PTW crashes and the role of perception

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Abstract
Power-two wheelers (PTW) are overrepresented in road accidents worldwide. Rider conspicuity has been long recognized as an important PTW crash contributory factor. The objective of this chapter is to examine the main determinants of riders' accident risk that are related to conspicuity issues. We perform a literature review to explore the role of conspicuity in PTW crash occurrences. We organize PTW conspicuity risk factors in (i) human-related, (ii) vehicle-related, and (iii) road environment-related factors. Human-related factors responsible for different information processing failures (alcohol, distraction, fatigue, and so on) have been largely unaddressed. Turning to accident frequency, empirical evidence indicates that conspicuity treatments should primarily target intersections (T-junctions in urban areas at daytime and roundabouts in inter-urban areas at nighttime). Absolute accident figures are higher at daytime. If considering accident severities instead, the priority should be given to nighttime treatments. Overall, the conspicuity hypothesis testing remains inconclusive as long as several data and methodological limitations hold on a present level.

1. Introduction

Power-two wheelers (PTWs) are a vulnerable class of road users with **increased accident frequency and severity** (Vlahogianni et al., 2012). In the early nineties, motorcycle death rate per mile-traveled was estimated to be 22 times the death rate for passenger cars (Preusser et al., 1995). In 2007, US motorcycle riders had a 34-fold higher risk of death in a crash than people driving other types of motor vehicles (NHTSA, 2007). In 2008, European motorcyclists represented 17% of road fatalities while only accounting for 2% of road users (IRTAD, 2009). In Greece this percentage is as high as 33% (IRTAD, 2013) while in Singapore it attains 49% with more than two motorcyclists being killed every week (Haque et al., 2012). Higher crash risk is associated to the fact that driver– and rider-related factors are much more prevalent in PTW accidents compared to vehicle- and environment-related factors. In particular, there exists a clear over-representation of inappropriate perception in PTW crashes (Van Elslande et al., 2013). One often discussed reason for perception failures is that PTW are less conspicuous than other motorized road users (Röβger et al., 2012). Consequently, gap acceptance is often inadequate due to the size-arrival illusion (Horswill et al., 2005); the latter refers to small objects being perceived to arrive later than larger ones. Besides conspicuity, car drivers seem to encounter difficulties in understanding PTWs'

maneuvers and, thus, fail to foresee PTWs' behavior; foresight is the result of the combination of circumstantial data and permanent knowledge and beliefs (Ragot-Court et al., 2012).

Conspicuity can be examined from two different angles; namely the **sensory and the cognitive perspective**. Sensory conspicuity is the visual distinction of an object due to its physical characteristics (Wulf et al., 1989). It refers to the extent to which an object can be distinguished from its environment because of its characteristics: angular size, eccentricity, brightness against the background, color, and so on. It reflects an object's ability to attract visual attention and to be precisely located as a result of its physical properties (Rogé et al., 2012). The size and vehicle dynamics of PTWs are such that they have lower sensory conspicuity (Gershin and Shinar, 2013). Cognitive conspicuity depends on the distinction of an object based on the observer's experiences and interests (Wulf et al., 1989). It is linked to the fact that an observer's focus of attention is strongly influenced by his expectations, objectives, and knowledge (Rogé et al., 2012). Interestingly, inappropriate expectations may be even more important in accident causation than the motorcyclist's physical properties (Hole et al., 1996). PTWs show lower cognitive conspicuity as they account for relatively few vehicle miles traveled compared to automobiles, especially in Western countries (Gershon et al., 2012). Furthermore, not all car drivers have previous PTW riding experience. Helman et al. (2012) distinguishes further among:

- visibility: the extent to which an object stands out from its surroundings when observers are *aware* of its location;
- search conspicuity: the extent to which an object stands out form its surroundings when observers are *searching* for it within a scene;
- attention conspicuity: the extent to which an object stands out from its surroundings when observers are viewing the scene, but *not searching* deliberately for the object.

Vision is the predominant sensory modality used when driving (Crundall, 2011). Consequently, **conspicuity is an important** issue to all road users: be it cyclists (see, for example, Lacherez et al., 2013; Madsen et al., 2013); pedestrians (see for example, Tyrell et al., 2004); or car drivers (see, for example, Alferdinck, 2004; Berg et al., 2007). However, evidence shows that vulnerable road users tend to underrate the role of visibility factors and conspicuity benefits (Lacherez et al., 2013) while overestimating their own conspicuity (Wood et al., 2013). Comparisons between bicycle and motorcycle crashes suggest that the majority of both crash types occur at intersections and are due to conspicuity issues (Haworth and Debnath, 2013). Nevertheless, PTWs seem to be more concerned due to a combination of factors including high speeds and acceleration rates (if compared to cyclists and pedestrians) and small size (if compared to other motorized road users).

Indeed, PTW conspicuity has been long been recognized as a critical PTW **crash contributory** factor. In 1975, the Greater London Road Safety Unit identifies a certain PTW overrepresentation in accidents. Detailed analysis of crash data followed. Results indicated that a major contributory factor was the failure of other drivers to observe PTWs in the general street scene (Lalani and Holden, 1978). Riders were then encouraged to wear bright clothing, preferably of fluorescent material and to switch on headlights during the daytime. A lot of research has been undertaken since 1975 on the so-called 'PTW conspicuity hypothesis'. Accident investigations have been carried out in many countries and report that between half and tree-quarters of motorcycle accidents involve collision with another vehicle (Huang and Preston, 2004). Markedly, most right-of-way (ROW) accidents involving PTWs are attributed to conspicuity (Pai et al., 2009) while drivers of other vehicles are at fault in the majority of two-unit motorcycle crashes (Haworth and Debnath, 2013).

In view of the above, this chapter's objective is to examine the main determinants of riders' accident risk which are related to conspicuity issues. We perform a literature review in order to explore the role of conspicuity in PTW crash occurrences. English-language publications were selected for relevance through a comprehensive search of major databases (see Table 1). The key words used in the search were: 'conspicuity' and 'motorcycles'. To be included papers were assessed against additional criteria; mainly relevance and publication date. The latter was thought to be critical as earlier literature reviews do exist. In the following section, we briefly discuss the effectiveness of conspicuity interventions. A detailed overview can be found in Chapter X. In the third section, we review PTW accident risks and severity outcomes. Finally, we summarize findings and provide conclusions.

2. Conspicuity interventions and contextual factors

PTW conspicuity risk can be defined as an increased probability of '*low'* conspicuity. As many previous studies show (Helman et al., 2012; Lin and Kraus, 2009; Pai, 2011; Wulf et al., 1989) the conspicuity level is changing, relative, and largely dependent upon contextual factors. PTW conspicuity may be related to the motorcycle, to other vehicles, to the riders themselves, to other drivers, to the road environment or to any combination of those factors. Moreover, they may be associated to exogenous or endogenous, modifiable or non-modifiable factors. For example, riders can use daytime running lights to decrease their probability of collision with another vehicle (Saleh et al., 2010), but they do not control ambient traffic conditions. Also, frontal, lateral, and rear motorcycle sensory conspicuity may differ significantly. Most importantly, conspicuity is not constant but changes with the time of day, the weather conditions, the urban environment, the presence or absence of other road users. A negative or neutral element, such as a dark jacket in nighttime conditions, may have a positive impact in daytime. Inversely, a daytime conspicuity intervention may prove to have a negative impact during nighttime. Therefore, it is difficult (if not impossible) to establish a rigorous taxonomy of conspicuity risks and to assess their impact under all possible circumstances. The related literature considers different road environments (rural vs. urban, intersections, light vs. heavy traffic), varying lighting conditions and driver attributes and has mainly focused on the following type of measures:

- vehicle lights (Cavallo and Pinto, 2012; Farmer and Williams, 2002; Jenness et al., 2011; Hole et al., 1996; Janoff and Cassel, 1973; Lenné and Mitsopoulos-Rubens, 2011; Muller, 1982; Perlot and Prower, 2003; Rumar, 1980; Smither and Torrez, 2010; Thomson, 1980; Umar et al., 1996; Yuan, 2000; Zador, 1985)
- rider clothing and motorcycle color (Burg and Beers, 1978; Gershon et al., 2012; Hole et al., 1996; Olson et al., 1981; Smither and Torrez, 2010; Watts, 1980; Williams and Hoffmann, 1979).
- rider experience (ACEM, 2004; Crundall et al., 2012; Crundall et al., 2008; Mitsopoulos-Rubens and Lenné, 2012)

3. Rider's accident risk

PTWs are believed to have a higher risk of getting involved in accidents compared to other vehicle drivers. If involved in accidents, PTWs are also more likely to experience severe injuries. In New Zealand, for instance, motorcyclists represent 13% of deaths and 9% of road injuries while motorcycles represent only 3.5% of registered vehicles (Helman et al., 2012). This overrepresentation is even greater if considering the lower mileage of motorcycles: they undertake around 0.5% of travel time or trip legs (Walton et al., 2013). Furthermore, the cause

of the majority of PTW accidents is human error and the most frequent human error is a failure to see the PTW within the traffic environment, due to lack of driver attention, temporary view obstructions or PTW low conspicuity (ACEM, 2004). Zador (1985) relates conspicuity to single-vehicle accidents. He claims that one fifth of PTW single-vehicle accidents result from riders trying to avoid other vehicles. However, low conspicuity is primarily associated with car-versus-motorcycle (CVM) collisions. Inadequate motorcycle visibility is an associated factor in 64.5% of CVM collisions and it is the sole identifiable cause of 21% of collisions (Williams and Hoffmann, 1979).

In CVM collisions, car drivers are mostly at fault: the most common motorcycle crash type is when an automobile maneuvers into the path of an oncoming motorcycle at intersection which involves a motorist infringing upon the motorcycle's right-of-way (ROW) (Helman et al., 2012; Pai et al., 2009; Wulf et al., 1989). The motorcycle's ROW is more likely to be violated at unsignalized T-junctions (Pai and Saleh, 2008), non-built-up roads and in poor light conditions (Pai et al., 2009). In an early effort, Fulton et al. (1980) reported that about 67% of near-misses and motorcycle accidents were due to another driver failing to detect the oncoming motorcyclist before emerging from a side-turning or before turning across the motorcyclist's path. Preusser et al. (1995) explored a US database of 2,074 crashes fatal to the motorcycle rider and conclude that approximately ¼ of total crashes are due to some other vehicle failing to grant the ROW and moving into the path of the motorcycle. ROW violations are involved in 40% of all CVM crashes in Great Brain (Clarke et al., 2007) and 64% of CVM crashes (Walton, 2010) in New Zealand. The frequency of this crash pattern is such that PTW ROW violation by another vehicle has become representative of both CVM collisions and conspicuity-related crashes. Umar et al. (1996) define conspicuity-related motorcycle accidents as "all accidents involving motorcycles travelling straight or turning onto a ROW and colliding with pedestrians and other vehicles". However, other crash types (single-vehicle accidents for example) and different pre-crash maneuvers (overtaking for example) may be also related to low PTW conspicuity. Inversely, PTW ROW violations may be due to reasons other than low conspicuity. Sometimes drivers do not look at all when pulling out of a junction; this is not a conspicuity issue (Helman et al., 2012). Nevertheless, this information is available only in laboratory experiments. Most of the accidents (65%) collected in straight sections were motor vehicle collisions between a passenger car and a PTW. Almost half of accidents occurred at darkness suggesting a problem of sensory conspicuity. (Spanish investigation within the project 2-BE-SAFE; Saleh et al., 2010).

First and foremost, car drivers violate motorcycle ROW because they 'look but fail to see' (LBFS). LBFS accidents happen when a driver pulls into the path of an oncoming motorcyclist and claims not to have seen him approaching (Herslund and Jorgensen, 2003). LBFS accidents mostly occur in daytime. Indeed, daytime PTW conspicuity is lower as, during nighttime, headlights provide a strong contrast to the lighting environment (Wulf et al., 1989). Secondarily, car drivers violate motorcycle ROW because they fail to correctly judge the path or speed of the PTW (Gould et al., 2012a). CVM collisions then occur as a result of drivers accepting an inadequate gap among conflicting traffic (Pai et al, 2009). Experimental evidence proves that drivers make more accurate judgments regarding the approach speed of cars than the speed of motorcycles; especially in nighttime conditions (Gould et al., 2012a). Motorcyclists often experience reduced visibility when wearing glasses, visors or wind shields (NPRA, 2004).

Lin and Kraus (2009) classify conspicuity in a Haddon's matrix as a pre-event risk factor related to human, vehicle, and environmental crash aspects. Besides the three interventions discussed previously, the following factors seem to be influential:

(i) Human factors

Age and gender have an impact on identification and reaction times or even on the effectiveness of conspicuity aids (Smither and Torrez, 2010). Elderly and female motorists appear to be over-represented in gap-acceptance crashes (Pai et al., 2008). Magazzu et al. (2006) suggest that motorcycle conspicuity is lower among older car drivers. Clarke et al. (2007) provide evidence that older and experienced drivers seem to have more problems detecting approaching motorcycles particularly at T-junctions. Injuries to riders are greatest in angle oblique collisions with elderly motorists while teenaged motorists seem to predispose riders to a greater injury risk in angle perpendicular crashes while (Pai, 2009). Furthermore, some authors attribute car drivers' failure at junctions to the higher workload during turning maneuvers at intersections (Hancock et al., 1990) or even to their negative view towards motorcyclists (Crundall et al., 2008). It should be noted that many human factors that are critical to road safety (fatigue, alcohol impairment, drug use, and so on) have not been examined under the conspicuity hypothesis.

(ii) Vehicle speed and distance

PTW distance from the viewer is not only a contributing conspicuity factor but also influences the effectiveness of different aids in increasing conspicuity (Gershon and Shinar, 2013). The possible influence of speed on low motorcycle conspicuity has been suggested by a number of authors (see Kim and Boski, 2001; Williams and Hoffmann, 1979). Clabaux et al. (2012) examined the effect of motorcyclists' speed on their involvement in LBFS accidents in France. The authors performed a kinematic reconstruction of 44 accident cases occurring in both urban and rural environments. Results indicate that in urban environments the approach speed of motorcyclists involved in LBFS accidents is significantly higher than in other accidents at intersections. In rural environments, the speed difference was not found to be significant.

(iii) Road environment

Motorcycles' ROW is more likely to be violated on non-built up roads (Pai et al., 2008). Nevertheless, evidence shows that PTW crashes mostly occur in urban areas while passenger cars are the most frequent collision partners (ACEM, 2004). In the ACEM study (2004), over half of PTW crashes took place at intersections while 90% of all PTW accidents occurred in light to moderate traffic conditions. Poor visibility conditions (horizontal curvature, vertical curvature, darkness) is responsible for increased motorcycle injury severity (Savolainen and Mannering, 2007). Poor sightline visibility and rider/bike conspicuity are likely to contribute to motorcycle accidents at intersections (NPRA, 2004). Moreover, riding in darkness without street lighting was related to severe motorcyclists' injury (De Lapparent, 2006; Pai and Saleh, 2007, 2008). Motorcyclists are found to be more vulnerable during night time at both intersections and expressways (Haque et al., 2009). Injuries resulting from early morning riding, in general, appear to be the most severe, especially in junctions controlled by stop, and give-way signs and markings (Pai and Saleh, 2007).

Haque et al. (2012) explored motorcycle crash occurrences in Singapore where motorcycles account for 16.3% of motorized vehicle fleet. The authors specified log-linear model over a database including a total of 13,568 occurring on expressways, at

intersections or away from intersections. Nighttime influence was found to increase crash risk particularly during merging and diverging maneuvers on expressways, and turning maneuvers at intersections. The authors suggest that this is due to nighttime conspicuity. Of course, conspicuity explains to an extent the latter but other factors may come into play as well: lower traffic volumes and higher speeds, more sensation-seeking and risk-taking behaviors, and so on. Intersections (poor sightline visibility and rider/bike conspicuity are likely to contribute to motorcycle accidents at intersections). Analyses of Spanish PTW crash data show that the most frequent type of intersection where accidents occurred is a roundabout (7 out of 8) in inter urban areas. Most of the accidents collected in these junctions occurred without daylight conditions so it could be suggested that kerbs should be painted with the aim of raising their conspicuity (Saleh et al., 2010).

Overall, accident studies and post-hoc crash investigations establish only indirect links between crash outcomes and conspicuity factors and interventions. The difficulty in directly associating conspicuity interventions to safety outcomes starts from the very definition of conspicuity-related motorcycle accidents that remains rather unclear. A second major barrier to establishing this link is that conspicuity-related factors cannot be collected from conventional (national) crash databases (Shaheed et al., 2012). In the absence of relevant data, researchers mainly perform before-after evaluations or longitudinal studies comparing crash data with and without the treatment. In all these cases, the presence of bias -due to site particularities or other reasons- cannot be excluded. A third methodological problem consists in comparing among subsets of crash dataset: single- vs. multi-vehicle motorcycle accidents, daytime vs. nighttime motorcycle accidents, and so on. Such comparisons juxtapose crashes with clearly different causes. Comparisons between groups of crashes with common causes (for example, car drivers' failure to detect a car) would be more appropriate. Besides, empirical evidence shows that CVMs are not that different from CVCs. Cercarelli et al. (1992) investigated 500 CVM crashes and compared them to over 3,000 CVC crashes. The analysis did not identify any consistent pattern between crash-type and lighting conditions. Walton et al. (2013) performed a case-control study between CVC and CVM crashes in New Zealand. This analysis again showed that CVM crashes are not easily distinguished from CVC crashes as they follow similar patterns.

We identified only two recent studies establishing empirical causal links between conspicuity and motorcycle accident risk. In 2004, the ACEM funded a comprehensive Motorcycle Accident In-Depth Study (MAIDS) project that covered five European countries: France, Germany, Italy, Spain, and the Netherlands. The authors compared 921 motorcycle accident cases with 923 controls and offered very interesting insight on conspicuity contributory factors. White PTWs were found to be over-represented in crash occurrences. Dark PTW rider clothing decreased conspicuity in 13% of all accidents. Wells et al. (2004) designed an innovative population based case-control study in New Zealand. The authors interviewed 463 motorcycle riders (cases) involved in car-motorcycle crashes resulting to the motorcyclist's injury or death. In the latter case, a proxy respondent was interviewed instead. In addition, 1,233 motorcycle riders were randomly recruited and interviewed (controls). Statistical analysis of responses revealed that injury crashes mainly occurred in urban zones with 50km/h speed limit, during the day, and in fine weather. Riders wearing reflective and fluorescent clothing had a 37% lower risk. The use of white helmet was associated with a 24% lower risk compared to black helmet. DRL was found to be associated with a 19% lower risk of involvement in injury crashes. No association was found between risk and the frontal color of rider's clothing or motorcycle

Turning to accident severity, head injuries are the most frequent in fatal motorcycle crashes accounting for about 50% of all motorcycle deaths (Kraus, 1989). Chest and abdominal injuries are the second most frequent cause comprising form 7% to 25% of deaths (Lin and Kraus, 2009). If all injury outcomes are considered, lower extremity injuries come first followed by upper extremity injuries (ACEM, 2004). As in the case of accident involvement, few are the studies linking conspicuity to severity outcomes in a consistent way. Pai (2009) examined how motorist's failure to give way affects motorcyclist injury severity at T-junctions in UK. Binary logit estimation results revealed that injuries are greater when a travelling-straight motorcycle on the main road crashes into a right-turn car from the minor road. Shaheed et al. (2011) used the Iowa crash database to explore differences in motorcycle severities in daylight and dark conditions. It seems that more severe car-motorcycle crashes are likely to occur in dark conditions. Furthermore, rear-end crashes caused by a 'non-motorcycle' vehicle hitting a motorcycle are less likely to result in severe injuries. On the contrary, a higher likelihood of major injuries was found in angle crashes with the 'non-motorcycle' vehicle turning left and the motorcycle moving straight.

4. Conclusions

The objective of this chapter was to examine the main determinants of riders' accident risk that are related to conspicuity by means of a literature review. We tried to establish a link between conspicuity risks/enhancements and PTW crash risk. Conspicuity risks are not to be confused with accident risks; they are two separate sets of risk factors. The conspicuity hypothesis testing consists in proving that an intersection exists between the two and in defining its elements. In that sense, the conspicuity hypothesis is not rejected for a treatment that is found to significantly enhance conspicuity **and** to significantly decrease PTW accident risk.

Empirical evidence shows that most PTW conspicuity crashes are related to PTW ROW violation by another vehicle and result to a collision between the two. These accidents seem to be most probable at non-signalized intersections, non-built-up roads and in poor light conditions. The most frequent collision partners are passenger cars. It should be noted though that other crash patterns exist and that not all PTW ROW violations are due to conspicuity issues. Unfortunately, common accident **records do not include specific information** on conspicuity aids at use at the moment of the accident. Also, laboratory experiments may simulate the driving environment but not the real-world crash conditions. In the absence of data, most researchers have either investigated PTW crash data through observational studies or explored the effectiveness of conspicuity treatments by means of laboratory experiments. In both cases, it is impossible to infer empirical links between conspicuity and accident involvement. On the contrary, population based case-control studies are very well suited but remain few in number. In-depth databases are rare but deliver a clearer picture – more research and investigations are needed. A limited number of in-depth investigations try to conclude on the conspicuity issues, due to specific information on the crash location combined with the crash time. Overall, the conspicuity hypothesis testing remains inconclusive as long as several data and methodological limitations hold.

Author	Date	Objective	Data	Method	Methodology	Conspicuity configuration	Findings
ACEM	2004	To better understand the nature and causes of PTW accidents	921 accidents (Europe, 999-2000); 923 controls	In-depth investigation	Case-control study	-motorcycle color -lighting conditions -headlamps on/off -motorcyclist clothing color	- White PTWs are over-represented in crash occurrences. - Car drivers holding a PTW license are less likely to commit perception failures - Dark PTW rider clothing decreased conspicuity in 13% of crashes
Clabaux et al.	2012	To examine the effects of motorcyclists' speed on LBFS accidents	44 LBFS accident cases (France)	In-depth investigation	Kinematic reconstruction	-motorcycle speed	- In urban environments, the motorcycles' speed involved in LBFS accidents is significantly higher -In rural environments, the speed difference is not significant
Clarke et al.	2007	To investigate the causal factors behind injury motorcycle accidents	1,790 injury accident reports involving motorcyclists (UK, 1997-2002)	In-depth investigation	Descriptive statistics	-motorcycle DRL -reflective clothing -both	- Perception problem mainly at T-junctions - Such accidents seem to involve older drivers with relatively high levels of driving experience
Haque et al.	2012	To study the effects of traffic, environmental, roadway factors on motorcycle crashes	21,922 crashes involving motorcycles (Singapore, 2004-2008)	Observational study	Statistical analysis (Log-linear model)		Nighttime influence increases crash risk particularly during merging and diverging maneuvers on expressways, and turning maneuvers at intersections.
Jenness et al.	2011	To determine the impact of car DRL use on motorcycle crashes	- Canada and northern US crash databases	Observational study	Statistical analysis (logistic regression)	DRL use for other vehicles	Widespread use of DRL in the vehicle fleet increases the relative risk for certain types of multi-vehicle motorcycle crashes.
Pai	2009	To examine how motorist's failure to give way affects motorcyclist injury severity at priority T-junctions	34,783 CMV injury accidents at T-junctions (UK, 1991-2004)	Observational study	Statistical modeling (binary logit)	-motorcyclist's attributes -crash characteristics -lighting conditions -motorcycle size	-injuries are greater when traveling-straight motorcycle on the main road crashes into a right-turn car from the minor road -teenaged motorists predispose riders to a greater injury risk in angle perpendicular crashes -injuries to riders are greatest in angle oblique collisions with elderly motorists
Pai et al.	2009	To examine the characteristics of automobile-motorcycle gap-acceptance accidents at priority T-junctions	-38,096 CMV injury accidents at T-junctions (UK, 1991-2005)	Observational study	Statistical analysis (mixed logit)	-motorcyclist's attributes -crash characteristics -lighting conditions -motorcycle size	-Motorcycles' ROW is more likely to be violated on non-built up roads and in diminished light conditions. -Elderly and female motorists appear to be over-represented in gap-acceptance crashes.

Preusser et al.	1995	To analyze fatal motorcycle crashes by crash type	-N=2704 fatal crashes occurring in the USA during 1992	Observational study	Classification and descriptive statistics	-	-motorcycle accidents involving an interaction with other vehicles account for over 26% of total crashes. -they occur more often at intersections, in urban areas, during times of the day when more traffic would be expected -typically the motorcyclist has the ROW and some other vehicle fails to grant this ROW moving into the path of the motorcycle.
Saleh et al.	2010	To evaluate the interaction between PTW accidents and infrastructure	National databases (2005 – 2007) from GR, IT, UK, ES, DE, AT; In-depth data from ES, DE, AT	Observational study + In-depth study	Macroscopic and Microscopic accident analyses; In-depth studies with road infrastructure data	-driving environment -road infrastructure relevant contributing factors -light condition/visibility	-Specific outputs on critical intersection types, light conditions, infrastructural/design elements -visibility/conspicuity regarding road infrastructure -cross-European investigation on PTW crash causes -Spanish data identify roundabouts in nighttime as critical regarding conspicuity - Motorcyclists often experience reduced visibility when wearing glasses, visors or wind shields
Shaheed et al.	2011	To investigate the effect of potential motorcycle conspicuity related factors on motorcycle crash severity outcomes	3,693 car-motorcycle crashes (Iowa, 2001-2008)	Observational study	-contingency tables -multinomial logit	-lighting conditions -rural/urban environment	Severe injury outcomes in: -dark conditions -angle crashes with the car turning left and the motorcycle moving straight -dry surface conditions
Umar et al.	1996	To explore the contributory factors of conspicuity-related motorcycle accidents	4,958 conspicuity-related motorcycle accidents (Malaysia, 1991-1993)	Observational study	Statistical analysis (GLM)	DRL for motorcycles	Running headlight reduces conspicuity-related motorcycle accidents by about 29%.
Wells et al.	2004	To investigate whether motorcycle crash injuries are associated with conspicuity	-463 motorcycle riders (cases) involved in injury accidents -1,233 riders (controls)	Population based case-control study	Statistical analysis	reflective or fluorescent clothing; headlight operation; color of helmet; color of clothing from waist up; color of clothing from waist down; color of motorcycle	Wearing reflective or fluorescent clothing and white or light colored helmets and using headlights in daytime could reduce injury crashes by up to one third.

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