



# Identification of Key Risk Factors Related to Serious Road Injuries and Their Health Impacts

**Deliverable 7.4**



**SafetyCube**



# Identification of key risk factors related to serious road injuries and their health impacts

Work package 7, Deliverable 7.4

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# Executive summary



Because of their high number and slower reduction compared to fatalities, serious road injuries are increasingly being adopted as an additional indicator for road safety, next to fatalities. Reducing the number of serious road injuries is one of the key priorities in the EU road safety programme 2011-2020. In 2013, the EU Member States agreed on the following definition of serious road traffic injuries: a serious road traffic injury is a road traffic casualty with a Maximum AIS level of 3 or higher (MAIS<sub>3+</sub>).

One recommendation created by the EU SUSTAIN project was to conduct "A more detailed study of the causes of serious road injuries, [which] could reveal more specific keys to reduce the number of serious injuries in the EU". This recommendation is addressed through the identification of crash-related causation and contributory factors for selected groups of casualties with relatively many MAIS<sub>3+</sub> casualties compared to fatalities and groups with a relatively high burden of injury of MAIS<sub>3+</sub> casualties.

This deliverable is made up of two parts brought together in order to determine the main contributory factors detailed above. This two-step approach initially identifies groups of casualties that are specifically relevant from a serious injury perspective using national level collision and hospital datasets from 6 countries.

Following the determination of groups of interest a detailed analysis of the selected groups using in-depth data was conducted. On the basis of in-depth data from 4 European countries the main contributory and causal factors are determined for the selected MAIS<sub>3+</sub> casualty groups.

Alongside the three preceding deliverables that have formed the major outputs of WP7, deliverable D7.4 is aimed at addressing serious injury policy at an EU levels. As such this report is broadly aimed at policy makers although the inclusion of results from in-depth data analysis also provides information relevant to stakeholders, particularly those working in vehicle design and manufacture or road user behaviour.

## SELECTION OF GROUPS OF MAIS<sub>3+</sub> CASUALTIES FOR FURTHER ANALYSIS (STEP 1)

The objective of this analysis was to select the relevant groups of serious road injuries (MAIS<sub>3+</sub> casualties) considering number of casualties and health impacts. Relevant groups of casualties are groups with:

- A relatively large number of MAIS<sub>3+</sub> casualties, in relation to fatalities
- Relatively large health impacts, quantified by Years Lived with Disability (YLD) in relation to Years of Life Lost (YLL)

The selection was based on hospital discharge register data and road fatality registers from the following countries: England, The Netherlands, Rhône region in France and Spain. In addition, some analyses were done on hospital discharge and other injury data from Austria and GIDAS data from Germany. Casualties were grouped according to transport mode, age and gender and EUROCCOST

injury group<sup>12</sup>. The distribution of casualties over transport modes, age and gender and over EUROCCOST injury groups was compared between fatalities and MAIS<sub>3+</sub> casualties and between YLL and YLD. Moreover, MAIS<sub>3+</sub> to fatality ratios and YLD to YLL ratios were calculated for each transport mode, each combination of age and gender and each EUROCCOST injury group.

The following groups of casualties are overrepresented among MAIS<sub>3+</sub> casualties and/or the burden of injury of these casualties compared to fatalities and are therefore selected for further in-depth analysis to determine risk factors:

- **Cyclists:** In all countries, cyclists show the highest MAIS<sub>3+</sub>/fatality ratio and YLD/YLL ratio of all transport modes. Further analysis of national crash statistics data shows that cyclists are often injured in crashes without motorized vehicles and that the most common types of injury obtained by MAIS<sub>3+</sub> casualties among cyclists are skull-brain injuries other than concussions, open head wounds and facial injuries and hip fractures.
- **0-17 yrs;** this age group shows a relatively large share in the number of MAIS<sub>3+</sub> casualties and the burden of injury of these casualties. Moreover, the average burden per casualty is relatively high for these casualties, due to a long remaining life expectancy. Further analysis of national crash data shows that 0-17 yrs MAIS<sub>3+</sub> casualties are relatively common among pedestrians and to lesser extent cyclists and that the most relevant injuries are skull-brain injuries other than concussions, open head wounds and facial injuries and femur shaft and knee/lower leg fractures. Another age group that could be considered relevant from a burden of MAIS<sub>3+</sub> injury perspective are casualties of 50 yrs and older. These casualties show a somewhat higher share in YLD compared to YLL in England and in the Netherlands, but not in the other countries.
- **Spinal cord injuries;** these MAIS<sub>3+</sub> injuries always result in long-term disabilities and therefore are a main contributor to years lived with disability of MAIS<sub>3+</sub> casualties in all four included countries. These injuries are relatively common among car occupants
- **Knee/lower leg fractures;** This EUROCCOST injury group has the highest share in the burden of injury of MAIS<sub>3+</sub> casualties in the Rhône region and in Spain and is the second largest group in England. Moreover, in all countries, the share in YLD is higher than the share in fatalities for these fractures. Further analysis on the basis of national crash statistics shows that knee/lower leg fractures are most common among powered two-wheelers and are relatively common among younger road traffic casualties. Also for femur shaft fractures, the share in YLD is higher than the share in fatalities. However, due to time constraints, this group was not selected for further analysis.

As not all EU-member states currently hold data on MAIS<sub>3+</sub> casualties, police reported serious road injuries were also investigated to determine whether they provide a good picture of the distribution of serious road injuries over transport modes and age and gender. This appears not to be the case. Due to a difference in injury severity definition and underreporting by the police, police reported serious road injuries show a different distribution over transport modes and age groups than hospital reported MAIS<sub>3+</sub> casualties. MAIS<sub>3+</sub> casualties among cyclists are for example heavily underreported by the police and therefore the share of cyclists is substantially underestimated when police reported injuries are used.

Finally, a comparison of MAIS<sub>3+</sub> to fatality ratios between the countries shows that ratios differ considerably between countries. As a result, MAIS<sub>3+</sub> to fatality ratios cannot easily be transferred

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<sup>1</sup> Polinder S, Meerding WJ, Toet H, van Baar ME, Mulder S, Van Beeck EF, the EUROCCOST reference group: A surveillance based assessment of medical costs of injury in Europe: phase 2. 2004, ErasmusMC and Consumer Safety Institute

<sup>2</sup> Polinder S, Toet H, Mulder S, van Beeck EF: APOLLO: The economic consequences of injury. Consumer and Safety institute. 2008, Amsterdam, the Netherlands



from one country to another. Consequently, it does not make sense to derive MAIS<sub>3+</sub> to fatality ratios on a European level.

## ANALYSIS OF GROUPS OF MAIS<sub>3+</sub> CASUALTIES IDENTIFIED (STEP 2)

For this analysis, in-depth collision investigation datasets were applied, as they contain more detailed information relating to the specific causation factors that lead to collisions or the mechanisms that contribute towards injuries; both of these can be considered weaknesses of national level datasets to some extent. Four of the five groups recommended by 'step 1' were taken forwards for analysis in this report, a decision to cover only four groups was made as a matter of expediency due to time constraints

The guidelines for the in-depth analysis stage were kept very open; this was predominantly due to the differences in the data collection, sampling and storage of information in the various datasets, but also to provide the national in-depth dataset experts a free reign over how best to provide and present results specific to the causation and contributory factors for the groups of interest. Analysis was conducted using data from four countries; data which is representative of the national picture from Germany and England (both in-depth), and regional data from Barcelona, Spain and The Netherlands (linked hospital and police data and in-depth respectively).

Combining the in-depth datasets for the four countries involved in the in-depth analysis resulted in over 70 thousand individual collisions. In total and across all groups identified through the initial selection process just over 1% of this dataset was analysed. This indicates that groups that have relatively large numbers of MAIS<sub>3+</sub> casualties in relation to fatalities, or relatively large health impacts in relation to Years of Life Lost exist in very small numbers within current and historic in-depth datasets.

In total data from four countries has been used resulting in an indication of the associated risk factors. The word 'indication' is used as it is not possible to provide statistically robust results for all the groups of interest across all countries, subsequently the results should be seen as a window into each group rather than a complete answer or solution to a problem.

The conclusions drawn from the data analysis show that:

**For cyclists of all age groups** the primary contributory factor as determined through the independent collision investigation is attributed to the other road user in more than half of the sample. Collisions involving a broad description of 'entering or crossing a priority road' are the most prevalent accident type with crashes where a cyclist does not give way, or get given right of way in a traffic situation most common. Some of these priority related crashes involve access to property rather than road junctions.

Over 90% of the causes attributed to cyclist collisions were 'human' factors such as distractions, emotions, attention, and physiological conditions<sup>3</sup>. Factors of perception (expecting, looking and planning), legal (disobeying signs or signals, unfit to drive due to alcohol or drugs) and attention (distraction, inattention) were much more prevalent for road users whose actions initiated the collision event<sup>4</sup>, particularly for injudicious actions attributed to cyclists. Besides the causation factors associated with driver or rider errors, crossing crashes are commonly associated with visibility/vision obscuration, road infrastructure factors and legal issues/infringements. Causation factors related to

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<sup>3</sup> These classifications are from the German ACAS classification under the general title of 'admission of information' although corresponding causal classification systems exist in other databases.

<sup>4</sup> In many collisions it was possible to determine the primary contributory factor that led to a collision and the road user this action was attributed to; this in effect provides a surrogate for "fault" but determined independently.

vision obscuration are present in nearly 50% of the cycle cases. The obscuration source is typically a parked or moving vehicle or issues related to infrastructure/road geometry.

Single vehicle cycle accidents are the second most common collision type across all country data but this shows regional differences, for example, single cycle collisions represented only 2% of English sample but 28% and 50% in the German and Netherlands datasets respectively. Distraction of the cyclist was a factor in around 20% of the single vehicle accidents<sup>5</sup>, leading to cyclists colliding with other road users or objects.

**For 0 to 17 yrs road users**, pedestrians and passengers of cars were the two largest groups in the sample of 0-17 yrs road users sustaining MAIS 3+ injuries. Cyclists and motorcycle riders were less evident in these data. The sample road users were most often involved in an accident as a pedestrian. They have a higher share of accidents when crossing the road as a pedestrian and have less driving accidents.

Across all road user types, crashes involving some form of crossing or turning were slightly over represented compared to collisions involving road users of other age groups. Riders of motorcycles and cyclists aged 0 to 17 yrs are only present in turning and crossing type collisions and crossing accidents were more frequently found among 0 to 17 yrs road users with MAIS 3+ injuries than among older road users with MAIS 3+ injuries.

Considering the causations, for drivers involved in a collision with a 0 to 17 yrs road user the most common causation factors were (i) exceeding the speed limit (ii) failed to look properly and (iii) distraction. Breaking down the 0 to 17 yrs group by road user type shows that common causal factors for cyclists were; (i) failed to judge vehicle path or speed, (ii) careless/reckless or in a hurry, and (iii) inexperience. Additional relevant causal factors related to perception (expecting, looking and planning) and conflict (interpersonal communications) were more prevalent for the 0 to 17 yrs cyclist sample than that in collisions involving other older road users.

The most common causation factors for pedestrians aged 0 to 17 yrs are related to the broad groups of 'perception' and 'conflict'. Additionally a range of more specific factors, involving 'information admission' factors such as a wrong focus of attention or attention hindered due to physiological conditions (includes factors such as alcohol and drugs alongside medical conditions and physical stress or fatigue) were present

The analysis of the accident causes reveals that most of the failures attributed to collisions involving a young road user are based on human failures, this includes a range of more specific factors, including 'information admission' factors such as a wrong focus of attention or attention hindered due to physiological conditions. Very few causes from the vehicle or the environment were found. This group did involve environmental causation factors which were almost completely limited to visual obstructions.

The majority of persons that suffered **spinal cord injuries** were car occupants in collision with fixed objects or other vehicles and within this sample, rollover crashes appear to be over-represented compared to other types of crashes. In rollover crashes all of the spinal cord injuries were from contact with an intruding roof.

Other impact types (front/rear/side) were underrepresented in the MAIS 3+ spinal cord injury sample, compared to those involved in other severe collisions. In general, for rear and side impacts, high levels

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<sup>5</sup> Although in every instance they were 'riding' accidents the databases used typically classed as them as 'driving' accidents due to limitations with data entry.

of vehicle crush and damage was seen. A similar picture was also apparent in frontal collisions where high levels of crush were seen from narrow impacts with small overlaps. The analysis into the cause of the car occupant spinal cord injuries in non-rollover crashes shows that they were mostly caused by the body movement and not a result of contact or direct trauma to the neck/spine itself. In the sample of MAIS 3+, car occupants did not have a high number of injuries recorded but the type and severity of these when they occurred were some of the most severely injured occupants compared to the average injury score. All spinal cord injuries irrespective of the type of collision were located in a small region of the upper spine between C1 and T1.

Motorcycle riders and cyclists also sustained spinal cord injuries but in smaller numbers and with mixed injury causes. Not surprisingly, cyclists and PTW riders were more likely to have a spinal cord injury from an external object such as the road surface, off road surface or road side furniture.

Riders of powered two-wheelers (PTWs) had the largest share of serious injuries within the MAIS 3+ **Knee and lower leg fractures** sample. Severely injured car occupants and pedestrians also often suffered lower leg or knee injuries, though not as frequently as PTW riders. Although evident in the sample cyclists who received MAIS3+ knee or lower leg fractures were not as prevalent.

Vulnerable Road Users (PTWs, pedestrians, cyclists) most frequently suffered lower leg or knee injuries in a collision with a car, whereas car occupants more often sustained their injuries from a collision with a fixed object such as a tree or pole.

The lower leg or knee injury was most frequently caused by impact with the front bumper of the collision opponent amongst Vulnerable Road Users. Additionally, PTW riders commonly received these injuries from impact with the front wing, rear bumper, or had collisions with the road infrastructure, receiving injuries from an impact with the road surface or guard rails.

Among car occupants, the majority (60%) received their lower leg or knee injury from impact with the interior of their vehicle during a collision. In the English data contacts causing the knee or lower leg fracture were from contact with the fascia panel, rigid bracketry behind the fascia panel, or the footwell. Other injury causation codes recorded for knee and lower leg fractures were from rigid bracketry behind the steering column, the lower A-pillar in the footwell, the pedals, the bulkhead, the back of a front seat or the interior of the side door. The average delta-V in the crash (change in velocity) from vehicle damage for car occupants receiving a MAIS 3+ lower leg or knee fractures was 45kmh. This makes the collisions within the highest 10% of Delta-V results recorded for all collision types. Additionally, for collisions that result in a MAIS 3+ knee or lower leg fracture the damage details recorded for the observable damage to the vehicle structures indicates that as the Delta-V increases cases of 'severe crush to the vehicle structure with associated intrusion' and 'massive impact damage with loss of vehicle integrity' become more prevalent.

The majority of passenger car collisions that resulted in MAIS 3+ lower leg or knee fractures were to the front of the vehicle and represented directions of force between 11 and 01 'o' clock. Where intrusion into the passenger compartment is seen (present in 54% of the English cases) the degree of this is relatively extensive with the average intrusion measure recorded as 32cm. 50% of the intrusion measures are recorded as over 20cm.

## RECOMMENDATIONS

### Recommendations for policy makers

In addition to reducing the number of fatalities, road safety policy making should also be aimed at reducing the number of MAIS3+ casualties and their health impacts. In that respect, the following groups are of special relevance as they show a relatively high number of MAIS3+ casualties in

relation to fatalities and/or relatively many years lived with disability (YLD, limited to MAIS<sub>3+</sub> casualties) compared to years of life lost (YLL): cyclists, 0-17 year olds, spinal cord injuries, knee and lower leg fractures and femur shaft fractures. Road safety policy especially aimed at these groups could further reduce health impacts of MAIS<sub>3+</sub> casualties.

The in-depth analyses in this report provide more detailed information on the casus of these crashes and therefore provide guidance for the further development of road safety policy. Concerning cyclists, the most relevant crash types are priority error related collisions and single bicycle collisions. Moreover, measures could be focused on reducing distraction and preventing vision obstruction. On the longer term, pro-active vehicle systems that can detect, predict and resolve priority or 'give-way' issues before they occur could be effective for reducing the number of MAIS<sub>3+</sub> casualties in bicycle – motor vehicle crashes.

Concerning 0 to 17 year old pedestrians, in-depth data indicates that crossing behaviour and crossing location choice could potentially increase the risk of vision or attention issues. It is therefore important to better understand crossing behaviour of young pedestrians, with particular emphasis on crossing point choice, judgement of vehicle speed and vision obscuration. Measures could be aimed at better assisting young pedestrians. Moreover, active vehicle safety systems should be able to deal with (unexpected) crossing behaviour of young pedestrians.

The injuries received by occupants of cars, particularly those in the knee/lower leg and spinal cord groups, indicates that there is still some work to be done in terms of passive safety. The large levels of intrusion seen both in planar collisions (front, side and rear) and in rollovers indicate that vehicle structural strength is still an important topic. Finally, vehicle design might also be further improved to better protect PTW users in collision with passenger cars.

Chapter 5 contains a first suggestion for potential countermeasures, selected from the SafetyCube DSS. It should however be noted that did report did not investigate whether these countermeasures are actually effective for reducing the selected groups of MAIS<sub>3+</sub> casualties. More research is needed aimed at designing effective measures to prevent the selected groups of MAIS<sub>3+</sub> casualties.

### **Recommendations for further research**

Further research would be useful to investigate differences in MAIS<sub>3+</sub>/fatality ratios between countries. It is feasible that the differences currently seen are for a large part due to differences in specific types of crashes and specific circumstances between countries. To understand these differences more completely it would be useful to see whether it is possible to derive comparable sets of MAIS<sub>3+</sub>/fatality ratios for different crash types.

The selected groups of MAIS<sub>3+</sub> casualties appear in small samples in the investigated in-depth databases. There is clearly a need for more data on the types and causes of the selected groups of MAIS<sub>3+</sub> casualties (0-17 year olds, cyclists, spinal cord injuries and knee/lower leg fractures). There is a risk that existing or future in-depth data collection methodologies and sampling protocols could miss relevant cases involving serious injury, for example by continuing to focus on fatal crashes.

# 1 Introduction



The purpose of this Deliverable is to determine which crash related factors and injury mechanisms contribute to crash types with relatively many serious road injuries (MAIS<sub>3+</sub> road traffic injuries) and/or a relatively high injury burden of serious road injuries. This Deliverable is produced within Work Package 7 of the Horizon2020 project SafetyCube.

## 1.1 SAFETYCUBE

Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities.

SafetyCube aims to:

1. develop new analysis methods for (a) Priority setting, (b) Evaluating the effectiveness of measures (c) Monitoring serious injuries and assessing their socio-economic costs (d) Cost-benefit analysis taking account of human and material costs
2. apply these methods to safety data to identify the key accident causation mechanisms, risk factors and the most cost-effective measures for fatally and seriously injured casualties
3. develop an operational framework to ensure the project facilities can be accessed and updated beyond the completion of SafetyCube, and
4. enhance the European Road Safety Observatory and work with road safety stakeholders to ensure the results of the project can be implemented as widely as possible

The core of the project is a comprehensive analysis of accident risks and the effectiveness and cost-benefit of safety measures focusing on road users, infrastructure, vehicles and injuries framed within a systems approach with road safety stakeholders at the national level, EU and beyond having involvement at all stages.

### 1.1.1 Work Package 7

Traditionally, road safety policy has been primarily aimed at reducing the number of road fatalities. In recent years however, serious road traffic injuries are increasingly being adopted as an additional indicator for road safety. Reducing the number of serious traffic injuries is one of the key priorities in the road safety programme 2011-2020 of the European Commission (EC, 2010). In 2013, the High Level Group on Road Safety, representing all EU Member States, agreed on a common definition of serious traffic injuries as road casualties with an injury level of MAIS 3+. In 2017 a target was set of reducing the number of serious road injuries in the EU by 50% between 2020 and 2030 (<http://etsc.eu/eu-sets-new-target-to-cut-serious-road-injuries/>).

Work Package 7 is dedicated to serious road traffic injuries (MAIS<sub>3+</sub>), their health impacts and their costs. The main objectives of this work package are to:

- Assess and improve the estimation of the numbers of serious road traffic injuries
- Determine and quantify health impacts of serious road traffic injuries
- Estimate economic and immaterial costs related to serious road traffic injuries
- Identify key risk factors related to serious road traffic injuries and their health impacts

Deliverable 7.1 'Practical guidelines for the registration and monitoring of serious traffic injuries' (Perez et al., 2016) assessed the estimation of the numbers of serious road traffic injuries in EU countries. Although the adoption of a common definition has certainly given an impetus for the collection of data, in many countries the process for estimating the number of MAIS<sub>3+</sub> casualties is still in an early stage or has not even started yet. Moreover, methods appear to differ considerably between countries, depending on the data that is available. Besides, methodological issues appear to affect the estimated number of MAIS<sub>3+</sub> casualties. In order to ensure that the estimated numbers of MAIS<sub>3+</sub> casualties are comparable across Europe, further harmonisation is certainly desirable. The guidelines developed within SafetyCube aim to contribute to this further harmonisation.

Deliverable 7.2 'Physical and psychological consequences of serious road traffic injuries' (Weijermars et al., 2016) discusses health impacts of (serious) road traffic injuries. On the basis of a literature review, health impact studies and burden of injury calculations it was shown that non-fatal (serious) road traffic injuries have a substantial impact, both at the individual level as for society as a whole. Ideally, road safety policies should also be aimed at reducing health impacts in addition to reducing the number of casualties. In this respect, it should be noted that also less severe injuries are very relevant from a health burden perspective.

Deliverable 7.3 'Costs related to serious road injuries' (Schoeters et al., 2017) presents cost estimates for European countries based on a survey. The survey revealed that costs related to serious road injuries vary considerably between countries. The cost per serious injury varies between €28,205 and €975,074, the total costs related to serious injuries varies between 0.04% and 2.7% of the country's Gross Domestic Product (GDP), and accounts for 14 to 77% of the total costs of road crashes. Medical costs and costs related to production loss account for about 18% of the costs of serious road injuries and are influenced by for example age, health status and injury sustained. Immaterial or 'human costs' represent a share varying from 10% to 91% of the total costs related to serious injuries. Their share depends on the method used to estimate these costs: when the recommended WTP method is applied, these costs tend to be much higher.

## 1.2 PURPOSE OF THIS DELIVERABLE

Traditionally, road safety policy has been primarily aimed at reducing the number of road fatalities. This method, albeit apparently successful in the continuing reduction in fatality numbers, fails to address the stagnation in, or increasing number of, road traffic crashes that cause non-fatal (serious) injuries. These serious injuries, in a comparable way to fatalities, result in considerable economic and human costs (Weijermars, Bos, & Stipdonk, 2015). However, contrary to fatalities these injuries often involve lifelong health effects and associated costs for the injured road user. Because of this, serious road traffic injuries are increasingly being adopted as an additional indicator for road safety. Reducing the number of serious traffic injuries is one of the key priorities in the road safety programme 2011-2020 of the European Commission (EC, 2010).

Work package 7 as a whole is tasked with providing more information into the costs and size of the serious road injury problem in Europe and deliverable 7.4 is specifically aimed at providing more information into the identification of the key risk factors associated with this group of serious road injuries.

To a certain extent, serious road injuries could be prevented by similar measures applied to fatalities, however, it is also conceivable that crashes resulting in serious road injury differ in their characteristics from fatal collisions or are influenced by other contributing factors and injury mechanisms not seen in these fatal crashes. Additionally, as was recommend in Deliverable 7.2, road safety policy setting should also be aimed at reducing long term health impacts. Serious road

collisions with large health impacts might be influenced by other contributory factors than serious road collisions with smaller health impacts.

Risk factors are important to understand as they form the first step towards developing countermeasures and a potential reduction in serious injury crashes; in other words, without knowing how and why these crashes occur it will be very difficult to reduce their numbers in any strategic or logical way.

The purpose of Deliverable 7.4 is to identify contributing factors and injury mechanisms that are of special relevance for seriously injured road traffic casualties with the output being twofold, firstly providing a methodology for the identification for at-risk groups i.e. seriously injured road user groups that are either disproportionately high in number compared to fatalities and/or have a bias towards long term or lifelong medical care. This process forms the initial step of the deliverable while also informing the subsequent in-depth analysis process and is wholly covered by chapter 3.

This second step, covered by chapter 4 is tasked with identifying the specific risk factors associated with these high risk groups by analysing data contained within in-depth collision investigations. This step of the report is predominantly exploratory but attempts to provide a first examination of the contributing crash causation factors of the samples of road collisions.

Following on from the data selection and data analysis processes, chapter 5 presents the conclusions and recommendations of this Deliverable. Further country specific information relating to both the determination of groups of interest ('step 1') and the in-depth analysis phase ('step 2') are included in the range of subsequent appendices.

# 2 Method



This chapter outlines the two step approach to a) Identify relatively high risk groups and b) Determine the real-world collision factors that lead to serious injuries or long term health effects.

The overarching purpose of SafetyCube Deliverable 7.4 is to identify the key risk factors related to particular groups of serious road injuries. The main contribution factors relevant for serious road injuries are identified following a two-step approach.

The first part of D7.4 addresses the selection of groups of casualties that are specifically relevant from a serious injury perspective, using national level collision and hospital datasets from 6 countries; this process can be seen as 'step 1' of D7.4. As a first step, groups of casualties that are of special relevance concerning MAIS<sub>3+</sub> injuries were selected. **The focus was to look for groups that are not yet covered when focussing on fatalities.** Therefore, relevant groups of casualties are groups with:

- A relatively large number of MAIS<sub>3+</sub> casualties, in relation to fatalities, i.e. a high MAIS<sub>3+</sub> to fatality ratio
- Relatively large health impacts, quantified by Years Lived with Disability (YLD) in relation to Years of Life Lost (YLL), i.e. a high YLD to YLL ratio

The second part of D7.4 involves a detailed analysis of the selected groups of casualties using in-depth data; this forms 'step 2' of D7.4. On the basis of in-depth data from England, Germany, Spain and the Netherlands, the main contributing factors are determined for the selected groups of MAIS<sub>3+</sub> casualties. The overall schematic of Deliverable 7.4 is shown in figure 1:

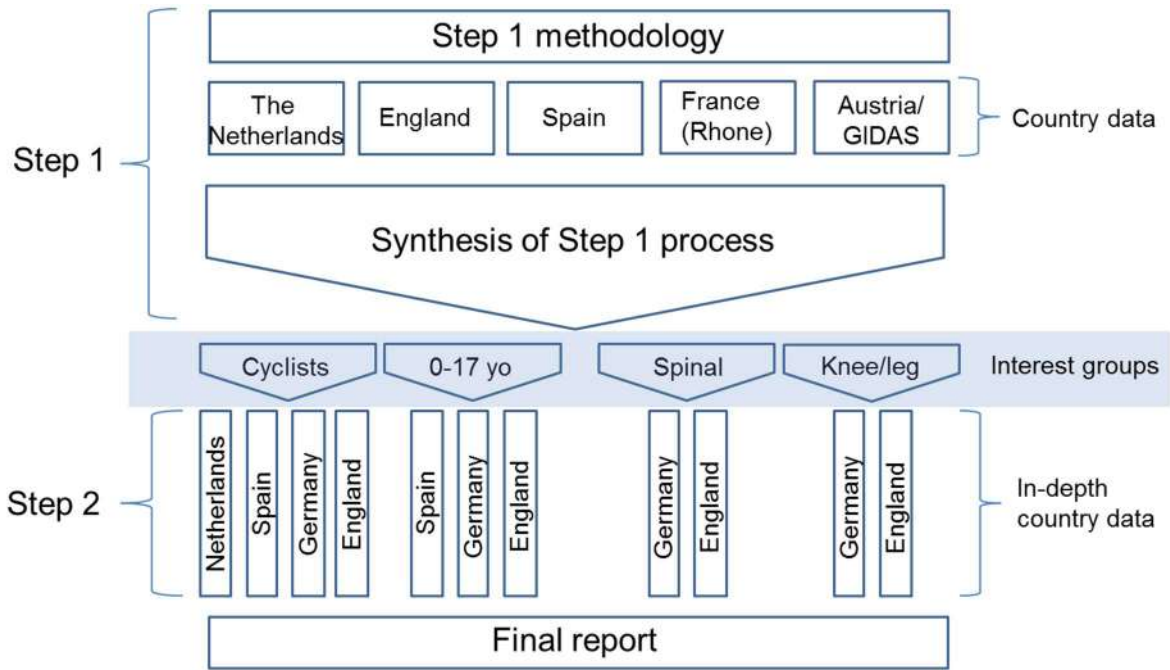


Figure 1: schematic of the D7.4 process as a whole including 'step 1' and 'step 2'



## 2.1 METHODOLOGY TO DETERMINE GROUPS OF MAIS<sub>3+</sub> CASUALTIES

The objective of initial analysis of national level collision and hospital datasets was to select the main groups of serious road injuries (MAIS<sub>3+</sub> casualties) considering number of casualties and health impacts. Relevant groups of casualties are groups with:

- A relatively large number of MAIS<sub>3+</sub> casualties, in relation to fatalities
- Relatively large health impacts, quantified by Years Lived with Disability (YLD) in relation to Years of Life Lost (YLL)

Groups of casualties were selected using national (or regional) crash statistics data, i.e. Hospital discharge register data and national road fatality registers. Characteristics that could be analysed using these data are:

- transport modes
- age and gender
- type of injury

The following figure (Figure 2) shows the schematic of the 'step 1' process including country data and selection of groups of interest.

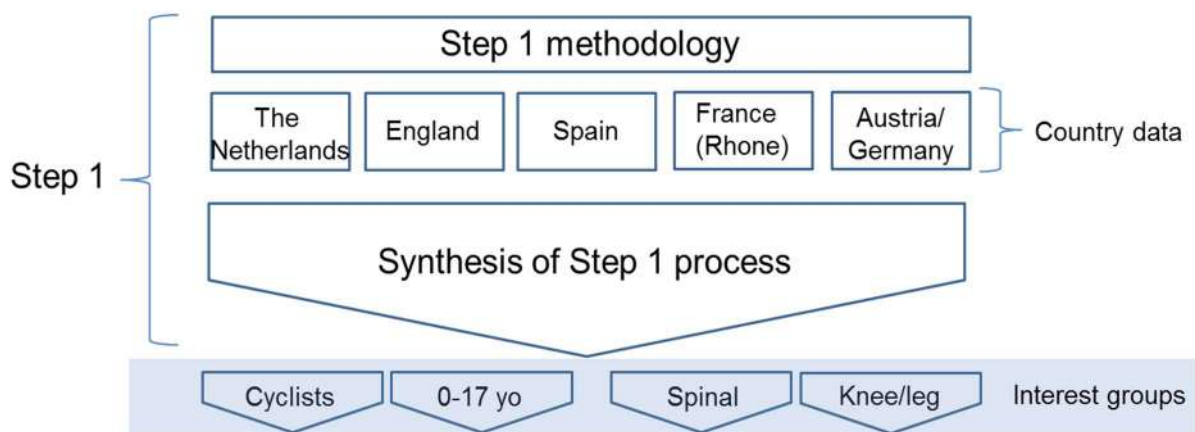


Figure 2: schematic of the 'step 1' process

In order to select the relevant groups of casualties, the distribution over transport modes, age and gender and type of injury was compared for fatalities and MAIS<sub>3+</sub> casualties and for YLL and YLD. Moreover, the numbers of MAIS<sub>3+</sub> casualties per fatality and the number of YLD per YLL are determined. Finally, the average YLD per casualty is calculated for different transport modes, combinations of age and gender and for different types of injury.

From Deliverable 7.1 (Perez et al., 2016) was concluded that not all EU-member states have data on MAIS<sub>3+</sub> casualties yet. Therefore, police reported serious road injuries were investigated to determine whether they provide a good picture of the distribution of serious road injuries over transport modes and age and gender<sup>6</sup>. In that respect, comparisons were made between the distribution of MAIS<sub>3+</sub> casualties and police reported serious road injuries over transport modes and combinations of age and gender and also calculated the number of MAIS<sub>3+</sub> casualties per police reported serious road injury for different transport modes and combinations of age and gender.

<sup>6</sup> Police data has no or limited information on type of injury.

For the selection of MAIS<sub>3+</sub> casualties in Hospital Discharge data, the guidelines presented in Deliverable 7.1 (Perez et al., 2016) were followed. The calculation of YLD is based on the method described in Deliverable 7.2 (Weijermars et al., 2017). Following the instructions in Appendix A, these analyses were executed for the following countries/regions: England, The Netherlands, the Rhône region in France and Spain. Moreover, some of the analyses or somewhat adapted analyses were possible for Austria and on the basis of GIDAS data from Germany. The data that was used in each country is described in more detail in Appendix B, together with the results for the individual countries.

In general terms, these groups of interest contain road users where the proportion of casualties that are seriously injured (defined as MAIS<sub>3+</sub>), or have high YLD (Years Lost to Disability), are over represented compared to these proportions in the group of fatalities. The two measures for this analysis is shown below:

- Relatively large health impacts, quantified by YLD in relation to YLL and/or
- A relatively large number of MAIS<sub>3+</sub> casualties, in relation to fatalities

### 2.1.1 Datasets.

For the analysis, national (or in some cases regional) crash statistics data is used. Data sources include hospital discharge register data, national road fatality registers and data on serious road injuries reported by the police.

These large scale datasets were used for this process as they are very good for showing the extent of crashes and injuries over large geographic regions. They do however provide limited or rudimentary information on the causes of crashes and are therefore not used so extensively for the analysis of in-depth datasets for the determination of risk factors.

#### The Netherlands – National Dataset

The MAIS<sub>3+</sub> serious road injuries are based on hospital discharge register data. Injury diagnoses are coded to the International Classification of Diseases, 9th edition (ICD-9), and the MAIS was derived using ICDmap90. As not all road traffic casualties can be recognised as such in the Hospital Discharge Data, the estimated number is approximately 17% lower than the actual number of MAIS<sub>3+</sub> road traffic injuries. Any biases over the variables used are unknown.

The number of fatalities is based on data from Statistics Netherlands (CBS). Statistics Netherlands determines the 'true' number of fatalities by combining police reports with two other sources: Death certificates and Court files of unnatural death. Data by mode, gender and the most detailed age grouping available were used in order to accurately determine the number of Years of Live Lost (YLL). For the Netherlands a decision was made not to use the CARE/CADaS database as this database is incomplete for the Netherlands; the police reporting rate is 84% on average during 2010-2014. The EURO COST injury group can be determined only for fatalities that died in the hospital.

For police reported Serious Injuries CARE/CADaS data were used. The national definition formally is "Admitted to hospital and hospitalized during at least one night". It is known from police-hospital linking studies that:

- Not all hospitalized casualties are seriously injured (MAIS<sub>3+</sub>);
- Not all serious injuries (MAIS<sub>3+</sub>) are reported by the police as hospitalized.

Therefore it is possible to assume that there will be differences between MAIS<sub>3+</sub> and Hospitalized casualties in number and in distributions.

Table 1 Overview of data used for the Netherlands

The Netherlands 2010-2014	Number	DALY
Fatalities (true number)	3.091	102.555 YLL
Fatalities in Hospital	1.153	
MAIS <sub>3+</sub> (reported in HDR)	27.611	81.400 YLD
Hospitalized (police reported)	12.847	

### England – national

The number of MAIS<sub>3+</sub> casualties is taken from the HES (Hospital Episode Statistics) database of hospital discharge data for England. The HES data covers casualties in England, not the whole UK, and only includes casualties who were admitted to a hospital. Injury diagnoses are coded to the International Classification of Diseases, 10th edition (ICD-10), and the MAIS was derived using the method developed at the University of Navarra for the Apollo project. Data from 2006-2010 (inclusive) were used as this is the most recent data available to us.

The data on fatalities and police recorded serious injuries are taken from the Department for Transport (DfT) 'STATS19' dataset, which is a record of all police-reported injury accidents in the UK. Records were selected for the years 2006-2010 and the data restricted to accidents in England only to be comparable with the HDR data. Whilst there are always inaccuracies in any dataset, it is expected that this data is a good representation of the number of fatalities as it is rare in the UK that a road traffic fatality is not reported to the police. To determine the injury severity of an accident the police follow DfT guidelines, however the police definition of a "serious" injury is not equivalent to a MAIS<sub>3+</sub> definition, and in fact is known to include a large number of MAIS<sub>1</sub> and 2 injuries.

Table 2 Overview of data used for England

England 2006-2010	Number	DALY
Fatalities (true number)	10,734	455,635 YLL
Fatalities in Hospital	2,175	
MAIS <sub>3+</sub> (reported in HDR)	40,291	129,727 YLD
Hospitalized (police reported)	110,226	

### France, Rhône department – national

In France, the number of MAIS<sub>3+</sub> casualties is estimated from the Rhône Registry linked with police data using an extrapolation process (see Perez et al., 2016).. For the current analysis, results are drawn from the Rhône Registry alone, and so the total numbers are not country-wide but only for the Rhône department (basically the Lyon metropolitan area, 1.6M inhabitants). The registry includes all road accident casualties suffering from at least one AIS<sub>1</sub> injury, hospitalized or not. All injuries were classified using AIS coding, then EUROCAST injury groups have been assigned to each AIS injury by a medical doctor following the recommendations of the Apollo project (concerning ICD9 or ICD 10).

Police reported hospitalized figures come from police reports for the Rhone department. The police recording suffer from underestimation which has been largely studied (Amoros et al., 2008, 2006),

and the definition of the hospitalization (admitted to hospital and hospitalized during at least one night) is not always met. On the contrary, the number of MAIS<sub>3+</sub> is reliable, as coming from the Registry, with almost no underestimation and directly coding of injuries in AIS score. This means that the number of police reported hospitalized and the number of MAIS<sub>3+</sub> are not easy to compare.

Fatalities are also included in the Rhône Registry even when not hospitalized. In that case, injury description comes from the forensic institute (comprehensive in case of autopsy, less comprehensive otherwise). The number of fatalities coming from the registry is then considered as the true number of fatalities.

Data from 2004 to 2014 were chosen in order to have comparable numbers with the other study examples.

Table 3 Overview of data used for the Rhône / France

Rhône / France 2004-2014	Number	DALY
Fatalities (true number)	740	29318 YLL
Fatalities in Hospital (reported in HDR)	740	
MAIS <sub>3+</sub> (reported in HDR)	5675	27776 YLD
Hospitalized (police reported)	8678	

**Spain – National Dataset**

In Spain, two data sources were used that include information at national level: police (from the National Traffic Authority, DGT) and National Hospital Discharge Register (CMBDAH), of the Spanish Health Information Institute (Ministry of Health, Social Policy and Equality). The register includes information from the network of public and private hospitals. It also includes hospitals specialising in neurological injuries.

MAIS<sub>3+</sub>, serious traffic injuries are identified from the National Hospital Discharge Register (HDR). Criteria for inclusion were to have E-codes for external causes of injury such E810-819, E826-829, E929, E988.5. When there is no information of external causes of injury (E-codes), information from insurance traffic companies allows identification of traffic casualties. That means that information on the mode of transport is missing for 41% of MAIS<sub>3+</sub>. Fatalities within 30 days after hospital admission as well as readmissions and scheduled admissions were excluded. MAIS has been derived with the icdpic module of Stata (Stata v11, StataCorp, College Station, TX). The period of study for this study is 2010 to 2013.

The numbers of fatalities are reported by the police and are provided by the National Traffic Authority (DGT). The number of serious road traffic injured reported to police were also reported (number of hospitalized according to police definition of serious casualty).

Table 4 Overview of data used for Spain

Spain 2010-2013	Number	DALY
Fatalities (police reported at 24h)	7,135	263,451 YLL
Fatalities in Hospital (reported in HDR)	230	5,560 YLL
Hospitalized (police reported)	44,832	
MAIS <sub>3+</sub> (reported in HDR)	33,847	87,124 YLD

**Austria**

For Austria, there are only limited possibilities to compare MAIS<sub>3+</sub> casualties with fatalities. This is due to the fact that the Austrian (ICD-10 based) Hospital Discharge Data (HDD) does not comprise external cause codes. Hence, the HDD based MAIS<sub>3+</sub> indicator for Austria does not comprise any mode of transport information. Comparisons of MAIS<sub>3+</sub> casualties with fatalities are therefore restricted to age and gender. Comparisons of overall hospital admitted casualties, though not MAIS<sub>3+</sub> cases, with fatalities by mode of transport, however, are possible, based on another data source, the IDB Austria.

IDB Austria is an emergency department (ED) based injury surveillance system that is part of the EU IDB Network. In 2014, IDB Austria consisted of a sample of five hospitals and a total of approximately 10.000 ED cases of both admitted (at least one overnight stay in hospital) and non-admitted (no overnight stay in hospital) patients. Injury patients are interviewed at random, face-to-face and injury cases coded by a specially trained data entry staff according the common EU IDB protocol for the Full IDB Data Set (FDS). As the IDB Austria does not contain ICD diagnoses no MAIS<sub>3+</sub> indicators can be derived from this data system. Alternatively, the percentage of casualties attending hospital who are admitted to hospital, the mean length of stay of hospital admissions or the nature and type of body part injured can be used as a rough indication of injury severity (e.g. for the Traffic Safety Basic Facts 2016 for European Road Safety Observatory).

To make use of a unique feature of the IDB, systematic information about non-admitted emergency department (ED) cases, the analysis for Austria includes also accident and injury characteristics for the group of non-admitted road crash victims who are less severely injured but much more frequent in number than admitted ones - and more frequent than the MAIS<sub>3+</sub> ones. See Appendix B for the results.

**Germany – in-depth**

All analysed data are obtained from the GIDAS in-depth accident data sample of the accident years 2005 to 2014. GIDAS (German In-Depth Accident Study) is the largest and most comprehensive in-depth road accident study in Germany. Since mid-1999, the GIDAS project has been investigating about 2,000 accidents per year in the areas of Hannover and Dresden and records up to 3,000 variables per crash. The project is supported by the Federal Highway Research Institute (BASt) and the German Association for Research in Automobile Technology (FAT). The sponsors and the investigation teams have access to the data.

In GIDAS, road traffic accidents involving personal injury are investigated according to a statistical sampling process using the “on-the-scene” approach. This means that teams are called promptly after the occurrence of any kind of road traffic accident with at least one injured person occurring in determined time shifts. In addition, the investigation areas were chosen in accordance with the national road network characteristics and the share between built-up areas and non-built-up areas.

GIDAS is sampling police reported accidents, thus is unable to address the issue of underreporting. Underreporting in Germany is mainly applicable for paediatric cyclists.

In the GIDAS data set, the injury severity is described following the national statistics metrics but also using the AIS code for every individual injury by direct coding.

The advantages of using GIDAS for the data analysis are

- Analysis of hospitalised, MAIS 3+ and fatalities of one sample
- Direct coding of AIS
- Inclusion of all fatalities (death occurred at the scene and in the hospital)

The disadvantages of using GIDAS for the data analysis are:

- Small sample size
- Underreporting applicable

Table 5 Overview of data used for Germany

GIDAS 2005 – 2014	Number	DALY
Fatalities	199	7,520 YLL
MAIS <sub>3+</sub>	970	2,714 YLD
Hospitalised	5,093	

Because of the relatively small number, no further analysis per transport mode, age group and injury group is made for Germany.

## 2.2 LIMITATIONS IN THE DETERMINATION OF MAIS<sub>3+</sub> GROUPS

The initial step of determining groups of interest for further analysis has the following limitations:

- The selection of interest groups is based on a relative high number of MAIS<sub>3+</sub> casualties or a relative high burden of injuries of these casualties in relation to fatalities or the burden of injury of fatalities. This approach could result in selection of groups of casualties with a low absolute number of casualties. When selecting groups, this limitation will be considered. This could result in a group not being selected because of low absolute number of casualties.
- As the methods for the estimation of the number of serious road injuries differ between countries (different ICD versions, different AIS versions, different ICD to AIS conversion tools), the numbers from different countries are not fully comparable to each other. These differences probably influence the MAIS<sub>3+</sub>/fatality ratios. However, there is high confidence that the selections of groups of interest are not heavily affected by differences in methodology.
- As countries estimated the numbers of serious road injuries using hospital data, not all road traffic casualties can be recognised as such. It is known that in the Netherlands only applying hospital data results in an underestimation of the number of MAIS<sub>3+</sub> casualties of approximately 17%. Any bias over the variables used are unknown, but we expect that consequences for the selection of interest groups are small.
- The in-depth data from Germany has a number of additional limitations as it is based on police reported casualties. Therefore, the distribution of MAIS<sub>3+</sub> casualties over transport mode, age and gender and EUROCCOST injury group might be biased for the German data.

### 2.3 METHODOLOGY FOR THE ANALYSIS OF IN-DEPTH DATASETS

One of the final outcomes of this deliverable is to determine the risk factors for the groups of interest identified through the initial group determination process. The analysis of in-depth datasets forms 'step 2' of the process, and necessitated the use of detailed, in-depth collision investigation data. This data, from four individual countries, was explored in order to find information on the causation and contributory factors associated with these particular groups. This step forms the lower half of figure 1 shown below in Figure 3

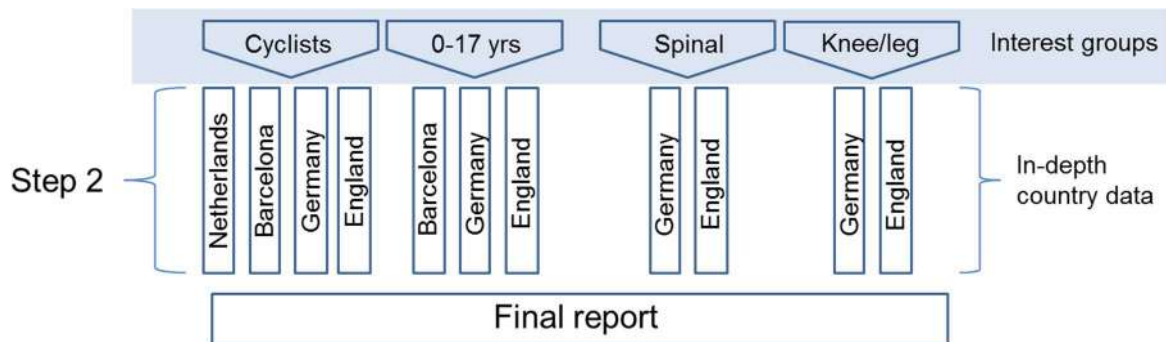


Figure 3: schematic of the 'step 2' process

Using only in-depth data<sup>7</sup> for this process has numerous benefits, but chiefly that in-depth datasets collect independent information on causation and other factors that contribute to collisions. This detail appears self-evident but distinguishes this type of data from large-scale, national, police-reported datasets by allowing detailed results to be presented on the causations of collisions with much more confidence. Conversely using large scale, police reported datasets are very good at showing the extent of crashes or injuries but are restrictive when used to show the causes of crashes. The result of using mass or national data will typically only show correlations between crash characteristics and not necessarily the causations factors themselves.

The scope of the analysis is broad. Some of the collisions, some of the road users and some of the injury groups will have been considered in other research, however it is likely that the decision for this analysis was not directed by a process of determining groups of interest based specifically on high injury burden, as such the whole process from the instigation of 'step 1' through to the determination of risk factors provides a unique opportunity to identify and study these groups in isolation.

The groups identified do represent a fraction of the EU collision constellation as a whole. This is the expected result of looking for the unknown, after all, if the injury burden was particularly large or existed within a dominant transport mode it would, in all likelihood have been studied previously. The task for this deliverable was to identify groups that had slipped below the primary focus of researchers and road safety stakeholders; the groups that exist just off the radar but are equally important to understand in order to reach goals such as 'vision zero' or reductions in health care costs.

As with most studies involving small groups and diverse data sets it will not be possible to provide results to a high level of statistical significance. Considering the sample size of each group of interest in the in-depth datasets (between 37 and 327 collisions) it is not practical nor in most cases possible to conduct significance tests on samples of this size. This was never the primary aim of the in-depth

<sup>7</sup> With the exception of the linked police and hospital records from the regional Barcelona dataset

analysis section of the deliverable as it would have been almost un-achievable to bring together a set of common data variables from four countries and synthesise it into a usable and understandable form. In fact it could be argued that approaching the study this way would have significantly hindered the usefulness of the results; reducing and removing all of the useful but incomparable subjective data and resulting in nothing more than a basic data set containing variables such as day of crash, time of crash, weather conditions, lighting conditions etc.

This isn't to say that this higher level information isn't useful, far from it, however it is expected that this data is available at a national or even EU level in greater quantities for analysis at a later date. What was clear from the beginning of the in-depth process was that collecting and analysing data at a national level would not provide quite the same answers as digging further into high quality, in-depth, collision investigation data. Using these data sets provides a huge leap forward in the understanding of collisions, particularly where small samples are predicted. In-depth collision data is something that EU member states excel at, with many previous EU funded studies a testament to this. Since this wealth of data is painstakingly recorded it seemed apt that the process of determining risk factors should capitalise on the benefits provided by in-depth data.

Another opportunity, provided by the combination of identifying the groups of high injury burden and the selected in-depth data sets, was that the analysis could be very open. As it was not possible to match variables between different country data sets so the decision was made not to try, instead it was to be up to individual data experts to direct their country specific analysis under one primary condition - to provide more information than a national accident reporting system could; this meant the focus was shifted from higher level data to factors such as the determination of causal factors, contributory factors, human functional failure analysis, interactions between different crash participants and any other detail information that could be gained from the various elements that build into an in-depth database.

### 2.3.1 Data sets

The following section provides some important information related to the specific in-depth datasets used for the in-depth analysis process. Information is included on a country basis identifying critical features of the data and the processes used to collect and record the information.

Because the datasets differ between countries it is highly important to understand how these differences can affect the overall combined results. Combining results of datasets from a variety of countries is not straight forward, even for national level collisions data. This step is made more complex when considering in-depth data as the multiplication factor of many incompatible variables contrives to make comparability even more challenging. A summary of the potential biases and limitations of this approach is included in section **Error! Reference source not found.**; however it is not possible to outline every possible effect on the analysis. For this it is advised that readers familiarise themselves with each dataset (or relevant dataset) so to gain a clearer understanding of the methodological phases taken for the in-depth analysis process so to avoid misreading or misrepresenting the results included within this chapter and appendices C to F.

### 2.3.2 Description of each data set used

#### England – In-depth

Data for England is drawn from three separate but closely related datasets. These datasets are referred to as RAIDs, CCIS and OTS.

The Cooperative Crash Injury Study (CCIS) is one of the world's largest studies of car occupant injury causation. The study ran uninterrupted between 1984 and 2010 and retrospectively investigated



more than 1200 passenger car crashes every year. Data was collected regionally by 3 groups covering different geographical areas. These areas were carefully chosen to make the collision location and crash type data representative of the national picture. The project had various funding methods over its duration but was predominantly driven by a consortium of the UK Department of Transport and various industrial sponsors. To make the data relevant for policy change and sponsor needs the criteria for inclusion in the study was for an occupant to be injured in a passenger car that was less than eight years old and for that vehicle to have been recovered from the scene (i.e. not driven away). There was a strong bias towards fatal and serious injury cases with only around 20% of the data made up of lower severities – this makes the injury profile dissimilar to the national picture but provides a wealth of information on more serious crashes and injuries. Data was derived from a detailed inspection of the vehicle including collision reconstructions, impact speed calculations, collision orientations and impact locations. Medical information of the occupants was derived in parallel from hospital visits or hospital notes which were AIS coded and matched to contact location determined from the vehicle inspection or a likely causation in the event of non-contact or no evidence. The aims of the study were to:

- Provide an in-depth understanding of injury causation to car occupants
- Provide information on the crashworthiness of vehicles
- Provide information on the performance and effectiveness of occupant protection systems (airbags, seatbelts)
- Provide a mechanism to identify and prioritise the need for improvements in vehicle safety

The On-the-spot (OTS) study ran between 1998 and 2009 and can be regarded as an evolution of the traditional 'retrospective' CCIS study. This study was also funded by the UK Department of Transport but instead of investigating vehicles a few days after a crash, involves crash investigations at the scene, typically within 10 minutes of the collision occurring. The study investigated 4744 collisions over the 11 year duration. This methodology necessitated having an investigation team on standby and a police officer as a team member to enable travelling under blue lights to the accident scene. The differences in comparison to the CCIS study enabled the study to collect 'volatile' data (debris fields, skid marks, rest positions, interview data) at the scene for all accidents types but also provided an opportunity for a particular emphasis on pedestrian and vulnerable road user accidents. Similar procedures to the CCIS study in regards to reconstructions and injury information was employed for the OTS study.

The final study from which data was drawn for D7.4 was the Road Accident In-Depth Study (RAIDs). This study was instigated after a brief hiatus after the closing of both CCIS and OTS studies, but followed broadly the same protocols; it ran between 2013 and 2016. The study itself can be seen as a combination of the two studies outlined above in that retrospective investigations were combined with an on-the-spot investigation team. Despite being based on the protocols of CCIS and OTS the study had a much broader scope and included sampling targets for passenger cars (now 5 years or newer), vulnerable road users, heavy vehicles and crashes leading to life changing injuries rather than the traditional approach focussing on fatal crashes. In total 1431 collisions were investigated with a 52/48 split for on-the-spot investigations compared to retrospective.

For the D7.4 in-depth analysis it was determined that the best quality and most relevant data for the use in this task would exist between 2006 and 2016. This period includes the tail end of the OTS and CCIS projects and, while also incorporating a small gap between projects, would also contain the most recent collision data from the RAIDs project up to 2016.

## The Netherlands – In depth

The Dutch dataset comprises injury crashes of cyclists aged 50 years and over without involvement of high-speed motorized vehicles<sup>8</sup>. Data was collected in both urban and rural areas across three different time frames over a total duration of 2 years from 2012 to 2014.

The process of investigation required timely notification of a relevant crash to the in-depth team by the ambulance service and the police in two provinces in the Netherlands, from this the investigation team receives basic information on the relevant crash including the address of the crash location, type of crash, age and gender of the cyclist involved. Based on this information, the team contacts the cyclists involved and if they are willing to cooperate (through informed consent), data collection was started. Data collection involved a semi-structured interview conducted with a psychologist and a bicycle examination using a standardised coding form.

For the most part data collection was carried out retrospectively, according to protocols set out in 2009 and coinciding with dedicated national and international training (Davidse, 2007, 2011). These protocols dictated that two team members, including one road safety engineer carried out a scene investigation involving the measuring of all road elements and recording images of the scene and video of the cyclists approach. Providing that the cyclist grants permission information of the cyclists' injuries were collected both during the interview and from the hospital.

The complete dataset results from this in-depth investigation protocol in which detailed information was collected about all aspects of the crash. This data also includes behaviour and background of the road users involved, type and condition of the bicycles involved, road layout and other characteristics of the crash location (e.g. presence and characteristics of obstacles on cycling facilities). Furthermore, information was gathered on general conditions such as weather and light conditions, sustained injuries and damage to the bicycles.

## Spain – Linked Regional

The data sources used were the Hospital Emergency Register for traffic injured in Barcelona (DUHAT) linked to the Registry of Accidents and Victims of Barcelona of the urban police of Barcelona (GUB).

The Hospital Emergency Register for traffic injured people includes the seven main public hospitals in Barcelona and is estimated to cover more than 85% of emergency traffic collisions in the city of Barcelona. Comparable information is available since 1997 and includes exhaustive information on emergency and discharge diagnoses.

The Registry of Accidents and Victims of Barcelona has a specific accident unit that records all collisions in which there has been someone injured or material damage with exhaustive information about the collision and its circumstances. Information about the injured persons and the drivers involved is also collected.

The hospital database has 135,567 registries and the police has 155,424. Through a process of probabilistic record linkage, 52,318 records have been linked. Taking into account that a maximum of 135,567 records can be connected (hospital records), the linkage percentage has been 39%. (Cirera E, Plasència A, Ferrando J & Arribas P, 2001)

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<sup>8</sup> Light mopeds are legally obliged to use cycle tracks in the Netherlands. Therefore crashes with light mopeds are included in the dataset.

## Germany – In-depth

All analysed data are obtained from the GIDAS in-depth accident data sample between the accident years of 2005 to 2014.

GIDAS (German In-Depth Accident Study) is the largest and most comprehensive in-depth road accident study in Germany. Since mid-1999, the GIDAS project has investigated about 2,000 accidents per year in the areas of Hannover and Dresden and records up to 3,000 variables per crash. The project is supported by the Federal Highway Research Institute (BASt) and the German Association for Research in Automobile Technology (FAT).

In GIDAS, road traffic accidents involving personal injury are investigated according to a statistical sampling process using an “on-the-scene” approach. This approach means that an investigation team is called promptly after the occurrence of a road traffic accident involving at least one injured person. The investigation areas are chosen in accordance with the national road network characteristics and the share between built-up areas and non-built-up areas, in addition the investigations are conducted in determined time shifts.

As such, and with the use of weighting factors, the collected accident data is considered adequately representative for the national situation allowing the GIDAS data to be scaled to the national situation.

### 2.4 LIMITATIONS IN THE IN-DEPTH ANALYSIS

One important factor to consider for this deliverable concerns the size of the serious injury problem across the European Countries and how this is represented in the analysis. At first glance it appears easy to conclude from the results of the in-depth analyses that the number of seriously injured road users in this study is small; this seems objectively true when looking at the sample sizes alone, however this does not tell the complete story and may be masked by a number of factors which are outlined in this section.

Figure 4 shows the general proportions of each crash severity in a simple schematic; across the countries used for the ‘step 1’ analysis this picture holds broadly true in that for each fatality there will be between 4 and 11 times the number of serious injury collisions and in turn, for each serious injury, a larger population of slight injury collisions. The process of determining groups of interest using large scale national datasets will provide findings in line with these proportions.

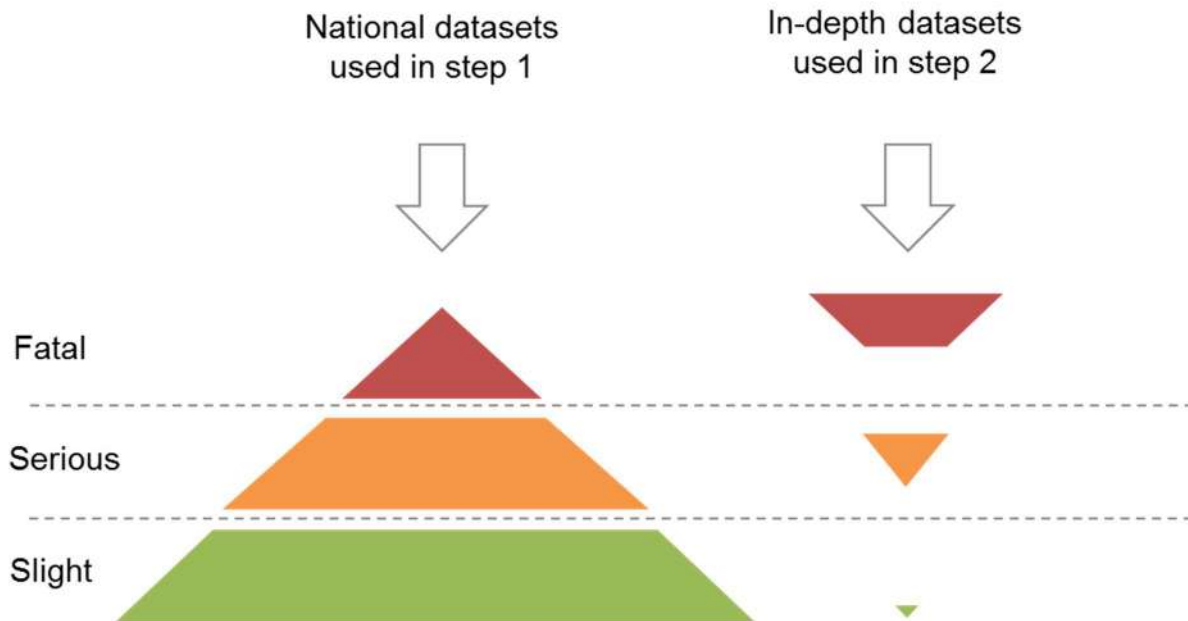


Figure 4: proportion of crash severity types for large scale and in-depth datasets

Although many in-depth datasets are representative of the national picture, typically through weighting the subsequent in-depth analysis was conducted on regionally collected in-depth data. The image on the right of the schematic shows the general collision proportions for a typical in-depth database. Although not in all cases, the proportion of collision severity recorded in these in-depth datasets could be seen to be diametrically opposed to the national picture; this is because traditionally fatal and serious collisions are prioritised for investigation over slight injury crashes.

This factor would appear to increase the proportion of serious injury crashes within an in-depth dataset; however this has to be balanced against the smaller absolute number of serious injuries within the database. Combining this factor with the removal of fatal and less serious crashes for the in-depth analysis and it is understandable that in some cases there could exist smaller samples than could be initially anticipated through the larger scale determination of groups of interest process.

As a result there is likelihood that the types of injury crashes shown in the relatively large samples derived through the 'step 1' process may not always be realised when data is collected regionally and scaled to the national picture.

Another major element that is necessary to understand lies in the representivity of the data used for the in-depth analysis. It can be seen that the differences of sample selection criteria between the datasets were too large for them to be brought together as a whole, however this potentially leaves many difficult issues which are identified and raised in the country specific overview of the data (2.4.1) however there will always be inherent biases and characteristics of each dataset used.

The limitations seen across the datasets makes it difficult to directly compare the conclusions of each group of interest between countries. In order to provide a common conclusion for each group of interest a stereotypical collision description or range of stereotypical collision descriptions have been written to describe the type of event(s) that lead up to road users in the interest groups becoming injured or sustaining a certain injury type.

This description does not describe one particular collision but instead attempts to encompass elements from the analysis of all collisions; as such this should be seen as a general description of a collision that *could* cause serious injuries (based on a review of the data seen) and not necessarily

what *has* caused serious injury (a description of an actual collision). The stereotypical scenario is not derived directly for the statistical results in the analysis but is guided by the dominant outcomes from the range of results.

This approach was taken rather than a traditional research question based approach due to the differing datasets and limitations within each. The differences encountered made conducting a simultaneous and systematic analysis of all four datasets almost impossible, instead the expertise of individual country analysts was sought, allowing freedom to explore further than a national level dataset would allow whilst still remaining focussed on revealing 'risk factors'.

In total, data from four countries has been used resulting in an indication of the associated risk factors. The word 'indication' is used as it is not possible to provide statistically robust results for all the interest groups across all countries. It should also be recognised that the data used for both analysis steps are limited to western European countries. This factor will result in a number of constraints but will primarily limit the direct use of the results and recommendations over a wider geographical region without additional consideration as to applicability and transferability.

This limitation is perhaps less critical for the two injury groups (spinal cord and knee/lower leg fractures), especially in countries with a relatively modern vehicle fleet and good restraint use but the road user groups involving pedestrians or cyclists are possibly less well protected in more Southern and Eastern European countries than they perhaps are in Germany and the Netherlands for example.

Further understanding of the biases and limitations can be appreciated with knowledge of the data collection and data entry processes; the following points attempt to reveal some of these:

**Selection of cases based on particular sampling methodologies:** Although the data contained within typical in-depth datasets is intended for detailed collision reconstructions and/or the determination of factors such as causation, none of the datasets used in this section are designed specifically for the needs of this particular deliverable; it is therefore feasible that there will be inherent biases in the quantity and type of collisions investigated which will be more closely aligned to the datasets intended purpose. For example, a typical collision investigation sampling methodology may focus on identifying cases that help answer the most important or relevant research questions for that particular country or region, this could be for fatal or life changing injury crashes for the most prevalent road user classes (passenger cars predominantly). The effect of this sampling could be to reduce numbers of cases that may be otherwise interesting but do not fit into the sample, for example pedal cyclists or pedestrians.

**Practicalities of investigation:** Another factor to bear in mind is the practicalities of actually conducting an investigation. In the case of an independent investigation team attending scenes or examining vehicles it is clear that serious or fatal collisions that involve motorised vehicles provide the best opportunity to record data as they remain on scene longer or are recovered to a secure site. This means that cases that involve vulnerable road users may not provide quite the same opportunities for investigation or that they may have missing information critical in the investigation process such as skid marks or rest positions. In addition the subjective data needed for a greater understanding of the factors that lead up to collisions can also be one sided for vulnerable road users as they are more likely to be injured in collision with a vehicle and are therefore unlikely to be available for interview.

**Database completion (Coding):** As with all things reliant on a human to process information then the effects of human nature can be seen. For this point it is necessary to differentiate between coding errors (which are inherent and difficult to spot in a database) and routine coding practices

which can be identified and accounted for. An example of this can be seen in the English data where contributory factors are coded; for this there are 8 broad groups (for example, legal factors, perception factors, judgement factors etc.) with a number of detail codes under these headings (for the 'legal' group these could be 'disobeyed a yield instruction' or 'legally unfit due to alcohol'). Where human nature effects this variable is in finding an easy or universal option to enter into the database if information is short or uncertainty exists; this potentially means that more detailed descriptions of contributory factors are replaced by a generic 'not further specified' option.

**Injury level:** AIS severity codes are linked to threat to life, as such a higher AIS severity code, for example an AIS 4 or 5, taken individually could indicate that road user survival is lower than an AIS 3 injury. This does not tell the full story as in many collisions a road user will likely receive multiple injuries of different severities. The limitation of this coding effect is evident in this report when considering the difference between spinal cord injuries (4.4) and knee/lower leg injuries (o) Because only seriously injured (i.e. survived, not killed) road users were included in the analysis and only the AIS 3+ injury for the identification of the group of interest was used (i.e. no reference made to other injury sustained) it is possible that a greater wealth of data will exist for road users receiving an AIS 3+ lower leg fractures than exists for road users receiving an AIS 3+ spinal cord injury as the threat to life illustrated by the available AIS severity codes and subsequent survival rate may vary considerably.

#### 2.4.1 Country specific Limitations in the in-depth data

##### England:

The following section covers the most important factors to consider when understanding the English data.

**Road user bias:** Knowing the aims of each study conducted in England provides some information as to why biases may exist in the samples used for D7.4 in-depth analysis. For example, all the studies will naturally be skewed towards motorised transport modes as this mode forms the majority of the overall traffic mix. This means that the combined data, used for the specific purpose of collection; to inform government about road safety issues predominantly involving motorised vehicles, will miss other elements of the traffic fleet such as vulnerable road users.

**Injured level bias:** Due to the specific requirements of the three English datasets it is understandable that there will be inherent bias in the injury level of the collisions investigated. For example, the CCIS database was tasked with understanding the most serious crashes involving vehicle passengers; it is therefore clear that the injury severity sampling methodology will focus on identifying cases that help answer this research question. The effect of this bias is likely to be an overrepresentation of fatal or life changing injury crashes. The effect of this bias is not clear on the in-depth sample for D7.4 but it will most likely result in a reduced number of the less serious injury cases that could have increased the sample number for the specific injury analysis section.

**Collision attendance bias:** In a similar way to the injury level bias but predominantly affecting the on scene cases there will be a bias evident in the attendance of an investigation team at the scene of a collision. In the case of an independent investigation team attending scenes or examining vehicles it is clear that serious or fatal collisions that involve motorised vehicles provide the best opportunity to record data as vehicles and casualties remain on scene longer or are recovered/moved to secure sites. This means that cases that involve vulnerable road users may not provide quite the same opportunities for investigation or that they may have missing information critical in the investigation process such as skid marks or rest positions. As an example, it was often the decision of the investigation team, based in one location, to investigate one of a number of collisions occurring within a 50mile radius. Considering travel time it was often decided that a collision involving motorised vehicles would still be in situ when the team arrived compared to a collision

involving a vulnerable road user. In addition this attendance bias impacts the subjective data needed for a greater understanding of the factors that lead up to collisions, this can in turn be one-sided for vulnerable road users as they are more likely to be injured in collisions with a vehicle and are therefore unlikely to be available for interview.

**Limitations in data:** Typically a database will be designed to form a dataset in a readily analysable form, ideally a form that suits the specific research questions set out by the project objectives. Because the analysis as set out by task 2 does not have a bespoke database it is understandable that the data held in some datasets is not quite the correct form for analysis. An example of the limitations in data in the English data is in the variable 'age'. This variable appears to be straight forwards to analyse except that when exporting data the age variable is 'banded' rather than being a continuous series. This is not a major concern if using the data for its express purpose, however for the in-depth analysis in this deliverable, particularly for the group '0-17 yrs' this poses a problem as the upper limit of the age required is covered by a '16-19 yrs' banding.

**Limitations in coding:** As with all things reliant on a human to process information then the effects of human nature can be seen. For this point it is necessary to differentiate between coding errors (which are inherent and difficult to spot in a database) and routine coding practices which can be identified and accounted for. An example of this can be seen in the English data where contributory factors are coded; for this there are 8 broad groups (for example, legal factors, perception factors, judgement factors etc.) with a number of detail codes under these headings (for the 'legal' group these could be 'disobeyed a yield instruction' or 'legally unfit due to alcohol'). Where human nature effects this variable is in finding an easy or universal option to enter into the database if information is short or uncertainty exists; this potentially means that more detailed descriptions of contributory factors are replaced by a generic 'not further specified' option.

#### **Netherlands:**

As shown in paragraph **Error! Reference source not found.**, 4 out of 5 Dutch cyclists gets severely injured in crashes without motorized vehicles. Therefore the Dutch in-depth studies focused on single-bicycle and bicycle-slow traffic crashes. This means that the collected data does not involve crashes with (high speed) motorized vehicles; these bicycle to car crashes could potentially lead to serious injuries.

It must also be noted the Dutch data concentrated on older cyclists, aged 50 and over. It is therefore possible that the results of a data analysis of crashes with younger cyclists could lead to different results.

This study entailed collecting and analysing detailed information about all aspects of the crash. Data collection was only started when the cyclist involved in the crash was willing to cooperate with an interview. Due to lack of contact information and lower response rates, some age groups could therefore be over or under represented in the database.

For the German and Spanish in-depth analysis, it was possible to compare the 'group of interest' directly with an alternative group to determine if the causation factors identified were specific to the group of interest. For example, in the German analysis, MAIS<sub>3+</sub> (non-fatal) cyclists were compared with MAIS<sub>3+</sub> (non-fatal) other road users, to examine whether the causation factors were unique to cyclist accidents or whether they were also present for other seriously injured road users. This method of comparison is very useful in identifying causation factors that are unique to a specific group, and may help us to understand why they are over-represented compared with other groups.

Unfortunately this was not possible with the data from England and the Netherlands, so the group of interest was examined as an isolated data set. This was predominantly due to the non-specific nature of the research question (*'what are the factors associated with a particular group'*), but also due to practical reasons related to data availability, ease of analysis and the composition of the database. For example, the NL dataset contains only older cyclists in collisions that did not involve a motorised vehicle, which itself is a very specific dataset already and so limits the ability to compare between groups.



# 3 Determination of interest groups



This chapter discusses for which groups of casualties the number of MAIS<sub>3+</sub> casualties is relatively high compared to the number of fatalities and/or the burden of injury of MAIS<sub>3+</sub> casualties is relatively high.

This Chapter discusses the selection of groups with relative high numbers of MAIS<sub>3+</sub> casualties compared to fatalities and/or relatively large health impacts. The selection of groups is mainly based on information from England, The Netherlands, Spain and the Rhône region in France. In addition, data from Austria and the GIDAS database is also applied. The data from Austria and the GIDAS database are not fully comparable to the data from the other countries and therefore the results are not shown in this chapter. However, relevant findings are mentioned. More information on the data available and on the results of the analyses of individual countries can be found in Appendix B.

## 3.1 ANALYSIS PER TRANSPORT MODE

### 3.1.1 Numbers of casualties

Figure 5 shows the distribution of fatalities, police reported serious road injuries and hospital registered MAIS<sub>3+</sub> casualties over transport modes for the different countries. The distribution of casualties over transport modes appears to differ between countries. However, in all countries, cyclists have a relatively large share in the number of MAIS<sub>3+</sub> casualties compared to their share in fatalities. Car occupants on the other hand, have a lower share in MAIS<sub>3+</sub> casualties than in fatalities. Both in the Rhône region in France and in the GIDAS data, also Powered Two Wheelers show a relative high share in MAIS<sub>3+</sub> casualties.

As mentioned before, the absolute shares differ between the countries; in the Netherlands, 60% of all MAIS<sub>3+</sub> casualties are a cyclist, whereas in the Rhône region in France this is only 15%. Moreover, in England and the GIDAS data set, the absolute share in MAIS<sub>3+</sub> casualties is highest for car occupants, and in the Rhône region, the absolute share in MAIS<sub>3+</sub> casualties is highest for Powered Two Wheelers. In Spain, the share of MAIS<sub>3+</sub> casualties is highest for other/unknown transport modes. This is due to a large percentage of MAIS<sub>3+</sub> casualties with an unknown transport mode (41%). When these casualties are excluded, the share of MAIS<sub>3+</sub> casualties is highest for Powered Two Wheelers. The results from this analysis typically follows the differences in modal exposure between the countries involved and can therefore be seen as an expected outcome of this type of analysis.

For the Netherlands it was possible to make a further distinction between cyclists injured in crashed with motorized vehicles involved –e.g. Bicycle – car crashes or bicycle – truck crashes - and crashes without the involvement of motorized vehicles, like bicycle-bicycle or single bicycle crashes. Most cyclists (78%) appear to be injured in a crash without motorized vehicles (shown by the line in the bar).

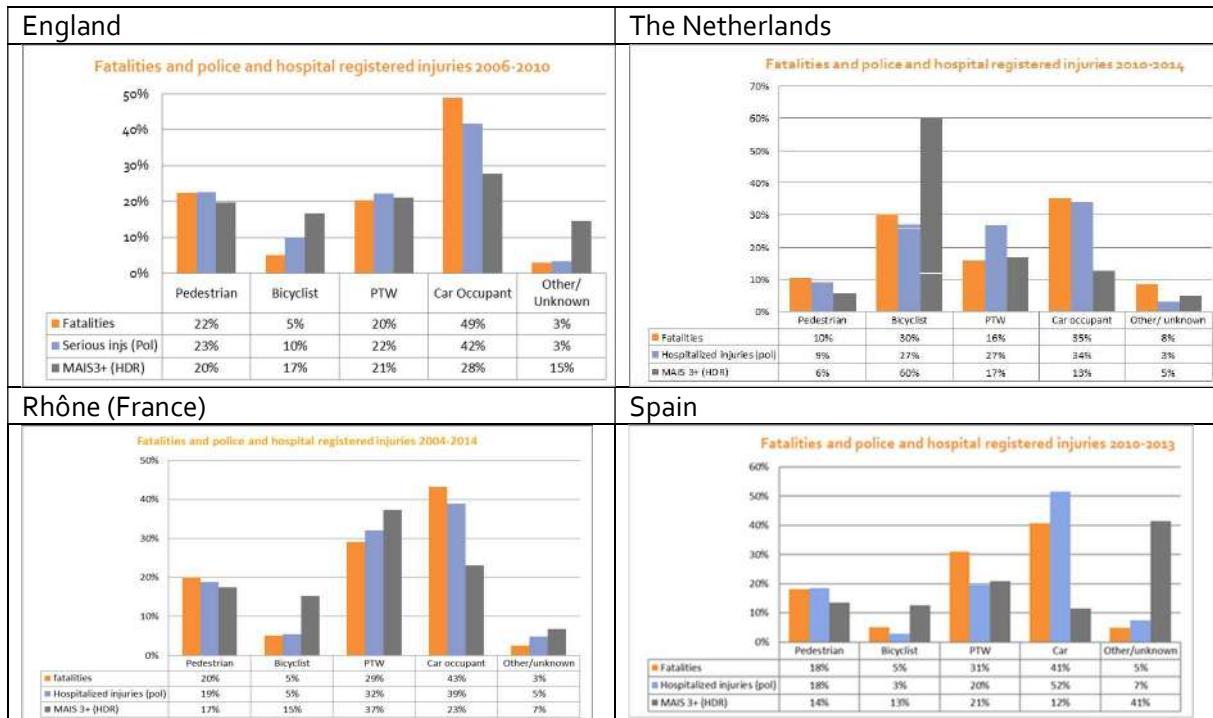


Figure 5: Distribution of fatalities, police reported serious injuries and hospital registered MAIS<sub>3+</sub> casualties over transport modes.

For Austria, it was not possible to compare MAIS<sub>3+</sub> casualties with fatalities, yet it was possible to compare hospital admitted casualties with fatalities. Also this comparison (see Appendix B) shows that cyclists have a relatively large share in injured casualties compared to fatalities. In Austria, more than 35% of all hospital admitted casualties are cyclists and cyclists have the highest absolute share in hospital admitted casualties of all transport modes. Also for PTW, the share in hospital admitted casualties was a little higher than the share in fatalities in Austria.

Table 6 shows the number of MAIS<sub>3+</sub> casualties per fatality for different transport modes. As their share in the number of MAIS<sub>3+</sub> casualties is higher than their share in fatalities, cyclists show the highest MAIS<sub>3+</sub> to fatality ratio of all transport modes (except from other/unknown in England and in Spain). In all four countries/regions, the ratio is lowest for car occupants. The ratios appear to differ between the countries. The average ratio is highest for the Netherlands and lowest for England. When looking at different transport modes, the Rhône region shows the highest ratio for most transport modes and England shows the lowest ratios. As a consequence of the large difference between the countries, it does not seem sensible to derive MAIS<sub>3+</sub> to fatality ratios on a European level. However, from these results can be concluded that cyclists are relevant from a MAIS<sub>3+</sub> perspective.

Figure 5 also shows that the distribution over transport modes differs between hospital registered MAIS<sub>3+</sub> casualties and police reported serious road injuries. In all four countries, the share of cyclists is much lower in police reported serious road injuries than in hospital registered MAIS<sub>3+</sub> casualties. Differences in distribution can be due to differences in severity definition and underreporting by the police. In general, serious road injuries reported by the police refer to hospitalized casualties. This also includes casualties with an injury severity MAIS<sub>2-</sub>. In case the distribution over injury severity MAIS differs between transport modes, difference in severity definition between police and hospital result in different distributions over transport mode. Concerning police registration, it is known that the transport mode and involvement of a motor vehicle influence the reporting rate: bicycle crashes,

single vehicle crashes, and in particular single bicycle crashes are less often being reported by the police (e.g. Amoros, Martin, & Laumon, 2006; Elvik & Mysen, 1999; Janstrup, Kaplan, Hels, Lauritsen, & Prato, 2016; Olszewski, Osińska, Szagała, Skoczyński, & Zielińska, 2016; Reurings & Stipdonk, 2011; Veisten et al., 2007) . In conclusion, police reported injuries do not provide a good picture of the distribution of serious road injuries over transport modes.

Table 6: Number of MAIS<sub>3+</sub> casualties per fatality for different transport modes in different countries.

Transport mode	England	Netherlands	Rhône (France)	Spain
Pedestrian	3	6	7	3
Bicyclist	12	21	27	21
PTW	4	11	10	5
Car occupant	2	4	5	1
Other/unknown	18	6	22	26
<b>Total</b>	<b>4</b>	<b>11</b>	<b>8</b>	<b>5</b>

3.1.2 Burden of injury

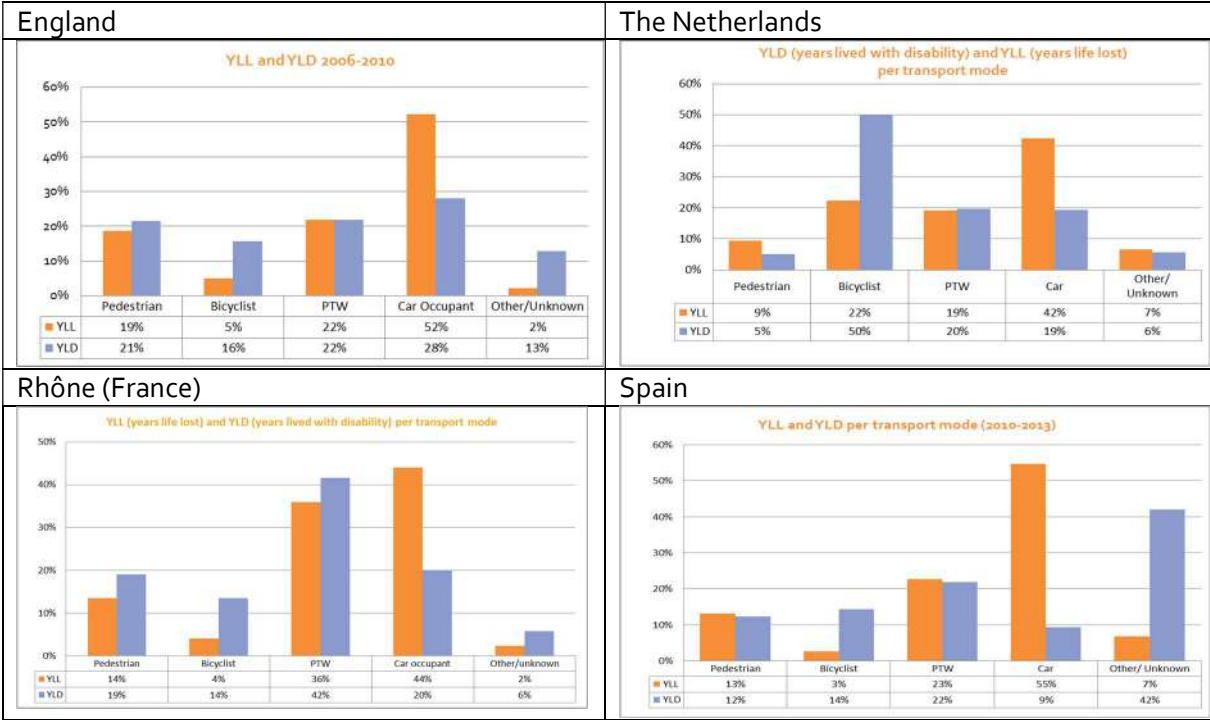


Figure 6: Distribution of Years of Life Lost (YLL) of fatalities and Years Lived with Disability (YLD) of MAIS<sub>3+</sub> casualties over transport modes.

Figure 6 shows that the distribution of the burden of injury differs between countries. In England, car occupants show the highest share in Years Lived with Disability (YLD) of MAIS<sub>3+</sub> casualties, whereas in The Netherlands, the share is highest for cyclists and in the Rhône region and Spain (excluding casualties with unknown transport mode) the share is highest for PTWs.

In all countries, cyclists show a higher share in the burden of injury of MAIS<sub>3+</sub> casualties compared to their share in the health burden of fatalities. In the Netherlands, half of all Years Lived with Disability of MAIS<sub>3+</sub> casualties are encountered by cyclists. Both in England and the Rhône region, also for pedestrians, the share in YLD is higher than the share in Years of Life Lost (YLL) and in the

Rhône region, also for PTW the share in YLD is higher than the share in YLL. For car occupants, the share in YLD is clearly lower than the share in YLL in all countries.

Table 7: Ratio between YLD related to MAIS3+ casualties and YLL for different transport modes in different countries.

Transport mode	England	Netherlands	Rhône (France)	Spain
Pedestrian	0.3	0.5	0.7	0.6
Bicyclist	0.9	2.1	1.7	3.6
PTW	0.3	1.0	0.6	0.7
Car occupant	0.2	0.4	0.2	0.1
Other/unknown	1.6	0.8	1.2	4.2
Total	0.3	1.0	0.5	0.7

As Table 7 shows, the YLD to YLL ratio is highest for bicyclists in all four countries. Also in the GIDAS data, the YLD/YLL ratio is highest for cyclists. In Spain, the burden of injury of MAIS3+ cyclist casualties is 3.6 times higher than the burden of injury of cyclist fatalities and in the Netherlands and the Rhône region, the burden of injury is (almost) a factor 2 higher for MAIS3+ cyclist casualties. In England, the burden is higher for cyclist fatalities. Overall, England shows lower YLD to YLL ratios than the other countries. This is mainly due to lower MAIS3+ to fatality ratios in England.

Table 8: average burden (YLD) per MAIS3+ casualty for different transport modes in different countries.

Transport mode	England	Netherlands	Rhône (France)	Spain
Pedestrian	3.5	2.8	2.7	4.7
Bicyclist	3.0	2.5	2.2	5.9
PTW	3.3	3.5	2.8	5.5
Car occupant	3.3	4.5	2.2	4.2
Other/unknown	2.8	3.4	2.1	5.3

Table 8 shows that the average burden per MAIS3+ casualty differs between transport modes and between countries. In England, the average burden per casualty is highest for pedestrians, whereas in the Netherlands, the average burden per casualty is highest for car occupants and in the Rhône region; the average burden per casualties is highest for PTWs. In all countries except Spain, the average burden per casualty is relatively low for cyclists. None of the transport modes show a much higher burden of injury per casualty compared to the other transport modes. For more information on the burden of injury per casualty for different transport modes see Weijermars et al (2016).

### 3.2 ANALYSIS BY AGE AND GENDER

Concerning the distribution over gender, in all countries, women show a slightly higher share in MAIS3+ casualties than in fatalities. The data from Austria shows that the share of women slightly declines with increasing injury severity. However, for most countries, the differences are small. Therefore, and because it is a quite large and diverse group of casualties it does not really make sense to select women as a group for a further analysis.

Figure 7 shows the distribution of fatalities, police reported serious road injuries and hospital registered MAIS3+ casualties over age groups. In all countries, the share of MAIS3+ casualties appears to be relatively high for road users aged 0-17 yrs. Also in Austria and in the GIDAS database, the share in MAIS3+ casualties is relatively high for children and adolescents. In addition to 0-17 yrs, in the Netherlands, 50-79 yrs also have a relatively high share in MAIS3+ casualties. In the GIDAS data, the share of MAIS3+ casualties is relatively high for 40-69 yrs. These groups do not come up as relevant groups in the other countries. As Table 9 shows, in these countries, the MAIS3+/fatality ratio is only clearly higher than average for 0-17 yrs and not for other age groups.

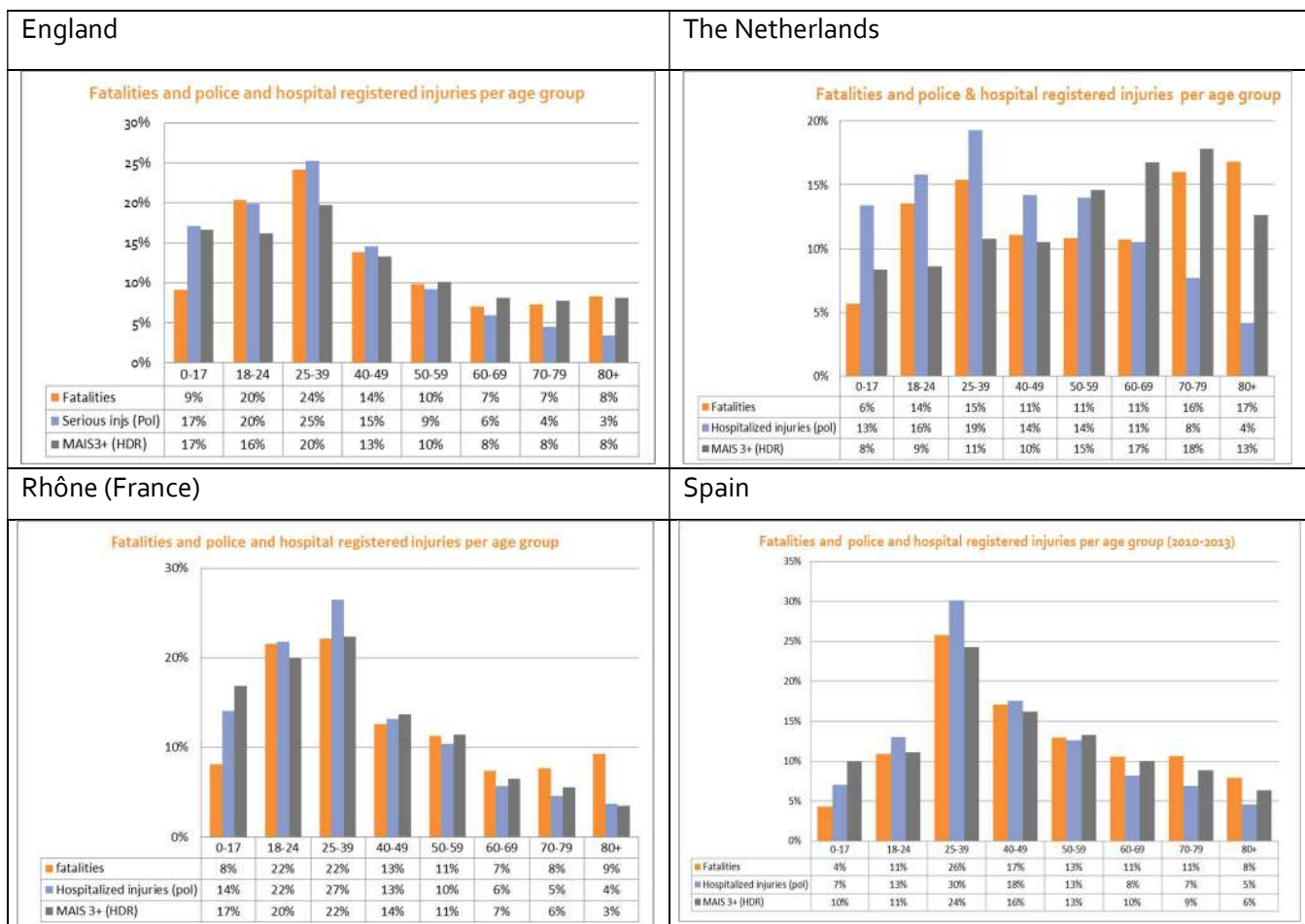


Figure 7: Distribution of fatalities, police reported serious injuries and hospital registered MAIS3+ casualties over age groups.

Further analysis by gender (see appendix) shows that in England, Spain, the Rhône region and in the GIDAS data, the MAIS3+ to fatality ratio is higher for males aged 0-17 yrs then for females aged 0-17 yrs (7 vs 6 in England, 13 vs 8 in Spain, 19 vs 12 in the Rhône region and 15 vs 4 in the GIDAS data), whereas in the Netherlands, the MAIS3+ to fatality ratio is higher for females than for males (17 for females aged 0-17 yrs compared to 15 for males aged 0-17 yrs).

Overall, the MAIS3+ to fatality ratio is comparable for males and females in England (both 4), Spain (both 5), and the Rhône region (8 for males and 9 for females) and higher for females than for males in the Netherlands (16 vs 9).

Table 9: Number of MAIS3+ casualties per fatality for different age groups in different countries.

Age group	England	Netherlands	Rhône (France)	Spain
0-17	7	16	17	11
18-24	3	7	8	5
25-39	3	7	8	5
40-49	4	10	9	5
50-59	4	14	8	5
60-69	4	17	7	5
70-79	4	12	6	4
80+	4	8	3	5
Total	4	11	8	5

Figure 7 shows that the distribution over age groups also differs between hospital registered MAIS<sub>3+</sub> casualties and police reported serious road injuries, especially in England and in the Netherlands. In both countries, younger age groups show a higher share in police reported injuries than in hospital reported casualties, whereas older age groups show a higher share in hospital reported casualties. As discussed in the previous section, differences can be due to differences in injury severity definitions and underreporting by the police. Regarding the differences in injury severity definition, it is known from the Netherlands (Weijermars, Stipdonk, Aarts, Bos & Wijnen, 2014) that the proportion of MAIS<sub>3+</sub> casualties within hospitalized casualties increases with age. This could explain why the share of elderly is higher in MAIS<sub>3+</sub> casualties than in police reported serious road injuries. On the other hand, according to Amoros et al. (2006) underreporting by the police is slightly higher for younger casualties than for older casualties. Alsop & Langley (2001) found that police reporting rates are lower for children (aged < 19). A similar conclusion was drawn by Watson et al. (2015). This would result in an overrepresentation of adult casualties in police statistics. Because the ratios differ between age groups, it can be concluded that police reported injuries do not provide a good picture of the distribution of serious road injuries over different age groups.

3.2.1 Burden of injury

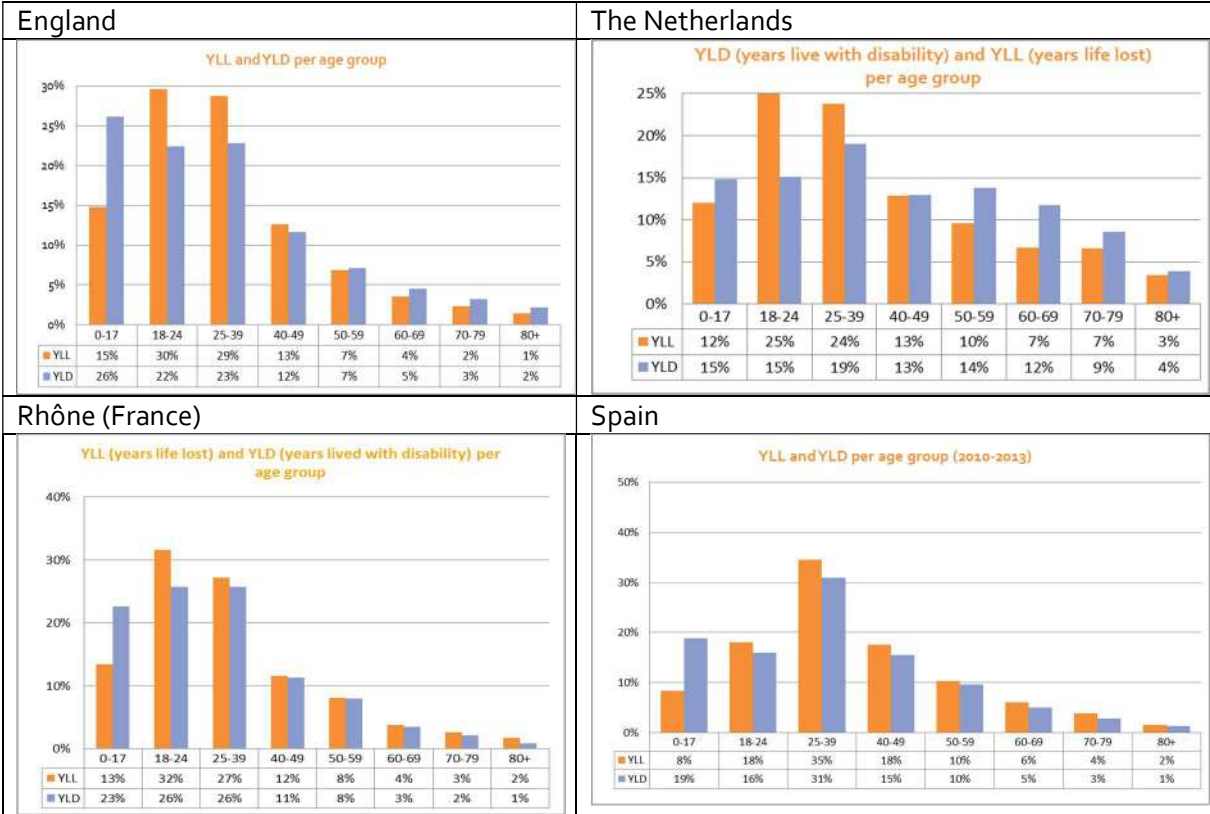


Figure 8: Distribution of Years of Life Lost (YLL) of fatalities and Years Lived with Disability (YLD) of MAIS<sub>3+</sub> casualties over age groups.

Figure 8 shows that in all four countries, 0-17 yrs show a higher share in the burden of injury of MAIS<sub>3+</sub> casualties compared to their share in the health burden of fatalities. The same is the case for the GIDAS data. In England, also the absolute share in YLD is highest for this age group, whereas in the other countries, the absolute share in YLD is highest for casualties of 25-39 yrs and in the GIDAS data the share is highest for 18-24 yrs. In England and the Netherlands, also for casualties of 50 yrs and older, the share in YLD is higher than the share in YLL. This can also be seen from the YLD to YLL ratios (Table 5). In all four countries, the YLD/YLL ratio is higher than average for 0-17 yrs, and in

England and the Netherlands, the ratio is also higher than average for age groups starting at 50 (NL) and 60 (EN) yrs or older.

Table 10: Ratio between YLD related to MAIS<sub>3+</sub> casualties and YLL for different age groups in different countries.

Age group	England	Netherlands	Rhône (France)	Spain
0-17	0.5	1.2	0.9	1.5
18-24	0.2	0.6	0.4	0.6
25-39	0.2	0.8	0.5	0.6
40-49	0.3	0.9	0.5	0.6
50-59	0.3	1.3	0.5	0.6
60-69	0.4	1.6	0.5	0.6
70-79	0.4	1.2	0.4	0.5
80+	0.5	1.0	0.3	0.6
Total	0.3	1.0	0.5	0.7

Further analysis by combinations of age and gender shows that for casualties aged 0-17 yrs, the YLD/YLL ratio is higher for males than for females in England, Spain and the Rhône region of France, whereas in the Netherlands the ratio is higher for females than for males. For casualties of 50 yrs and older, the YLD/YLL ratio is higher for females than for males both in England and in the Netherlands.

Table 11: average burden (YLD) per MAIS<sub>3+</sub> casualty for different age groups in different countries.

Age group	England	Netherlands	Rhône (France)	Spain
0-17	5.0	5.4	3.3	10.0
18-24	4.5	5.5	3.2	7.5
25-39	3.7	5.3	2.9	6.7
40-49	2.8	3.7	2.1	5.0
50-59	2.3	2.8	1.7	3.8
60-69	1.8	2.0	1.3	2.6
70-79	1.3	1.4	1.0	1.7
80+	0.9	0.9	0.7	1.1
Total	3.2	3.0	0.9	10.0

Table 11 shows that in general, the average burden per MAIS<sub>3+</sub> casualty decreases by age. This is due to a decrease in remaining life expectancy as age increases. For more information about the average burden per person see Deliverable 7.2 (Weijermars et al., 2016).

### 3.2.2 Selection of interest group(s)

In all countries, 0-17 year olds appear to have a relatively large share in the number of MAIS<sub>3+</sub> casualties and in the burden of injury of these casualties. In most countries, the MAIS<sub>3+</sub> to fatality ratio and YLD/YLL ratio are highest for road traffic casualties aged 0-17 yrs. Moreover, the average burden per casualty is relatively high for these casualties, due to a long remaining life expectancy. Therefore, these casualties are selected as the main group for further analysis. Other age groups that could be considered relevant from a burden of MAIS<sub>3+</sub> injury perspective are casualties of 50/60 yrs and older. These casualties show a somewhat higher share in YLD compared to YLL in respectively the Netherlands and England. However, this is not the case in the Rhône region of France and in Spain and is the main reason that in this Deliverable focuses on casualties aged 0-17 yrs. 0-17 yrs have a share of 8% to 17% in the number of MAIS<sub>3+</sub> casualties and a share of 15% to 26% in the burden of injury of MAIS<sub>3+</sub> casualties and are therefore also relevant concerning absolute numbers.

### 3.3 ANALYSIS PER TYPE OF INJURY

Concerning the analysis per type of injury, we applied the EUROCCOST injury classification (Polinder et al., 2004). The EUROCCOST injury classification consists of 39 types of injury, such as concussion, 'other skull-brain injury' and open head wound. It is important to note that in England, Spain and the Netherlands, only for fatalities that died in the hospital the injury group is known. The majority of the road traffic fatalities die before they arrive in the hospital, i.e. on the scene or in the ambulance. Therefore, the distribution over EUROCCOST injuries is not representative for all fatalities. For Germany and the Rhône region, we have information on the type of injury for casualties that died on scene as well; that provides a better indication of the type of injuries of fatalities.

Because, for most countries, we only have information on fatalities that die in the hospital, we do not show the MAIS<sub>3+</sub> to fatality and the YLD/YLL ratio and we did not determine the distribution of YLL over the EUROCCOST injury groups. Also for police reported serious injuries, the type of injury is not known. Therefore, the structure of this section is slightly different from the other sections and the results concerning numbers of casualties and burden of injury are combined.

Furthermore, we should note that some of the MAIS<sub>3+</sub> casualties have multiple injuries. Further analysis (see Appendix B) shows that in the Netherlands, almost 50% of all MAIS<sub>3+</sub> casualties have multiple injuries. These injuries can be AIS<sub>2-</sub> or AIS<sub>3+</sub>. For our analysis, we selected MAIS<sub>3+</sub> casualties and subsequently determined the EUROCCOST primary injury group applying the hierarchical scheme proposed by Polinder et al. (2008) using all injuries (both AIS<sub>3+</sub> and AIS<sub>2-</sub>) of the MAIS<sub>3+</sub> casualty. Only taking into account AIS<sub>3+</sub> injuries when selecting the primary injury or taking into account all AIS<sub>3+</sub> injuries when determining the distribution of injuries over the body, slightly changes the results. However, analyses on Dutch data show that the general conclusions are not affected by this choice.

Figure 9 shows the distribution of fatalities (for some countries limited to fatalities in the hospital), MAIS<sub>3+</sub> casualties and YLD over the main EUROCCOST injury groups. Only EUROCCOST injury groups with a share of more than 5% in either fatalities, MAIS<sub>3+</sub> casualties or YLD are included in the graph.



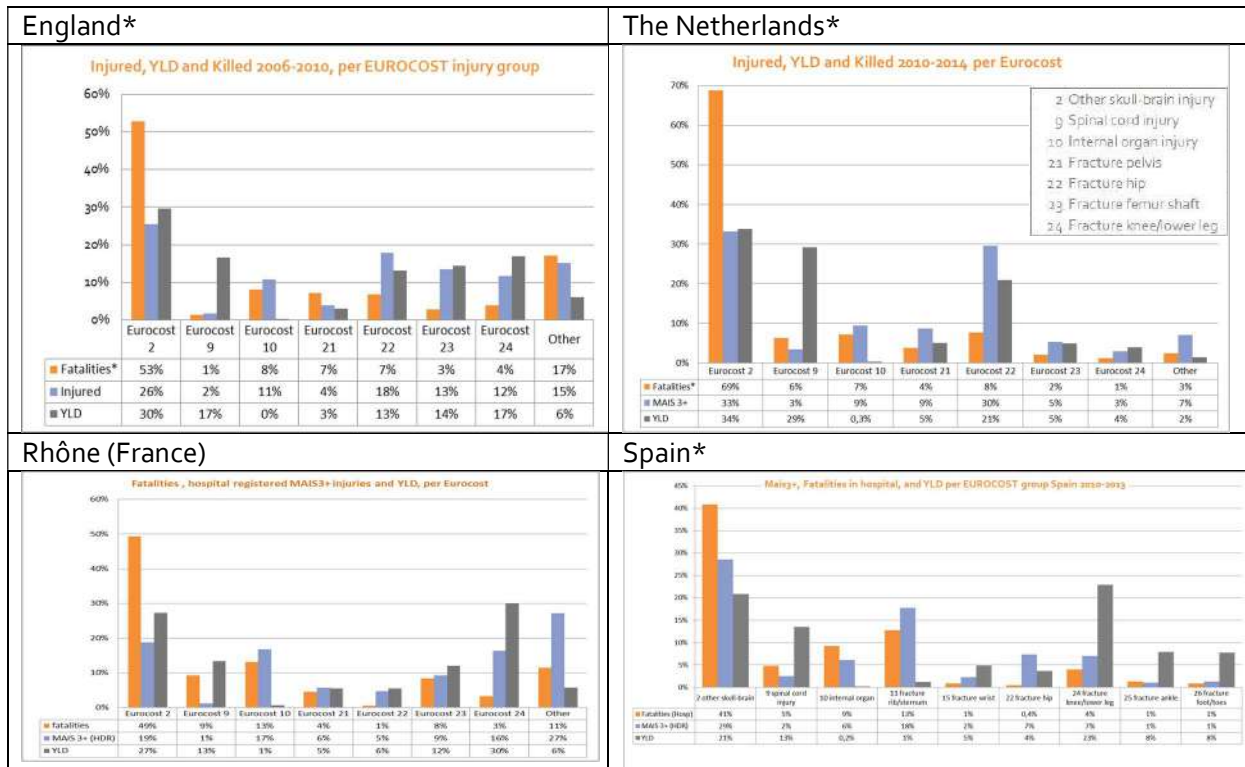


Figure 9: Distribution of fatalities, MAIS<sub>3+</sub> casualties and Years Lived with Disability (YLD) over the main (share >5%) EUROCOSt injury groups. \*for England, The Netherlands and Spain, only fatalities that died in the hospital are included in the analysis.

In all four countries, EUROCOSt group 2: 'skull-brain injuries other than concussions, open head wounds and facial injuries', has the highest share in fatalities and in MAIS<sub>3+</sub> injuries. This is also the case for Austria and the GIDAS data. In England, the Netherlands and the GIDAS data, this EUROCOSt injury group also has the highest share in YLDs of MAIS<sub>3+</sub> casualties. In the Rhône region and in Spain it is the second contributor to YLD. However, in all four countries, the share in MAIS<sub>3+</sub> casualties and the share in YLD is clearly smaller than the share in fatalities. Therefore, this group is not selected for further analysis.

In the Rhône region of France and in Spain, EUROCOSt group 24: 'fractures of knee/lower leg' has the highest share in YLD. In England, fractures in knee/lower leg are the second largest contributor to YLD, together with spinal cord injuries (EUROCOSt group 9). In the GIDAS data, knee/lower leg fractures are the fourth main contributor.

Spinal cord injuries are one of the main contributors to the burden of injury of MAIS<sub>3+</sub> casualties in all four countries and in the GIDAS data. This is due to a very high average burden per casualty, compared to other types of injuries. Moreover, as was seen in Deliverable 7.2 (Weijermars et al., 2017), all casualties with spinal cord injuries encounter lifelong disabilities.

In the Netherlands, also hip fractures (EUROCOSt group 22) have a relatively high share in the number of MAIS<sub>3+</sub> casualties (30%) and in the burden of injury of these casualties (21%). More than 80% of these casualties are cyclists. Hip fractures have a smaller share in the burden of injury in the other countries: 13%, 9%, 6% and 4% in respectively England, GIDAS, the Rhône region and Spain.

In the GIDAS data, femur shaft fractures are the 3th main contributor to the burden of injury of MAIS<sub>3+</sub> casualties, after skull-brain injuries and spinal cord injuries and are responsible for 13% of

the YLD of MAIS<sub>3+</sub> casualties. Both in England and in the Rhône region, these fractures are the fourth contributor to the burden of injury of MAIS<sub>3+</sub> casualties. Moreover, femur shaft fractures have a higher share in YLD than in fatalities in all countries.

### 3.3.1 Selection of interest group(s)

On the basis of the results of all countries together, the following groups are selected for further analysis:

- Spinal cord injuries
- Fractures in knee/lower leg
- Femur shaft fractures.

Spinal cord injuries result in long-term disabilities and therefore are a main contributor to years lived with disability of MAIS<sub>3+</sub> casualties in all four countries that were included in the analysis. We should mention that the absolute number of MAIS<sub>3+</sub> casualties that encounter spinal cord injuries is relatively small. In the four countries included in the analysis, spinal cord injuries make up only 1% to 3% of all MAIS<sub>3+</sub> casualties. However, because of their large health impacts, they are responsible for 13% to 29% of the burden of injury of MAIS<sub>3+</sub> casualties.

Knee/lower leg fractures have the highest share in the burden of injury of MAIS<sub>3+</sub> casualties in the Rhône region and in Spain and is the second largest group in England. Concerning absolute numbers, 3% to 16% of all MAIS<sub>3+</sub> road traffic casualties have knee/lower leg fractures and these injuries are responsible for 4% to 30% of the burden of injury of MAIS<sub>3+</sub> casualties. Therefore, also this group is selected for further analysis using in-depth data.

Femur shaft fractures are responsible for quite a large part of the burden of injury in both the Rhône region of France and England (respectively 30% and 14% of the burden of injury of MAIS<sub>3+</sub> casualties). Moreover, in all four countries, the share in MAIS<sub>3+</sub> casualties and in the burden of injury is larger than the share in fatalities for femur shaft fractures. Therefore, this group could also be relevant. However, because of time constraints, this group was not further analysed in 'step 2'.

## 3.4 FURTHER ANALYSIS

This chapter provides a first further analysis of the selected groups of casualties using hospital data.

### 3.4.1 Cyclists

Cyclists were selected because they show the highest MAIS<sub>3+</sub> to fatality ratio and YLD to YLL ratio of all transport modes in all four countries.

On the basis of Dutch data, a distinction can be made between cyclists injured in crashes with motorized vehicles being involved, e.g. cyclist – car crashes, and cyclists injured in crashes without motorized vehicles being involved, e.g. a single bicycle crash. Almost 4 out of 5 cyclists (78%) are injured in a crash without motorized vehicles being involved. For fatalities, this number is more difficult to estimate. It was usually estimated using police reported fatalities, but crashes without motorized vehicles are known to be heavily underreported by the police. Schepers et al (2017) recently estimated the number of fatalities in cyclist crashes without motorized vehicles using cause of death statistics and estimated that about one quarter of the cyclists are killed in crashes without motorized vehicles (1996-2014).

Appendix B shows the distribution of MAIS<sub>3+</sub> cyclist casualties over age and gender and over types of injuries. In the Netherlands, the share of women cyclists is relatively large among MAIS<sub>3+</sub>

casualties compared to fatalities; about 46% of the MAIS<sub>3+</sub> casualties are female. This cannot be seen in the other countries; both in England and the Rhône region, about 80% of the MAIS<sub>3+</sub> cyclist casualties are male and in Spain more than 90% are male. In England, the Rhône region and Spain, male cyclists aged 0-17 yrs appear to be a very relevant group as they have the highest share in the number of MAIS<sub>3+</sub> casualties as well as in the burden of injury of MAIS<sub>3+</sub> casualties and their share in MAIS<sub>3+</sub> and YLD is larger than in fatalities and YLL. For the Netherlands, a further distinction can be made between cyclists injured in crashes with motorized vehicles and cyclists injured in crashes without motorized vehicles. The share of cyclists aged 0-17 yrs appears to be clearly higher in crashes with motorized vehicles; 13% of the MAIS<sub>3+</sub> cyclist casualties in crashes with motorized vehicles involved are aged 0-17 yrs, compared to 5% in crashes without motorized vehicles.

Concerning the type of injury, Appendix B shows that both in England and the Netherlands, the most common types of injury of cyclists are hip fractures (41% of MAIS<sub>3+</sub> casualties in both countries) and skull-brain injuries other than concussions, open head wounds and facial injuries (respectively 38% and 32% of MAIS<sub>3+</sub> casualties in England and the Netherlands). In Spain, almost half of the MAIS<sub>3+</sub> cyclist casualties has skull-brain injuries other than concussions, open head wounds and facial injuries as a main diagnosis. In the Rhône region, the most common type of injury of MAIS<sub>3+</sub> cyclist casualties is a broken elbow/forearm; 25% of the MAIS<sub>3+</sub> injured cyclists have a broken elbow or forearm as the main EUROCCOST injury group<sup>9</sup>. Other skull brain injuries (22% of MAIS<sub>3+</sub> cyclist casualties) and hip fractures (12%) are the second and third most common type of injury among cyclists. A broken elbow/forearm results in a relatively low burden of injury per casualty. As a consequence, the share in the burden of injury of cyclist MAIS<sub>3+</sub> casualties in the Rhône region is only 5% for elbow/forearm fractures. In the Rhône region, the share in the burden of injury is highest for other skull brain injuries (34%) and for fractures in knee/lower leg (18%). Other skull brain injuries also have the highest share in YLD of cyclist MAIS<sub>3+</sub> casualties in England, Spain and the Netherlands. However, in England and in the Netherlands, hip fractures are the second largest group concerning YLD whereas in Spain spinal cord injuries are the second largest group.

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<sup>9</sup> Please note that these injuries are mainly open/comminuted/displaced fractures of radius or ulna that were coded in AIS98 (codes AIS98 752804, 752806753204,753206). In AIS2005, some of these fractures have a lower AIS score.

The distribution of injuries and burden of injury over the body can be visualised by the so-called burden of injury body profiles. These profiles in Figure 10 indicate that the types of injuries differ between cyclists injured in crashes with motorized vehicles and in crashes without motorized vehicles. Casualties in crashes without motorized vehicles often have hip injuries, whereas cyclists injured in crashes with motorized vehicles more often obtain head injuries. Moreover, for cyclists injured in crashes with motorized vehicles, spinal cord injuries have a relatively high share in the burden of injury.

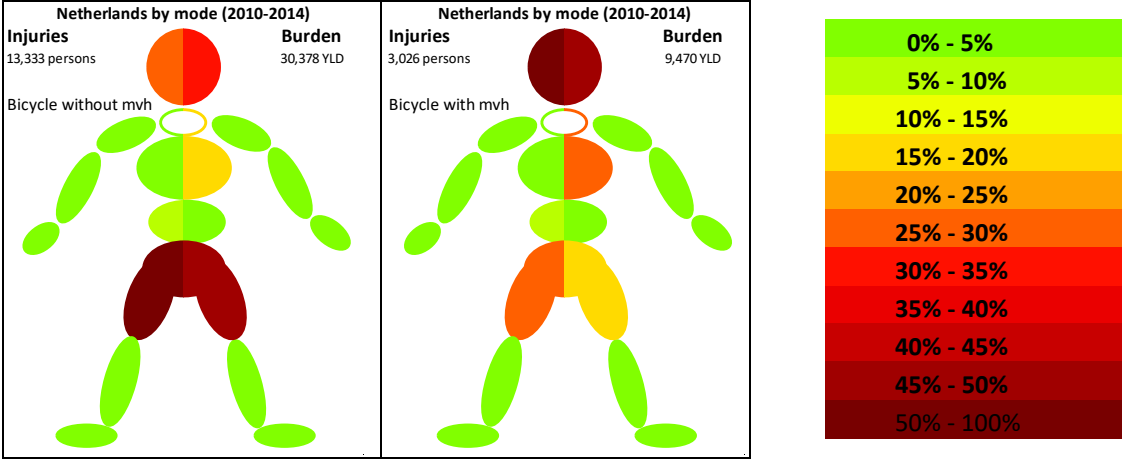


Figure 10: burden of injury body profile of MAIS<sub>3+</sub> cyclist casualties in crashes without motorized vehicles (left) and crashes with motorized vehicles (right).

**3.4.2 0-17 year olds**

In all countries, road users aged 0-17 yrs appear to have a relatively large share in the number of MAIS<sub>3+</sub> casualties and in the burden of injury of these casualties. Moreover, the average burden per casualty is relatively high for these casualties, due to a long remaining life expectancy. Therefore, these casualties are selected as the main group for further analysis.

Further analysis of 0-17 yrs MAIS<sub>3+</sub> casualties shows that the share of pedestrians is relatively large for this age group. Besides, in England, Spain and the Rhône region, the share of cyclists is relatively high as well. In the Netherlands the share of cyclists is lower than average for 0-17 yrs, although also cyclists aged 0-17 yrs have the highest share amongst MAIS<sub>3+</sub> casualties of all transport modes. In the Netherlands, the share in PTW is relatively high for 0-17 yrs MAIS<sub>3+</sub> casualties, both compared to fatalities and compared to other age groups.

Further analysis by EUROCCOST injury group shows that skull brain injuries other than concussions, open head wounds and facial injuries (EUROCCOST group 2) have the highest share in MAIS<sub>3+</sub> casualties of 0-17 yrs. Moreover, their share is higher for 0-17 yrs than for all age groups together. Other injuries that are relatively common among 0-17 year old MAIS<sub>3+</sub> casualties are femur shaft fractures (EUROCCOST group 23) and fractures to knees and lower legs (EUROCCOST group 24, not in Spain).

**3.4.3 Spinal cord injuries, knee/lower leg fractures and femur shaft fractures**

Spinal cord injuries result in long-term disabilities and therefore are a main contributor to years lived with disability of MAIS<sub>3+</sub> casualties in all four countries that were included in the analysis. Therefore, this group is selected for further analysis using in-depth data in chapter 4. Further analysis on the basis of crash statistics (Appendix B) shows that spinal cord injuries are relatively common among car occupants; the share of car occupants is higher for spinal cord injuries than for all injuries

together in all four countries. The age distribution of spinal cord injuries is comparable to the age distribution of all injuries together.

Knee/lower leg fractures have the highest share in the burden of injury of MAIS<sub>3+</sub> casualties in the Rhône region and in Spain and is the second largest group in England. Therefore, also this group is selected for further analysis using in-depth data. Further analysis on the basis of crash statistics (Appendix B) shows that knee/lower leg fractures are most common among powered two-wheelers. In all four countries, powered two-wheelers have the highest share in YLD among MAIS<sub>3+</sub> casualties with knee/lower leg fractures of all transport modes (except from other/unknown in Spain, due to a large share of unknown). Powered two-wheelers are responsible for 34% (England) to 50% (Rhône region) of the burden of injury of MAIS<sub>3+</sub> casualties with knee/lower leg fractures. Moreover, knee/lower leg fractures are relatively common among younger road traffic casualties. The share of casualties aged 0-17 yrs is higher for knee/lower leg fractures than for all injuries together.

Femur shaft fractures are responsible for quite a large part of the burden of injury in both the Rhône region of France and England (respectively 30% and 14% of the burden of injury of MAIS<sub>3+</sub> casualties). Moreover, in all four countries, the share in MAIS<sub>3+</sub> casualties and in the burden of injury is larger than the share in fatalities for femur shaft fractures. Like knee/lower leg fractures, this injury is most common among powered-two wheelers. In all four countries, powered two-wheelers have the highest share in YLD among MAIS<sub>3+</sub> casualties with femur shaft fractures of all transport modes (except for unknown in Spain). Moreover, like knee/lower leg fractures, these fractures are relatively common among younger casualties. This group is not analysed in the in-depth determination of risk factors, because of time constraints.

### 3.5 CONCLUSION

The following groups of casualties are overrepresented among MAIS<sub>3+</sub> casualties and/or the burden of injury of these casualties compared to fatalities and are therefore selected for further analysis in the next chapter:

- Cyclists; often injured in crashes without motorized vehicles, most relevant injuries are skull-brain injuries other than concussions, open head wounds and facial injuries and hip fractures
- Road users aged 0-17 yrs; often pedestrians and to a lesser extent cyclists, most relevant injuries are skull-brain injuries other than concussions, open head wounds and facial injuries and femur shaft and knee/lower leg fractures.
- Spinal cord injuries; result in lifelong disability and are relatively common among car occupants
- Knee/lower leg fractures; most common among powered two wheelers and relatively common among younger casualties.

The group of Femur shaft fractures identified above was reserved from the final in-depth analysis stage as it was decided that a more thorough analysis on four groups, two road user groups and two injury groups, would provide stronger, more detailed results than including a fifth group. In addition the results from the determination of groups of interest, although clearly identifying Femur shaft fractures as a group of interest were not as strong as those for spinal cord and knee/lower leg fractures.

The results in this chapter show that the MAIS<sub>3+</sub> to fatality ratio differs considerably between countries. Partly, these differences can be due to differences in the selection of MAIS<sub>3+</sub> road traffic casualties in hospital data. England for example used ICD-10 whereas the Netherlands still applied ICD-9. As a result of these differences, estimated numbers of MAIS<sub>3+</sub> casualties and therefore also MAIS<sub>3+</sub> to fatality ratios are not fully comparable between countries. Furthermore, also differences in prevalence of specific crash types may contribute to differences in MAIS<sub>3+</sub> to fatality ratios. For

example, it could be the case that bicycle crashes in the Netherlands are more often single bicycle crashes with a lower impact than bicycle crashes in other countries. This might partly explain the high MAI<sub>3+</sub> to fatality ratio for cyclists in the Netherlands.

As a result of the differences between countries, MAIS<sub>3+</sub> to fatality ratios cannot easily be transferred from one country to another it does not make sense to derive MAIS<sub>3+</sub> to fatality ratios on a European level. We should also note that the MAIS<sub>3+</sub> to fatality ratios that are calculated in this Deliverable are probably an underestimation of the actual MAIS<sub>3+</sub> to fatality ratios. The reason for this is that the number of serious road injuries is estimated using hospital data only and therefore probably is an underestimation of the actual number of serious road injuries. However, most of the relevant groups seem to be similar for all countries included in the analysis, although the relevant EUROCCOST injury groups show some differences.

Concerning the use of police reported serious road injuries, it can be concluded that police registration does not provide a good picture of the characteristics of MAIS<sub>3+</sub> casualties. Due to a difference in injury severity definition and underreporting by the police, police reported serious road injuries show a different distribution over transport modes and age groups than hospital reported MAIS<sub>3+</sub> casualties. MAIS<sub>3+</sub> casualties among cyclists are for example heavily underreported by the police and therefore the share of cyclists is substantially underestimated when police reported injuries are used.

# 4 Analysis of in-depth datasets



This chapter discusses the main contributing factors and injury mechanisms for the groups of casualties that were selected in the previous chapter.

## 4.1 INTRODUCTION

Following on from the results of the determination of interest groups analysis this section outlines the process of analysing in-depth datasets to determine factors that contribute to or cause collisions related to four of the groups identified.

In total data from four countries has been used resulting in an indication of the associated risk factors. The word 'indication' is used as it is not possible to provide statistically robust results for all the interest groups across all countries, subsequently the results contained in this section should be seen as a window into a previously under researched group rather than a complete answer or solution to a problem.

Each group of interest identified (with the exception of femur shaft fractures) is discussed in its own chapter with only the main findings and interesting results contained in the body of the report. In order to illustrate the risk factors identified through the analysis a summary of the analysis is presented in addition to the main findings from each country.

To conclude each group a stereotypical collision description or range of stereotypical collision descriptions have been written to describe the type of event(s) that lead up to road users in the interest groups becoming injured or sustaining a certain injury type. This description does not describe one particular collision but instead attempts to encompass elements from the analysis of all collisions; as such this should be seen as a general description of a collision that *could* cause serious injuries (based on the data seen) and not necessarily what *has* caused serious injury (a description of an actual collision).

This approach was taken rather than a traditional research question based approach due to the differing datasets used in the analysis. The differences encountered made conducting a simultaneous and systematic analysis of all four datasets almost impossible, instead the expertise of individual country analysts was sought, allowing freedom to explore further than a national level dataset would allow whilst still remaining focussed on revealing 'risk factors'.

### 4.1.1 Groups of interest

As determined by the initial 'step 1' process (Chapter 3) the following groups of overrepresented MAIS<sub>3</sub>+casualties were selected for further analysis in this chapter:

- Cyclists; often injured in crashes without motorized vehicles, most relevant injuries are skull-brain injuries other than concussions, open head wounds and facial injuries and hip fractures
- Road users aged 0-17 yrs;
- Spinal cord injuries; result in lifelong disability and are relatively common among car occupants

- Knee/lower leg fractures most common among powered two wheelers and relatively common among younger casualties.

The group of Femur fractures identified was reserved from the final in-depth analysis stage as it was decided that a more thorough analysis on four groups, two road user groups and two injury groups, would provide stronger, more detailed results than including a fifth group. In addition the results from the determination of groups of interest, although clearly identifying Femur fractures were not as strong as those for spinal cord and knee/lower leg fractures.

The following sections take each group of interest in turn.

## 4.2 CYCLISTS

### 4.2.1 Group definition

Although the group definition has been determined through the initial process differences may exist within the country specific datasets which may have an effect on the overall analysis. The group definition makes no exemptions to e-bikes (or other forms of electrically assisted bicycles) or to tricycles or hand-cranked bicycles although the numbers in the data will most likely be tiny in comparison to 'traditional' bicycle designs. An overview of the country specific group definitions used for this section is shown below:

#### England

The group for this section of the analysis is cyclists. A 'Cyclist' in the English data includes anyone riding a bicycle or tricycle (both pedal and hand-cranked) and electrically assisted bicycles. There are no further restrictions applied to the definition of this group other than they should be injured in a road traffic collision (any severity). In keeping with the group of interest determination process the selected cyclists for this analysis will have sustained a MAIS 3+ injury but not be killed (within 30 days).

For England, two in-depth databases contained relevant information for analysis (as outlined in section 4.1.1). The outstanding dataset includes only injuries to car occupants and as such does not include any cyclists. Both the datasets selected for this section use an 'on-scene' approach; these are the On the Spot study and the Road Accident In Depth Study.

#### The Netherlands

The Dutch dataset comprises injury crashes of cyclists aged 50 years and over without involvement of high-speed motorized vehicles. As such the primary data selection for 'cyclists' was already made with only a subsequent selection made for MAIS 3+ injured individuals.

#### Germany

The group for this section of the analysis is cyclists. There are no further restrictions applied to the definition of this group in the GIDAS dataset other than they should be classed as a cyclist (i.e. not pushing a bicycle) and be injured in a road traffic collision.

#### Spain: Barcelona region

The group for this section of the analysis is cyclists. There are no further restrictions applied to the definition of this group other than they should be classed as a cyclist (i.e. not pushing a bicycle) and be injured in a road traffic collision.



#### 4.2.2 Data used

##### England

The following table shows the data used for the analysis of cyclists in England. Only one data set was available for the analysis (more information available in appendix XX)

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ cyclists	% of total cases available	% of total MAIS 3+ cases available
OTS	4744	257	31	0.6%	12%
RAIDS	1431	268	17	1.2%	6.3%
<b>Total</b>	<b>6175</b>	<b>525</b>	<b>48</b>	<b>0.9%</b>	<b>9.1%</b>

The proportion of MAIS 3+ injured cyclists in the English datasets appears to be quite low at 0.9%. This will be due to a number of factors (more of which can be seen in **Error! Reference source not found.**). To provide some context on this number two surveys, the British Social Attitudes survey<sup>10</sup> and the Active People Survey<sup>11</sup> indicate that between 5% and 9% of the population cycle once a week with only 3 to 4% cycling more frequently than this. Considering MAIS 3+ cyclist casualties as a proportion of all MAIS 3+ casualties in the datasets provides more consistent findings with reported casualty figures, for example, data for the reported collisions in Great Britain indicates that 14% of the MAIS 3+ casualties recorded in 2015 were cyclists. Considering this information the total proportion of MAIS 3+ cyclists available in the English In-depth datasets appears more realistic.

##### Germany

Data for the cyclist sample is shown below:

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ cyclists	% of total cases available	% of total MAIS 3+ cases available
GIDAS	5292	971	189	3.5%	19.4%

Filtering the overall MIAAS 3+ sample for cyclists provides a sample of 189 individual road users. This is nearly 20% of the total MAIS 3+ population.

Data contained on the causation of crashes is derived from the ACAS system. Data is only available on this from the GIDAS cases which were collected in Hannover since the year 2007.

##### Netherlands

The Dutch dataset comprises injury crashes of cyclists aged 50 yrs and over without involvement of high-speed motorized vehicles. Data was collected in both urban and rural areas across three different time frames over a total duration of 2 years from 2012 to 2014. The following table illustrates the NL cyclist sample:

Dataset	Total cases	Total MAIS 3+ cyclist Sample	% Total cases
NL	93	16	17%

The higher proportion of MAIS 3+ cyclists present in the Dutch sample will be as a result of the cyclist specific dataset and the fact that cases do not involve collisions with motorised vehicles. In

<sup>10</sup> <https://www.gov.uk/government/collections/statistics-on-public-attitudes-to-transport>

<sup>11</sup> <https://www.gov.uk/government/collections/walking-and-cycling-statistics#publications-released-during-2015>

addition the older target group for the data collection (50 yrs and older) may have adverse effects on the severity of the injury outcomes for this cyclist group leading to more MAIS 3+ injuries as a proportion of the total case number.

**Spain**

The Spanish dataset containing information of emergency traffic collisions in Barcelona contains 52,033 linked records between 2003 and 2015; within this sample 74 cyclists sustained a MAIS 3+ injury and survived the accident. This is 0.14% of the total records but 5.4% of the recorded number of cyclists in the sample.

Dataset	Total cases	Total MAIS 3+ cyclist Sample	% Total cases
Barcelona	52033	74	0.14%

**Combined sample**

Combined data available for cyclists sustaining MAIS 3+ injuries but not killed

Dataset country	Total cases with cyclists and MAIS 3+ injury	Composition of cases from countries
England	48	14.7%
Germany	189	57.8%
Netherlands	16	4.9%
Barcelona	74	22.6%
<i>Total</i>	<i>327</i>	<i>100%</i>

**4.2.3 Summary of main findings**

Analysis of in-depth datasets is available for four countries, England, German, The Netherlands and Spain. In total this sample includes 327 cases where a cyclist sustained a MAIS 3+ injury in a collision on the road. A full overview of the analysis of in-depth datasets is available in appendix C.

Examining the results for the cycle sample provides some interesting information as to the cause of collisions. Considering cycling does not involve licensing or mandatory testing (although an understanding of road rules is expected) the role in which the cyclists played in the causation of crashes is equally split between all road users involved. For example in the Dutch data the role in which other road users played is a contributory factor in more than half of the cyclist sample, this is echoed in the English data where there is an almost equal split in primary contributory factors between cyclists and motorised vehicle drivers.

One of the most common collision types for cyclists in the MAIS 3+ sample detailed above were collisions where a road user does not give or get given right of way in a traffic situation. As there are often a range of different crash types used to describe the above situation a generalised term that can be used to describe these is 'crossing or turning' collisions. Grouping them as 'crossing or turning' is valid as in all forms they generally involve some form of cross traffic or junction and therefore more potential conflict with other road users.

Crossing or turning crashes were identified as an important group in all of the datasets with the possible exception of the Spanish dataset where the presence of an intersection did not significantly increase MAIS 3+ injury risk, although pedestrian crossing points did raise the injury risk. In England and Germany the proportion of crashes involving turning or crossing was 56% and 52% respectively

whereas in the Dutch data this figure was reduced to around 19% potentially by the different dataset used.

These crossing and turning crashes, unlike single vehicle collisions covered below will most likely involve another road user, in this case the majority involve a passenger car for both the English and German datasets. In fact it can be seen that for crossing and turning crashes the collision opponent is a motorised vehicle (car, van, truck) in around 75% of the cases. Despite the mix of motorised vehicles and vulnerable cyclists this collision pattern is dissimilar to fatal cycle crash types where higher speed roads and heavy vehicles in urban areas are also present among crossing and turning crashes.

Examining the causation factors associated with turning and crossing crashes provides more detail on the types and nature of the errors and interactions seen. In the English data crossing and turning groups of crashes have 2.5 times the number of causation factors in the broad groups of 'perception' and 'conflict' than in other crash types (rear end crashes, merging crashes and other crash types) This is perhaps expected as perception (expecting, looking and planning) and conflict (communication with other road users) are very likely to be attributed to crashes that by their very nature rely on these factors. Other less common but over represented factors do exist such as attention issues and legal factors, in fact this injudicious action is closely linked to primary contributory factors that led to collisions and is over represented for cyclists whose actions led to a collision. The dataset from Barcelona also indicates that cyclists are more likely to receive a MAIS 3+ serious injury when a driver does not respect a crossing point when used by a cyclist.

Driver or rider error through attention factors is similarly over represented but appears to be more closely linked to the drivers of motorised vehicles; whether this error directly led to a collision occurring or not. This information is useful as countermeasures can be applied to target these causations; for example as cyclists make errors based around legal/injudicious action then the target could be education or the redesign of infrastructure to provide for cyclists as well as motorised traffic; this step could also resolve the driver attention factor as clearer signalling or road layouts could make cyclists more visible or predictable on the carriageway.

Single vehicle cycle crashes are particularly evident in the German and Dutch datasets representing approximately 30% and 50% of the total cases respectively. The characteristics of these crashes are varied but they generally happen on straight sections (i.e. away from intersections) and are as such often classed as 'driving accidents'. Driving accidents are the second largest group in the German data (accounting for 28% of all cycle crashes. A major factor in the collisions occurring in the Netherlands is distraction (20% of the cases) causing the cyclist to veer off course and collide with obstacles potentially exacerbated by the cycle facility being too narrow. In the German data the causes of the single vehicle collisions are more complex. However it can be seen that the largest group of causation factors are attributed to 'Information admission' where relevant information could have been acquired by the cyclist but it was not; this could be through distraction but also emotional state (anger, hurry, stress, sensation seeking), impairment (Alcohol, drugs medication, fatigue) and attentional issues (wrong focus of attention, over complex situation).

One factor that was identified in the Dutch data was obscuration of the cyclists' vision, particularly where collisions with obstacles were concerned. This factor is mirrored by the English data where vision obscuration accounts for nearly 50% of the cases; compared to the English dataset as a whole this result makes the recorded occurrence of vision obscuration in the MAIS 3+ cyclist sample around seven times the baseline dataset value for all collision types.

## England

- Equal split in cause between cycles and motorised vehicles

- Accident types are predominantly longitudinal collisions, crossing collisions and turning collisions
- Vision obscuration is present in nearly 50% of the cycles cases
- When collisions occur factors related to perception and conflict are the most common and more prevalent than that in other collisions
- Drivers whose actions initiated a collision event have more perception factors than cyclists
- Cyclists have more conflict factors than drivers
- Crossing collisions are dominated with factors related to perception and conflict but also have significant levels of legal and attention factors compared to other crash types
- Longitudinal crashes have more judgement and impairment factors than other crash types. This represent as threefold increase over other longitudinal crash types
- Factors of perception, legal and attention are much more prevalent for road user whose actions led to a collision.
- Crashes are commonly caused by driver/rider error or reaction, followed by injudicious actions and behaviour or experience issues – drivers are nearly twice as likely to have a driver error or reaction causation assigned compared to cyclists
- Cyclists whose actions initiated a collision have more injudicious actions attributed to the causation than all other crashes
- Besides driver/rider errors, crossing crashes are commonly associated with vision issues, road infrastructure and legal causations
- Merging or turning crashes are strongly linked to driver/rider error or reaction

### Germany

- Entered or crossed priority road most prevalent accident type – this is significantly more prevalent among cyclists than other road users with the same injury severity
- Single vehicle accidents second most common
- For detailed accident types those occurring on a straight stretch of road and those due to a road user entering a junction/crossing and not giving way to a cyclist on a cycle path are most common
- Accidents at property access are quite frequent among cyclist compared to other road users
- Collisions with cars are most common followed by collisions with an object – this could be the road surface.
- Over 90% of the causation attributed to cyclist collisions were human factors and within this group causations involving the admission of information (distractions, emotions, attention and physiological conditions) were most common

### Netherlands

- The role in which other road users played is a contributory factor in more than half of the cyclist sample
- Distraction as a factor in around 20% of the crashes causing cyclists to collide with other road users or objects
- Road factors identified were that bicycle facilities and carriageways were too narrow creating conflict between cyclists

### Spain: Barcelona region

- Cyclists aged over 64 yrs (with regarding to the group of 18-34 yrs) are more likely to be seriously injured.
- Regarding the causes of the collision, cyclists injured in a collision in which a driver has not respected the pedestrian crossing are more likely to be seriously injured.

#### 4.2.4 Stereotypical crash scenarios

##### Scenario A

A cyclist veers off course either unintentionally through distraction or from an external factor such as changes in road layout or something hitting the front wheel. The cyclist goes on to hit a feature (for example a kerb) before running off the road, losing balance and falling off sustaining injuries from the road surface. The outcome of this scenario is associated with the limited width of the roadway/bicycle facility and/or the position of the cyclist on the roadway/bicycle facility.

##### Scenario B

A cyclist is injured when they are not given right of way (or do not give way) at a junction where a road intersects a cycle path/route or accesses property. The cause of the crash is related to legal/right of way issues and driver/rider attention factors; it is also likely that sight distances are restricted. Typically the role in which the other road user played is contributory in the collisions with miscommunication between cyclists and vehicle drivers (or between cyclists and cyclists) also a factor in the collision.

##### Scenario C

A cyclist is injured when he/she encounter unexpected road furniture (e.g. bollard) on the bicycle facility or carriageway. The collision is associated with restricted visibility or because the road furniture is poorly placed or 'announced'. The cyclist collides with the road furniture and sustains injuries from the road surface.

### 4.3 YOUNG ROAD USERS - 0-17 YRS

#### 4.3.1 Group definition

Although the group definition has been determined through the initial process small differences may exist within the country specific datasets which may have an effect on the overall analysis. The full results of the analysis of in-depth datasets are available in appendix D.

#### England

The group for this section of the analysis is 0-17 yrs. There are no further restrictions applied to the definition of this group other than they should be between the ages of 0 and 17 (inclusive) and be injured in a road traffic collision in any transport mode. In keeping with the group of interest determination process the selected road user will have sustained a MAIS 3+ injury but not be killed (within 30 days)

For England three databases contain relevant information for analysis (as outlined in section **Error! Reference source not found.**), however only one could be used for the analysis of this age group. Data from the OTS and CCIS datasets could not be used as the age information was not provided.

#### Germany

The group for this section of the analysis is 0-17 yrs. There are no further restrictions applied to the definition of this group other than they should be between the ages of 0 and 17 (inclusive) and be injured in a road traffic collision in any transport mode

### Spain: Barcelona region

The group for this section of the analysis is 0-17 yrs. There are no further restrictions applied to the definition of this group other than they should be between the ages of 0 and 17 (inclusive) and be injured in a road traffic collision in any transport mode

#### 4.3.2 Data used

##### England

The following table shows the data used for the analysis of 0 to 17 yrs in England. Only one data set was available for the analysis (more information on the specifics of this decision is available above and in Appendix D)

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ 0 – 17yrs	% of total cases available	% of total MAIS 3+ cases available
<b>RAIDS</b>	1431	268	25	1.7%	9.3%

##### Germany

The GIDAS database contains 5292 available road users who were involved in collisions between 2005 and 2014, within this 971 sustained a MAIS 3+ injury and survived the accident. This is 18% of the total road users.

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ 0 – 17yrs	% of total cases available	% of total MAIS 3+ cases available
<b>GIDAS</b>	5292	971	65	1.2%	6.7%

Filtering this for road users aged 0-17 yrs provides a sample of 65 individual road users. This is nearly 6% of the total MAIS 3+ population.

Data contained on the causation of crashes is derived from the ACAS system. Data is only available on this from the GIDAS cases which were collected in Hannover since the year 2007.

### Spain: Barcelona region

The Barcelona region dataset containing information of emergency traffic collisions in Barcelona contains 52,033 linked records between 2003 and 2015, within this sample 110 casualties aged 0 to 17 yrs sustained a MAIS 3+ injury and survived the accident. This is 0.2% of the total and 3.9% of all 0 to 17 yrs in the regional dataset.

Dataset	Total cases	Total 0-17 yrs and MAIS 3+ injury	% of sample in cases
<b>Barcelona</b>	52033	110	0.2%

#### Combined sample

Combined data available for road users aged 0 to 17 yrs sustaining MAIS 3+ injuries but not killed

Dataset country	Total cases with 0-17 yrs and MAIS 3+ injury	Composition of cases from countries
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<b>England</b>	25	12.5%
<b>Germany</b>	65	32.5%
<b>Barcelona</b>	110	55%
<i>Total</i>	<i>200</i>	<i>100%</i>

### 4.3.3 Summary of main findings

Analysis of datasets is available for three countries, in-depth data from England and Germany, and linked data from the Barcelona region of Spain. In total this sample includes 200 cases where a 0 to 17 yrs road user sustained a MAIS 3+ injury but was not killed in a collision on the road.

As could be expected of this sample group the road user types injured are skewed towards forms of transport that require no license or aren't restricted to an age limit such as walking or cycling. This does not represent a limitation or bias in the data but reflects the road user types populated by road users aged 0 to 17. Pedestrians in particular are shown to be at particular risk in the German and Spanish data and, although not large in absolute numbers, are shown to be over represented in the English data; this emulates the results seen in initial group determination process.

Considering pedestrians in the 0 to 17 yrs sample it can be seen that crossing type collisions and collisions with cars are of particular interest as they are more common with this age group than older age groups. This is potentially useful in determining countermeasures with the data on causation and contributory factors allowing some insight into the specific types of failures.

For example the in-depth English data shows that pedestrians are likely to have causation factors assigned that are related to the broad groups of 'perception' and 'conflict'. The perception element is interesting as this general causation group covers elements relating to the pedestrian expecting, looking or planning, but is most often associated with causation factors relating to vision obscuration on and off the carriageway or due to carriageway geometry. This potentially indicates that there may be more to the individual crashes than simple errors or misjudgements.

In the in-depth German data the causation factors related to young road users, the majority of which are pedestrians, are based on human failures. This general group covers a range of more specific factors, including 'information admission' factors such as a wrong focus of attention or attention hindered due to physiological conditions (includes factors such as alcohol and drugs alongside medical conditions and physical stress or fatigue).

Information relating to the propensity of 'human factors' errors in crashes is not particularly surprising in itself as factors relating to human error tend to form the majority of causation factors applied to all common accident types. The information in this report does however show that there are potentially interesting factors with which to form countermeasures, for example understanding the crossing behaviour/crossing location choice of young pedestrians which could potentially increase the risk of vision or attention issues and/or the reintroduction of basic road safety education for young or teenage pedestrians.

The other factor that is common across all three countries in the analysis of 0 to 17 yrs road users is the frequency of two wheeler casualties amongst the young road user group. These appear in the German and Barcelona data as the largest group (if cyclists and PTW users are combined) and although small in absolute numbers in the English data still form nearly 15% of the road users (7 cyclists and PTWs involved, 50 road users in total).

The most common type of collisions for two wheelers were accidents when crossing or turning, both of which are over represented in the 0 to 17 sample compared with older age groups in both the in-

depth German and English data (no data on collision type available for the regional Spanish linked data). Collisions that occur when crossing or turning account for 100% of the two-wheeler road users in the English data and between 50% and 75% of the respective groups in the German data.

In-depth data from England indicates that this large group of crashes is associated with rider error or reaction (i.e. failed to look properly, poor turn or manoeuvre or junction issues) and by a smaller element of factors relating to behaviour or inexperience (i.e. careless, reckless, nervous or aggressive riding). Contrary to the pedestrian crashes there does not appear to be vision/obscuration issues related to these crashes. Further analysis of these causation codes indicates that two wheelers are much more commonly associated with 'looked but did not see' errors, incorrect anticipation of the speed or path of another vehicle or misjudgements of vehicle movement than other road users.

One additional finding from this sample is that the in-depth English data appears to present a different picture for passengers in cars aged 0 to 17 yrs. These road users account for over 50% of the MAIS 3+ injuries in the English sample compared to 19.8% in Germany (1% in Spain 1 although non-comparable data collection protocols) despite the English and German data collection protocols being quite similar. In England these collisions appear to be associated with head on and crossing/turning crashes and are influenced predominantly by impairment or distraction alongside smaller proportions of driver error and behaviour. By comparison in Germany, although occurring at a lower frequency, passengers injured in cars aged 0 to 17 yrs had similar causation factor (distraction from inside the vehicle) assigned to drivers of the vehicles.

#### 4.3.4 Key points from the individual datasets

##### England – in depth

- Over half of the road users aged 0-17 yrs sustaining MAIS 3+ injuries were passengers of cars.
- Crashes injuring road users aged 0 to 17 yrs involving some form of crossing or turning are all slightly over represented compared collisions injuring all other road users
- Pedestrian crashes are also over represented in the 0 to 17 yrs sample compared to all crashes.
- Riders of motorcycles and cyclists aged 0 to 17 yrs are only present in turning and crossing type collisions.
- The most common causation factors for other road users involved in cyclist crashes were exceeding the speed limit, failed to look properly and distraction in vehicle.
- The most common causation factors for cyclists aged 0 to 17 yrs were; failed to judge vehicle path or speed, careless/reckless or in a hurry and inexperience.
- When collisions occur factors related to perception and conflict are the most common and more prevalent than that in other collisions

##### Germany – in depth

- The most common group of injured 0 to 17 yrs road users were pedestrians, typically in collision with a car
- Young road users with MAIS3+ injuries were more often involved in an accident as a pedestrian and less often as a car occupant. They have a higher share of accidents when crossing the road as a pedestrian and have less driving accidents.
- Crossing accidents are more frequently found among young road users with MAIS 3+ injuries than among older road users with MAIS 3+ injuries.
- The analysis of the accident causes reveals that all the failures of young road are based on human failures – no causes from the vehicle or the environment were found



## Spain: Barcelona region – linked police/medical

- Motorcycle users and pedestrians significantly more likely to be MAIS 3+ injured compared to moped riders (reference group)
- Road users who did not use safety systems, whether in a motorised vehicle or on a two wheeler were likely to be seriously injured.
- Regarding the type of the crash, people 0-17 yrs old who were run over are more likely to be seriously injured
- Cases where a 0 to 17 yrs was involved in a lateral collision, a rear-end collision or a collision in dense traffic conditions appear protective with less likelihood of a seriously injury evident.

### 4.3.5 Stereotypical crash scenarios

#### Scenario A

A passenger aged 0 to 17 yrs is injured in a car in a vehicle to vehicle or vehicle to object collision. The cause of the crash is related to exceeding the speed limit and distractions within the vehicle. Errors made on the lead up to the collision indicate that the driver of a car perceived incorrectly the likely motion of their or another vehicle and that in doing so the driver adopted a path in conflict with another road user.

#### Scenario B

A pedestrian aged 0 to 17 yrs is injured in a collision with a motorised vehicle while crossing the road. The cause of the collision is related to an intentional breach of rules but also involves an element of wrong expectations, particularly regarding the behaviour of others or problems with the judging the speed and distance of others, amongst all these factors visibility problems dominate.

#### Scenario C

A two wheeler user aged 0 to 17 yrs is injured in a collision with another vehicle when crossing or turning at a road junction. The crash is instigated by rider error on the part of the 0 to 17 yrs, particularly failing to look properly and issues with manoeuvring or turning around the junction. There is no vision obscuration, the rider did look, but failed to see another vehicle or misjudged its speed or movement.

## 4.4 CASUALTIES WITH SPINAL CORD INJURIES

### 4.4.1 Group definition

Although the group definition has been determined through the initial process small differences may exist within the country specific datasets which may have an effect on the overall analysis. The full results of the analysis of in-depth datasets are available in appendix E. An overview of the country specific group definitions used for this section is shown below:

#### England

The group for this section of the analysis are persons who sustained a MAIS 3+ spinal cord injury but survived. There are no further restrictions applied to the definition of this group other than they should be injured in a road traffic collision.

For England, three databases containing relevant information for analysis (as outlined in section **Error! Reference source not found.**) could be used. All the datasets selected record detailed injury causation data.

## Germany

The group for this section of the analysis are persons who sustained a MAIS 3+ spinal cord injury and survived. There are no further restrictions applied to the definition of this group in the GIDAS dataset other than they should be injured in a road traffic collision.

### 4.4.2 Data used

#### England

The following table shows the data used for the analysis of spinal cord injuries in England. In total three datasets were available for the analysis as they included detailed information on injuries and their causation.

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ knee/lower leg cases	% of total cases available	% of total MAIS 3+ cases available
CCIS	10610	1798	8	0.07%	0.44%
RAIDS	1431	268	4	0.3%	1.49%
<b>Total</b>	<b>15354</b>	<b>2066</b>	<b>12</b>	<b>0.07%</b>	<b>0.5%</b>

The proportion of road users who sustained a MAIS 3+ spinal cord injury but did not die in the English data appears to be very low. This will be due to a number of factors, the most significant of which is that these injury types are very rare and especially rare in cases where the road users survived. Because the datasets used in the English data are skewed towards more serious crashes resulting in fatalities or life changing injuries the low number seen here could be as a result of most casualties dying with this injury.

#### Germany

Data for the MAIS 3+ spinal cord sample is shown below:

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ knee/lower leg cases	% of total cases available	% of total MAIS 3+ cases available
GIDAS	5292	971	25	0.4%	2.57%

Filtering the overall MAIS 3+ sample for spinal cord injuries provides a sample of 25 individual road users. This is 2.5% of the total MAIS 3+ population.

#### Combined sample

Combined data available for MAIS 3+ spinal cord injuries

Dataset country	Total cases with spinal cord MAIS 3+ injury	Composition of cases from countries
England	12	32.5%
Germany	25	67.5%
<b>Total</b>	<b>37</b>	<b>100</b>

#### 4.4.3 Summary of main findings

Analysis of in-depth datasets is available for two countries, England and Germany. In total this sample includes 37 cases where a road user sustained a MAIS 3+ spinal cord injury in a collision on the road.

The sample for spinal cord injuries appears to be exceptionally small considering the size of the overall in-depth datasets for both England and Germany. The overall number represents significantly less than 1% of all cases recorded (37 cases in a total sample of 22077).

Despite the small numbers seen the spinal cord injury group is an interesting one. Overall nearly three quarters of the total sample of road users who received a spinal cord injury were car occupants. This isn't overly surprising in itself as the majority of cases seen in the individual country datasets will be occupants of vehicles, however the consistency between the country data with respect to the injury causation indicates that there is more that can be achieved with vehicle crashworthiness.

One specific injury causation factor for car occupants, is that of 'body movement' in the German data and 'non-contact' in England is potentially interesting and covers a considerable proportion of the spinal cord injuries in both the combined German and English car occupant sample. In reality, as can be seen in the analysis of the English injury causation data, the spinal cord injury is likely as a result of other factors such as high energy impacts combined with restraint systems creating severe flexion/extension of the neck. In some cases, this may be exacerbated or instigated by a head contact with the A-pillar/side glass area or the inside of the windscreen. Despite being classed as a 'non-contact' type injury the mechanisms related to these spinal cord injuries are likely to be significantly more complex than this simple description alludes to.

In addition, the cases of supported roof intrusion and roof contacts in the English and German data suggests that roof strength, particularly in rollover situations, can have a large impact on the occurrence of spinal cord injuries in car occupants. In the English dataset all occupants were belted indicating that the injury mechanism is likely more related to the level and severity of the roof crush than the role played by occupant movement within the vehicle.

Related to this are the high levels of crush associated with narrow overlap collisions in the English data, this factor presents a difficult situation for the protection of occupants, particularly controlling head movement and reducing the loads on the Cervical spine from where all the spinal cord injuries in the English database are located. The complexities of the head and neck movements in these collision types can be seen as similar to that described in body movement/non-contact injury causation.

Considering the comparability of the car occupant spinal cord injury data, one group of spinal cord injuries that appear as an anomaly are the vulnerable two wheeler users in Germany. There were no occurrences of spinal cord injuries to these groups in the English data despite a large number of these road users appearing in the English datasets

#### England

- All spinal cord injuries seen in the English data were to car occupants
- Rollovers were over represented in sample compared to the dataset average
- In rollover crashes all of the spinal cord injuries were due to supported contact with roof intrusion

- Sample occupants do not have many injuries recorded but the type of injuries make them some of the most severely injured occupants compared to the dataset average
- Frontal impacts are underrepresented in sample compared to the dataset average
- In frontal impacts high levels of vehicle crush/damage and narrow impacts predominate
- All spinal cord injuries irrespective of the type of collision are located in a small region of the spine between C1 and T1

## Germany

- The majority of persons that suffered spinal cord injuries were car occupants (60%) in collision with an objects or other vehicles
- Motorcycle riders and cyclists also appear in the spinal cord sample but in smaller numbers with much more mixed injury causations
- The analysis of the causes of the injuries shows that for car occupants injuries to the spinal cord are mostly caused by the body movement
- Cyclists and PTW riders are more likely to have a spinal cord injury caused by an external object such as the road surface, off road surface or road side furniture.

### 4.4.4 Stereotypical crash scenarios

#### Scenario A

A car occupant, restrained correctly in a vehicle is involved in a rollover crash, as the vehicle rolls over high levels of roof crush are seen which is supported by the road surface/ground. This high energy event forces the roof downwards into the occupant space loading the occupants head and neck and causing a spinal cord injury.

#### Scenario B

A car occupant, restrained correctly in a vehicle is involved in a frontal collision. The damage pattern forms a narrow overlap causing substantial vehicle crush. The occupant moves forwards in the vehicle against the restraint system which creates a high energy flexion/extension movement of the neck causing a spinal cord injury. This flexion/extension may be exacerbated by a head contact to the A-pillar, windscreen or side glass.

#### Scenario C

A cyclist or motorcyclist is involved in a collision with an object which causes the rider to fall to the ground. The rider strikes the ground or road side furniture which causes a spinal cord injury typically through high energy flexion/extension of the neck.

## 4.5 CASUALTIES WITH KNEE/LOWER LEG INJURIES

### 4.5.1 Group definition

The EUROCCOST injury group used through the initial process differentiated between injury types to this region, for example soft tissue lower leg injuries and skeletal (fracture) injuries to the lower leg. Subsequently only fractures were to be considered for the in-depth analysis. Because EUROCCOST groups are not commonly used in in-depth databases an overview of the AIS coding manual concerning these body regions and severities indicates that an AIS 3+ injury in this region is the highest severity possible. These injuries are related to very extreme outcomes for the road users involved and will predominantly be limited to fractures which are potentially complex in nature, typically 'open' fractures involving an overlying soft tissue wound

Although the group definition has been determined through the initial process small differences may exist within the country specific datasets which may have an effect on the overall analysis. An overview of the country specific group definitions used for this section is shown below:

**England**

The group for this section of the analysis are persons who sustained a MAIS 3+ knee or lower leg fracture but survived. There are no further restrictions applied to the definition of this group other than they should be injured in a road traffic collision.

The three datasets provided different search and 'query' functions for identifying the relevant injuries. To ensure consistency between the different datasets a list of the AIS codes which fit the definition of the initial group definition process was compiled and compared with the sample cases. Due to the duration of some of the studies only AIS 90 coding was available for the earlier studies; these were excluded to remove coding discrepancies but also because vehicle and infrastructure design has changed considerably in the 30 years since these cases were collected.

For England, three databases containing relevant information for analysis (as outlined in section **Error! Reference source not found.**) could be used. All the datasets selected record detailed injury causation data.

**Germany**

The group for this section of the analysis are persons who sustained a MAIS 3+ knee or lower leg fracture injury but survived. There are no further restrictions applied to the definition of this group in the GIDAS dataset other than they should be injured in a road traffic collision.

**4.5.2 Data used**

**England**

The following table shows the data used for the analysis of knee or lower leg fractures in England. In total three datasets were available for the analysis as they included detailed information on injuries and their causation.

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ knee/lower leg cases	% of total cases available	% of total MAIS 3+ cases available
CCIS	10610	1798	29	0.27%	1.61%
OTS	4744	257	16	0.34%	6.23%
RAIDS	1431	268	12	0.83%	4.47%
<b>Total</b>	<b>16785</b>	<b>2323</b>	<b>57</b>	<b>0.34%</b>	<b>2.45%</b>

The proportion of road users who sustained a MAIS 3+ knee or lower leg fracture but did not die in the English data appears to be very low. This will be due to a number of factors, the most significant of which is that these injury types are often associated with other more serious medical outcomes which more often result in a fatality. In addition, the number of knee and lower leg fractures which have an AIS severity of 3+ are limited with only complex or open fracture types seen; this could make them appear less common than other lower leg or knee fractures which have an AIS severity less than 3.

**Germany**

Data for the MAIS 3+ knee or lower leg fracture sample is shown below:

Dataset	Total cases available [all severities]	Total MAIS 3+ cases available	Total sample of MAIS 3+ knee/lower leg cases	% of total cases available	% of total MAIS 3+ cases available
<b>GIDAS</b>	5292	971	173	3.26%	17.8%

Filtering the overall MAIS 3+ sample for knee or lower leg fractures provides a sample of 173 individual road users. This is nearly 18% of the total MAIS 3+ population.

### Combined sample

Combined data available for MAIS 3+ knee and lower leg fractures

Dataset country	Total cases with knee/lower leg MAIS 3+ injury	Composition of cases from countries
<b>England</b>	57	24.7%
<b>Germany</b>	173	75.3%
<i>Total</i>	<i>230</i>	<i>100</i>

### 4.5.3 Summary of main findings

The full results of the analysis of in-depth datasets are available in appendix F with an overview of the main findings below:

Within the MAIS<sub>3+</sub> road user sample who sustained a knee or lower leg fracture, riders of powered two-wheelers (PTWs) represented the largest share.

Severely injured car occupants and pedestrians also often suffered lower leg or knee injuries, though not as frequently as PTW riders.

Although evident in the sample cyclists who received MAIS<sub>3+</sub> knee or lower leg fractures were not as prevalent.

In general, vulnerable road users (PTWs, pedestrians, cyclists) most frequently suffered lower leg or knee injuries when in collision with a car, whereas car occupants more often sustained their injuries from collision with an object (e.g. tree).

For vulnerable road users, the lower leg or knee injury was most frequently caused by impact with the front bumper of the collision opponent.

Additionally, PTW riders commonly received these injuries from impact with the front wing, rear bumper, or had collisions with the road infrastructure, receiving injuries from an impact with the road surface or guard rails.

For car occupants, the majority received the lower leg or knee injuries from impact with the dashboard of their own vehicle during a collision.

The average delta-V (change in velocity) calculated from vehicle damage for car occupants who received a MAIS 3+ lower leg or knee fractures was 45kmh. This makes the collisions within the top 10% highest Delta-V results recorded for all collision types.

Additionally for collisions that result in a MAIS 3+ knee or lower leg fracture the damage details recorded for the observable damage to the vehicle structures indicated that as the Delta-V increased cases of 'severe crush to the vehicle structure with associated intrusion' and 'massive impact damage with loss of vehicle integrity' became more prevalent.

60% of the occupant contacts recorded as causing the knee or lower leg fracture in the English data were from the facia panel, rigid bracketry behind the facia panel or the footwell.

Other injury causation codes recorded for knee and lower leg fractures were from rigid bracketry behind the steering column, the lower A-pillar in the footwell, the pedals, the bulkhead, the back of a front seat or the interior of the side door.

The majority of passenger car collisions that resulted in MAIS 3+ knee or lower leg fractures were to the front of the vehicle and represented directions of force between 11 and 01 'o' clock (where 12 'o' clock represents straight ahead).

Where intrusion into the passenger compartment is seen (present in 54% of the English cases) the degree of this is relatively extensive with the average intrusion measure recorded as 32cm. 50% of all the intrusion measures are recorded as over 20cm

# 5 Conclusions and recommendations



## 5.1 DISCUSSION

Previous research that looked into characteristics of serious road casualties, searched for crashes with relatively many serious and fatal casualties in relation to less severe casualties (e.g. Rovšek, Batista, & Bogunović, 2017; Theofilatos, Graham, & Yannis, 2012; Yasmin, Eluru, Bhat, & Tay, 2014). More recent research focused on groups of casualties with high absolute numbers of serious road injuries ((Aarts et al., 2016; Ferreira, Amorim, & Couto, 2017). Aarts et al (2016) looked for common characteristics of crashes with serious road injuries for each transport mode including data from nine EU member states. They for example found that cyclist crashes are slight to heavily male dominated whereas MAIS<sub>3+</sub> pedestrian casualties have a quite equal distribution between males and females. Ferreira et al. (2017) used a binary logit model to investigate the factors for serious but non-fatal traffic accidents in and around Porto (Portugal). They found for example that people aged 65+ and men have an increased risk of a serious injury.

The groups that were indicated by both Aarts et al (2016) and Ferreira et al (2017) are to a large extent similar to groups that are relevant for fatalities. Therefore, we specifically looked for groups of casualties with relatively many MAIS<sub>3+</sub> casualties in relation to fatalities. In that way, we selected groups that are specifically relevant from a serious injury perspective, in addition to groups that are already taken into account from a fatality perspective. In addition, we also took into account long-term impacts of serious road injuries. As we recommended in Deliverable 7.2 'Physical and psychological consequences of serious road traffic injuries' (Weijermars et al., 2016), road safety policy should also be aimed at reducing long term health impacts. As long term health impacts differ between different groups of casualties, we also looked for groups of casualties with relatively large long-term health impacts.

The research from the determination of groups of interest provides information about MAIS<sub>3+</sub> to fatality ratios and YLD to YLL ratios for different groups of road users in a number of countries. The ratios appear to differ considerably between countries. These differences are probably partly due to differences in the selection of MAIS<sub>3+</sub> road traffic casualties in hospital data. Furthermore, also differences in prevalence of specific crash types may contribute to differences in MAIS<sub>3+</sub> to fatality ratios. Because the ratios differ considerably between countries it does not seem sensible to derive a generic set MAIS<sub>3+</sub>/fatality and YLD/YLL ratios that are applicable to all countries or the EU in general.

Although the relevant groups of casualties are quite comparable between countries, there appear to be some differences between countries. In two of the countries, casualties aged 50+, also appeared to be relevant from a burden of injury perspective. Moreover, the relevant EUROCCOST injury groups appeared to differ a little between the countries. As we only included 6 countries, there might be some groups of casualties that are relevant for a number of countries. Individual countries could make their own analysis and further analyse the groups that are relevant for their countries.

With the continued lack of progress in reducing serious casualties across European member states the numbers within the in-depth sample which, at the time of writing go back over 10 years in some instances, are likely to rise.



It is difficult and understandably beyond the scope of this report to estimate or predict this change, however with an increase in general road safety factors such as increased cycling and walking, an aging population, increased driving/commuting distances the effect could be considerable and hinder the improvements in a reduction of serious injuries across all traffic modes.

In addition, and because the number of cases included in the in-depth analyses is relatively small it will be necessary to continue with some form of investigation if the reduction in MAIS 3+ injuries is seen as a priority. Currently the large scale datasets collected and analysed at a national level are missing vital information as to why and how these types of collisions are occurring. There is a need for in-depth data to reveal more detail into the specific factors which contribute to these injuries; this is something that a national level dataset cannot currently do.

As a result of the limited in-depth samples seen, only an indication of the associated risk factors can be provided as it is not possible to provide statistically robust results for all the interest groups across all countries. Subsequently any results should be seen as a window into a previously under researched group rather than a complete answer or solution to a problem.

Continuing to concentrate solely on the MAIS 3+ groups identified and analysed through the steps outlined in this report and using similar datasets may continue to result in relatively sparse data. A possible reason behind this is that collision datasets were historically not purely focussed on collecting information on serious injuries with many being skewed towards fatal collisions; this effect could result in latency between serious injuries occurring and data collection protocols changing to record them.

The apparent paucity of serious injuries of the type highlighted through the initial group determination process within the in-depth data could lead to difficulties in developing countermeasures as the overall picture may not be sufficiently detailed to draw robust conclusions. Conducting a review of other EU member state in-depth datasets may be a useful additional step that could be conducted in order to determine whether the small number of cases seen is a reality on the roads or an artefact of the data collection protocols.

Considering the results from the in-depth analysis shows some close comparison between country data but also some anomalies. For example, there is close comparisons between the injury causations for car occupants sustaining MAIS 3+ spinal cord injuries, this is particularly evident for those road users in rollover events with roof intrusion. Similarly, the common crash types and associated causation factors appear to have some close comparison for MAIS3+ cyclists in crossing and turning collisions.

Studying previous work on MAIS 3+ injuries, particularly through the SUSTAIN study (Aarts et al., 2016) it can also be shown that some of the elements that contribute to the crashes and injuries in the samples that form 'step 2' of this deliverable are also seen for the wider MAIS 3+ group across Europe. For example, instances of "failures in looking" and "judgement" are present for the cyclist group in the SUSTAIN study and are reflected by high occurrences of "perception" and "judgment" in the SafetyCube analysis; a similar picture is also seen for "loss of control" causations for occupants of vehicles across both studies and for "speed" or speed-related causations for both vehicle occupants and pedestrians.

These consistencies make the process of continued analysis and the subsequent development of countermeasures potentially easier. Conversely there are also some anomalies with the results of the in-depth analysis which would certainly benefit further analysis.

Why is it, for instance, that the greatest proportion of road users aged 0 to 17 yrs in England are injured as a passenger in a car when the other countries show the largest group to be pedestrians? Is it possible that the dataset used for the English analysis perhaps favoured the inclusion of more motorised vehicles over VRUs? The difference however is striking and certainly not explained by England being more motorised compared to Germany, the Netherlands or Spain which is patently false.

Similarly the role of single vehicle cycle crashes on the MAIS 3+ cycle sample in the Netherlands and Germany is of primary importance for policy making in countries with currently low but rapidly increasing cycling numbers. Understandably the data which shows this characteristic is from countries with high cycling numbers and associated facilities but the question remains a larger one than this deliverable can answer.

One major advantage of analysing in-depth datasets is the availability of detailed causation and contributory factors. Previous analysis on these factors has been conducted by the SUSTAIN project which looked at MAIS 3+ casualties across pedestrians, cyclists, motorcyclists and car occupants. Clearly this division of groups does not match with the groups identified through the initial group determination process with the exception of cyclists. The cyclist contributory factor results from the SUSTAIN project indicate that failures in looking or judgement, careless or reckless behaviour and vision obscuration issues are present in large numbers of cases. At this higher level the in-depth analysis in this report shows some similar findings, however it is also possible to provide more detail into the specific causation factors across a range of situations, conditions and road user groups involved in cycle collisions, for example the in-depth analysis provides much more detail on where and how vision obscuration causation factors are present enabling countermeasure design to be more precisely applied.

For all road users combined the causation factors for MAIS 3+ casualties reported in the SUSTAIN project can be refined into a relatively restricted list mostly focussed on looking and judgement factors, speed related factors, loss of control factors and reckless/careless factors. This information is valuable as it fits well with the general causation factor occurrence from the in-depth analysis and therefore provides a larger knowledge base but begins to lose its power when identifying where countermeasures should be directed. The major advantage of the in-depth analysis is that it is possible to identify, for example where particular causation factors occur, how they occur, why they occur, when they occur and who the causation factors are attributed to, thereby providing an evidence base from which countermeasures can be designed.

Although the data analysis did not generally compare the groups of MAIS 3+ crashes with other less serious or more serious injury crashes the data generated through the analysis should perhaps not be taken as exclusive to these groups, certainly some of the characteristics identified such as distraction is seen throughout transport modes and is estimated to be a contributory factor in between 7% and 10% of fatal collisions<sup>12</sup>. That is not to say that the analysis contained in this report is not valuable, in fact it tells us that despite their relative rarity the causes and contributory factors that lead up the specific MAIS 3+ crashes contained in this report can be seen and tackled across a range of other severities. In other words, the groups of road users and injury types identified through this study may already be covered to some extent by existing road safety policy.

The results presented in this report do not provide a complete answer for policy making but rather provide more evidence and explanations for the design and implementation of road safety measures and policy. Due to the primary data source used for the in-depth analysis there is missing

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<sup>12</sup> NHTSA estimate distracted driving accounts for 10 percent of all crash fatalities, killing 3,179 people in the US in 2014 and nearly 7% of police reported fatal crashes in the UK have a distraction causation factor attributed to them.

information relating to travel behaviour (exposure) as well as risk factors relating to these specific groups: For example two of the groups analysed; cyclists and road users aged 0 to 17 often participate in urban traffic or as vulnerable road users and are perhaps, due to their age, more inclined towards risky behaviour not seen with older age groups using motorised vehicles. This evidence, although alluded to in the causation factors is not explicit but only implied.

Another factor that requires further analysis and investigation is the effect of vulnerability on the sample. It could be seen that crashes with cyclists on rural roads are more frequently fatal (based on likely impact speeds and associated injuries) thereby providing a larger sample of less severely injured cyclists involved in collisions on urban roads (based on lower likely impact speeds). The result of this effect could be that the data contained in in-depth datasets may only look at a sub-set of a sub-set and could therefore miss the wider picture, for example, in this case missing out crashes of higher impact speeds or on rural roads.

Additionally it is possible that there is an information/data bias towards the more prevalent or more protected road user group. This may be different between countries and could differ based on the purpose of the in-depth data collection, but it may influence the availability of the data or skew the results to one group or another. An example of this can be seen with research into cycle crashes where it is more common to gather information from drivers of motorised vehicles as they are less likely to be injured and available for interview. This effect can have a bias towards the collision causation (you only hear one side of the story) and subsequently countermeasures are based on potentially misleading information.

## 5.2 CONCLUSIONS

As opposed to fatalities as a result of a road traffic collision, MAIS<sub>3+</sub> casualties have only relatively recently attracted the sole attention of researchers with recent EU level reports<sup>13</sup> covering the most common causes of these injuries. This report does not attempt to replicate this work in dealing with the largest or most common groups of seriously injured road users, instead the task for this deliverable was to identify groups with relatively high injury to fatality rate or a relatively high health burden; these groups have potentially slipped below the primary focus of researchers and road safety stakeholders but are equally important to understand in order to reach goals such as 'vision zero' or reductions in health care costs.

The first step in the process was to identify the groups of interest. This was achieved by analysing national level collision and hospital datasets from 6 countries. The results from the step 1 process shows that the MAIS<sub>3+</sub> to fatality ratios differ considerably between these countries, therefore, MAIS<sub>3+</sub> to fatality ratios cannot easily be transferred from one country to another, making it impractical to derive MAIS<sub>3+</sub> to fatality ratios on an European level. However, most of the relevant groups appear to be similar for all countries included in the analysis, although the relevant EUROCOST injury groups show some differences.

Concerning the use of police reported serious road injuries, it can be concluded that police registration does not provide a good picture of the characteristics of MAIS<sub>3+</sub> casualties. Due to a difference in injury severity definition and underreporting by the police, police reported serious road injuries show a different distribution over transport modes and age groups than hospital reported MAIS<sub>3+</sub> casualties. MAIS<sub>3+</sub> casualties among cyclists are for example heavily underreported by the police and therefore the share of cyclists is substantially underestimated when police reported injuries are used.

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<sup>13</sup> [https://ec.europa.eu/transport/road\\_safety/sites/roadsafety/files/injuries\\_study\\_2016.pdf](https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/injuries_study_2016.pdf)

Despite the differences in the datasets between countries for the group determination process there are clear groups of road users who are over represented in terms of MAIS 3+ injuries or years lost to disability. The following groups are selected for further analysis on the basis of in-depth data:

- Cyclists; often injured in crashes without motorized vehicles, most relevant injuries are skull-brain injuries other than concussions, open head wounds and facial injuries and hip fractures
- Road users aged 0-17 yrs; often pedestrians and to a lesser extent cyclists, most relevant injuries are skull-brain injuries other than concussions, open head wounds and facial injuries and femur shaft and knee/lower leg fractures.
- Spinal cord injuries; result in lifelong disability and are relatively common among car occupants
- Knee/lower leg fractures, most common among powered two wheelers and relatively common among younger casualties.

Also femur shaft fractures have a relatively high share in the burden of injury of MAIS3+ casualties compared to their share in fatalities. However, because of time constraints, this group is not selected for further analysis.

The next step undertaken through the in-depth analysis process was to determine the crash causation or contributory factors that affect these particular groups. At a dataset level it is widely acknowledged that no single database provides enough information to give a complete picture of serious road traffic injuries and to fully understand underlying injury mechanisms. This is where the in-depth data sets are so important.

In total four in-depth country datasets were used from Germany, England, Spain and The Netherlands. Importantly these datasets were chosen as they contain information that relates to the specific causation factors that lead to collisions or the mechanisms that contribute towards injuries; both of these can be considered weaknesses of national level datasets to some extent. The following sections cover results from the analysis of in-depth datasets for each of the topics identified through the initial group determination process.

### Conclusions for road users aged 0 to 17 yrs

Passengers of cars and pedestrians were the two largest groups in the sample of old road users aged 0-17 yrs sustaining MAIS 3+ injuries. Cyclists and motorcycle riders were less evident in the sample.

MAIS 3+injured were most often involved in an accident as a pedestrian. They have a higher share of accidents when crossing the road as a pedestrian and have less driving accidents.

Across all road user types, crashes involving some form of crossing or turning were slightly over represented compared to collisions involving road users of other age groups. Riders of motorcycles and cyclists aged 0 to 17 yrs are only present in turning and crossing type collisions and crossing accidents are more frequently found among young road users with MAIS 3+ injuries than among older road users with MAIS 3+ injuries.

For drivers involved in a collision with a 0 to 17 yrs road user the most common causation factors were exceeding the speed limit, failed to look properly and distraction in vehicle.

The most common causation factors for 0 to 17 yrs cyclists were; failed to judge vehicle path or speed, careless/reckless or in a hurry and inexperience.

When collisions occur factors related to perception (expecting, looking and planning) and conflict (interpersonal communications) are the most common and more prevalent than that in collisions involving other age/road user groups.

The analysis of the accident causes reveals that most of the failures of young road users are based on human failures. Human failures in this context include a range of more specific factors, including 'information admission' factors such as a 'wrong focus of attention' or 'attention hindered due to physiological conditions'. Very few causes from the vehicle or the environment were found

The most common causation factors for 0 to 17 yrs pedestrians are related to the broad groups of 'perception' and 'conflict'. This group did involve environmental causation factors which were almost completely limited to visual obstructions.

### Conclusions for Cyclists

For cyclists of all age groups the primary contributory factor as determined through the independent collision investigation is attributed to the other road user in more than half of the sample. Drivers of vehicles involved in a cycle crash were judged to be nearly twice as likely to have caused the crash compared to cyclists.

Accident types are predominantly longitudinal collisions, crossing collisions and turning collisions. Collisions involving entering or crossing a priority road were the most prevalent accident type, with crashes involving a cyclist failing to give way or not given right of way in a traffic situation most common; some of these related to property access rather than road junctions.

Besides causation factors associated with driver/rider errors, crossing crashes are commonly associated with vision issues, road infrastructure factors and legal issues/infringements

Single vehicle cycle accidents second most common collision type across all country data but this shows regional differences (single cycle collisions are 2% of England sample but 28% and 50% from Germany and Netherlands respectively).

Over 90% of the causation factors attributed to cyclist collisions were human factors and within this group causations specifically involving the admission of information (Distraction, emotions, attention and physiological conditions) were most common. Distraction of the cyclist is a factor in around 20% of the crashes leading to cyclists colliding with other road users or objects.

Vision obscuration is present in nearly 50% of the cycle cases. The obscuration source is typically another parked or moving vehicle or issues related to infrastructure/road geometry.

Factors of perception (expecting, looking and planning), legal (disobeying signs or signals, unfit to drive due to alcohol or drugs) and attention (distraction, inattention) are much more prevalent for the road user whose actions led to a collision particularly for injudicious actions attributed to an cyclist.

### Conclusions for spinal cord injuries

The majority of persons that suffered spinal cord injuries were car occupants in collision with fixed objects or other vehicles.

Within the car occupant sample Rollover crashes appear to be over represented in sample compared to the expected crash type pattern for all other injury severities. In rollover crashes all of the spinal cord injuries were due to supported contact with roof intrusion.

Other impact types (frontal/rear/side) are underrepresented in the MAIS 3+ sample compared to the expected crash type pattern for all other injury severities. In general for these other impacts high levels of vehicle crush/damage are seen with narrow impacts prevalent in the frontal impact sample. The analysis into the cause of the car occupant spinal cord injuries in non-rollover crashes shows that they are mostly caused by the body movement and not a result of contact or direct trauma to the neck/spine itself.

Sample MAIS 3+ occupants do not have a high number of injuries recorded but the type and severity of these injuries make them some of the most severely injured occupants compared to the average injury score. All spinal cord injuries irrespective of the type of collision are located in a small region of the upper spine between C1 and T1

Motorcycle riders and cyclists also appear in the spinal cord sample but in smaller numbers with much more mixed injury causations Cyclists and PTW riders are more likely to have a spinal cord injury caused by an external object such as the road surface, off road surface or road side furniture.

### Conclusions for knee and lower leg fractures

Within the MAIS<sub>3+</sub> road user sample who sustained a lower leg or knee fracture, riders of powered two-wheelers (PTWs) represented the largest share. Severely injured car occupants and pedestrians also often suffered lower leg or knee injuries, though not as frequently as PTW riders. Although evident in the sample cyclists who received MAIS<sub>3+</sub> knee or lower leg fractures were not as prevalent.

In general, vulnerable road users (PTWs, pedestrians, cyclists) most frequently suffered lower leg or knee injuries when in collision with a car, whereas car occupants more often sustained their injuries from collision with an object (e.g. tree).

For vulnerable road users, the lower leg or knee injury was most frequently caused by impact with the front bumper of the collision opponent. Additionally, PTW riders commonly received these injuries from impact with the front wing, rear bumper, or had collisions with the road infrastructure, receiving injuries from an impact with the road surface or guard rails.

For car occupants, the majority received the lower leg or knee injuries from impact with the interior of their vehicle during a collision. 60% of the contacts recorded as causing the knee or lower leg fracture in the English data were from the fascia panel, rigid bracketry behind the fascia panel or the footwell. Other injury causation codes recorded for knee and lower leg fractures were from rigid bracketry behind the steering column, the lower A-pillar in the footwell, the pedals, the bulkhead, the back of a front seat or the interior of the side door.

The average delta-V (change in velocity) calculated from vehicle damage for car occupants who received a MAIS 3+ lower leg or knee fractures was 45kmh. This makes the collisions within the highest 10% of Delta-V results recorded for all collision types. Additionally, for collisions that result in a MAIS 3+ knee or lower leg fracture the damage details recorded for the observable damage to the vehicle structures indicates that as the Delta-V increases cases of 'severe crush to the vehicle structure with associated intrusion' and 'massive impact damage with loss of vehicle integrity' become more prevalent.

The majority of passenger car collisions that resulted in MAIS 3+ lower leg or knee fractures were to the front of the vehicle and represented directions of force between 11 and 01 'o' clock and where

intrusion into the passenger compartment is seen (present in 54% of the English cases) the degree of this is relatively extensive with the average intrusion measure recorded as 32cm. 50% of the intrusion measures are recorded as over 20cm

## 5.3 RECOMMENDATIONS

### 5.3.1 Overall recommendations

In addition to reducing numbers of casualties, road safety policy making should be aimed at reducing the numbers of serious road injuries (MAIS<sub>3+</sub> casualties) and long-term health impacts of these casualties. Groups of casualties that should additionally be considered from a serious injury perspective are:

- Cyclists, including cyclists injured in crashes without motorized vehicles involved
- Road users aged 0-17 yrs
- Spinal cord injuries
- Knee/lower leg fractures (and femur shaft fractures, which are not analysed in this report)

For the group determination process ('step 1') further research would be useful to investigate differences in MAIS<sub>3+</sub>/fatality ratios between countries. It is feasible that the differences currently seen are for a large part due to differences in specific types of crashes and specific circumstances between countries, for example, the high MAIS<sub>3+</sub>/fatality ratio in the Netherlands might be due to a relatively high share of (lower impact) single bicycle crashes and a relatively low share of (high impact) car/truck bicycle crashes. To understand these differences more completely it would be useful to see whether it is possible to derive comparable sets of MAIS<sub>3+</sub>/fatality ratios for different crash types.

Overall the findings presented for the analysis of in-depth datasets could support the concept that measures known to be effective for the prevention of fatal crashes could also be effective in the reduction of serious injuries for groups with relatively large number of MAIS<sub>3+</sub> casualties or relatively large health impacts. The results seen for some of the groups identified in this analysis have some significant crossover with other EU level MAIS 3+ injury analysis (SUSTAIN) and show some strong similarities between the factors involved.

In terms of recommendations specific to the analysis of in-depth datasets there are potentially two different and opposing outcomes that can be seen. The first is that collisions that result in MAIS 3+ injuries with long term health impacts are potentially rare in the in-depth data sample. A risk of concluding that this is good news for the road safety community is that existing or future in-depth data collection methodologies and sampling protocols could continue to miss relevant cases involving serious injury, for example by continuing to focus on fatal crashes.

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Many of the causations and contributory factors identified through the analysis of in-depth datasets can be seen for other collisions, associated with other road user groups or for different injury

severities. The scope of this deliverable did not allow a comparison between the samples identified in this report and other injury groups however it is expected that there will be some parallels, for example, it is probable that samples of slight and/or fatal injury crashes could have similar causations to those seen in the MAIS<sub>3+</sub> sample. This information is potentially be useful as it could be necessary to explore these similarities between causation and contributory factors across different groups if in-depth MAIS <sub>3+</sub> collision cases continue to be present in relatively small sample numbers.

### 5.3.2 Recommendations by road user type

#### Recommendations for young pedestrians

When 0 to 17 yrs road users are seriously injured as a pedestrian they are often involved in a collision with a motorised vehicle while crossing the road. The details of these collisions indicate that crossing behaviour and crossing location choice of young pedestrians could potentially increase the risk of vision or attention issues.

A recommendation from this analysis is therefore to understand more fully the behaviour of young pedestrians, mainly in respect to road crossing and with particular emphasis on crossing point choice, judgement of vehicle speed and vision obscuration. Linked to this recommendation would be to also review the current or future performance of active safety systems in vehicles to determine whether the systems can accurately and reliably determine the pedestrian behaviour identified.

The finding of crash causal factors relating to vision obscuration for pedestrians is important to understand further as this factor is also present in cycle crashes albeit to a larger degree. This finding is potentially important as it could impact a number of different road safety elements from infrastructure design through to education and also active collision avoidance technologies fitted to vehicles.

#### Recommendations for young car occupants

For young car passengers seriously injured in collisions there is no significant evidence to indicate that the driver of the vehicle was of a similar age. This factor goes against traditional expectations of increased risk to young passengers when they are passengers of a vehicle driven by a young driver; this could indicate that there are additional factors at play in these collisions such as the poorer protection afforded to rear seat occupants who are likely to be younger compared to older front seat occupants.

One recommendation from this finding is to focus on the injury mechanisms behind the serious injuries received by these occupants as there is less evidence to indicate that the serious injury is as a result of a young driver problem and more as an overall passive protection problem. In addition the passengers of vehicles recorded in the sample are of an age where child seat regulation and use are not relevant to the injury outcome; further work should therefore be conducted into standard fitment restraint systems and designs rather than the providers of child restraint systems

#### Recommendations for Cyclists of all ages

Cyclists are a relatively heterogeneous group with many differing results and findings. This makes the process of determining recommendations potentially difficult as results from one subset of the larger group, for example older cyclists may have different outcomes compared to younger cyclists. The following recommendations are for cyclists as a whole irrespective of the group analysed in the in-depth data (i.e. cyclist findings are derived from the 'cyclists' group as well as cyclists appearing in the 0 to 17 yrs sample).



Intersections crashes appear to be a common outcome with cyclists as they do with other Vulnerable Road Users. The frequency of cyclist collisions at intersections in this deliverable highlights the fact that there is more work to be done in resolving conflict and determining priority when it comes to junctions or crossing traffic. This is a relatively common finding for cyclists but it does indicate that serious injuries such as those discussed in this deliverable can occur at junctions and are not entirely restricted to higher speed road sections where greater injury severities and fatalities are more commonly seen.

It is conceivable that currently active technologies and detection systems in vehicles are limited in their ability to provide full support at intersections; this is primarily due to a disparity between the field of view typically provided by a sensor array and the restricted visibility characteristic of many junctions, but also in part to them being reactive (i.e. the system can typically only detect and react if a cyclist is identified as in conflict with the vehicle) whereas the complex nature of intersections may require an alternative approach and a shift to more pro-active systems that can detect, predict and resolve priority or 'give-way' issues before they occur. This recommendation possibly transcends the requirement on manual vehicle control currently dominant in vehicle fleets but could become much more critical when vehicle autonomy is more commonplace.

The number of collisions at property access (i.e. the point where private property meets public access at footways, cycle facilities or road ways) is also an interesting finding which brings into focus the design and use of cycle facilities alongside property boundaries but separated from the road. Again, priority/give-way issues are seen however the infrastructure could differ significantly from current safe junctions design and may in many cases not be seen as a traditional junction at all by either party. This potential 'grey area' in road use could mean that the long standing right of way rules are potentially misunderstood especially when motorised vehicles have to cross a footway/cycleway to reach the main carriageway while cyclists use a path separate from the majority of motorised traffic. Safer junction design for cyclists is increasingly well understood but it could be important to widen the net to cover areas where motorised vehicle come into conflict with vulnerable road users away from traditional junctions.

Single vehicle bicycle crashes are a common group in countries with high cycling rates and are a potentially difficult crash type to mitigate. Bicycles are fundamentally vulnerable to instability due to their two wheels in line design and lack the ability to have systems fitted for active control such as those now commonly seen in motorised vehicles including powered two wheelers. The instigation of the single vehicle bicycle crashes is mixed; however one causation factor seen across many of these events is distraction of the cyclist. Although there is no dominant distraction source seen in the analysis it may be necessary to understand more fully the factors that lead up to these collisions and appropriate countermeasures from other transport modes, for example mobile phone use.

Recommendations for this group are harder to determine but understanding the loss of control mechanisms and injury outcomes more fully would provide more information on the issue; the study sample in Deliverable 7.4, although small in size indicates that narrow infrastructure design, causing or requiring cycles to slow or stop and distraction leading to loss of control are factors that could be addressed in countermeasure development.

### **Recommendations for car occupants of all ages**

A number of recommendations are evident from looking at the results relevant to car occupants. Car occupants are quite a broad group in the analysis of in-depth datasets encompassing road users in the 0 to 17yrs group, spinal cord injuries group and knee/lower leg injuries group.

The injuries received by occupants of cars, particularly those in the knee/lower leg groups and spinal cord groups indicates that there is still some work to be done in terms of passive safety. The large levels of intrusion seen both in planar collisions (front, side and rear) and in rollovers indicates that vehicle structural strength is still an important topic despite the influx of secondary and active safety technologies.

One recommendation that is clear from the spinal cord group is the continuation of work into passenger car roof strength as the high levels of intrusion seen merits further investigation. In addition it could also be necessary to understand more fully the interaction between roof intrusion and occupant movement and whether restraint systems provide adequate location of the occupant in a rollover event.

An interesting result from the analysis that warrants further investigation is the effect of Delta-V on the collisions severity, particularly for frontal collisions and often, but not always, associated with narrow impacts and small overlaps. The average Delta-V recorded in this analysis is some way short of the 64 km/h impact velocity used for EuroNCAP offset deformable barrier test (and lower even than the 50km/h regulatory test speed) and although this is intended to address a high proportion of fatal and severe injury accidents there appears to be a disparity between the continued improvement in EuroNCAP scoring at these speeds and the occurrence of knee/lower leg injuries in this study.

Full scale crash testing in the US has shown that narrow impacts with small overlaps (impacts covering 25% of the total vehicle width) perform differently to the larger offset (40% of the total vehicle width) EuroNCAP deformable barrier test. One recommendation coming from this report would be to consider the introduction of a test of this type into the current protocols. This is especially pertinent considering the additional injury burden that complex lower extremity fractures can have on vehicle occupants.

### **Recommendation for PTW users**

Riders and passengers of powered two wheelers are present in a number of the groups considered through the analysis of in-depth datasets. Like cyclists they have similar collision locations with many collisions occurring where vehicle paths cross or turn. Due to the small number of PTW users in the sample (and only present if they are below the age of 17 yrs), robust conclusions and recommendations on the specifics of these crashes are difficult to draw. Instead it could be necessary to understand better the similarities and/or differences between powered two-wheeler and cycle crashes that involve crossing or turning to determine whether countermeasure development has significant crossover.

In terms of the injury causations for motorcyclists, contact with a rigid surface is common in both the spinal cord and knee/lower leg fracture results. This finding appears primarily straightforward as any rigid or immovable object presented to a motorcyclist will likely elicit some form of harm; this appears to be the case in most instances with the road surface, off road surface and road side furniture providing the primary injury causation. The results for knee/lower leg fractures for PTW users differs slightly and indicates that, in addition to the aforementioned factors, vehicle surfaces are common causes of injury.

The vehicle surfaces recorded of front bumper, front wing and rear bumper, are not typically 'aggressive' vehicle components such as bull bars or other stiff structural components and could be considered the normal areas where Vulnerable Road User protection could be applied, particularly with respect to the front bumper. This point raises a further recommendation to understand more

clearly the impact speeds, impact locations and injury mechanisms involved in motorcycle to vehicle impacts in order to determine whether these collisions are within the remit of current or future vehicle pedestrian protection design and whether regulation or design standards could be adapted to cover PTW users.

5.3.3 Table of recommendations

The table of specific recommendations below is derived from the SafetyCube Decision Support System. The table contains three columns, these are: (i) column one covering the group selected through the 'step 1' process, (ii) column two covering the specific risk factors determined through the in-depth analysis process and related to the specific groups and (iii) column three which contains the scientific overview for the specific recommendations taken from the Decision Support System.

The recommendations shown below were selected using the group and specific risk terms included in columns one and two. This enabled the SafetyCube DSS to be interrogated for measures relating to the specific groups and risks identified in this deliverable. In some cases the recommendation returned from the search terms was not always absolutely specific, for example, recommendations relating to Pedestrians with vision obstruction may include general countermeasures for vision obstruction involving other vulnerable road users as there was no disaggregation between pedestrians, cyclists or PTW users.

The information contained in the recommendations column is not exhaustive as there will be in most instances other countermeasures that could provide a variety of road safety effects. What the recommendations column does contain however is scientifically verified results for a range of different measures for road users, infrastructure and vehicles.

The information contained within the recommendation column covers three broad aspects, these are (i) the name of the recommendation as it appears in the SafetyCube DSS, (ii) the colour code applied to the specific recommendation to identify whether it is **Effective**, **Probably effective** or an **Unclear result**<sup>14</sup> and (iii) a short description of the recommendation (if necessary) and an overview of the scientific findings behind the effectiveness of the recommendation.

Group	Risk	Recommendation
Cyclists 0 - 17 yrs	Collisions while crossing or turning	<b>Channelisation</b> <b>Effective</b> Channelisation of junctions is a physical measure of road safety to improve safety at intersections by traffic flow separation, sight improvement and the simplification of driving patterns and right of way rules. In general, channelisation of junctions seems to reduce accident frequency. Differences between the effectiveness of different types of channelisation of junctions like left-turn lanes or right-turn lanes are however difficult to quantify.
		<b>Road safety audits</b> <b>Probably effective.</b> It can be seen that road safety audits and inspections measures can have a positive effect on road safety. In a minority of cases their impact can be seen as inconclusive (or has isolated

<sup>14</sup> The SafetyCube DSS also includes a further categorisation of 'ineffective' however these appear in limited numbers in the DSS and do not provide additional knowledge into suitable countermeasures.

		negative effects), but results still indicate an overall crash mitigation.
		<p><b>Road safety inspections implementation</b>  <b>Probably effective.</b>  It can be seen that road safety audits and inspections measures can have a positive effect on road safety. In a minority of cases their impact can be seen as inconclusive (or has isolated negative effects), but results still indicate an overall crash mitigation.</p>
		<p><b>Identification of high risk sites (accident black spots)</b>  <b>Probably effective.</b>  It can be seen that high risk site treatment measures have an overall positive effect on road safety. In a minority of cases the impact of the countermeasure may remain unverified or could show an isolated negative effect.</p>
		<p><b>Convert junction to roundabout</b>  <b>Probably effective.</b>  Evidence from studies on this countermeasure presents mainly positive effects, however in some instances roundabouts may lead to higher crash rates for cyclists.</p>
		<p><b>Convert 4-leg junction to staggered junction</b>  <b>Probably effective.</b>  The conversion of 4-leg junctions to staggered T-junctions appears to reduce injury crash occurrence, especially when the amount of side road traffic is high. At sites where the latter is low, an increase in crash occurrence is seen. However, although there were different results for different exposures, staggering junctions has mainly positive effects on road safety</p>
		<p><b>Traffic signal installation (for uncontrolled junctions)</b>  <b>Probably effective</b>  It can be seen that the installation of traffic signals have a mostly positive effect on road safety. Results show that the countermeasure does efficiently change road safety levels in most cases.</p>
		<p><b>Improve skewness / junction angle</b>  <b>Unclear result.</b>  The improvement of skewness or junction angle refers to the redesigning of junctions. Junctions are described as skewed when roads are not crossing at a right angle (90 degrees). Thus, improving skewness concerns the geometric layout of the junction. The improvement of skewness or junction angle may reduce crash occurrence and might also have positive effects on driving performance, but reported effects are not statistically significant.</p>
	Vision obstruction	<p><b>Sight distance treatments</b>  <b>Effective.</b>  Sight distance treatments at junctions seem to reduce crash occurrence. In addition, mostly positive effects on driver behaviour (e.g. decrease in drivers' speed) can be seen, in addition intended sight obstructions might have positive effects on driver behaviour.</p>

		<p><b>Education – Pedestrian skills training for children</b>  <b>Probably effective</b>  There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, some studies had mixed results and those with follow up results suggested that the benefit of training may reduce over time.</p>
	Judging vehicle speed and/or path	<p><b>Installation of section control &amp; speed cameras</b>  <b>Effective.</b>  Results for this countermeasure consistently show that section control and fixed speed cameras have favourable effects on the number of crashes that occur [all road users]</p>
		<p><b>General road safety campaigns</b>  <b>Probably effective</b>  There is some indication that campaigns are beneficial for road safety on various levels. Meta-analyses show an association with accident reduction, increased safe behaviours and risk awareness. However, no such effect was seen with behaviours such as drink-driving or safety relevant attitudes. Furthermore, the evidence is drawn from studies that vary strongly, mainly regarding the design of the evaluated campaigns.</p>
		<p><b>Education of children, pre-school and primary school</b>  <b>Probably effective</b>  There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, some studies had mixed results and those with follow up results suggested that the benefit of training may reduce over time.  <i>[N.B. although the literature behind this recommendation is based on pedestrians it is probable that the countermeasure could also be applicable to cyclists]</i></p>
	Experience/behaviour	<p><b>Education – Pedestrian skills training for children</b>  <b>Probably effective</b>  There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, some studies had mixed results and those with follow up results suggested that the benefit of training may reduce over time.  <i>[N.B. although the literature behind this recommendation is based on pedestrians it is probable that the countermeasure could also be applicable to cyclists]</i></p>
		<p><b>General road safety campaigns</b>  <b>Probably effective</b>  There is some indication that campaigns are beneficial for road safety on various levels. Meta-analyses show an association with accident reduction, increased safe behaviours and risk awareness. However, no such effect was seen with behaviours such as drink-driving or safety relevant attitudes. Furthermore,</p>

		the evidence is drawn from studies that vary strongly, mainly regarding the design of the evaluated campaigns.
PTW users 0 - 17 yrs	Collisions while crossing or turning	<b>Road safety audits</b> <b>Probably effective.</b> It can be seen that road safety audits and inspections measures can have a positive effect on road safety. In a minority of cases their impact can be seen as inconclusive (or has isolated negative effects), but results still indicate an overall crash mitigation.
		<b>Road safety inspections implementation</b> <b>Probably effective.</b> It can be seen that road safety audits and inspections measures can have a positive effect on road safety. In a minority of cases their impact can be seen as inconclusive (or has isolated negative effects), but results still indicate an overall crash mitigation.
		<b>Identification of high risk sites (accident black spots)</b> <b>Probably effective.</b> It can be seen that high risk site treatment measures have an overall positive effect on road safety. In a minority of cases the impact of the countermeasure may remain unverified or could show an isolated negative effect.
		<b>Convert junction to roundabout</b> <b>Probably effective.</b> Evidence from studies on this countermeasure presents mainly positive effects, however in some instances roundabouts may lead to higher crash rates for cyclists.
		<b>Convert 4-leg junction to staggered junction</b> <b>Probably effective.</b> The conversion of 4-leg junctions to staggered T-junctions appears to reduce injury crash occurrence, especially when the amount of side road traffic is high. At sites where the latter is low, an increase in crash occurrence is seen. However, although there were different results for different exposures, staggering junctions has mainly positive effects on road safety
		<b>Traffic signal installation (for uncontrolled junctions)</b> <b>Probably effective</b> It can be seen that the installation of traffic signals have a mostly positive effect on road safety. Results show that the countermeasure does efficiently change road safety levels in most cases.
		<b>Improve skewness / junction angle</b> <b>Unclear result</b> The improvement of skewness or junction angle refers to the redesigning of junctions. Junctions are described as skewed when roads are not crossing at a right angle (90 degrees). Thus, improving skewness concerns the geometric layout of the junction. The improvement of skewness or junction angle may reduce crash occurrence and might also have positive effects on driving performance, but reported effects are not statistically significant.

Pedestrians 0 – 17 yrs	Vision obstruction while crossing	<p><b>Sight distance treatments</b> <b>Effective</b></p> <p>Sight distance treatments at junctions seem to reduce crash occurrence. In addition, mostly positive effects on driver behaviour (e.g. decrease in drivers' speed) can be seen, in addition intended sight obstructions might have positive effects on driver behaviour.</p>
		<p><b>Education – Pedestrian skills training for children</b> <b>Probably effective</b></p> <p>There is some evidence, including a meta-analysis, that behaviour based education/training for children in pedestrian skills can improve the skills that children require to cross the road. However, some studies had mixed results and those with follow up results suggested that the benefit of training may reduce over time.</p>
		<p><b>Implementation of marked crosswalks</b> <b>Unclear result</b></p> <p>The safety impact of marked crosswalks remains somewhat unclear, especially the impact on pedestrian crash rate. Some studies find no significant effects of marked crosswalks on the number of crashes, while some find significant increases in the number of crashes at some locations or for some groups of road users. However, a significant reduction in crash severity is consistently found in literature</p>
Drivers in collision with a road user 0 – 17 yrs	Speed	<p><b>Installation of section control &amp; speed cameras</b> <b>Effective.</b></p> <p>Results for this countermeasure consistently show that section control and fixed speed cameras have favourable effects on the number of crashes that occur [all road users]</p>
		<p><b>Reduction of speed limit</b> <b>Effective</b></p> <p>Speed and road safety are inversely correlated. In that context, speed limit reduction has a significant positive impact on road safety. Studies observed a decrease of fatal crashes, of serious injuries, and also of other kind of injuries. The effects seem larger for a high level of initial speed than for a low level. No evidence of negative effects of speed limit reduction has been found. However, some studies lack statistical analyses and should be considered with care</p>
		<p><b>Installation of Speed Humps</b> <b>Effective</b></p> <p>Studies on the safety effects of speed hump installation show that accident rates and vehicle speeds are reduced when installed. In half of the analysed studies, the results were significant. In the other half of the studies, no statistical analysis was undertaken, so it is not known whether these results were significant. However, what is clear is that none of the results showed that speed humps resulted in increased speeds or accident rates. Hence, it can be concluded that installing speed humps reduces road safety risk</p>

		<p><b>Implementation of 30km/h (20mph)-Zones</b>  <b>Effective</b>  The results from the available literature show that, overall, vehicle speeds and accident/casualty rates reduce when 30km/h (or 20mph) zones are implemented. Where available, the results are statistically significant for a variety of conditions. However, two of five studies did not undertake a statistical analysis, but many of the non-significant results showed speed reductions and lower accident/casualty rates. This suggests that, overall, 30km/h zones do improve safety</p> <hr/> <p><b>Fines, demerit point system and general patrolling</b></p> <p><b>Licence suspension - Effective</b>  Studies indicate that licence suspension (or licence revocation) is an effective measure for reducing violations and crashes of (repeat) offenders.</p> <p><b>Increasing traffic fines - Probably effective</b>  There is evidence that higher fines are associated with less traffic violations, but effects may be limited in time and place</p> <p><b>Demerit point systems - Probably effective</b>  There is some indication that Demerit Point Systems can reduce road safety risk, however in practice the effects wear off rather quickly.</p> <hr/> <p><b>Awareness raising and campaigns – Speeding</b>  <b>Probably effective</b>  Results show that anti-speeding campaigns can have significant positive effects on road safety (behaviour). However, some campaigns are combined with enforcement activities others do not indicate long-term effects or do not take other indirect effects into account like changes in traffic</p> <hr/> <p><b>Implementation of Traffic Calming Schemes</b>  <b>Probably effective</b>  The results from the available literature showed that overall, accident and casualty rates reduce when calming schemes traffic are installed and these results are statistically significant. However, the studies included in all 3 meta-analyses and Yannis et al. (2003) are fairly dated (1980s/1990s), and without newer studies to support the findings, it is unclear whether these results would have been replicated if more recent studies/data had been available. Also in Høye (2014), none of the primary studies were controlled for regression to the mean, so the effects found may be over-estimated. However on balance, it appears that traffic calming schemes do improve safety</p> <hr/> <p><b>Intelligent speed adaptation/speed limiter/speed regulator</b>  <b>Probably effective</b>  The effects of speed adaptation devices in cars are mostly positive in reducing crash frequency, vehicles’ mean speed and drivers exceeding the speed limit. Furthermore, the coded studies encompass several topics and have good levels of quality</p>
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		and consistency. However, there are a number of findings which cannot be strongly supported due to lack of statistical tests
	Distraction	<p><b>Autonomous Emergency Braking AEB (City, interurban)</b> <b>Effective</b></p> <p>The bibliographic review on the effectiveness of AEB city &amp; interurban suggests that the colour code Green (effective) should be given. While no studies were found dealing with AEB interurban, five studies were found dealing with AEB city and all suggesting that it has a positive effect on road safety.</p> <p><b>Autonomous Emergency Braking AEB (pedestrians &amp; cyclists)</b> <b>Effective</b></p> <p>The bibliographic review on the effectiveness of AEB pedestrian &amp; cyclist suggests that the colour code Green (effective) should be given. All studies establish that AEB pedestrian &amp; cyclist has (or would have) a positive effect on road safety.</p> <p><b>Law and Enforcement -Distraction: Laws restricting the mobile phone use and enforcement of driving while using the mobile phone</b> <b>Unclear result.</b></p> <p>The effects of implementing laws and increasing enforcement against mobile phone use while driving are mixed. To date, studies have shown positive, positive without statistical evaluation, non-significant and even negative effects.</p>
	Observation	<p><b>Education - Hazard perception training</b> <b>Effective</b></p> <p>The results from the available literature indicate that hazard perception training/education can significantly improve the hazard perception skills of drivers as well as reduce accident rates and speeds. As most of the studies performed statistical analyses, and the vast majority of the results were statistically significant, there is evidence that hazard perception training brings about enhanced hazard avoidance skills. Consequently, drivers who have undertaken hazard perception training are less likely to cause accidents or drive with high speeds, thus it can be concluded that hazard perception training reduces road safety risk</p>

Group	Risk	Recommendation
Cyclist (all ages)	Collisions while entering or crossing a priority road	<p><b>Channelisation</b> <b>Effective</b></p> <p>Channelisation of junctions is a physical measure of road safety to improve safety at intersections by traffic flow separation, sight improvement and the simplification of driving patterns and right of way rules. In general, channelisation of junctions seems to reduce accident frequency. Differences between the effectiveness of different</p>

		<p>types of channelisation of junctions like left-turn lanes or right-turn lanes are however difficult to quantify.</p>
		<p><b>Road safety audits</b>  <b>Probably effective.</b>  It can be seen that road safety audits and inspections measures can have a positive effect on road safety. In a minority of cases their impact can be seen as inconclusive (or has isolated negative effects), but results still indicate an overall crash mitigation.</p>
		<p><b>Road safety inspections implementation</b>  <b>Probably effective.</b>  It can be seen that road safety audits and inspections measures can have a positive effect on road safety. In a minority of cases their impact can be seen as inconclusive (or has isolated negative effects), but results still indicate an overall crash mitigation.</p>
		<p><b>Convert 4-leg junction to staggered junction</b>  <b>Probably effective.</b>  The conversion of 4-leg junctions to staggered T-junctions appears to reduce injury crash occurrence, especially when the amount of side road traffic is high. At sites where the latter is low, an increase in crash occurrence is seen. However, although there were different results for different exposures, staggering junctions has mainly positive effects on road safety</p>
		<p><b>Traffic signal installation (for uncontrolled junctions)</b>  <b>Probably effective</b>  It can be seen that the installation of traffic signals have a mostly positive effect on road safety. Results show that the countermeasure does efficiently change road safety levels in most cases.</p>
		<p><b>Traffic sign installation; traffic sign maintenance</b>  <b>Effective</b>  On the basis of both study and effect numbers, the installation and maintenance of traffic signs appear to have positive effects on road safety. There are cases when the impact is inconclusive, but these instances are in the minority. Furthermore, the coded studies encompass several topics and have good levels of quality and consistency. For the reasons mentioned above, the overall impact of traffic sign installation and maintenance is characterized as effective</p>
		<p><b>STOP/YIELD signs installation or replacement:</b>  <b>Unclear result</b>  From studies on the effects of the installation or replacement of stop/yields signs at junctions it appears that only the installation of two-way stops and four-way stops significantly reduces crash occurrence. Installing one-way stops might reduce crash occurrence, but reductions were not statistically significant. This applies also to the installation of yield signs. The replacement of stop signs by yield signs however appears to significantly increase crash occurrence</p>

	<p><b>Traffic signal reconfiguration:</b>  <b>Unclear result</b>  On a basis of both study and effect numbers, traffic signal reconfiguration measures have an unclear effect on road safety. The positive effects do not outnumber the negative ones by a safe (large) margin, and many outcomes are either not directly related to road safety or are not statistically significant</p> <p><i>[topic addresses pedestrian crossing phase which may have parallels with a cyclist crossing phase]</i></p>
Vision issues while crossing	<p><b>Sight distance treatments</b>  <b>Effective</b>  Sight distance treatments at junctions seem to reduce crash occurrence. In addition, mostly positive effects on driver behaviour (e.g. decrease in drivers' speed) can be seen, in addition intended sight obstructions might have positive effects on driver behaviour.</p>
Single vehicle cycle crashes	<p><b>Increase shoulder width:</b>  <b>Probably effective</b>  Several studies have found a positive effect of increasing shoulder width on road safety. However, for some circumstances (e.g. injury and property damage only shoulder related crashes on multilane roads) significant negative estimates were found</p> <p><i>[results are typically for motorised vehicles but parallels could be drawn for cycles]</i></p>
	<p><b>Law and Enforcement -Distraction: Laws restricting the mobile phone use and enforcement of cycling while using the mobile phone</b>  <b>Unclear result.</b>  The effects of implementing laws and increasing enforcement against mobile phone use while driving are mixed. To date, studies have shown positive, positive without statistical evaluation, non-significant and even negative effects.</p>
	<p><b>Cycle lane treatments; increase of cycle lane width</b>  <b>Unclear result</b>  According to existing research, the installation of a cycle lane may have a positive or negative effect on road safety. A not physically separated cycle lane could reduce injury accidents for cyclists. The effect is greatest at road intersections. On the other hand, a physically separated cycle track may increase the number of accidents, particularly cycle accidents at intersections.</p>
Legal (disobeying signs/signals, alcohol, drugs)	<p><b>Effectiveness of Road Safety Campaigns</b>  <b>Probably effective</b>  There is some indication that campaigns are beneficial for road safety on various levels. Meta-analyses show an association with accident reduction, increased safe behaviours and risk awareness. However, for other outcome variables</p>

		such as drink-driving or safety relevant attitudes, no such effect was found. Furthermore, meta-analysed studies vary strongly, mainly regarding the design of the evaluated campaigns.
		<p><b>Awareness raising and campaigns – Driving under the influence</b></p> <p><b>Probably effective</b></p> <p>There is some indication that drink-driving campaigns have a positive impact on attitudes towards drink-driving and even on the related accident occurrence. There is less evidence of the effectiveness of designated driver programmes.</p>

Group	Risk	Recommendation
Road users sustaining spinal cord injuries	Rollover occurrence for passenger vehicles	<p>Electronic stability control</p> <p><b>Effective</b></p> <p>Results consistently show that the Electronic Stability Control (ESC) system reduces road safety risk. ESC is mandatory in many countries supported by the many indicators that prove ESC to be beneficial.</p>
	Roof strength for passenger vehicles and movement of occupant	<p><b>Rollover protection system</b></p> <p><b>Unclear result</b></p> <p>A number of studies from the U.S. show that there is a relationship between roof crush and injury severity in rollover crashes. However no literature is available on the effectiveness of certain measures to reduce roof crush.</p>
		<p><b>Seatbelt</b></p> <p><b>Effective</b></p> <p>The recommendation for the use of 3-point seat belt measure is effective, referring to the unanimous and high positive effect regarding prevention of injuries and fatalities during a crash for which this type of occupant safety system is designed.</p>
	High levels of crush and intrusion	<p><b>EuroNCAP frontal impact</b></p> <p><b>Effective</b></p> <p>EuroNCAP publishes safety performance data continuously. Vehicle crash performance has steadily improved after the introduction of EuroNCAP tests. The scientific literature contains positive evaluations of EuroNCAP's contribution to improved frontal impact protection. There is no doubt that the introduction of the consumer test programmes and the regulations have caused the manufacturers to compete and improve their vehicles' safety features.</p>
	Impacts with road/off road surface or road side furniture	<p>PTW protective equipment</p> <p><b>Probably effective</b></p> <p>International literature indicates that the use of Powered Two Wheeler protective equipment in the form of motorcycle specific jackets, trousers, gloves and boots provides a protective effect, reducing the level of injury sustained in the event of a collision.</p>

Group	Risk	Recommendation
Road users sustaining knee/lower leg injuries	PTW users in collisions with vehicles	<p>PTW protective equipment</p> <p><b>Probably effective</b></p> <p>International literature indicates that the use of Powered Two Wheeler protective equipment in the form of motorcycle specific jackets, trousers, gloves and boots provides a protective effect, reducing the level of injury sustained in the event of a collision.</p>
	Vehicle occupants in collision with fixed objects	<p><b>Lanekeeping systems</b></p> <p><b>Unclear result</b></p> <p>Some literature was found on Lane departure warning systems, no relevant literature evaluating the effect of Lane keeping assist systems was found. The available literature mostly describes the benefit of LDW systems by identifying the target population (share of crashes that could have been addressed by a LDW system). Little is known however about the number of cases where LDW would have been effective.</p>
	PTW uses in impact with road infrastructure/surface/guardrail	<p><b>PTW protective equipment</b></p> <p><b>Probably effective</b></p> <p>International literature indicates that the use of Powered Two Wheeler protective equipment in the form of motorcycle specific jackets, trousers, gloves and boots provides a protective effect, reducing the level of injury sustained in the event of a collision.</p>
	Vehicle passengers striking facia panels	<p><b>EuroNCAP frontal impact</b></p> <p><b>Effective</b></p> <p>EuroNCAP publishes safety performance data continuously. Vehicle crash performance has steadily improved after the introduction of EurpoNCAP tests. The scientific literature contains positive evaluations of EuroNCAP's contribution to improved frontal impact protection. There is no doubt that the introduction of the consumer test programmes and the regulations have caused the manufacturers to compete and improve their vehicles' safety features.</p>
	High levels of crush and intrusion	<p><b>EuroNCAP frontal impact</b></p> <p><b>Effective</b></p> <p>EuroNCAP publishes safety performance data continuously. Vehicle crash performance has steadily improved after the introduction of EurpoNCAP tests. The scientific literature contains positive evaluations of EuroNCAP's contribution to improved frontal impact protection. There is no doubt that the introduction of the consumer test programmes and the regulations have caused the manufacturers to compete and improve their vehicles' safety features.</p>
		<p>Frontal impact regulation (ECE R94)</p> <p><b>Probably effective</b></p> <p>Most results in the literature estimate safety benefits between generations of cars or according to certain types of impacts, this masks the effect of one specific regulation or the progress due to the rising effect of consumer test programs. All results or estimations for this measure fail to consider the requirements of the active safety devices or the possible migration of the type of impacts due to their generalisation on future vehicles; therefore</p>

		it is not possible to conclude whether this recommendation is fully effective.
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# Table of abbreviations

<b>ACAS</b>	German causation factor coding system
<b>AIS</b>	Abbreviated Injury Scale
<b>BAST</b>	German Federal Highway Research Institute
<b>CARE</b>	EU Community database on road accidents
<b>CBS</b>	Statistics Netherlands
<b>CCIS</b>	Cooperative Crash Injury Study
<b>CMBDAH</b>	National Hospital Discharge Register for Spain
<b>DGT</b>	Spanish National Traffic Authority
<b>DSS</b>	Decision Support System
<b>DUHAT</b>	Hospital Emergency Register for traffic injured in Barcelona
<b>EC</b>	European Commission
<b>EU</b>	European Union
<b>FAT</b>	German Association for Research in Automobile Technology
<b>GDP</b>	Gross Domestic Product
<b>GIDAS</b>	German In-Depth Accident Study
<b>GUB</b>	Registry of Accidents and Victims of Barcelona of the urban police of Barcelona
<b>HDD</b>	Hospital Discharge Data for Austria
<b>HES</b>	Hospital Episode Statistics - database of hospital discharge data for England.
<b>ICD-10</b>	International Classification of Diseases, 10 <sup>th</sup> Edition
<b>IDB</b>	Austrian emergency department based injury surveillance system
<b>MAIS</b>	Maximum abbreviated injury score
<b>OTS</b>	On The Spot study
<b>PTW</b>	Powered Two Wheeler
<b>RAIDS</b>	Road Accident In-Depth Study
<b>STATS19</b>	Dataset of police-reported injury accidents in the UK
<b>YLD</b>	Years Lived with Disability
<b>YLL</b>	Years of Life Lost





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# Appendices