Nighttime Cycling: Accidents, Lights, and Laws in Europe
Abstract for the International Cycling Safety Conference 2013

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ABSTRACT

The German Cyclists' Federation ADFC has studied the subject of bicycle accidents at dusk and in the dark in Europe and has considered the results of a survey of the European Cyclists' Federation ECF on national regulations for bicycle lights. Based on references and evaluated European and national statistics the study searched for correlations between the accident situation and the use of bike lights. Some results for Germany, the Netherlands, Switzerland and Austria (D, NL, CH, A):

- 1/3 to 40% of cyclists ride in the dark without lights or with partially defective lights.
- About 7% of bicycle accidents at night are due to missing or defective lighting. Based on all bicycle accidents, they are an estimated 1-4%.
- Although only 10% of bike rides take place at night, in these four countries about 20% of fatal bicycle accidents occur during nighttime, in other EU countries even up to 40% and more.
- Nocturnal bicycle accidents usually have more severe consequences. The risk of being killed on the bike at night is significantly increased, especially out of town.

A comparison of these four neighbouring European countries shows that cyclists there have
- similar proportions of nighttime accidents,
- similar proportions of defective or missing bicycle lights and
- a similarly increased risk of accidents and injuries at night.

These countries have or had, however, very different legal regulations for bicycle lights:
- Bicycles may only be sold with lights (A – revised in October 2013).
- Only dynamo lights are allowed (D – battery lights legalized since August 2013).
- Battery lights are allowed (NL, CH, A. D since August 2013).
- Battery lights on cyclists are also allowed (NL).

This suggests that the different rules have only a marginal impact on the safety of bicycle traffic in the dark. Only a small number of nighttime accidents can be clearly attributed to the lack of lights: Other major risk factors are driving or riding under the influence of alcohol, higher driving speeds on empty roads at night and impaired night vision especially in older drivers.

Keywords: cycling accidents, bicycle lighting, lighting regulations.

1 The importance of bike lights in accidents

1.1 Proportion of cyclists without active illumination

Bicycle lights have made significant progress in recent years. LED lights are not as vulnerable as filament lamps which often become defective. However, even in countries where bicycles are an everyday means of transportation, and are often ridden during the evening or at night, relatively few cyclists travel on the road with proper lighting. According to a Swiss study about a third of cyclists ride with no functional lighting and 17% without lighting at all [1]. In a sample of a Swedish university town of 896 cyclists 72% had no lawful lighting [2]. In Germany, nearly 40% of cyclists ride in the dark with poor lighting or without any lighting at all (counted in eleven cities by the German automobile club ADAC in 2009) [3]. These figures were confirmed by regional samples of the German Cyclists' Federation ADFC in Tübingen and Nürnberg in November 2009 [4] and backed up by studies from Switzerland and Austria [5]. Dutch research from 2005 shows that 63% to 65% of cyclists have a light; i.e. 35% to 37% are without lighting [6]. Another Dutch study carried out in 2009/2010 among 17,245 cyclists found 62% of them riding with proper lights. Cyclists in the four largest cities of the Netherlands and youths and young adults seemed to ride their bikes more often without lights at night than inhabitants of smaller towns and older age groups [7].

On the other hand, lighting problems not just confined to the bicycle. In Germany, defective or badly adjusted lights are found to be the most common malfunction in motor vehicles tested for roadworthiness. According to an evaluation by the TÜV Report 2008 [8], more than a third (35.6%) had minor or significant deficiencies in the lighting system. Inspections carried out by workshops for the German traffic safety organisation Deutsche Verkehrswacht each year in October show that over 35% of drivers are traveling with improper illumination. This is a very similar number as for the bike lights. In automotive lighting a high degree of redundancy – the main lights to the front and back of the car are in pairs and are backed by position lamps - prevents that malfunction of a single light bulb causes a complete blackout. In the case of bicycle lights the failure of a single lamp results in a 50% failure of the entire lighting system. For bicycles, only the reflectors provide some compensation for the frequent lack or loss of active lighting.

1.2 Night accidents of cyclists in Switzerland and Germany

If we take figures from the Swiss Council for Accident Prevention (Beratungsstelle für Unfallverhütung, bfu) [1] we see that at night there are a disproportionate number of bicycle accidents.

Only about 10% of bicycle trips are taken at night, whereas about 20% of bicycle accidents occur at this time [1]. However, accidents at night can be caused by factors other than the light conditions, such as the influence of alcohol (on the cyclists or other road users). Alcohol consumption takes place more often at night rather than during the day and brings an increased accident risk. In Germany only 9% of all traffic accidents in 2010 occurred between 22.00 and 06.00, but nearly half of the total were alcohol-related accidents [9].

The Federal Statistical Office of Germany (Destatis) [10] publishes an annual summary of the official accident statistics. In 2011 399 cyclists were killed on German roads, looking at both accidents in town or out of town and in daylight, dusk and at night (in relation to bicycle lighting we must also include the accidents at dusk and dawn).

This study found that in 2011, in adverse visibility conditions 68 cyclists were killed (17% of all deaths), including 34 urban cyclists (9 at dusk, 25 at night) and 34 outside urban areas (4 at dusk, 30 at night). In daylight there were 205 urban cyclist fatalities and 126 cyclists killed outside urban areas; 331 in total. This is a ratio of 38% fatalities in adverse darkened conditions to 62% fatalities in daylight conditions.

What is also striking in the German road accident statistics is the equivalent number of dusk and night fatal bicycle accidents in both cities *and* outside the city, both at 34, striking because the vast majority of cyclists can be found in cities. In 2009 in Germany there were 75,797 cyclists accidents, including 68,435 urban and 7362 outside urban areas; 462 were fatal. Of these, 259 died in town and 203 out of town. Outside built-up areas there are only 10% of bicycle accidents involving injuries or fatalities, but they account for 44% of the deaths. In 2009, of the 259 urban cyclist fatalities 38 (15%) occurred in the dark; for the highway the figure was 39 of 203 (19%). Of the 239 urban cyclists killed in 2011, 34 (14%) lost their lives in twilight or darkness, while out of town fatalities under these lighting conditions numbered 34 of 160 (21%). The risk of suffering a fatal accident outside of urban areas is thus several times higher (10% of accidents, 44% of deaths) compared with urban accident and increases again in twilight or darkness by up to 50%. But the majority of fatal bicycle accidents in Germany happen on country roads (outside of urban areas) during daylight hours. The more severe consequences of accidents during the day or at night are likely to be largely due to the high vehicle speeds in the extra-urban traffic.

The official road accident statistics in Germany show "accidents and casualties and lighting conditions" for 2011 for all road users giving the following figures:

- Injury accidents total 306,266,
- Of which during daylight 229,391 (74.9%),
- Of which at dusk 15,304 (5.0%)
- Of which during the night 61,571 (20.1%)
- For twilight and darkness together this amounts to (25.1%)

4,009 people were killed

- Of which during daylight 2552 (63.6%),
- Of which at dusk 187 (4.7%)
- Of which during the night 1270 (31.7%),
- For twilight and darkness together this amounts to 36.4%.

So with respect to all road users traffic accidents in dusk and at night bring worse consequences accounting for one quarter of the casualties, but more than a third of those killed.

Based on 2011 figures the numbers of fatally injured cyclist at dusk and at night were 17%, in 2010, the percentage was 19.5%. These figures from Germany are close to the calculated value for Switzerland, 20% nighttime bicycle accidents, and suggest a significantly increased risk for cyclists in twilight or darkness, both in terms of the probability of accidents and the severity of the accident. However due to the lack of known exposure data in Germany (such as number of trips, or km travelled etc.) definite statements about the extent of the increased accident risk cannot be identified.

Many cyclists will not cycle in the dark. In Germany, the bulk of the accidents occur in the summer, on days with short hours of darkness. An evaluation of the Berlin bicycle accidents in 2010 found the following figures [11]:

- From 6:00am accidents start to pick up and increase constantly.
- The accident peak is reached between 15:00 to 15:59.
- The hours between 16:00 to 18:59 have a similar, almost uniformly high number of accidents.
- A fall in accident numbers occurs from 21:00.
- In the summer months, accidents are frequently reported well into the late evening.
- In the autumn and winter months, the number of accidents drops sharply at the latest from 20:00.

In big cities like Berlin still with a high cycling modal share in autumn and winter, many people will cycle even at dusk and dawn, for instance on their way to school or work. School and commuter traffic tends to vary less with the seasons (i.e. to be more steady over seasons) than leisure traffic. A statement as to whether the proportion of bicycle accidents in the dark corresponds to the share of cycling during the dark times of the day is not possible, however, because data on the distribution of cycling over 24 hours are not available for Berlin or Germany.

1.3 Cyclist fatalities during darkness or twilight in the EU

1.3.1 Monthly data

Data from the EU is available for the distribution of cyclist fatalities per month and by hour of day [12]. From the CARE Database 37% of cyclist fatalities in 2009 in the EU-23 countries occurred in July, August and September. The proportion of cyclist fatalities during January, February and March is only 14%. This is less than the proportion of car occupant fatalities during these months of 24%. There is no clear trend in the incidence of cyclist fatalities by month in individual countries. The peak for the EU-23 countries occurred in July (13%) and the fewest fatalities occurred in January (6%) [12]. Again, the actual number of cyclists on the road in summer (with short hours of darkness) and in winter is not known. Given that there will be more cyclists during these times this probably explains the higher accident numbers in summer. Also slippery wet conditions of many European winters may contribute to high-severity accident injuries, independent of the lighting conditions.

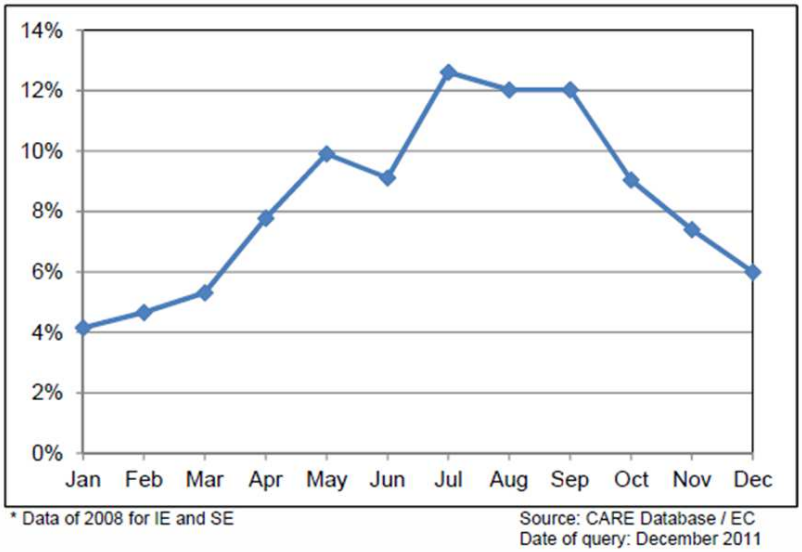

Figure 1: Proportion of cyclist fatalities per month in 2009, EU-23 (DaCoTa Figure 4 [12])

1.3.2 Daily data

The next figure presents the distribution of cyclist fatalities over 24 hours for the EU-22 countries. A large percentage occurred during the 16:00-20:00 hours' time period (27%). Also between 08:00 and 12:00 and 12:00-16:00 hours, more cyclists are involved in fatalities (24% and 23% respectively) than during other times of the day. Compared to other modes of transport, the share of bicycle fatalities raises during the day. There is no clear trend for individual countries, for example: the fatality proportion between 4:00 and 8:00 was slightly above average in Denmark and Sweden; between 8:00 and 12:00 it was above average in Spain and the UK [12].

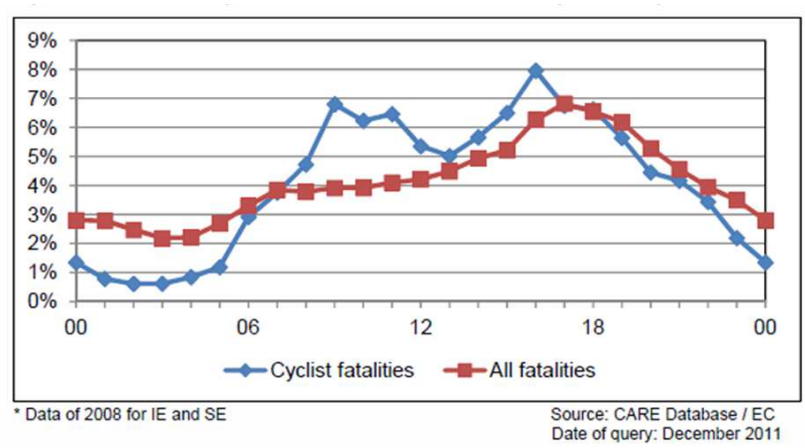

Figure 2: Distribution of cyclist fatalities and of all road fatalities by hour of day in 2009, EU-22 (DaCoTa Figure 5 [12])

1.3.3 Light conditions data

The role of light conditions on the incidence of cyclist fatalities is demonstrated in figure 3. Some of the fatalities between 16:00 and 20:00 hours may be related to lighting conditions: around 25% of accidents happened in the dark. Accidents between 08:00 and 16:00 hours have few fatalities related to darkness, and relatively few to twilight [12]. These are the daylight hours, with the highest proportion of fatal cyclist accidents.

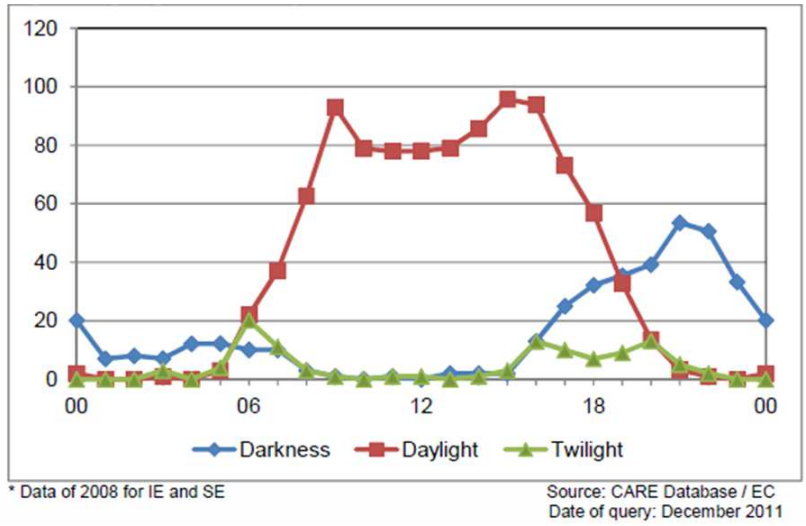

Figure 3: Lighting conditions for cyclist fatalities in 2009, EU-22 (DaCoTa Figure 6 [12])

According to the number of cyclist fatalities in the EU-21, a share of about 20% for fatal accidents during darkness or twilight is typical of countries like Germany, France, the Netherlands and Sweden. Switzerland as a non-member is not included in these statistics though it has a share of about 20% as well. The average for the EU-21 in 2009 was 30%. The range is from 15% in Finland to 52% in Portugal and even 100 % in Ireland (due to the low casualties in absolute figures). Among the larger countries, the proportion was around 40% in the Czech Republic, Hungary, Poland and Romania [12].

	Darkness	Daylight	Twilight	Number known	Total	% dark or twilight
BE	17	69	3	89	89	22%
CZ	29	48	7	84	84	43%
DK	4	21	0	25	25	16%
DE	77	366	19	462	462	21%
EE	3	4	-	7	7	43%
IE	13	-	-	13	13	100%
EL	8	6	1	15	15	60%
ES	13	38	5	57	57	33%
FR	26	128	8	162	162	21%
LV	11	13	2	26	26	50%
LU	1	1	-	2	2	50%
HU	42	61	-	103	103	41%
NL	24	110	3	137	138	20%
AT	9	29	1	39	39	26%
PL	96	226	49	371	371	39%
PT	13	14	2	29	29	52%
RO	42	91	24	157	157	42%
SK	4	15	0	19	22	21%
FI	2	17	1	20	20	15%
SE	5	21	1	27	30	22%
UK	24	80	-	104	104	23%
EU-21	463	1357	127	1947	1.954	30%

* Data of 2008 for IE and SE

Source: CARE Database / EC
Date of query: December 2011

Table 1. Number of cyclist fatalities by lighting conditions in 2009, EU-21 (DaCoTa Table 7 [12]).

A major problem is that the CARE Database does not give exposure figures, i.e. the number of cycling trips, or km travelled etc. during dark. However the fact remains that almost one-third of killed cyclists (30%) in the EU-21 countries were killed when lighting was poor. Even if the number of cyclists on the road over 24 hours is not known for these countries we can assume that this share exceeds the proportion of cycling trips taken in twilight or darkness by far. This share is about 10% in countries in which the bicycle is a part of everyday transport (like Switzerland and even more so the Netherlands) and can be assumed to be lower where cycling is mainly a leisure activity for which daylight is preferred.

1.4 Seriously injured cyclists in nighttime crashes in the Netherlands

A recent study from the Netherlands [6] states that there has been no previous research in the Netherlands into how dangerous it is for cyclists to ride their bikes in the twilight and by night (this is also true for the rest of Europe). It says that this is one of the reasons why it cannot yet be determined how much bicycle lighting generally contributes to road safety, in other words, how many casualties it saves among cyclists. The main difference between the figures given in this Dutch study and those for Germany and other EU members reported so far is that exposure (distances travelled by bicycle or number of trips) under different lighting conditions was taken into account because of the Dutch SWOV data on the daily mobility of cyclists. Dividing the number of casualties by the distance travelled by bicycle (in millions of kilometers) gives the casualty rate for each light condition: the higher the rate, the more casualties per kilometer travelled.

Also included in the study are analyses of serious (road) bicycle injuries as well as fatalities. Furthermore, casualties among cyclists are distinguished between casualties in crashes involving a motorized vehicle and casualties in crashes with no involvement of a motorized vehicle. Reurings [6] states that most of the seriously injured cyclists accidents were involved in daylight crashes, both those involving and those *not* involving a motorized vehicle. This is an expected result, as more cycling takes place during daytime. But in the dark there are *relatively* more casualties among cyclists than in daylight hours. During the period 1993-2008, the percentage of cyclists who were seriously injured in motor vehicle crashes in the dark fluctuated between 14% and 17%. For seriously injured cyclists in crashes *not* involving motorized vehicles the percentage increased from 13% in 1993 to 23% in 2008. However, only 10% of the dis-

tance cycled is travelled in the dark, which allows the conclusion that the casualty rate for cyclists is higher in the dark than in daylight. 10 % is also the same as the share given for Switzerland [1], in spite of the obviously different cycling culture in both countries.

In the dark, the casualty rate is usually higher in the early morning (i.e. between midnight and the beginning of dawn) than it is in the evening (between the end of dusk and midnight). For seriously injured cyclists in crashes involving motorized vehicles the casualty rate in the dark during the morning hours is roughly twice as high as in other lighting conditions. Until 2001, these rates declined for the different light conditions, since then they have been fluctuating. However in recent years the casualty rates in the dark seems to be increasing. For seriously injured cyclists in crashes without motorized vehicles being involved, the early morning casualty rate in the dark in 1993 was a factor of 4 higher than in other light conditions, and in 2008 this was a factor of 10 higher. This casualty rate shows an increase by a factor of 2.6 for the period 1993-2008.

When we look at the casualty rates per age category and light condition, we see that for all age categories the casualty rate is highest in the dark. From this we may conclude that the casualty rate is higher in the dark than it is in daylight because cycling in the dark is indeed more dangerous and not because those cyclists travelling in the dark have an increased casualty rate in all conditions. Especially for those in the age group 18-29 year-old in particular it is dangerous to cycle in the dark (compared to their overall casualty rate). There are, however, clear indications that it is not only the dark, but also the use of alcohol which plays a crucial role in the high casualty rate for this group. In 1993, 24% of the 18-24 year-old cyclists who were seriously injured on a weekend night in a crash without motorized vehicles being involved had used alcohol (according to information in the hospital registration); this increased to 58% in 2008. Also among the 25-59 year-olds alcohol use is relatively high and increasing: 21% in 1993 and 44% in 2008.

Days are shorter in winter and relatively more cycling takes place in the dark: in winter 36% of bicycle mobility takes place during dusk and dark as opposed to some 5% in spring and summer and about 19% in autumn. When it is also taken into account that it can be slippery in winter, the casualty rate for cyclists could be expected to be highest in winter. This is indeed the case for cyclists in motorized vehicle crashes, although the rate is not much higher in winter than it is in other seasons. The casualty rate for cyclists in *non*-motorized vehicle crashes, on the other hand, is highest in summer.

The relationship between using bicycle lights (and their quality) and the casualty rate when cycling in dark and dusk has not been investigated in this study. It is difficult to investigate, because it is not known whether or not cyclists who were involved in a crash had working lights on their bicycle [6]. This is confirmed in another Dutch study published in 2008 which points out that no literature in English, Dutch or German could be found on the relation of bicycle lighting and traffic safety [13]. A recent SWOV-Factsheet states that it has not been well investigated if cycling with lights benefits traffic safety. It points out that this is an important subject of study as its answer could give the police useful hints for law enforcement [14].

2 Technical deficiencies or lack of bike lights as cause

It is however possible to find data on the technical deficiencies, or lack of lights, as a cause of an accident. This is not the same thing as looking at the relationship between the *use* (and quality) of bicycle lights and the casualty rate, rather this looks at the *non-use* of bicycle lights. Information on technical defects (here: the lighting defects) as an accident cause could not be found for the EU as a whole, but could be found in some individual countries. In the German Federal Statistical Office report of 2011 [15], technical defects were attributed to four bicycle fatalities the main cause of which could be put down to defective lights. Therefore defective lighting is considered the most common technical defect which led to a fatal accident. However considering the total number of bicycle fatalities of 399, bicycle fatalities due to defective lights are 1%. In accidents involving personal injury, the proportion of accidents due to defec-

tive lights of bicycles is only 0.7% [10]. Then the defective lights of bicycles had only a minor role for the accident. However since defective lighting accidents only occur in darkness or twilight, it is appropriate that bicycle accidents with defective lights are seen in relation to only those accidents in darkness in twilight; 4 out of 68 (in dusk and dawn) 5.9%, and 4 of 55 (in the dark) 7.3%.

This percentage is comparable to figures given by the Swiss bfu. In their safety dossier, they speak of 4% bicycle accidents due to defective lights. Because the number of cyclists riding at night is much smaller than during daylight hours, the share of victims of accidents without lights is not negligible (or marginal) any more when related to the trips taken during periods of darkness. The above figures are derived from police reports from the scene. For the police officer, it is not always detectable with certainty whether the technical deficiency was an important cause of the accident. The same applies to the statement of the cyclist who would often prefer to distract the authorities from his misconduct by presenting the technical fault as the cause of the accident [1]. In other words this is very much open to charges of under reporting but also over reporting.

2.1 Alternative causes of nighttime accidents and research needs

The SWOV study [6] did not systematically investigate the possible explanations for the higher rates during dusk and dark. A first recommendation was to develop policies to discourage 'cycling under the influence' (p. 56). The link between the use of bike lights (and their quality) and the risk of cycling in twilight and darkness mentioned in the SWOV report has also not been studied. It is difficult to study, says the report, because it is not known whether the cyclist crashed in a bicycle light related accident ("Dit is ook moeilijk te onderzoeken, omdat niet bekend is of de fietsers die betrokken zijn bij ongevallen al dan niet licht voerden"). The proportion of cyclists in annual censuses who cycle at night with lights is fairly constant since 2005 (63% - 65%).

Generally night-time accidents result in more severe injuries. Higher vehicle speeds due to empty roads at night, a higher number of drivers under the influence of alcohol with deficits in vision and reaction and the problems of elderly drivers with night vision impairment all contribute to this. According to estimates from German experts in traffic medicine, one in seven motorists is affected by 'night blindness'. Working bicycle lights enable these high-risk drivers to perceive and recognize cyclists better (and earlier) and give them the opportunity to respond in time to avoid a collision. This is also true for motorists with normal vision as the visual performance of the human eye at night generally drops to 5% of the daytime value.

In daylight, in good visibility and with good eyesight a cyclist or a pedestrian can be seen at a great distance. At night it is very different: The high beam of automobile headlights is designed so that the illumination is about 150 meters. The low beam however must not blind oncoming traffic which brings the visibility down to about 40 to 70 meters. Braking distances for cars at speeds of 70 - 80kph are approximately between 50 – 80 metres depending on road conditions.

2.2 bfu and Switzerland: Fixed versus plugged lighting

Fixed lighting provision (fixed on the bike as opposed to being detachable) was abolished in Switzerland on 1st February 1994. Currently bicycles must have at least a white (in front) and a red (behind) static light, these must be seen from 100m, they may be fixed or removable and the lights must not dazzle oncoming traffic [16]. The Swiss Council for Accident Prevention (bfu) periodically examined the light rates of Swiss bicycles and the progression of cycling accident figures. In its report of 1996 [5], the bfu states that only 50% of cyclists rode at night with proper lighting and one-third are completely without lighting. Moreover, the number of injured cyclists aged 15 - 19 years old in the dark as a proportion of number of accidents rose from 19.5% in 1992 to over 21 in 1994.

If fixed lighting was on the bicycle it was found to be broken in about 25% of cases, the main defect being a failed bulb (40%), followed by defective cables (25%). More recently with the rise of LED lighting as the state of the art, defects of the light bulb may be increasingly eliminated. Therefore technical defects can be eliminated as the main reason for lightless trips. Rather, in most cases there are no lights on the bicycle [1]. The authors came to a similar conclusion in 1996 by proving that permanently fixed lights had a higher rate of use than detachable lights. Accordingly, cyclists ride more often with their lights on in the dark if these are permanently attached to the bike (as with dynamo-driven lighting) than if the lights are detachable such as battery lights [5].

In the current road safety dossier of 2012 bfu gives visibility a high potential for road safety. Even though better visibility alone would not prevent single accidents, a large part of the collisions with other road users could be avoided, even in daylight. At night, the use of bicycle lights would have to be increased significantly. Likewise, more reflectors must be used. The authors want to implement this in particular by raising awareness amongst cyclists on this issue through providing advice and information to consumers. They criticize the lack of cyclists' risk awareness and feel that this explains the low rate of lights used, and see the possibility for better enforcement measures by the police. More police checks or educational measures could lead to a greater awareness of cyclists and therefore to a higher awareness of risk. The Swiss legislator is advised to make the dynamo as an "inexhaustible source of energy" compulsory again to power the lighting system. Germany is held up as an example (but has revised its dynamo law in August 2013). Mountain and racing bikes could be exempt from this requirement because in sport-oriented bicycle models only battery lights would be justified [16].

3 Comparison between similar countries on the influence of lighting regulations – Austria, France, Germany, The Netherlands and Switzerland

These European countries have similar numbers of bicycle use with defective lights, or with no light use as well as a similar proportion of cycling accidents in twilight or darkness of about 20% (though slightly higher in Austria of 26%). They also have similar increased risk and severity of accidents during night time cycling (though no exposure figures are available for France).

Their differences include the use of the bicycle in everyday use (for example Germans travel about 300km per year, the Dutch travel about 900km per year, we can assume the French figure would be considerably less). There are also differences in legal lighting requirements:

- Germany – Dynamos are required by law, they must be permanently attached, battery lights alone are not permitted (recently allowed since August 2013), no obligation to sell bicycles equipped with lights
- Austria – Battery lights are allowed and they can be detachable, there is a legal obligation to sell bicycles equipped with lights (recently abolished in October 2013)
- Switzerland - Battery lights are allowed and they can be detachable, must be seen from 100m, no obligation to sell bikes equipped with lights
- Netherlands – Battery lights are allowed, detachable or fixed to the body of the rider, there is no obligation to sell them with the bike
- France – Battery lights are allowed, there is a duty to sell lights with bikes though this is rarely maintained.

So even though there seem to be similar rates of bicycle accidents in the dark and of the use of bicycle lights, these countries have very varied legal and technical requirements. This suggests that the different rules do not have a large effect on the use of lights or on accident figures and have only a marginal impact on the safety of bicycle traffic in the dark. Only a small number of nighttime accidents can be clearly attributed to the lack of lights: Other major risk factors are driving or riding under the influence of alcohol, higher driving speeds on empty roads at night and impaired night vision especially in older drivers.

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