Deliverable D1.1 Powered Two-Wheelers – Road Traffic Accident Scenarios and Common Injuries

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D1.1 Powered Two-Wheelers – Road Traffic Accident Scenarios and Common Injuries

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Executive Summary

Comprehensive literature review has been performed related to analyses of road traffic accidents involving powered two-wheelers (PTW). It became obvious that many projects, in particular European research projects, studies from French and Italian research institutes and from Australia have been working on this topic; however, results can hardly be compared since the definitions of many variables vary, different injury coding are used and all analysed in-depth accident datasets are based on greatly differing inclusion criteria.

The PIONEERS project took this burden and established definitions for relevant Accident Scenarios and body regions which may form a new common understanding and will accelerate harmonization processes in this research field. Furthermore, several datasets from Europe and Australia (Compilation of macrostatistical European accident data as well as data from national statistics and in-depth accident investigations) of latest years have been analysed to provide a current understanding of the accident occurrence of powered two-wheelers.

The European accident database CARE provided the information that PTW users account for 17% of all killed road traffic participants. Eighty-eight percent of moped and ninety-four percent of motorcycle riders fatalities were males. The fatality rates for PTW users are high especially for young riders, aged 15-17 for moped riders and aged 18-24 as well as above 50 years for motorcycle riders. Most moped fatalities occurred in urban areas, whereas the majority of motorcycle fatalities occurred in rural areas. The wide range in the distribution of PTW fatalities by area and road type mostly reflects the different share of mopeds and motorcycles in a country. The CARE dataset has also been analysed towards the PIONEERS Accident Scenarios and revealed that the Accident Scenario 3 (L3 vehicle vs. passenger car / taxi) is of highest importance, followed by AS6 (single L3 vehicle accidents) and AS1 (L1 vehicle vs. passenger car / taxi). With that, CARE shows comparable results to those gained by the analysis on national level.

Latest data of six in-depth accident datasets from countries such as Germany, Italy, France and Australia have been analysed with regard to questions (“requests”) by project partners focusing on distributions of the Accident Scenarios, sample characteristics (sex, age, body weight, body height), types of motorbikes, collision parameters, most common injuries and the performance of personal protective equipment.

Due to the comprehensive tables of results for most of the analysed in-depth data requests by the project partners, only a selection of results could be shown within this report. Other results are made available by direct data exchange on request.

In addition, a comparison between European and Australian accident occurrence and rider injuries has been conducted. Due to difficulties harmonizing category definitions and different specialisations of in-depth crash data available in each jurisdiction, a number of discernible characteristics were observed. Australian riders appear to prefer sports style of PTWs with very little representation of scooter style PTWs while scooter, step-through or maxi-scooter type PTWs were more prevalent in Europe. However, the most common demographics of riders injured in crashes, in terms of sex (male), age (16-35 years of age) and height (161-180 cm tall), is the same in all analysed countries. Rib and lung injuries were among the most common AIS 2+ injuries across both Australian and European databases. Urban two-participant crashes at

intersections were a prevalent cause of serious injuries to PTW riders in all countries, pointing to a priority scenario for further attention.

The analysis of accident data requires always consistent information. To ensure proper analyses in future, there is an urgent need of the harmonization of several key variables used in road traffic accident investigations.

Legal Disclaimer

Abbreviations and Acronyms

Acronym	Definition / Description
AIS	Abbreviated Injury Scale
BAAC	National accident statistics from France (Bulletin d'Analyse des Accidents Corporels de la Circulation)
BRON-DHD	Ministry of Infrastructure and Environment, Dutch Hospital Data & SWOV
CARE	Community database on Accidents on the Roads in Europe
CIREN	Crash Injury Research (USA)
COST327	European Co-operation in the Field of Scientific and Technical Research (COST) Motorcycle Safety Helmets (COST327)
CzIDAS	Czech In-Depth Accident Study
DESTATIS	Federal Statistics Office of Germany
DIANA	Spanish In-depth accident database
DGT	National accident statistics from Spain (Dirección General de Tráfico)
EDA	French in-depth accident study by IFSTTAR (Etudes Détallées d'Accidents)
EHLASS	European Home and Leisure Accident Surveillance System
GIDAS	German In-Depth Accident Study
ICD	International Classification of Disease
ICECI	WHO International Classification for External Causes of Injuries
IGLAD	Initiative for the global harmonization of accident data
InSAFE	In-depth Study of accidents in Florence (University of Florence)
ISS	Injury Severity Score
ISTAT	National accident statistics from Italy
LMU	Ludwig-Maximilians-Universität Munich
KSI	Killed and seriously injured
MAIDS	Motorcycle Accidents In Depth Study
NASS	National Automotive Sampling System (NHTSA, USA)
NHTSA	National Highway Traffic Safety Administration (USA)
OECD/OCDE	Organisation for Economic Co-operation and Development (OECD; French: Organisation de coopération et de dévelopement économiques, OCDE)
PPE	Personal Protective Equipment
PTW	Powered Two-Wheeler
RAIDS	Road accident in-depth accident studies, Department for Transport, UK

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1 Summary of literature review

In the last few decades several road traffic accident data analyses have been performed world-wide to identify safety issues concerning riders of powered two-wheelers. This document highlights selected sources of this knowledge filtered towards the interests of the PIONEERS consortium (e.g., definition of accident scenarios and the usage of personal protective equipment) to support its technical work.

1.1 Accident scenarios

The SUSTAIN project (Aarts, et al., 2016) has analysed various European accident databases to identify issues related to seriously injured (MAIS 3+) road traffic participants.

In most countries, cars are the most common crash opponent for severely injured motorcyclists (42%-59%) and two active road users are most commonly involved in the crash (46%-67%). Single vehicle crashes and crashes into fixed objects are also very common. Particularly in Sweden, single vehicle crashes outnumber the crashes where a car is the crash opponent.

The impact location for severe motorcyclist crashes is most often to the front, with side-impacts as the second most frequent. Those databases that provide information on the manoeuvre show that a turning manoeuvre or going straight (sometimes in a bend) are common in severe motorcyclist crashes.

Location characteristics: In some countries, rural road crashes outnumber those on urban roads: 45%-55% rural crashes are observed in the Netherlands and Sweden. Other countries have most severe motorcyclist crashes on urban roads: 53%-60% urban crashes are observed in Germany and the UK, but this finding may be due to biases related to the scope of in-depth data sources, which mainly cover more urban areas. At least, we can conclude from this that severe motorcyclist crashes are not a major problem on motorways. The Czech Republic data shows more crashes on urban roads, but this includes other powered two-wheelers like moped riders, which might account for this somewhat different pattern.

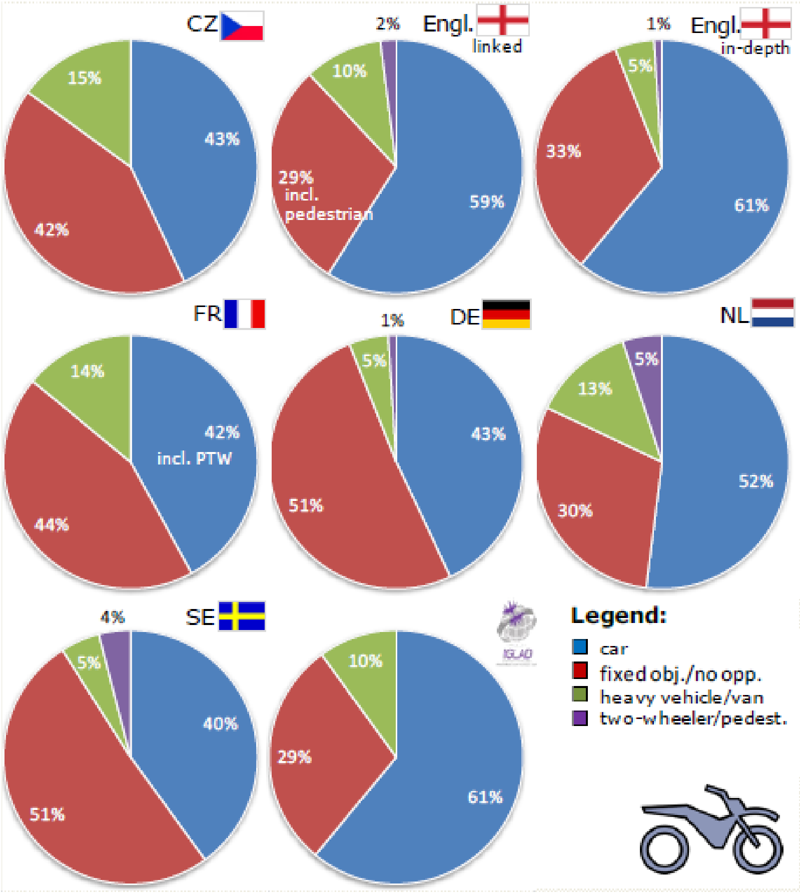


Figure 1: Most important crash opponents in crashes that lead to severely injured motorcyclists in Czech Republic (CzIDAS data), England (linked: STATS19-HES), England (RAIDS/OTS), France (Rhône trauma register data), Germany (GIDAS), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from IGLAD, source (Aarts, et al., 2016)

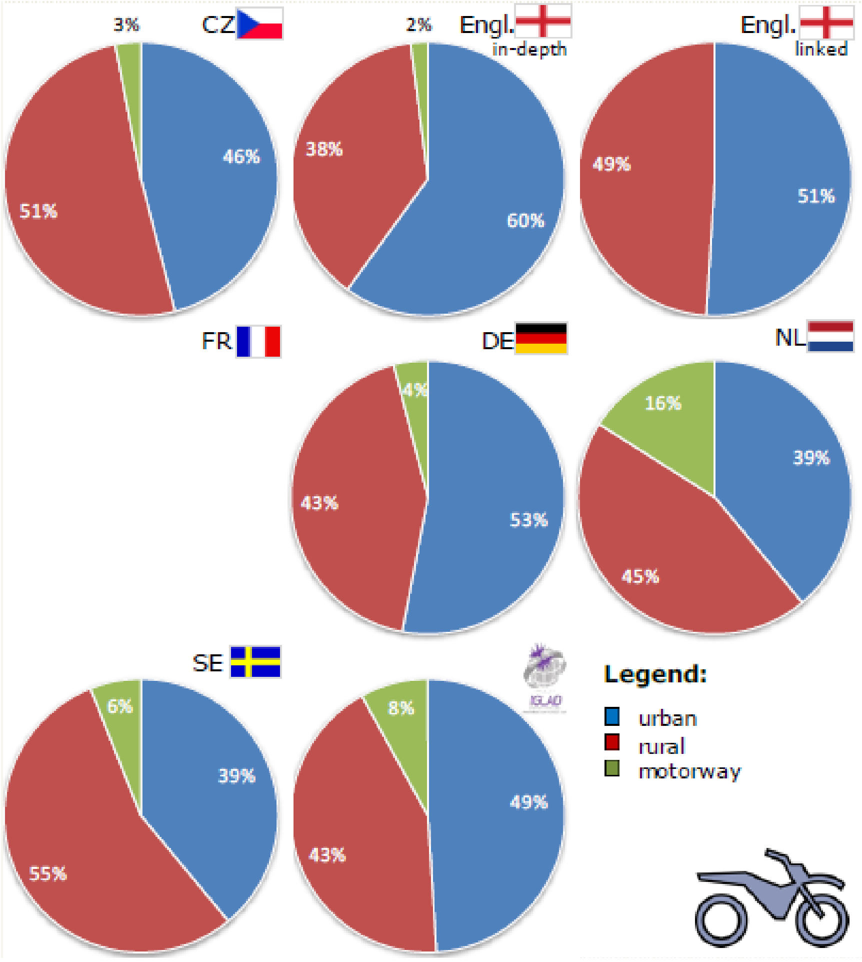


Figure 2: Main road types where crashes occur in which motorcyclists get severely injured in Czech Republic (CzIDAS data), England (linked: STATS19-HES), England (RAIDS/OTS), France (Rhône trauma register data), Germany (GIDAS), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from IGLAD, source: (Aarts, et al., 2016)

Within the APROSYS project (EU project APROSYS - Advanced Protection Systems, 2006) the data analysts observed, at a national level, similar findings and trends regarding PTW accidents in the following four countries: Germany, Italy, Netherlands, and Spain, between 2000 and 2002. No weighted data.

The most frequent and dangerous accident scenarios were on urban roads “moped and motorcycle against a car in intersections” and “moped and motorcycle against a car in straight roads” as well as on non-urban roads “motorcycles against a car in intersections”, “motorcycle against a car in straight roads” and “single vehicle accidents”.

Comparing crash configuration between in-depth data and ISO-13232 standard, the ISO standard showed different scenarios compared to in-depth data, although no clear main scenarios could be distinguished within the in-depth data.

The PISa project (EU project PISa - Powered Two Wheelers Integrated Safety, 2009) conducted a review of PTW accident data available from the major European accident studies, including

APROSYS (Advanced PROtection SYStems), MAIDS (Motorcycle Accident In-Depth Study), SafetyNet, TRACE (Traffic Accident Causation in Europe) and various national studies.

To identify information about rider behaviour and manoeuvre efficacy, the project defined 15 pre-crash accident configurations (AC) to identify the way in which the vehicles approach the site of the accident. Each of these configurations, see Table 1, can occur in more than one of the accident scenarios, depending on the road/vehicle combination.

Table 1: Accident Configurations (AC) identified in PISa

AC 1	The PTW and the other vehicle are both crossing the X-junction going straight on
AC 2	The PTW is going straight-on when the other vehicle coming from the opposite direction turns left and crosses PTW's path
AC 3	The PTW is overtaking the other vehicle driving in the same direction when the other vehicle turns left, crossing PTW's path
AC 4	The PTW is going straight-on when the other vehicle coming from intersecting road turns left and enters PTW's path
AC 5	The PTW is filtering queuing traffic when other vehicle coming from intersecting road travels across the queue and turns left, crossing also PTW's path
AC 6	The PTW is filtering queuing traffic when other vehicle coming from intersecting road travels across the queue and turns left, crossing also PTW's path
AC 7	The PTW is filtering queuing traffic/parked cars when another vehicle pulls out of the queue, entering PTW's path
AC 8	The PTW is going straight-on when the leading vehicle slows down/stops
AC 9	The PTW is going straight-on when the other vehicle coming from the opposite direction overtakes another vehicle and enters the PTW's lane
AC 10	The PTW turns left at a junction and crosses the path of the vehicle coming from the opposite direction
AC 11	The PTW turns left at a junction and crosses the path of the vehicle coming from that intersecting road
AC 12	The PTW turns left/right at a junction and enters the path of the vehicle coming from behind on that intersecting road
AC 13	The PTW overtakes a vehicle and enters the lane where another vehicle is coming from the opposite direction
AC 14	The PTW is going straight-on when the following vehicle collides it from behind
AC 15	Technically single vehicle accident is when the PTW does not hit other vehicles. But for the purposes of the present classification, the accident is considered a single vehicle when only PTW is involved in the causation. Typically, this kind of accidents occurs when PTW is moving at high speed and the rider loses control of the vehicle

The MYMOSA project (EU project MYMOSA - Motorcycle and Motorcyclist Safety, 2010) analysed data coming from MAIDS and DEKRA reports. In 80% of accidents, two vehicles were involved and of this 60% were cars. In 54% occurring at intersections the causal factor was mainly human (37% PTW rider, 50% Other Vehicle (OV) driver). Fifty-two percent of PTWs had an engine below 125cc. Scooters were the most frequent vehicle type (38%).

Prior the precipitating event, the PTW was travelling straight in 67% of the cases, as well as the OV travelling in a straight line in 56% of the cases. After the precipitating event, the majority of PTWs were still moving straight and forward (63%) and only a small percentage of them changed their travelling direction.

For the OVs, the percentage of those vehicles that did not change their travelling direction was 38%, while in the 32% of cases the OV turns left. In 65% of cases, no avoidance manoeuvre has been performed by the driver. The rider was braking in 49% of the cases.

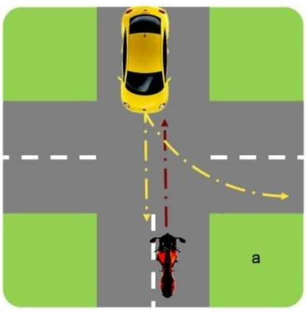
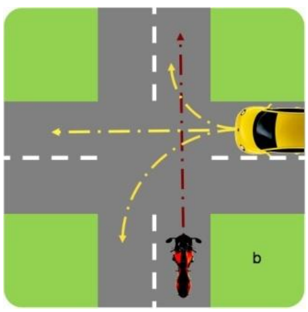
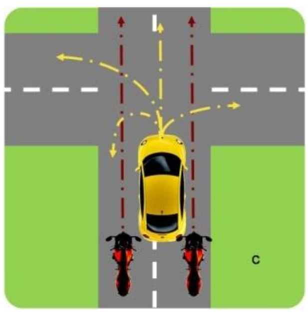
The mean travelling speed was 37 km/h and 65 km/h for mopeds and motorcycles respectively. The mean impact speed was 32 km/h and 54 km/h for mopeds and motorcycles respectively.

In the vehicle-to-vehicle crashes, 65% of PTWs had an impact speed between 30-60 km/h and only 6% had an impact speed more than 100 km/h. The OV impact speed was less than 41 km/h in 74% of cases. In single-vehicle crashes, 60.2% were between 40-80 km/h.

Another analysis focused on 207 accidents within the MAIDS dataset. The main selection criteria were: no mofa, no impairment, alcohol, drugs, environmental contributing factors and vehicle contributing factors, only PTW vs. car accident and top five accident configurations.

From this analysis, three different Priority Accident Configurations (PACs) were defined by means of similar collision typology, see Table 2 (Penumaka, et al., 2014).

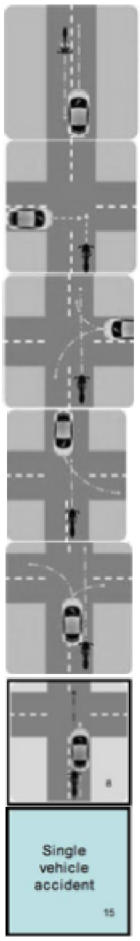
Table 2: Priority Accident Configurations (PACs) defined in MYMOSA

PAC 1	PAC 2	PAC 3
Passenger car is travelling in a straight-line path in the direction opposite to PTW or making a left turn crossing the PTW path while coming in the opposite direction	Passenger car is travelling in a straight-line crossing PTW perpendicular path or making a left turn manoeuvre crossing the PTW path, or making a right turn manoeuvre joining the PTW path	Passenger car is travelling in a straight-line path in the same direction or making a left/right turn manoeuvre crossing the PTW path, or making a U-turn manoeuvre crossing the PTW path
		

Within MOTORIST (EU project MOTORIST - MOTOrcycle Rider Integrated SafeTy, 2018) an analysis of MAIDS data was conducted to obtain relevant information concerning the highest risk scenarios and manoeuvres involved (Huertas-Leyva, et al., 2019). The criteria followed were based on the Penumaka study (Penumaka, et al., 2014) and the PISA project (EU project PISa

- Powered Two Wheelers Integrated Safety, 2009). Finally, seven scenarios were defined as shown in Table 3.

Table 3: Accident Scenarios derived in Motorist



1-OP/ST: vehicles from **OPposing** directions, opponent vehicle travelling **STraight**
2-AD/ST: vehicles from **ADjacent** directions, opponent vehicle travelling **STraight**
3-AD/TU: vehicles from **ADjacent** directions, opponent vehicle **TUrning**
4-OP/TU: vehicles from **OPposing** directions, opponent vehicle **TUrning**
5-SA/TU: vehicles from **SAme** direction, opponent vehicle **TUrning**
6-SA/RE: vehicles in **SAme** direction, PTW impacting **REar** of the other vehicle
7-SV: Single Vehicle Accident

The analysis showed that the scenarios 2 and 5 were the most frequent in PTW's accidents, while the scenario 4 was the one where it was more likely to have MAIS 3+ injuries.

MOSAFIM (EU project MOSAFIM - Motorcyclists road safety Improvement through better behaviour of the equipment and first aid devices, 2013) analysed literature (MAIDS, APROSYS, SIM) along with new data (databases MAIDS, NASS, fatality data from LMU and DIANA). Regarding injury mechanisms, it was found that the object most frequently struck by PTW is a car, followed by the road or roadside furniture resulting from single vehicle loss of control. The most common injury-causing impact opponent was the ground/roadway for all the body regions.

In MAIDS (ACEM, 2009) the most frequently reported first collision contact point for the PTW was the centre front (28.9% of all cases). The most frequently reported first collision contact point for the Opponent Vehicle was the left side (21.9% of all cases).

1.2 Accident contributing factors

The main results coming from the literature review of APROSYS (EU project APROSYS - Advanced Protection Systems, 2006) concerning the motorcycle-to-vehicle crashes from 1980 to 2005 were described as follows:

- Car driver often fails to give way to a motorcycle, especially when 1) a car is turning left and a motorcycle is approaching from the opposite direction and 2) a car is turning left/right onto a priority lane on which the motorcycle is approaching.
- Overtaking by the motorcycle on the left side when the car is turning left is an important accident scenario.
- Motorcycle speeding is often an important causation factor.

MOTORIST (EU project MOTORIST - MOTOrcycle Rider Integrated SafeTy, 2018) also reviewed previous European projects such as APROSYS SP4, MYMOSA and SIM project, as well as conducted another analysis of the MAIDS database. The main conclusions were:

- Human error (perception or reaction) is the primary contributing factor in most accident;
- A passenger car with gross mass between 800 and 2000 kg is the most common Opponent Vehicle;
- Most accidents occur at intersections (T-Intersection, Cross-Intersection);
- The crash speed of OV during the simulation of realistic impacts should be taken in the range of 16.5km/h, 56 km/h and 95.5 km/h;
- Crash speed of PTW for specific legal categories should be
    - L1: (32 ± 11) km/h → 21 km/h, 32 km/h, 43 km/h
    - L3: (53 ± 18) km/h → 35 km/h, 53 km/h, 71 km/h;
- Gross mass of PTW for simulations should be for L1 around 80 kg and for L3 around 125 kg and 200 kg.

MOTORIST also suggested that more attention should be paid to reducing crash velocity and protecting the motorcycle operator/passenger during high speed accidents and described that visibility limitations and the type of illumination do not have significant influence on PTW accidents.

TRACE (EU project TRACE - Traffic Accident Causation in Europe, 2008) reported that "In the case of accidents between a PTW and other vehicle, the most frequent human error was a failure in perceiving the PTW by another vehicle driver (associated to the traffic environment, traffic scanning error, lack of other vehicle driver attention, faulty traffic strategy or low conspicuity of the PTW). To decrease accidents where unsafe acts, from riders or other vehicles drivers, were a contributing factor, the following counter measures were suggested: 1) reinforcement of educational campaigns to highlight to all road users the importance of considering motorcyclists as vulnerable road users and to drive in a manner taking into account that a motorcycle is more difficult to perceive, 2) re-educate drivers and riders through retrain courses, especially those who committed a serious traffic violation and 3) specific campaigns for motorcycle riders highlighting that taking risks while riding can cause very serious injuries to themselves, to their passengers and to other potential vulnerable road users such as pedestrians."

For severe motorcycle crashes, the following contributing crash factors were found in (Aarts, et al., 2016) to be most common:

- Failure to look properly (40%)/vision affected (34%);
- Speeding or inappropriate speed for conditions (26-34%);
- Loss of control (25%);
- Poor turn/manoeuvre (25-31%);
- Failed to judge path or speed of another road user (23%);
- Careless/reckless behaviour (23-43%).

1.3 Injuries of PTW riders

In terms of injuries, in (EU project APROSYS - Advanced Protection Systems, 2006) different in-depth accident datasets were considered. LMU and MAIDS-TNO datasets have a higher proportion of severe injuries compared to the GIDAS where 67% of the PTW users were slightly injured. In LMU and MAIDS-TNO datasets, the proportion of serious head, neck and thorax injuries is larger than that found in the GIDAS dataset. For the LMU and the GIDAS datasets, the car and the road were the most frequent objects involved in the primary impact with the rider/passenger. Primary impact occurs to the lower extremity most often (25-60%), followed by the head, upper extremities, and thorax. The injury severity at upper and lower extremities is usually minor (AIS 1).

Contact with the car causes more severe injuries to the head, thorax, and abdomen than contact with other objects. Accidents with a larger distance between the point-of-impact and point-of-rest for the rider/passenger were associated with a higher upper and lower extremity injury severity.

The MOSAFIM project (EU project MOSAFIM - Motorcyclists road safety Improvement through better behaviour of the equipment and first aid devices, 2013) analysed the injury severity of motorcyclists per body region:

Thorax: Concerning critical or fatal accidents (LMU&DIANA), the thorax is the most frequent body region sustaining the maximum AIS score (MAIS). Thoracic injuries are often severe or critical (MAIS 3+) and they are major contributors to reduced survival following head injury. It has been found that this body region is likely to register life-threatening injuries, i.e. around 30% of thorax injuries at medium or high speeds have an AIS value equal or higher than 4.

Neck/Cervical spine: Most neck injuries are minor, typically contusions, abrasions or lacerations. Cervical spine injuries are under-represented among PTW riders compared to other road users. Nevertheless, cervical spine injuries account for nearly a half of the MAIS 6 injuries recorded in the MAIDS database.

<u>Spine:</u> Concerning spine injuries, the thoracic (54%) and lumbar spine account for 90% of all vertebral injuries. Like cervical spine, the lumbar spine is seldom injured but is likely to show high severity scores.

Furthermore, indirect trauma was found to be the most common injury mechanism for neck and spine AIS2+ injuries whereas direct trauma was the most frequent mechanism detected for thorax AIS2+ injuries (MAIDS database).

SUSTAIN (Aarts, et al., 2016) reported that severely injured motorcyclists are dominated by males (91%-96%). In the databases with PTW (CzIDAS, Rhône trauma registry and IGLAD), the share of males is somewhat lower. Most casualties (95%) are the rider of the motorcycle. Dominant age groups are youngsters (18-24 years) and in Sweden, Germany, the Netherlands and the UK also middle-aged adults (around 40 years old). In Germany, this group of middle-aged adults is the most dominant.

For motorcyclists, the body regions most frequently severely injured are the thorax and lower extremities. Head injuries and injuries to the upper extremities are also common.

Thorax injuries are most frequently found in single vehicle crashes and crashes with a fixed object, while lower extremity injuries are particularly found in crashes with a car.

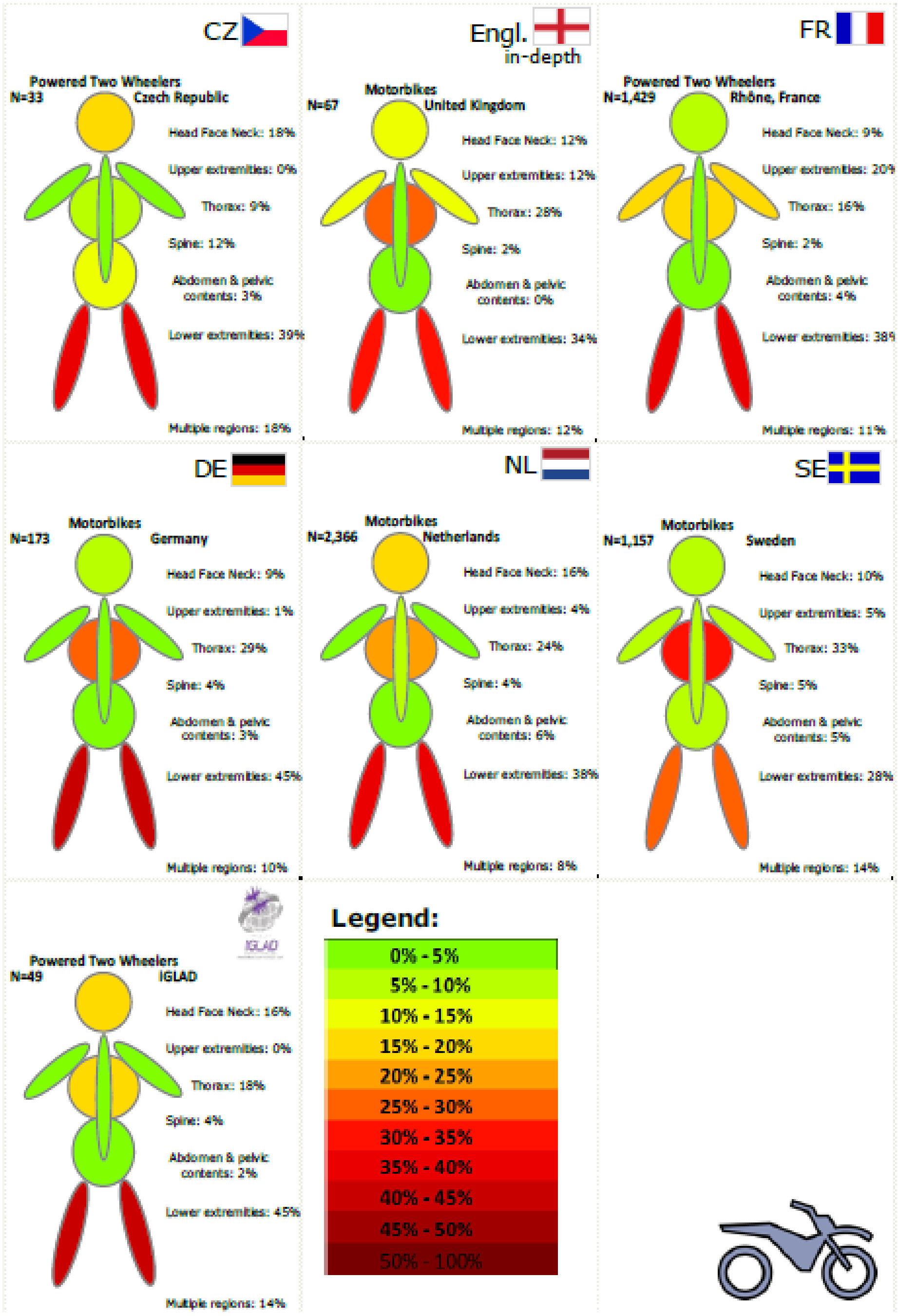


Figure 3: Overview of injured body regions of MAIS3+ motorcyclists in Czech Republic (CzIDAS data), England (linked: STATS19-HES), England (RAIDS/OTS), France (Rhône trauma register data), Germany (GIDAS), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from IGLAD, source: (Aarts, et al., 2016)

In MAIDS (ACEM, 2009), a total of 3644 injuries were reported. Most injuries were reported to be minor lacerations, abrasions or contusions. Lower extremity injuries made up 31.8% of all injuries, followed by upper extremity injuries which made up 23.9% of all injuries. Head injuries accounted for 18.7% of all reported injuries. Most upper and lower extremity injuries occurred as a result of impacts with the opponent vehicle or the roadway.

Data from Australia has been reported in (Meredith, et al., 2014) and (Meredith, et al., 2016). Pelvic injury occurred in 21.3% of participants in two convenience samples of crash involved motorcyclists: one of riders who were admitted to hospital in New South Wales, Australia; and another of riders involved in a crash with at least one participant transported to hospital in South Australia. The most frequent (85% of cases) cause of pelvic injuries to crashed motorcyclists was direct contact with the motorcycle fuel tank, and this primarily involved the motorcycle impacting another moving vehicle. Fractures and external injuries were the most common types of pelvic injury from fuel tank contact. Pelvic injury complexity, in terms of failure of more parts of the bony pelvis, appeared to increase with greater impact speeds. Pelvic injuries were predominantly sustained by riders of sports motorcycles (13 cases), followed by cruiser (8 cases), standard (4 cases), touring (1 case) and café racer type motorcycles (1 case). Controlling for motorcycle type, the likelihood of pelvic/abdominal injury significantly increased with fuel tank angle. These factors suggest an influence of motorcycle design on pelvic injury risk which needs further investigation.

1.4 Performance of Personal Protective Equipment (PPE)

2-Be-Safe (EU project 2-Be-Safe - 2-Wheeler Behaviour and Safety) found that helmeted riders show a significantly lower injury frequency in all types of injuries compared to unhelmeted riders. Head injuries are the main cause of death among motorcycle riders. There is evidence that a share of riders do not properly wear or fasten the helmet (e.g., size, position, use of chin-strap), or do not wear a helmet at all, although this is a legal requirement throughout the EU countries. Research on issues related to helmet use, and vision and hearing (McKnight, et al., 1995) indicated that wearing motorcycle helmets neither restricts the ability to hear horn signals nor the likelihood of visually detecting a vehicle in an adjacent lane prior to initiating a lane change.

In MAIDS(ACEM, 2009)there were cases of helmets coming off the riders' heads due to improper fastening of the retention system or helmet damage during the crash sequence. In 69% of cases, helmets were found to be effective at preventing or reducing the severity of head injury.

Although helmet use is widely accepted by PTW users and proven beneficiary during accidents, there are still issues with relation to the helmet design that need to be tackled. (Federation of European Motorcyclists Associations (FEMA), 2009) emphasizes the problems of helmet use in hot climates and during summer, as well as other issues such as the induced limited vision, the "noisy" design, the weight and the fogging of the visor when riding in the rain. Moreover, eye protection significantly reduces crash involvement (Hurt, et al., 1981),(Hurt, et al., 1984) because it prevents vision degradation caused by wind blast and foreign objects in the eyes. Eye protection also reduces eye injury, both while riding and in crashes (Hurt, et al., 1984). Because motorcyclists are usually separated from the motorcycle during a crash, protective equipment attached to the motorcycle, e.g. so called 'leg protectors' or airbags, is less likely to be effective than protective clothing. Regarding protective apparel, (Ulleberg, 2003) demonstrated that the use of protective clothing reduces the severity of injuries on hands, feet, legs and arms (33%-

50% reduction in injury severity). However, (Reeder, et al., 1996) underlined that the use of protective clothing is not always preferred, as the riders experience it as fashionably or economically unacceptable.

The MOSAFIM project (EU project MOSAFIM - Motorcyclists road safety Improvement through better behaviour of the equipment and first aid devices, 2013) explained that neither in the USA nor in the European Union is there a performance testing standard for neck protection devices (neck braces) used on motorcycles. Although their usage is limited, greater efforts should be made to define test standards for these protectors and their beneficial effects should be promoted.

APROSYS (EU project APROSYS - Advanced Protection Systems, 2006) highlighted that leg protectors reduce leg injuries but may well cause an increase in thoracic and head injuries.

FEMA summarized results from the RIDERSCAN project (the Bock, 2015) and described that “the vast majority of European motorcyclists [...] take their own safety precautions. The top 3 are: 1. Motorcycle gloves, 2. Motorcycle helmet (fluorescent not so much yet), 3. Motorcycle jacket with protectors. Most riders also use: 4. Motorcycle boots, 5. Motorcycle trousers with protectors. Worth noting is that there are almost no between-country differences in taking these personal top 5 safety precautions.

The project VOIESUR (VOIESUR - Vehicle Occupant Infrastructure Road user Safety Study, 2016) reported that where the PTW wore a properly fastened crash helmet prior to the accident, the crash helmet remained in place after the impact in 87% of cases. This figure is higher than the results observed in older studies (in particular (ACEM, 2004)). This may be due to the effects of improved fastening system technologies in recent years. In personal injury accidents, the crash helmet remained on the user's head in 99% of cases, indicating the highly effective nature of the fastening system. However, where the crash helmet was not fastened prior to the accident, it did not remain on the user's head after the accident in almost all cases.

Some 19% of fatal accidents involving a PTW are accidents in which the PTW user does not hit a vehicle or fixed obstacle at the roadside. In these cases, the user simply falls onto the road or verge. Among these 19% of cases (175 fatal accidents involving PTW users), almost 80% of users were wearing a crash helmet correctly but were nevertheless killed. This observation highlights the importance of wearing other safety equipment in addition to the crash helmet (back protection, airbag jacket, protective jacket, etc.). The use of this type of equipment was extremely limited in the accidents studied.

Overall, around 66% of PTW users involved in fatal accidents wore at least one item of equipment. This rate was significantly higher among users of heavy motorcycles (83%) than among light motorcycle and moped users (33% and 26% respectively). Furthermore, this rate was also higher among drivers (68%) than among passengers (38%). Of the 13 light motorcycle and moped passengers, none wore any item of equipment other than a crash helmet. This difference between the behaviour of passengers and drivers, and between heavy motorcycle users and light motorcycle and moped users, is also reflected in the crash helmet wearing rate.

Within PROMOTO (Serre, 2012) various simulations, with and without airbags, were carried out to analyse the influence of different parameters: impact speed, impact area, types of impact (perpendicular and lateral positions of the pendulum), and types of impactors. For each test configurations, the applied load was analysed and the chest compression was measured to estimate rib fractures. The researchers used the AIS scale to quantify the benefits of the tested, new safety system. For various loads on a large chest area, the study showed that the airbag increased motorcyclists' safety. Indeed, for each simulation, no injury was observed when the airbag was used for impact speeds below 40 km/h. When an impact with an aggressive object was modelled (like a pavement/kerb), the injury level significantly increases up to AIS 5 (multiple rib fractures, flail chest) depending on the thickness and pressure used for the airbag. However, it should be noted that for an airbag with a pressure of 1.3 bar and a thickness of 11cm, the AIS is significantly decreased to an AIS 2 (2-3 rib fractures).

The project EFFIGAM (Gilets airbags pour motocyclistes: quelle efficacité réelle pour quelle vitesse?) (Serre, 2019) aims to evaluate the level of protection offered by airbag jackets for PTW users. This study is based on a double approach which combines real accident data collected with a field survey and experimental data obtained in laboratory.

The accident study showed that globally the airbag jacket is well perceived by their users who highlight its protective effects. However, the protective effect of airbag jackets is mainly in cases of falling from the motorcycles at low speeds and less so in direct impacts against an obstacle. Some specific cases show that a direct impact at 40km/h or a falling at 60km/h with an airbag jackets cannot avoid serious injuries on the trunk (AIS3+). Experimental tests show that an airbag jacket has a protection level superior to a classical back protector but they highlight that an airbag jacket has limited protection for impact speeds upper than 40km/h. This threshold impact speed for airbag jacket effectiveness differs by impact configuration. Crash tests also show differences between the type of airbag jacket in terms of pressure and trigger time.

The Gear Study (de Rome, et al., 2011) showed that protective clothing for motorcyclists is associated with reduced hospitalization rates and a reduced crash injury risk and severity. In particular, garments fitted with body armour were associated with substantial reductions in the risk of any injury, controlling for impact speed and type of impact. The greatest benefits were in soft-tissue injury prevention and particularly open wounds, while benefits for fracture prevention were not detected. Relatively high protective clothing failure rates, even at estimated impact speeds below 40 km/h, suggested a need for improved quality control of motorcycle protective clothing.

(Meredith, et al., 2014) performed an analysis of 117 cases from the Gear study (de Rome, et al., 2011) in which the participant had been injured and medical records were available looking at the distribution and type of crash damage to motorcyclists' clothing and rider injuries. The most frequent injury type was contusions (54%), followed by abrasions (31%), lacerations (14%), and burns (1%). Laceration, contusion and abrasion injuries occurred most frequently in Zone 1 regions of motorcycle clothing, as specified in European Standard EN 13595, whereas burn injuries did not follow this trend. Burn injuries occurred most frequently in Zone 2.

An in-depth investigation of 92 motorcycle crashes in Sydney, Australia was described in (Meredtih, et al., 2015) and highlighted that skin abrasion injuries can still occur when motorcycle clothing does not completely abrade through and the skin does not come into direct contact with the road surface. In 90 instances where an external clothing region was identified as having an abrasive contact that could have resulted in abrasion injury, but without completely holing through, abrasion injury from the lining material occurred in 46 of these 90 samples. The knee had the highest number of abrasion injuries due to material contact (39%), followed by the elbow (17%). Fleecy cotton knit and heavy cotton work-wear pants had the highest proportion of abrasion injury resulting from abrasive contact, with 100% of the abrasive contact resulting in skin abrasion injury. Polyester mesh (75%) and Kevlar (63.6%) also had a high proportion of abrasion injuries from abrasive contact. Binary logistic regression models found no significant association between the coefficient of friction of the clothing worn (measured against an artificial skin substitute) and the occurrence of abrasion injuries while controlling for rider age and impact speed.

In Australia the Austroads Motorcycle In-depth Crash Study was conducted to examine causal relationships between human, vehicle, road and other environmental factors and motorcyclists in serious injury crashes in NSW and Australia (Brown, et al., 2015). Lack of helmet use was very rare for this collection of Australian riders and most riders chose to wear full-face style helmets. Head injury was uncommon. Most crash related impact damage to the helmet occurred to the front of the helmet or the face of the rider supporting the need to extend the coverage of the Australian motorcycle helmet standard. Full-face helmets provided better protection than open-face helmets.

Riders who wore clothing specifically designed for motorcycle use had lower frequency of abrasions and lacerations. There appeared to be little additional benefit provided from impact protectors. The variability in effective injury prevention of motorcycle protective clothing available to Australian riders indicated there was significant scope for improvement.

Further knowledge was gained based on the NeuRA ARC project and the CRS study (Meredith, et al., 2014), (Meredtih, et al., 2015), (Meredith, et al., 2016), (de Rome, et al., 2016), (Meredith, et al., 2017), (Albanese, et al., 2017), (Meredith, et al., 2019). The Cambridge abrasion method included in the European Standard for measuring abrasion resistance appears to be appropriate in relating how well protective clothing performs in real world crashes. However, in terms of the probability of injury with time to hole through clothing material as measured in the Standards test, the pass-fail criteria used is not optimum based on real world crash case data. No assessment of the relationship between garment failure mechanism in the real world and in this test method was made and this is something that should be done in the future. This work has also shown that there is some risk of abrasion injury from interaction of the material used to line protective clothing and the rider's skin when the outer material does not abrade through. This characteristic of protective clothing is not controlled in any product standard and there is currently no standardized test available.

For impact performance, the European Standard method of measuring force transferred through an impact protector may not, by itself, adequately represent performance of impact protectors in the real world. The pass-fail criteria using the European Standard test for energy attenuation may not be adequate, with the performance criteria appearing too low based on the probability of injury in real crashes. In addition, impact energy attenuation testing of in-use impact protectors in garments worn by Australian riders indicates a large variability in performance. There are distinct differences in injury protection performance observed between knee and shoulder impact protection indicating there may be a need for different performance criteria for impact protectors designed to protect different body regions.

Riders wearing gear with poor thermal management properties are at risk of physiological strain when riding for long periods in very hot conditions. Heat is a disincentive to the use of protective clothing. There is no relationship between good abrasion resistance and poor thermal management qualities with some current garments able to provide both good abrasion resistance and acceptable thermal management properties. Assessment methods designed to measure vapour permeability of clothing appear to be appropriate for assessing thermal management of motorcycle protective clothing.

Besides heat, motorcyclists report other barriers to using protective clothing including cost (especially for younger riders), availability of fashionable clothing (especially for women and commuters) and ability to find clothing that provides a good fit (especially for women and larger riders). Motorcyclists are not only concerned with crash protection with regards to garment quality, but are also interested in durability, appropriateness for different weather conditions and thermal properties.

Kathmann et al. reported in (Kathmann, 2019) that in Germany in 2018 98% (cp. 99% in 2017) of the motorised two-wheel drivers and nearly all of their passengers wore safety helmets. Further, 62% (cp. 59% in 2017) of the drivers and 44% (cp. 47% in 2017) of the passengers used any additional protective equipment. Complete motorcycle clothing was worn by 29% (cp. 29% in 2017) of the drivers and 13% (cp. 11% in 2017) of the passengers.

Efficiency of PPE (incl. helmets)

Wu et al. investigated in (Wu, et al., 2019) the effectiveness of full-face helmets against facial injuries. Previously, the effectiveness of helmet use in preventing or reducing the severity of head injuries was widely studied and demonstrated (Hurt, et al., 1981), (Khor, et al., 2017), (Liu, et al., 2008), (Moskal, et al., 2008). However, the effectiveness of different types of helmets in reducing facial or non-facial head injuries received much less attention owing to the scarcity of information on helmet type in crash data. A few articles did study the association between helmet type and facial or non-facial head injuries (Cannell, et al., 1982), (Ramli, et al., 2014), (Ramli, et al., 2016), (Vaughan, 1977),(Yu, et al., 2011). About facial injuries, three studies found that full-face helmets provided more protection than other types. For a full-face helmet, Vaughan showed that the risk of injury to the face was reduced by a half or two-thirds (Vaughan, 1977); Brewer reported a 73%

reduction in the relative risk of sustaining facial fracture (Brewer, et al., 2013). Whitaker found that the rate of facial injury among wearers of full-face helmets was lower than for wearers of other types (7% vs. 24%) (Whitaker, 1980). Two other studies suggested that full-face helmets afforded better protection than the 'jets' or other helmets (Cannell, et al., 1982), (Ramli, et al., 2014). In France, a previous study showed that helmeted moped riders suffered more facial injury than helmeted motorcyclists (13% compared to 8%), which, according to the authors, could be the consequence of better facial protection afforded by full-face helmets that are more often used by motorcyclists (Moskal, et al., 2007).

As regards non-facial head injuries, some studies reported that other types of helmet were associated with a higher risk of non-facial head injuries than full-face helmets (Brewer, et al., 2013), (Tsai, et al., 1995), (Yu, et al., 2011), while others studies did not find that the type of helmet made any difference in terms of non-facial head protection (Ramli, et al., 2014), (Vaughan, 1977).

A recent study was conducted in France in 2016 to evaluate if a full-face helmet effectively protects against facial injuries. This study is based on postal survey on motorized two-wheeler crashes. A total of 7,148 riders of Powered two-wheelers (PTW) injured in a crash between 2010 and 2014 and identified through the Rhône Trauma Registry were invited to complete a questionnaire to collect detailed information about their accidents. The analysis was based on data for 405 helmeted riders who declared having received an impact on the head. Facial and non-facial head injury risks were estimated according to helmet type (full face or other) by logistic regression, controlled for type of object hit by the head (and gender for risk of non-facial head injury), and weighted to take non-response into account.

Among crash victims who suffered head impact, 9% were female and 48% were aged between 14 and 24 years. For a large majority of victims, the crash occurred on a leisure trip (48%) or commute (38%). More than a third of victims were riding a moped (cylinder less than 50 cc). In terms of MAIS (Maximum Abbreviated Injury Scale), half of victims only sustained a minor injury (MAIS 1) and 15% at least a severe injury (MAIS ≥ 3). Eighty victims suffered from facial or non-facial head injuries (19%), 13 of them had serious head injuries (MAIS 3+), and 27 had a loss of consciousness. Non-facial head injury alone was present in 13% of victims and facial injury alone in 9%. Among facial injuries, the most frequent (53%) were abrasions, wounds and mucosal skin bruises. Simple bone injuries (39%) comprised bone fractures to the nose, jaw, eye socket, mandible or teeth. More complex ones were often located on the maxilla, sometimes leading to craniofacial separation.

Three-quarter of helmeted PTW drivers were wearing a full-face helmet at the time of the accident. The risk of facial injury was not associated with gender, age, cylinder capacity, type of accident or driving speed. It was associated, on the other hand, with the object hit during head impact, and the type of helmet worn. The risk of facial injury was much higher in cases of collision with a vehicle or with a fixed object on the road or roadside, compared to a collision with the ground itself. Victims wearing a full-face helmet were about three times less likely to have sustained injury to the face, compared to victims wearing another type of helmet (adjusted OR = 0.31; 95% CI: 0.11-0.83). Therefore, this study confirmed that a full-face helmet offers better protection against facial injury than other types of helmet.

On the other hand, the presence of non-facial head injury did not vary significantly according to whether a full-face or other helmet was worn (adjusted OR = 0.84; 95% CI: 0.33-2.13). Thus, this study did not reveal any difference in risks of non-facial head injuries according to helmet type.

Wu has also evaluated the efficiency of the PPE in his thesis on causes and consequences of PTW accidents (Wu, 2018) considering that several works have already been performed on this topic such as (Aldman, et al., 1981), (Hurt, et al., 1981), (Erdogan, et al., 2013), (Brown, et al., 2015), (de Rome, et al., 2011), (Schuller, et al., 1982), (ACEM, 2009).

From a global point of view, the evaluation of the efficiency of PPE appears as difficult and rarely performed due to the complexity of the accident configuration and the lack of information concerning the impact of the motorcyclist, injuries, and PPE wore during the accident. However, many of these studies agree that PPE protects against light injuries (AIS 1 or 2) but not necessary against more severe injuries. Moreover, PPE ensures protection against burns on soft tissue like skin but are less efficient in preventing fractures.

The work by Wu is based on an epidemiologic study including about 1,000 PTW accidents (years 2010-2014). Among this sample, PPE worn by the motorcyclists were:

- ✓ 806 gloves,
- ✓ 653 jackets,
- ✓ 458 boots,
- ✓ 269 back protectors,
- ✓ 200 trousers

Maximum injury severity was 525 times MAIS 1, 291 MAIS 2, 116 MAIS 3, 15 MAIS 4, 4 MAIS 5 and the injured body segments were 598 Lower Extremities, 467 Upper Extremities, 158 Head/face, 153 skin, 133 Thorax and 131 spine.

Statistical studies showed that injury risks of upper and lower extremities are reduced when PPE are worn (Ratio: 0.71), but not of the thorax. Abrasions of extremities are significantly reduced with PPE (ratios between 0.24 and 0.60) but not of the thorax. Contusions, fractures, sprain etc. are not reduced with PPE except for the foot. Boots reduce ankle fracture (ratio: 0.43). These results are in accordance with literature.

Another study by Serre et al. (Serre, et al., 2013) deals with the problem of the passive safety for motorcyclists when the climatic conditions are hot. The objectives were to analyse and evaluate the protective clothing considered as “light” (designed for hot conditions) in a sliding configuration on the road. The studied equipment was essentially clothes such as jacket, trouser, gloves and boots. All the tested jackets, trousers and gloves meet the current standards concerning the particular protection (elbow, shoulder, knee, back). They are the best-selling of the first French provider of protective clothing “Holding Trophy”. The work was composed by two complementary parts: an experimental approach and a numerical one.

For the experimental approach, two series of three tests each had been performed with Post-Mortem Human Subjects (PMHS). The first test series consisted of performing slides on a road surface at about 30 km/h while the second series was performed with a speed of approximately 50 km/h. For each test-series, one test was done using “light” protective clothes, one with “heavy” clothes (designed for winter conditions) and one test without specific equipment (only T-shirt and classical trousers made in cotton were used). At 30 km/h the sliding distance of the subject was about 4 m for a duration of less than 1 s (see Figure 4). At 50 km/h the PMHS sliding distance is about 10 m, lasting about 1.5 s. No injuries were observed when the subject was wearing protective clothes, either light or heavy. However, some skin burns were identified when the PMHS wore only a T-shirt and a cotton trouser (see Figure 5). Obviously, it can be concluded that the protective clothes have sufficient efficiency for small slides (under 10 m) even if more abraded area was observed on light clothes compared to heavy ones.

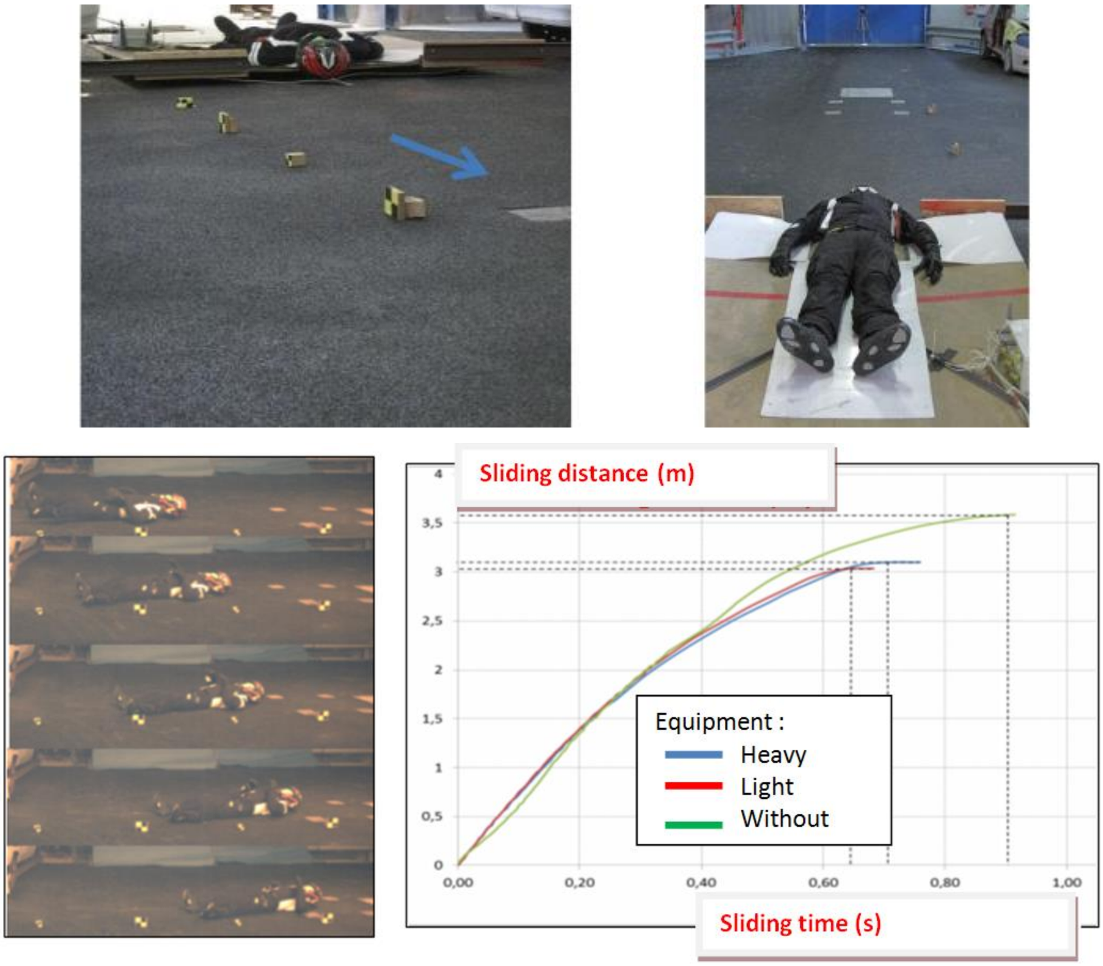


Figure 4: Results from three experimental tests performed at 30 km/h

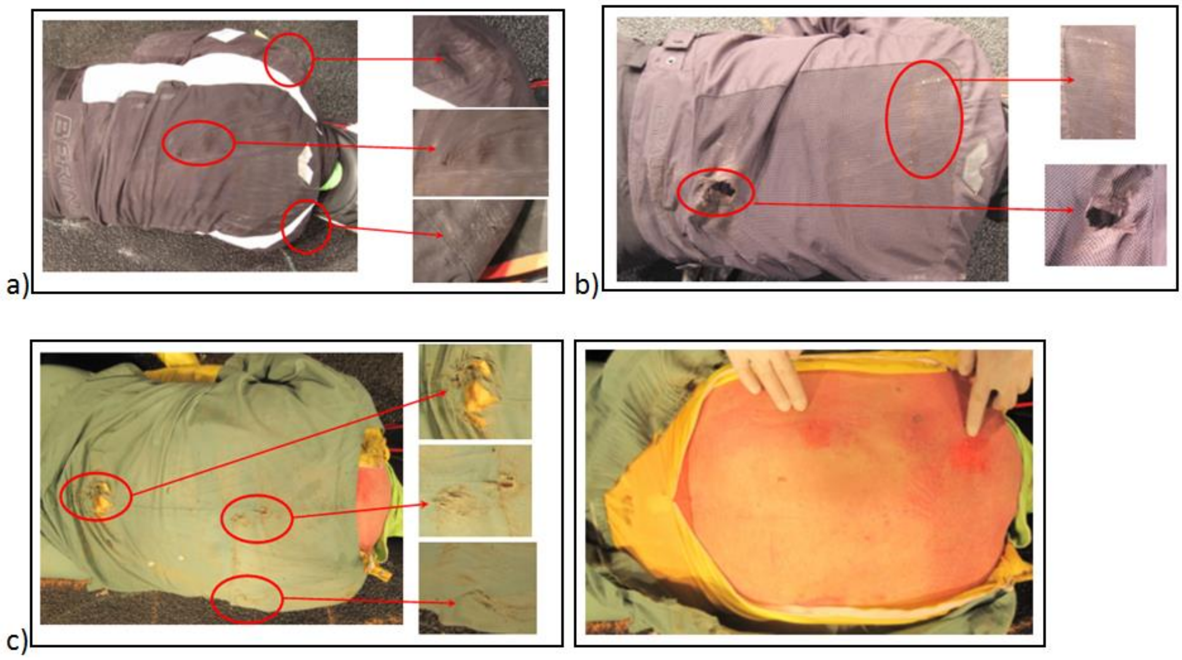


Figure 5: Abrasions and burns observed on clothes and PMHS during test at 30km/h with "heavy" clothes (a) "light" clothes (b) and without specific equipment (c)

From a numerical simulation point of view, 360 multibody simulations were performed to identify the influence of different parameters on the slide. Considered parameters were the motorcyclist speed on the road (from 10 km/h to 60 km/h), his orientation (0°, 30°, 90°, 180°) and his position relatively to the ground (supine, prone, on the side, huddled up). Results show that the sliding distance is up to 30 m for a time duration under 3 s. Numerical simulations allowed quantification of an average friction force of 4,000 N whereas the maximum force can reach 12,000 N. The human body segments which have suffered from highest loadings were the trunk and the lower legs.

1.5 PTW riders' behaviour, conspicuity and acceptance of risk

2-Be-Safe's study on risk awareness abilities demonstrates that there are no significant differences at an inter-country level (EU project 2-Be-Safe - 2-Wheeler Behaviour and Safety, 2011). By contrast, significant differences were observed between commuters and sport-riders: commuters tend to underestimate the criticality of riding situations.

The assumption that sports bike riders have a riskier riding behaviour could not be confirmed: Riders in groups had safer riding behaviour than PTW riders who ride alone No relation between the conspicuity of the helmet and the clothing, and the number of conflicts could be demonstrated. Riders consider risky behaviour (under certain conditions) as a normal (typical) behaviour, although they are aware of the criticality. Several critical behaviour patterns have been mentioned and justified by an attentive and skilled riding behaviour and certain circumstances.

Varying riders' clothing (bright clothes, reflective warning vests, and dark clothes) can enhance riders' conspicuity in certain situations but the effects are strongly mediated by the background conditions (e.g. lighting conditions) and by the characteristics of the driving situation (e.g. urban vs. rural traffic environment).

Results revealed advantages in terms of a better detection and faster identification for yellow coloured headlights, ABLS ('Alternating Blinking Light System') and additional lights on the fork and handlebars for motorcycles (T-light configuration).

APROSYS (EU project APROSYS - Advanced Protection Systems, 2006) showed that accident avoidance by the PTW rider is rarely successful: the majority of the riders did not apply any evasive manoeuvre except for some data where the rider brakes in about 50% of the cases. Nonetheless, braking is the most common action encountered, but PTW speed reductions prior to the crash are not very large. Less than 50% reach a speed reduction of 25 km/h.

A large number of accidents is caused by perception failures of both OV driver and PTW rider. Nonetheless, unsafe riding conditions (e.g. speed, wrong decision) were also frequent. The most important factor was the "human factor" (act, perception, and decision).

In both MAIDS-TNO and DEKRA datasets the PTW crashed in an upright position (54% and 56% respectively). Crashes in no upright position (no fall) occurred between 12% and 27%.

1.6 Influence of infrastructure

Concerning the motorcycle-infrastructure interaction, the authors of APROSYS (EU project APROSYS - Advanced Protection Systems, 2006) stated that there is a small number of papers in the literature. In the in-depth dataset, there was a small amount of data about this type of accident. Nonetheless, some conclusions have been drawn: PTW and rider impacts into roadside-barriers occurred at small impact angles at high speeds, and more often in the upright position than sliding on the ground. These impacts mostly cause injuries to the head and the lower extremities. There were indications of trees and poles being even more hazardous. Detailed analysis revealed that impacts to guardrails may cause comparably severe injuries as seen in impacts with a pole obstacle located on the roadside.

According to the OECD report (International Transport Forum, 2015), road environment factors can have an important influence on the crash severity, even if they are rarely the primary cause of crashes. For example, the MAIDS study (MAIDS) shows that the road and surrounding environment were a primary cause in 8% of all PTW crashes. An environmental perturbation can be easily managed by a car driver but be a challenge for a PTW rider. The following points highlight the influence of infrastructure on PTW accidents:

- The radius of a curve has a strong impact on the ability to control the PTW. About 30% of PTW crashes occur in or after a curve and curves with a small radius increase the crash risk (ACEM, 2006)

- About one third of fatal PTW crashes occur at a junction (intersection or roundabout) and the severity of a PTW crash at an intersection is higher than of other road users (CERTU, 2010). One of the explanations is the presence of road signs or other objects that can reduce the visibility.
- PTWs are also more sensitive to roadway surface conditions because of the potential to reduce the amount of friction(Vias institute (former IBSR), 2005) (Flanders Ministry of Mobility and Public Works, 2008). Elements of the road surface (gully tops, drainage grates, manhole covers, tram rails, etc.) can be a risk factor for PTWs because they can induce irregularities in the road surface level and difference in skid resistance which can be problematic, leading to loss of stability. In some countries, kerbs and delineation posts are sometimes used to separate lanes or to delineate the side of the road but these elements can provoke a loss of stability for PTWs (Vias institute (former IBSR), 2005).
- The presence of debris, pollution and fallen loads can also create unsafe conditions for motorcyclists. As an example, falling leaves from trees, gravel, mud and liquids (e.g., fuel) can cause local slippery spots (Vias institute (former IBSR), 2005).
- Water on the roads due to insufficient drainage or extreme weather reduces the skid resistance.
- Obstacles (vegetation, construction, road equipment, etc.) can compromise visibility by either obscuring or limiting sight distance. According to (Vias institute (former IBSR), 2005), obstacles contribute to a minor proportion of PTW crashes but they are responsible for a relative high number of fatalities. (Ding et al, 2019, to be published) shows that 3% of PTWs rider impacts were against narrow objects (guardrail post, guidepost, traffic sign pole, metal or concrete mast, tree, etc.) and 1.1% against a wide object (fence, wall, etc.).
- Road restraint systems can be very aggressive for PTW riders and they contribute to between 2% to 4% of all PTW fatalities. Impacts to non-protected posts of guard rails can be critical(EU project APROSYS - Advanced Protection Systems, 2006) (EU project 2-Be-Safe - 2-Wheeler Behaviour and Safety, 2010). Wire rope can be considered as the most aggressive forms of road restraint systems (EU project SMART RRS - Innovative concepts for smart road restraint systems to provide greater safety for vulnerable road users, 2013) but other works shows no significant differences with other type of guard rails (Rizzi, et al., 2012). (Ding et al, 2019, to be published) found 3.1% of rider impacts were against a crash barrier.

The UNSW Transport and Road Safety Research study investigated motorcycle crashes into roadside barriers (Grzebieta, et al., 2010), (Bambach, et al., 2010), (Bambach, et al., 2011), (Bambach, et al., 2014). A small proportion of motorcyclist fatalities occur due to collision with roadside barriers (6% in Australia and 2% in New Zealand). Of these, the majority involve steel W beam barriers, followed by concrete and wire rope barriers. In fatal motorcycle to barrier collisions, the mean pre-crash speed was found to be 100.8 km/h at an impact angle of 15.4°. There was equal representation of motorcyclists impacting the roadside barrier in an upright position and motorcyclists sliding into the barrier. The thorax region had the highest incidence of injury and severity, followed by the head. Wire rope barriers were found to cause around half the fatality rate of W beam and concrete barriers. Collisions with posts and poles were significantly more likely to result in serious or fatal injuries than barriers, supporting the use of barriers in front of such fixed objects to improve safety for motorcyclists. A simulation study found that rub-rail systems prevented serious thoracic injury and at low impact angles ≤15° prevented serious head-neck injury.

2 Method and analysed datasets

2.1 Approach, Accident Scenarios and Use Cases

2.1.1 Overall approach for the analyses

The focus of Task 1.1 and hence this report is to understand the detailed characteristics of accidents involving Powered Two-Wheelers (PTWs) that are of special interest for the PIONEERS project.

To gain a substantial overview of the road traffic accidents with involvement of PTWs in Europe, an extensive literature review focusing on seriously and fatally injured riders was performed from which extracts were documented in Chapter 0.

New analyses identified Key Accident Scenarios in Europe (KASE) and responses to different requests from various parts of the project provide valuable detailed information regarding the most relevant crash parameters such as impact speed, impact configuration etc. In addition, analyses were emphasized towards understanding injury patterns and considering different injury levels (classified as slight, serious, most serious, fatal and the AIS scale) in general and for specific scenarios. Data from Australia was analysed in a similar way for comparison.

To get a common understanding of wordings and to reach the highest possible level for any comparisons, several definitions were agreed among the partners such as for “Accident Scenarios” and “Use Cases”.

Firstly, results and accident data analysis from international scientific studies, papers and previous EC projects (i.e. MAIDS, APROSYS SP4, PISA, MYMOSA and SIM) were reviewed along with other national projects related to PTW safety.

Second, new analyses have been conducted using latest accident data from various European countries to obtain a current and broader overview of the crash occurrence involving PTWs in Europe and Australia.

Third, analyses of in-depth crash databases have been performed regarding detailed injury information of PTW riders, causation of crashes as well as the most relevant crash parameters such as impact speed, impact configuration and environmental conditions. These analyses are devoted primarily to the task of documenting a representative sample of individual road traffic accidents with a high level of detail compared to knowledge gained by the analysis of national statistics. To answer the questions arising within PIONEERS, all technical Work Packages had been asked for their needs and expectations regarding the accident data analyses. Finally, these needs were summarized to “requests”. Some of these requests were answered by the results made available in this report. Other requests could only be answered by providing comprehensive data files which could not be transferred into this report.

National accident statistics were analysed from Germany, Italy, France, Spain and Australia. In addition, the in-depth databases GIDAS (Germany), iGLAD (Worldwide), EDA (France), MAIDS (Europe), IN-SAFE (Italy), and two datasets from Australia and one fatality dataset from LMU (Germany) were analysed.

Finally, the focus of the analyses can be summarized to:

1) On vehicles of categories L1 and L3.[1]
2) On single PTW accidents and accidents with two participants (PTW vs. passenger car or other).
3) On seriously and fatally injured casualties in accidents involving PTWs regarding national databases. Slight injuries to be considered for distinct questions / requests to in-depth databases.
4) Analysing latest accident data.
5) Using widely definitions provided in standards and from previous projects.
6) Analysis of various datasets, but:
    - Direct comparison of results only on European and national level (high level data); and
    - Using single datasets to answer distinct questions (mostly in-depth level).

2.1.2 Accident Scenarios and Use Cases

The wording “Accident Scenarios” is used in several publications but does have diverse meanings. Within PIONEERS “Accident Scenarios” (AS) are defined by the project’s requirements:

1) AS need to be based on variables that are relevant for PIONEERS but also on variables included in the different national databases (Germany, Spain, Italy, France, Australia).
2) AS should be close or the same compared to the definitions of previous projects, see also Section 1.1.
3) AS need to allow distinguishing between PIONEERS Use Cases (see below).

Finally, eight Accident Scenarios (AS1 – AS8) have been defined allowing to compare high-level groups of relevant road traffic accidents involving PTWs, see Table 4. Most importantly, separations were chosen regarding the number of accident participants and the collision opponent (in particular passenger cars).

Table 4: PIONEERS‘ Accident Scenarios

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)							
	Accidents with two participants involving at least one PTW				**Single PTW accidents**		**Accidents with at least three participants involving at least one PTW**	
	L1 versus		L3 versus		L1	L3	L1	L3
	car	others	car	others				
Urban and rural roads (w/o motorways)	**AS1**	**AS2**	**AS3**	**AS4**	**AS5**	**AS6**	**AS7**	**AS8**

[1] Based on Regulation (EU) No 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles

In addition to the specified Accident Scenarios, two Use Cases have been defined which aim to describe more specific groups of riders in typical and for PIONEERS relevant conditions, see Table 5.

Table 5: PIONEERS' Use Cases

Use Case 1	Urban commute. This use case is particularly linked to scooters, urban areas and therefore lower impact speeds.
Use Case 2	Leisure ride. This use case is particularly linked to motorcycles, rural areas and therefore higher impact speeds.

Mapped on the definitions for the Accident Scenarios and separating further into the road classes "urban roads" and "rural roads (without motorways)", Table 6 shows the link between the Use Cases and the Accident Scenarios for the most relevant accidents of AS1 – AS6. Another breakdown was done regarding the Accident Scenarios location, separating for urban and rural roads (without motorways).

Table 6: Link between Accident Scenarios and Use Cases

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				**Single PTW accidents**	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U**	**AS2-U**	**AS3-U**	**AS4-U**	**AS5-U**	**AS6-U**
Rural (w/o motorways) **Use Case 2**	**AS1-R**	**AS2-R**	**AS3-R**	**AS4-R**	**AS5-R**	**AS6-R**

Another breakdown of the road classes into "straight", "intersection", "curve/bend" and "Others/Unknown" was also considered, see Table 7. This table was also used as basis for the analyses conducted with the national accident datasets for three consecutive years, see Chapter 3 for results.

Table 7: Template for analyses of national accident datasets based on definitions for PIONEERS' Accident Scenarios and Use Cases

Accident Scenarios		Number of accidents with outcome of killed or seriously injured casualties (KSI)					
		Accidents with two participants involving at least one PTW				**Single PTW accidents**	
		L1 versus		L3 versus		L1	L3
		car	others	car	others		
Urban	Straight						
	Intersection						
	Curve/bend						
	Others/Unknown						
	Sum	Use Case 1	Use Case 1	Use Case 1	Use Case 1	Use Case 1	Use Case 1
Rural (w/o motorways)	Straight						
	Intersection						
	Curve/bend						
	Others/Unknown						
	Sum	Use Case 2	Use Case 2	Use Case 2	Use Case 2	Use Case 2	Use Case 2

2.2 Injury Definitions for body regions

2.2.1 Documentation and analysis of injuries

The Abbreviated Injury Scale © is a global tool to document injuries and grade them by severity on an ordinal scale. The AIS is updated approximately every 10 years to account for changes in clinical treatment. Between different versions of the AIS translation functions are provided, however, always coming with a loss of information, as AIS versions are not compatible. The latest AIS version of 2015 is available since 2017.

Most of the partners with in-depth databases have injury data documented by AIS codes in detail. In some data only the highest injury severity value per AIS chapter is documented. The Partners' injury data are documented by AIS90, AIS98, AIS2005 update 2008, and AIS2015. As for the in-depth analysis it is more important to detect single injuries it was refrained from translating AIS codes to one compromise version with consequent losses of information. Injury severity values (like the mentioned maximum values per AIS chapter) cannot be translated in any case.

2.2.2 Body regions literature review

A literature review on body regions presented in projects or publications concerned with the analysis and prevention of accidents and injuries, especially of powered two-wheeler riders, showed that there is no common definition and understanding of "body regions".

For example, sometimes the head is regarded together with the face, sometimes the head goes together with the neck, but excluding the face; further, the neck itself sometimes includes the cervical spine, and sometimes not.
The Abbreviated Injury Scale AIS © (AAAM, 2008) defines six body regions for calculation the Injury Severity Score (ISS) and lists all injury codes in 9 chapters, which are often named as and are often taken for analysing body regions, see Table 8.

Table 8: Abbreviated Injury Scale – Chapters and ISS body regions

	Abbreviated Injury Scale	
	Chapters	ISS body regions
body regions definition comment	CHAPTERS, organisation of injuries, each chapter except spine contains external injuries	detailed coding rules and assignments which injury code from which chapter goes to which ISS area
Region 1	Head	Head and neck (including cervical spine)
Region 2	Face	Face
Region 3	Neck	Thorax (including thoracic spine)
Region 4	Thorax	Abdomen (including lumbar spine)
Region 5	Abdomen and pelvic content	Extremities
Region 6	Spine	External
Region 7	Upper Extremities including shoulder girdle	
Region 8	Lower Extremities including pelvic girdle	
Region 9	External&Other	

One publication provided definitions on body regions based on ICD codes (McIntyre, 2011) and a definition related to AIS for the CIREN database is published (Schneider, et al., 2011), however, not focussing on PTW injuries. The IGLAD database does also not focus on PTW, however defines body regions according to AIS chapters. The EU injury database gives definitions on body regions, however, also not based on AIS, see also (Schick, et al., 2019).

The most famous PTW projects MAIDS (ACEM, 2009), COST327 (EU project COST327 - Motorcycle Safety Helmets, 2001)and APROSYS (EU project APROSYS - Advanced Protection Systems, 2006) did not define any body regions; however, in those cases it is possible to assume how body regions were most probably defined. Another paper (Meredith, et al., 2014) focuses on pelvic injuries in PTW and gives a rough definition on the body region pelvis, however not for other body regions. Another five EU funded projects concerned with injuries in PTW did not give definitions; however, sometimes a reference to MAIDS was provided (PISa, SIM, Motorist, MOSAFIM, Mymosa).

In Table 9 the body regions of two European projects, the two publications with definitions, and the EU injury database (EU IDB AI) (European Commission) are pictured to show the variation in defining body regions. In Appendix A.1 a complete list on the results of literature review towards body regions is given.

Table 9: Definitions for body regions in literature (see also the List of Abbreviations of this report)

Source	CIREN database by NHTSA	Study on PTW	EU project on PTW	EU project on PTW	Eurosafe injury database
Reference	Schneider LW et al., TIP, 2011	McIntyre 2011	COST327	MAIDS	https://ec.europa.eu/health/indicators_data/idb_en
body regions definition in methods yes/no	yes	yes	no	no	yes
body regions definition comment	based on AIS	based on ICD	related to AIS	related to AIS	Based on ICECI and EHLASS
body region1	Head/Face	Head/Skull	Head and face	Head and face	Head/skull
body region2					Face (excl. eye)
body region3					Eye
body region4	Neck		Neck/CervicalSpine	Neck	Neck
body region5	Cervical Spine				
body region6	Thorax	Trunk	Thorax/ThoracicSpine	Thorax	Chest wall
body region7	Thoracic Spine				
body region8	Abdomen		Abdomen&LumbarSpine	Abdomen	Abdominal wall
body region9	Lumbar Spine				
body region10		Nerve/Other Spinal		Spine	Thoracic/lumbar spine
body region11					Internal organs
body region12	Shoulder	Upper Limb	Upper extremities	Upper Extremities	Upper arm/shoulder
body region13	Arm				Elbow
body region14	Elbow				Lower arm
body region15	Forearm				Wrist
body region16	Wrist				Hand
body region17					Fingers
body region18	Pelvis	Lower Limb	Pelvis	Pelvis	Pelvis

body region19	Hip		Lower Extremities	Lower extremities	Hip
body region20	Thigh				Upper leg
body region21	Knee				Knee
body region22	Leg				Lower leg
body region23	Ankle				Ankle
body region24	Foot				Foot
body region25					Toes
body region26				Whole Body	Multiple body parts
body region27					Other
body region28					Unknown

For the definition of body regions for the PIONEERS project, three aims were followed: first, questions towards PPE should be enabled to be answered, second, the body regions should be communicable and easy to understand, and third the body regions should be derivable from most of the available in-depth databases, see also (Schick, et al., 2019).

As at least five providers of in-depth data are able to define body regions based on the 6-digit unique numerical identifier (UNI) of the AIS Code it was decided to use the AIS as a basis for definition. IGLAD and MAIDS analyses will need to remain on the AIS chapter level.

It was also clear, that body regions are only needed to give overviews for certain questions, and for further in-depth analysis the single injuries will still be available independent from their belonging to any body region. Therefore, it was refrained from separating e.g. foot from ankle from lower leg from knee from thigh, but to regard the lower extremity. As a special injury that PTW suffer from is the pelvic fracture with consequent injury to the pelvic content, see (Meredith, et al., 2014), the PELVIS was defined as a body region combining bony injury, injury to internal organs of the pelvis and the soft tissue, see (Schick, et al., 2019).

Superficial skin injuries are only of help in case they are coded in the according AIS chapter that can be aligned to the body regions. Databases that document those injuries only in general (AIS codes 9******.*) without using localizer 2 of the AIS codebook are not of any help if the improvement of PPE is the study question. Therefore, no “External” body region is defined.

2.2.3 PIONEERS body regions

As a consequence of the aforementioned missing harmonized definitions for the body regions and the specific questions of the PIONEERS project dealing with PTW safety, new definitions have been defined, see (Schick, et al., 2019) and Table 10, which may be handled as standard for any future related work.

Table 10: PIONEERS definitions for body regions

body region name	Body region short-cut	definition by AIS codes – include the following codes to body regions:
Head & face	HF	all codes of chapter 1 AND chapter 2 in AIS
Neck & Cervical Spine	NCS	all codes of chapter 3 in AIS AND cervical spine (part of chapter 6 in AIS): first digit of Unique numerical identifier (UNI) "6", fourth digit "2", AND the codes "600099.9", "600999.9", and "613000.6"
Thorax & Thoracic Spine	TTS	all codes of chapter 4 in AIS AND thoracic spine (part of chapter 6 in AIS): first digit of UNI "6", fourth digit "4", AND the codes "620099.9", and "620999.9"
Abdomen & Lumbar Spine	ALS	all codes of chapter 5 in AIS except Pelvis (see there) AND lumbar spine (part of chapter 6 in AIS): first digit of UNI "6", fourth digit "6", AND the codes "630099.9", and "630999.9"
Upper Extremities	UE	all codes of chapter 7 in AIS
Lower Extremities	LE	all codes of chapter 8 in AIS except Pelvis (see there)
Pelvis (Bone and pelvic content)	P	AIS codes 811001.4, 811010.5, 813001.4, 816010.1, 816011.1, 816012.2, 816013.3 AND UNI starts with 8561, 8562, 5206, 5208, 5210, 5404, 5406, 5424, 5426, 5430, 5432, 5435, 5436, 5440, 5446, 5450, 5452, 5454, 5456

2.3 European Accident Statistics (CARE)

Community database on Accidents on the Roads in Europe (CARE)

The purpose of the CARE system is to provide a powerful tool that makes possible the identification and quantification of road safety problems throughout Europe, evaluation of road safety measure efficiency, determination of Community action relevance and to facilitate the exchange of experiences in this field.

The CARE database was founded in 1992 and it is still active. Its specialization is in all accidents that are registered by the national police, hospitals and emergency services. The organization responsible is the EU. The database is financed by EU and national statistics offices.

The accidents recorded are from Europe and the minimum injury to include the case in the database has to be slightly injured. The total number of variables per accident collected is lower than 100.

More information about CARE database can be found under:

https://ec.europa.eu/transport/road_safety/specialist/statistics_en#

The analysis performed within PIONEERS required information about several variables which are described in the Common Accident Data Set (CaDaS), Version 3.6. These variables are summarized with their description in Table 11.

Table 11: Description of variables used within the PIONEERS CARE analysis

Variables used for PIONEERS analysis	Description
Moped	Two or three wheeled vehicle equipped with internal combustion engine, with size less than 50 cc and maximum speed that does not exceed 45 km/h (28mph).
Motorcycle (in U-2 Transport mode, TU type group)	Sum of the following: *Motorcycle up to 125cc* - Two or three wheeled motor vehicle, with engine size up to 125 cc, or maximum speed exceeding 45km/h (28 mph). *Motorcycle over 125cc* - Two or three wheeled motor vehicle, with engine size more than 125 cc. *Motorcycle not specified*
Slightly injured	Total number of people slightly injured. Injured (although not killed) in the road accident and hospitalized less than 24 hours or not hospitalized.
Seriously injured (at 30 days)	Total number of persons seriously injured corrected by correction factors when needed (see point 8.1). Injured (although not killed) in the road accident and hospitalized at least 24 hours.

Fatally Injured (at 30 days)	Total number of persons fatally injured corrected by correction factors when needed. Death within 30 days of the road accident, confirmed suicide and natural death are not included.
Injury Type Not Known	Total number of persons with an unknown injury type. The injury severity of the road user was not recorded, or it was unknown.
Victims	This measure ia a total of Fatally injured (at 30 days) + Seriously Injured (at 30 days) + Slightly Injured + Injured (injury severity not known).

2.4 National Accident Statistics (DESTATIS, ISTAT, BAAC, DGT)

DESTATIS German Official Road Accident Data (Source: DESTATIS)

The legal basis for the German Official Road Accident Statistic is the law on the statistics on road traffic accidents. Pursuant to this, federal statistics are compiled on accidents due to vehicular traffic on public roads or places, with persons killed or injured or involving material damage. According to the Law, the police authorities whose officers attended the accident are liable to report. This implies that the statistics cover only those accidents which were reported to the police. These are primarily accidents with serious consequences. Especially traffic accidents involving only material damage or slight personal injuries are to a relatively large extent not reported to the police. Pursuant to Article 1 of the Law on Statistics of Road Traffic Accidents only those accidents are recorded which are due to vehicular traffic, i.e. accidents involving only pedestrians are not covered by these statistics.

Survey records for the statistics of road traffic accidents are the copies of the standard traffic accident notices (Verkehrsunfallanzeige) as used for the entire Federal Republic which are completed by the police officers attending the accident. After its transfer to data recording media, the information included in the accident notices is tabulated on a monthly and annual basis at the statistical offices of the "Bundesländer". The Bundesländer results are compiled to the federal result.

Accidents are subdivided according to the severity of the consequences:

- Traffic accidents involving personal injury;
- Severe accidents involving material damage;
- Other accidents under the influence of intoxicating substances; and
- Other accidents involving material damage.

The criterion for the allocation is in each case the most serious consequence of the accident. Accidents with personal injury imply that irrespective of the amount of the material damage persons were killed or injured. Severe accidents involving material damage are accidents whose cause of accident is an irregularity or an offence concerning participation in road traffic. At the same time the motor vehicle has to be towed away from the place of accident because of a damage (motor vehicle not ready to drive). This includes accidents under the influence of intoxicating substances. With full details recorded are all other accidents with material damage where a road user involved was under the influence of intoxicating substances (other accidents under the influence of alcohol or other intoxicating substances). All other accidents involving material damage are only numerically recorded by the locality of accidents (in town/village, out of town/village, on motorways).

For each accident registered in the official German Road Accident Statistic detailed information is available on time and place of accident, road class, light conditions, type and kind of accident, number of road users involved, consequences of accident and the cause of the accident (weather condition, road surface condition, obstacles).

<u>Casualties</u>

Casualties due to road traffic accidents are subdivided in:

Fatalities: all persons who died within 30 days as a result of the accident

Severely injured: all persons who were immediately taken to hospital for inpatient treatment (of at least 24 hours)

Slightly injured: all other injured persons

More information about DESTASTIS database can be found at the following link:

https://www.destatis.de/DE/Publikationen/Thematisch/TransportVerkehr/Verkehrsunfaelle/VerkehrsunfaelleM.html

ISTAT

ISTAT is a national database from Italy whose specialization is all type of accidents. It was founded in 1990 and it is still active. It is financed by National statistics office. The data type is Mass and its specialization is all accidents recorded by police. It is collected by national police and its geographical coverage is Italy. The minimum injury to include the case at the database is slightly injured. The total number of variables is 105.

More information about ISTAT database can be found at the following link:

https://www.istat.it/en/archivio/202807

BAAC (Bulletin d'Analyse des Accidents Corporels de la Circulation)

BAAC is a French database of road traffic accident involving physical injury. It is specialised in all type of accidents, it was founded in 1993 and it is still active. It is financed by France government and the responsible organization is the French Road Safety Observatory.

The type of data is mass and the minimum injury to include the case at the database is slightly injured. The total number of variables is 65.

More information about BAAC database can be found at the following link:

https://www.data.gouv.fr/fr/datasets/base-de-donnees-accidents-corporels-de-la-circulation/

DGT (dirección general de tráfico) database

DGT database is the Spanish national accident database. It is specialised in all type of accidents and its data type is mass. The organization was founded in 1959 and it is still active. It is financed by the Spanish government. In this database all the accidents were recorded by police. The type of database is mass and the responsible organization is DGT which is the Spanish Road Safety Department.

The accidents that are recorded are from Spain and the minimum injury to include the case at the database has to be slightly injured. The total numbers of variables are more than 100 for each accident and road user. More information about DGT database can be found at the following link:

http://www.dgt.es/es/seguridad-vial/estadisticas-e-indicadores/

2.5 In-depth Accident Statistics (GIDAS, IGLAD, InSAFE, LMU, MAIDS, EDA)

GIDAS

The German In-Depth Accident Study (GIDAS) was founded in 1999 and is a co-operation between the Federal Highway Research Institute (BASt) and the German Automotive Research Association (FAT). Investigation teams record data of road traffic accidents involving personal injury in two regions of Germany (cities of Hanover and Dresden and their surrounding regions). The traffic accident research team of the Medical School of Hanover (MHH) is funded by BASt, whereas the team Verkehrsunfallforschung an der TU Dresden GmbH (VUFO) is commissioned by the FAT. Data are collected on each day a year in two 6 hour shifts per day per team which are changing weekly in an alternating manner according to a statistical investigation plan.

The investigation teams document all relevant information on vehicle equipment, vehicle damage, injuries of persons involved, the rescue chain, as well as the accident conditions, at the scene. Individual interviews of persons involved are followed by detailed surveying of the accident scene based on existing evidence. In addition to documentation at the scene of the accident, all information available retrospectively is collected in close collaboration with police, hospitals and rescue services. Each documented accident is reconstructed in a simulation program. The entire course of the accident is reconstructed, starting with accident lead-in phase and the reaction of the involved vehicles, to the collision and finally vehicle end position. Characteristic variables such as braking deceleration, starting speeds and collision speed, as well as angle-changes are determined. The documentation scope obtained in GIDAS reaches up to 3,000 encoded parameters per accident.

www.gidas.org

IGLAD (Initiative for the global harmonization of accident data)

IGLAD is a global in-depth dataset to improve road and vehicle safety. The standardized data scheme enables comparison between datasets. The database contains accidents with at least one injured person. The number of variables collected per accident is 130.

IGLAD was initiated by Daimler AG, ACEA and different research institutes and announced as a working group at the FIA Mobility Group in October 2010. Supported by FIA and ACEA, the goal of the group was to define a common standardized accident data set as an effective foundation for developing and measuring road safety policy endorsements and interventions. This initiative shall also establish how this data set helps to achieve the goals of the “European Road Safety Action Programme” and the „Decade of Action for Road Safety“.

The IGLAD project is divided by different phases, starting with phase 1 and including cases since 2007. Phase 2 of the project started in 2014 and ended at the end of 2016, including up to 3,100 cases from 11 different countries. Phase 3 of the project started in 2017 and according to forecasts, will collect cases from the current 13 data providers for the year periods 2015-2016, 2016-2017, 2017-2018. The 12 data providers that delivered data are VUFO GmbH and BASt (Germany), Applus+ IDIADA Group (Spain and Czech Republic), Uni Firenze (Italy), Uni Adelaide (Australia), JP Research (India), NHTSA (USA), LAB (France), SAFER (Sweden), VSI at Graz University of Technology (Austria), SHUFO (China) and CATARC (China) reached by the end of 2018 and stored in the database a quantity close to 5,000 accident cases.

More information about IGLAD database is available in the following website:

www.iglad.net

InSAFE

InSAFE is an in-depth study of injury causation factors. It was founded in 2010 and it is still active. It is financed by the Department of Industrial Engineering at University of Florence, Italian foundations and European projects and the responsible organization is the Mobility and Vehicle Innovation Group (MOVING). The total number of recorded accidents is 300 cases approximately, among them around 60 PTWs.

The data geographical coverage is local, specifically in cities of Florence and Prato and surrounding municipalities. The minimum injury for an accident to be recorded is severely injured. The specific data set selection is all accidents with injured people and the number of variables collected per accident is 1050.

More information about InSAFE database is available in the following website:

http://moving.unifi.it/en/in-safe/

LMU

LMU-fatalities is a collection of accident and injury data on autopsied traffic fatalities. Data collection started in 2004 and is still on-going. It is financed by Institute of Legal Medicine and the responsible organization is biomechanics/accident analysis group. The total number of recorded accidents is 1000 approximately, among them around 160 PTWs.

The data geographical coverage is local, specifically in Southern Bavaria and the minimum injury for an accident to be recorded is fatal. The specific data set selection is road traffic accident or accident with transport vehicle with fatality with autopsy and the number of variables collected per accident is up to 950.

MAIDS

MAIDS is an in-depth investigation of accidents involving powered two-wheelers. The aim of the study was to better understand the nature and causes of PTW accidents causes of accidents involving trucks. The objectives were:

- Identification of causes and consequences of the accidents that involve PTWs in pre-identified sampling areas.

- The definition of risk factors (environmental, mechanical and human related) in PTW accidents.

- The comparison of the accident data with exposure data (or population-at-risk) in order to identify potential risk due to single factors (i.e. alcohol, age, PTW type, road conditions…).

- The application of results to develop countermeasures suitable for reducing the frequency and the severity of PTW accidents.

It was founded in 1999 and it was active until 2001. It was financed by ACEM and EU and the responsible organization is ACEM. This database specialization's is PTWs. The total number of recorded accidents is 921 (PTWs). The data is collected by special data collection teams of MAIDS. The data geographical coverage is international, specifically in France, Germany, Netherlands, Spain, and Italy. The minimum injury for an accident to be recorded is slightly injured. The number of variables collected per accident is up to 2000.

More information about the MAIDS database is available in the following website: http://www.maids-study.eu/

EDA (Etudes Détallées d'Accidents)

The objective of EDA is the identification of accident mechanisms and the definition of risk factors (environmental, mechanical and human related) in all types of accidents. It was founded in France in 1992 and it is still active. It is financed by French government and the responsible organizations are IFSTTAR - TS2 – LMA. The total number of recorded accidents is 1200 approximately. The data is collected by scientist's teams of psychologists and technicians in real time on the accident scenes. The data geographical coverage is local, specifically in area of salon de Provence and there is no minimum injury for an accident to be recorded. The specific data set selection is all accidents and the number of variables collected per accident is up to 650.

2.6 Australian Statistics (New South Wales in-depth crash sample, Centre for Road Safety data)

New South Wales (NSW) in-depth crash sample

NSW in-depth Motorcycle Study database was founded in 2012 and it was active until 2014. It was headquartered in Sydney, Australia, it was financed by Austroads & NSW Centre for Road Safety and the responsible organization is NeuRA in collaboration with the Centre for Automotive Safety Research (CASR) and the Monash University Accident Research Centre (MUARC).

Its objectives were the identification of causes and consequences of accidents that involve PTWs in pre-identified sampling areas. The total number of recorded accidents is 102 and its specialization is motorcycles recruited after admission to hospital. The data is collected by special data collection teams of NeuRA.

More information about the database is available in the following website:

https://www.onlinepublications.austroads.com.au/items/AP-R489-15

NSW Centre for Road Safety (CRS) data

CRS data is a database from Australia used to monitor crash and injury statistics and for road safety analysis and research work, strategic planning and policy development. It is financed by NSW government. The data type is mass and it is collected by NSW Police, NSW Health and State Insurance Regulatory Authority. Minimum inclusion criteria is a police reported crash.

More information about CRS database can be found at the following link (Not all variables are in open access on this website):

https://roadsafety.transport.nsw.gov.au/statistics/index.html

3 Results from European and Australian accident statistics (national level)

3.1 General facts on European Level

3.1.1 CARE (Traffic Safety Basic Facts)

Regularly, accident figures from Europe collected within the CARE dataset are analysed by experts regarding certain topics ("Traffic Safety Basic Facts", e.g., related to the safety of powered two-wheelers or older road users). The resulting tables and figures are made publicly available. The latest publication on "Motorcycles and Mopeds" (European Commission, June 2017) revealed various information which can be summarized to:

Development of accident figures:

- In the EU, the number of moped rider fatalities decreased by almost 57% between 2006 and 2015.
- The number of motorcycle rider fatalities decreased by about 28% between 2006 and 2015.
- Motorcycling is the mode of transport for which the number of fatalities decreased least between 2006 and 2015.
- In 2015, riders of PTW made up 18% of the total road accident fatalities in the EU.

Differences between European countries:

- In most EU countries the majority of PTW fatalities are motorcycle riders.
- The fatality rate of PTW in 2015 is particularly high in Greece.
- The most significant reduction in the number of motorcycle and moped fatalities between 2006 and 2015 occurred in Greece, Slovenia and Cyprus.

Rider characteristics (age and sex):

- In 2015, 91% of moped and 94% of motorcycle riders fatalities were males.
- The least decrease of moped rider fatalities was recorded in the 50-64 years old age group.
- Despite an overall downward trend, the number of motorcycle rider fatalities increased for riders older than 50 years.
- The enormous differences between countries in the age pattern of PTW fatalities indicate differences in the modal split for certain age groups, e.g. the 65+ years old moped riders.
- The fatality rates for PTWs users are high especially for young riders, aged 15-17 for moped riders and 18-24 for motorcycle riders.
- For motorcycles, almost the half of female riders who were killed were passengers; for mopeds more than 8 out of 10 female riders who were killed were drivers.

Location of the accidents:

- The majority of moped fatalities occurred in urban areas whereas the majority of motorcycle fatalities occurred in rural areas.

- The wide range in the distribution of PTW fatalities by area and road type mostly reflects the different share of mopeds and motorcycles in a country.
- The highest percentage of fatalities occurring at junctions are found for cyclists and powered two-wheelers' riders.

Time (months):
- More than two thirds of PTW fatalities occurred from April to September.
- The number of moped fatalities does not vary over the months as much as the numbers of motorcycle fatalities.

3.1.2 EU IDB

By 2012, thirteen Member States routinely collected data in a sample of hospitals and contributed them to the EU injury Database (EU Injury Database (EU IDB AI)).
According to estimates based on the EU IDB more than four million people are injured annually in road traffic accidents. One million of those have to be admitted to hospital.

34% of the moped and motorcycle casualties who attended a hospital were admitted to the hospital; their average stay in hospital was almost ten days. Fractures (of any type) account for more than 40% of all injuries inflicted on moped and motorcycle casualties attending a hospital.

Figure 6 shows exemplarily an overview of injured body parts of hospital treated patients using different modes of transport. Injuries to the upper and lower extremities were found most frequently for motorcyclists and moped riders.

Another breakdown regarding the type of injuries is shown in Table 12 for motorcycle and moped riders compared with all road user groups. Fractures, contusions and bruises have been coded most often.

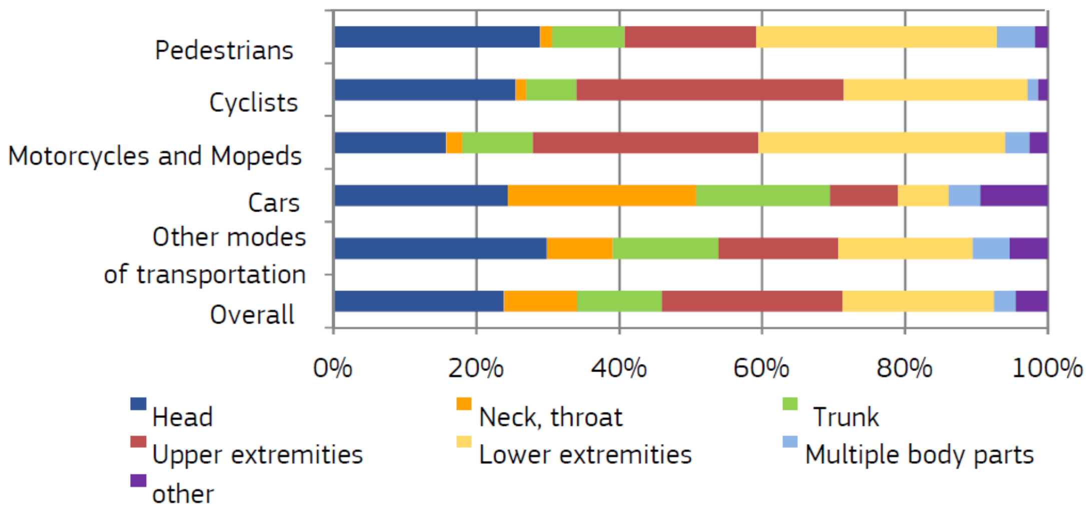


Figure 6: Body part injured by mode of transport (source: EU Injury Database – hospital treated patients. N=73,600. N(admitted)=23,568 (DE, DK, LV, MT, AT, NL, SE, SI, CY, years 2005-2008))

Table 12: Top ten types of injury in mopeds and motorcycles (source: EU Injury Database – hospital treated patients. N=73,600. N(admitted)=23,568 (DE, DK, LV, MT, AT, NL, SE, SI, CY, years 2005-2008))

	Mopeds & motorcycles	All road user groups
Contusion, bruise	26%	34%
Fracture	42%	27%
Open wound	10%	10%
Distortion, sprain	3%	8%
Concussion	6%	7%
Other specified brain injury	2%	2%
Luxation, dislocation	2%	2%
Injury to muscle and tendon	1%	2%
Abrasion	1%	1%
Injury to internal organs	1%	1%
Other specified types of injury	6%	6%
Total	100%	100%

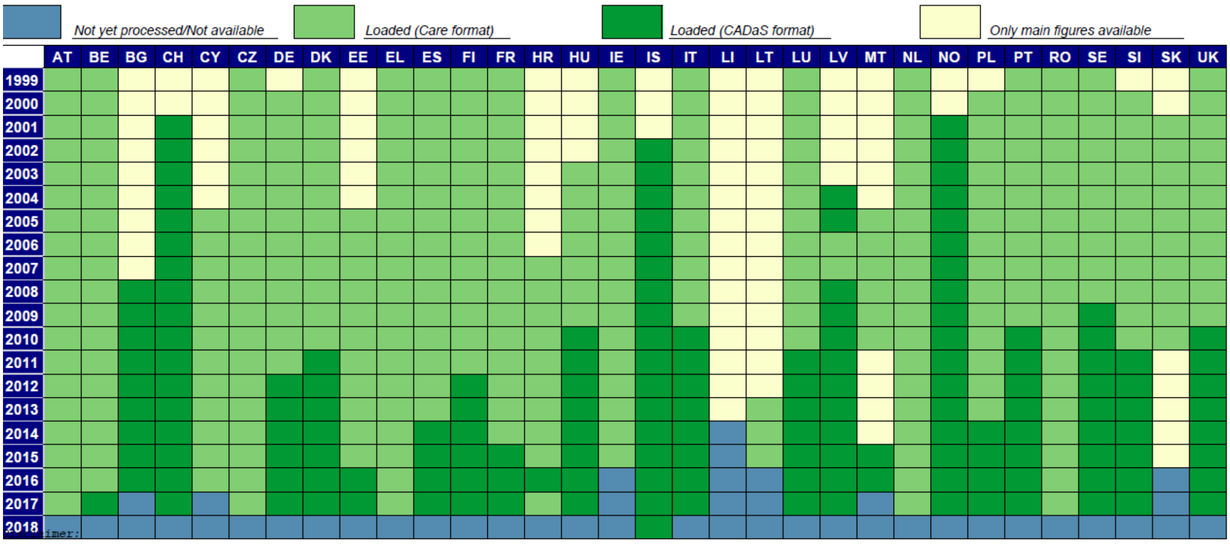
3.2 CARE analysis (European level) with respect to PIONEERS Accident Scenarios and Use Cases

Latest data of the CARE dataset, see Section 2.3, has been analysed with special regard to the Accident Scenarios and Use Cases defined in the PIONEERS project, see Section 2.1.2 and considering the available variables as described in Section 2.3.

3.2.1 Data availability

CARE is rich on data from European countries; however, not every country is reporting in the same way and within the same time period. Therefore, all respective analyses require a check about the current data availability. The present analysis is based on the data availability on country level according to Table 13. It can be seen that data is available in different formats for different countries in different years. Moreover, not all countries report all requested variables to the CARE group and/or using the same definitions.

Table 13: CARE data availability on country level (date: 07 May 2019)



BG-2010, BG-2011, BG-2012, BG-2013, BG-2014, BG-2015	Traffic unit type Goods vehicle does not include lorries with semi-trailer which are grouped into other motor vehicle type
BG-2016	Traffic unit type variable : Motorcyles and lorries are reported as unknown
CH-2001, CH-2002, CH-2003, CH-2004, CH-2005, CH-2006, CH-2007, DE-2012, IT-2010, IT-2012, IT-2013, NO-2004, NO-2005, NO-2006, NO-2007, NO-2008, NO-2009, RO-2008	New Accident datasets have been reloaded. Figures and/or variables may have changed
DE-2012, FI-2012, IT-2011, IT-2012	New CADAS model adopted - Some unconsistencies with previous series coming from CARE may appear
DE-2014	Changes on Traffic Unit Type grouping method were applied - Some breaking on relevant series may appear
ES-2012	National format dataset initially loaded to Care and afterwards migrated to CADaS through common conversion rules may generate some slight differencies on variable assignments
FI-2014	As announced by the Member State, some differences exist with National Publications either on Indicators and type of Represented Injuries
FR-2015, FR-2016	Values of variable P-4 (Person Nationality) refer to the Country of Residence
HR-2013, HR-2014, HR-2015	Accident datasets have been reloaded. Variables about NUTS have changed
IT-2016	Lorries without trailer weight unknown included in category --> Goods vehicle under 3.5t mgw
NL-2015	Please note that there might be some discrepancies on figures between 2015 and previous years

European Commission

European Commission
Source: CARE

Last refresh date of the document: 07/05/2019
Page Number 1 of 1

3.2.2 Results

Data from accident years 2013-2017 (as far as completely documented by now) have been analysed using the CARE database during July 2019. For the present analysis, the following filter criteria were applied:

- PTW assigned as moped or motorcycle;
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one seriously or fatally injured casualty; and
- Accidents on urban and rural roads (without motorways).

Accordingly, the CARE analysis revealed 203,980 accidents including mopeds and motorcycles (PTWs). Note: there is no coding of L1 or L3 vehicles in CARE; therefore, “mopeds” account for L1 and “motorcycles” for L3 vehicles, respectively. The distribution of this dataset related to PTW type and the accident scenarios is shown in Table 14.

The accident opponent “car” includes taxis. The accident opponent “Other” includes: agricultural tractor, bus or coach, heavy goods vehicle, lorry under 3.5 t, moped, motorcycle, pedal cycle, pedestrian, unknown.

Table 14: CARE dataset including 24 countries, years 2013-2017, N = 203,980 accidents (100%) – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				**Single PTW accidents**	
	L1 („moped“) versus		L3 („motorcycle“) versus		L1 „moped“	L3 „motorcycle“
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 23,988 11.8%**	**AS2-U 8,932 4.4%**	**AS3-U 46,919 23.0%**	**AS4-U 14,071 6.9%**	**AS5-U 12,433 6.1%**	**AS6-U 18,714 9.2%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 5,927 2.9%**	**AS2-R 2,753 1.3%**	**AS3-R 24,962 12.2%**	**AS4-R 8,995 4.4%**	**AS5-R 5,187 2.5%**	**AS6-R 31,099 15.2%**
Sum	**14.7%**	**5.7%**	**35.2%**	**11.3%**	**8.6%**	**24.4%**

The dataset comprised data from 24 European countries. A complete list with these countries and the absolute numbers of PIONEERS relevant accidents (AS1 – AS6) with outcome of fatal or seriously injured casualties as sum of the years 2013-2017 (as far as reported) is shown in Appendix A.2. Note: the CARE expert group does its best to gather harmonized data from all participating countries, but nonetheless different definitions of variables may lead to wrong interpretations of the data.

With respect to the table in Appendix A.2, Figure 7 shows the distribution of the KSI accidents relevant to mopeds for the respective PIONEERS Accident Scenarios (AS1, AS2 and AS5). Overall, the distributions of Accident Scenarios among the countries appear to be similar to each other, neglecting larger differences for Cyprus. Note: Malta did not report any relevant moped accident.

Furthermore, Figure 8 shows the distribution of the KSI accidents relevant to motorcycles for the respective PIONEERS Accident Scenarios (AS3, AS4 and AS6). Overall, the distributions of Accident Scenarios among the countries appear to be similar to each other, neglecting larger differences for Cyprus and Malta.

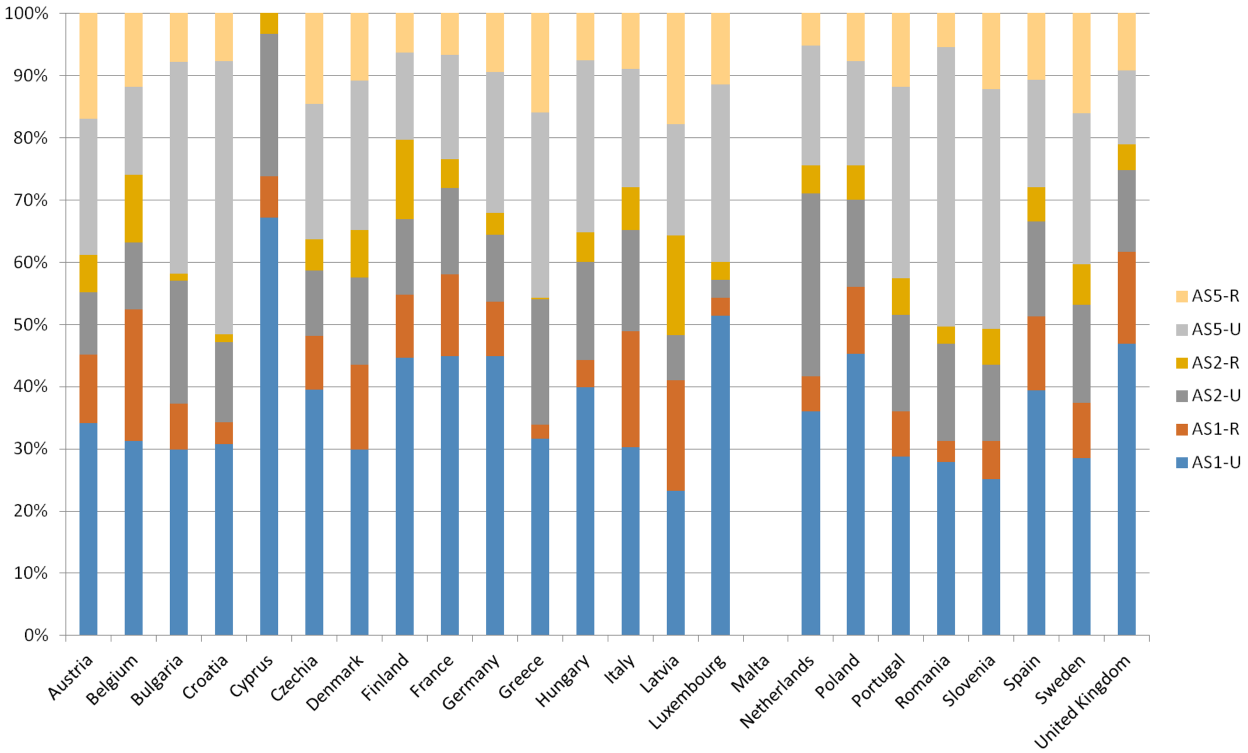


Figure 7: Distribution of KSI accidents involving <u>mopeds</u> by PIONEERS Accident Scenarios, CARE, years 2013-2017

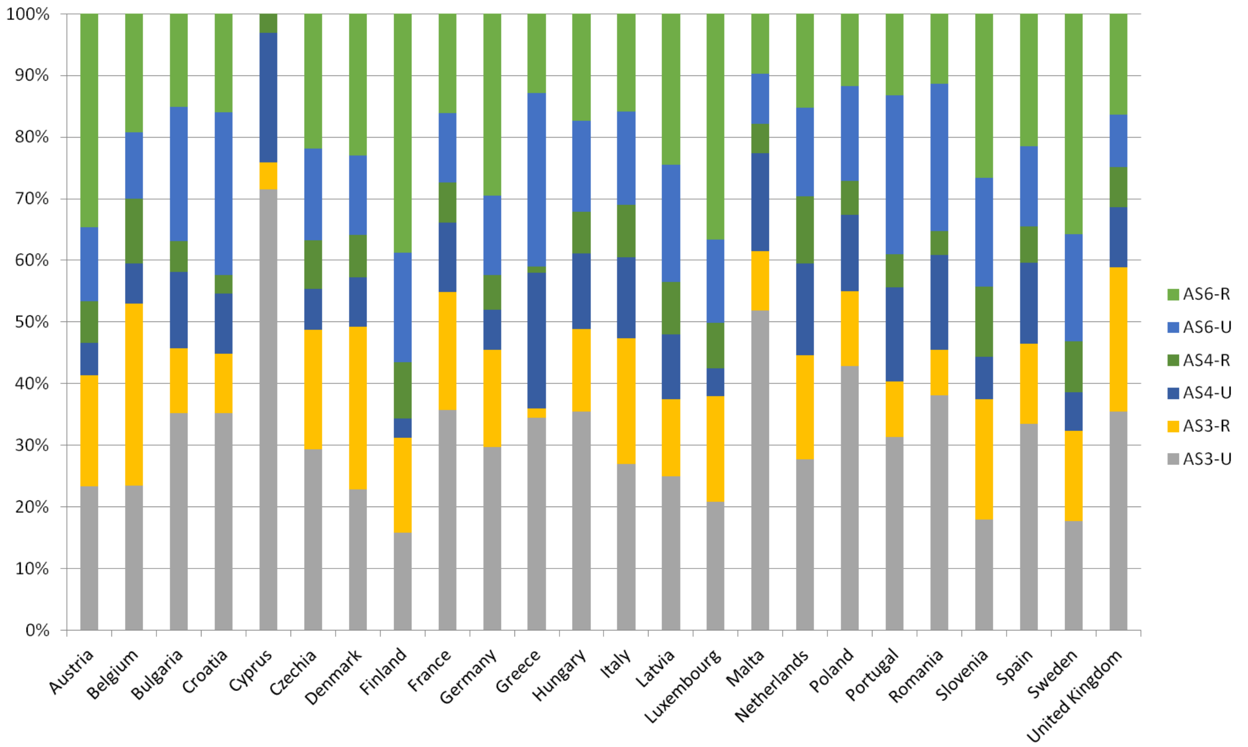


Figure 8: Distribution of KSI accidents involving <u>motorcycles</u> by PIONEERS Accident Scenarios, CARE, years 2013-2017

3.3 Italy

3.3.1 Accidents with at least one killed person

The Italian national accident data (ISTAT) has been analysed for the years 2014-2016 regarding accidents with at least one killed person and involvement of a PTW (L1 or L3). The results are shown in Figure 9.

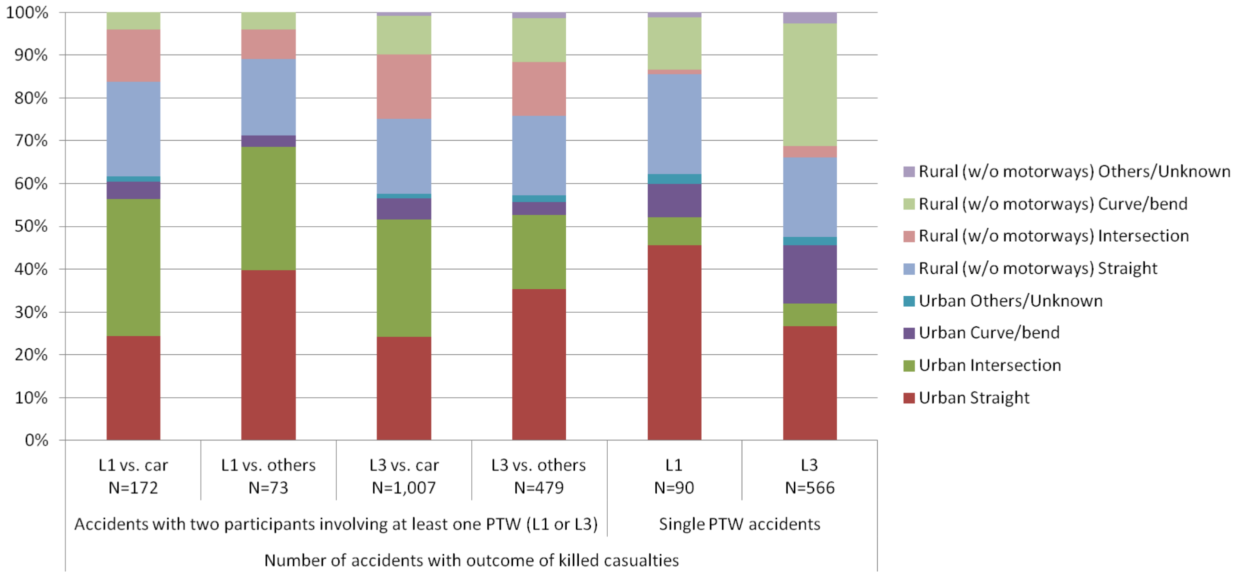


Figure 9: Italy – Accidents with at least one killed person and involvement of a PTW (L1 or L3), ISTAT, years 2014-2016

It can be seen that accidents between one L3 and one passenger car, followed by L3 single accidents take place most frequently. Further, accidents with L3 vehicles against passenger cars play a similar role in both, rural and urban areas. Straight road alignments and accidents at intersections dominate in urban areas, whereas curves have higher shares in rural areas. Single L3 accidents are dominant on rural roads with curve/bend and on straight urban roads.

3.3.2 Accidents with at least one killed or injured person

The Italian national accident data (ISTAT) has been analysed for the years 2014-2016 regarding accidents with at least one killed or injured person (any injury severity) and involvement of a PTW (L1 or L3). The results are shown in Figure 10.

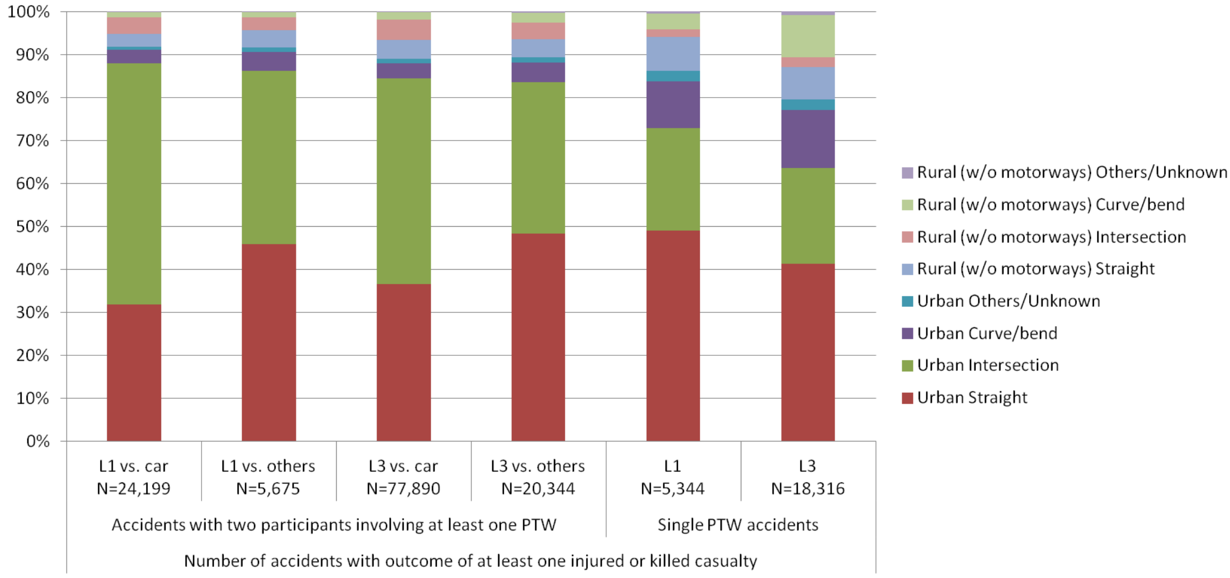


Figure 10: Italy – Accidents with at least one killed or injured person and involvement of a PTW (L1 or L3), ISTAT, years 2014-2016

It can be seen that accidents between one L3 and one passenger car dominate clearly all other Accident Scenarios with nearly 78,000 accidents. Accidents between one L3 and any other road traffic participant and L3 single accidents are following with around 20,000 accidents each. Accidents with two participants take place in rural areas with around 85% of all accidents. Most of these accidents happen at intersections, followed by straight road alignments. Single accidents occur in urban areas in around 80% of all respective accidents, pre-dominantly on straight road alignments, followed by intersections and curves.

3.4 France

3.4.1 Accidents with at least one killed person

The French national accident data (BAAC) has been analysed for the years 2014-2016 regarding accidents with at least one killed person and involvement of a PTW (L1 or L3). The results are shown in Figure 11.

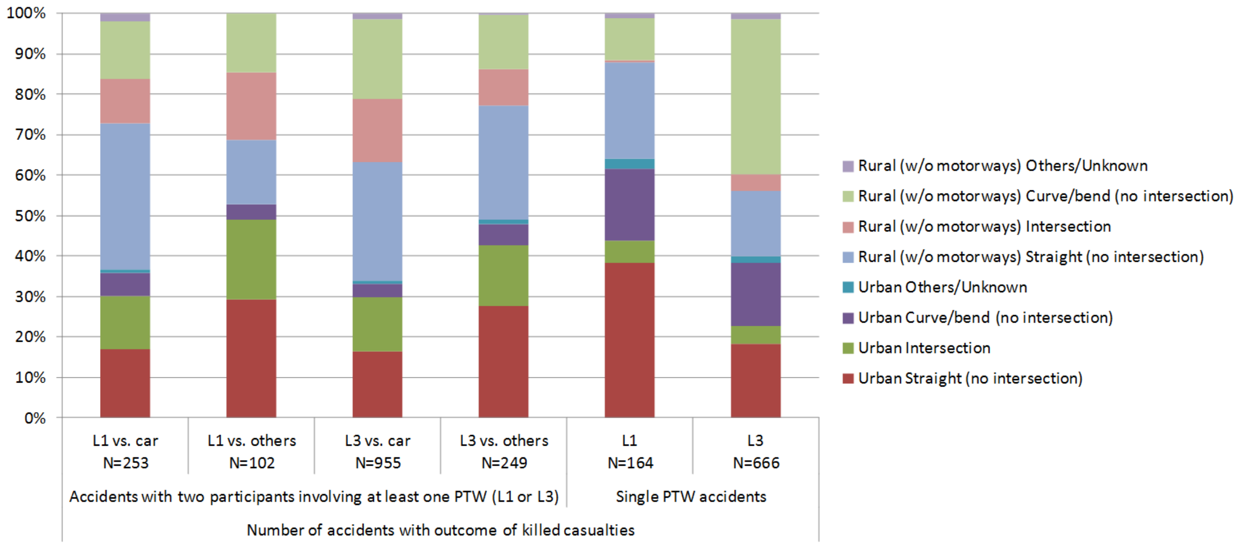


Figure 11: France – Accidents with at least one killed person and involvement of a PTW (L1 or L3), BAAC, years 2014-2016

It can be seen that accidents between one L3 and one passenger car, followed by L3 single accidents take place most frequently. Further, accidents against passenger cars play a dominant role in rural areas (especially on straight roads). Single L3 accidents are dominant on rural roads with curve/bend.

3.4.2 Accidents with at least one killed or seriously injured person

The French national accident data (BAAC) has been analysed for the years 2014-2016 regarding accidents with at least one killed or seriously injured person and involvement of a PTW (L1 or L3). The results are shown in Figure 12.

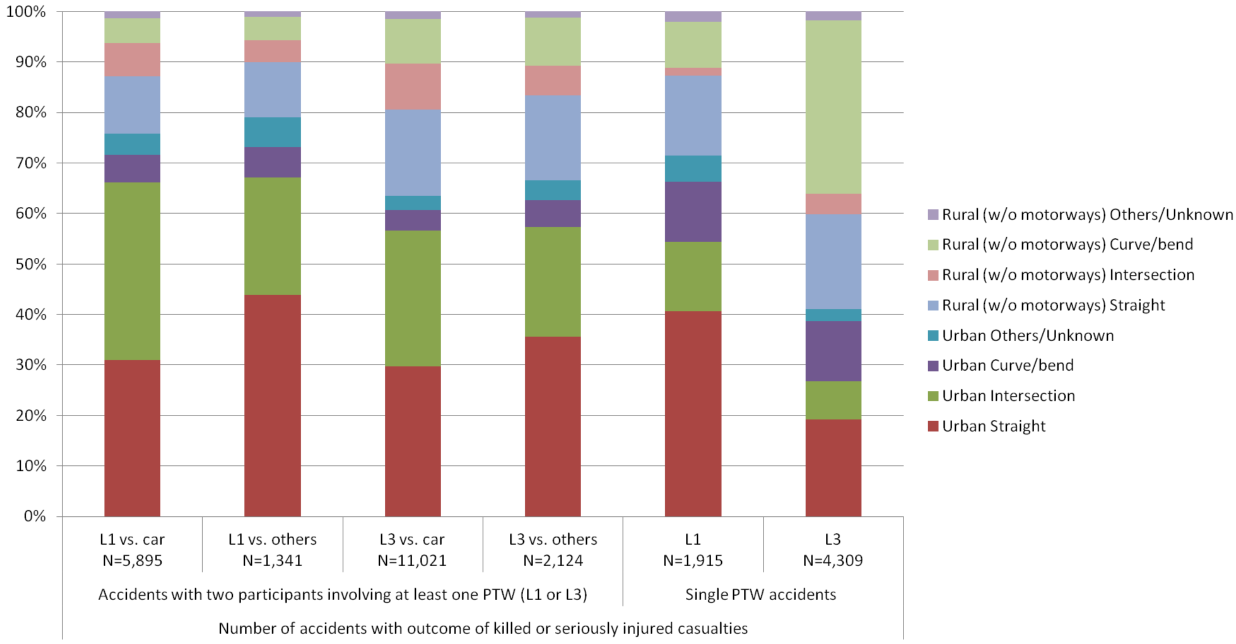


Figure 12: France – Accidents with at least one killed or seriously injured person and involvement of a PTW (L1 or L3), BAAC, years 2014-2016

It can be seen that severe accidents between one L3 and one passenger car dominate clearly all other Accident Scenarios with around 11,000 accidents. Accidents between one L1 vehicle and one passenger car, L3 single accidents and accidents between one L3 and any other road traffic participant are following. Accidents with two participants take place in urban areas with around 65-75% of all accidents. Most of these accidents happen at straight road alignments, followed by intersections. Single L1 accidents occur in urban areas in around 70% of all respective accidents mostly on straight road alignments, whereas L3 single accidents occur in around 40% on urban roads and with a high share of around 30% on rural roads with curves.

3.5 Spain

3.5.1 Accidents with at least one killed person

The Spanish national accident data (DGT) has been analysed for the years 2014-2016 regarding accidents with at least one killed person and involvement of a PTW (L1 or L3). The results are shown in Figure 13.

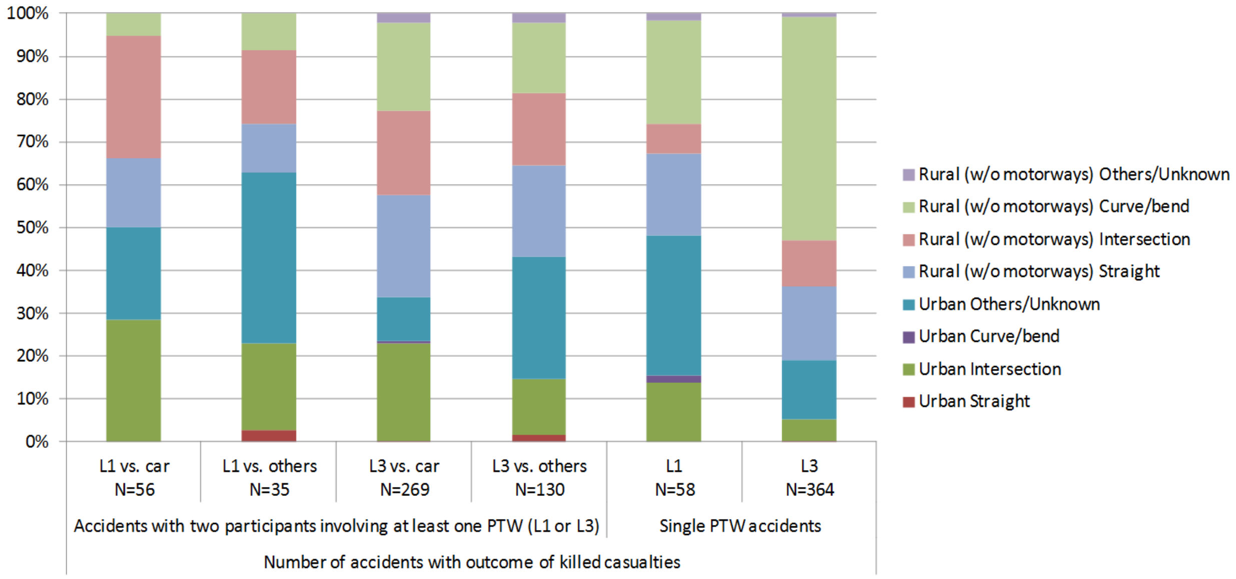


Figure 13: Spain – Accidents with at least one killed person and involvement of a PTW (L1 or L3), DGT, years 2014-2016

It can be seen that L3 single accidents, followed by accidents between one L3 and one passenger car take place most frequently. Further, accidents against passenger cars play a dominant role in rural areas and single L3 accidents are dominant on rural roads with curve/bend. It has to be noted that the data analysed contained high shares of unknown road layout in urban areas.

3.5.2 Accidents with at least one killed or seriously injured person

The Spanish national accident data (DGT) has been analysed for the years 2014-2016 regarding accidents with at least one killed or seriously injured person and involvement of a PTW (L1 or L3). The results are shown in Figure 14.

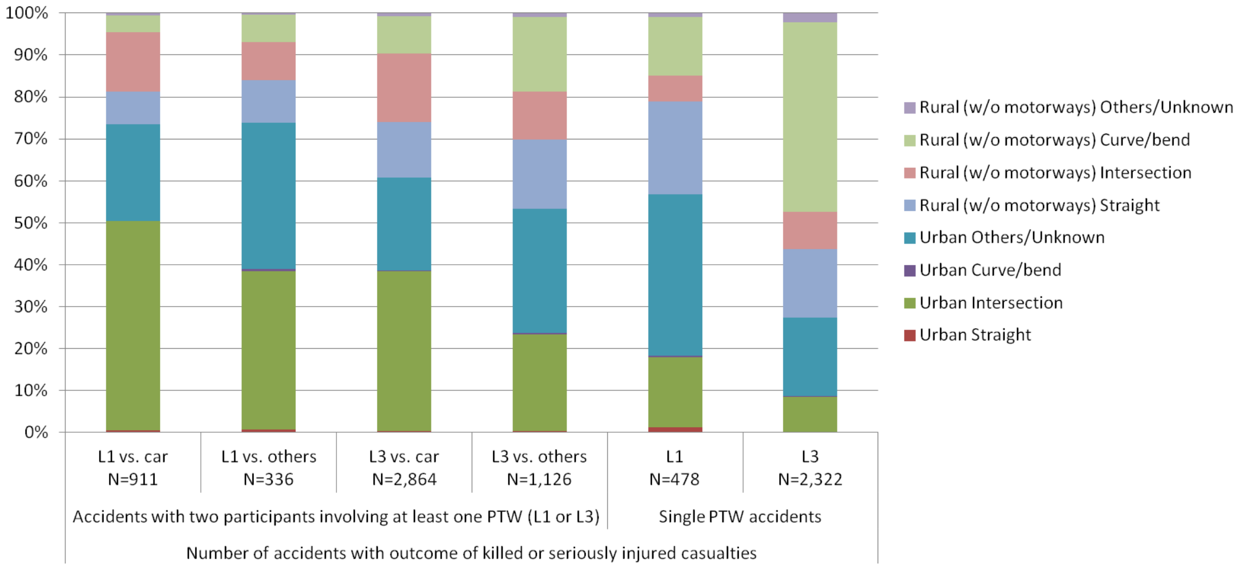


Figure 14: Spain – Accidents with at least one killed or seriously injured person and involvement of a PTW (L1 or L3), DGT, years 2014-2016

It can be seen that severe accidents between one L3 and one passenger car and L3 single accidents occur most often. Accidents with two participants take place in urban areas with around 55-75% of all respective accidents. Most of these accidents happen at intersections. The location of many others was not coded. Single L1 accidents occur in urban areas in around 55% of all respective accidents, whereas L3 single accidents occur in around 28% on urban roads and with a high share of around 45% on rural roads with curves.

3.6 Germany

3.6.1 Accidents with at least one killed person

The German national accident data (Destatis) has been analysed for the years 2015-2017 regarding accidents with at least one killed person and involvement of a PTW (L1 or L3). The results are shown in Figure 15.

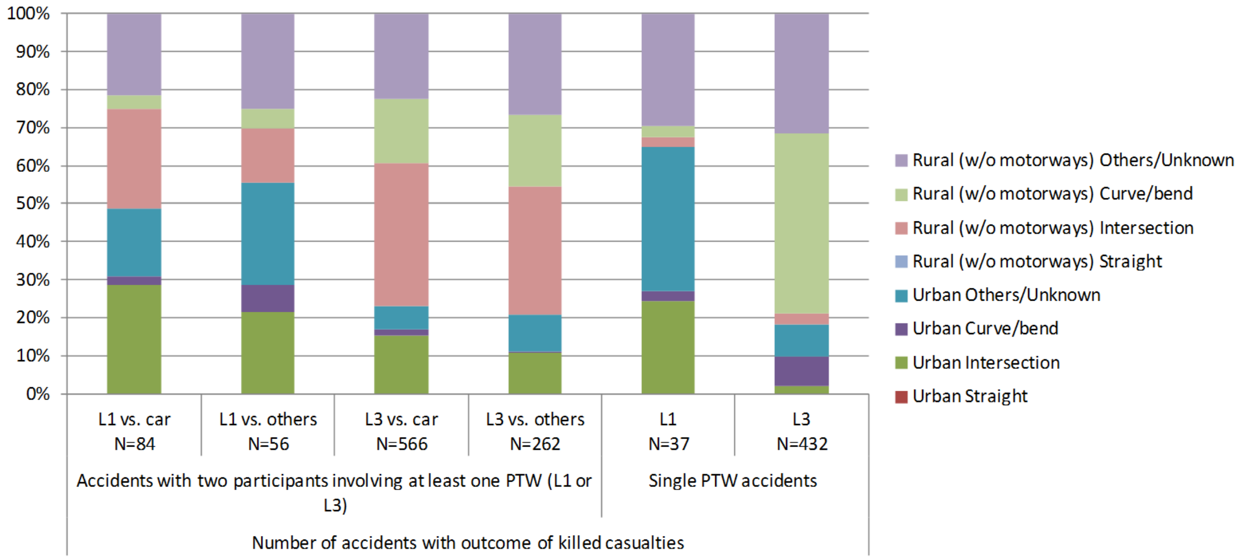


Figure 15: Germany – Accidents with at least one killed person and involvement of a PTW (L1 or L3), Destatis, years 2015-2017

It can be seen that accidents between one L3 and one passenger car, followed by L3 single accidents take place most frequently. Further, accidents against passenger cars play a dominant role in rural areas (especially on intersections). Single L3 accidents are dominant on rural roads with curve/bend. It has to be noted that the German national statistics cannot distinguish for "straight" roads, therefore these cases are included in "Others/Unknown".

3.6.2 Accidents with at least one killed or seriously injured person

The German national accident data (Destatis) has been analysed for the years 2015-2017 regarding accidents with at least one killed or seriously injured person and involvement of a PTW (L1 or L3). The results are shown in Figure 16.

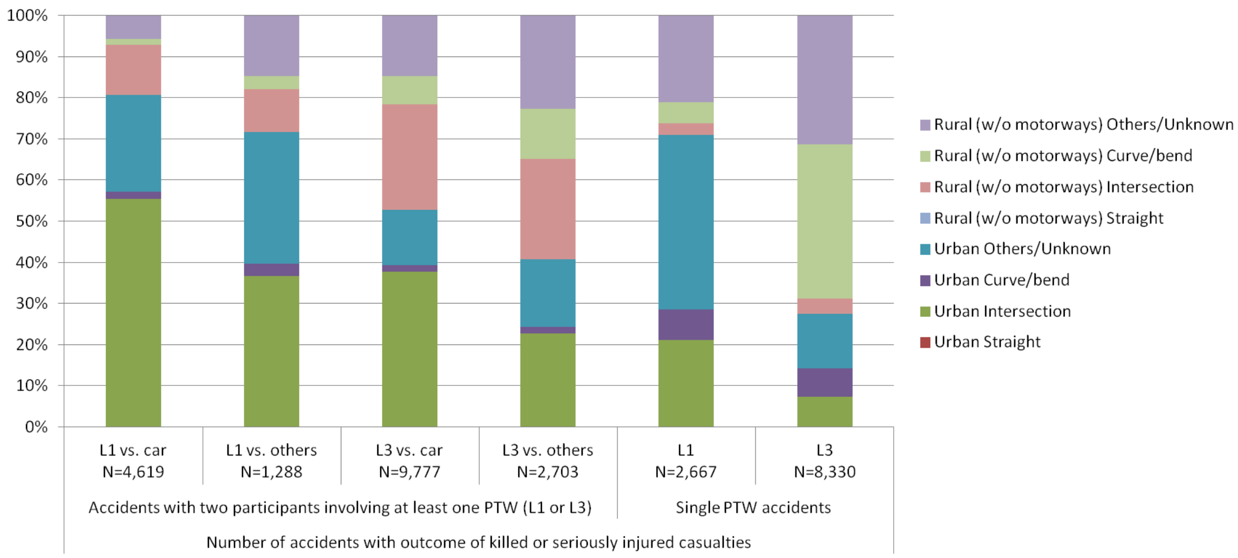


Figure 16: Germany – Accidents with at least one killed or seriously injured person and involvement of a PTW (L1 or L3), Destatis, years 2015-2017

It can be seen that severe accidents between one L3 and one passenger car occur most often, followed by L3 single accidents and accidents between one L1 and one passenger car.

Accidents with one L1 vehicle and another road participant take place in urban areas with around 70-80% of all respective accidents. Most of these accidents happen at intersections or the location was not specified as important for the accident causation.

Accidents with one L3 vehicle and another road participant take place in urban areas with around 40-50% of all respective accidents. Most of these accidents happen at intersections or the location was not specified as important for the accident causation.

Single L1 accidents occur in urban areas in around 70% of all respective accidents mostly on road alignments which were not specified and thus, classified as not important for the causation of the accident. L3 single accidents occur in around 28% on urban roads and with a high share of around 35% on rural roads with curves.

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3.7 Australia

Australian accident statistics (New South Wales) are based on (considerable) different definitions compared with the European statistics shown in the previous Sections. This includes for example that the available data from Australia of years 2015-2017 does not offer information explicitly for vehicles of category L1 or mopeds. Therefore, analyses have been focused on accidents with maximum two participants and involving at least one motorcycle in the first impact; hence, Accident Scenarios 3, 4 and 6. Road types could be distinguished regarding a straight or curved alignment with the location types "intersection" or "non-intersection". Crashes occurring within the conurbation areas of greater Sydney, Newcastle and Wollongong were classified as urban crashes while crashes occurring in the rest of NSW were classified as rural. Crash opponent "car/light truck" includes car/car derivatives and trucks <4.5 tonnes tare.

3.7.1 Accidents with at least one killed person

The Australian national accident data from NSW has been analysed for the years 2015-2017 regarding accidents with at least one killed person and involvement of a PTW (motorcycle). The results are shown in Figure 17.

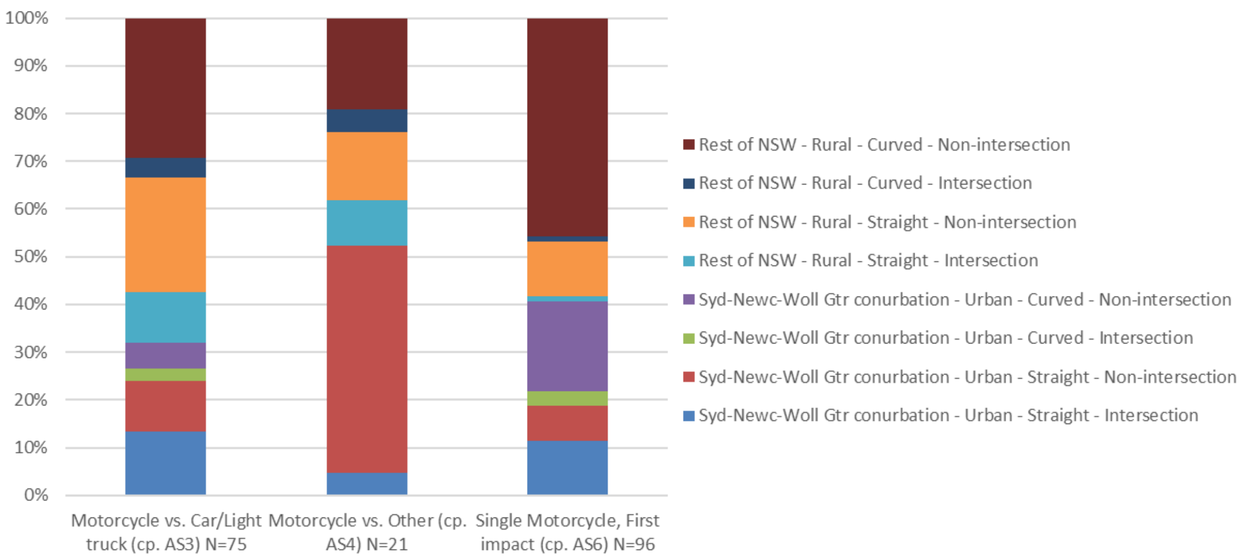

Figure 17: Australia (NSW) – Accidents with at least one killed person and involvement of a PTW (motorcycle), years 2015-2017

It can be seen that motorcycle single accidents followed by accidents between one motorcycle and one passenger car / light truck occurred most frequently. Predominantly, these accidents happened on rural roads (~60-65%). On rural roads, curved road alignments show particularly high shares of accidents. Non-intersection accidents dominate for single motorcycle accidents.

3.7.2 Accidents with at least one killed or seriously injured person

The Australian national accident data from NSW has been analysed for the years 2015-2017 regarding accidents with at least one killed or seriously injured person and involvement of a PTW (motorcycle) and a known location of the accident spot. The results are shown in Figure 18.

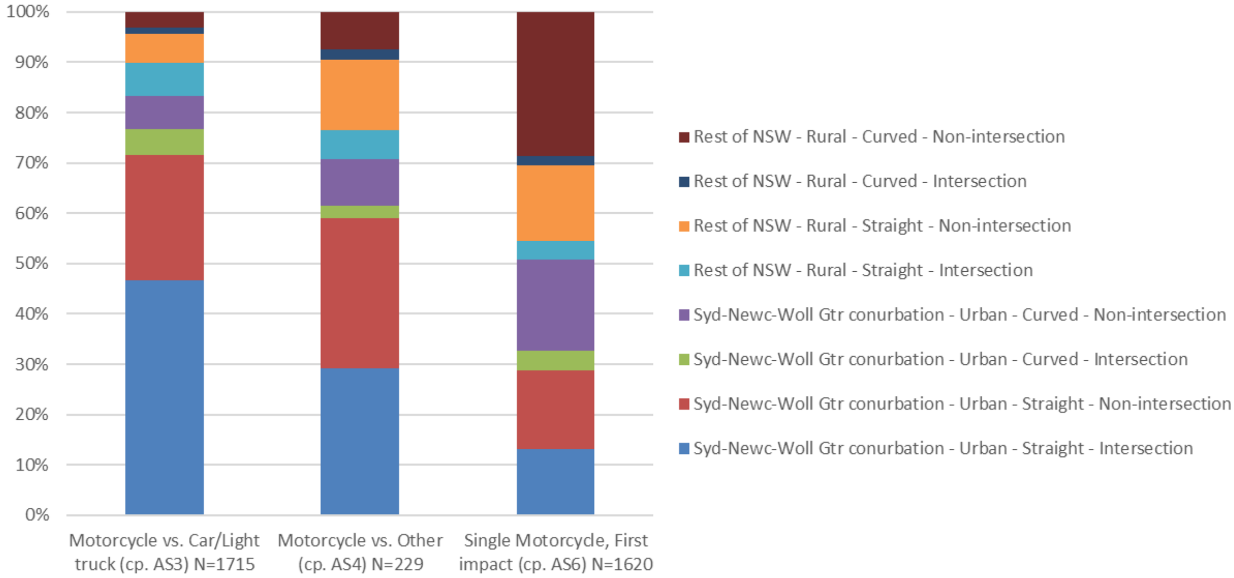

Figure 18: Australia (NSW) – Accidents with at least one killed or seriously injured person and involvement of a PTW (motorcycle), known locations, years 2015-2017

It can be seen that accidents between one motorcycle and one passenger car / light truck followed by motorcycle single accidents occurred most frequently. Predominantly, these accidents happened on urban roads (~50-80%). On urban roads, straight road alignments show the highest proportion of crashes. Non-intersection accidents dominate for single motorcycle accidents.

4 Results from analyses of in-depth datasets

4.1 Distribution of the available in-depth data per AS

4.1.1 GIDAS

Data from accident years 2005-2018 (as far as completely documented by now) have been analysed using the GIDAS database with date of December 2018. For the present analyses, the following filter criteria were applied:

- PTW assigned as vehicle category L1 or L3
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one seriously or fatally injured casualty
- Accidents on urban and rural roads (without motorways)
- Assignments to PIONEERS' accident scenarios and body regions

According to Section 2.1.2 the GIDAS analysis revealed 1,000 accidents including 1,064 riders or passengers of L1 and L3 vehicles (PTWs). Thereof, 1,042 PTW casualties suffered from injuries. The inner distribution of this dataset related to the accident scenarios is shown in Table 15.

Table 15: GIDAS dataset – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				**Single PTW accidents**	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 150 15.0%**	**AS2-U 43 4.3%**	**AS3-U 295 29.5%**	**AS4-U 60 6.0%**	**AS5-U 52 5.2%**	**AS6-U 87 8.7%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 21 2.1%**	**AS2-R 11 1.1%**	**AS3-R 106 10.6%**	**AS4-R 28 2.8%**	**AS5-R 18 1.8%**	**AS6-R 129 12.9%**
Sum	**17.1%**	**5.4%**	**40.1%**	**8.8%**	**7.0%**	**21.6%**

4.1.2 InSAFE

Data from accident years 2010-2018 have been analysed using the InSAFE database. For the present analyses, the following filer criteria were applied:

- PTW assigned as vehicle category L1 or L3;
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one seriously or fatally injured casualty
- Accidents on urban and rural roads (without motorways)
- Assignments to PIONEERS' accident scenarios and body regions

According to Section 2.1.2 the analysis revealed 57 accidents including 58 injured riders or passengers of L1 and L3 vehicles (PTWs). The inner distribution of this dataset related to the accident scenarios is shown in Table 16.

Table 16: InSAFE dataset – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				**Single PTW accidents**	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 9 15.8%**	**AS2-U 1 1.8%**	**AS3-U 32 56.1%**	**AS4-U 7 12.3%**	**AS5-U 2 3.5%**	**AS6-U 2 3.5%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 1 1.8%**	**AS2-R 0 0%**	**AS3-R 3 5.3%**	**AS4-R 0 0%**	**AS5-R 0 0%**	**AS6-R 0 0%**
Sum	**17.5%**	**1.8%**	**61.4%**	**12.3%**	**3.5%**	**3.5%**

4.1.3 EDA

Data from accident years 2005-2018 have been analysed using the EDA accident case library. For the present analyses, the following filer criteria were applied:

- PTW assigned as vehicle category L1 or L3
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one seriously or fatally injured casualty
- Accidents on urban and rural roads (without motorways)
- Assignments to PIONEERS' accident scenarios and body regions

According to Section 2.1.2 the analysis revealed 45 accidents including 48 injured riders or passengers of L1 and L3 vehicles (PTWs). The inner distribution of this dataset related to the accident scenarios is shown in Table 17.

Table 17: EDA dataset – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				**Single PTW accidents**	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 5 11.1%**	**AS2-U 0 0%**	**AS3-U 8 17.8%**	**AS4-U 1 2.2%**	**AS5-U 1 2.2%**	**AS6-U 4 8.9%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 5 11.1%**	**AS2-R 1 2.2%**	**AS3-R 10 22.2%**	**AS4-R 2 4.4%**	**AS5-R 3 6.7%**	**AS6-R 5 11.1%**
Sum	**22.2%**	**2.2%**	**40.0%**	**6.7%**	**8.9%**	**20.0%**

4.1.4 LMU

Data from accident years 2004-2016 have been analysed using LMU in-house data on fatal PTW accidents. For the present analyses, the following filter criteria were applied:

- PTW assigned as vehicle category L1 or L3;
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one fatally injured PTW rider;
- Accidents on urban and rural roads (without motorways);
- Assignments to PIONEERS' accident scenarios and body regions; and
- No overrun.

According to Section 2.1.2 the analysis revealed 139 accidents including 143 fatally injured riders or passengers of L1 and L3 vehicles (PTWs). The inner distribution of this dataset related to the accident scenarios is shown in Table 18.

Table 18: LMU fatalities dataset – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				Single PTW accidents	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 7 5.0%**	**AS2-U 2 1.4%**	**AS3-U 18 12.9%**	**AS4-U 1 0.7%**	**AS5-U 0 0%**	**AS6-U 7 5.0%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 6 4.0%**	**AS2-R 1 0.7%**	**AS3-R 48 34.5%**	**AS4-R 27 19.4%**	**AS5-R 0 0%**	**AS6-R 22 15.8%**
Sum	**9,4%**	**2.2%**	**47.5%**	**20.1%**	**0%**	**20.9%**

4.1.5 IGLAD

Data from accident years 2012-2015 have been analysed using the IGLAD database (status of member year 2018). For the present analyses, the following filer criteria were applied:

- PTW assigned as vehicle category L1 or L3
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one seriously or fatally injured casualty
- Accidents on urban and rural roads (without motorways)
- Assignments to PIONEERS' accident scenarios and body regions

According to Section 2.1.2 the analysis revealed 120 accidents including 125 injured riders or passengers of L1 or L3 vehicles. The inner distribution of this dataset related to the accident scenarios is shown in Table 19.

Table 19: IGLAD dataset – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				Single PTW accidents	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 29 23.2%**	**AS2-U 11 8.8%**	**AS3-U 32 25.6%**	**AS4-U 15 12.0%**	**AS5-U 0 0%**	**AS6-U 2 1.6%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 4 3.2%**	**AS2-R 2 1.6%**	**AS3-R 17 13.6%**	**AS4-R 9 7.2%**	**AS5-R 0 0%**	**AS6-R 4 3.2%**
Sum	**26.4%**	**10.4%**	**39.2%**	**19.2%**	**0%**	**4.8%**

4.1.6 NSW in-depth crash database

Data from accident years 2012-2014 have been analysed using the NSW in-depth crash database. For the present analyses, the following filer criteria were applied:

- PTW assigned as vehicle category L3 (note: no L1 vehicles are involved in the dataset)
- Single PTW accidents and accidents with two participants (PTW vs. passenger car, other PTW or other road traffic participant) that could be assigned to one of the Accident Scenarios 1-6;
- Accidents with at least one seriously or fatally injured casualty
- Accidents on urban and rural roads (without motorways)
- Assignments to PIONEERS' accident scenarios and body regions

According to Section 2.1.2 the analysis revealed 87 accidents including 88 injured riders or passengers of L3 vehicles (PTWs; note: no L1 vehicles are involved in the dataset). The inner distribution of this dataset related to the accident scenarios is shown in Table 20.

Table 20: NSW in-depth crash database – inner structure of relevant PIONEERS accidents

Accident Scenarios	Accidents with outcome of killed or seriously injured casualties (KSI)					
	Accidents with two participants involving at least one PTW				Single PTW accidents	
	L1 versus		L3 versus		L1	L3
	car	others	car	others		
Urban **Use Case 1**	**AS1-U 0 0%**	**AS2-U 0 0%**	**AS3-U 27 31.0%**	**AS4-U 17 19.5%**	**AS5-U 0 0%**	**AS6-U 15 17.2%**
Rural (w/o motorways) **Use Case 2**	**AS1-R 0 0%**	**AS2-R 0 0%**	**AS3-R 8 9.2%**	**AS4-R 8 9.2%**	**AS5-R 0 0%**	**AS6-R 12 13.8%**
Sum	**0%**	**0%**	**40.2%**	**28.7%**	**0%**	**31.0%**

4.2 Casualties variability – sample characteristics

All available in-depth datasets, except for MAIDS, have been analysed regarding the riders' sex, age, body weight and height. In addition, the analyses focused on MAIS 1+ and MAIS 3+ injured casualties in the Accident Scenarios AS3 und AS6, hence, involving accidents between a L3 vehicle (motorcycle) and a car or single L3 vehicle accidents. Note: provided numbers related to MAIS 1+ injured casualties include MAIS 3+ injured persons.

The parameters age, body weight and body height had been grouped in the same way among the analysing partners to achieve useful results regarding any comparison between the datasets, see Table 21. However, it has to be noted that the databases use clear different investigation approaches, and each is based on individual sampling criteria, see also Section 4.1.

Table 21: In-depth datasets, Sample characteristics, Parameter groups and their labels

Parameter	Age groups	Body weight groups	Body height groups
Labels	< 16 years 16 – 35 years 36 – 50 years > 50 years Unknown	< 50 kg 51 – 79 kg 80 – 99 kg > 99 kg Unknown	< 160 cm 161 – 180 cm > 180 cm Unknown

4.2.1 Sex

The available GIDAS dataset comprised 614 MAIS 1+ (88.4% male) and 199 MAIS 3+ (94.5% male) injured casualties. The distribution related to sex and AS3 and AS6, respectively, can be seen in Figure 19. Differences between males and females are relatively low regarding their proportional involvement in the different Accident Scenarios. Both sexes show high shares of about 40% in the AS3-U, hence accidents between one L3 vehicle and a car in urban areas. Higher injury severities were found on rural roads.

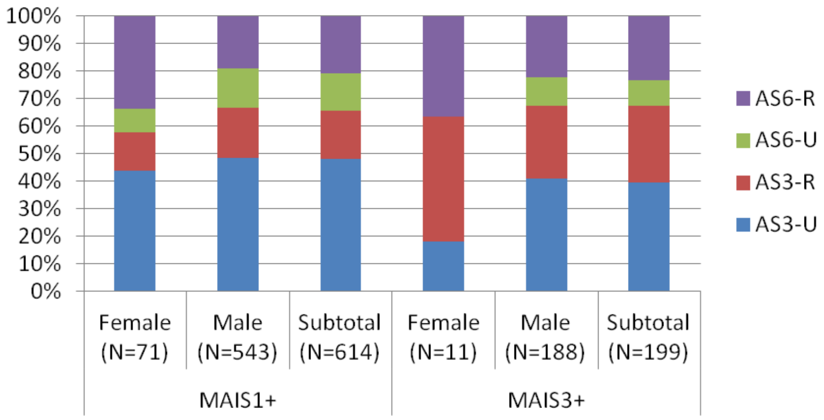

Figure 19: Sample characteristics – Sex – GIDAS

The available LMU Fatalities dataset comprised 98 MAIS 3+ (93.9% male) injured casualties (note: all casualties in the dataset had injury severities of at least MAIS 3). The distribution related to sex and AS3 and AS6, respectively, can be seen in Figure 20. There were no cases involving females in AS3-U accidents. The remaining shares for AS3-R, AS6-U and AS6-R are similar comparing both sexes and considering the small number of cases with women. Both sexes show highest shares of about 50% in the AS3-R, hence accidents between one L3 vehicle and a car in rural areas.

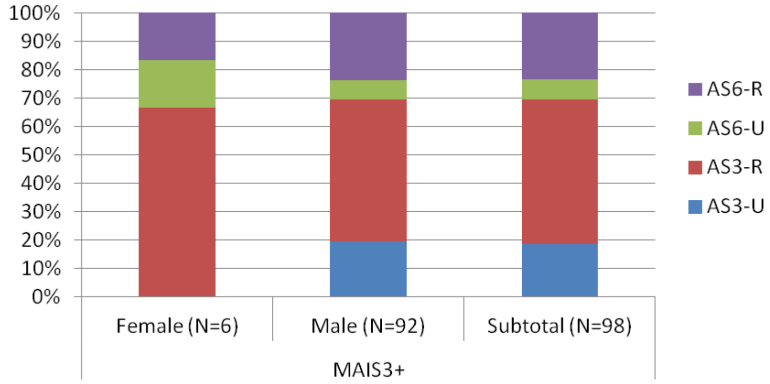

Figure 20: Sample characteristics – Sex – LMU Fatalities

The available IGLAD dataset comprised 53 MAIS 1+ (86.8% male) and 31 MAIS 3+ (90.3% male) injured casualties. The distribution related to sex and AS3 and AS6, respectively, can be seen in Figure 21. Differences between males and females are relatively low regarding their proportional involvement in the different Accident Scenarios and considering the low number of cases with women. Both sexes show high shares of about 40-60% in the AS3-U, hence accidents between one L3 vehicle and a car in urban areas, and about 30-40% in AS6-R. Higher injury severities were found on rural roads.

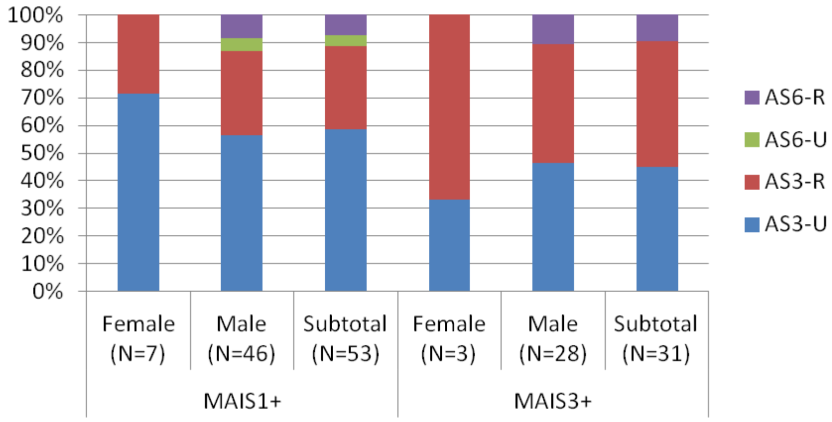

Figure 21: Sample characteristics – Sex – IGLAD

The available InSAFE dataset comprised 38 MAIS 1+ (100% male) and 36 MAIS 3+ (100% male) injured casualties. The distribution related to sex and AS3 and AS6, respectively, could not be established as no females were in the dataset. Related to males only, there is a clear dominance of AS3-U, hence accidents between one L3 vehicle and a car in urban areas, for both injury severity levels (note: there are only two casualties sustaining injuries of AIS 1 or AIS 2), see Figure 22.

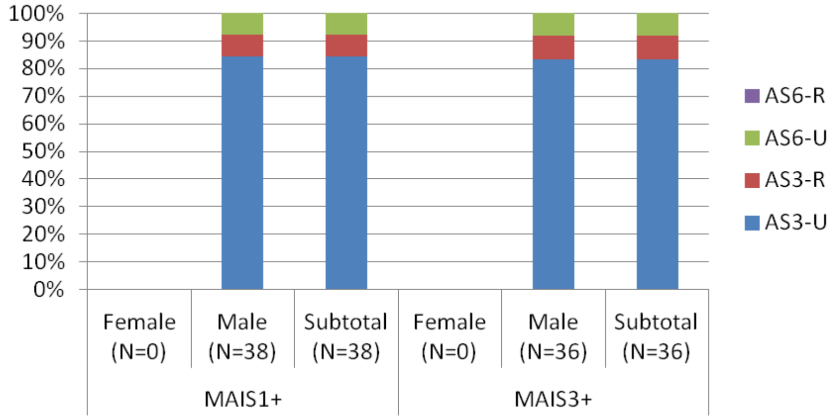

Figure 22: Sample characteristics – Sex – InSAFE

The available EDA dataset comprised 78 MAIS 1+ (94.9% male) and 26 MAIS 3+ (96.2% male) injured casualties. In other two cases the sex was unknown. The distribution related to sex and AS3 and AS6, respectively, can be seen in Figure 23. Due to the low number of female casualties, comparisons between the sexes should be avoided based on the available data. Related to males only, around 30-35% of the accidents could be assigned to AS3-U and around 30% were assigned to AS3-R. Single L3 accidents accounted for around 35% of the accidents. Higher injury severities were found on rural roads.

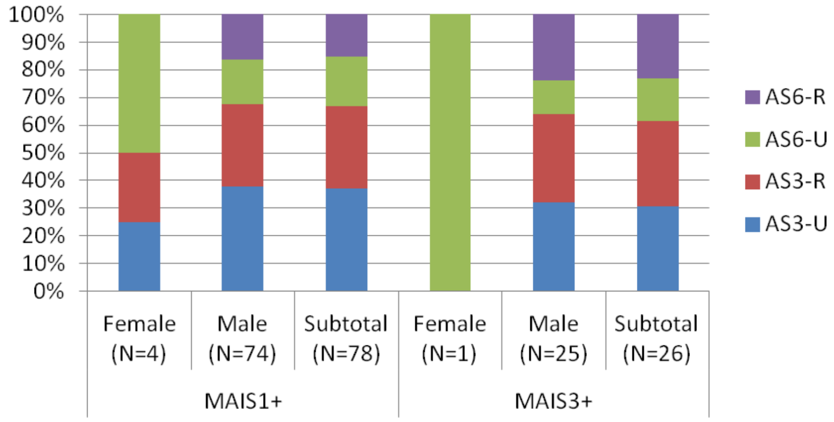

Figure 23: Sample characteristics – Sex – EDA

The available Australian NSW dataset comprised 62 MAIS 1+ (93.5% male) and 27 MAIS 3+ (92.6% male) injured casualties. The distribution related to sex and AS3 and AS6, respectively, can be seen in Figure 24. Differences between males and females are relatively low regarding their proportional involvement in the different Accident Scenarios. Both sexes of MAIS 1+ injured riders show high shares of about 40% in the AS3-U, hence accidents between one L3 vehicle and a car in urban areas. Higher injury severities were found on rural roads.

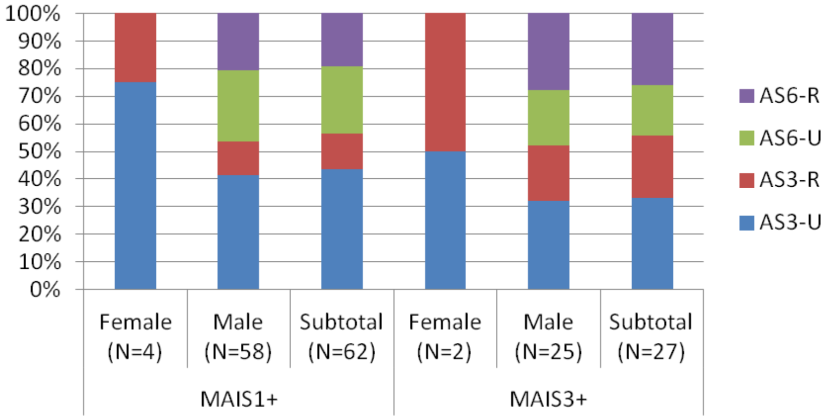

Figure 24: Sample characteristics – Sex – NSW

4.2.2 Age

The available GIDAS dataset comprised 614 MAIS 1+ and 199 MAIS 3+ injured casualties. The distribution related to age and AS3 and AS6, respectively, can be seen in Figure 25. Around 40-50% of all casualties were between 16 and 35 years old. The share of single L3 vehicle accidents is also dominated by this age group. Older riders (51 years or more) were injured in around 15-20% of all accidents and most often involved in accidents against a passenger car. There are hardly riders below the age of 16.

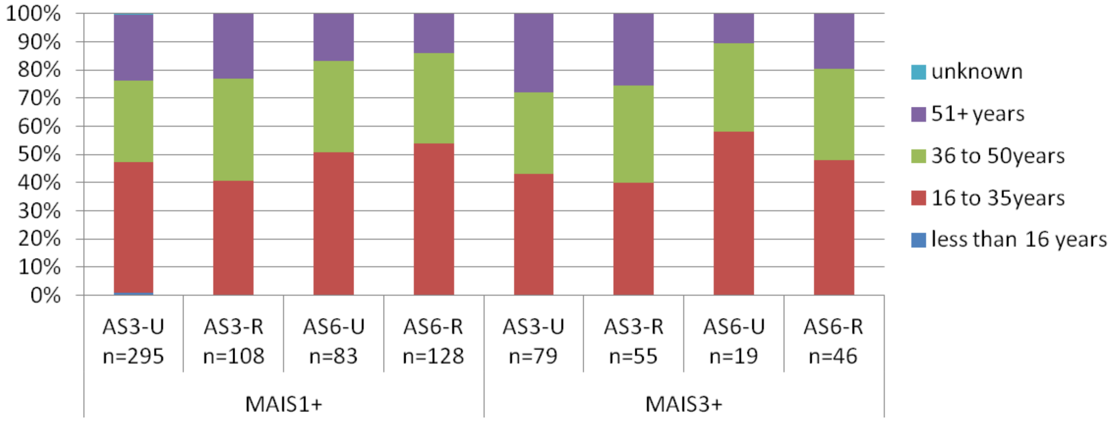

Figure 25: Sample characteristics – Age – GIDAS

The available LMU Fatalities dataset comprised 98 MAIS 3+ injured casualties. The distribution related to age and AS3 and AS6, respectively, can be seen in Figure 26. The number of casualties and the shares of the different age groups varied a lot comparing the Accident Scenarios. In accidents against cars (AS3), young (16-35 years) and mid-aged riders (36-50 years) dominate clearly compared to older riders. However, the share of riders aged 51 years or more increases apparently in L3 single vehicle accidents (AS6). Here, the highest share has been reached in single L3 accidents; however, the number of associated casualties (n=7) is rather low. A few cases included riders aged below 16.

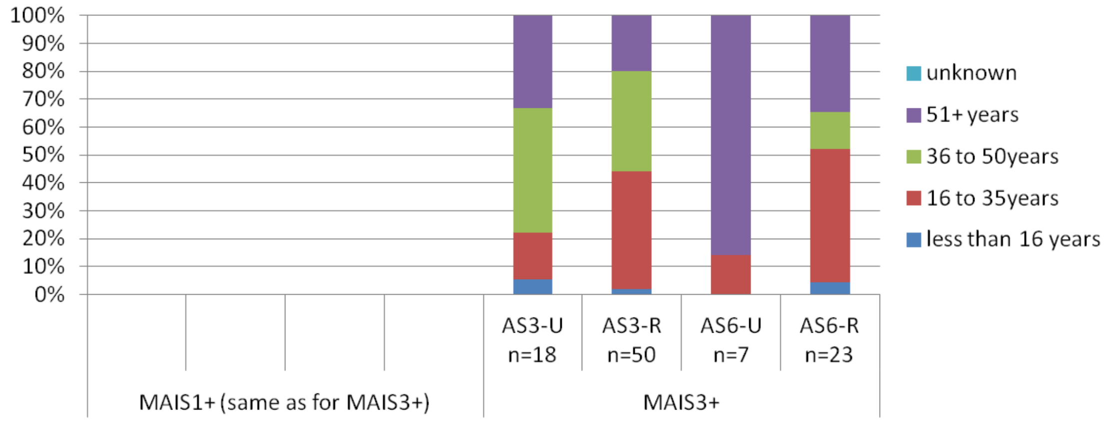

Figure 26: Sample characteristics – Age – LMU Fatalities

The available IGLAD dataset comprised 53 MAIS 1+ and 31 MAIS 3+ injured casualties. The distribution related to age and AS3 and AS6, respectively, can be seen in Figure 27. Around 40-70% of all casualties were between 16 and 35 years old and another around 25-30% were aged 36-50 years in nearly all Accident Scenarios. Deviating results were found for AS6-U and AS6-R which could be due to the low number of cases associated to these scenarios. Riders above the age of 50 years were mostly involved in single L3 accidents. The share of single L3 vehicle accidents is also dominated by this age group. There are no riders below the age of 16. There is nearly no age difference between the groups of MAIS 1+ and MAIS 3+ injured riders.

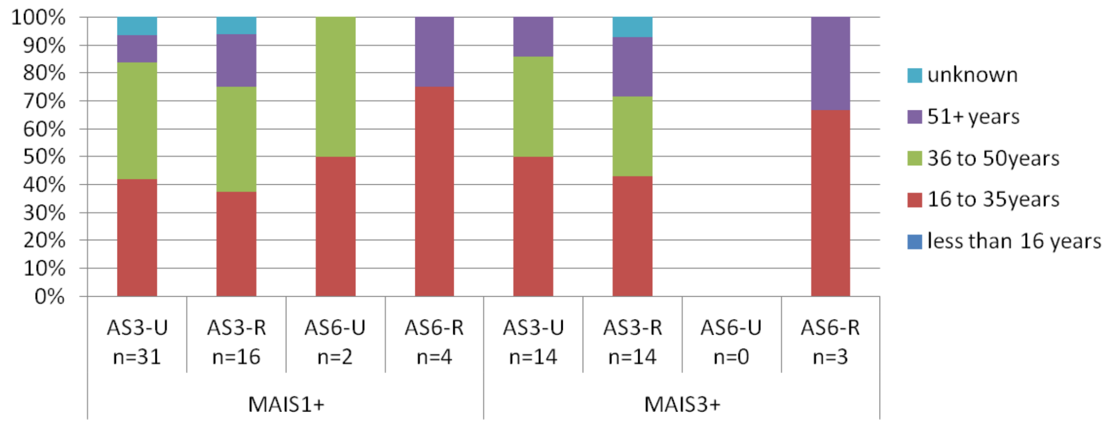

Figure 27: Sample characteristics – Age – IGLAD

The available InSAFE dataset comprised 38 MAIS 1+ and 36 MAIS 3+ injured casualties. The distribution related to age and AS3 and AS6, respectively, can be seen in Figure 28. More than 50% of all casualties were between 16 and 35 years old. Remaining shares were similarly distributed for the age groups 36-50 years and at least 51 years, but older casualties (51 years and above) were recorded more often on rural roads. Note: only a few cases were available for analysis regarding AS3-R, AS6-U and AS6-R. Single L3 vehicle accidents are dominated by the riders aged 16-35 years. There are no riders below the age of 16.

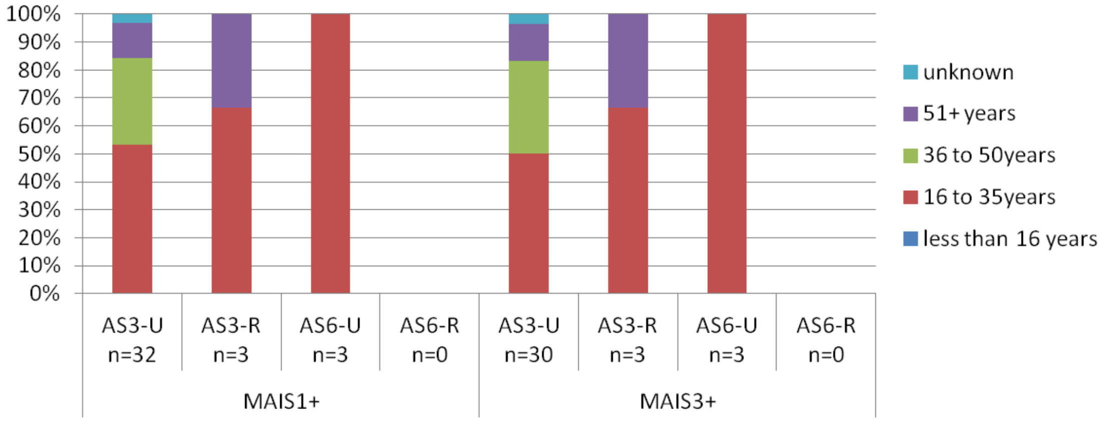

Figure 28: Sample characteristics – Age – IGLAD

The available EDA dataset comprised 80 MAIS 1+ and 28 MAIS 3+ injured casualties. The distribution related to age and AS3 and AS6 can be seen in Figure 29. In nearly all Accident Scenarios around 25-55% of all casualties were between 16 and 35 years old and around 30% were aged 36-50 years, respectively. Single L3 vehicle accidents are dominated by young riders aged 16-35 years with around 50%. Another 30-35% of the casualties are aged 36-50 years and the remaining 15-20% are older than 50 years. Generally, older riders (51 years or more) were seen more often in accidents on rural roads. There are no riders below the age of 16. There is nearly no age difference between the groups of MAIS 1+ and MAIS 3+ injured riders, considering also that the number of casualties with unknown age is around 20% in AS3-R.

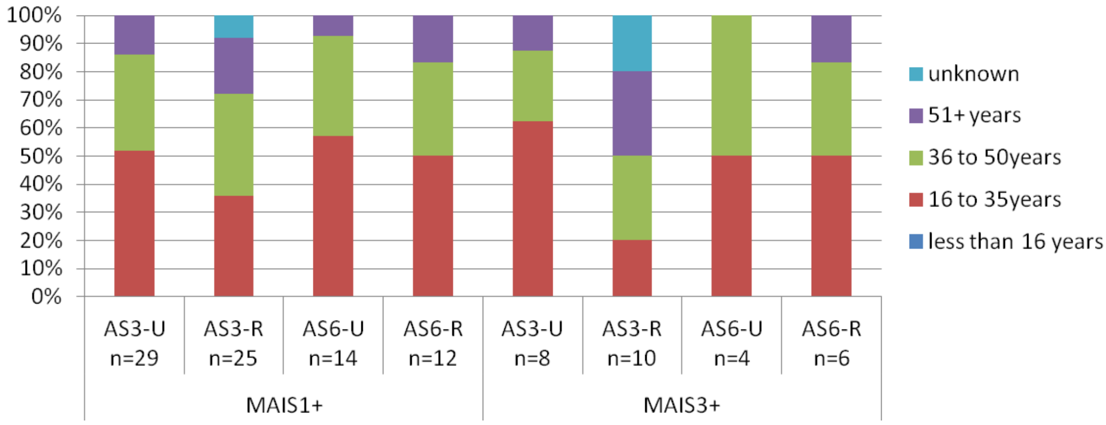

Figure 29: Sample characteristics – Age – EDA

The available NSW dataset comprised 62 MAIS 1+ and 27 MAIS 3+ injured casualties. The distribution related to age and AS3 and AS6 can be seen in Figure 30. The shares of the age groups differed considerably with respect to the Accident Scenarios. AS3-U is dominated by young riders (16-35 years) with a share of around 70%, whereas this age group made up only about 15-35% in AS3-R, hence in accidents against a passenger car on rural roads. With regard to single L3 accidents there is a trend that riders aged above 35 years sustain more often severe injuries (AIS 3+) compared with younger riders. There are no riders below the age of 16.

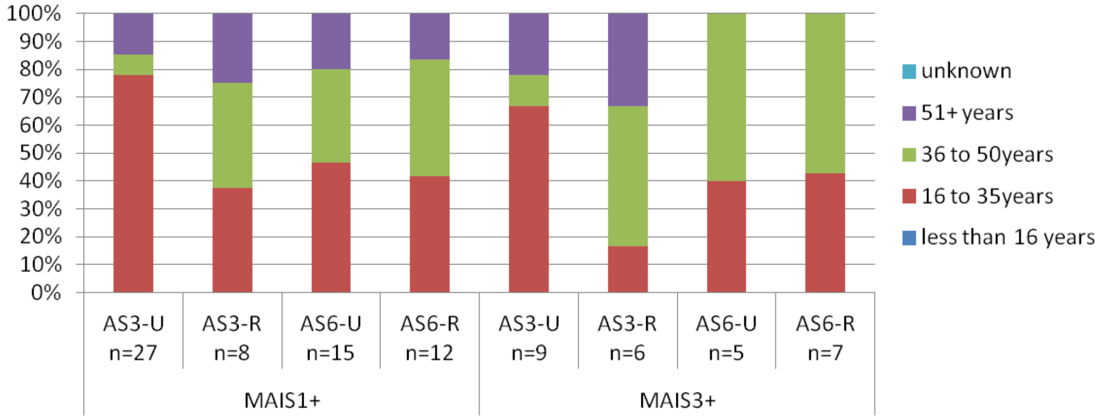

Figure 30: Sample characteristics – Age – NSW

4.2.3 Body height

The available GIDAS dataset comprised 614 MAIS 1+ and 199 MAIS 3+ injured casualties. The distribution related to body height and AS3 and AS6 can be seen in Figure 31. Respecting that the body heights of around 25% of all casualties were unknown; at least around 40% of all riders were between 161 and 180 cm tall in nearly all Accident Scenarios. The corresponding share of riders being taller was at least 10-25%. Nearly no difference can be seen between the different injury severity groups. Outstanding, riders being taller than 180 cm were found often in L3 single vehicle accidents on rural roads. There are hardly riders below the body height of 161 cm.

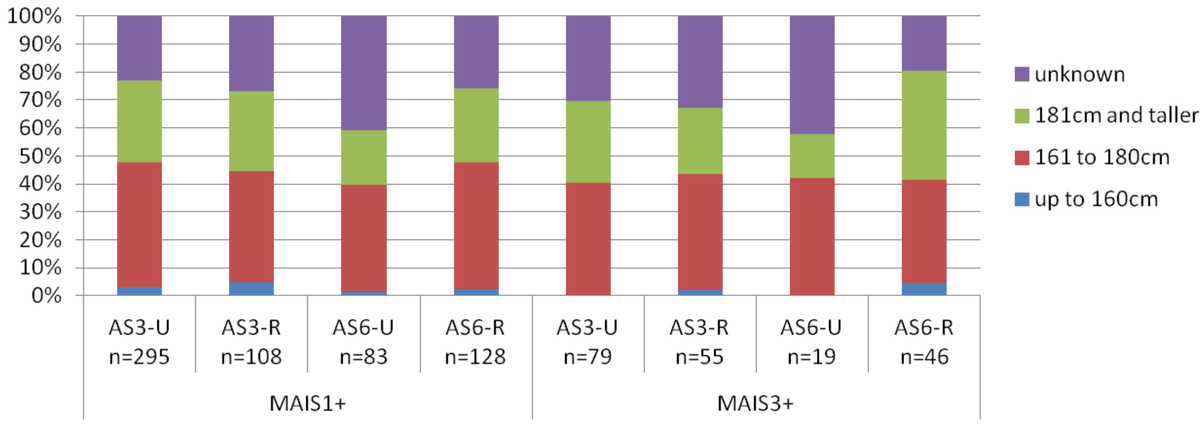

Figure 31: Sample characteristics – Body height – GIDAS

The available LMU Fatalities dataset comprised 98 MAIS 3+ injured casualties. The distribution related to body height and AS3 and AS6 can be seen in Figure 32. Around 60-75% of all riders were between 161 and 180 cm tall in all Accident Scenarios. The remaining proportions of around 25-40% are assigned to riders being taller than 180 cm. Generally, riders with a body height of 161-180 cm were found more often in accidents on rural roads compared with riders being taller than 180 cm. There are hardly riders below the body height of 161 cm.

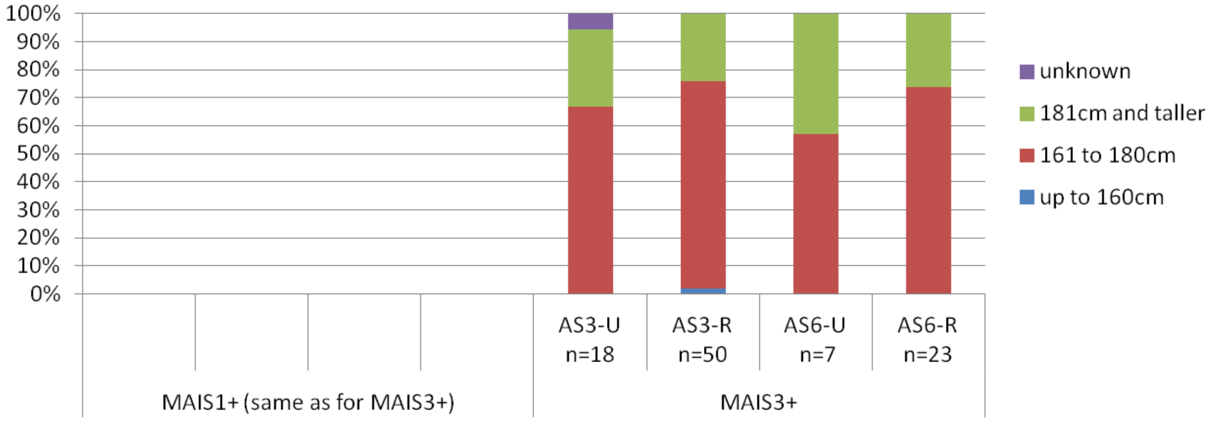

Figure 32: Sample characteristics – Body height – LMU Fatalities

The available IGLAD dataset comprised 52 MAIS 1+ and 31 MAIS 3+ injured casualties. The distribution related to body height and AS3 and AS6 can be seen in Figure 33. It can be seen that there is a very high number of cases without information about the riders' body heights. Hence, no clear statements can be made on the body height distributions using this subset from IGLAD.

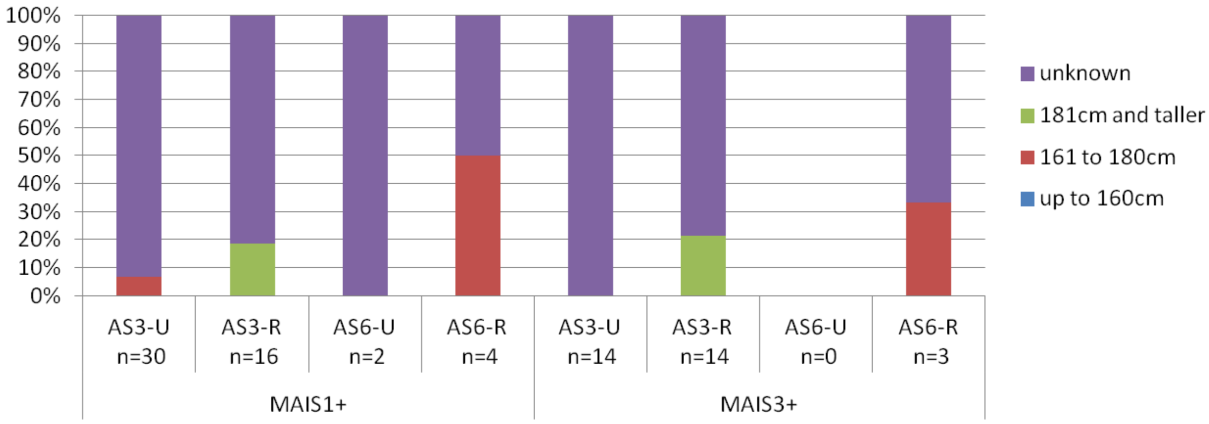

Figure 33: Sample characteristics – Body height – IGLAD

The available InSAFE dataset comprised 38 MAIS 1+ and 36 MAIS 3+ injured casualties. The distribution related to body height and AS3 and AS6 can be seen in Figure 34. It can be seen that there is no case assigned to AS6-R (single L3 accidents on rural roads). Nearly all riders were between 161 and 180 cm tall.

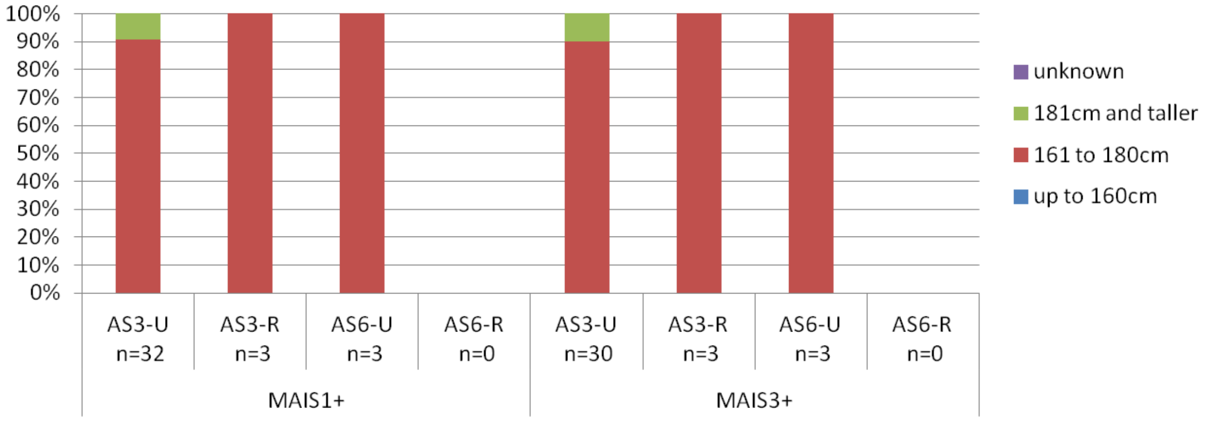

Figure 34: Sample characteristics – Body height – InSAFE

The available EDA dataset comprised 80 MAIS 1+ and 28 MAIS 3+ injured casualties. The distribution related to body height and AS3 and AS6 can be seen in Figure 35. Respecting that the body heights of around 25% of seriously injured (MAIS 3+) casualties were unknown; at least 50-80% of all riders were between 161 and 180 cm tall in nearly all Accident Scenarios. The corresponding share of riders being taller was at least 10-25%. Nearly no difference can be seen between the different injury severity groups (except for the number of unknown body heights). There are hardly riders below the body height of 161 cm.

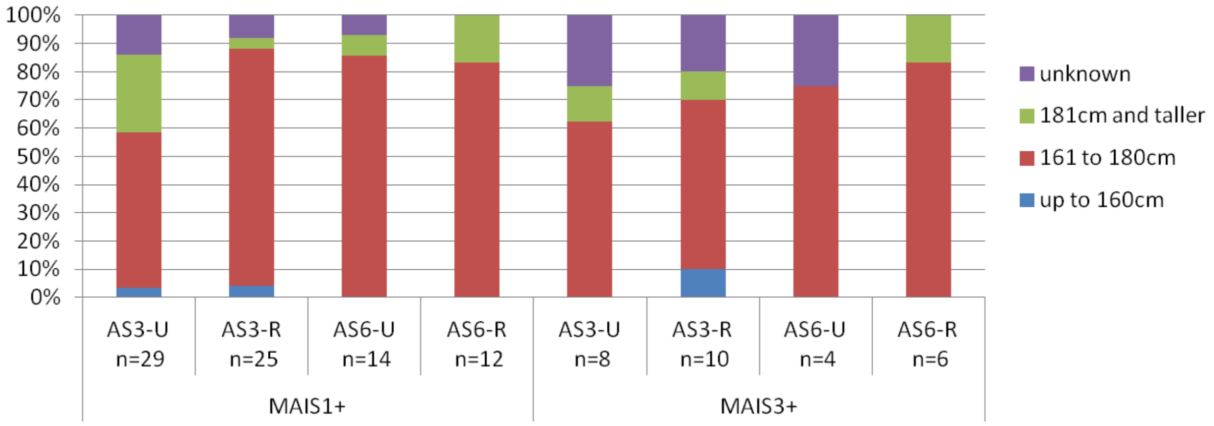

Figure 35: Sample characteristics – Body height – EDA

The available NSW dataset comprised 61 MAIS 1+ and 27 MAIS 3+ injured casualties. The distribution related to body height and AS3 and AS6 can be seen in Figure 36. Around half of all riders were between 161 and 180 cm tall in all Accident Scenarios. The corresponding share of riders being taller was around 20-55%. Around 10% of all riders are up to 160 cm tall. Nearly no difference can be seen between the different injury severity groups. In L3 single vehicle accidents on urban roads (AS6-U) riders being taller than 180 cm were recorded more often being injured compared to smaller riders.

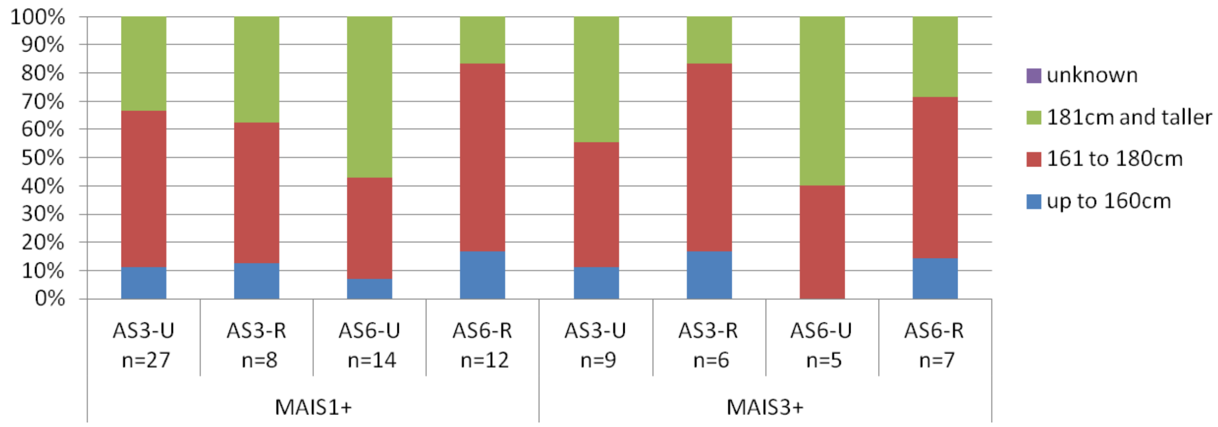

Figure 36: Sample characteristics – Body height – NSW

4.2.4 Body weight

The available GIDAS dataset comprised 614 MAIS 1+ and 199 MAIS 3+ injured casualties. The distribution related to body weight and AS3 and AS6 can be seen in Figure 37. Respecting that the body weights of around 30% of all casualties were unknown; at least around 25-30% of all riders had a body weight of 51-79 kg. A similar proportion was found for body weights of 80-99 kg in all Accident Scenarios. At least around 10% of all riders are 100 kg heavy or more. Nearly no difference was found comparing the different injury severity groups and body weight distributions. There are hardly riders below the body weight of 50 kg.

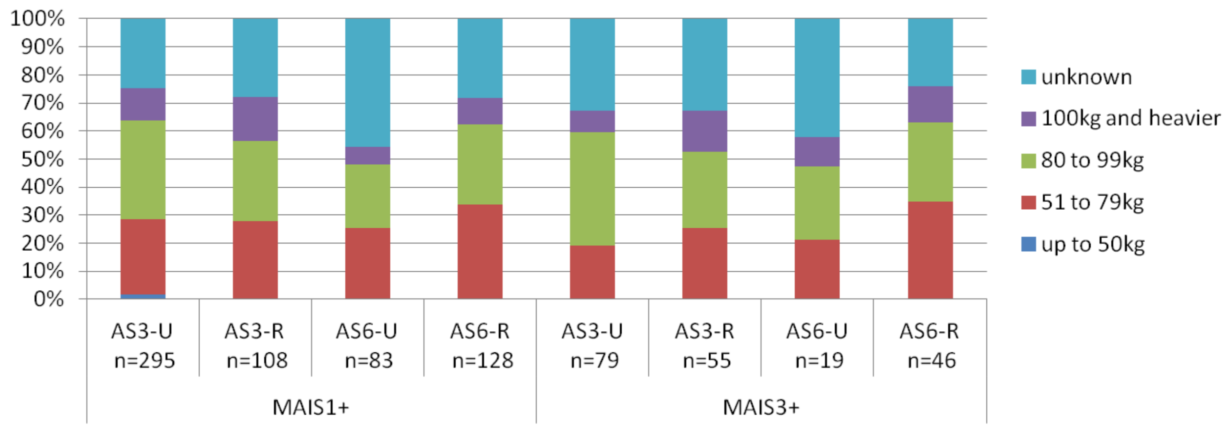

Figure 37: Sample characteristics – Body weight – GIDAS

The available LMU fatalities dataset comprised 98 MAIS 3+ injured casualties. The distribution related to body weight and AS3 and AS6 can be seen in Figure 38. Around 40-50% of all riders had a body weight of 80-99 kg in all Accident Scenarios. Around 15-30% of all riders have a body weight between 51 kg and 79 kg, except for AS6-R (L3 single vehicle accidents on rural roads) where the corresponding share is at about 40%. Around 15-30% of all riders are 100 kg heavy or more. Nearly no difference was found comparing the different injury severity groups and body weight distributions. There are hardly riders below the body weight of 50 kg.

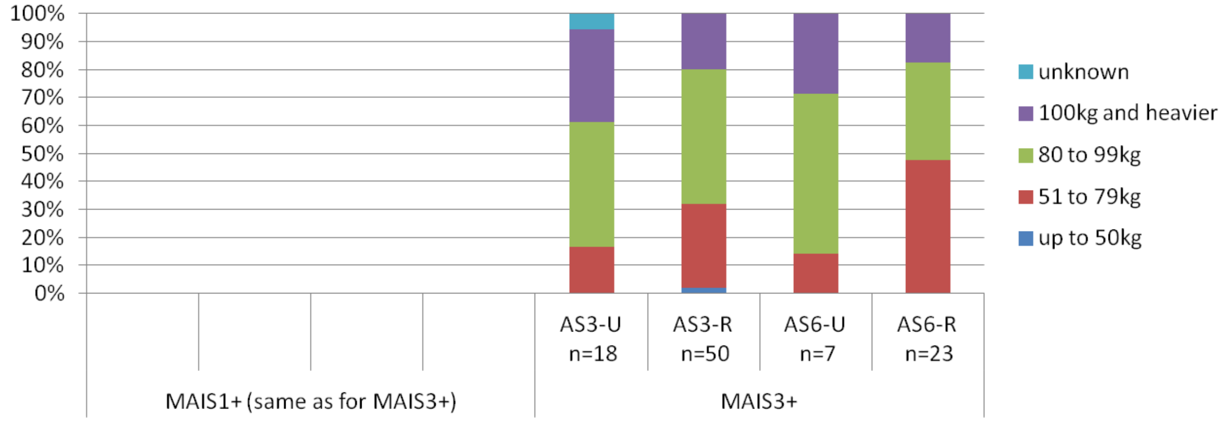

Figure 38: Sample characteristics – Body weight – LMU Fatalities

The available IGLAD dataset comprised 52 MAIS 1+ and 31 MAIS 3+ injured casualties. The distribution related to body weight and AS3 and AS6 can be seen in Figure 39. It can be seen that there is a very high number of cases without information about the riders' body weights. Hence, no clear statements can be made on the body weight distributions using this subset from IGLAD.

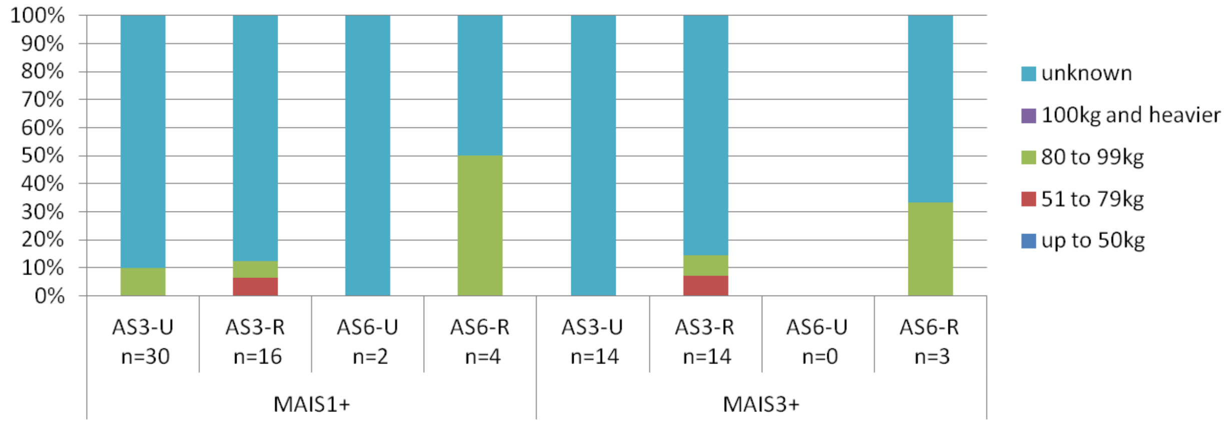

Figure 39: Sample characteristics – Body weight – IGLAD

The available InSAFE dataset comprised 38 MAIS 1+ and 36 MAIS 3+ injured casualties. The distribution related to body weight and AS3 and AS6 can be seen in Figure 40. Around 60-65% of all riders had a body weight of 51-79 kg. The remaining share of around 35-40% was assigned to persons with a body weight of 80-99 kg in all Accident Scenarios. Nearly no difference was found comparing the different injury severity groups and body weight distributions. There are neither riders having a body weight of less than 50 kg nor above 99 kg.

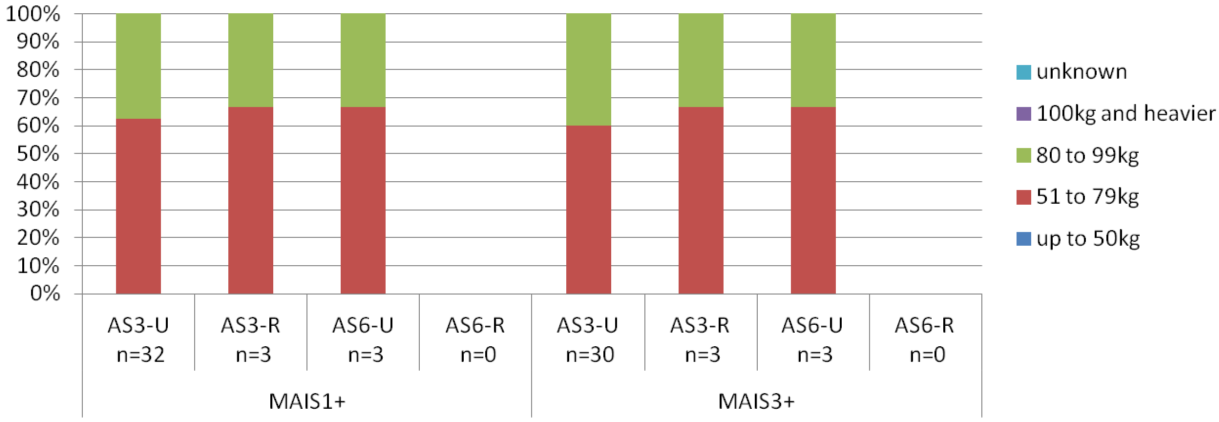

Figure 40: Sample characteristics – Body weight – InSAFE

The available EDA dataset comprised 80 MAIS 1+ and 28 MAIS 3+ injured casualties. The distribution related to body weight and AS3 and AS6 can be seen in Figure 41. Respecting that the body weights of around 10-25% of all casualties were unknown (except for AS6-R); at least around 40-60% of all riders have a body weight of 51-79 kg and at least 30% have a body weight of 80-99 kg in all Accident Scenarios. Around 10% of all riders have a body weight of 100 kg or more. These higher body weights were in particular found for the lower injury severities of MAIS 1 or 2. There are no riders having a body weight of less than 50 kg.

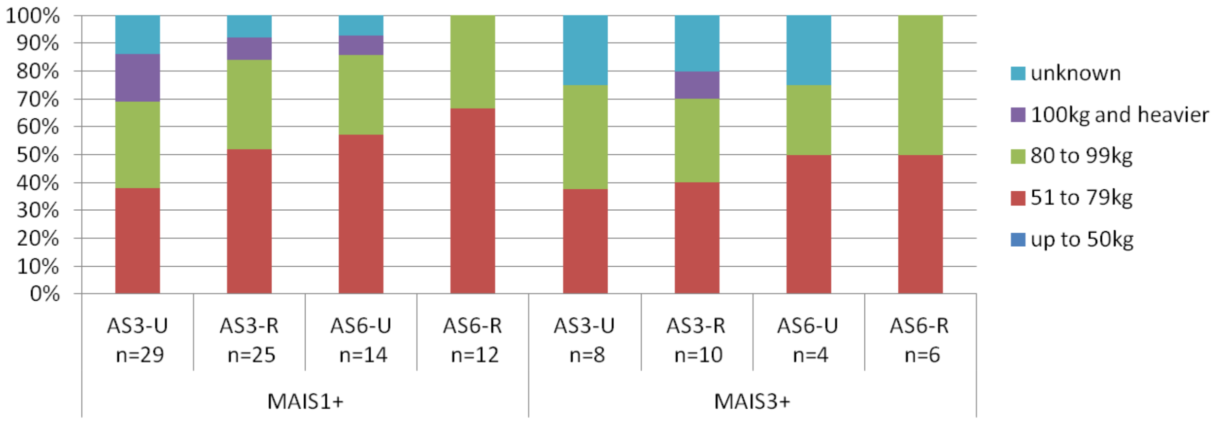

Figure 41: Sample characteristics – Body weight – EDA

The available NSW dataset comprised 62 MAIS 1+ and 27 MAIS 3+ injured casualties. The distribution related to body weight and AS3 and AS6 can be seen in Figure 42. Around 50-70% of all riders have a body weight of 80-99 kg in all Accident Scenarios except for AS3-U where the share of riders with body weights between 51 kg and 79 kg is considerably higher compared to other any other Accident Scenario. Around 10-30% of all riders have a body weight of 100 kg or more. These higher body weights were in particular found for the AS3, hence L3 vehicle accidents against cars (or light trucks). There are no riders having a body weight of less than 50 kg.

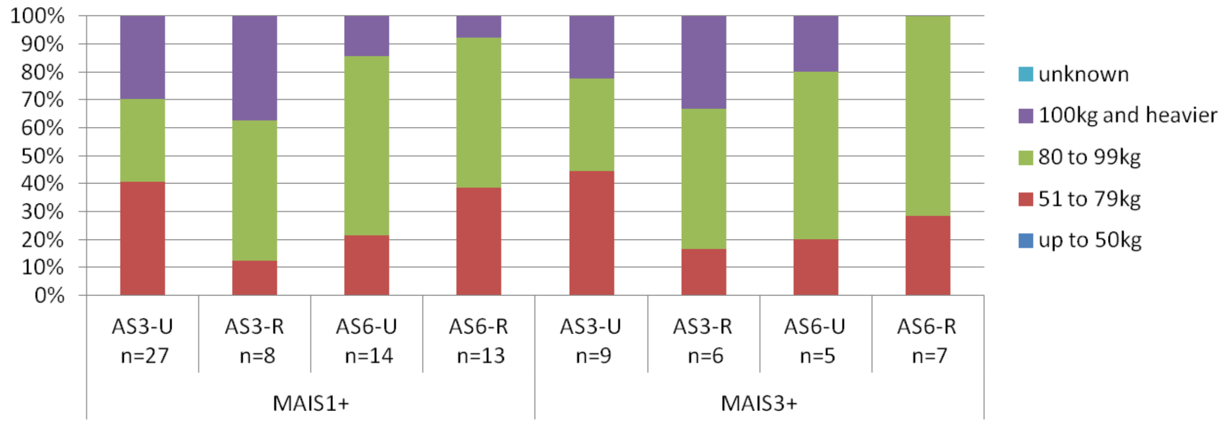

Figure 42: Sample characteristics – Body weight – NSW

4.3 Types of motorbikes

With the aim to address the design of specific PPE for each riding style, the distributions of PTW types were analysed for AS 3 and AS 6, hence, focusing on vehicles of category L3.

4.3.1 Types of motorbikes – PIONEERS definition

All available in-depth datasets contain the information about the specific PTW type involved in the respective accidents. However, these types differ greatly necessitating a common PIONEERS definition. The definition is based widely on the "OECD methodology" (OECD, 2008) and the coding system used by GIDAS, see Table 22.

The extended definitions of PTW types are herewith reported (adopted from OECD methodology):

- **Conventional street**, any L1 or L3 motorcycle that is of a conventional design where the rider is typically in a somewhat less marked forward crouch position during normal vehicle operation.
- **Sport**, any L1 or L3 vehicle which has drop handlebars, a small windscreen and an aerodynamic fairing. The rider is typically in a forward crouch position during normal vehicle operation.
- **Cruiser**, a motorcycle with upright or pulled back handlebars, and large fenders. These vehicles typically have large padded seats with a low seat height. The rider sits upright or slightly reclined during normal vehicle operation.
- **Chopper**, any L1 or L3 vehicle that has been modified with an extended front fork assembly. These vehicles are usually fitted with extended upright handlebars to accommodate a more reclined riding position.
- **Touring**, a motorcycle which is primarily designed for travel on highways or motorways. These motorcycles are fitted with side luggage compartments, rear cargo box and may or may not have trailers. There is also typically a large fairing windscreen on the front of the motorcycle.

- **Sport-touring**: any L1 or L3 vehicle that is of such a design that the operator remains in a forward inclined position while operating the vehicle.
- **Scooter**, any L1 or L3 vehicle equipped with floorboard for the rider's feet. The riding position is upright with the feet firmly planted on the floorboard.
- **Step-through**, any L1 or L3 vehicle which has an area between the steering head and the seat which slopes downwards from the steering head to an area located beneath the level of the seat. There is no floorboard present on a step-through motorcycle.
- **Enduro**, any L1 or L3 vehicle with block/trials universal or semi-knobby tires with or without high raised fenders. Since these vehicles are capable of both on road and off road use they will be fitted with signal lamps and other road safety features to make it legal for use on streets. Tire size is usually bigger than sport and conventional styles, and the saddle is generally long and narrow. The riding position is typically upright.

Table 22: PIONEERS type of motorbikes definition and examples

PIONEERS	OECD	GIDAS	*Example 1*	*Example 2*	*Example 3*
Chopper	Chopper	Chopper			
Enduro	Enduro	Enduro			
Touring	Touring Sport-touring	Tourer, Reisekrad			
Sport / Conventional	Sport Conventional street	Sportkrad			
Scooter	Scooter	Roller			

Others	Step-through	Mofa, PTW nfs			
	Cruiser				

4.3.2 L3 PTW types

The resulting distribution of L3 PTW types of the available data from France, Germany (LMU fatal cases) and Italy are shown in Figure 43 and compared with GIDAS and MAIDS data (Figure 44).

The GIDAS dataset, which is more nationally representative, shows that the Sport/Conventional style was the most frequently PTW type involved on urban and rural crashes and in crashes involving a car or a single PTW vehicle. This could also be seen in the MAIDS, LMU fatalities, EDA and IGLAD datasets. On the other hand, the “InSAFE” dataset showed that the scooter style was the most frequent PTW type involved in urban crashes even if the Sport/Conventional style was in the second position. Nonetheless, also EDA, LMU fatalities (excluding the category “others”) and IGLAD datasets show the scooter style in second position.

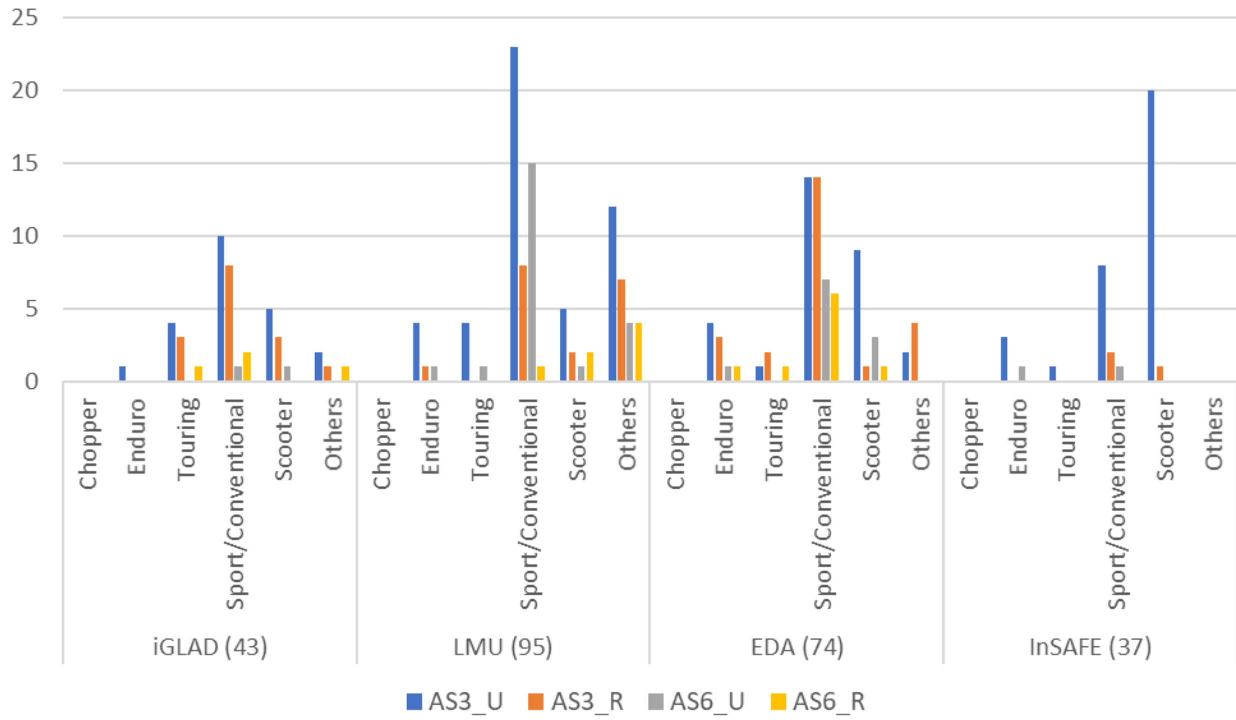

Figure 43: iGLAD, LMU, EDA and InSAFE L3 PTW types for AS 3 and AS 6

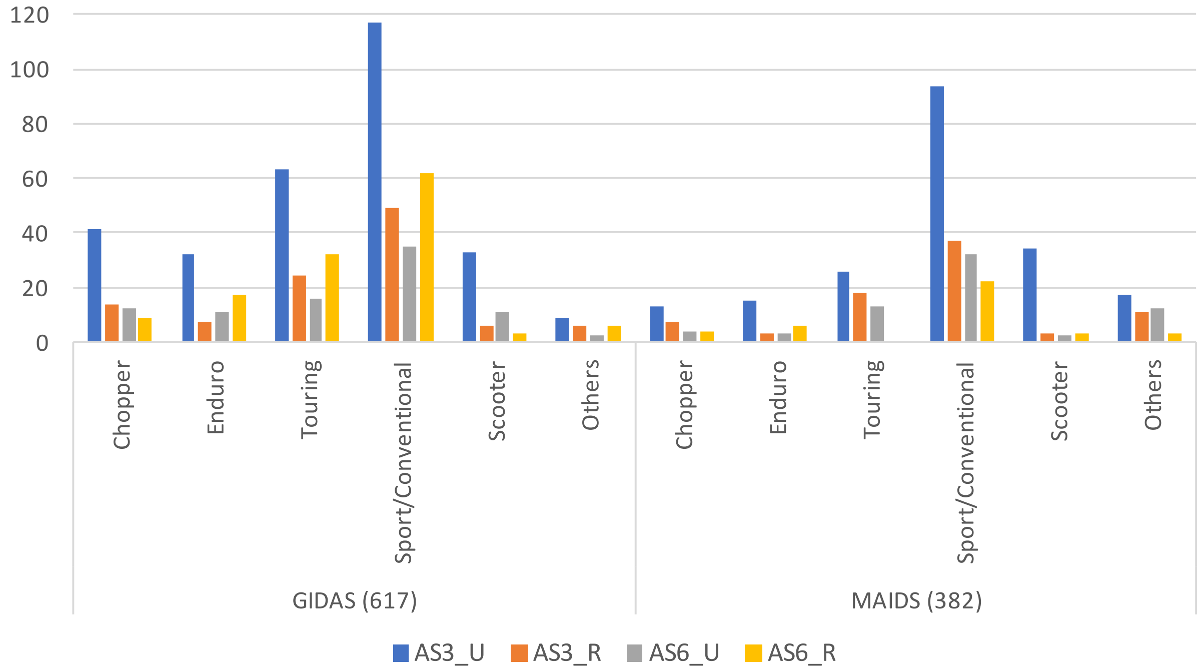

Figure 44: GIDAS and MAIDS L3 PTW types for AS 3 and AS 6

4.4 Collision parameters

4.4.1 Collision parameters definition

The collision parameters used in the conducted analyses have been defined according to (OECD, 2008) and (ISO 13232-2):

- **PTW Impact speed**, estimated by accident reconstruction techniques immediately prior to first PTW/OV contact [km/h or m/s].
- **PTW Output speed**, post impact speed estimated by accident reconstruction techniques immediately after the PTW/OV contact ended [km/h or m/s].
- **Opponent Vehicle (OV) Impact speed**, estimated by accident reconstruction techniques immediately prior to first PTW/OV contact [km/h or m/s].
- **Collision angle**, is the angle between the PTW x-axis and the OV x-axis measured in a clockwise direction from the PTW x-axis as viewed from above, immediately prior to first PTW/OV contact [degree] (See Figure 45).
- **Principal Direction of Force (PDOF)**, is the direction of the resultant crash force upon the subject vehicle
- **First PTW contact point**, see Figure 46.
- **First OV contact point**, see Figure 47.

- **Opponent type**, is the object type impacted by the PTW. The following categories were used:
    - **Car**, any passenger car, SUV or VAN
    - **Other**, any truck, bus, PTW, bicycle, pedestrian

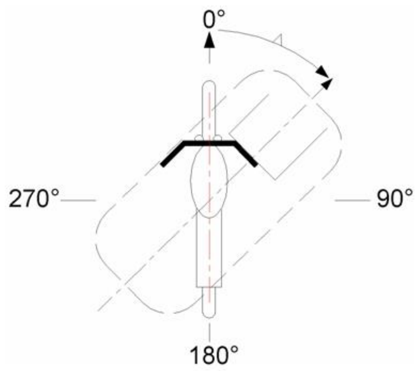

Figure 45: Collision angle

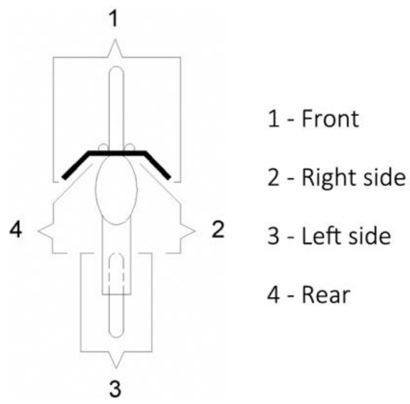

Figure 46: First PTW contact point

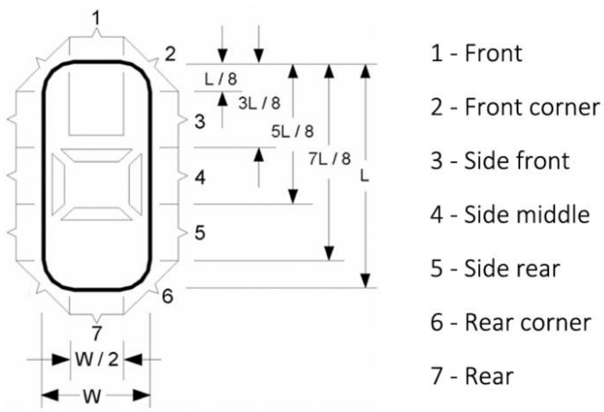

Figure 47: First OV contact point

This report describes the PTW and OW impact speed distributions in Accident Scenario 3 in Section 4.4.2.

Other collision parameters are detailed, among other sources, in the PIONEERS Deliverable 1.3 (to be published) and in (Wisch, et al., 2019 (to be published)).

4.4.2 PTW and OV impact speed in AS3 (L3 PTW vs. Car)

The resulting distribution of the L3 PTW and the OV impact speed of the available data from EDA, InSAFE and iGLAD databases for the AS3 are shown in Figure 48 and Figure 49. The dataset was based on 113 cases totally.

The PTW impact speed was often higher than the OV impact speed. Fifty-one percent of the PTWs (58/113) showed a crash speed between 30-60 km/h, while 71% (60/84, 29 unknown information) of the OVs showed an impact speed between 0-25 km/h.

L3 vehicles more frequently crashed with a speed ranging between 25-35 km/h and 45-60 km/h, while the OV more frequently crashed with a speed ranging between 10-25 km/h.

In urban crashes (AS3-U) (79 cases), PTWs showed the highest rate in the range between 40-60 km/h (35.5%) and in the range between 20-40 km/h (31.5%) (Figure 50). On the other hand, OVs more often showed to be involved in crashes at impact speed between 0-20 km/h (57.0%) (Figure 51).

In rural crashes (AS3-R) (34 cases), the rate of the PTWs impact speed was still in the range between 40-60 km/h (67.5%), followed by the range 20-40 km/h (26.5%) (Figure 52). The range 0-20 km/h was still the most frequent OV impact speed (Figure 53).

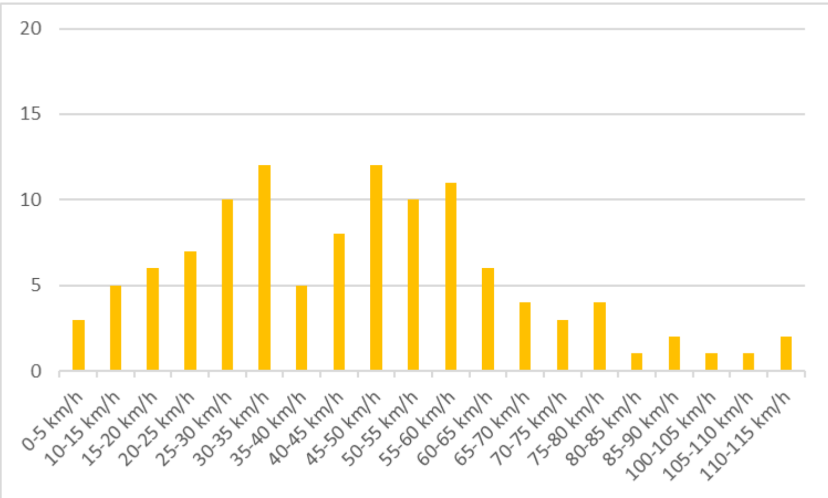

Figure 48: L3 PTW impact speed in the AS3 (113 cases)

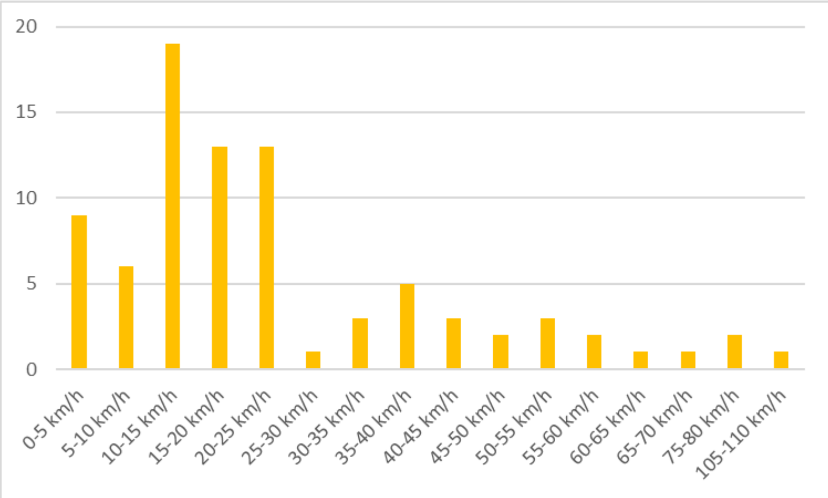

Figure 49: OV impact speed in the AS3 (113 cases)

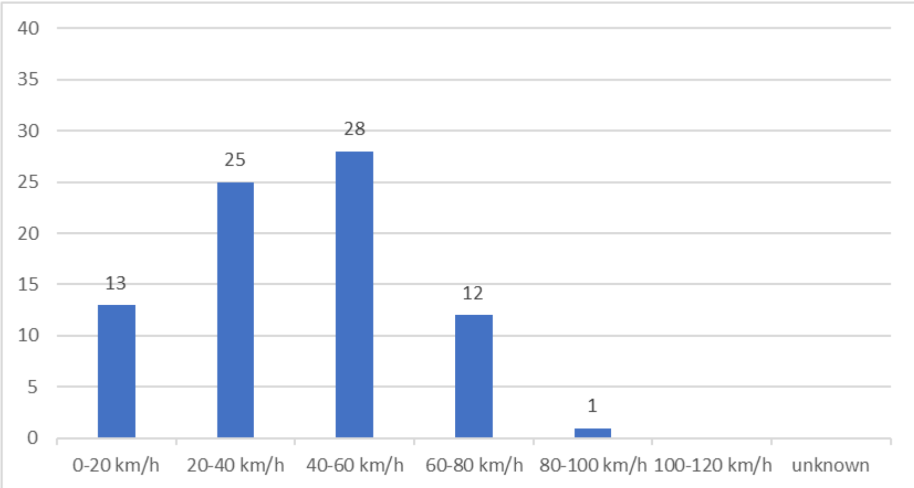

Figure 50: L3 PTW impact speed in the AS3 urban (79 cases)

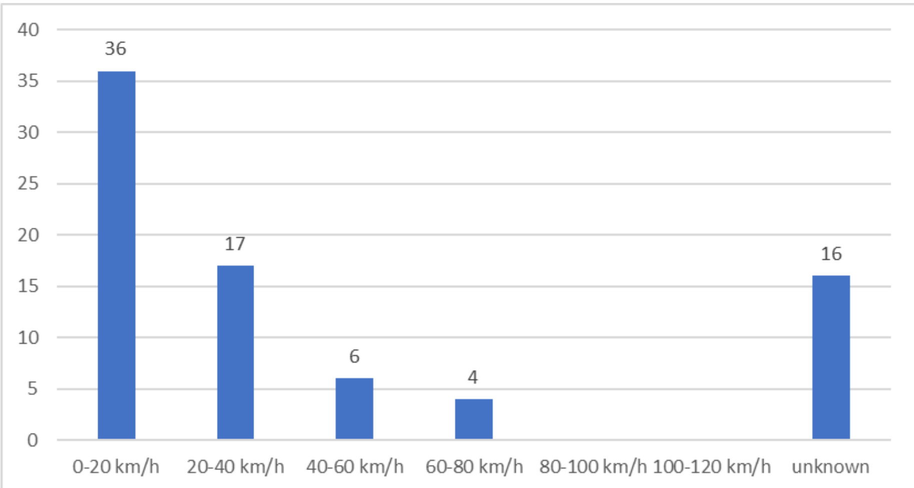

Figure 51: OV impact speed in the AS3 urban (79 cases)

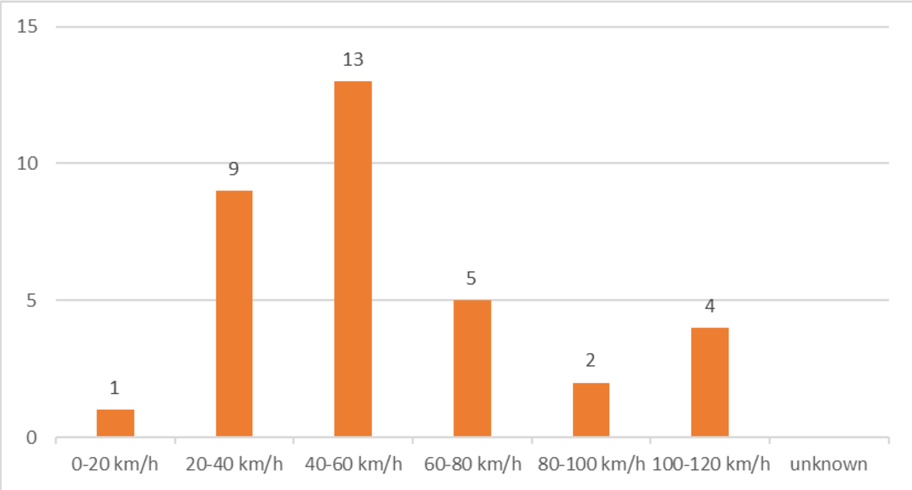

Figure 52: L3 PTW impact speed in the AS3 rural (34 cases)

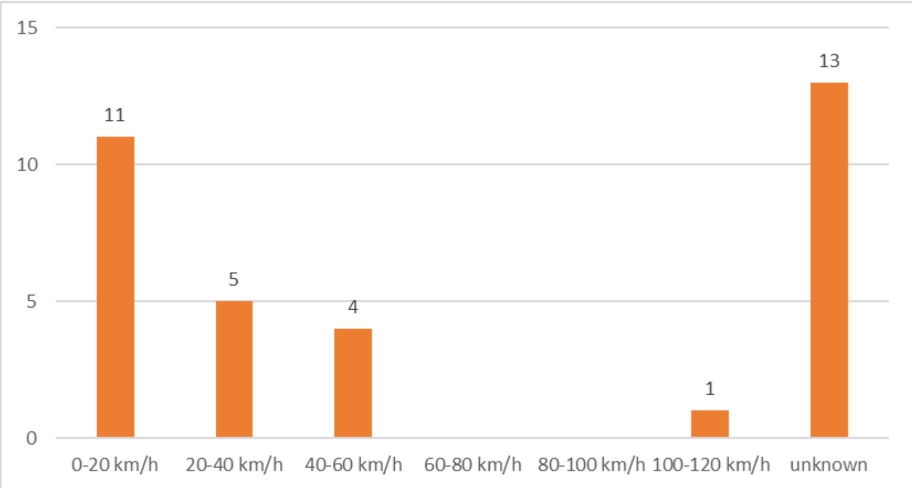

Figure 53: OV impact speed in the AS3 rural (34 cases)

4.5 Low-sider accidents

The NSW in-depth dataset was analysed to determine the proportion of low-sider crashes. A low-sider crash was defined by a single PTW loss of control crash precipitated by a loss of traction where the rider ejects from the PTW on the low side of the vehicle.

Within the NSW in-depth crash sample there were 5 confirmed low-sider crashes, representing 5.7% of the total crashes (87 crashes) and 18.5% of the single PTW crashes (27 AS6 crashes). Four out of the five low-sider crashes occurred in an urban setting and one occurred in a rural setting.

There was insufficient detail in the NSW in-depth crash sample to define the PTW speed or PTW trajectory prior to the loss of control.

4.6 Most common injuries

The in-depth datasets GIDAS, InSAFE, LMU fatalities, EDA and NSW have been analysed towards the most common injuries for all Accident Scenarios and for accidents involving L3 vehicles (against cars and single vehicle accidents) explicitly.

The injury data of the abovementioned datasets are documented by different AIS coding standards: AIS90, AIS98, AIS2005 update 2008, and AIS2015. As for the in-depth analysis it was more important to detect single injuries it was refrained from translating AIS codes to one compromise version with consequent losses of information. Table 23 shows the AIS injury coding standards which were used for analysis in the following Sections.

Table 23: AIS coding standard used for analysis by in-depth dataset

AIS coding	GIDAS	InSAFE	LMU fatalities	EDA	NSW
AIS 90				X	
AIS 2005 update 2008	X	X			X
AIS 2015			X		

4.6.1 Four- and six-digits AIS injury coding

To analyse the sustained injuries of the PTW riders and passengers more in detail, it has been decided to use the AIS coding and considering the PIONEERS' definition of body regions, see Section 2.2.

However, the counting of injuries is not trivial using the AIS codes as on the one hand a single slight but also a severe injury may be coded as one AIS injury each, meaning a complex injury is often covering other (individually slighter) injuries which are directly affected. As example, if three ribs were broken, you may count three individual injuries, but in terms of AIS coding this is one coded injury only. On the other hand, the counting of many slight single injuries may cause misinterpretations regarding the idea of ranking the most important injuries in the case of a severely (or fatally) injured casualty. Note: the complete AIS code (6 digits plus AIS injury severity coding: “xxxxxx.x”) was not conceived for such counting.

Therefore, the authors of this report decided to answer in two ways, if a request asks for “x most common injuries”. Firstly, the analysis should be run using the complete AIS code (6-digits) and count each AIS coded injury as many times as it appears in the respective dataset. Second, the analysis should focus on the first four digits of the AIS code by aggregating the results on person level, i.e., for example: two fractures of the femur are two single injuries; however, their 4-digit-AIS code is the same, hence this AIS code is only counted once. However, a limitation of this approach is that for example fractures of the left and right femur would be counted as one AIS coded injury only. Positively, this 4-digits approach helps avoiding any copyright issues with AIS©.

<u>Example</u>

Table 24 provides exemplarily, generic injury information of four persons A-D with five injuries each.

Table 24: Example for analysis with four- and six-digits AIS codes (for simplification, AIS coded injuries were replaced by generic injury codes.)

Person	Injury 1	Injury 2	Injury 3	Injury 4	Injury 5
A	A12345	**A45678**	A34567	**A45678**	**A45678**
B	**B12345**	**B12345**	B34567	B45678	B56789
C	C12345	**B12345**	**C45678**	**C45678**	**C45678**
D	D12345	D23456	D34567	D45678	D56789

Analysing the data regarding step 1 (6-digits) and step 2 (4-digits) results in the listings of Table 25 and Table 26, respectively.

Table 25: Example for 6-digits analysis

Number	"Injury Codes"		Number	"Injury Codes"		Number	"Injury Codes"
1	A12345		1	B45678		1	D23456
1	A34567		1	B56789		1	D34567
3	A45678		1	C12345		1	D45678
3	B12345		3	C45678		1	D56789
1	B34567		1	D12345			

Table 26: Example for 4-digits analysis (per row aggregation on person level; total number of injuries of this dataset is 14 (instead of 15) since the injury "B123" is available twice)

Person	„Injury Codes" (4-digits)					No. of injuries
A	A123	A345	**A456**	-	-	3
B	**B123**	B345	B456	B567	-	4
C	C123	B123	**C456**	-	-	3
D	D123	D234	D345	D456	D567	5

4.6.2 Per body region

Each dataset has been analysed towards the individual injuries per PIONEERS body region, see Section 2.2.3. As all datasets are based on accident inclusion criteria related to higher injury severities, a comparison of the different body regions was done based on injuries with a severity of at least AIS 2 or higher and is summarized for the dataset LMU Fatalities, InSAFE and GIDAS in Table 27. It can be seen that the results are quite different between the datasets.

For example, 96% of the injuries in the Thorax&ThoracicSpine body region of the (killed) casualties of the LMU fatalities dataset had an AIS injury severity of at least AIS 2 and hence, were ranked as being most important. Overall, the results of the LMU fatalities and the InSAFE datasets show similar trends. GIDAS results differ which can be explained by the fact that many slightly injured PTW riders are part of the dataset. Nevertheless, the following four body regions can be highlighted throughout all three datasets: Thorax&TS, Head&Face, UpperExtremities and LowerExtremities.

Table 27: Share of patients with AIS 2+ injuries per body region ("n" refers to the number of casualties available for this analysis)

Body region	LMU fatalities (n=143) Rank / Percentage	InSAFE (n=58) Rank / Percentage	GIDAS (n=982) Rank / Percentage
Head&Face	**2 / 80%**	**2 / 57%**	4 / 14%
Neck&CS	6 / 49%	6 / 19%	7 / 5%
Thorax&TS	**1 / 96%**	**1 / 88%**	**3 / 19%**
Abdomen&LS	**3 / 73%**	4 / 40%	5 / 8%
UpperExtremities	4 / 61%	**3 / 41%**	**2 / 35%**
Pelvis	7 / 38%	7 / 14%	6 / 7%
LowerExtremities	5 / 51%	5 / 31%	**1 / 37%**

4.6.3 AIS 1+ injuries, 4-digits

Each dataset has been analysed towards the individual top ten injuries (4-digit coding), see Section 4.6.1, and per PIONEERS Accident Scenarios (All and AS3+AS6 separately), see Section 2.1.2.

Consequently, Table 28 shows the top ten most common AIS 1+ injuries (4-digits) of PTW riders recorded in GIDAS including Accident Scenarios 1-6. Table 29 shows the same approach but the underlying data was reduced to L3 vehicle riders assigned to the Accident Scenarios 3 and 6 to highlight the priorities for this PTW group. It can be seen that both tables confirm the priorities identified for GIDAS in Section 0.

Table 28: GIDAS – Top ten most common injuries (4-digits), All Accident Scenarios

		AIS1+, AIS 4-digits, ALL AS	N.
10 most common injuries Total (based on 1,042 people)	8104	Lower Ext Skin/subcutaneous/muscle contusion; hematoma	280
	8102	Lower Ext Skin/subcutaneous/muscle abrasion	277
	7102	UpperExt Skin/subcutaneous/muscle abrasion	218
	1610	Cerebral Concussion and DAI	211
	7104	UpperExt Skin/subcutaneous/muscle contusion; hematoma	187
	4104	Thorax Skin/subcutaneous/muscle contusion; hematoma	142
	4502	Rib Cage	137
	8544	Fibula [Malleoli] fracture	90
	4414	Lung	88
	8106	Lower Ext Skin/subcutaneous/muscle laceration	88

Table 29: GIDAS – Top ten most common injuries (4-digits), Accident Scenarios 3+6

		AIS1+, AIS 4-digits, Total of AS3+AS6	N.
10 most common injuries Total (based on 655 people)	8104	Lower Ext Skin/subcutaneous/muscle contusion; hematoma	164
	8102	Lower Ext Skin/subcutaneous/muscle abrasion	145
	1610	Cerebral Concussion and DAI	131
	7102	UpperExt Skin/subcutaneous/muscle abrasion	121
	7104	UpperExt Skin/subcutaneous/muscle contusion; hematoma	116
	4104	Thorax Skin/subcutaneous/muscle contusion; hematoma	106
	4502	Rib Cage	99
	8106	Lower Ext Skin/subcutaneous/muscle laceration	61
	4414	Lung	58

Table 30: InSAFE – Top ten most common injuries (4-digits), All Accident Scenarios

		AIS1+, AIS 4-digits, ALL AS	N.
10 most common injuries Total (based on 56 people)	4414	Lung	38
	4502	Rib cage	30
	1406	Cerebrum	28
	4422	Haemothorax	22
	1502	Base	16
	6504	Disc, thoracic spine	15
	2512	Orbit	12
	2518	Zygoma	11
	5442	Spleen	11
	9102	Soft tissue injury, abrasion	11

Table 31: InSAFE – Top ten most common injuries (4-digits), Accident Scenarios 3+6

10 most common injuries / Total (based on 37 people)	AIS1+, AIS 4-digits, Total of AS3+AS6		N.
	4414	Lung	24
	1406	Cerebrum	19
	4502	Rib cage	19
	4422	Haemothorax	14
	1502	Base	10
	2512	Orbit	9
	6504	Disc, thoracic spine	9
	9102	Soft tissue injury, abrasion	8
	5442	Spleen	7
	7509	Scapula	7

Table 32: LMU fatalities – Top ten most common injuries (4-digits), All Accident Scenarios

10 most common injuries / Total (based on 142 people)	AIS1+, AIS 4-digits, ALL AS		N.
	4502	Rib Cage	117
	8102	Lower Ext Skin/subcutaneous/muscle abrasion	112
	4422	Thoracic injury, Haemothorax	107
	7102	UpperExt Skin/subcutaneous/muscle abrasion	104
	1406	Cerebrum	99
	4414	Lung	97
	7104	UpperExt Skin/subcutaneous/muscle contusion; hematoma	90
	8104	Lower Ext Skin/subcutaneous/muscle contusion; hematoma	82
	1104	Scalp contusion	80
	5418	Liver	74

Table 33: LMU fatalities – Top ten most common injuries (4-digits), Accident Scenarios 3+6

10 most common injuries / Total (based on 98 people)	AIS1+, AIS 4-digits, Total of AS3+AS6		N.
	4502	Rib Cage	79
	4422	Thoracic injury, Haemothorax	77
	8102	Lower Ext Skin/subcutaneous/muscle abrasion	75
	7102	UpperExt Skin/subcutaneous/muscle abrasion	70
	1406	Cerebrum	67
	4414	Lung	67
	7104	UpperExt Skin/subcutaneous/muscle contusion; hematoma	60
	8104	Lower Ext Skin/subcutaneous/muscle contusion; hematoma	60
	2104	Face Skin/subcutaneous/muscles contusion; hematoma	52
	5418	Liver	52

Table 34 shows the top ten most common AIS 1+ injuries (4-digits) of PTW riders recorded in EDA including Accident Scenarios 1-6. Table 35 shows the same approach but the underlying data was reduced to L3 vehicle riders assigned to the Accident Scenarios 3 and 6 to highlight the priorities for this PTW group.

Table 34: EDA – Top ten most common injuries (4-digits), All Accident Scenarios

	AIS1+, AIS 4-digits, ALL AS		N.
10 most common injuries Total (based on 102 people)	8102	Lower Ext Skin/subcutaneous/muscle abrasion	43
	7102	UpperExt Skin/subcutaneous/muscle abrasion	30
	8104	Lower Ext Skin/subcutaneous/muscle contusion; hematoma	14
	8508	Knee	14
	8106	Lower Ext Skin/subcutaneous/muscle laceration	12
	1604	Consciousness	11
	4502	Rib Cage	9
	8502	Ankle	9
	6402	Cervical spine, Cord contusion/laceration	7
	2106	Wound	6

Table 35: EDA – Top ten most common injuries (4-digits), Accident Scenarios 3+6

	AIS1+, AIS 4-digits, Total of AS3+AS6		N.
10 most common injuries Total (based on 61 people)	8102	Lower Ext Skin/subcutaneous/muscle abrasion	22
	7102	UpperExt Skin/subcutaneous/muscle abrasion	12
	8508	Knee	10
	8106	Lower Ext Skin/subcutaneous/muscle laceration	9
	6402	CS Cord contusion/laceration	6
	7510	Shoulder	6
	8104	Lower Ext Skin/subcutaneous/muscle contusion; hematoma	6
	8502	Ankle	6
	1604	Consciousness	5
	4502	Rib Cage	5

Table 36: NSW – Top ten most common injuries (4-digits), All Accident Scenarios

	AIS1+, AIS 4-digits, ALL AS		N.
10 most common injuries Total (based on 92 people)	8102	Abrasion	49
	7102	Abrasion	33
	7104	Hematoma	33
	8104	Hematoma	33
	4502	Rib cage	22
	8544	Fibula	14
	8561	Pelvic ring	14
	4414	Lung	12

It needs to be acknowledged, that abrasions and contusions occur to more or less all patients, independent of their overall injury severity. For preventing KSI AIS3+ injuries need to be addressed. However, the overview shows that protective clothing for preventing AIS1 injuries like abrasions should cover the lower extremities first, followed by the upper extremities.

4.7 Performance of helmets

PIONEERS partners investigated the performance of helmets regarding the following three major questions:

1) Which helmet areas show most frequently damages / contact points?
2) Which types of damages occur and where on the helmet?

4.7.1 Helmet contact areas

As basis for the analyses a common helmet area coding scheme could be identified for the datasets EDA, GIDAS, InSAFE and NSW, see Figure 54.

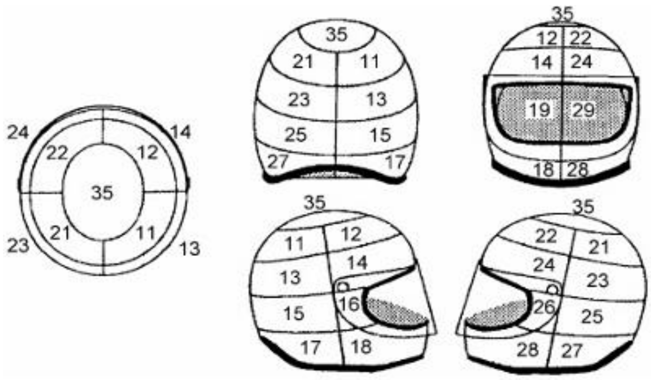

Figure 54: Coding scheme of helmet areas used in EDA, GIDAS, InSAFE and NSW (ACEM, 2009)

The resulting distribution of helmet contact areas of the available data from France, Germany, Italy and Australia for all AS is shown in Figure 55. It can be seen that all areas are hit but the areas 13-15, 18-19, 23-26 and 28 are affected most frequently. Note: helmet contact areas could mostly only be identified by any kind of damage, including traces of wiping, to the helmet.

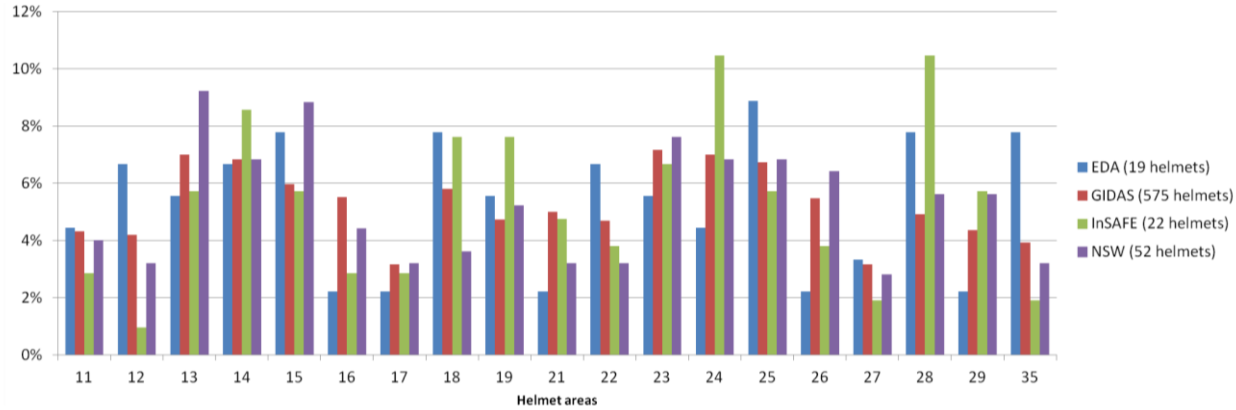

Figure 55: Distribution of helmet contact areas (EDA, GIDAS, InSAFE, NSW)

Data from the dataset LMU fatalities are based on a different coding scheme, see Figure 56. The distribution of the related contact regions is shown in Figure 57. It can be seen that the regions 6, 8, 9 and 17 were impacted most frequently which is in line with the findings above.

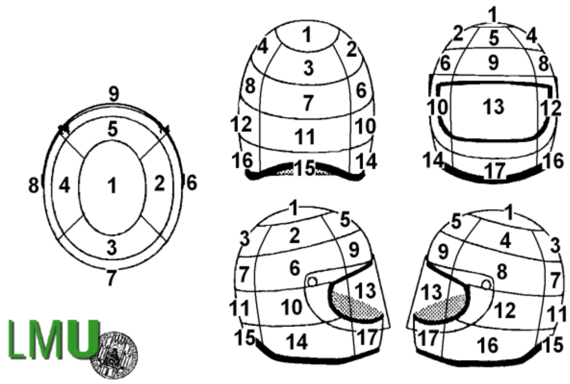

Figure 56: Coding scheme of helmet areas used in "LMU fatalities"

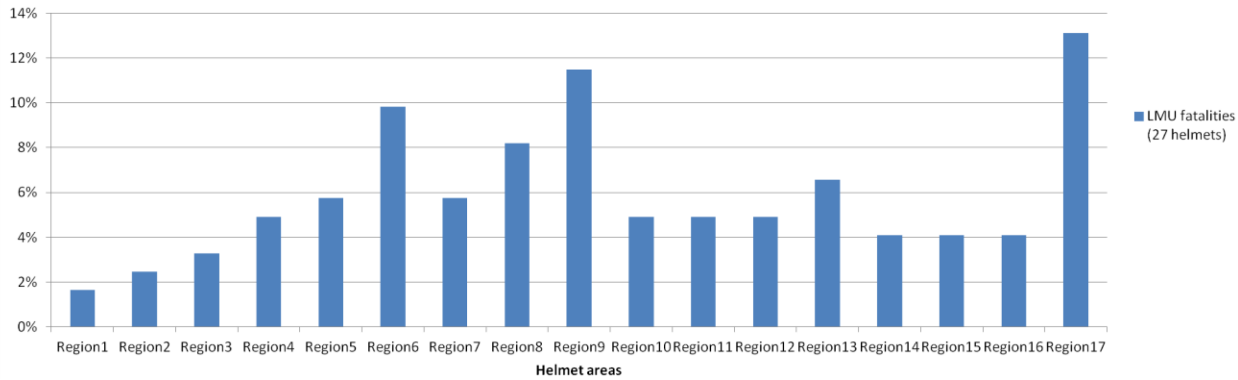

Figure 57: Distribution of helmet contact areas (LMU fatalities)

4.7.2 Helmet damages on outer shell

Helmet damages have been identified according to the categories summarized in Table 37 and based on the helmet contact areas introduced in Section 4.7.1. Note: the Australian NSW dataset included a few times information on tyre marks. If any, these damages have been added to the group "delamination". "Delamination" is not coded in GIDAS.

Table 37: Helmet damage types on outer shell and examples

Damage type	**Example 1** (pictures from (Thomas, 2009))	**Example 2**	**Example 3**
Abrasion, scuff, scratch			
Crack, fracture			
Delamination			

Figure 58 shows the comparison of the results from the datasets EDA, GIDAS, InSAFE and NSW related to the distributions for abrasions. It can be seen that abrasions were found most often in the helmet areas 13-15, 18-19, 23-25 and 28-29 which is in line with the findings above.

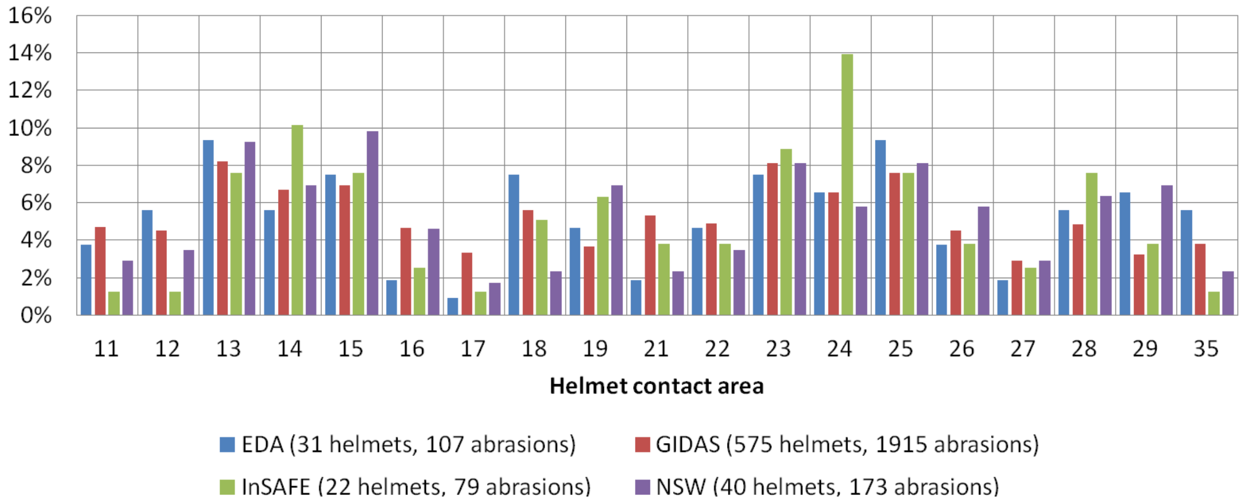

Figure 58: Helmet damages on outer shell - abrasions per helmet area

Figure 59 shows the comparison of the results from the datasets EDA, GIDAS, InSAFE and NSW related to the distributions for cracks/fractures. It can be seen that cracks/fractures occur most often in the helmet areas 18, 19, 28 and 29.

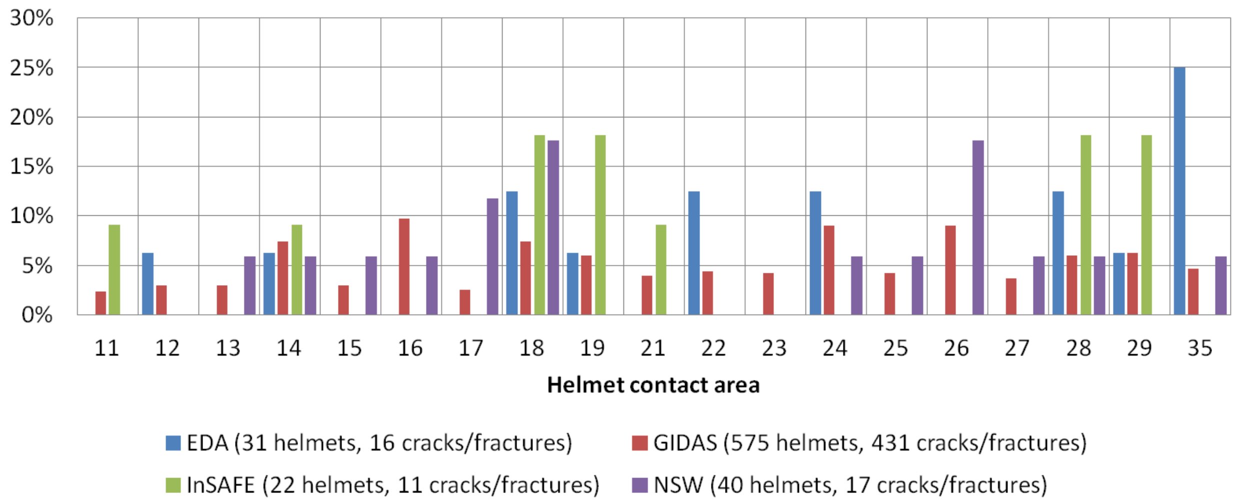

Figure 59: Helmet damages – cracks/fractures per helmet area

Figure 59 shows the comparison of the results from the datasets EDA, GIDAS, InSAFE and NSW related to the distributions for delamination (note: GIDAS has no special coding on delamination damages). It can be seen that delamination occurs most often in the helmet areas 13, 14, 18, 22 and 35.

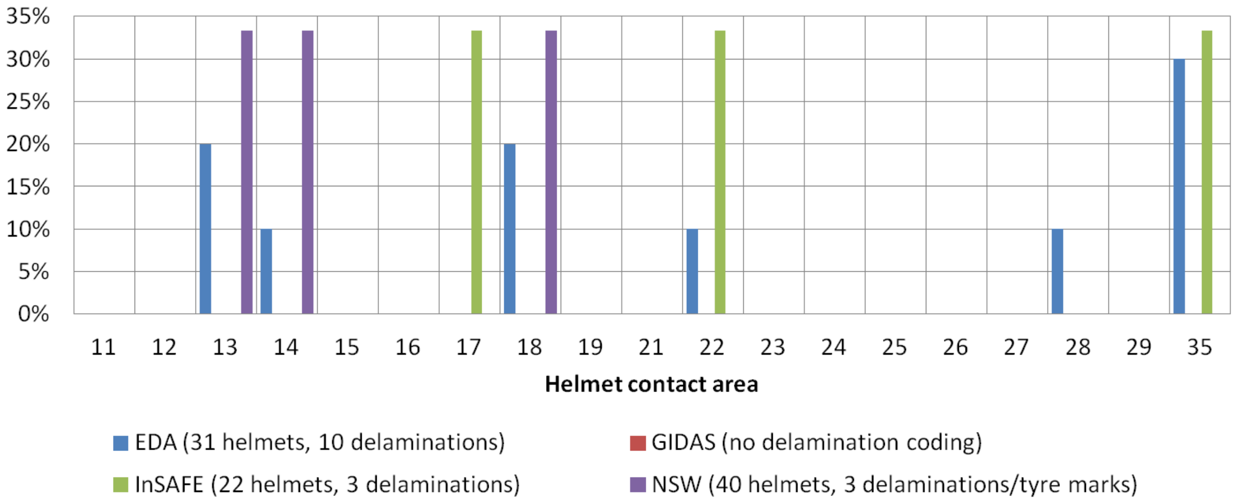

Figure 60: Helmet damages – delamination per helmet area

5 Comparison of crashes and rider injuries in Australia and Europe

PTWs are used for a range of different purposes in different parts of the world. In many large European cities, PTWs are commonly used for commuting while in countries such as the US and Australia, recreation is a more prevalent reason for riding (Harrison, et al., 2005) (Haworth, 2012). National differences in PTW fleets, road characteristics and environmental risk factors can influence PTW crash characteristics and how riders are injured. Identifying similarities and differences in the profile of PTW crashes and resulting injury patterns is important for identifying globally relevant countermeasures. Here we compared PTW crash scenarios, rider demographics and injuries sustained in Australia and four European countries.

5.1 Method

PTW crash data were extracted from national or regional crash databases, specifically DESTATIS (Germany), ISTAT (Italy), BAAC (France), DGT (Spain) for years 2014-2016 and the NSW Centre for Road Safety (NSW, Australia) for years 2015-2017, see also Chapter 2. Crashes were classified as occurring in a rural or urban environment and whether the crash occurred at an intersection, a straight (non-intersection) or a curved (non-intersection) section of roadway. Crashes were also divided by PTW type (L1, engine <50 cc and max speed <50 km/h, and L3, engine >50 cc or max speed >50 km/h) and crash participants (single PTW crashes, versus one passenger car and versus one other vehicle type; more than two participant crashes were excluded). Three injury outcomes were examined: a killed casualty; at least one seriously injured casualty, but no one killed; and, at least one slightly, but not seriously or fatally injured.

Further data were collected from in-depth crash investigation datasets, specifically InSAFE (Italy), EDA (France), LMU fatalities (Germany), GIDAS (Germany), IGLAD (international) and NSW in-depth crashes (NSW, Australia) databases, see also Section 2.5. These in-depth databases have different specialisations. For example, the NSW in-depth crashes dataset was collected to identify the causes and consequences of crashes resulting in hospitalization whereas the LMU dataset is made up of fatal cases with autopsy data. In the same manner as the national statistics, crashes were classified as rural/urban and based on PTW type and crash participants. Rider demographics by gender, age (1-15, 16-35, 36-50, 50+ years) and stature (<160, 161-180, 180+ cm) were compared. PTW type comparisons were based on the following categories: cruiser, dual purpose, general purpose/conventional street, off-road/enduro, scooter/step-through/maxi scooter, sports and touring. The most common AIS 2+ injuries in each in-depth dataset were identified and further divided by crash scenario and by body region. Data is descriptively compared between different jurisdictions.

5.2 Findings

In NSW, Australia, the incidence of L1 type vehicles is very low. As a result, the national statistics comparisons involve only L3 type vehicle riders and crash characteristics. Rural PTW crashes with two participants were the most prevalent type of crash resulting in fatalities in NSW, Australia (32%), Germany (51%) and France (41%) while rural single PTW crashes were the most prevalent fatal crash type in Spain (39%) and urban PTW crashes with two participants predominate in Italy (38%). When considering crashes with at least one seriously injured casualty, but no one killed, the most prevalent crash type was in an urban environment with two participants for all countries (NSW, Australia 45%, Germany 31%, France 51%, Spain 40%, Italy data not available). With respect to the road environment, fatal rural crashes typically occurred at a non-intersection location for all countries while fatal urban crashes most commonly occurred at intersections (Australia and Germany) or straight roadway sections (France and Italy), see Figure 61. For serious injury crashes, the most prevalent single road environment category was urban intersections for NSW, Australia (35%), Germany (25%) and Spain (26%) while in France the most common single category was urban crashes on a straight road (29%).

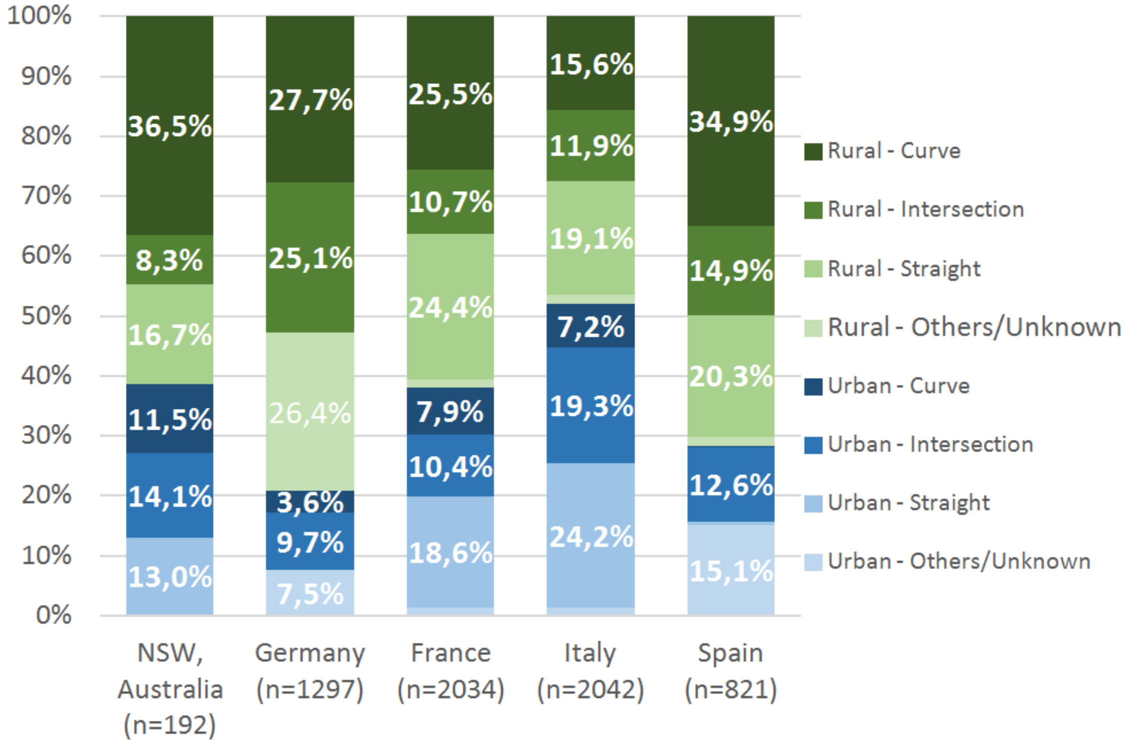

Figure 61: Distribution of crash configuration for fatal crashes in years 2014-2016 involving PTWs by rural/urban and road environment. For Germany, straight roads are included within the others/unknown designation.

PTW riders in the in-depth crash datasets were predominately male (NSW 94%, EDA 87%, LMU 94%, InSAFE 100%), 16-35 years of age (NSW 56%, EDA 43%, LMU 37%, InSAFE 58%) and were 161-180 cm tall (NSW 54%, EDA 57% of known cases, LMU 71%, InSAFE 92%). Sports style PTWs were most common within Australian data, most prevalently involved in an urban crash with a passenger car (47%). Scooter, step-through or maxi scooter PTWs were the largest group in the Italian InSAFE data (57%) and were also most often involved in crashes with another vehicle in an urban setting (95%).

Injury to the rib cage and lungs were among the five most common injuries within NSW, LMU, GIDAS and InSAFE data (Figure 62). Fractures to the pelvic ring and fibula were among the most common in NSW and GIDAS, while haemothorax and cerebrum injuries were prevalent within LMU fatalities and InSAFE.

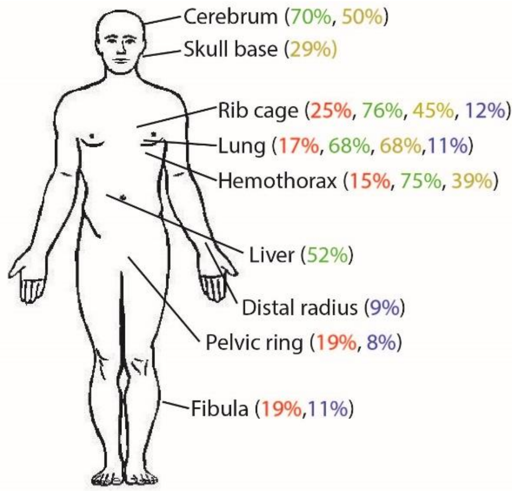

Figure 62: Five most common AIS 2+ injured body parts within in-depth crash databases showing percentage of victims sustaining each injury from NSW (red), LMU fatalities (green), InSAFE (yellow) and GIDAS (blue).

5.3 Discussion

It is difficult to discern whether the comparisons made in this study are reflective of similarities and differences between countries due to difficulties harmonizing category definitions (for example urban/rural and road environment designations) as well as different specialisations of in-depth crash data available in each nation. We are continuing to compile data to allow close comparison of the characteristics and definitions in each dataset. Nevertheless, this study suggests that while Australian riders appear to prefer a different style of PTW (sports) compared to Europe (scooter), the most prevalently injured population sex, age and height are the same in all countries. Rib and lung injuries were among the most common AIS 2+ injuries in all analysed in-depth databases indicating priorities for a PIONEERS focus. The identified prevalence of urban, two-participant crashes at intersections resulting in serious injuries to PTW riders in all countries points to priority accident scenarios for further analysis in PIONEERS.

6 Summary of key findings

6.1 European compilation of accident data (CARE)

- CARE does not allow specific analyses regarding vehicles of categories L1 or L3, therefore, the classifications of “moped” and “motorcycles” have been used instead.
- PTW users account for 17% of all killed road traffic participants
- 88% of moped and 94% of motorcycle riders fatalities were males
- The fatality rates for PTWs’ users are high especially for young riders, aged 15-17 for moped riders and aged 18-24 as well as above 50 years for motorcycle riders
- The majority of moped fatalities occurred in urban areas, whereas the majority of motorcycle fatalities occurred in rural areas.
- The wide range in the distribution of PTW fatalities by area and road type mostly reflects the different share of mopeds and motorcycles in a country.
- Accident Scenario 3 (L3 vs. car) is of highest importance, followed by AS6 (single L3 accidents and AS1 (L1 vs. car). With that, CARE shows comparable results to those gained by the analysis on national level.

6.2 National statistics

- Nearly all countries use country-specific definitions; therefore, comparisons have to be considered with care. Especially, Australia uses different definitions for many variables.
- Similar findings for France, Italy, Spain and Germany regarding Accident Scenarios 1-6
- Most frequent: AS3 (L3 vs. passenger car) and AS6 (L3 single accidents)
- Accidents against passenger cars dominant in rural and urban areas, with most occurring at intersections
- Single L3 accidents are dominant on rural roads with a curve/bend and straight urban roads
- Considering the absolute number of cases, PIONEERS Use Case 2 is more important than Use Case 1 regarding traffic safety
- A few differences are seen comparing accidents with at least one killed person and accidents with at least one killed or seriously injured person (KSI)

6.3 In-depth data

All datasets show biases compared with their national statistics. GIDAS is closest to its national statistics. All datasets are based on individual investigation criteria.

6.3.1 Body regions being relevant for PTW

The comparison of GIDAS, InSAFE, LMU, and NeuRA data showed that especially the KSI casualties suffer from thorax injuries in around 90%, with rib cage injuries between 45% and 76% and lung injuries in about 68% of the KSI. Next relevant is the head with 57% to 80% of KSI suffering from injury in that body region, with a share of 60% to 70% showing injury to the brain.

For the GIDAS and NeuRA data which contain a higher share of slightly injured PTW riders, the body regions of relevance are the upper and lower extremities followed by the thorax. In these areas the most frequent body parts injured are also the rib cage, followed by comparable shares for pelvic bone, fibula and distal radius fractures.

6.3.2 Inner structure

Most frequent: accidents between one L3 and one passenger car, followed by L3 single accidents. Overall, urban accidents dominate.

6.3.3 Sample characteristics of accidents involving L3 vehicle(s)

Sex:

- Around 90% of all injured L3 vehicle riders were male. This share is even higher for higher injury levels (MAIS 3+).
- Higher injury severities were found on rural roads for both sexes.
- Most often accidents were assigned to AS3-U or AS3-R for both sexes, hence accidents involving one L3 vehicle and a passenger car on urban or rural roads.

Age:

- Most often the shares of the age groups varied considerably with respect to the different Accident Scenarios.
- Generally, around 50% of all casualties were between 16 and 35 years old and another share of around 25-30% were aged 36-50 years in nearly all Accident Scenarios.
- In accidents against cars (AS3), young (16-35 years) and mid-aged riders (36-50 years) dominate clearly compared to older riders (51+ years).
- Single L3 vehicle accidents are dominated by the age group of 16-35 years with around 50%.
- Older riders (51 years or more) were injured in around 20% of all accidents and most often involved in L3 single vehicle accidents, but also closely following in accidents against passenger cars. Generally, older riders (51 years or more) were seen more often in accidents on rural roads.

- There are nearly no riders injured in on-road crashes below the age of 16.
- There is almost no age difference between the groups of MAIS 1+ and MAIS 3+ injured riders.

Body height:

- At least 50% of all riders were between 161 and 180 cm tall among nearly all Accident Scenarios. This share is higher in South European countries.
- The share of riders being taller than 180 cm is around 10-25%.
- In L3 single vehicle accidents (AS6) riders being taller than 180 cm were recorded more often being injured compared to smaller riders.
- Almost no difference regarding the riders' body heights could be seen comparing the different injury severity groups (MAIS 1+ and MAIS 3+).
- There are only a few riders below 161 cm in stature.
- Comparing the different datasets, the share of no knowledge about the body height is about 25% in average.

Body weight:

- Comparing the different datasets, the share of no knowledge about the body weight is about 25% in average.
- Independently from any distinction between the Accident Scenarios around 30-50% of all riders had a body weight of 51-79 kg and around 35-50% of all riders had a body weight of 80-99 kg, hence both body weight groups show comparable proportions. Around 15% of all riders have a body weight of at least 100 kg.
- Almost no differences were found comparing the injury severity groups and body weight distributions.
- On-road injured riders with a body weight of less than 51 kg are rare.

6.3.4 Types of motorbikes

GIDAS shows that the Sport/Conventional style was the most frequently PTW type involved on urban and rural crashes and in crashes involving a car or a single PTW vehicle. This could also be seen in the MAIDS, LMU fatalities, EDA and IGLAD datasets. On the other hand, the InSAFE dataset showed that the scooter style was the most frequent PTW type involved in urban crashes even if the Sport/Conventional style was in the second position. Nonetheless, also EDA, LMU fatalities (excluding the category "others") and IGLAD datasets show the scooter style in second position.

6.3.5 Collision parameters in L3-to-Car (AS3) crashes

- Overall the passenger car impact speed was lower than the PTW impact speed.
- Fifty-one percent of the PTWs showed a crash speed between 30-60 km/h.

- Seventy-one percent of the OVs showed an impact speed between 0-25 km/h.
- L3 vehicles more frequently crashed with a speed ranging between 25-35 km/h and 45-60 km/h.
- The OV more frequently crashed with a speed ranging between 10-25 km/h.
- Both in urban (AS3-U) and rural (AS3-R) roads
  - PTWs showed the highest impact speed rate in the range between 40-60 km/h (35.5%, 67.5%) and in the range between 20-40 km/h (31.5%, 26.5%).
  - OVs more often showed to be involved in crashes at impact speed between 0-20 km/h (57.0%, 52.0%).
- In urban crashes (AS3-U), about one-third (34%) of the PTWs had an impact speed above the typical speed limits. The PTW high speed looks to be an important factor in terms of injury outcome, especially if a possible pre-crash braking is considered.

6.3.6 Most common injuries

The following four body regions can be highlighted throughout the analysed datasets: Thorax&TS, Head&Face, UpperExtremities and LowerExtremities.

At least moderate injuries (AIS 2+) were most frequently found in the thorax (rib cage, lung, and haemothorax), the brain, and abrasions of severity AIS 1 were most frequently found in the lower extremities, followed by the upper extremities.

It needs to be acknowledged, that abrasions and contusions occur to more or less all patients, independent of their overall injury severity. For preventing KSI AIS 3+ injuries need to be addressed. However, the overview of injuries shows that protective clothing for preventing AIS 1 injuries like abrasions should cover the lower extremities first, followed by the upper extremities.

6.3.7 Performance of helmets

The analysis of several in-depth databases from France, Germany, Italy and Australia for all AS revealed that all helmet areas are hit but the areas 13-15, 18-19, 23-26 and 28 are affected most frequently, i.e. left and right side of the face and back of the head as well as the left chin area.

Abrasions on the helmets were found most often in the helmet areas 13-15, 18-19, 23-25 and 28-29 which is in line with the general findings and including the right side of the chin. Cracks/fractures occur most often in the helmet areas 18, 19, 28 and 29, i.e., the chin and helmet visor area.

6.4 Comparison of accident occurrence and rider injuries in Europe and Australia

While it is difficult to carry out direct comparisons between European and Australian accident occurrence and rider injuries due to difficulties harmonizing category definitions and different specialisations of in-depth crash data available in each jurisdiction, a number of discernible characteristics were observed. Australian riders appear to prefer sports style of PTWs with very little representation of scooter style PTWs while scooter, step-through or maxi-scooter type

PTWs were more prevalent in Europe. However, the most common demographics of riders injured in crashes, in terms of sex (male), age (16-35 years of age) and height (161-180 cm tall), is the same in all analysed countries. Rib and lung injuries were among the most common AIS 2+ injuries across both Australian and European databases. Urban two-participant crashes at intersections were a prevalent cause of serious injuries to PTW riders in all countries, pointing to a priority accident scenario for further attention.

7 Conclusions

Comprehensive literature review has been performed related to analyses of road traffic accidents involving powered two-wheelers. It became obvious that many projects, in particular European research projects by the EU, studies from French and Italian research institutes and from Australia have been working on this topic; however, results can hardly be compared since the definitions of many variables vary, different injury coding are used and all analysed in-depth accident datasets are based on greatly differing inclusion criteria. The PIONEERS project took this burden and established definitions for relevant Accident Scenarios and body regions which may form a new common understanding and will accelerate harmonization processes in this research field. Furthermore, several datasets from Europe and Australia (Compilation of macrostatistical European accident data as well as data from national statistics and in-depth accident investigations) of latest years have been analysed to provide a current understanding of the accident occurrence of powered two-wheelers.

Due to the comprehensive tables of results for most of the analysed requests by the project partners, only a selection of results could be shown within this report. Other results are made available by direct data exchange on request.

The analysis of accident data requires always consistent information. To ensure proper analyses in future, there is an urgent need of the harmonization of several key variables used in road traffic accident investigations.

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Appendix A.1

Literature review on body regions Part 1, EU Projects and IGLAD

Source	IGLAD database	EU-Project on PTW	EU-Project on PTW
Reference	http://iglad.net/web/ page.aspx?sid=10771	PISa	SIM
body regions definition in Methods yes/no	yes	no	no
body regions definition comment	based on AIS Chapters	related to AIS	related to AIS
body region1	Head w/o face	Head and face	Head and face
body region2	Face		
body region3	Neck w/o spine	Neck	Neck
body region4	Thorax w/o shoulder	Thorax	Thorax
body region5	Abdomen	Abdomen	Abdomen
body region6	Spine	Spine	Spine
body region7	Upper Extremities	Upper extremities	Upper extremities
body region8	Lower extremities	Lower Extremities	Lower Extremities
body region9	not specified injuries	Whole Body	Whole Body
body region10		Pelvis	Pelvis

Literature review on body regions Part 2, EU Projects

Source	**EU-Project on PTW**	**EU-Project on PTW**	**EU-Project**
Reference	Motorist	MOSAFIM	Serious Injuries Study
body regions definition in Methods yes/no	no	no	no
body regions definition comment	related to AIS	related to AIS	related to AIS
body region1	Head (face?)	Head	Head/neck/face
body region2	?	cervical spine	
body region3	Neck	Neck	

body region4	Thorax	Thorax	Thorax
body region5	Abdomen	Abdomen	abdomen and pelvic content
body region6	Spine	Spine w/o cervical	Spine
body region7	Upper extremities	Upper extremities	Upper Extremities
body region8	Lower Extremities	Lower Extremities	Lower Extremities
body region9			Whole surface and multiple regions
body region10	Pelvis	Pelvis	

Literature review on body regions Part 3, other paper

Source	**Paper_Ircobi**	**Paper_AAP**	**Paper_Ircobi**
Reference	Pedder 1990*	Peek-Asa 1996**	Frederiksson 2016***
body regions definition in Methods yes/no	no	no	no
body regions definition comment	related to AIS	related to AIS	related to AIS
body region1	Head	Head	Head and face
body region2	Face	Face	Cervical spine
body region3	Neck (Cervical_Spine?)	Neck	Neck
body region4	Chest	Chest	Thorax
body region5	Abdomen	Abdomen	Abdomen
body region6	Spine-Thoracic	Spine	
body region7	Upper Extremities	Upper Extremities	Upper Extremities
body region8	Lower Extremities	Lower Extremities	Lower Extremities
body region9			unspecified
body region10	Pelvis		

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**Peek-Asa C, Kraus JF, Injuries sustained by motorcycle riders in the approaching turn crash configuration, Accid Anal Prev. 1996 Sep;28(5):561-9.
***Fredriksson R, Sui B, Powered Two-Wheeler Accidents in Germany with Severe Injury Outcome - Accident Scenarios, Injury Sources and Potential Countermeasures, IRC-16-11, Ircobi Conference 2016, p 8-19

Appendix A.2

CARE dataset used for analysis in PIONEERS (status of July 2019)

Table 38: Number of accidents with outcome of fatal or seriously injured casualties by PIONEERS Accident Scenarios, sum of years 2013-2017, CARE

	AS1-U	AS1-R	AS2-U	AS2-R	AS3-U	AS3-R	AS4-U	AS4-R	AS5-U	AS5-R	AS6-U	AS6-R
Austria	1241	401	364	219	1687	1302	374	490	796	615	871	2496
Belgium	503	342	174	174	599	757	166	267	228	191	276	492
Bulgaria	73	18	48	3	253	75	89	36	83	19	156	108
Croatia	373	42	156	16	791	217	218	67	532	93	591	360
Cyprus	41	4	14	2	163	10	48	7				
Czechia	87	19	23	11	694	459	159	185	48	32	353	518
Denmark	262	120	123	66	147	170	51	44	211	95	83	148
Finland	70	16	19	20	40	39	8	23	22	10	45	98
France	6050	1781	1856	626	9827	5270	3113	1781	2266	904	3109	4424
Germany	6529	1258	1575	493	12228	6515	2645	2324	3290	1379	5310	12139
Greece	115	8	73	1	984	42	626	31	108	58	801	366
Hungary	988	107	391	117	1078	405	371	206	686	187	447	528
Italy	166	102	89	38	885	668	427	281	104	49	496	519
Latvia	26	20	8	18	50	25	21	17	20	20	38	49
Luxembourg	18	1	1	1	60	49	13	21	10	4	39	105
Malta					128	24	39	12			20	24
Netherlands	2811	448	2295	346	668	405	360	261	1509	407	345	367
Poland	1411	337	435	172	2259	634	656	284	524	240	814	616
Portugal	307	78	165	63	556	161	271	95	328	127	458	235
Romania	361	44	203	35	686	134	276	70	581	71	432	204
Slovenia	66	16	32	15	128	140	49	81	101	32	126	190
Spain	1391	419	535	196	4241	1651	1670	737	609	376	1649	2726
Sweden	167	52	92	38	216	177	76	101	142	94	211	435
United Kingdom	932	294	261	83	8551	5633	2345	1574	235	184	2044	3952