour?

The effect of public lighting on behaviour has not been determined consistently. Some studies find that improved visibility due to public lighting leads to drivers seeing intersections sooner and therefore also adapting their speed earlier (Rockwell, 1969, as described in Beyer & Ker, 2009). Other studies, however, did not find differences in speed due to public lighting (Mäkelä & Kärki, 2004; Elvik et al., 2009). A Dutch study found that a reduction in luminance by switching off every other light pole had no effect on road user behaviour (Martens, 2005).

Other studies indicate that public lighting has a negative effect. These studies show that people feel safer when public lighting is present, which makes them less alert and lets them take more risks, e.g. by driving at higher speeds (Assum et al., 1999). Such research findings, however, do not mean that public lighting has a negative road safety effect; it does not change the fact that public lighting has a positive effect on the number of crashes. At the most, it could be concluded on the basis of this study that public lighting would have a greater effect on the number of crashes if no such compensatory behaviour would occur (Assum et al., 1999).

What is the effect of a reduction of the present luminance?

Increasingly, studies also investigate whether road safety deteriorates if the present luminance is reduced. This is the result of the increased interest in energy, environmental, and cost-reducing measures (e.g. AVV, 2006a; Martens, 2005). A well-known measure in relation with this is the concept of dynamic public lighting. Dynamic lighting encompasses different methods; one example being dimmable public lighting that makes it possible to vary between two or more amounts of light. The basic assumption here is that the required luminance of public lighting is determined by the traffic and weather conditions. A Dutch study into this type of dynamic public lighting investigated its effect on driving behaviour, perception and acceptance (Hogema & Van der Horst, 1998). It concluded that if the conditions are favourable (low traffic volume, dry weather), a (much) lower luminance can be used than is customary, viz. 20% of the normal level.

Another method to reduce the public lighting level is by partly switching off facilities like light poles. In a Dutch study into the consequences of such a reduction in luminance, every other light pole alongside a provincial road was switched off (with the exception of intersections and roundabouts, where the luminance remained unchanged). No negative effects were found on driving behaviour, safety perception and subjective workload (Martens, 2005). An international meta-analysis at the level of crashes, however, indicates that a 50% reduction of luminance is accompanied by an increase in injury crashes of about 17% and of about 27% in material damage only crashes (Elvik et al., 2009).

[2] The meta-analysis carried out by Elvik et al. (2009) contained sufficient results for a number of categories (injury crash on all roads, motorways and roads in rural areas) to correct for publication bias. Publication bias refers to the misrepresentation which occurs due to the fact that research findings are mainly published when they are significant or positive, which means that studies with negative or unclear findings receive too little attention. Because not all categories have been corrected for this bias, this fact sheet only presents the uncorrected findings, so that the results can be compared.

What is the effect of light poles as collision objects?
Public lighting can have a negative effect on road safety because they are collision objects. Annually, at least 400 crashes with fatalities or serious road injuries in which a light pole has been involved are registered in the Netherlands (*Table 3*). From this viewpoint it would be desirable for the light poles to be placed as far from the carriageway as possible; this is, however, unfavourable from the lighting angle. Guidelines for the width of the so-called obstacle-free zone are available for all road types (see SWOV fact sheet *Safe road shoulders*).

Severity	2005	2006	2007	2008	2009
Crash with fatalities	29	22	25	29	23
Crash with serious road injury/injuries)	132	116	127	114	105

Table 3*. Registered crashes in which a light pole is involved (sources: Ministry of Transport, Dutch Hospital Data - LMR).*

The severity of crashes can be limited by using crash-friendly light poles (CROW, 2002c, 2002d). A crash-friendly light pole is constructed in such a way that it offers little resistance and breaks off when it is hit by a vehicle. This makes the risk of serious injury considerably lower than for crashes with light poles that are not crash-friendly. Crash-friendly light poles have been shown to reduce the risk of personal injury by 50% (Elvik et al., 2009). Therefore, a crash-friendly light pole can also be placed in the obstacle-free zone without using a guarding facility (CROW, 1999; AVV, 2006b). However, a crash-friendly light pole must be placed in such a way that it does not cause further damage if it falls over after a crash (CROW, 2002d). Hence, light poles that are made of crash-friendly material like aluminium are still crash-unfriendly when they are higher than 10 m (CROW, 2004b,d).

Is public lighting cost-effective?
Of course, light poles do not only have benefits; there are also the costs of, for example, materials and energy. This raises the question whether the benefits outweigh these costs. Recent Norwegian data indicates that for most roads (with the exception of motorways) lighting roads that were previously unlit is cost-effective from a traffic volume of 15.000 or more vehicle per day (Elvik et al., 2009). Dutch research indicated that public lighting is cost-effective for most Dutch roads at somewhat lower luminances and with cheaper systems (Schreuder, 1996). Depending on the luminance, public lighting is cost-effective on motorways at traffic volumes of about 42,000 vehicles per day, and on other rural roads at volumes of more than 12,500 vehicles per day. However, Schreuder (1996) indicated that the roads that were used as a reference in his study were of an above-average safety level. He therefore suspected that public lighting could already be cost-effective at lower traffic flows.
Norwegian data indicates that increasing luminance on already lit roads is hardly ever cost-effective, irrespective of traffic volume (Elvik et al., 2009). Dutch research also showed that an increase of the then customary luminance on rural roads was not cost-effective (Schreuder, 1996, p. 265; see NNI, 2002 for the present guidelines). However, that same study found that increasing luminance in urban areas is indeed cost-effective.

What is the effect of public lighting on social safety?
In addition to its road safety, public lighting also has important implications for social safety, especially in urban areas (CROW, 2004a). Dutch research, for example, indicates that fewer criminal activities were reported in areas with higher luminance than in areas with lower luminance (Schreuder, 1992). Several international studies have found that the presence of public lighting not only has a positive effect on delinquency, but also has a positive effect on the fear of being subject to crime (Eck, 2002).

Conclusion
Public lighting is used to facilitate visual perception on times and at places where natural light sources are insufficient. Several studies have shown that public lighting has a predominantly positive road safety effect. Illuminating previously unlit roads generally results in fewer and less serious crashes. Public lighting has a greater effect on fatal crashes in rural areas than in urban areas. At intersections, on the other hand, public lighting seems to have a greater effect in urban areas. Moreover, public lighting appears to have a greater effect on the risk of vulnerable road users (pedestrians, cyclists, moped riders) than on drivers of motor vehicles. Increasing luminance on roads that are already lit, has considerably less effect. Research into the effect of public lighting on behaviour gives an

inconsistent picture, due to there being studies which indicate that public lighting causes drivers to see intersections sooner and to adapt their speed earlier, as well as studies which show that public lighting has no effect or even a reverse effect on traffic behaviour, like people who drive faster after an increase in luminance. No negative effects on behaviour were found when the existing luminance was decreased. Research into crashes, however, indicated that reducing luminance by 50% led to an increase in the number of crashes. Public lighting can have a negative road safety effect because the light poles are collision objects. The severity of crashes with light poles can be reduced by using crash-friendly light poles. Cost-effective application of public lighting seems to be possible for most roads in the Netherlands, in urban as well as in rural areas. Increasing luminance on already lit roads, however, is not cost-effective. Finally, in addition to its road safety effect, public lighting also has an effect on social safety. Public lighting has a positive effect on delinquency as well as on the fear of being subject to crime.

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