Chapter 4. Factors contributing to powered two-wheeler crashes and their severity

This chapter discusses the most frequent factors contributing to powered two-wheeler (PTW) crashes. They are described following the traditional interaction between the three basic components of the traffic system: PTW riders and other road users, road environment and vehicle factors.

PTW rider-related crash factors

Some factors involve the riders themselves and notably relate to the various parameters characterising the states and conditions of the powered two-wheeler (PTW) riders: their motivations, physical states, experience and awareness, etc. Research literature has shown that factors such as speeding, impaired riding, non-respect of traffic rules and lack of experience, notably the experience of the vehicle driven, are the main human-related contributing factors in PTW crashes.

The increased flexibility and performance (engine power/vehicle mass) of motorcycles may influence their riders and facilitate inappropriate or dangerous manoeuvres, especially in regard to overtaking, negotiating bends, crossing intersections and filtering. These manoeuvres may be the most characteristic types of motorcyclist violations.

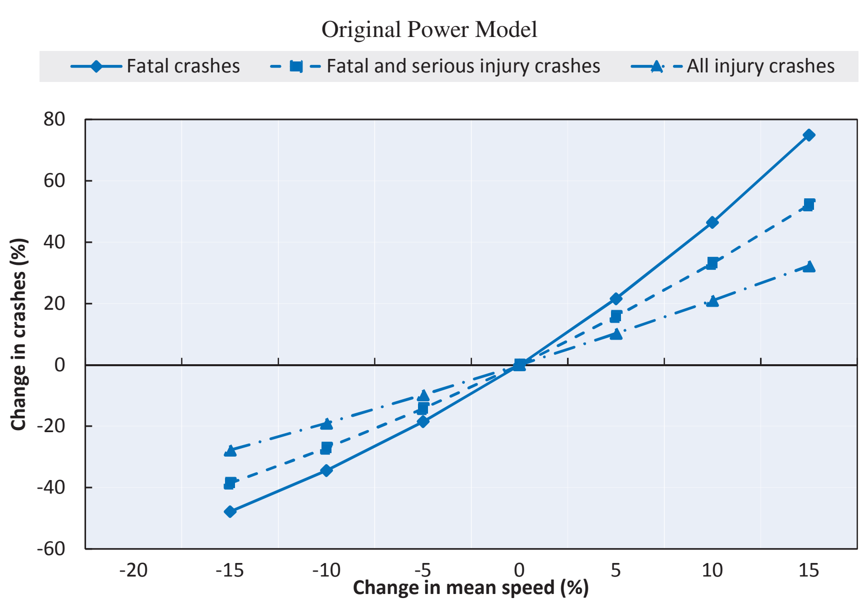
The likelihood that motorcyclists will respect traffic rules is strongly correlated with other characteristics such as age, experience, engine power and social influence. A recent study (Wu et al., 2012) shows that the probability of a rider running through a red light is higher for young and middle-aged riders, when the rider is alone, when there are fewer riders waiting, and when there are other riders already ignoring the red light.

Excessive and inappropriate speed

It is well known that excessive and inappropriate speed features in a large number of crashes. As shown by the Nilsson model (Nilsson, 1994), the risk of being killed in a crash varies exponentially with change in speed. While there is discussion on the exact value of the exponent when taking account in particular the initial speed (Elvik, 2013), the overall shape of the curve is not debated among researchers (see Figures 4.1 and 4.2).

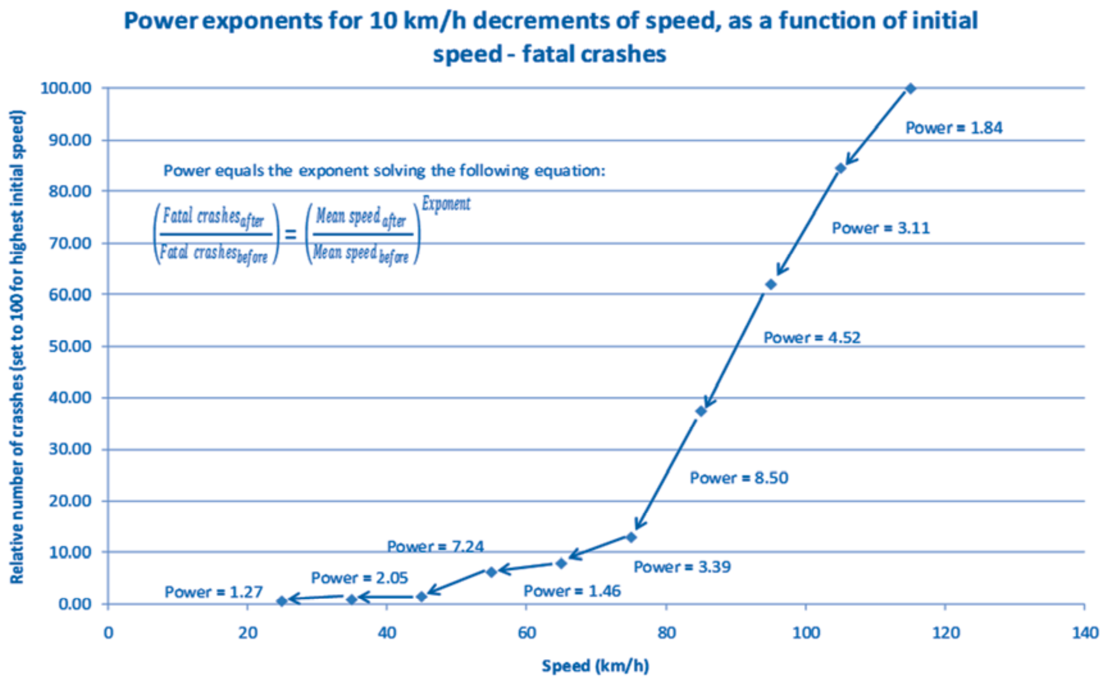
While there is no modelling specific to PTWs, as the average speed of PTWs is generally higher than for passenger cars, there is no doubt that the model at least applies.

Figure 4.1. **Power model representing the relationship between change in mean speed and changes in crashes**



Source: Nilsson.

Figure 4.2. **Reparameterisation of the Power**



Source: Elvik.

Speed is a complex factor which can influence the crash process at the different stages of its production:

- At the driving phase, an excessive speed can put the driver of a vehicle in a non-optimal driving condition by limiting the time available for information processing and/or by limiting the dynamic capacity for adequate regulation. Thus, by favouring the production of some errors and mistakes, speed can act as a crash-producing factor.
- At the emergency phase, an inappropriate speed can prevent the driver from efficiently regulating the vehicle direction and deceleration in such a way as to compensate for a delicate situation. Thus speed can also act as a factor that impedes vehicle control.
- At the collision phase, speed will systematically constitute an aggravating factor, drastically increasing the crash severity due to the kinetic energy dissipated during the crash.

Speeding mainly concerns riders of motorcycles and is less common among moped riders (Blackman, 2012; Langley et al., 2000). Excessive (i.e. over the speed limit) and inappropriate (e.g. not adapted to the circumstances, even if within the legal limits) speed is responsible for about 2/3 of single vehicle fatal crashes (Lardelli-Claret et al., 2005; Shankar et al., 1992). The speed risk is more important for young riders (Lardelli-Claret et al., 2005; Mullin et al., 2000; Wells et al., 2004).

Riding a PTW with an excessive or inappropriate speed is a common type of unsafe riding behaviour. Because of their small size and their acceleration capacity, PTWs allow overtaking others and approaching bends at high speed and quickly inserting into traffic compared to four-wheel motorised vehicles.

Speeding is a bigger problem for PTW crashes, compared to other modes. On average, motorcyclists ride at higher speeds than cars and PTW crashes usually occur at higher speeds than car crashes (Horswill et al., 2005). Speed differences between motorcyclists and car drivers are higher on rural roads, as are speed violations (Guyot, 2008). Walton et al., 2012) report that motorcycles and scooters travel through T-junctions about 10% faster than other traffic and are 3.4 times more likely to be exceeding the speed limit than cars.

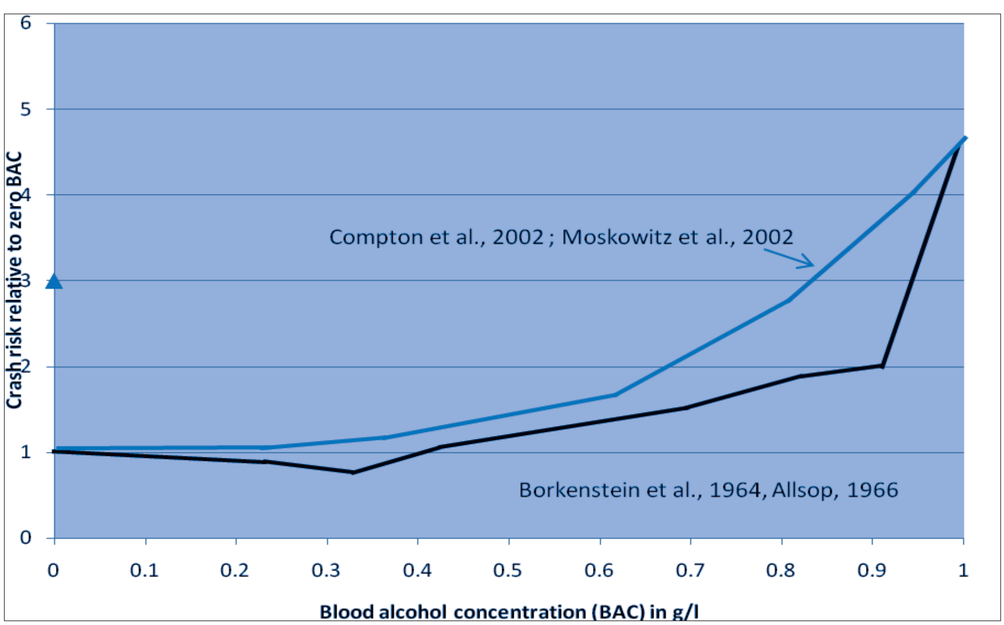
In 2004 in France, nearly half of the PTW casualties occurred while the riders were driving above the legal limit (ONISR 2006a). In the United States, in 2011, 35% of all motorcycle riders involved in a fatal crash were speeding, compared to 22% for passenger car drivers (NHTSA 2013). However, there are regions in the world where efforts have led to less speed differences between PTW and other motorised vehicles.

Impaired riding: alcohol, drugs and fatigue

Alcohol

The impact of alcohol consumption on driving performance is well demonstrated (Borkenstein et al., 1974; Compton et al., 2002; Moskowitz et al., 2002) as illustrated in Figure 4.3 for car drivers. Similarly, the consumption of alcohol is associated with increased risk of fatal crashes among PTWs (Evans 2004; Kasantikul et al., 2005; Luna et al., 1984; Shibata et al., 1994, Rag et al., 2012). Given the complexity of riding a powered two-wheeler, the risk for PTW riders is expected to be larger, although few studies have clearly examined this (Creaser et al., 2009). There is some evidence that ability to safely ride a motorcycle is impaired at lower alcohol concentrations than is the ability to safely drive a car. In an early Texas study, the BACs of motorcycle riders and car/truck drivers who were arrested for driving while under the influence were compared (Watson and Garriott, 1992). While both groups were clearly impaired, this was evident at lower BACs for the motorcycle riders than the car/truck drivers.

Figure 4.3. **Drivers' blood alcohol concentrations and the relative risk of police-reported crash involvement**



Source: Borkenstein et al. (1974), Compton et al. (2002), Moskowitz et al. (2002), Allsop (1966), in WHO (2004).

In addition, several international studies show that riders with a BAC above the limit have a higher probability of speeding and not wearing a helmet than a rider who has not been drinking (SARTRE4, 2012. Peek-Asa et al., 1996; Soderstrom et al., 1993).

Except for Sweden and Australia, data regarding the prevalence of alcohol in fatal crashes among different road users show a higher share of alcohol-related crashes among killed riders compared to car drivers (Table 4.1). In addition, alcohol-related crashes are usually more severe (i.e. lead to a fatality) for PTW, which implies that for the same BAC, the severity of the crashes is higher for the PTW than for the other road users (McLellan et al., 1993; Soderstrom et al., 1993; Soderstrom et al., 1995; Williams et al., 1985).

- In Sweden, on the other hand, the percentage of alcohol-related crashes is the same for PTW and car drivers, i.e. about 24%.
- In France, the percentage or riders having drunk alcohol is higher among moped than motorcyclist for both injury and fatal crashes (Guyot, 2008). In France, in 2012, 8.4% of moped riders and 5.2 % of motorcycle riders involved in an injury crashes had a BAC above the limit (6.6% for car drivers). For fatal crashes, these percentages are 36% for moped riders, 21% for motorcyclists and 21% for car drivers (ONISR 2013).
- In the United States, in 2011, a higher percentage of motorcycle riders had a BAC above the legal limit of 0.8 g/l than any other type of motor vehicle operator. The percentages of alcohol impaired drivers involved in a fatal crash were 29% for motorcycles, 24% for passenger cars, 21% for light trucks and 1% for heavy trucks. 30% of all fatally injured motorcycle riders had a BAC above the legal limit of 0.8 g/l and 42% of motorcycle riders who died in single vehicles crashes had a BAC above the limit (NHTSA, 2013) (see Table 4.1).

Table 4.1. **Share (%) of alcohol-related crashes for PTW and car drivers**

(i.e. BAC above the limit)

Country	**Fatal crashes**		**Injury crashes**	
	PTW	**Car drivers**	**PTW**	**Car drivers**
Sweden (2005-08)	24%	23%	n-a	n-a
United States (2011)	29%	24%		
France (2012)	21% for motorcycle 36% for mopeds	21%	5.2% for motorcycle 8.4% for mopeds	6.6%
Australia (1999-2003)	26%*	26%	n-a	n-a

Source: survey of the Working Group.

* Includes alcohol and other drugs.

Studies have shown that alcohol was present in 29 to 75% of PTW rider fatalities (Drummer *et al.* 2003; Holubowycz et al., 1994; Hurt et al., 1981; Larsen et al., 1987; Preusser et al., 1995) and between 13% and 60% of PTW riders injured (Holubowycz et al., 1994; Kasantikul et al., 2005; Luna et al., 1984; McLellan et al., 1993; Sun et al., 1998). On average, PTW riders involved in fatal crashes have a higher BAC than those involved in injury crashes (Holubowycz et al., 1994).

Similarly for car drivers, PTW alcohol-related crashes may involve more often young men (Holubowycz et al., 1994; McLellan et al., 1993; Williams 1979). Studies also show an overrepresentation of alcohol related crashes at night time (Kasantikul et al., 2005; Peek-Asa et al., 1996;

Williams et al., 1985), during the week-end (Holubowycz et al., 1994; Kasantikul et al., 2005), and at high speed (Colburn et al., 1993; Peek-Asa et al., 1996; Soderstrom et al., 1993).

Drugs

As for alcohol, the effect of drugs can be amplified for PTWs as riding a PTW requires more balance, co-ordination and accuracy than driving a car (Van Elslande et al., 2003). The consumption of drugs, in addition to the consumption of alcohol, mainly by young people, during the weekend nights should not be ignored (Assailly et al., 2002).

Very few studies focus on the relationship between drug consumption and crash risk for PTWs; most focus on the prevalence of different types of drugs among injured riders (Drummer et al., 2003; Longo 2000; Soderstrom et al., 1993; Soderstrom et al., 1995; Mclellan et al., 1993; Sun et al., 1998; Williams et al., 1985). In these studies, the proportion of vehicle controllers consuming drugs is higher among PTW riders compared to car drivers (Drummer et al., 2003; Longo et al., 2000; Soderstrom et al., 1995; Sun et al., 1998; Williams et al., 1985) and the proportion of drivers or riders positive both to alcohol and drugs cannot be neglected (Drummer et al., 2003; Williams et al., 1985).

Results from the French case study[1] in the European DRUID project, suggest that among drivers involved in fatal crashes, drivers of motorised two-wheel vehicles, especially moped drivers, have a higher prevalence of alcohol and cannabis than other road users.

Table 4.2. **Prevalence of drug consumption among different road users**

Road user type	n	Alcohol	Cannabis	Amphet.	Cocaine	Opiates
Bicyclist	131	22.1%	3.8%	0.0%	0.0%	0.0%
Moped driver	217	55.8%	14.3%	1.4%	1.4%	0.9%
Motorcycle driver	1 018	32.9%	9.0%	0.4%	0.4%	0.9%
Car driver	7 455	28.5%	7.5%	0.8%	0.5%	1.0%
Van driver	340	13.2%	5.0%	0.9%	0.3%	0.3%
Truck driver	1 092	3.8%	1.9%	0.2%	0.5%	0.3%
Other	266	9.8%	0.4%	0.0%	0.0%	0.4%

Positivity (blood dosage):
Alcohol ≥ 0.1 g/l, THC ≥ 1 mg/ml, Amphet ≥ 20 mg/ml, Cocaine ≥ 10 mg/ml, Opiates ≥ 10 mg/ml.

Source: DRUID, French Case study.

A US study (NHTSA, 2007) based on roadside surveys of alcohol and drug use by drivers showed that compared to other road users, motorcyclists had the greatest percentage of drug positive results, mainly at night-time. In addition, the study showed that drug prevalence was higher for riders who were not using a helmet.

Age and experience

Age

The relationship between age and risk is complex. While younger riders may exhibit riskier behaviours leading to an increased crash risk, older riders may have a higher risk of severe injuries in a crash due to their greater physical fragility.

Young people, in general, have a higher crash risk. As for the other modes, the higher risk of young motorcyclists can be explained by the combination of a lack of experience and a propensity to adopt risky behaviours (speeding; consumption of alcohol or drugs; riding for fun, etc.) (Chesham et al., 1993; Ryan et al., 1998).

Several studies show that crash risk decreases with age, which is mainly explained by a decrease in the distance ridden every year (Chang et al., 2006; Harrison et al., 2005; Lin et al., 2003; Mullin et al., 2000). On the other hand, studies also show an increased risk for riders over 60 years of age (Lardelli-Claret et al., 2005). This can be explained by a decrease in their ability and riding performance and difficulty in managing complex riding situations (Ryan et al., 1998).

The population aged 40-60 is increasingly represented in motorcycle crashes, mainly due to a significant increase in the number of PTW riders of this age group (SafetyNet, 2010).

Lack of experience

Studies show the importance of experience in traffic – not only as a PTW rider, but also as a car driver. Experience with riding a PTW also decreases the crash risk: the more distance travelled on a motorcycle, the lower the risk per kilometre (Mullin et al., 2000). The experience of driving a car contributes to a decrease in crash risk as a PTW rider among young people: those with more practice as a car driver have a lower crash risk when riding a motorcycle (Reeder et al., 1995), reflecting a positive transfer of experience.

A recent study (Bellet et al., 2012) investigates four populations of motorcyclists in terms of experience: professional riders (e.g. policemen), experienced riders, young and novice riders. The results show that cognitive abilities in both hazard detection and situational criticality assessment depend on riding experience: professional and experienced riders obtained better results than novice and young riders for hazard perception (i.e. shortest reaction time), and the latter also underestimate the situational risk and seem overconfident in their abilities to manage the situational risk.

More than for passenger cars, the experience of the vehicle ridden itself seems to be important. In the motorcycle fleet, there is a higher diversity of vehicle types, which may require a period of adaptation to a new vehicle. As an indicator of this, the number of kilometres driven with the same vehicle (familiarity with the PTW) has been proved to be strongly associated with a decrease in fatal or severe crashes, even more so than with other aspects of rider experience (Mullin et al., 2000). For example, people who borrow a motorcycle have a higher crash risk than people who own their motorcycles (Haworth et al., 1994; Mullin et al., 2000; Reeder et al., 1995).

Finally, increased crash risk is often found among those not holding a valid licence (Haworth et al., 1994; Hurt et al., 1981; Lardelli-Claret et al., 2005; Lin et al., 2003; Magazzu et al., 2006; Reeder et al., 1999; Rutter et al., 1996; Wells et al., 2004).

Perception and awareness

As seen in Chapter 3, the three most common crash scenarios for motorised two-wheeled vehicles (motorcycles and mopeds) are as follows:

- The motorcyclist/moped rider has a single vehicle crash while riding along a road and losing control (e.g. at a curve).

- The motorcyclist/moped rider approaches a junction and hits, or is hit by, a car driver who fails to see the two-wheeler in time.
- A car driver turns left (or right in countries where driving is on the left) and fails to yield the right-of-way to a motorcyclist/moped rider coming in the opposite direction.

Except for single vehicle crashes, these scenarios show that an important element of crashes involving motorcyclists is car drivers failing to give right-of-way to motorcyclists. According to a large body of research, this is mainly because the car driver fails to see the motorcyclist. For example, the MAIDS project (ACEM, 2009) examined over 900 crashes in five countries (France, Germany, Italy, Spain and the Netherlands) involving a motorised two-wheeled vehicle (motorcycle/moped). The study concluded that in over 36% of the cases, the driver of the other vehicle did not see the two-wheeler; while in 12% of the cases, the rider of the two-wheeler failed to see the other vehicle.

Perception issues vis-à-vis PTW

In situations where a car driver fails to give way to a PTW rider, the car driver often admits having looked in the direction of the motorcyclist prior to manoeuvring, but not having seen the rider who was theoretically visible (Wulf et al., 1989). These crashes are called "looked-but-failed-to-see" crashes (Clarke et al., 2007; Koustanaï et al., 2008) or "motorcycle conspicuity-related crashes" (Radin-Umar et al., 1996; Wulf et al., 1989); and are often characterised by a high level of severity (Pai, 2009).

"Fail to look" and "look but fail to see" are the two main categories of perceptual errors that contribute to crashes (Staughton and Storie, 1977). The first one can be explained by inadequate visual screening: failing to look at the correct location at the correct moment (e.g. the blind spot). The second is due more to the weakness of our perceptual system, which under certain conditions (time constraints, too many sources of information) can fail to see what is however in our visual field. This is one of the reasons explaining why car drivers have difficulties in detecting PTWs.

Perception and awareness of PTWs by other road users have been recognised as part of the critical points characterising the problems of interaction of these vehicles within the traffic system. It notably deals with the intrinsic difficulty of a motorcyclist to be seen by other road users – concept referred in the literature as its low *detectability* or *conspicuity* (e.g.(Hurt et al., 1981; Preusser et al., 1995; Yuan, 2000).

Weaknesses of the human visual perceptual system

The traffic environment is very demanding on human perceptual capacities, due to high speed and complex situations sometimes pushing these capacities to their limits. This can lead to failing to perceive unexpected, unusual pieces of information, as is sometimes the case with PTWs because they present a different shape, a different behaviour, and they are more difficult to detect due to their smaller frontal size.

Detection is not the only challenge for the perceptual system: detection alone does not ensure the correct processing of visual information. It is common for PTWs to be detected on the road, but their distance and approach speed are not assessed properly by the observer (Pai, 2011). Poor PTW perception can have an impact on each stage of the information-processing chain, from detection to decision making.

The complex causes of perceptual problems

Numerous parameters may contribute to detection and evaluation challenges for car drivers in the presence of a PTW. These parameters can relate to the human visual system's capabilities, characteristics of the environment, and characteristics of the PTW as a perceptual object.

- Small size of PTW: The smaller frontal dimensions of PTWs on the road are the most commonly mentioned explanatory element of the specific difficulty to perceive them (e.g. (Hurt et al., 1981; Wulf et al., 1989). Physical characteristics of PTWs often push the capacity of the human sensory system to its limits, explaining the difficulty to detect it and evaluate its approach.
- Obstructed visibility: By its size, a PTW is more easily hidden by an object or vegetation than a larger vehicle.
- PTW rider behaviour: PTW riders' behaviour can also indirectly contribute to the fact that they are not easily perceivable. PTWs can surprise other road users by deviating from behavioural standards with their manoeuvres, for example by their positioning (e.g. riding in the blind spots of cars), speeds and acceleration capacity and confound the perceptual strategies of car drivers (Ragot et al., 2012; van Elslande, 2009).
- The low familiarity of PTW for most car drivers due to their relative rarity in traffic poses cognitive challenges for car drivers: The low level of expectation that automobile drivers have concerning motorcyclists is the main reason why they do not perceive them (Rogé et al., 2012; Gershon et al., 2012).

The road environment

Road environment factors can have an important influence on the crash severity, even if they are rarely the primary cause of crashes. For example, according to the MAIDS study, the road and its environment were a primary cause in 8% of all PTW crashes. Nevertheless, powered two-wheeler riders are more sensitive to road design and maintenance than car drivers. An environmental perturbation can be easily managed by car driver but be a challenge for a PTW rider.

Road design, condition and maintenance

The design of roadway elements influences how a road user interacts with the roadway. These elements include bends, junctions, the road surface and the roadside.

Curves

The radius of a horizontal curve has a strong impact on the ability to control the trajectory of the vehicle and is a factor for higher crash risk. About 30% of all PTW crashes occur in or after a curve, compared to 21% of crashes of other vehicles. Curves with small radii are more difficult to handle and poor road conditions in a curve significantly increase the crash risk for motorcyclists (ACEM, 2006).

Junctions

About one third of fatal PTW crashes occur at a junction (intersection or roundabout), compared to only 14% for cars. The severity of a PTW crash at an intersection is higher than for other road users (CERTU 2010). Road signs or other objects installed near intersections can significantly reduce visibility and make it more difficult to detect road users coming from other directions.

A series of Belgian studies (Daniels et al., 2010; De Brabander and Vereeck, 2007) supported the common finding that roundabouts reduce injury crashes overall, but identified that roundabouts are not as beneficial for vulnerable road users (pedestrians, cyclists and PTW users). Daniels et al. (2010) demonstrated that mopeds, bicycles and motorcycles were involved in more single-vehicle crashes than was expected given the mode share of each vehicle. There were fewer moped crashes at more recently constructed roundabouts (roundabouts that are more likely to be "turbo roundabouts"), and crashes involving mopeds were more likely to occur on three-legged roundabouts. While the overall safety benefits of roundabouts result from their geometry forcing conflicting traffic to slow down, the greater manoeuvrability of PTWs may mean that PTWs do not slow down and so are more liable to single-vehicle crashes. Improving sufficient skid resistance on roundabouts is therefore crucial for PTWs. Roundabouts that are not sufficiently visible (particularly at night) can present obstacles themselves.

Road surface quality

PTWs are more sensitive to roadway surface conditions than other motorised vehicles. Several factors can cause unsafe conditions for motorcyclists by reducing the amount of friction (skid resistance) or creating an uneven travel surface, including: surface rutting, corrugation, potholes, pavement swelling, etc. (IBSR, 2005; MOW, 2008). Longitudinal joints between lanes present a small zone with different skid resistance or a small irregularity in the road surface. Steel expansion joints, sometimes used on bridges, can destabilise a PTW (SETRA, 2002; CROW, 2003).

Elements of the road surface (gully tops, drainage grates, manhole covers, tram rails, etc.) can also be a risk factor for PTWs (IHIE, 2010; MOW, 2008; ERF, 2009; CROW, 2003), because of their different surface characteristics (skid resistance) than the surrounding pavement. Additionally, these elements can induce irregularities in the road surface level (see Figure 4.4).The difference in skid resistance between a road marking and the surrounding road surface can be problematic leading to loss of stability (ACEM, 2006; ERF, 2009; IHIE, 2010). When poorly designed or executed, there is a risk of water pooling on the surface of the road marking. Wear caused by traffic deteriorates the characteristics of the road markings rapidly. Renewal of a marking without removal of the old layer can negatively lead to an "elevated" layer and may cause loss of stability. (ACEM, 2006; CROW, 2003).

Traffic calming devices used to reduce vehicle speeds can induce a loss of grip to the road surface and destabilise the PTW (ACEM, 2006; ERF, 2009; MOW, 2008). In some countries, kerbs and delineation posts are sometimes used to separate lanes or to delineate the side of the road. However, when crossed by a PTW, even at moderate speed, there is a high risk for loss of stability (IBSR, 2005).

Debris, pollution and fallen loads on the road surface

Debris, pollution and fallen loads on the road can create unsafe conditions for motorcyclists. Overhanging trees and other vegetation can create unsafe conditions on the road surface: falling leaves (from overhanging trees and other vegetation), gravel, earth, mud and liquids can cause local slippery spots or hide local road surface defects (IBSR, 2005). Gravel, earth, mud and liquids influence the skid resistance of the surface. Discharged fuel can be slippery, difficult to detect by the motorcyclist, and difficult to remove (IBSR, 2005). This is more dangerous in curves and on roundabouts where a sufficient grip is particularly important for PTWs.

Aquaplaning/Hydroplaning

Water on the road surface can have different origins (e.g. insufficient or blocked drainage, extreme weather, road surface evenness problems, etc.) and reduces the skid resistance, which is even more of a problem for PTWs than other road users.

Roadside

Obstacles (vegetation, construction, road equipment, etc.) in the inner curve or at intersections can compromise visibility by either obscuring or limiting sight distance. Road users travelling from different directions will have more difficulties detecting each other (MOW, 2008). Although they contribute only to a minor portion of PTW crashes, obstacles are responsible for a relatively high number of fatalities (IBSR, 2005). Obstacles considered as 'safe' or not aggressive for car users can be very aggressive for PTWs, resulting in fatalities or severe injuries (CROW, 2003).

Road restraint systems / barriers

Road restraint systems are beneficial for passenger cars, but can be very aggressive for PTW riders in the event of a collision with them. Crashes with road-restraint systems or barriers contribute to between 2% and 4% of all PTW fatalities. Impacts to non-protected posts – particularly the exposed sharp parts – of guard rails can be critical (CIDAUT, 2006 and 2-BE-SAFE, 2009).

Generally speaking, any unprotected post is a real danger for motorcyclists. According to the European Smart Road Restraint System (SMARTRSS), wire rope safety barriers are considered as among the most aggressive forms of road restraint systems for PTW riders (Universita degli Studi di Firenze, 2013). However, according to Rizzi et al. (2012) no significant differences are found between wire-rope and other types of discontinuous guard rails. Nevertheless they found that the position of the motorcyclist when impacting the guard rail is the most important influence on the overall outcome of the collision.

Road maintenance works

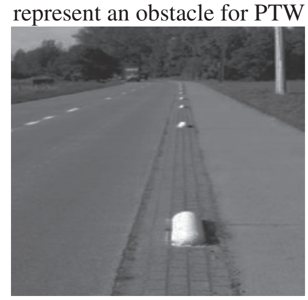
Local spot repairs or surface treatments (surface dressing) that are not properly executed create a risk so that these repaired sections are a (temporary) hazard for PTWs. Insufficient adherence, too much loose chippings or an insufficient amount of gravel or antiskid aggregates (e.g. for local repairs with cold asphalt) can locally reduce the skid resistance (CROW, 2003; IHIE, 2010). During resurfacing, the exposed scarified pavement that is left open to traffic before the new surface is laid can represent an additional hazard for motorcyclists (CROW, 2003).

Figure 4.4. **Infrastructure hazards related to road design and maintenance**

Natural stone paving elements and cast iron gully tops; slippery when wet

Intersection - road sign hides traffic coming from the left

Road delineation elements represent an obstacle for PTW

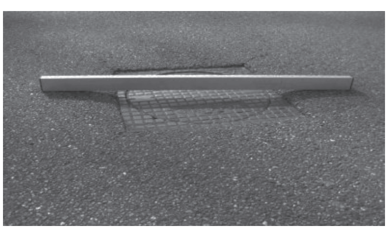


Different paving material in the inner border creates a zone with different skid resistance

Joints

Traffic calming – speed humps

Level difference between gully top and road surface



Road markings can reduce the skid resistance

Tram rails

Rutting

Collapsed side

Source: AWV, BRRC, http://www.motorcyclenews.com/.

Weather conditions

Weather is rarely a primary factor in PTW crashes. Studies in Europe, Australia and the United States based on in-depth crash investigations, suggest that adverse weather conditions are a contributory factor in less than 10% of PTW road crashes (Hurt et al., 1981; ACEM 2003; Johnston et al., 2008). These results are partly explained by the fact that weather conditions have an important impact on PTW mobility: as daily users are more likely to shift to other modes of transport, and occasional users (e.g. recreation users) may postpone their trip.

Adverse weather conditions for PTWs may also refer to high temperatures, which may equally affect riding comfort and safety; however, further research is needed to understand their impact on riding behaviour.

The vehicle

The contribution of technical defects to PTW crashes ranges according to studies from 5.1% (MAIDS, 2009) to 8% (European Commission, 2012). A study from Victoria, Australia found that vehicle defects were relatively common in crashed motorcycles and contributed to about 12% of motorcycle crashes, compared with 3% of car crashes (Rechnitzer, Haworth & Kowadlo, 2001. Tyre and brake defects are the most frequent problems. Tyre failure may create a risk of serious personal injury or death. To reduce the risk of tyre failure, it is strongly recommended to follow all safety information regarding tyre inflation, tyre loading, tyre damage, tyre size selection, etc.

While both crash involvement and the prevalence of defects increased with vehicle age for cars, this was not the case for motorcycles because motorcycle crashes often involved inexperienced riders with newer motorcycles (with fewer defects) than more experienced riders.

Some vehicle defects clearly contribute to the occurrence of crashes. However, challenges exist in identifying systems that can adequately identify and reduce the occurrence of such defects. Even when periodic inspection programs exist, a significant percentage of vehicles still have defects, rendering the vehicles ‘unroadworthy’. Yet only some of these defects appear to contribute to crashes. This would suggest that only in certain circumstance are defects contributing factors in crashes. This conclusion is not at all surprising as crashes can result from a large number of factors and a chain of events, with vehicle defects being just one of these factors.

Vehicle characteristics (or their absence) can contribute to PTW crashes and their severity in several ways: they can make the vehicle more difficult to control, they can encourage or facilitate dangerous behaviours by the rider, they can be defective or malfunction and thus contribute to crash causation or they can fail to provide protection in a crash.

As mentioned in Chapter 3, the existing studies are inconclusive regarding the effect of engine displacement on motorcycle crash risk. Two literature reviews were conducted (Mayhew et al., 1989; van Honk et al., 1997) and highlight the lack of evidence linking engine displacement and the occurrence or gravity or a crash. An analysis combining the results of 13 studies found that the association between the vehicle displacement and the occurrence of a crash is lower when adjusted with age, gender and kilometres driven, than when the results do not adjust with these factors (Elvik et al., 2009).

The power of the PTW engine does not by itself explain a higher crash rate. There are a number of associated factors such as the type of vehicles (sport, tourism, trail), exposure conditions (day or night driving, length of the trip), age of the riders which influence riding behaviours. For example, Bjornskau et al. (2012) reported that sport bikes (i.e. racing replica bikes) showed significantly increased crash risk in Norway. As seen in Chapter 3, in the United States, a study (Teoh, 2010) showed an increased crash risk for certain types of motorcycles. It also shows that this increase in risk is often associated with risky behaviours such as speeding and drink driving (see Table 4.3). There is need for further research to establish the association between the PTW displacement and the occurrence or severity of a crash.

Table 4.3. **Relative prevalence of driver and crash characteristics**
United States, data for 2000 and 2003 to 2008

	Speeding	Driver error	BAC 0.08+ g/dL	Helmeted	No motorcycle license	Single-vehicle crash	9 p.m. to 6 a.m. crash
Touring vs. cruiser/standard	0.90*	0.95*	0.82*	0.96*	0.65*	1.08*	0.90*
Sport touring vs. cruiser/standard	1.45*	1.05	0.30*	1.67*	0.47*	0.94	0.49*
Sport/unclad sport vs. cruiser/standard	1.70*	1.22*	0.53*	1.49*	1.24*	0.95*	0.77*
Supersport vs. cruiser/standard	1.86*	1.28*	0.44*	1.56*	1.25*	0.98	0.80*
10 year increase in driver age	0.88*	0.95*	0.88*	1.07*	0.75*	1.01	0.80*
Female vs. male	0.67*	0.97	0.51*	1.20*	0.66*	1.00	0.57*
Calendar year (1 year increase)	1.00	0.98*	1.01	1.01*	1.02*	1.00	1.00

* Statistically different than 1.00 at the 0.05 level.

Source: Teoh (2010).

Association of risk factors

Risk factors are often correlated and sometimes interdependent. Risky behaviour, such as riding a PTW at a high speed, under the influence of alcohol, without a helmet, without a valid licence, or without daytime running light, has been identified as a possible explanation of the higher risk for young men in addition to their lack of experience (Lin et al., 2003; McLellan et al., 1993; Rutter et al., 1996; Chesham et al., 1993).

Research has shown the following association of risks:

- Compared to a driver with a valid licence, those without a valid licence have a higher probability to not wear a helmet, to drive above the speed limit, to drive under the influence of alcohol and without daytime running lights (Peek-Asa et al., 1996; Reeder et al., 1996).
- Riders not wearing a helmet are more likely to ride above the speed limit (Shankar et al., 1992). Moreover, individuals who are impaired are more likely not to wear protective equipment (NHTSA, 2007).
- Riding under the influence of alcohol is associated with riding above the speed limit, not wearing a helmet and not having a valid licence (Hundley et al., 2004; Luna et al., 1984; Nelson et al., 1992; Peek-Asa et al., 1996; Soderstrom et al., 1993).

Conclusions

Most crashes are the result of a combination of factors intervening differently at different steps of the crash process (pre-crash, crash, post-crash). Some of these factors (e.g. alcohol, speed, etc.) act more directly and preventing them appears to be an obvious way to reduce road trauma. Driver and rider-related behaviour factors are often considered more prevalent in PTW crashes, compared to vehicle and road environment factors. However, while acting more indirectly, other factors and elements (i.e. lack of experience, road infrastructure, etc.) should not be forgotten as a potential complementary and efficient ways to promote traffic safety.

As found for other road users, speeding and consumption of alcohol and/or drugs are critical in the occurrence and severity of crashes. Operating a PTW requires more co-ordination and balance than operating a car, which explains why impaired riding is even more problematic for PTW riders.

A large number of crashes involve problems of perception or appraisal by the other vehicle operator. The over-representation of inappropriate perception in PTW crashes suggests a specific problem of detectability (conspicuity) of PTWs. The problem of perception is complex and cannot be reduced to the simple fact that PTWs are physically less visible than other vehicles. There are many causes behind the poor detectability of PTWs and these are often connected to each other and with the general parameters of the driving context. Indeed, this problem can be explained by the visual characteristics of PTWs, by the sensory capabilities of the human perceptual system, by the atypical behaviour of PTWs and by the expectations that road users develop.

Road environment factors have an important influence on crash severity (e.g. roadside obstacles and barriers, speed reduction installations) rather than on crash occurrence. A more frequent combination of road crash contributory factors is found in PTW crashes, compared to other road users crashes, which results in the multiplication of the relative risk. In addition, road design and maintenance can also be an essential means to promote the “right” behaviour in terms of speeds and manoeuvres undertaken, and in terms of understanding and expectancy of traffic situations. This is true for all road users, but it applies specifically to PTWs who are, by their nature, more sensitive than other road users to any roadway irregularities (road surface, weather conditions, etc.).

While it has been shown that vehicle technical failures are only minor contributors to PTW road crashes, vehicle improvements have potential to affect rider behaviour and improve rider safety (see Chapter 7).

Even if human behaviour and characteristics are often considered the most frequently represented contributing factors in crashes; this does not mean that a solution to improve safety conditions for PTWs must only focus on behaviours. A Safe System approach is required to change behaviour by acting on a range of levers, including the infrastructure, the vehicle and the system as a whole.

Note

1. The DRUID deliverables distinguished age, gender, time of day and substance type; but only the French case study distinguished different road users.

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