European Commission

European Road Safety Observatory

Road Safety Thematic Report - Cyclists

This document is part of a series of 20 thematic reports on road safety. The purpose is to give road safety practitioners an overview of the most important research questions and results on the topic in question. The level of detail is intermediate, with more detailed papers or reports suggested for further reading. Each report has a 1-page summary.

The topic “Cyclists” is also addressed in the “Facts and Figures – Cyclists”, presenting more detailed and up-to-date European data in addition to this qualitative analysis.

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Contents

Summary

Cyclists and road safety

In this report cyclists are defined as users of a conventional bicycle or a pedelec. The first of these is solely human-powered while the latter is a collective name for electric powered bicycles that offer pedal assistance. The pedelec is a bicycle that delivers power when the cyclist pushes the pedals and only up to a speed of approximately 25 km/h. Pedelecs are sometimes referred to as e-bikes: officially, however, e-bikes are powered two-wheelers with an electric engine that moves forward without the cyclist pedalling.

Cyclists are vulnerable in traffic and constitute the only road user group in the EU where the number of fatalities has not declined since 2010. Reasons for the stagnation in the levels of cyclist fatalities might include the increased popularity of cycling or other factors such as the lack of safe cycling infrastructure. Furthermore, the relative proportion of serious injuries in crashes involving a cyclist has not declined: this increased from 7% in 2010 to 9% in 2019.

Fatal cyclist crashes mostly involve motor vehicles. In 2019 in the EU this was the case in around seventy percent of the fatal crashes. Reliable EU-wide data on serious injuries are lacking. It should be noted that bicycle crashes are significantly underreported, in particular crashes without the involvement of motorised vehicles. Hence, the actual share of bicycle-car crashes can be expected to be lower. As with other crashes, cyclist crashes are mostly caused by a combination of different crash factors. Infrastructural factors which contribute to the occurrence of bicycle crashes often include the general lay-out of the road or, in case of bicycle crashes involving motor vehicles, the absence of bicycle infrastructure. Furthermore, behavioural factors play an important role: unsafe behaviour of both cyclists and other road users (e.g. speeding, distraction, red light running, driving under the influence) increases crash risk.

Countermeasures

With respect to *infrastructure*, cyclists can benefit from several measures. To prevent crashes with motor vehicles, it is important to separate cyclists from motor vehicles, for example by means of bicycle routes or separate bicycle tracks. Effective measures to reduce the speed of motor vehicles on intersections for instance include speed humps. To prevent crashes which do not involve motor vehicles, the following infrastructural measures are recommended: no obstacles on the bicycle track, visual road alignment, sufficiently wide bicycle tracks, and a road surface that is skid resistant and free of cracks and potholes.

With respect to the *bicycle,* adequate lighting is important for cyclists in order to be seen at night by other road users. Finally regarding p*rotective measures,* bicycle helmets can protect against head and brain injuries in the case of a fall or crash. Windshield airbags on cars can reduce cyclist injuries in the case of a crash. Technological developments such as intelligent speed assistance in cars will discourage car drivers from driving too fast in e.g. 30 km/hour zones.

1 Highlights

- Cyclists are the only road user group where the number of fatalities and serious injuries has not declined since 2010.
- 1 in 10 recorded road deaths is a cyclist, rising to 1 in 7 on urban roads
- Nearly half of cyclist fatalities (47%) involve an older cyclist (65 years and over).
- Lack of bicycle infrastructure increases the risk of bicycle-motor vehicle crashes.
- Quality of the road and general lay-out play a role in the occurrence and outcome of bicycle crashes.

2 What is the problem?

Cyclists are vulnerable in traffic and constitute the only road user group where the number of fatalities has not declined in since 2010. In 2019, more than 2,000 road deaths among cyclists in Europe were reported by the police. This means that almost one in ten recorded fatalities in traffic is a cyclist. Furthermore, the share of serious injuries in crashes involving a cyclist did not decline: their relative proportion increased from 7% in 2010 to 9% in 2019 (European Commission, 2021a). However, the volume of this share is probably much greater, due to under-reporting of these crashes (e.g. Shinar et al., 2018).

Fatal cyclist crashes mostly involve motor vehicles. In 2019 in the EU this was the case in around seventy percent of the fatal crashes. Reliable EU-wide data on serious injuries are lacking. It should be noted that bicycle crashes are significantly underreported, in particular crashes without the involvement of motorised vehicles. Hence, the actual share of bicycle-car crashes can be expected to be lower. For example, Dutch research (Aarts et al., 2020) shows that, in the Netherlands, the share of single bicycle crashes amounts to around 20% for bicycle fatalities and 82% for bicycle serious injuries. A recent review on single-bicycle crashes estimates that this share varies between 52% and 85% (Utriainen et al., 2022).

3 How do cyclists participate in traffic?

In this report, cyclists are defined as users of a conventional bicycle or a pedelec. The first of these is solely human-powered while the latter is a collective name for electric powered bicycles that offer pedal assistance. The pedelec is a bicycle that delivers power when the cyclist pushes the pedals and only up to a speed of approximately 25 km/hour (BIKE Europe, 2017). Pedelecs are sometimes referred to as e-bikes: officially, however, e-bikes are powered two-wheelers with an electric engine that moves forward without the cyclist pedalling (BIKE Europe, 2017).

Cycling is popular and is promoted for health, wellbeing and the environment (Martino et al., 2010). Unfortunately, at EU level little information is available on cycling kilometres travelled. Eight countries have collected some data; the distance cycled per inhabitant is highest for the Netherlands, 865 kilometres, and lowest for Great Britain, 80 kilometres (Adminaitė & Jost, 2020). Furthermore, a recent study examined whether the amount of cycling in 14 European countries has changed due to bicycle promotion policies over the past decades. Distances cycled ranged from 30 to 900 kilometres per person, per year and have remained fairly constant since 1990. However, cycling in the capitals of the 14 countries did increase since 1990 (Schepers et al., 2021).

In countries where cycling is popular, there is a strong increase in the use of pedelecs. In the Netherlands, for example, the total distance cycled by pedelec has increased across all age groups (KiM, 2020). The pedelec is especially popular among cycling seniors, with nearly half of their cycling kilometres covered by pedelec in 2019 (KiM, 2020).

4 Cyclists and road safety

4.1 Crash risk[1]

Between 2010 and 2019, the number of fatalities in cyclist crashes increased whereas these numbers dropped for other modes of transport. In 2019, more than 2,000 cyclists died in traffic in the EU and the proportion of seriously injured cyclists rose on average from 7% in 2010 to 9% in 2019.

In relation to their share in the population, cycling seniors are over-represented in cyclist road fatalities (47% in 2019), while 0-24 year-olds are under-represented (8% in 2019). In general, the highest proportion of cycling fatalities can be observed in countries where cycling is popular (e.g. the Netherlands, Denmark, Belgium, Germany).

At EU level, the proportion of men in cyclist fatalities is high (82%). In countries where cycling is common (e.g. the Netherlands, Belgium, Germany, Denmark), the share of male fatalities is lower than the EU average, while their share is higher in Spain, Greece and Portugal, where 9 out of 10 cyclist fatalities are male.

Most cyclist fatalities occur in crashes with motor vehicles. However, most cyclists are seriously injured in single bicycle crashes, i.e. crashes without involvement of other (motor) vehicles. Fatal bicycle crashes typically occur during the day of the working week and have a seasonal peak during summertime. The number of fatal crashes is twice as high in June-September as in the winter months (December to February). This is most likely related to the fact that cycling is more frequent in summer than in winter

More than half (58%) of fatal cyclist crashes occur on urban roads, mostly on road stretches (67%) and to a lesser extent at junctions (17%). The proportion of crashes at junctions is higher for fatal cyclist crashes compared with fatal road crashes as a whole (10%).

4.1.1 Under-reporting of bicycle crashes

Bicycle crashes are largely under-reported compared with motor vehicle crashes. This is especially true when no motor vehicle is involved in the crash, for example, when a cyclist

[1] This section draws largely from European Commission. (2021). Facts and Figures Cyclists.

collides with an obstacle or another cyclist (Schepers et al., 2015). An international survey study of more than 7,000 cyclists showed that on average only 10% of all crashes were reported to the police (Shinar et al., 2018). Factors associated with reporting levels were the type of crash, the type of vehicle involved, and injury severity (Shinar et al., 2018). Even fatal crashes without involvement of motor vehicles are under-reported in police records (Schepers, Stipdonk, et al., 2017). This background should be taken into account when evaluating the road safety of cyclists (Nieuwkamp & Schoeters, 2018).

4.2 Typical crash circumstances

4.2.1 Crashes with motor vehicles

Crashes between cyclists and motor vehicles typically occur in locations where they meet, e.g. intersections, crossing facilities and locations, and where cyclists are not separated from other traffic (Schepers et al., 2020). In 2019, 67% of cyclist fatalities occurred on road stretches, 17% at an intersection, and 2% at a roundabout. Compared with all road fatalities, the proportion of cyclist fatalities is lower on road stretches and considerably higher at intersections (European Commission, 2021a).

A European in-depth study into crashes involving two-wheelers investigated - amongst other things - crashes in which a cyclist had collided with a motor vehicle (N=116; Morris et al., 2018). Fatal bicycle crashes or crashes involving seriously injured road users typically (in 45% of the cases) occurred in two types of crash scenario: so-called crossing scenarios where the bicycle and the motor vehicle came from perpendicular directions; and a turning scenario, where the cyclists turned left (in UK right) in front of the motor vehicle (Morris et al., 2018).

A German naturalistic cycling study showed that there are no differences in crash involvement of pedelecs and conventional bicycles, except at intersections. At intersections, the crash involvement of pedelecs was twice as high compared to the conventional bicycle; car drivers did not give priority to the pedelec (Petzoldt, Schleinitz, Heilmann, et al., 2017).

4.2.2 Crashes without motor vehicles

International review studies have shown that among injured cyclists, single-bicycle crashes constitute a significant number of all injuries. (Schepers et al., 2015; Utriainen et al., 2022). These are crashes where no other vehicles are involved or crashes where the cyclist collides with stationary obstacles (e.g. kerb, bollards).

An in-depth analysis of single bicycle crashes in Denmark showed that the majority of contributory factors in self-reported single-bicycle crashes were skidding on water or ice (60%), road design (24.9%, e.g. kerbstones, obstacles close to the road, maintenance of the road), and to a much lesser extent the condition of the cyclist (e.g. alcohol, 1.4%; speed, 4.6%; distraction, 4.6%) (Olesen et al., 2021).

Similar findings were found in a Finnish study that investigated the characteristics of commuters' single bicycle crashes: more than 60% were related to infrastructure, e.g. slippery road surface (Utriainen, 2020).

An in-depth study involving 50+ cyclists in crashes without motor vehicles was carried out in the Netherlands (Boele-Vos et al., 2017). Three main types of crashes were identified:

- Fall from a bicycle
- Colliding with an object
- Colliding with another cyclist or road user travelling at low speed.

4.3 Contributing crash factors

Usually a combination of several crash factors leads to a road crash. The next section discusses the contributing factors that lead to bicycle crashes.

4.3.1 Infrastructure

The quality of the road and the general road lay-out play a role in the occurrence and outcome of bicycle crashes. Poor quality and uneven (e.g. potholes) road surfaces are often a contributing factor in crashes without motor vehicles or single bicycle crashes. Typical causes are (e.g. Algurén & Rizzi, 2022; Boele-Vos et al., 2017; Schepers & Klein Wolt, 2012; Utriainen, 2020):

- Invisible obstacles
- Lack of markings alongside the road
- Bicycle track and/or road that are too narrow
- Slippery roads due to rain, ice, snow, wet leaves.

One very important factor is the availability of dedicated cycling infrastructure. The absence of dedicated cycleways increases the risk of bicycle crashes with motor vehicles. A recent study showed that controlled for kilometres travelled by bicycle and by motor vehicle, 50-60% less bicycle crashes occur on roads with separated bicycle tracks compared to those with marked or painted bicycle lanes (van Petegem et al., 2021).Also, two-way bicycle tracks have a higher risk of crashes with motor vehicles at unsignalized intersections as compared with one-way bicycle tracks (as discussed in Prati et al., 2018).

4.3.2 Bicycle

The extent to which the bicycle itself plays a role in the occurrence of crashes is difficult to establish and is also not systematically recorded. Bicycles are vehicles that require balance and at low speeds they are unstable (Schwab & Meijaard, 2013) and may increase the risk of falls (Boele-Vos et al., 2017; Kovácsová et al., 2016). To reduce falls while (dis)mounting the bicycle, (older) cyclists could benefit from lower saddle heights (Boele-Vos et al., 2017).

Pedelecs offer pedal support, allowing higher speeds to be achieved with the same effort. In general, cyclists ride faster on pedelecs than on conventional bicycles (Dozza et al., 2016; Schleinitz et al., 2017; Twisk et al., 2021; Vlakveld et al., 2015). Speed is an important factor in the occurrence and outcome of crashes in general. In theory, this also applies to cyclists: however, so far no objective data exists to support this or not.

Furthermore, pedelecs are heavier than bicycles without pedal support. This affects the riding characteristics of the pedelec, especially when (dis)mounting the pedelec and keeping balance at low speeds (Twisk et al., 2017). Loss of balance with pedelecs has featured as a crash causation factor in surveys (Haustein & Møller, 2016; Hertach et al., 2018).

In a Swiss survey (Hertach et al., 2018) of among both pedelec and speed pedelec [2]riders, one third of the respondents (34%) indicated that inability to maintain balance during, for example, an evasive manoeuvre had contributed to the occurrence of the single bicycle crash. According to most respondents (82%), this would also have happened if they had been riding a conventional bicycle. The 18% who reported bicycle characteristics as a crash factor often mentioned weight and balance. In a Danish survey on the crash involvement of pedelec riders (amongst other things), one in ten respondents (10.2%) mentioned the weight of the bicycle and/or balance as factors contributing to safety-critical incidents (Haustein & Møller, 2016).

4.3.3 Behaviour

Unsafe traffic behaviour by other road users (e.g. speeding, distraction, red light running, and impaired driving) increases the risk of bicycle crashes. Cycling crashes can also be caused – consciously or unconsciously – by potentially unsafe cycling behaviour, although this seems to play a lesser role (Olesen et al., 2021). This paragraph discusses the role of cyclists' behaviour in crashes. It must be noted, however, that most studies come from the typical cycling countries and in particular from the Netherlands. Extrapolating the results to countries with substantially lower bicycle traffic and fewer bicycle facilities is difficult.

Cycling under the influence of alcohol

Although, studies have shown that alcohol seems to play less of a role in cycling (Olesen et al., 2021), there is some evidence that alcohol contributes to the crash risk of cyclists (Olkkonen & Honkanen, 1990).. There are no recent studies that quantify the risk of cycling under the influence of alcohol. The most recent study dates from the nineties (Olkkonen & Honkanen, 1990) and showed that crash risk for cyclists increases as the blood alcohol content (BAC) increases: the risk of being injured while cycling with a BAC of 1.0 g/l is at least ten times higher than for a sober cyclist (Olkkonen & Honkanen, 1990). In the past decades, the number of seriously injured hospitalized young intoxicated cyclists (15-29 year olds) in crashes without motor vehicles at night in the weekend increased; nearly half of them had used alcohol (Houwing et al., 2015). Alcohol measurements in nightlife situations in two Dutch cities showed that 62% of cyclists were under the influence of alcohol and 42% above the legal limit (BAC > 0.5 g/l; de Waard et al., 2016). A retrospective survey of cyclists treated in emergency departments showed that the proportion of injured cyclists under the influence of alcohol is highest for 18-24-year-olds (32%) and lowest for injured cyclists under the age of 17 (2%) and 65 and over (4%).

Red light negation by cyclists

Red light running is often reported among cyclists. A Dutch observation study has given some insight into red light running for three different age groups. Young cyclists (<20 years) and adult cyclists (20-64 years) ran the red light in 35% and 24% of times

2. Speed pedelecs are categorized as mopeds by EU legislation (BIKE Europe, 2017)

respectively, whereas older adults (>65 years) still ran the red light in 22% of cases (Van der Meel, 2013). A German naturalistic cycling study with 90 participants riding their own bicycles showed that they experienced nearly 8,000 red light situations. In 16.2% of situations they ran the red light; men violated the red light more often (17.2%) than women (14.9%) and older cyclists had a reduced violation rate (12.8%) compared to other age groups (17.8%) (Schleinitz et al., 2019). It is likely that crash risk increases when cyclists run a red light, because of the increase in the number of possible conflicts with other road users. However, the extent to which risk increases is (still) unknown.

Mobile phone use while cycling

Recent Dutch surveys and observational studies show that many cyclists engage in potentially distracting activities. In one survey, more than half the cyclists (56%) between the ages of 12 and 80 reported sometimes using their phones while cycling (Van der Kint & Mons, 2019). In this study on all mobile phone activity, young people (aged 12-17) were shown to use their phones while cycling more often than adults. Both adult and young cyclists reported using their phones most often to read messages (38% and 55.5% respectively) or send messages (33% and 54% respectively), to set navigation (33% and 36% respectively), or to take pictures or record videos (33% and 43% respectively). A survey study among Danish (mean age 46.18) and Dutch (mean age 45.93) cyclists - at the time when handheld use of phones was forbidden in Denmark but still legal in the Netherlands - established that believing there were no rules on handheld phone use increased the likelihood of using the handheld phone while cycling (Brandt et al., 2022). Listening to music also proves to be very popular among cyclists, in particular young people. Over 70% of 16-18-year-old cyclists reported sometimes listening to music while cycling (Stelling-Konczak et al., 2017). Recent research (Dingus et al., 2019) shows that accessing the screen of a mobile phone while driving (e.g. for searching the internet or for texting) increases crash risk 2.5 times. Whether smartphone use by cyclists increases the crash risk to the same extent is still unknown (Kamphuis et al., 2020). An in-depth analysis of self-reported single bicycle crashes in Denmark (Olesen et al., 2021) showed that distraction is only in a small number of cases a contributory factor.

Speed choice

Naturalistic cycling studies show that cycling speeds on pedelecs is on average 1.7 to 3.6 km/h higher than on conventional bicycles (Dozza et al., 2016; Schleinitz et al., 2017; Twisk et al., 2021; Vlakveld et al., 2015). Speed is an important factor in the occurrence and outcome of road crashes in general: the higher the speed, the more crashes and the more serious the injuries. In theory, this also applies to cyclists, however, so far there is no objective empirical data to verify this. An in-depth analysis of self-reported single bicycle crashes in Denmark (Olesen et al., 2021) showed that speeding contributed to only a small number of cases.

5 Countermeasures

5.1 Infrastructure

5.1.1 Measures to prevent crashes with motor vehicles

Cycling infrastructure can be improved by constructing bicycle routes and separate bicycle tracks. An important aspect of this is the separation of heavy traffic and bicycles and safer design of 30- and 50 km/hour roads (SWOV, 2020).

For instance, in the Netherlands speed-reducing measures at unsignalized intersections (e.g. speed humps) have prevented 2.5% of cyclist fatalities (Prati et al., 2018; Schepers, Twisk, et al., 2017).

Furthermore, the overall safety effect of one-way bicycle tracks on busy roads is positive. Research shows that the likelihood of bicycle-motor vehicle crashes is lower with bicycle tracks that are 2-5 metres away from the intersection area compared to intersections with bicycle lanes or no bicycle facility at al. Physical separation of bicycle facilities along road sections reduces even further these type of crashes (Schepers et al., 2011; Schepers, Twisk, et al., 2017).

5.1.2 Measures to prevent crashes without motor vehicles

Recommendations on infrastructure can be derived from knowledge of the causes of bicycle crashes without motor vehicles (e.g. Davidse et al., 2014; Schepers, 2013). Design principles for bicycle tracks can be summarized as follows (CROW, Design guide for bicycle traffic):

- No obstacles on or alongside the bicycle track
- Road alignment is visually guided with edge and centre line markings
- Bicycle tracks are sufficiently wide
- Road surface is even, skid-resistant, free of cracks, and clean
- Kerbs and road shoulders are forgiving.

Research is needed to evaluate the effectiveness of these recommendations.

5.2 Bicycle-related measures

Adequate lighting on the bicycle prevents bicycle-motor vehicle crashes because cyclists are more visible (Schepers et al., 2019).

To prevent crashes while (dis)mounting the bicycle it is important that the bicycle fits the cyclists, i.e. allowing (older) cyclists to put both feet on the ground when stopping and dismounting.

One problem that still seems to be in evidence is the fact that other road users underestimate the speed of a pedelec and therefore make wrong and dangerous (crossing) decisions (Petzoldt, Schleinitz, Krems, et al., 2017). Improving the recognizability of the pedelec, possibly in combination with information about the characteristics of pedelecs, could help improve the expectations of other road users. How recognizability can be improved will have to be further investigated.

Motor skills decline with age. This means, among other things, that looking over the shoulder while maintaining balance becomes increasingly difficult. This problem could be solved with a rear-view mirror on the bicycle, but it could also help younger cyclists gain a better view of the traffic situation behind them. A recently developed rear-view assistant could also warn the cyclist when other vehicles are about to overtake the cyclist and prevent startling the cyclist (Engbers et al., 2018).

5.3 Protective measures

5.3.1 Bicycle helmets

Evidence has shown that bicycles helmet protect cyclists from head and brain injuries (European Commission 2021b, p. 11). In the case of a fall or crash, the use of a bicycle helmet has been found to reduce fatal head/brain injury by 71% on average (Høye, 2018). If all cyclists aged 70 and older were to wear helmets in the Netherlands, the number of fatalities would decrease by 45-50 annually (Weijermars et al., 2019). Helmets are not obligatory but their use has been promoted. Denmark has been successful in promoting bicycle helmet use through awareness campaigns. Bicycle helmet use in city traffic has increased from 33% in 2015 to 47% in 2020 (Olsson, 2021).

5.3.2 Vehicle design

In 2019 the General Safety Regulation[3] was adopted and mandates a range of safety features on new motor vehicles. These systems can contribute to the safety of cyclists. For example:

- Vulnerable road user detection and warnings on the front and side of vehicles (trucks and buses) especially when making turns
- Vulnerable road user improved direct vision from the driver's position (in the case of trucks and buses)
- Intelligent Speed Assistance (ISA) which will often dissuade drivers from driving above the indicated speed limit (cars, vans, trucks, buses)
- Head impact zone enlargement for pedestrians and cyclists -safety glass in case of crash (cars and vans)

5.3.3 Airbags on cars

Airbags on cars have been developed to protect pedestrians and cyclists from impact with the hood and windshield of a car. Simulation studies by TNO have shown that windscreens that have been fitted with airbags that cover the windscreen in case of collision, the head impact for cyclists is reduced by approximately 75% (Rodarius et al., 2008).

3. https://ec.europa.eu/growth/sectors/automotive-industry/safety-automotive-sector_en

5.4 Enforcement

Enforcement can be targeted at unsafe traffic behaviour that contributes to bicycle crashes. Enforcement can focus both on motor vehicles (to prevent behaviour that endangers cyclists such as speeding, distraction, close passing etc) as well as cyclists (to prevent unsafe cycling behaviour such as insufficient lighting, red light negation, and handheld phone use).

5.5 Other measures

Further development of education activities and police enforcement could improve cycling safety. There are various traffic education programmes for different groups of cyclists (primary school pupils, secondary education, elderly). These programmes often focus on improving knowledge and skills. Little research has been carried out on the impact of traffic education on the behaviour and crash rate of cyclists. The studies that have been conducted concern mainly younger cyclists and/or suggest that the effects are minor. It also seems relevant to focus on higher order skills, e.g. hazard perception. Hazard perception training courses for cyclists have, for example, being developed in Finland and Belgium (Lehtonen et al., 2016; Zeuwts et al., 2017).

6 Further reading

SWOV fact sheets on cyclists, pedelecs and speed-pedelecs, bicycle helmets, infrastructure for pedestrians and cyclists: https://www.swov.nl/en/facts-figures

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